Government of Malawi

National Commission For Science And Technology

THE SECOND NATIONAL COMMISSION FOR SCIENCE AND TECHNOLOGY RESEARCH DISSEMINATION CONFERENCE

Research and Innovation: a catalyst for sustainable development

CONFERENCE PROCEEDINGS

28th -29th September 2017,

Mangochi, Malawi

THE SECOND NATIONAL COMMISSION FOR SCIENCE AND TECHNOLOGY RESEARCH DISSEMINATION CONFERENCE,

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The National Commission for Science and Technology (NCST) and Malawi Public Policy Research and Analysis Project (MPPRAP) in the Ministry of Finance, Economic Planning and Development extend their heartfelt acknowledgements to all institutions and individuals that made the Second NCST Research Dissemination Conference possible. Special recognition is extended to all conference participants without whom the research dissemination conference would not have been successful. The Commission profoundly acknowledges efforts by the Conference Organising Committee, the Technology Transfer Section and the Documentation Services Section for the successful organization of the research dissemination conference and production of the proceedings. NCST also appreciates the support of heads of institutions towards the participation of their researchers.

The Government understands the importance of evidence for decision making, and that is why NCST partnered with MPPRAP in organizing this research conference. This is against the understanding that there is increasing demand for evidence in policy making and implementation. Government is committed to promoting evidence-based policies in Malawi through research, dissemination, networking and coordination. Researchers are therefore, encouraged to continue producing high-quality evidence that is relevant to the country.

Gratitude goes to the Board, Management and Staff of NCST; the Steering and Technical Committee Members and Staff of MPPRAP; and Management and Staff of the Ministry of Finance, Economic Planning and Development for working together in organising this conference. Most importantly, the Government of Malawi is also grateful to the African Capacity Building Foundation (ACBF) for financially supporting the organization of this conference.

The Commission shares the conviction that research and development has little or no impact if its results are not shared and utilized to inform decision making.

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INTRODUCTION

The importance of research and development for socio-economic development is recognized world over. Significant developments that have been made in the fields of education, health, agriculture, natural science, environment, climate change, engineering, information, communication, telecommunication and social sectors have largely been attributed to research and development.

Malawi also recognises the role of research and development as evidenced by the establishment of various research and development institutions in all key sectors including the establishing of the National Commission for Science and Technology (NCST). NCST was established by the S&T Act no.16 of 2003 to advise Government and other stakeholders on all matters of science, technology and innovation. Its mission is to promote, support, coordinate and regulate the development and application of science, technology and innovation, so as to create wealth in order to improve the quality of life. NCST therefore, collaborates with the industry, government, private sector and development partners as well as the academia to promote research as a tool to facilitate sustainable development.

One of the strategies for promoting research is dissemination of research results through conferences as they give an opportunity for researchers to showcase, engage and share knowledge with a more diverse audience drawn from various sectors. Most importantly, conferences provide a platform for interacting, networking, contributing and learning about recent advances and emerging issues in various fields of interest and expertise. In addition, conferences advocate for Science and Technology by instilling curiosity and innovative thinking in participants.

In this regard, NCST in collaboration with Malawi Public Policy Research and Analysis Project (MPPRAP) organised the second research dissemination conference from 28th -29th September 2017 at the Sunbird Lakeshore International Conference Centre in Mangochi under the theme *"Research and Innovation: a Catalyst for Sustainable Development*. The theme of the conference coincided with the time the country was advancing the third Malawi Growth and Development Strategy (MGDS III) which domesticated Sustainable Development Goals (SDG's) that recognise the importance of research and innovation. It was therefore anticipated that the outcomes of the conference would go a long way in promoting research and innovation to enhance sustainable development and inculcate a culture of *evidence based policy decision making*.

The implementation process for the conference involved, a call for abstracts from 16th May to 16th June 2017 in the print and electronic media under the following subthemes;

(a) Energy, Industry and Engineering
The subtheme covered alternative energy sources, renewable energies, construction technologies, industrial needs assessment, among others.

(b) ICT and Knowledge Management
The subtheme covered the role of ICT in education and health, cyber security, open access, telecentres and database management systems.

(c) Health and Population
The major areas of focus under this subtheme included HIV and AIDS, nutrition, food science, food safety, hygiene and sanitation, sexual health and reproduction and health systems.

(d) Agriculture, Irrigation and Food Security

The subtheme addresses advancements and contemporary knowledge in agriculture, irrigation and food security research and innovation.

(e) Education, Social Sciences and Humanities

The subtheme focused on use of technologies in teaching and learning, teacher motivation, inclusive education, technical and vocation education, active and innovative learning, traditional leadership, cultural and social issues.

(f) Environment, Climate Change and Natural Resources

The subtheme addressed issues relating to climate change adaptation and mitigation, waste management, Green-house gases emissions and environmentally sound technologies and innovations.

(g) Technology, Innovation and Entrepreneurship

This subtheme addressed issues ranging from nanotechnology, value addition and processing as well as entrepreneurship are addressed.

A total of 263 abstracts were received, screened and peer reviewed in compliance with the requirements outlined as follows: title of the research, objectives of the study, methods to be used to achieve the objectives, clear summary of the results, recommendations and format for the abstracts. A total of ….were selected for presentation at the conference.

These conference proceedings only contain full papers that were submitted by presenters under the aforementioned subthemes.

ENERGY, INDUSTRY AND ENGINEERING

National Commission of Science and Technology (NCTS)
2017 Research Dissemination Conference Proceedings

High utilization efficiency of $NiCo_2O_4$ supported on porous graphene as noble metal-free catalysts for ORR.

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ABSTRACT

Due to the π-π interaction of graphene (GR) layers, GR sheets tend to aggregate irreversibly to graphite during the application process. In addition, nanoparticles supported on GR layers are easily sandwiched or secluded inside the stacked layers and therefore not efficient exposure for catalysis. To address the irreversible aggregation of GR and increase the utilization efficiency of supported nanoparticles, in this work, porous GR (PGR) was prepared using SiO_2 as a template and used as support for the $NiCo_2O_4$. The porous structure provided larger surface area and more opportunity for the exposure of supported $NiCo_2O_4$. Due to the porous structure of PGR, the $NiCo_2O_4$ supported on PGR were not hidden by aggregated GR layers and were highly exposed to target molecules. Compared with $NiCo_2O_4$/GR, the electrocatalytic activity of $NiCo_2O_4$ supported on PGR is effectively increased accompanied with the high utilization efficiency of $NiCo_2O_4$ supported on PGR. By combination of the catalytic properties of highly exposed $NiCo_2O_4$ and structural properties of PGR, the $NiCo_2O_4$/PGR is highly active, cheap and selective noble-metal free catalysts for oxygen reduction reaction (ORR) in alkaline solution. In addition, the ORR activity of $NiCo_2O_4$/PGR is increased accompanied with the decrease of pore size of PGR. $NiCo_2O_4$/PGR is potential efficient and inexpensive noble metal-free ORR catalysts with good long term stability in alkaline solution.

Keywords: catalyst, graphene layer, *$NiCo_2O_4$,* oxygen reduction reaction.

INTRODUCTION

Fuel Cells (FCs), a clean and high efficiency device that directly converts chemical energy from fuel into electricity through chemical reaction with oxygen or another oxidizing agent, has drawn a great deal of attention in terms of both fundamentals and applications[1]. The oxygen reduction reaction (ORR) is the most important reaction in energy converting systems for FCs. Generally, the ORR kinetics is rather slow at cathode. In order to speed up the ORR kinetics to reach a practical usable level in FCs, a cathodic ORR catalyst is required. At the current stage in technology, platinum (Pt)-based materials are known to be the most reactive catalysts for ORR at the cathode in FCs[2]. However, despite considerable research efforts in Pt-based catalysts, large scale commercialization is still restricted mainly by their high cost, poor durability, scarcity, and slow electron transfer kinetic. Therefore increasing numerous efforts have been devoted to substituting Pt-based catalysts with low cost materials such as nitrogen-doped carbon materials[3-6].

The nitrogen-doped nanomaterials have been proposed as promising metal-free catalysts for the ORR because of their superior electrocatalytic activity, low cost, long durability and environmental

friendliness. The nitrogen-doped carbon catalysts are highly active toward ORR and exhibit higher electrocatalytic activity than pristine carbon. Their higher electrocatalytic activity could be attributed to the nitrogen-doped graphitic structure which produces more sites for ORR, allowing the easier adsorption of oxygen and subsequent reduction [2, 3, 7]. Among these carbon nanomaterials, graphene (GR) is a single atomic plane of graphite which has been largely used in electrochemical studies as catalysts or catalyst support material. Heteroatoms-doped GR has been studied with high electrochemical performance for ORR with long-term durability and high tolerance to methanol[3, 8-13].

Some researchers have suggested that the use of non-precious metals with low cost and high activity offers an effective way to significantly reduce catalyst cost without compromising the performance of alkaline FCs[10, 14-24]. The transition metals such as cobalt or nickel are such a class of promising candidates for the FCs applications [14, 18, 20]. Their mixed valencies are beneficial for easy ion transportation [7, 25, 26]. Among them, spinel has particularly drawn a great deal of interest and considerable efforts have been devoted to its electrochemical applications in ORR[15, 17, 21, 26-28]. The spinel shows high electrochemical performance in supercapacitors[29, 30], lithium-ion batteries[31, 32], and electrocatalysts[33, 34].The spinel also exhibited good ORR performance with better fuel crossover resistance and long-term durability in alkaline medium which is attractive candidate for low cost, earth-abundant electrocatalysts for ORR catalysis. The combination of spinel and GR leads to the formation of composites that can take full advantages of each kind of material and increase the ORR activity of spinel[15, 17, 21, 35].

Many GR-based catalysts have been developed but despite their high electrocatalytic activity for the ORR, there exist some problems. For example the nitrogen precursors in these works have chemicals which are poisonous to humans (such as acetonitrile[36],pyridine[37], aniline[38], pyrrole[9] and ammonia gas[39]), some precursors are expensive and the preparation processes of these nitrogen doped carbon nanomaterials are complex. Meanwhile, GR sheets usually stack together because of their special single layer structure through π-π interaction [40, 41]. The surface of GR is then much affected by the overlapping of the sheets due to the reversible aggregation which negatively affects its application in electrochemical studies. The irreversible stacking of GR sheets causes active sites for ORR to easily fill the spaces between GR sheets or hidden inside the stacked GR, then being absent for catalysis. Due to the irreversible agglomeration, nanoparticles or nanoscaled materials supported on GR layers are easily sandwiched between aggregated GR sheets or secluded inside the stacked layers and the utilization efficiency of supported nanoparticles is limited. Therefore, it remains a challenge to develop a simple and effective method to prepare catalysts based on GR for the ORR applications. More efforts are being applied in improving the ORR activity of carbon-based catalysts, and this work focuses much on porous graphene (PGR)[42-45]. The lifting of the aggregation of the GR sheets can facilitate the exposure of the active sites and effectively increase the catalytic activity of GR-based catalysts.

Recently, the modification of GR into porous structure through template-directed chemical vapor deposition is also an effective method to prevent the irreversible stack of GR sheets and increase the surface area of GR[12, 46, 47]. In addition, Graphene oxide (GO)self assembles on the surface of the template and its reduction and the removal of the template result into GR with pores that were initially occupied by the template particles[48-50]. PGR-based materials have attracted much attention due to their porous structure and attained properties from GR. The porous structure provides a large surface area for more active sites and also favors ion transport with small scale diffusion distances which result into high electrochemical performance [42-45]. But to the best of our knowledge, few studies are done on the ORR applications of nanoparticles/PGR.

In the present work, we developed a simple synthesis strategy for the development of $NiCo_2O_4$/PGR as effective catalysts for ORR. This was done by the use of SiO_2 as a template material and with

surface modifications by -NH_3 groups. The electrostatic interaction between the positives of SiO_2 and the negatives of GO in water with subsequent centrifugation of the mixed suspensions resulted into the SiO_2 particles wrapped by GO sheets. After the reduction of GO by thermal treatment, the removal of SiO_2 particles by HF acid resulted into PGR formation. Thereafter, PGR was reacted with nickel nitrate, cobalt nitrate and hexamethylenetetramine in water through reflux. The product was obtained after centrifugation and then pyrolysis. The catalysts were prepared and transferred to a cleaned glassy carbon (GC) electrode and performance was studied. The increased distance between porous layers effectively lifts the aggregation of GR sheets thereby having a large exposure of the active sites for supported $NiCo_2O_4$. The introduction of $NiCo_2O_4$ into PGR sheet improves the electronic structure of PGR and provides a good ORR activity. The publications indicate that $NiCo_2O_4$ possesses a much better electronic conductivity than single metal oxides [26, 27, 51]. The combination of PGR and $NiCo_2O_4$ promotes the performance of $NiCo_2O_4$/PGR resulting from the inherited unique properties of both materials. The large surface area and a large number of macropores of $NiCo_2O_4$/PGR create high density of active surface sites for ORR and then give a superior electrochemical performance for ORR.

Although spinel/GR was used as ORR catalysts in recent publications [16, 17, 21, 35, 52], the difference of our methodology is the use of PGR as support for spinel and the utilization efficiency and catalytic activity of $NiCo_2O_4$ are well improved. A large difference in ORR performance exists between $NiCo_2O_4$/PGR and $NiCo_2O_4$/GR owing from the presence of active sites of $NiCo_2O_4$. The active sites in $NiCo_2O_4$ supported on GR are hidden inside the aggregated sheets and the utilization efficiency of $NiCo_2O_4$ on GR is restricted, while $NiCo_2O_4$ supported on PGR are exposed to oxygen and the utilization efficiency of $NiCo_2O_4$ on PGR is enhanced. As noble metal free catalysts, $NiCo_2O_4$/PGR shows much better fuel cross over resistance and long term durability than the commercial used Pt/C in alkaline medium.

MATERIALS AND METHODS

Reagents

Graphene oxide (GO), silicon dioxide, cobalt nitrate, nickel nitrate, hexamethylenetetramine, (3-aminopropyl) triethoxysilane (APTES), tetraethylorthosilicate (TEOS), alcohol, ammonia, HF acid and Nafion were used in the experiment. All chemical reagents used in the experiments are of analytical grade and used as received without further purification.

Apparatus and methods

Cyclic voltammetry (CV), rotating disc electrode (RDE), and rotating ring-disk electrode (RRDE) experiments for the ORR were performed with a CH 830b Electrochemical Analyzer (CH instruments, China) and CHI 750 D respectively. Transmission electron microscopy (TEM) images were obtained using a JEM-2100F transmission electron microscopy (JEOL, Japan) operating at 200 kV. X-ray photoelectron spectroscopy (XPS) measurements were conducted using Thermo ESCA LAB spectrometer (USA). The nitrogen adsorption desorption isotherm was performed on an ASAP 2020 (Micromeritics, USA). X-ray diffraction (XRD) pattern was obtained on an X-ray D/max-2200vpc (Rigaku Corporation, Japan) instrument operated at 40 kV and 20 Ma using Cu radiation (kα=15406nm). GC, Ag/AgCl electrode (KCl saturated) and platinum were used as working, reference and counter electrode respectively. The electron number (*n*) transferred in ORR process is calculated based on the Koutecky-Levich equation:

$$\frac{1}{J} = \frac{1}{J_k} + \frac{1}{B\omega^{0.5}}$$

Where J is the current density, J_k is the kinetic current densities, and B is a Levich constant, which could be found from the slope of the K-L plots based on the Koutecky equation as follows:

$$B = 0.2nFD^{2/3}v^{-1/6}C_{O_2}$$

Where F is the Faradic constant (F=96486C mol^{-1}), D is the diffusion coefficient of O_2 in the electrolyte solution (D=1.9×10^{-5} cm^2 s^{-1}), v is the kinematic viscosity of the electrolyte (v=0.01 cm^2 s^{-1}) and C_{O_2} is the concentration of the oxygen in the electrolyte (C_{O_2} =1.2×10^{-6} mol cm^{-3}). The n values and the percentage of H_2O_2 calculated from RRDE can be determined by the following equation (N is RRDE collection efficiency with value of 0.37.):

$$n = \frac{4 \times I_D}{(I_D + \frac{I_R}{N})}$$

$$H_2O_2\% = \frac{200 \times I_R}{(I_D \times N + I_R)}$$

Material preparation

Synthesis of SiO_2 template

SiO_2 was prepared by the Stobers's method and the preparation of $NiCo_2O_4$/PGR is summarized in a scheme 1. Silica was synthesized by hydrolysis and condensation of TEOS in alcohol with ammonia as a surface functionalizing material [53]. First, ethanol and ammonia of known volumes were mixed and then a known volume of TEOS was added drop wise into the above solution after 5 minutes with a magnetic stirring. APTES was added after 5 h and the solution was continuously stirred for 12 h. Thereafter the mixture was centrifugated and the SiO_2 particles were washed with water and ethanol then dried at 80°C for 24 h. Three different SiO_2 templates were synthesized in which the first had 8.75 mL TEOS, 12.5 mL NH_3 and 250 mL of ethanol while the second had 20 mL TEOS, 15 mL NH_3 and 250 mL of ethanol. Finally the third template had 20 mL TEOS, 25 mL NH_3 and 250 mL of ethanol. The adding quantity of reactants was measured by volume. In this work, SiO_2 particles with the diameter of 110, 190 and 300 nm were used as template for the preparation of PGR. All the vessels were covered with plastic membrane to prevent ammonia volatilization so as to achieve good productivity.

Synthesis of PGR-X

GO was prepared according to modified Hummers' method[54]. 50 mL of GO (1.4 mg mL^{-1}) solution was added to SiO_2 solution in water. The mixture was continuously stirred for 24h and then GO/SiO_2 particles were collected through centrifugation. The particles were washed with de-ionized water before being dried in an oven at 80°C for 24h and pyrolised at 800°C for 3h under nitrogen. The product was then mixed with HF acid, magnetically stirred, thereafter centrifugated and dried at 80°C.

Synthesis of $NiCo_2O_4$/PGR and $NiCo_2O_4$/GR

PGR or GR (32 mg) was mixed with nickel nitrate (16 mg), cobalt nitrate (32 mg) and hexamethylenetetramine (80 mg) in 25 mL of water and stirred for 24h under hydrothermal reflux at 90°C. The solution was then centrifugated, thereafter washed with water and dried at 70 °C then pyrolised at 300°C in the air.

Electrode preparation and modification

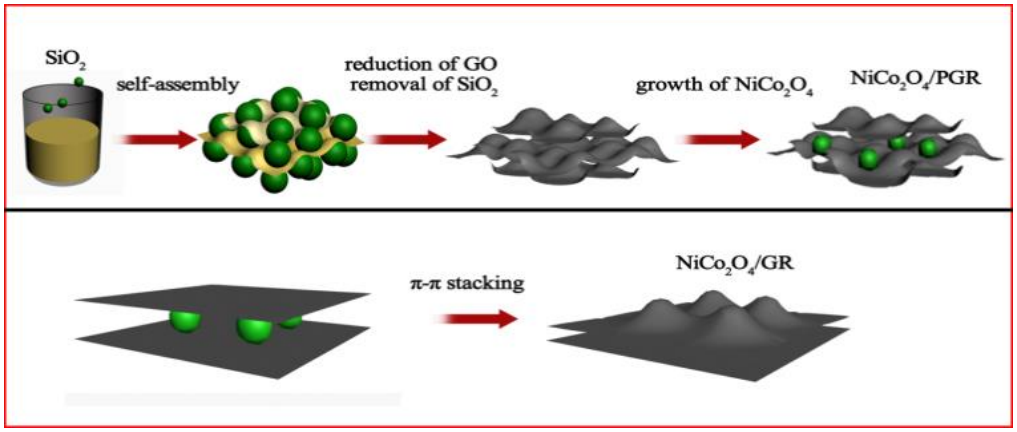
Catalyst ink was prepared by mixing 2 mg of the catalyst powder into 1 mL of Nafion solution with ultra-sonication for 2h. GC was polished carefully with alumina powder and cleaned with de-ionized water and ultra-sonication. In this work, the loading amount of different catalysts was 0.14 mg cm^{-2} (geometric surface area of electrode).

RESULTS AND DISCUSSION

Structural characterization of PGR and $NiCo_2O_4$/PGR

The preparation of $NiCo_2O_4$/PGR is demonstrated in Scheme 1. In this study, the electrostatic interaction force between SiO_2 and GO is essential for the preparation of PGR. Figure S1A shows

SEM image of SiO_2 in which its crystalline ball like structural particles are observed of size 110 nm. Figure S1B is the SEM image of GO depicting a curled morphology consisting of a thin sheet-like structure. The SEM image of GO/SiO_2 is given by Figure S1C in which SiO_2 particles are wrapped by GO sheets. This information obtained from the SEM images assures that PGR can be effectively synthesized by the method in Scheme 1.



Scheme 1 Preparation pathway of porous $NiCo_2O_4$/PGR

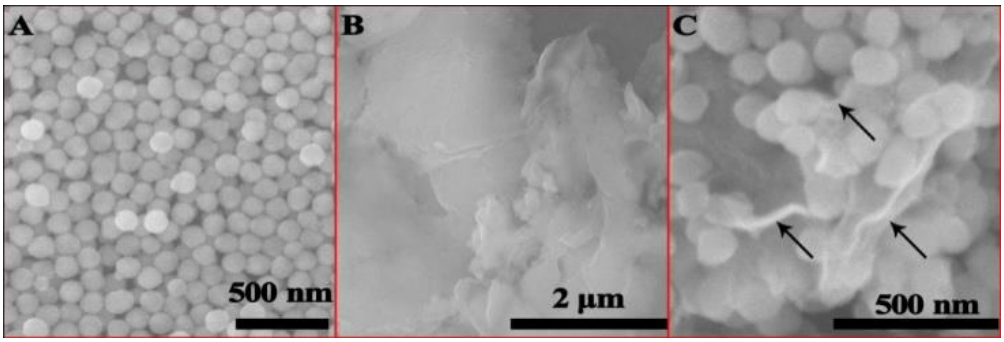


Figure S1 A: SEM image of silica (SiO_2), B: SEM image of GO and C: SEM image of (SiO_2 + GO).

Figure 1 shows SEM and TEM images of the morphology and structures of PGR and GR materials. The SEM image in A and TEM image in B depict a nonporous layered structure of GR while SEM image C and TEM image D depict a macroporous sheet like structure of PGR which is absent in GR. The removal of SiO_2 particles resulted into the formation of PGR with many pores that were initially occupied by the SiO_2 particles. The porous structure of PGR is maintained after the removal of SiO_2 template because of the interlinking of GR sheets in its 3D structures. However, The SEM image of PGR shows some pores larger than the size of the SiO_2 template. Many aggregated SiO_2 particles are wrapped by GO layers and partial surface of aggregated SiO_2 is not fully covered by GO. The removal of the aggregated SiO_2 particles produced pores larger than the size of the template.

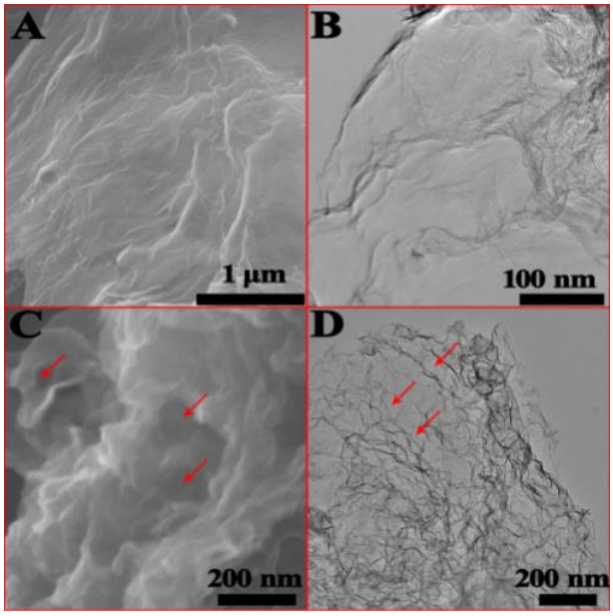


Figure 1: SEM images of (A) GR and (C) PGR-110. TEM images of (B) GR and (D) PGR-110.

The porous nature of PGR-110, PGR-190, PGR-300 and GR was further examined by nitrogen adsorption-desorption isotherms in Figure 2. The Brunauer-Emmett-Teller (BET) specific surface areas of PGR-110, PGR-190, PGR-300 and GR are 309.4, 252.0, 221.2 and 182.8 m^2 g^{-1} respectively. There is a decrease in the BET surface areas of the PGR samples with the increase in the particle size of template. This is why PGR-110 has a large surface area than PGR-190 and PGR-300 attributed to its smaller particle size. The BET surface areas of PGR samples are larger than of GR, indicating the presence of porous structure in PGR materials in agreement to earlier measurements. The inset of Figure 2 is the pore size distribution of PGR-110, PGR-190 and PGR-300 produced by different SiO_2 template size. There is an indication of many pores with a large even distribution produced by the removal of SiO_2 particles in PGR. The high surface area and porous structure of PGR-110 are essential for the exposure of nanoparticles' active sitesand mass transfer for ORR. Compared with PGR-110, the surface area of $NiCo_2O_4$/PGR-110 decreased to 204m^2g^{-1} in Figure S3. Meanwhile, the main pore size has decreased to 50nm indicating the successful growth of $NiCo_2O_4$ on the PGR-110.

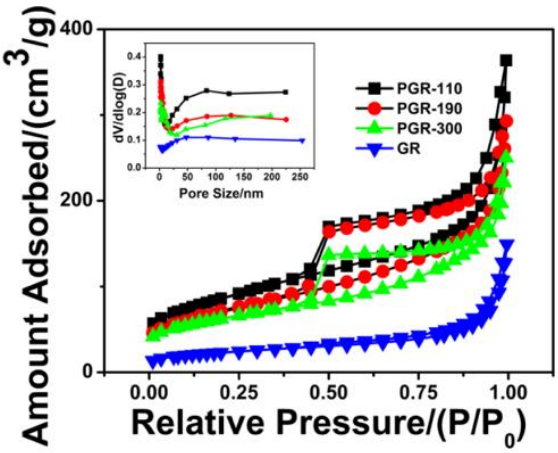


Figure 2: Nitrogen adsorption-desorption isotherms of PGR-110, PGR-190, PGR-300, and nonporous GR. Inset: Pore size distribution of PGR-110, PGR-190, PGR-300, and nonporous GR.

The XRD pattern of GO in Figure S2 shows a clear peak at 2θ of 10.26°, attributing to the diffraction from its well defined layered structure with an interlayer basal spacing of 0.86 nm, which is bigger to 0.34 nm of the original graphite. The absence of a peak at 10.26° indicates the total change in the regular layered structure of GO. The emergence of different peaks in $NiCo_2O_4$/PGR-110 XRD pattern in comparison to PGR-110 pattern explains that $NiCo_2O_4$ particles were well deposited on PGR-110.

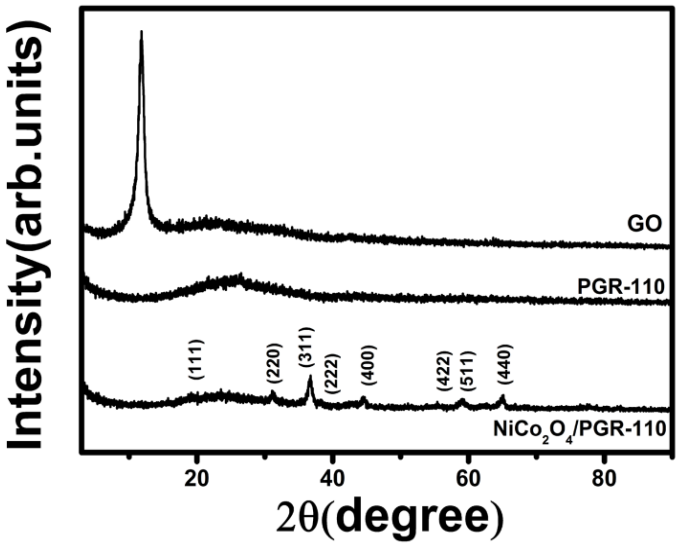


Figure S2: XRD patterns of GO, PGR-110 and $NiCo_2O_4$/PGR-110.

TEM characterization was conducted to determine the microstructures of $NiCo_2O_4$/PGR and $NiCo_2O_4$/GR of which $NiCo_2O_4$/PGR-110 was chosen as a representative of the other $NiCo_2O_4$/PGR samples, $NiCo_2O_4$/PGR-190 and $NiCo_2O_4$/PGR-300. Figure 3A shows TEM image of $NiCo_2O_4$/PGR-110 in which the sheet like structure is normally retained after the formation of porous structure. Many pores around 110 nm were formed by the removal of the SiO_2 particles and are fully seen on the framework of $NiCo_2O_4$/PGR-110 which is illustrating the same information as in SEM image of Figure 1C. Furthermore, the TEM image shows the presence of $NiCo_2O_4$ particles on the PGR-110 plane by white circular images. This is an indication of a successful deposition of $NiCo_2O_4$ on PGR-110. In order to investigate further the structure of $NiCo_2O_4$/PGR-110, the HRTEM imaging was carried out. As shown on the inset of Figure 3A, the $NiCo_2O_4$/PGR-110 exhibits an interspacing of 0.244 nm. In support to the information in TEM image 3A, a porous sheet-like structure with interconnected macropores randomly dispersed on the framework with $NiCo_2O_4$ is revealed by SEM image of $NiCo_2O_4$/PGR-110 in Figure 3B. TEM image of Figure 3C indicates the nonporous structure of $NiCo_2O_4$/GR due to the absence of pores in the GR structure but with $NiCo_2O_4$ particles on its plane shown by white foursquare images, which is agreed by its SEM image in Figure 3D . The absence of SiO_2 in the TEM and SEM images explains the excellent removal of SiO_2 by acid etching. This information obtained from TEM, SEM and XRD indicates no obvious change of the porous structure of PGR-110 after the deposition of $NiCo_2O_4$ particles. This is an indication of a successful deposition of $NiCo_2O_4$ in the PGR-110 framework.

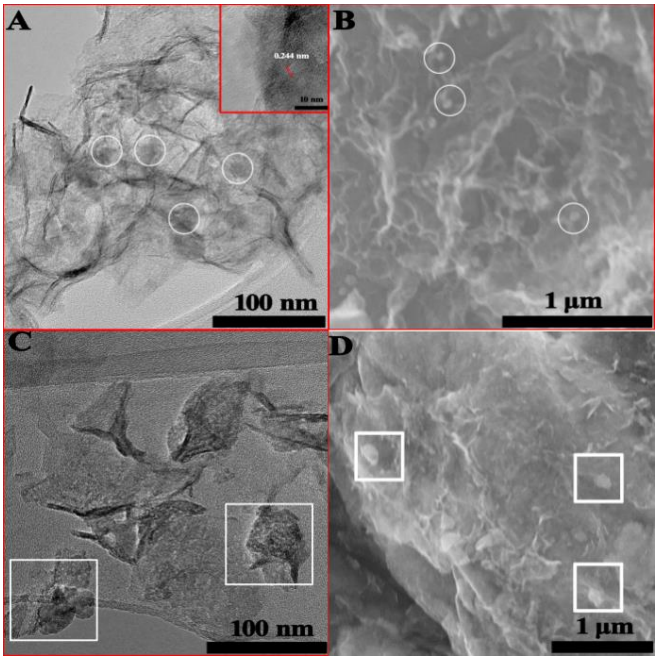


Figure 3: (A) TEM and (B) SEM of $NiCo_2O_4$/PGR-110 (C) TEM and (D) SEM of $NiCo_2O_4$/GR. Inset of (A):HRTEM of $NiCo_2O_4$/PGR-110.

XPS measurements were carried out to determine the elemental composition of $NiCo_2O_4$/PGR-110. Figure 4A shows the survey spectra of GO with dominant peaks of C-O and C=O. The oxygen-containing components of C 1s in Figure 4B are then highly suppressed, indicating the excellent removal of oxygen-containing groups in GO by thermal reduction. The XPS survey in Figure 4C shows no presence of Si 2p in $NiCo_2O_4$/PGR-110 which clearly explains a successful removal of SiO_2 in PGR-110 formation as a template. This indicates no any presence of residue silicon in the sample. Fig. 4D is a survey spectrum of Co 2p at binding energy range of 775-805 eV while Fig. 4E is the Ni 2p spectrum at a binding energy range of 850-880eV in $NiCo_2O_4$/PGR-110. These confirm that the sample has Co and Ni as expected. The XPS survey spectra explain that $NiCo_2O_4$ can be successfully deposited on PGR in agreement with TEM and XRD measurements.

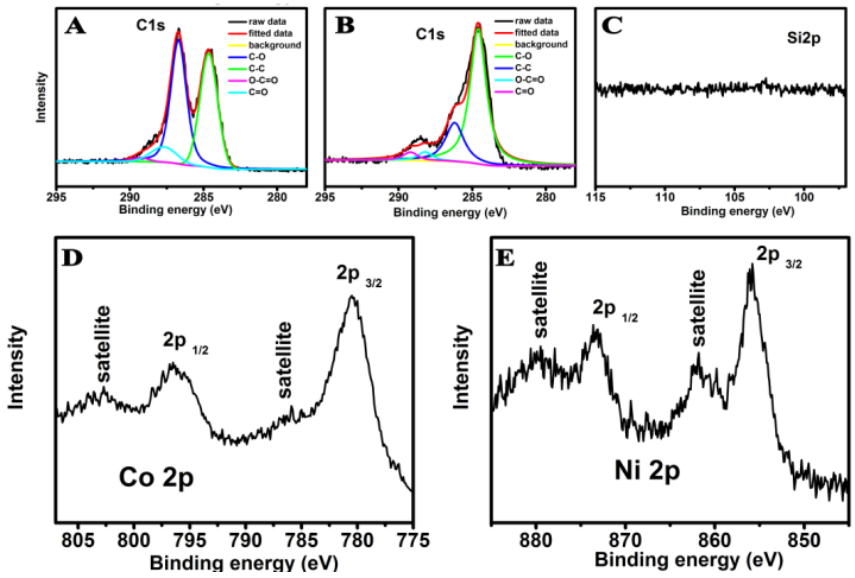


Figure 4: C 1s XPS spectra of (A) GO, (B) $NiCo_2O_4$/PGR-110. (C) Si 2p XPS spectra of $NiCo_2O_4$/PGR-110. (D) Co 2p and (E) Ni 2p XPS spectra of $NiCo_2O_4$/PGR-110

Electrocatalytic performance of $NiCo_2O_4$/PGR-110 for ORR

To determine the ORR activity of $NiCo_2O_4$/PGR-110, the electrocatalytic properties of $NiCo_2O_4$/PGR-110 (black) in O_2-saturated 0.1 M KOH aqueous solution at a scan rate of 50 mV s^{-1} were examined using CV. For comparison, CVs of Pt/C (red), PGR-110 (blue) and $NiCo_2O_4$/ GR (green) in O_2 saturated 0.1 M KOH aqueous solution were also measured. As shown in Figure 5A, the CVs of all the catalysts under the study have specific cathodic peaks, corresponding to the reduction of oxygen. The reduction peak potentials for oxygen are -0.14, -0.20, -0.30 and -0.45 V for Pt/C, $NiCo_2O_4$/PGR-110, $NiCo_2O_4$/GR and PGR-110 respectively (Table S1). The reduction peak potential of oxygen at $NiCo_2O_4$/PGR-110 is positive than that of $NiCo_2O_4$/GR (around -0.35 V) [21]. In addition, the onset potential of $NiCo_2O4$/PGR-110 (-0.12 V) is positive than those of $CoFe_2O4$/GR (-0.136 V) [17], Fe_3O4/nitrogen-doped GR aerogel (-0.19 V) [22], and $CuCo_2O4$/nitrogen-doped GR (-0.14 V vs. SCE) [52]. However, the onset potential is negative than the $MnCo_2O4$/nitrogen-doped GR (-0.09 V) [55] and Mn_3O_4/nitrogen doped GR (-0.075 V vs. SCE) [56]. This indicates a significant positive shift of peak potential for $NiCo_2O_4$/PGR-110 compared to $NiCo_2O_4$/GR, PGR-110 which explains the significant contributions of the porous structure and $NiCo_2O_4$ particles to high electrochemical activity of $NiCo_2O_4$/PGR-110. This is also shown by their peak current densities which are -0.67, -0.61, -0.15 and -0.54 mA cm^{-2} respectively. The deposition of $NiCo_2O_4$ particles into PGR-110 is clearly seen by comparing the electrochemical reduction of oxygen between $NiCo_2O_4$/PGR-110 and PGR-110. This information agrees with a belief that the presence of $NiCo_2O_4$ is also responsible for the high ORR activity. The interactions of Co and Ni with other elements result into a favourable situation for the ORR [25, 51].The presence of active sites for ORR activity in the $NiCo_2O_4$/PGR-110 structure is shown by the big difference in the electrochemical activity of$NiCo_2O_4$/PGR110 and $NiCo_2O_4$/GR. This explains high utilization efficiency of $NiCo_2O_4$ supported on PGR for ORR.

In further determination of the high electrocatalytic performance of $NiCo_2O_4$/PGR-110, RDE experiments were carried out at the Pt/C, PGR-110, $NiCo_2O_4$/PGR-110 and $NiCo_2O_4$/GR electrodes in O_2-saturated 0.1 M KOH at a scan rate of 5 mV s^{-1} and rotation rate of 1600 rpm and the results are shown in Fig. 5B. The current densities at -0.60 V of Pt/C, $NiCo_2O_4$/PGR-110, PGR-110 and $NiCo_2O_4$/GR are around -3.37, -2.82, -1.34 and-1.52 mA cm^{-2} respectively. The inset depicts the onset potentials of Pt/C, $NiCo_2O_4$/PGR-110, $NiCo_2O_4$/GR and PGR-110 which are -0.04, -0.12, -0.16, and -0.18 V respectively. These show that $NiCo_2O_4$/PGR-110 is indeed active electrocatalysts towards ORR that produces much higher electrocatalytic activity closer to commercial Pt/C catalysts in support to the earlier CV experiments. The higher electrocatalytic activity of $NiCo_2O_4$/PGR-110 than of $NiCo_2O_4$/GR can be clearly confirmed by its higher current density which better explains the huge contribution done by the porous structure and high utilization efficiency of $NiCo_2O_4$ for ORR. The presence of the $NiCo_2O_4$ has contributed much to the performance of $NiCo_2O_4$/PGR-110 for ORR in comparison to the electrocatalytic activity of PGR-110. The transition metals or transition metal oxides (such as Ni, Co, Co_3O_4, NiO and spinel) are a class of promising candidates for the ORR [25, 28, 55-59]. Their mixed valencies are beneficial for easy ion transportation and rich redox reactions[7, 25, 26]. Therefore the combined performances of PGR-110 and $NiCo_2O_4$ have made $NiCo_2O_4$/PGR-110 to be excellent catalysts for ORR.

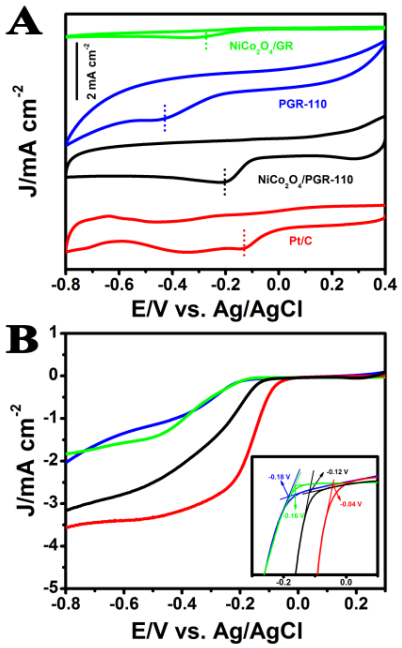


Figure 5: (A) CVs and (B) LSV cures of Pt/C (red), $NiCo_2O_4$/PGR-110 (black), $NiCo_2O_4$/GR (green), and PGR-110 (blue) in oxygen-saturated 0.1 M KOH. Inset of B: the amplification of LSVs for Pt/C, $NiCo_2O_4$/PGR-110, $NiCo_2O_4$/GR, and PGR-110. Scan rate of CVs: 50 mV s^{-1}. Scan rate of LSVs: 5 mV s^{-1}. Rotation rate: 1600 rpm.

The surface area and pore size of a catalyst support can be easily altered through the use of template of different size. An experiment was carried out to determine the effect of pore size on electrocatalytic performances of $NiCo_2O_4$/PGR samples. Figure 6A compares CV results in determining pore size effect on ORR activity in 0.1 M KOH solution at $NiCo_2O_4$/PGR-110 (solid line), $NiCo_2O_4$/PGR-190 (dash line) and $NiCo_2O_4$/PGR-300 (shot dot line) electrodes.

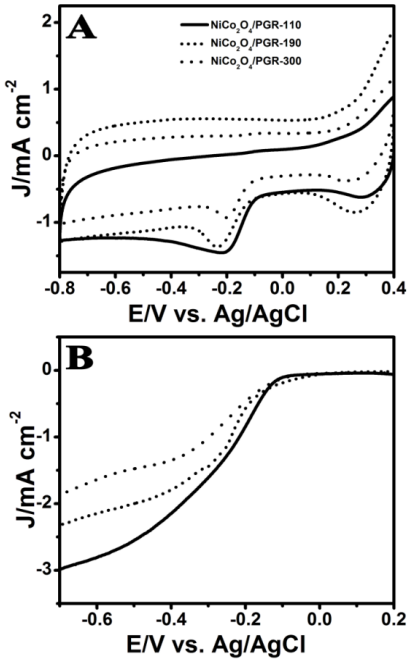


Figure 6: (A) CVs and (B) LSVs of $NiCo_2O_4$/PGR-110 (solid line), $NiCo_2O_4$/PGR-190(short dot), and$NiCo_2O_4$/PGR-300 (short dash) in oxygen-saturated 0.1 M KOH. Scan rate of CVs: 50 mV s^{-1}. Scan rate of LSVs: 5 mV s^{-1}. Rotation rate: 1600 rpm.

A high electrocatalytic performance is observed at $NiCo_2O_4$/PGR-110 with a peak current density of about -0.61 mA cm^{-2} compared to-0.53 mA cm^{-2} at $NiCo_2O_4$/PGR-190 and -0.49 mA cm^{-2} at $NiCo_2O_4$/PGR-300 and reduction peak potentials of -0.20, -0.22, and -0.20 V for $NiCo_2O_4$/PGR-110, $NiCo_2O_4$/PGR-190 and $NiCo_2O_4$/PGR-300 respectively. This result indicates the high electrocatalytic performance of $NiCo_2O_4$/PGR-110 compared with the other samples. This is due to its large surface area which provides more opportunity for the exposure of $NiCo_2O_4$. The use of large particle size template led to low surface area of PGR-300 which is not essential or favorable for the exposure of $NiCo_2O_4$. $NiCo_2O_4$ was less utilized in PGR-300 due to the low surface area. This has led to a low electrocatalytic performance of $NiCo_2O_4$/PGR-300 compared to $NiCo_2O_4$/PGR-110 and $NiCo_2O_4$/PGR-190. This information is in agreement with RDE results in Figure 6B in which the current densities of $NiCo_2O_4$/PGR-110, $NiCo_2O_4$/PGR-190 and $NiCo_2O_4$/PGR-300 are -2.82, -2.16 and -1.66 mA cm^{-2}respectively at -0.60 V. Both CV and RDE results show that $NiCo_2O_4$/PGR-110 is of high electrocatalytic activity than the other two catalysts. This indicates large contribution of particle size on the electrochemical performance of catalysts in ORR.

To investigate more into the electron transfer kinetics involved in the ORR, the RDE experiments of $NiCo_2O_4$/PGR-110 in the O_2-saturated 0.1 M KOH solution under different rotating rates were further examined. As shown in Figure 7A, the measured current densities show an increase with increasing rotating rate due to the facilitated diffusion of the electrolytes. The corresponding Koutecky-Levich plots (Figure 7B) at different electrode potentials show good linearity. The electron numbers *n* transferred per O_2 molecule involved in the oxygen reduction at $NiCo_2O_4$/PGR-110 electrode was determined by analyzing the diffusion and kinetically limited regions, using the Koutecky-Levich (K-L) equation. The link between *n* and potential at $NiCo_2O_4$/PGR-110 is given by Figure 7C. The *n* value for $NiCo_2O_4$/PGR-110 is estimated to be 3.87, indicating a 4 electron pathway. The ORR in alkaline solution occurs either via the four electron reduction pathway where O_2 is directly reduced to OH^- or the two electron transfer reduction pathway in which H_2O_2 is formed as an intermediate. The 4 electron pathway is generally preferred because it gives a fast oxygen reduction rate. Therefore the electron transfer kinetics at $NiCo_2O_4$/PGR-110 was further investigated by the RRDE measurements. Fig. 7D shows RRDE results at $NiCo_2O_4$/PGR-110 and Pt/C in which the *n* value was further determined in Fig. 7E. The *n* value was found to be between 3.85-3.93 in the potential range of -0.8 to -0.30 V. This agrees with the 4 electron pathway indicated in Fig. 7C. The link of H_2O_2% and potential at $NiCo_2O_4$/PGR-110 and Pt/C is shown by Figure 7F. The result shows a low H_2O_2% of less than 25% at $NiCo_2O_4$/PGR-110 during the experiment but decreased with a decrease in the potential. The low production of H_2O_2 and estimated four-electron transfer suggest that oxygen reduction undergoes mainly four electron pathway by direct reduction of oxygen to OH^-.

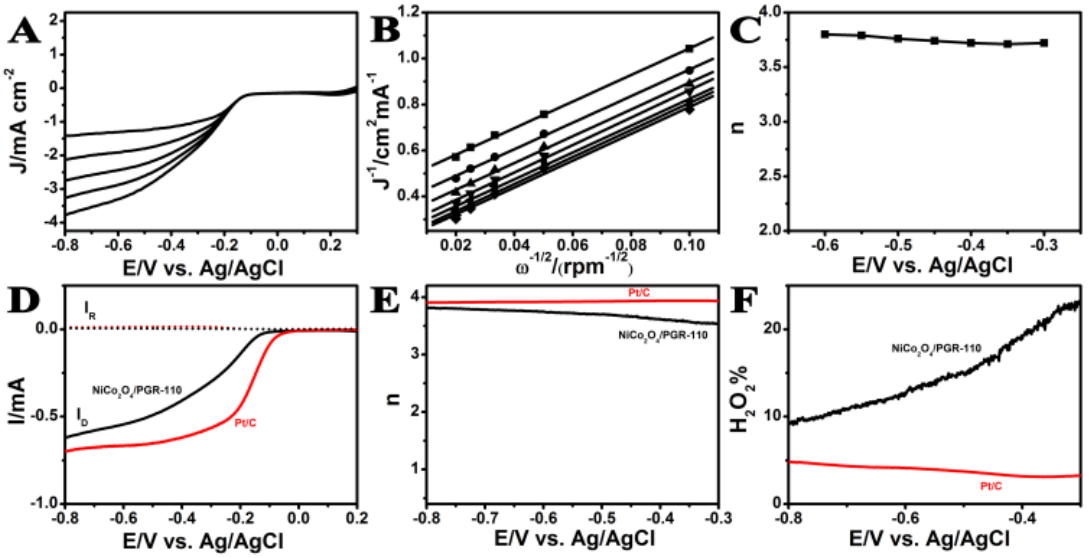


Figure 7: (A) RDE ORR curves of $NiCo_2O_4$/PGR-110 electrode at rotating rates: 100, 400,900, 1600, 2500 rpm in oxygen--saturated 0.1M KOH solution scan rate $5mVs^{-1}$.(B) K-L plots of the $NiCo_2O_4$/PGR-110 electrode from data extracted in Fig. 7A.(C) The relation between *n* and potential at $NiCo_2O_4$/PGR-110 electrode.(D) RRDE curves of Pt/C (red) and $NiCo_2O_4$/PGR-110 (black).(E) The relation between *n* and potential at Pt/C and $NiCo_2O_4$/PGR-110.(F) The relation of H_2O_2yield (%) and potential at Pt/C and $NiCo_2O_4$/PGR-110.

Stability of $NiCo_2O_4$/PGR-110

The stability and tolerance to crossover of ORR are major concern in FCs. The superiority of $NiCo_2O_4$/PGR-110 as electrocatalysts for the ORR is further demonstrated by evaluating their stability and tolerance toward methanol. Figure 8A shows the durability evaluation at $NiCo_2O_4$/PGR-110 and Pt/C electrodes at a rotation rate of 1600 rpm. The result indicated a small decrease of current of about 18 percent at $NiCo_2O_4$/PGR-110 compared to a large decrease at Pt/C of about 35 percent after 30,000s maintaining the recommended stability for the entire process. Figure 8B shows that $NiCo_2O_4$/PGR-110 is stable and much immune to methanol crossover effect. The introduction of methanol in KOH solution at 800 s has no greater effects on the oxygen reduction activity. This is different to the Pt/C in which its original activity changes heavily upon addition of methanol which can be due to oxidation of methanol at Pt/C. This implies that $NiCo_2O_4$/PGR-110 may perform as methanol-tolerant catalysts in FCs since the long-term stability and tolerance of catalysts are of major consideration in FCs.

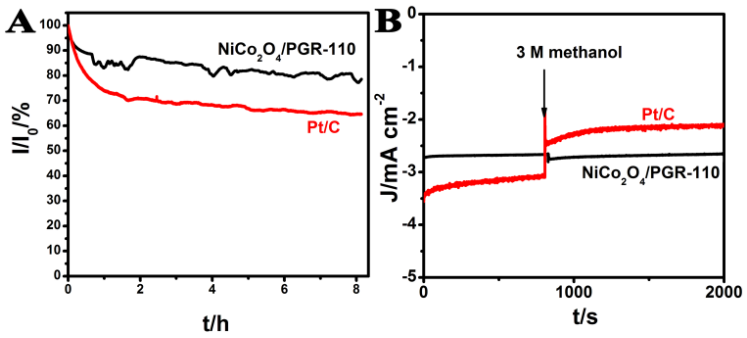


Figure 8: (A) Durability evaluation of $NiCo_2O_4$/PGR-110 (black) and Pt/C (red) after 30,000s (almost 9 h) at a rotation rate of 1600, (B) Current-time response for $NiCo_2O_4$/PGR-110 and Pt/C with addition of 3M methanol in 0.1M KOH electrolyte at 800s.

CONCLUSION

In summary, $NiCo_2O_4$/PGR-110 with sheet porous structure was prepared by using SiO_2 as a template with surface functionalization of $-NH_3$ groups which resulted into large surface area of $NiCo_2O_4$/PGR-110. The surface area and porous structure are essential for the exposure of $NiCo_2O_4$ and also create a high utilization efficiency of $NiCo_2O_4$ for ORR. $NiCo_2O_4$/PGR-110 exhibits excellent catalytic activity for ORR in alkaline solution with better long term stability and tolerant to methanol than commercial Pt/C catalysts. The study also indicates that the size of SiO_2 template affects much on the electrocatalytic activity for oxygen reduction. The activity decreases with the increase in the particle size due to the creation of small surface area as obtained from N_2 adsorption desorption isotherm, which is assumed to cause the low activity of $NiCo_2O_4$/PGR-300 as compared to $NiCo_2O_4$/PGR-110 and $NiCo_2O_4$/PGR-190. The reaction kinetics study confirms that the oxygen reduction at $NiCo_2O_4$/PGR follows a 4 electron pathway with excellent long-term stability and tolerance to crossover effect to methanol. Therefore, $NiCo_2O_4$/PGR-110 may be taken as a potential efficient, less expensive and environmental friendly catalysts in replacement to Pt/C.

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Bioenergy Potential and Future Prospects in Malawi

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ABSTRACT

Future energy security and environmental issues are major driving forces for increased biomass utilization globally and especially in developing countries like Malawi. In order to enhance energy security while reducing environmental impact, the government of Malawi has established a policy to develop domestic energy resources to increase energy stability and to sufficiently meet the future demand. Bioenergy is one of the renewable energy sources that can readily replace fossil fuels, while helping to reduce greenhouse gas emissions and promoting sustainable rural development. This paper applied a scenario-based analysis to explore Malawi's future energy demand, supply and associated greenhouse gas emissions from 2015 to 2050 using the Long-range Energy Alternatives Planning (LEAP) model. It analyzes the feasibility of future scenarios based on moderate and high use of biofuels in the transportation and electricity generation sectors with the aim of determining their possible impact on the Malawian energy system. This work also evaluates the efficient use of biofuels in the residential sector, particularly in the rural sub-sector. Three scenarios are enacted over the study period (2012-2050) which include business-as usual (BAU), moderate penetration (MOD), and high (enhanced) growth (HG). In the base scenario, fossil fuels are assumed as the dominant source of energy, where as in the two alternative scenarios moderate and high biofuel penetration diffusion curves are constructed and discussed on the basis of their technical and economic feasibility. Simulation results indicate that the use of ethanol, biodiesel and electricity obtained from primary biomass may account for 12% of the total energy consumed in the high scenario for all selected sectors. CO_2 emission reduction-including the emissions saved from the reduction in the non-sustainable use of fuelwood in the rural residential sector-is equivalent to 67.25 million tons of CO_2 and would account for 14% of the CO_2 emitted by electricity supply and transportation sectors when the base and high scenario are compared by 2050.

Keywords: Biofuels, Bioenergy, Greenhouse gas mitigation, LEAP model

INTRODUCTION

As in most less developed countries, Malawi faces the dual challenges of pursuing economic growth and environmental protection. In order to promote economic development and environmental protection it is imperative for the country to consider new paradigms for energy production and consumption, thus incorporating the exploitation of its renewable energy resources. Bioenergy is considered as one of the key renewable energy sources of the future owing to its large potential, economic viability and various social and environmental benefits (Hall & House, 1995; Johansson et al., 1993). Bioenergy is also promoted due to its potential to offer benefits such as the development of a new export industry; increased employment, income and livelihood activities; reduced reliance on foreign fossil fuel reserves; improved security of energy supply (Berndes & Hansson, 2007; Meyer et al., 2008; Sharma et al., 2016).

Bioenergy can help secure energy supply and mitigate climate change by reducing greenhouse gas (GHG) emissions by displacing petroleum in the transport sector, by displacing fossil-based electricity, and sequestering atmospheric carbon (Lemoine et al., 2010; Okudoh et al., 2014). It offers an attractive solution as a renewable energy source that can address rural energy gaps and generate employment in the rural areas. Biomass is considered as a potential resource for meeting increasing demand, substituting fossil resources, as well as contributing to the policy goals of combating climate change, securing energy supply, stimulating the rural economy, and to the broader goal of sustainable development (Fujino et al., 1999; Koh & Hoi, 2003; Verdonk et al., 2007; Yue et al., 2001). It is abundantly available in considerable quantities within Malawi. Moreover, biomass is a versatile energy source that can be used for the production of heat, power, transport fuels as well as bio-based materials and chemicals (Slade et al., 2014).

Biomass resources are potentially the world's largest and most sustainable energy resource, comprising approximately 220 billion oven-dry tonnes (or 4500 EJ)[1] of annual primary production. Worldwide, biomass ranks fourth as an energy resource, providing approximately 10% of total primary energy supply (50 EJ $year^{-1}$) ; represents 14% out of 18% renewable energy in global energy mix; and accounts for roughly 80% of the energy derived from renewable sources (IEA, 2009; WEC., 2016). Biomass contributed 370 TWh of electricity production in 2012 (IEA, 2016). Biomass is also the most important source of energy in developing countries, providing ~38% of their energy, particularly in rural areas where it is often the only accessible and affordable source of energy (Dumanli et al., 2007). Estimates of the resource base have varied widely in the past, but a range 200 - 400 EJ yr^{-1} has been proposed (Jurginger et al., 2006). IEA (2008) has projected that bioenergy could supply over 20% of the world's primary energy by 2050. UNFCCC (2008) has claimed bioenergy can supply 800 EJ yr^{-1}, which is far more than total world energy use today. The IPCC Special Report on Renewable Energy (SRREN) suggests that the global bioenergy potential could be as high as 500 EJ yr^{-1}, compared to current fossil energy use (Chum et al., 2012). van Zyl et al. (2010) suggest that 0.1 EJ yr^{-1} is the moderate value of the Malawian bioenergy potential whereas 0.5 EJ yr^{-1} is a high estimation.

Malawi is one of the countries that is experiencing a severe energy crisis leading to adverse social and long term economic problems. The country is faced with chronic electricity crisis that has resulted in the crippling of most sectors of the economy. NSO (2017) estimates that only 11% of Malawians are connected to the national grid and the connected populations are exposed to frequent power outages. Overall, the nation's power generation units have been chronically unable to meet system demand over past decade. Primary energy supplies of the country consist of hydropower, biomass, petroleum products, coal and other renewable energy sources. In 2008, the total primary energy use in Malawi was estimated at 4125.97 ktoe in which 2.8% was from hydroelectricity, 6.4% from petroleum, 2.4% from coal and 88.5% from biomass (Gamula et al., 2013; Taulo et al., 2015). Traditional biomass fuels represent about 3640 ktoe or 97% of the primary energy consumption, of which 59% is used in its primary form as firewood (51%) and residues (7%), while the remaining 41% are converted into charcoal (Kambewa & Chiwaula, 2010; NSO, 2017). More than 90% of the biomass consumption in the country is for cooking and heating purposes in domestic and commercial sectors; nearly 90% of the population depends on fuel wood and other forms of biomass for their daily cooking (Makungwa et al., 2013). Traditional biomass use, mainly for cooking and heating is characterized by low efficiency of use and drudgery (Karekezi & Ranja, 1997). The unsustainable extraction and use of traditional biomass energy leads to: degradation of the local environment and forests; deforestation, and the consequent loss of forest products; soil erosion and loss of biodiversity; and domestic air pollution affecting human health (Sudha et al., 2003).

[1] EJ = 1 Exajoule = 10^{18}J = 1000 Petajoule

In Malawi, biomass appears as one of the most promising alternatives energy sources for electricity generation, due to the large amount of agricultural, forest and livestock activities. In addition, biomass is widely available, less intermittent and uniformly distributed, when compared to some renewable sources, such as wind power and solar photovoltaic, among others. Several drivers provide impetus for promoting development of the bioenergy sector in Malawi. On the one hand, the increasing reliance on fossil fuels in problematic. Lacking abundant supply of domestic fossil-based energy resources, the country is obligated to import a large amount of petroleum products to meet domestic demand. Not only does petroleum consumption cost the country a huge amount of foreign currency, arising with it is a concern about environmental quality. On the other hand, bioenergy has the potential to become a fundamental piece in a sustainable energy system, contributing not only to the country's energy diversification strategy but also to the appropriation of emerging energy technologies. It can contribute to the reduction of greenhouse gas emissions, the generation of new jobs in rural areas and the improvement of income distribution. Furthermore, the resulting substitution of current energy imports, mainly petrol and diesel, is important for economic and national security reasons. The country also aims to increase its percentage of energy derived from renewable energy resources from 0.4% in 2008, to 7% by 2020, and 10% by 2050. Biomass energy could contribute to achieving this goal but currently only a small fraction of total renewables.

Energy models are used in policy making to assess future energy demand, the impacts on the economy and environment, as well as the economic, environmental, and social impacts of technology, and policy choices. Modelling tools are required to explore and quantify scenarios. The existing long-term energy and emission scenarios that have been developed are either heavily aggregated at the regional levels or they are focused on the industrialized countries except in few cases (Shrestha et al., 2007). For example, Fischer and Schrattenholzer (2001) and (Berndes et al., 2003) have reviewed global studies on bioenergy potentials, and it appears that despite the optimistic expectations regarding future use of bioenergy, there is lack of studies analyzing economic potentials and impacts. In particular, there appear to be lack of studies addressing important link between agricultural and raw markets, including for example alternative uses of wood, and the bioenergy market. Also, impacts on other sectors-such as forestry, forest industries and other agriculture-of a growing bioenergy sector do not seem to be clearly understood, probably due to limited availability and use of models integrating the different sectors in appropriate ways.

Motivated by this fact and the rapidly changing economic and demographic structures in developing countries, it is of interest to have country specific assessments of energy system development and its associated environmental implications in developing countries over a long-term. There are no sector specific studies focusing on interrelationship between biomass use and the environment in Malawi. In this study, three different scenarios are created for electricity generation, transportation and the residential sector up to the year 2050. The hypotheses of such scenarios are based on the behavior of macroeconomic variables as well as the substitution of fossil fuels for biofuels. Particular assumptions are applied for each scenario and energy consuming sector in order to simulate annual growth of biofuel use. In the case of residential sector, this assumption is related to the use of more efficient wood-burning and biogas stoves. Furthermore, a profile of bioenergy consumption has been obtained for all sectors considered in each scenario. Finally, the corresponding amount of avoided CO_2 emissions is calculated using the IPCC emissions factors.

The paper is structured as follows: Section 2 describes the methodology used in this study elaborating the model, formulation of policy scenarios, and the relevant data used with the source. Analyses of results and key findings are presented in Section 3. The final section provides the conclusion.

MATERIALS AND METHODS

Model structure and sectors

This study was done with the 2017 version of the LEAP (Long-range Energy Alternatives Planning system) model (Heaps, 2016). The LEAP model was developed by the Stockholm Environmental Institute (SEI) and Boston University (Zhao et al., 2011). LEAP is a widely-used software tool for energy policy analysis and climate change mitigation assessment. It can be used to develop various scenarios of projected energy demand and environmental impact based on how energy is consumed, transformed, and generated in a given region or economy under a range of values for parameters such as population increase, gross domestic product, income, etc. (Cai et al., 2008).The LEAP model uses a bottom-up approach wherein end-use technology-level data are used to develop long-term and high-level scenarios (Mondal et al., 2010; Shin et al., 2005). It is a best suited for forecasting energy systems in the mid to long term (typically between 20 and 50 years (Connolly et al., 2010). Furthermore, it allows the evaluation of the corresponding environmental emissions of different energy policies and technologies in energy consumption and supply. LEAP has a flexible data structure when compared with top-down and other hybrid models. It is also rich in technical and end-user details (Emodi et al., 2017; Yang et al., 2017). Thus, LEAP is useful for analyzing current energy patterns and to simulate alternative energy futures, along with environmental emissions under a range of user-defined assumptions. More information regarding the LEAP modelling tool can be found in (Heaps, 2016).

LEAP has been widely used for system analysis and energy planning on local, regional, and national levels (Connolly et al., 2010; Guo et al., 2003; Huang et al., 2011; P. Manzini et al., 2001; Urban et al., 2007). Areas of application range from the electricity sector (Cai et al., 2007; Islas et al., 2002) to the industrial sector (Cai et al., 2007; Kumar et al., 2003), the transportation sector (Islas et al., 2007; F. Manzini, 2006; Shabbir & Ahmad, 2010), and the residential and commercial sectors (Davoudpour & Ahadi, 2006; Kadian et al., 2007; Yanbing & Qingpeng, 2005). LEAP can simulate the costs associated with each technology (both capital and operating costs) as well as the external costs of environmental pollutants (Connolly et al., 2010). It has a built-in technology environmental database (TED), which includes the emission factors for different technologies and different fuels.

The LEAP modelling method is based on building an energy use and supply database and extending it to simulate various long-term energy scenarios. The developed scenarios can be studied further in terms of emissions and costs for a particular region or country (Suganthi & Samuel, 2012). The model consists of four modules: demand, transformation, resource, and a technology and emissions database. It is flexible enough to allow for the configuration of the analysis of energy demand on its own. However, it is typically used with the optional analysis of energy transformation (conversion of primary energy into secondary energy forms), and resources (system primary energy resources) for energy balance comparison and energy system simulation. Further details can be found elsewhere (Heaps, 2016; Suganthi & Samuel, 2012).

Several methods of energy demand analysis can be applied to calculate energy use per demand sub-sector. In the case of the model developed for this study, main economic activities were used as a means of disaggregating the energy demand into five sectors: residential, commercial, industrial, agricultural, and transportation. The main emphasis of this model was on three largest demand sectors; industrial, transport and residential, with simpler representation of the agriculture and commercial (service) sectors. Each individual demand sector is disaggregated into sub-sectors, end-use, and technologies which consume and convert to energy services. End-use and energy technologies are characterized by a set of parameters, such as penetration rate, saturation share, fuel consumption, energy efficiency, energy intensity, and activity drivers.

Data and data sources

The data used in the model range from technology-level energy intensity data to macroeconomic data such as gross domestic product (GDP), population growth, and fuel price projections. Data were obtained from various publically available database and the literature, such as statistical information, government publications of official energy data, utility statistics, journal articles, book chapters, research reports, and also through consultation with experts. The principle sources are Ministry of Natural Resources, Energy & Mining, National Statistical Office, Ministry of Finance and Economic Planning, and Road Traffic Directorate. Data obtained from the original source were processed to meet the input requirements in LEAP model to develop a base year data set.

Key Assumptions

To use LEAP model, the data needs to be organized in current accounts such as types of energy intensity, activity level of energy uses, population, growth rate, GDP, etc. In 2008, Malawi's population was 13.1 million (NSO, 2008) with the national gross domestic product (GDP) of 5.7 billion dollars (CIA, 2015). Based on an estimate, Malawi's population will increase with an average growth rate of 2.8% per year, with the annual GDP growth rate of 5.4% up to 2031 (GoM, 2011). In this study, the population and the GDP growth rate are assumed to be stable and continuing to grow at that same rate until the end of 2050. According to the National Statistical Office (NSO), the average household size in the whole country is 4.7 persons (NSO, 2008). The household size in Malawi is also assumed to be the same through the base year until the end year of this study. Urbanization is the main factor to limit the urban and rural population. Based on the world development indicators, urban area in Malawi will increase to around 50% in the year 2050, while in the base year, the urban area is 20% (UN-HABITAT, 2010).

Scenario description

The year 2015 is chosen as the base year for the study. The actual demand side energy intensity of energy technologies and the projections of the energy supply side development are determined based on the data available from the National Statistical Office and historical energy system evolution between 1996 and 2008. Base year macroeconomic data such as population, GDP, the number of households, and the projections of future growth of these factors are used to develop different scenarios for the time horizon 2015 – 2050. Three scenarios are constructed to predict future energy requirements these include Business-as-usual (BAU) scenario, which is a reference (REF) scenario and two alternative scenarios which include Moderate diffusion (MOD) and High growth (HG) scenario. These scenarios are primarily governed by four factors: economic growth, proportion of energy types, efficiency of energy devices, and energy intensity.

Business-as-usual scenario

In this scenario, fuels derived from biomass, petroleum and hydropower are assumed as the most-used options. Thus, in the power sector, all new capacity additions are based on hydroelectricity. In the residential sector, biomass is the most used fuel in both urban and rural areas. With regard to the transportation sector, petrol, paraffin and diesel are the most used fuels.

Due to the lack of recent data, 2015 was selected as the reference year. Malawi's 2015 energy balance is reproduced in LEAP's Demand and Transformation programs. In so doing, future energy demand of the following end-use sectors can be calculated: household, industrial, transport and sector self-consumption. After this, and based on (CIA, 2015; GoM, 2011; UN-HABITAT, 2010), the following assumptions are used: (i) constant economic growth-gross domestic product (GDP) of 5.4%, (ii) constant population growth of 2.8% and 37 million inhabitants by year 2050 (MEPD, 2010). (iii) Constant end-use demand structure. (iv) Energy and electricity demand grows at 5.4% per year-same as GDP. (v) The installed power capacity increases by 281% (850 MW installed between 2011 and 2021) up to the year 2021 (MCA, 2009). After 2021, the installed power grows at 3% per year. Three percent of the new electricity requirements is devoted to satisfy the peak power

demand by geothermal and biogas.

Malawi's GDP of 5.4% is calculated considering its historical behavior: GDP grew at an average annual growth rate (AAGR) of 2.1% between 1998 and 2005, but it fell to 1.2% in 2002. After 2006, it grew at an average annual growth rate of 7.5% and then reached 9.7% in the year 2009 (World Bank, 2009). Thus, the 5.4% value chosen for this study is exactly the historical average annual growth rate of Malawi's GDP between 1964 and 2009. Likewise, Malawi's electricity demand of 5.3% is calculated according to its historical behavior: electricity demand grew at an AAGR of 6.8% between 1966 and 2008, but it fell to 4% in the 1990s. From 1980 to 2008, the growth rate of electricity demand had always been greater than the GDP AAGR. However, and due to improvements in energy efficiency of end-use technologies, this difference has been decreasing. Hence, it is assumed that this tendency remains and reaches zero by 2015 and 0.8% below the GDP AAGR by the year 2050. The electricity demand AAGR is 6% between 1996 and 2050, identical to the assumed GDP AAGR. According to this historical path, installed power capacity grew at an AAGR of 0.5% below the electricity demand AAGR from 1965 to 2008. Therefore, it is assumed that this capacity grows at an AAGR of 2% after year 2015. Table 1 shows the input data values for all macroeconomic variables in 2008 and their corresponding annual growth rates thereafter.

Alternative bioenergy scenarios

As previously mentioned, Malawi's technical bioenergy ranges from 100 PJ to 500PJ/year (Fischer & Schrattenholzer, 2001). This potential is equivalent to 27% and 75% of the Malawian primary energy supplied in 2008 (134PJ), respectively. Table 2 shows this potential classified by different type of bioenergy sources. Wood fuel contribute with up to 67% of this bioenergy potential, farming fuels with 23% and organic municipal solid wastes (MSW) with just 15%. As of 2002, bioenergy use in Malawi amounted to 105 PJ and accounted for 95% and 21% of the estimated potential, respectively. In the two alternative scenarios, the substitution of fossil fuels for biomass fuels is analysed in all selected economic sectors. Thus, moderate and high bioenergy penetration scenarios are simulated. Table 3 shows the biofuels and energy technologies that can replace fossil-based options in electricity generation-including cogeneration and electricity for self-supply purposes-traditional cookstoves in the household sector, and diesel and petrol in the transport sector.

Table 1: Values of Malawian macroeconomic variables in 2015

Variable	***Units***	***Value (2015)***	***AAGR***
Population[2]	10^6 inhabitants	16.9	3.1%
GDP[3]	Billion of current USD	5.474	
Installed power capacity[4]	MW	351	

Table 2: Bioenergy resource potential in Malawi evaluated in 2015

Bioenergy sources	Energy potential(PJ/year)
Woody biomass	4270.3
From natural forests	-
From forest plantations	-
Residues from sawmills and forest extraction	-
Farming fuels	
From crop residues	96.9
Residues from agro-industry	2.2
Animal wastes	-
From energy crops	583.5
Municipal waste residues	-
Total	4952.9

Source: Gondwe et al. (2017), Taulo et al. (2015)

The emerging phase is characterized by high average annual penetration rates that range from 30 to 50% owing to the process of innovation. When innovation is introduced, its adoption begins from almost zero. The penetration rate grows exponentially with the awareness of the new technology and the number of early adopters. In this paper, the emerging phase is generally divided in two stages, both with high values, but in the second stage the diffusion rate decreases due to the high growth. The emerging phase ends when selected biofuel energy technology options cover from 6.5% to 9.55 of the fuels substituted in the base scenario. High and moderate bioenergy scenarios assume that biofuels are introduced in electricity generation, transportation and household sectors at different penetration rates, which reflects its diffusion during the emerging and maturity phases. Table 4 shows, for most cases, the emerging phase –divided in two stages and their corresponding penetration rates-with the purpose to reflect its slowing pace after a quick start. These penetration rates are assumed to be feasible from a technical, economical and institutional point of view.

Table 3: Emerging and commercially available biofuel-energy technology options that allow fossil fuels to be substituted with biofuels

Biofuel	***Energy technology***	***Substitute fuel/technology***
Commercially available		
Biogas from sanitary landfills	Gas turbines	Residual fuel oil in steam turbines
Forest and crop residues	Incinerators	Residual fuel oil in steam turbines
Any petrol and ethanol blending	Flexible internal Combustion engines (ICE)	Petrol ICE and Ethanol ICE
Biodiesel	Diesel ICE	Diesel
Fuelwood	Efficient wood burning stoves	Traditional fuelwood stoves
Cattle residues	Biodigesters and biogas stoves	Traditional fuelwood stoves
Emerging		
Forest plantations, forest residues and bagasse	Biomass integrated gasification combined cycle (BIGCC)	Natural gas combined cycle (NGCC)

Table 4: Assumed AAGR in the emerging and maturity phases of the considered biofuel-energy technology options up the year 2050

	Emerging phase		Maturity phase
	1st stage	2nd stage	
Electricity generation			
Residues-incinerators	2010-2020	2021-2035	2036-2050
High scenario (%)	38.0	31	20
Moderate scenario (%)	30.0	22	17
Biogas from landfills and cattle residues	2010-2020		2036-2050
High scenario (%)	24		18
Moderate scenario (%)	18		16
Energy plantations	2015-2050		
High scenario (%)	38		
Moderate scenario (%)	31.4		
Baggasse-BIGCC	2015-2025		2026-2050
High scenario (%)	10		8
Moderate scenario (%)	8		5
Transport sector			
Ethanol-ICE	2012-2018	2019-2030	2031-2050
High scenario (%)	45	30	20.5
Moderate scenario (%)	40	30	13
Biodiesel ICE	2012-2018	2019-2030	2031-2050
High scenario (%)	30	28	22
Moderate scenario (%)	20	18	15
Household sector			
Fuelwood-efficient cookstoves	2013-2020	2021-2035	2036-2050
High scenario (%)	50	35	21.7
Moderate scenario (%)	45	32	19.6

RESULTS AND DISCUSSIONS

This section presents the results obtained from the simulation using the LEAP program as well as an assessment of the physical and environmental effects of the previously discussed alternative scenarios.

Electricity generation

In the high-penetration scenario, all four biomass-based energy-technology options for electricity generation, this capacity would reach an installed power capacity of 387 MW by 2015 and 1931 MW by 2050. In terms of electricity generation, this capacity would produce 12 PJ in 2015 and 61 PJ in 2050. Bioenergy input requirements would account for 7.1% and 18.2% of the total energy consumed in the electricity sector by 2015 and 2030, respectively. With regard to the avoided CO_2

emissions, they would represent 0.7% and 15.5% of the base scenario's emissions in 2015 and 2050. These figures would amount to 0.6 and 21.6 million tons by 2015 and 2050, respectively (see Table 5).

In the moderate scenario, all four biomass-based energy technology options for electricity generation would reach an installed capacity of 19 MW by year 2015 and 38 MW by year 2050. This power capacity may represent an annual electricity generation of 4 PJ in 2015 and 130 PJ in 2050. Bioenergy input requirements would account for 0.5% and 5.2% of the total energy consumed in this sector by 2015 and 2050, respectively. CO_2 emissions would be reduced by 2.3% and 10.3% with respect to the base scenario in years 2015 and 2050, respectively. This reduction would be equivalent to 0.3 million tons of avoided CO_2 by 2015 and 8.2 million tons by 2050.

Transport sector

Ethanol

In the high-penetration scenario, ethanol consumption would grow from 0.689 PJ in 2015 to 0.977 PJ in 2050. Ethanol's contribution would be 0.68% and 7% of the total energy used in the transport sector by 2015 and 2050, respectively. The participation share of ethanol in the petrol vehicle sector would be 1.27% in 2015 and 16% in 2050. The corresponding non-biogenic CO_2 avoided emissions would add up to 1.23 million tons in the year 2015 and 32.07 million tons of CO_2 in 2050. This reduction in CO_2 emissions would account for 1.27% and 16%, respectively, when compared with petrol emissions.

In the moderate scenario, bioethanol consumption would reach 0.4 PJ in the year 2015 and 0.69 PJ in 2050 and would be equivalent to only 0.48% and 6.71% of total energy use in the transportation sector, respectively. The participation share of ethanol in the petrol vehicle sector would be 0.8% in 2015 and 5% in 2050. With regard to the corresponding avoided non-biogenic CO_2 emissions, this scenario would add up to 0.77 million tons in the year 2015 and 12.34 million tons of CO_2 in 2050. These avoided emissions would represent a reduction of 0.6% and 6% in CO_2 emission levels.

Biodiesel

In the high penetration scenario, biodiesel consumption would grow from 3PJ in 2015 and 14 PJ by 2050. Biodiesel's participation in the transport sector would be 0.2% and 2.4% of the total energy consumed by diesel-fueled vehicles in 2015 and 2050, respectively. The participation share of biodiesel in the diesel vehicle sector would be 1.3% in 2015 and 23% in 2050. Additionally, the corresponding avoided CO_2 emissions would sum up to 0.72 million tons 2015 and 21.6 million tons in 2050. This reduction in CO_2 emissions would account for 1.3% and 15%, respectively, when compared with diesel emissions.

In the moderate scenario, biodiesel consumption would reach 4.2 PJ in 2015 and 67 PJ in 2050 and would be equivalent to 0.3% and 2.7% of total energy used in the transportation sector, respectively. The contribution of biodiesel to the diesel vehicle sector would represent 0.9% and 7.8% of the participation share in 2015 and 2050. Total avoided CO_2 emissions would amount to 0.51 million tons in the year 2015 and 7 million tons in the year 2050, corresponding to a reduction in CO_2 emissions of 0.92% and 10%, respectively, when compared with diesel emissions (see Table 8).

Ethanol and biodiesel

In the high penetration scenario, ethanol and biodiesel consumption would reach 20 PJ in 2015, increasing up to 110 PJ in 2050. The contribution of these biofuels to the total amount of energy used by the transport sector would be 1.02% in 2015 and 20.19% in 2050. Furthermore, biofuels would participate with 1.2% and 17% of the share in diesel and petrol vehicle sectors by 2015 and 2050. Avoided emissions of non-biogenic CO_2 would amount to 1.95 million tons of CO_2 in 2015 and 49.43 million tons in 2050. This would represent a reduction of 1.28% and 19.67% by 2050.

In the moderate scenario, ethanol and biodiesel consumption would reach 21 PJ by 2015 and 514 PJ by 2050. The contribution of ethanol and biodiesel with respect to the total amount of energy used by the transportation sector would be 0.72% in 2015 and 9.4% in 2050. Additionally, the participation share of biofuels in diesel and petrol vehicle sectors would be 0.83% in 2015 and 10.11% in 2050. Finally, avoided non-biogenic CO_2 emissions would be 1.28 million tons in 2015 and 27 million tons in 2050. These avoided emissions would account for a reduction in CO_2 levels of 0.83% and 10.24% in years 2015 and 2050.

Household sector

The proposed introduction of efficient wood-burning and biogas cookstoves developes into a large net reduction of fuelwood demand, therefore avoiding large emissions from deforestation and forest degradation. Generally, estimates of the carbon mitigation potential depend on the fuelwood savings associated to the improved cookstoves, fuelwood type, geographical and climate conditions among other variables. Nevertheless, a conservative average carbon mitigation for fuelwood cookstoves was calculated for Malawi which is 0.5 tC/cookstove-year. Assuming this average value as representative for all Malawian conditions, the total saved CO_2 in a high scenario would be approximately 0.12 million tons of CO_{2eq} by 2015 and 6.2 million tons of $CO_{2\ eq}$ by 2050 (see Table 10). Additionally, the annual fuelwood consumption would be reduced 0.35% in comparison to the base scenario, resulting in 0.08 million tons of unconsumed fuelwood in year 2015. Afterwards, fuelwood consumption would reach a maximum in 2027 and then decrease progressively. Towards 2050 the reduction in fuelwood consumption would amount to 4.05 million tons and would be equivalent to savings of 15.35%. The number of efficient cook stoves introduced in 2015 would be 64,000 and 3,400,000 in 2050. Their consumption would change from 14 PJ in 2015 to 98 PJ in 2050, representing 12% and 35% of the total fuelwood used in the household sector, respectively. The rest of this fuel wood would be used in traditional cookstoves.

In the moderate scenario, the total carbon emissions saved would be 0.08 million tons of CO_{2eq} in 2015 and 3.2 million tons of CO_{2eq} by 2050 (see Table 10). The annual fuelwood consumption would be 0.25% less than the consumption in the base scenario by the year 2015 and would total 0.05 million tons of fuelwood savings. Later, fuelwood consumption would reach a maximum in 2043 (see Fig) and then would decrease progressively. In 2050, the consumption reduction with respect to the base scenario would be 2.11 million tons of fuelwood and would be equivalent to 8.9% savings. The number of efficient cookstoves introduced in 2015 would be 20,000 and 456,000 in 2050. Their consumption would change from 24.52PJ in 2015 to 47 PJ in 2050, accounting for 6% and 11% of total fuelwood used in household sector, respectively. The rest of this fuelwood would be used in traditional cookstoves.

General results

In the high penetration scenario, the use of biofuel energy technology options in electricity generation, transportation and household sectors would reach 55.9PJ by 2015 and 207PJ by 2050 (see Fig) and would be equivalent to 0.2% and 9% of the total consumed energy by these sectors, respectively. Furthermore, avoided CO_2 emissions from power generation, transportation and household sectors would amount to 1.2 million tons of non-biogenic CO_2 by 2015 and 67 million tons of CO_2 by 2050(see fig). These avoided emissions would account for 0.54% and 13% of the total CO_2 emitted by electricity generation and transport sectors in the base scenario.

In the moderate scenario, the total estimated penetration of bioenergy generation, transportation and rural household sectors would reach 23P by 2015 and 867 PJ by 2050 and would be equivalent to 0.3% and 5% of the total consumed energy by these sectors, respectively. Additionally, the avoided CO2 emissions from electricity generation, transportation sector and the avoided emissions from deforestation and forest degradation in the rural household sector would total 1.7 million tons of CO2 by 2015 and 23 million tons of Co2 by 2050. These avoided emissions would account for 0.34% and 5% of the total emissions of electricity generation and transportation sectors in the base scenario, respectively.

CONCLUSIONS

The present prospective study shows that the use of bioenergy in a high penetration scenario may be increased substantially in order to reach up to 12% of Malawi's total energy supply in electricity generation, transportation and rural residential sectors by 2050. Transport sector is expected to be the major consumer with up to 6% of the total energy consumed in all included sectors, followed by power generation (3.6%) and residential (0.45%) sectors. The use of fuelwood in traditional cookstoves may be equivalent to 15% of the total bioenergy participation in electricity generation, transportation and rural household sectors.

When our calculations are analyzed by sector, they indicate that the participation of bioenergy in electricity generation may represent 13% of all electricity produced in 2050. Similarly, the participation of bioenergy (ethanol and biodiesel) in the transportation sector may represent 5% of the liquid fuels in this sector. With regard to the household sector, the saturation of the efficient cookstoves is only 30%, which indicates that there is still a big substitution potential in this area.

Furthermore, the more intensive use of bioenergy, under the scenarios depicted in this paper, would help reduce up to 9% of the annual CO2 emissions in electricity generation and transport sector by 2050. The major reduction potential is found in transportation (8%), followed by the electricity sector (3%). The deployment of only 45% of the low estimated bioenergy potential (PJ/year) may reduce as much as 34 million tons of Malawi's CO_2 emissions in electricity generation and transportation sector by 2050 and would be equivalent to 4% and 8% of the 1990 and 2002 national CO_2 emissions, respectively. Carbon emissions saved through the utilization of efficient cookstoves in the rural household sector would amount to 3.2 million tons of CO2eq in 2050. This potential would be equivalent to 5% of total avoided emissions in electricity generation and transportation sector by 2050. What is more, it is equivalent to 8% of 2002 captured CO_2 in national managed forests and enough to offset their net CO_2 emissions.

These results point out that it is essential for the current energy system to evolve towards an ever-greater use of bioenergy as a substitute for fossil fuels in order to achieve environmental sustainability. Therefore, if Malawian bioenergy resources are not developed in a timely manner, Malawi would be losing the opportunity to diversify the country's energy system. At the same time, jobs would not be created, and the under development in rural areas and the social problems associated with poverty would remain for a long time. The use of bioenergy would allow Malawi to foster sustainable development strategies, particularly in the rural sector.

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Understanding the Products and Services that the Industry in Malawi Needs: An Industrial Needs Assessment Study Approach

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ABSTRACT

Results are presented for a study that was conducted to identify the research, training and technology needs as well as outreach and extension gaps of the industry with a focus on some selected key sectors. The study was conducted to guide University's Industrial Research Centre on operations that address the pressing needs of the country towards economic growth. Three areas of focus based on the country's Development Strategies were: (i) Agriculture and agro-processing; (ii) Energy; and (iii) Industrial Development. Organizations and companies that are producing one or more products in the three focus areas were surveyed in November, 2016. Data was collected using a stratified sampling procedure within various subgroups in the targeted sectors. Key informants from various levels within the targeted entities were purposively identified in Lilongwe, Blantyre, Zomba, Mulanje, Chiradzulu and Thyolo. Some participants outside these areas participated through Google online survey. The appropriate sample size for the study was 96 organizations and companies. However, the study targeted 160 organization to minimize possible non-response bias. A total of 98 organizations actually participated in the study. Secondary data on prevailing challenges and issues in the targeted sectors was also sourced from Malawi Confederation of Chambers of Commerce and Industry and the National Statistical Office to supplement the data. The study results show a number of pertinent issues and challenges, which include; research, training, and technology needs, and outreach and extension gaps that exist within these three key sectors. Interventions have been designed to resolve the challenges to foster industrial growth and development for the socio-economic development of Malawi.

Keywords: Industry, Needs assessment, Energy, Agro-processing, Development, Malawi

INTRODUCTION

A "needs assessment" is a systematic set of procedures that are used to determine needs, examine their nature and causes, and set priorities for future action (Gupta et al, 2007). Comprehensive needs assessment studies are often necessary for institutions that are newly established, expanding their portfolios, or being restructured or reorganized in terms of goals, objectives and operations. This is usually important as it helps organizations to learn about the existing issues and problems faced by the clientele in order to design the right products and services. The Malawi University of Science and Technology (MUST) has established an Industrial Research Centre, which aims at offering programs, products and services to the general public in line with the university's goals, vision and objectives.

Malawi still remains in the bottom 10% of the world's poorest countries with a per capita Gross Domestic Product (GDP) based on purchasing-power-parity (PPP) of about USD 1,100 in 2015 (CIA World Factbook, 2015). The country's GDP composition by sector is 35.5% agriculture, 19.9% industry and 44.6% services (CIA World Factbook, 2015). These statistics show that Malawi's economy is generally Agro-based with 80% of livelihoods being dependent either on

production, transportation, processing or marketing of agricultural products. According to the 2016 business climate survey report by MCCCI, the economic growth trend for Malawi remains stagnant and unstable; and the macroeconomic environment continues to remain threatening as a number of pertinent issues affecting business growth and the economy at large remain unattended year after year. The report further highlights some major issues currently impending the industry in Malawi including the lack of appropriate and advanced technologies to improve productivity and quality of products, poor and unreliable energy and water supply or delivery and scarcity of skilled human resources. There is a need, therefore, for the academic and research institutions to embark on operations that are relevant and significant in terms of addressing the problem facing Malawi.

According to the Malawi Government's National Development Agenda, (i) Agriculture and agro-processing; (ii) Energy; and (iii) Industrial Development are some of the important areas of concern within the key priority areas of the national development agenda. MUST as a Science and Technology University is focusing on the development and testing of technologies and innovations that increase industrial productivity and spur economic growth in the priority sectors of the country. Therefore, the objective of this study was to identify gaps in research, innovations and technology development in the three priority sectors.

Specifically, the objectives of the industrial needs assessment were to;

i. Determine the kind of training and outreach programs that should be developed and delivered.
ii. Develop a better understanding of the technology and innovation needs currently facing Malawi's industry.
iii. Develop a better understanding of the industrial research needs of the country.
iv. Develop a prioritized list of the identified industrial needs based on importance rating.

MATERIALS AND METHODS

The Study Design

The design of the study was descriptive cross sectional that utilized quantitative data collection and analysis methods to identify technological and innovation gaps that exist in industry in Malawi.

The Target Study Participants

The study participants were companies and organizations that are players or are significantly engaged with activities that involve agriculture, energy and industrial development. As such, organizations and companies within different clusters of the targeted sectors like production, processing or value addition, marketing or trade, and education among others were targeted.

Some experts and intellectuals were identified and interviewed as key informants. These included senior civil servants, policy makers, analysts and academia in the targeted sectors. Information concerning the needs and demands of the industry collected from the key informants helped to guide, validate and also verify the data collected from the various organizations and companies. Key informants generally understand the sectors better, thus, holding important information that the study needed. Key informant interviews were, therefore, carried out first so as to get expert's opinions and suggestions, which are key in validating and verifying information about the concerns, demands and needs of the targeted sectors. These however were primarily not the key focus of the study. As such, interviews with these key informants were used to guide the industrial surveys or questionnaires. According to Gupta et al, (2007) key informant interviews are a very useful tool for obtaining expert's opinions on a given subject and also for planning and informing needs assessment surveys or questionnaires.

Sampling and Sample Size

Stratified sampling procedure was used for the data collection in this assessment because there existed various subgroups within the targeted sectors. Key informants from various levels of the value-chain within the targeted sectors were purposively sampled or identified. This was based on proximity targeting those experts who were reachable within the selected study areas and also those who were available on Google survey. These interviews helped to provide more information and expert's opinion and Intel on the areas of needs and intervention in these targeted sectors.

Organizations and companies in the targeted sectors of agriculture, agro-processing, energy and industrial development were sampled. Stratified sampling was employed to ensure that each level of the value-chain within the selected sectors is proportionally represented in the sample (Rothwell and Kazanas, 1998). However, for agriculture, since our focus is on value-addition or agro-processing, a higher weight was assigned to the agro-processing subsector in the agricultural value-chain. Similarly, a higher weight was assigned to the alternative energy or power generating subsector within the energy subsector.

Data Collection Tool

A Semi-Structured questionnaire with both open ended and closed ended questions was used as tool for collecting data from the targeted stakeholders. A combination of tools was employed to gather the required data which included, key informants interviews and surveys. Two surveys, enumerator administered and Google were employed. Based on population of the stakeholder organizations and companies in the selected sectors of the country (About 800 registered and operating organizations and companies are involved in agriculture, energy and industrial development according to the Malawi yellow pages records), an appropriate sample size of 100 organizations and companies was determined to ensure the data is as representative as possible for valid inferences. This sample size was determined from the formula by Edriss (2003); $n = (Z2)(P)(1-P)/e2$ where; Z is value of a standard normally distributed variate, which for a 95% confidence interval takes the values of 1.96; P is the proportional of industries targeted out of the total number of all industries in Malawi. In this study the P was set at 0.50 since the actual proportion is hither to unknown. The e is allowable error, and since the study is sub-national, a marginal error of about ± 10% was allowed. Using this formula, the appropriate sample size is 96 and was rounded off to 100.

RESULTS AND DISCUSSIONS

Data was collected from 98 organizations, of which 23% were representatives of public organizations including government departments, research institutions and training institutions. About 56% represented the private companies and 21% represented non-governmental organizations, companies or businesses.

Distribution of Survey Respondents by Type of Work

Organizations specified the type of work they were involved and the results show that the choices were not mutually exclusive because some institutions were engaged in more than one type of work. The institutions surveyed by type of work are shown in Figure 1.

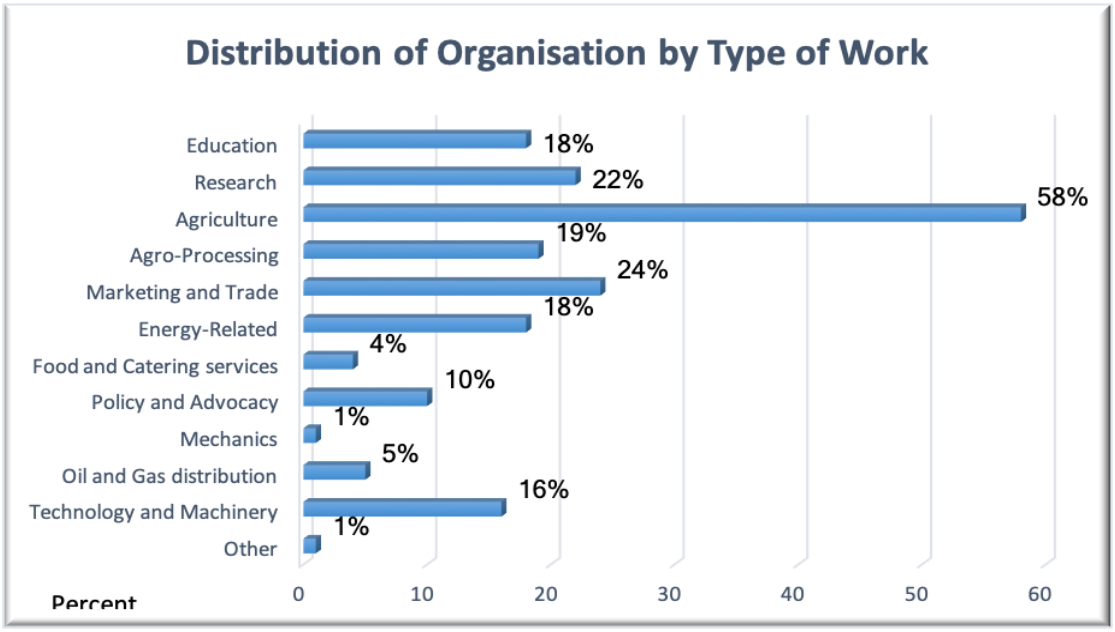

Figure 1: Distribution of the sampled institutions by type of business involved

Most of the respondents were involved in agriculture, followed by marketing and trade, research, education and energy related.

Agriculture and agro-processing Sector

Descriptive statistics and quantitative results on challenges, research, training and technology needs for the agriculture and agro-processing respondents are presented in Table 1.

Table 1: Descriptive Statistics for the Agriculture and Agro-processing Sector

Variables of Interest	Agriculture	Agro-processing
Players (%)	58%*	19%*
Access to desired technology (%)	57% **	31% **
Access to specialized training (%)	49% **	27% **
Access to research labs and workshops (%)	50% **	22% **
Training Needs Rating	Low	Average
Research Needs Rating	Average	High
Technology Needs Rating	High	High

Notes: The two sectors are not mutually exclusive, * is for percent out of entire sample, ** is for percent out of specified category

Of the total respondents, 58% were involved in agriculture while 19% of the respondents were in agro-processing. Of all the agro-based organizations, 57% accessed the desired technology, which was in the form of traditional, appropriate manuals, appropriate motorized and modern advanced technology. Only 31% of the respondents in the agro-processing field accessed appropriate agro-processing technologies. In addition, most of them were unsatisfied with the current technologies in use because they were either obsolete of inefficient. In both the agriculture and agro-processing fields, less than 50% accessed specialized training in production, processing technologies, food processing standards such as HACCP, intellectual Property Rights (IPRs) and agri-entrepreneurship skills. The participants indicated that the training programs were costly because they are run by private institutions and not by the government. Consequently, most respondents reported that they have training gaps year by year and this gap adversely affected their productivity. Results show that the proportion of organizations that access the desired technology in the agricultural sector is larger

than that of the agro-processing sub sector due to government interventions such as input subsidy, research and extension programs.

Of the agro-based organizations, 50% accessed laboratory and workshops for tests, experiments and trials at the government owned Research Stations such as Chitedze, Bvumbwe, Lunyangwa, Makoka, Chitala, Kasinthula, Meru and Baka. Facilities and expertize at these stations are accessed free of charge or at a reasonable and affordable fee. However, agro-processing laboratories and facilities are not available and the organizations seek such services at the Malawi Bureau of Standards, University of Malawi and LUANAR. However, state of the art technologies are not available in the country, hence gaps exists on training, technologies, laboratories and workshops.

Existing challenges in the Agro-processing sector

The existing challenges in the agro-processing sector are summarized in Figure 2. There are a number of challenges that the agro-processing industry is currently facing (Figure 2). The challenges include lack of awareness or access to information about food safety management systems (HACCP) and also lack of information about product quality and standards in line with standards and regulations by the Malawi Bureau of Standards (MBS) and International Standards Organization (ISO). There were 52% percent of the organizations in agro-processing that reported these two factors as serious impediments. These challenge originates from the fact that there are currently very few institutions that are committed to dissemination of information and training on issues of quality, standards and HACCP practices since MBS is primarily a regulatory body on the issues and not a service provider and trainer. Consequently, most organizations especially SMEs and start-ups have challenges in accessing such specialized training.

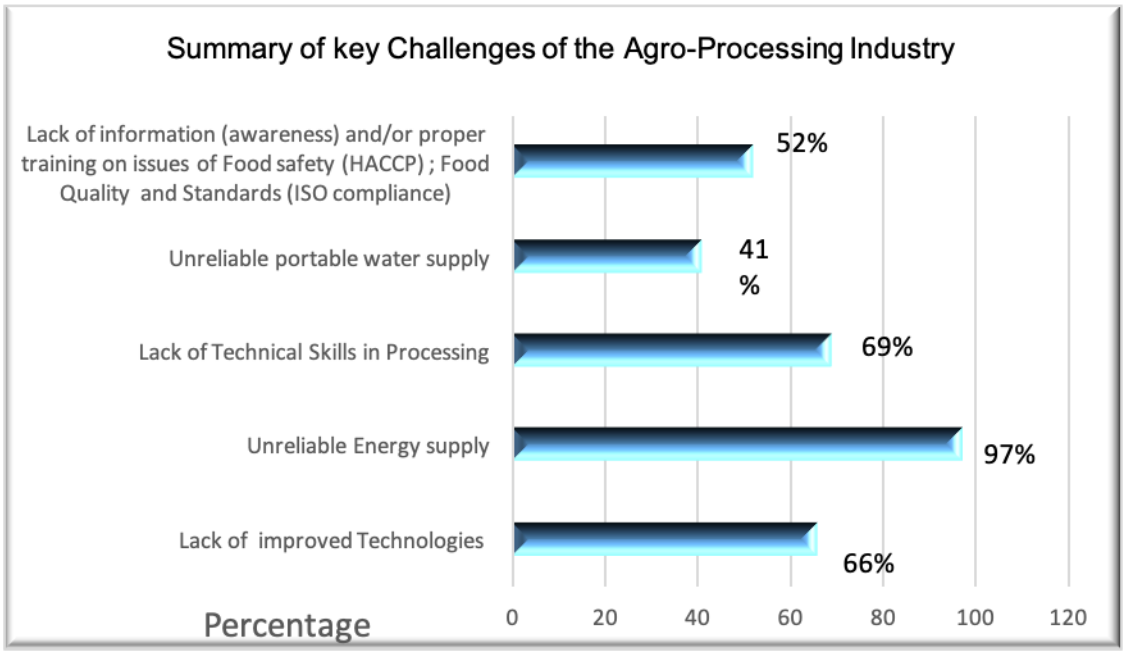

Figure 2: Key challenges of the Agro-processing Industry

About 41% of organizations reported unreliable portable water supply as a challenge to production. Human capital deficit was another challenge that 69% of the organizations indicated as a pertinent challenge. Basically, the study revealed that there is a significant gap in terms of technical skills in maintenance and operation of production plants and heavy machinery. Most organizations are currently forced to hire technical specialists or machine operators from South Africa due to lack of specialists with advanced technical skills in operation and maintenance of processing plants in

Malawi. Besides, about 97% of sampled organization indicated unreliable power supply as a big challenge. The frequently experienced blackouts and power outages result into loss of productive time. In addition, perishable ingredients and raw materials get spoilt in storage due to lack of electricity. Finally, the lack of effective or improved technologies for processing agricultural produce was another challenge indicated as a major impediment by about 66% of the sampled organization. This is reported to affect productivity and quality of output hence the need for improved technologies and innovation.

The ranking of the key challenges by the participants is shown in Figure 3. Unreliability power supply is the most pressing challenge for the industry. The lack of improved technologies was rated second, followed by the lack of technical skills. The lack of information and training on safety, quality and standards was ranked forth while portable water availability was considered the least pressing problem with only 12% of the respondent rating it as important. This is due to the fact that most organizations stated that they have water reservoirs as a solution to the problem (Figure 3).

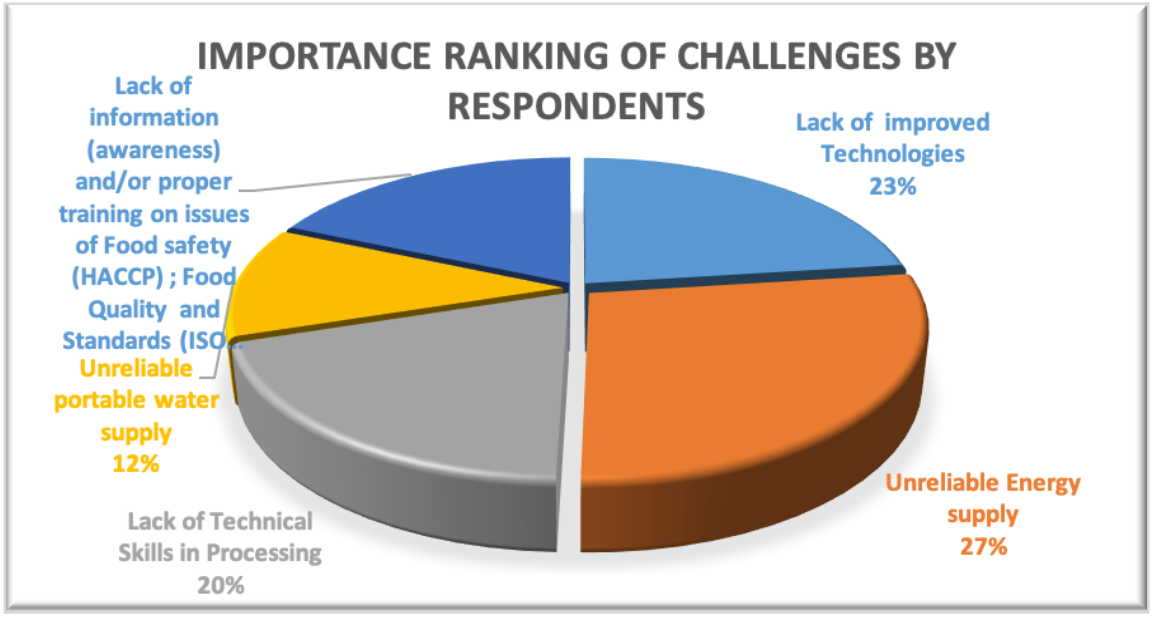

Figure 3: Ranking of Agro-processing challenges by respondents

Research Needs of the Agro-processing Sector

The research needs of the agro-processing sector are shown in table 2. The most pressing research need for the sector is preservation, which probably is coming from the most pressing problem of electricity black outs (Table 2). The other most pressing research need is on product safety, quality and standards. If the industry in Malawi is to penetrate the international market, there is a need to develop products that are safe, of good quality and of international standards.

Table 2: Agro-processing Research Needs

Research Needs In Agro-Processing	Percentage of Entire Sample (%)
Product safety, quality and standards	61%
Testing & certifications on food safety management systems.	47%
Agro-processing research laboratories	58%
Agro-processing product development workshops	49%
Alternative preservation and storage technologies of agricultural produce	63%

One of the most pressing needs for the sampled respondents is lack of expertise in food safety, quality and standards. Some respondents explained that they have no access to experts in this field. Some organizations (47%), which comprised mostly food processors, had challenges accessing safety management system certifying agents or organization in Malawi. This is the case because as a country, Malawi still does not have food safety management systems (HACCP practices) certifying organization or agents. These results agree with those reported by Busch, (2000); Henson and Reardon, (2005) which indicate that most developing countries are unable to access high value international markets because of non-tariff barriers like product safety and quality standards. These standards are universal in market economies and thus, play a fundamental role in the organization of supply chains for most products and services including traditional marketing systems. Generally, for the agro-processing industry, in the present era, certification to such set of standards is the minimum entry requirement for higher-value markets for agro-products, not only in industrialized countries but also in developing countries' higher-income markets. As such, for a business to enter such markets it has to be aware and comply with the standard in order to take advantage of better markets. However, with slackness in issues of safety, quality and standards, accessing or penetrating global high value markets is impossible. As such, this is considered a serious challenge for agro-processing sector especially food processors in Malawi.

There is also a need for agro-processing laboratories with state of art equipment and facility for analytical tests and experiments. In addition, there is also a need for product development workshops or maker-space for innovators and entrepreneurs to carry out their product trials and development. Such workshops need to be fully equipped with all relevant tools, technical expertise, and technologies to ensure that innovators in agro-processing are able to work out, develop and materialize their conceptualized products. It was also pointed out that a majority of innovators or entrepreneurs within the industry are generally financially unable to acquire or rent out space and facilities for use in the process of nurturing and developing their ideas or innovations into products or services. As such, there is need for development of fully equipped workshops and innovators hubs for various product development as a form of asset financing (workspace, equipment or facility leasing) for start-up entrepreneurs and innovators.

Training needs of the agro-processing sector

Training needs or knowledge gaps in the Agro-processing industry are summarized in Table 3. The most pressing training needs for the industry in Malawi are to do with Intellectual Property rights (Table 3).

Table 3: Agro-processing Sector Training Needs

Training Needs In Agro-Processing	Percentage of Entire Sample (%)
HACCP Practices and food safety awareness	42%
HACCP and food safety training programs	67%
Technical skills in Product development and packaging	71%
Training in intellectual property rights	82%

The need for HACCP practices was mainly mentioned by the small and medium enterprise businesses in the food processing sector that have problems accessing information. In addition, short term training on HACCP practices and food safety issues was requested by the respondents in the food industry. These organizations reported that they were aware of food safety management system but not well informed about the detailed procedures and practices. Results show that human resources with technical skills on product development are in the greatest need. There is a need to re-orient training in technical colleges and universities so that they do not produce graduates with managerial skills but technical skills for product development. Besides, those institutions offering technical skills are not focused on building the capacity of scholars' technical skills at an advanced level. As such, most organizations reported outsourcing personnel with advanced technical skills like operation or maintenance of boiler plants, aircrafts, and heavy machineries from South Africa. Results also show lack of knowledge on intellectual property issues by the highest proportion of the respondents. There is therefore a need to train the respondents on intellectual property rights.

Technology and innovation needs of the agro-processing sector

Most of the respondents (63%) indicated the need for improved technologies and innovations for preserving or storing agricultural produce as well as processed products. Agricultural produce is generally perishable, thus, requiring special handling and storage procedures which tend to increase production costs. Besides, seasonality of agricultural produce limits processors from being as productive as desired due to scarcity of raw materials, which are also expensive during the lean period. There is, therefore, a serious need for storage and preservation technologies or innovations that are efficient and cheaper. The technologies will reduce cost of storage while also extending the availability period of the agricultural produce throughout the year. FAO (2013) reported that 20% of agricultural produce in Africa is lost during and after harvesting due to poor harvesting and storage technologies and also due to lack of appropriate processing or preservation technologies.

A gap was also reported in the processing technologies. Most companies indicated that they are currently still using traditional or outdated technologies to process agricultural produce. Therefore, there is a need to improve or update the current technologies so as to increase productivity and quality of industrial products. Increased productivity will ensure competitiveness of Malawian products on the global market. Similarly, most organizations under agriculture also indicated that due to lack of appropriate harvesting technologies, they continue to lose most of their produce during and after harvesting. Poor technologies in agriculture results to poor quality of produce, which result into low farm-gate prices for the producers and compromises quality of the final products.

The Energy Sector

The responses from the energy sector are presented and comprise; energy usage statistics, challenges, research, training and technology needs.

Situation of the Energy Industry

The study revealed that there are generally very few players involved in energy generation and supply. Previously, electricity generation was monopolized by ESCOM. The study also found that currently private players are not involved in distribution of power as ESCOM remains a monopoly in energy distribution. Generally, large scale organizations like ESCOM continue to dominate the supply of electricity in Malawi.

In the liquid fuels and gas sector, there are a few large scale suppliers. The sector has oil companies like Puma Energy Limited, Petroda, Total Malawi, ENGEN, Enegerm, Mt Meru and Injena. These oil companies dominate the supply and distribution of fossil fuels like petrol, diesel and paraffin across the nation while a few other companies like ETHCO, Press Cane and BERL are supplying bio-fuels, such as Bio-ethanol and Bio-diesel.

Malawi as a nation is generally dependent on renewable fuels. This correlates with reports by Biomass Energy Strategy (2009) that biomass fuel (firewood and charcoal) account for about 88.5% the country's energy requirements. Statistics further indicate that liquid fuels and gas (petroleum and Biofuels) account for 6.3% of energy requirements while hydro-electricity and coal account for 2.8 and 2.4%, respectively. All households in Malawi accounts for 83% of all energy consumption, with industry using only 12%, transport 4% and the service sector 1%. The NSO (2012) reported that 85.7% of the population in Malawi use paraffin in hurricane and pressure lamps for lighting, 7.2% use electricity, 2.2% use candles, 2.6% use firewood and 1.4% use other alternative means of lighting like solar. For cooking, about 88% of the population use firewood, 8% use charcoal, 2% use electricity, 1% use paraffin and gas and 1% use other means such as crop residues or animal dung.

A summary of the energy usage in Malawi by sectors is shown in Table 4.

Table 4: Total Energy Consumption by Fuel Type in Malawi

FUEL TYPE	SECTOR					
	Households (TJ/Year)	Industry (TJ/Year)	Transport (TJ/Year)	Services (TJ/Year)	**Total (TJ/Year)**	**Contribution %**
Biomass	127,574	10,004	270	452	**138,300**	**88.5%**
Petroleum	672	3,130	5,640	558	**10,000**	**6.3%**
Electricity	1,798	2,010	35	477	**4,320**	**2.8%**
Coal	5	3,481	15	174	**3,675**	**2.4%**
Solar	±0	±0	±0	±0	**±0**	**±0%**
Wind	±0	±0	±0	±0	**±0**	**±0%**
Geo-thermal	0	0	0	0	**0**	**0%**
Total	**130,049**	**18,625**	**5,960**	**1,661**	**156,295**	
(%)	**83.2 %**	**11.9%**	**3.8%**	**1.1%**		**±100%**

Source: Malawi Biomass Energy Strategy, 2009.

Current Challenges in the Energy Sector

There are a number of challenges that the energy sector is currently facing including the lack of appropriate technologies for the various alternative energy sources. The key challenges are presented in Figure 4. Most organizations indicated lack of appropriate technology as a key impediment to adequate power generation in Malawi. This includes technologies for power generation using solar or wind and efficient technologies for production of biofuels and biogas. Lack of proper technical skills in renewable energy technology including skills in proper sizing, installation and maintenance of power generating equipment especially for solar, wind, biogas and micro-hydro technologies was also reported as a key challenge (Figure 4). Most participants also reported on the lack of technicians with advanced technical skills including calculation of energy requirements and appropriately sizing panels, turbines (Figure 4). There is also lack of advanced technical skills on proper installation in terms of determining the accurate angles when setting up panels based on solar resource availability and determination of proper height and location based on wind speed and topography.

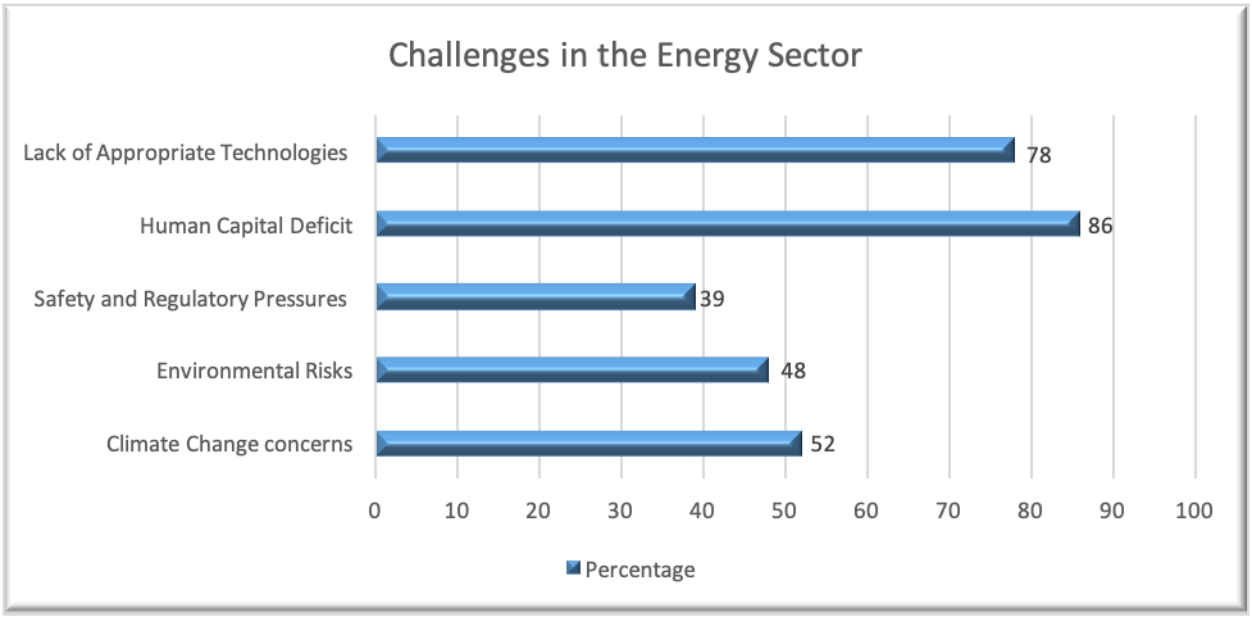

Figure 4: Current Challenges in the energy sector

Furthermore, the respondents also indicated safety and regulatory pressures as another challenge in the sector (Figure 4). Most of these organizations, however, were those dealing with supply of non-renewable energy fuels like liquid fuels, gas and coal. These organizations also indicated lack of awareness on safety procedures by consumers or end users as a potential risk that may affect acceptance of the alternative energy technologies such as bio-fuels, gas and coal (Figure 4). Lack of proper training on safety procedures and regulations was another issue pointed out as a challenge.

In addition, about 48% of the organizations also indicated environmental risks and concerns associated with energy generation as an issue. In fact, it was pointed out that there are generally high costs associated with carrying out proper Environmental Impact Assessment (EIA) studies before investing in non-renewable energy power plants or machinery. This also includes costs associated with proper control of pollution or damage to the environment, which is inevitable for most non-renewable energy sources like coal. Lastly, climate change concerns which bring in variability and unpredictability in availability of natural energy resources like solar, wind and hydro was also reported as a major risk since efficiency of generation becomes unpredictable and variable depending on the prevailing weather conditions.

When the participants ranked the challenges, it was revealed that human capital deficit in terms of technical skills (32%) is the most pressing challenge for this industry. Lack of appropriate technology (28%) was the other highly ranked challenge. The environmental risks and concerns, (15%), climate change concerns and issues (13%) and the concerns about safety and regulatory pressures 12%) were lowly ranked by the respondents.

Research needs of the energy sector

The results of the research needs of the energy sector are shown in Table 5. Although all the sectors (Solar, Biogas, Wind, Micro-hydro, coal energy generation, bio-gass and Bio-fuels) were ranked as important, Solar, Biogas, wind energy, coal energy generation and bio-fuels were highly ranked by the respondents (Table 5).

Table 5: Research Needs in Energy Sector

Research Needs In Energy	Percentage of Entire Sample (%)
Solar Energy	87%
Biogas Energy	89%
Wind Energy	77%
Micro Hydro	59%
Coal Energy Generation	69%
Biomass	53%
Bio-fuels	61%

Results show that the participants highly ranked the sectors, which can contribute to electricity power generation. A number of areas need further research and development work. It was noted that there are some major gaps in relevant data generation, storage and technology development for renewable energy sources like solar, wind, micro hydro, geothermal, biomass and non-renewables like coal. Regarding solar energy, it was reported that there is a gap in generation and storage of data on solar resource availability, solar intensity period during the day or year and also across locations (i.e. with data on locations with abundant solar resource). This was reported to be a challenge as it affects important calculations necessary for proper sizing and installation of panels. As such, technicians are currently unable to appropriately position and install the panels for efficient solar harvesting. Basically, very few institutions are engaged in generation and storage of such relevant data and mostly those involved do not collect or store detailed data (i.e. they mostly focus on some selected locations like airports. Hence, In terms of solar energy, there is need for researchers to engage in relevant data generation on solar resource availability including locations with abundant solar resources, intensity period during the day and year to ensure effective calculation of panel installation angles and position for each district where potential for solar power generation exits.

It was also reported that most projects (e.g. solar village projects in Mzimba and Nkhotakota amongst others) involved in solar energy generation have sustainability problems since replacement of batteries for storage of power is an issue. Batteries are the most expensive part of the solar power system, hence, there is need for new power storage technologies that may be efficient and affordable. The results call for the need to look into possibilities of reverse engineering and localizing the batteries to ensure availability of cheaper solar systems. Similarity, there is also a need to look into likelihoods of locally fabricating solar panels. There is, therefore, need for further research and development work on solar power generation with a focus on hybrid systems such as solar-wind power generating systems or solar-hydro power generating systems at both medium and large scale production levels.

Likewise, for wind energy, it was reported that there is a gap in terms of generation and storage of relevant data including wind speed and variation during the day and across the year, topography, infrastructure and vegetation for each district especially those with abundant wind resource. As such, there is also need for researchers to engage in collection of relevant data required for setting up wind energy generating systems for each district especially those with abundant wind resource. In addition, there is also need for further research and development in efficient wind energy generating technologies.

In terms of hydro energy, it was reported that there is need for further research in new technologies for water harvesting and reserving as it was pointed out that Malawi usually has a lot of water during the rainy season to the point of flooding in some districts with not much being done to maximize utilization of the water. Unfortunately, the country continues to experience water scarcity during dry seasons as a result of poor water drainage, harvesting and reserving for power generation and irrigation. It was thus pointed out that there is need for more technologies and innovations in water harvesting and reserving for power generation.

Regarding geothermal energy, it was reported that not much is currently being done to generate power using geothermal technologies despite the country having a number of geothermal spots. As such, it was pointed out that there is need for further research on feasibility of geothermal energy generation. This also includes research and development work on technologies for geothermal energy generation. Issues of safety were also raised to ensure reduced environmental risks and damage as well as safety at generation locations.

For biomass research, it was pointed out that regardless of the numerous environmental regulations and negative externalities associated with biomass energy, many Malawians continue to use biomass energy because it is currently the cheapest source of energy in the country (Kambewa et al, 2007). As such, it was highlighted that there is need to invest in research that will lead to development of efficient charcoal making technologies so as to ensure increased charcoal output per tonne of wood compared to the existing indigenous charcoal making technologies. Besides, research and development work on efficient technologies for making charcoal briquettes or pellets using waste biomass was also pointed out as another area that requires further research.

In the biofuels, it was pointed out that the only challenge is production of adequate volumes to meet demand without competing with food production and supply. As such, it was reported that there is a need for improved technologies in production of biofuels. This includes technologies that would take up a wide range of agricultural wastes including waste from crops, fruits, vegetables or even wild fruits as raw materials for production of bio-fuels like ethanol.

For the non-renewables energy resources like gas and coal, it was reported that there is need for efficient burning technologies. This also includes technologies that are safer and cleaner, that is, burning stoves or technologies that have accessories like traps to capture harmful gases. It was thus, reported that the key issues with non-renewables energy sources like coal includes climate change and pollution concerns associated with them. Hence research on the association between non-renewable energy sources and climate change is recommended.

Training Needs of the Energy Sector

The Training needs or technology gaps in the energy sector are summarized in Table 6. Results show that there is need to increase awareness on safety and regulatory issues for each energy resource especially those that require special procedures for handling and use (i.e. biofuels, coal and biogas). It is important to note that this would be necessary to ensure Malawi engages in successful generation and distribution of energy from a number of alternative sources. Training program on issues of regulations and safety procedures were also indicated as a need especially considering the

liberalization of power generation, which allows more players to be engaged into power generation.

Table 6: Training Needs in Energy Sector

Training Needs In Energy	Percentage of Entire Sample (%)
Safety and Regulation awareness	75%
Safety and Regulation training programs	66%
Technical skills in Solar technology (panel + battery+ invertor) sizing and installation	65%
Technical skills in wind turbine sizing and installation	67%
Training in intellectual property rights	84%

It was also reported that there is need for both long-term and short-term technical training in renewable energy technology sizing, installation and maintenance with much focus on technical skills for systems that require accuracy in installation to ensure efficiency as well as to avoid damage by overload as a result of poor sizing or installation. This was based on background that there is currently a gap in terms of specialists with advanced technical skills in sizing, installation and maintenance of panels for solar energy systems. The skills include calculation of kilowatt rating based on energy requirements to avoid damage of the system due to overloading and calculation of installation position and angle based on location's solar resource availability and distance to the equator. Besides, it was also reported that there is need for orientation training programs for users to ensure proper care and maintenance of the system. This was also applicable to wind energy systems which also require advanced technical skills in sizing and installation of wind turbines including calculation of appropriate installation height and position based on location's wind speed, vegetation and infrastructure. Based on the study's finding in terms of respondents' familiarity to Intellectual Property Rights issues, it was also noted that there is also a need to raise awareness on issues of intellectual property rights in the sector as well as offer an introductory short-term training course.

Technology and Innovation Needs of the Energy Sector

Table 7: Technology and Innovation Needs in Energy Sector

Technology and Innovation Needs In Energy Sector	Percentage of Entire Sample (%)
Solar Technologies (Batteries)	87%
Biogas Technologies	45%
Wind Energy Technologies	79%
Micro Hydro technology	65%
Coal Energy Generation	41%
Geo-thermal	29%
Biofuels	56%

The study also revealed that there is a huge gap in terms of use of advanced or improved technologies in the sector. For solar energy systems, there is a need for cheaper, efficient and long lasting power storage technologies. This is because the key challenge with solar power systems is storage of power especially considering that batteries are very expensive.

Besides, it was also reported that there is need for improved technologies with much focus on development of better, cheaper and more efficient design of wind turbines, biogas plant and micro hydro technologies. In terms of bio fuels, there is need to look into improved and more efficient

design of biofuel production plants or systems that accept a variety of agricultural wastes as raw materials including wild non-edible fruits.
For geothermal energy technologies, currently, there is not much being done, hence, there is need to look into adaptation and localization of appropriate and efficient technologies required in generation of geothermal energy so as to explore the geothermal energy option toward adequate power generation in Malawi. Similarly there is also need for clean and efficient coal burning technologies including cook stoves and power generating technologies to ensure efficiency and reduced pollution. This includes development of coal plant accessories like traps for harmful gas and dust to mitigate or reduce pollution.

Industrial Development
Results on the study of the existing industry show that gaps exist on collaborations, linkages and partnerships of the academia or researchers and the business sector or industry and society. These gaps signal a need for more outreach and extension programs to help trigger growth in the industry. This study has therefore identified outreach and extension gaps in industrial development because government and institutional policies spurs industrial growth and development. Hence academia and research institution have key roles to influence decisions through knowledge generation for policy guidance, technology development, outreach and extension programs.

Outreach and Extension Gaps in the Agro-processing Sector
The study identified outreach and extension gaps in the agro-processing sector. The results indicate that there is not much collaboration between experts in agro-processing in the academia and research on one hand, and those in the business sector or industry. Organizations reported that there are very few "academia to business sector" exchange programs. This disconnection is affecting performance and growth of the industry as the academia is unable to take up the numerous opportunities existing in the business sector to apply knowledge and improve operations in industry (Table 8).

Table 8: Outreach and Extension Gaps in Agro-Processing

Outreach and Extension Gaps In Agro-Processing	Percentage Of Entire Sample (%)
Expertise in Processing (exchange programs)	41%
Expertise in agro-processing technology (Technical skills)	59%
Agri-business development and management hubs (Incubation)	65%
Marketing and market linkages	53%

At the broadest level, the measure of effective application of knowledge to production of goods and services for the industry is still very low. Similarly, there is a lack of the practical perspective in training since graduates are not given the platform to engage in significant practical application of the theory learnt in class through such programs. Besides, very few experienced industrial technicians are given classroom opportunity through such programs to pass on the practical aspects of the subject matters taught to graduates.

Further, there is need to establish programs that will target building capacity in terms of advanced technical skills through industrial attachments and apprenticeship. In addition, the study also indicates a pressing gap in terms of outreach and extension including the lack of innovation or business development and management hubs or incubators for agro-processors. About 65% of organizations indicated lack of incubators for innovations or start-ups in agro-processing as an issue in the industry. These incubators are expected to increase value addition, and improve quality of products to enable access to international markets. Lastly, results show that about 53% of the organizations indicated having a gap or need in terms of market and financial services linkages.

This challenge was mostly reported by SMEs who mostly have huge risks and problems in accessing information.

Outreach and Extension Gaps in the Energy Sector

The outreach and extension gaps in the energy sector are summarized in Table 9. Similar to the agro-processing sector, the outreach and extension gaps in the energy sector include the lack of collaboration between experts in the academia or research on one side and the business sector or industry on the other. About 44% percent of the organizations in the sector also indicated that there is a gap in terms of exchange programs. Such training programs are necessary for upgrading the skills of workforce to adopt the latest manufacturing technologies, management techniques and quality management systems enabling them to compete in the international markets.

Exchange programs (where experts from developed countries visit the developing countries) or study visits to the developed countries (where employee visit high industrialized companies abroad) should be conducted to give exposure to new developments taking place in the global arena. This also includes exchange programs between the academia and industry through extension learning activities that use knowledge already held by industry as they engage with new information. These learning activities imply (i) helping organizations in the industry to define problems, opportunities and avenues to address them; (ii) improving skills to solve practical problem and (iii) end-users engagement during development of new practices or technologies.

Table 9: Outreach and Extension Gaps in Energy Sector

Outreach and Extension Gaps In Energy	Percentage Of Entire Sample (%)
Expertise in Energy (exchange programs)	44%
Expertise in energy generation (Technical skills)	73%
Energy Laboratory to test quality of technologies	68%
Energy technology and innovation (Incubation)	60%

In addition, it was pointed out that there is need to establish programs that will target building capacity in terms of advanced technical skills in renewable and non-renewable energy technologies. This also includes provision of tests and certificates of competence in these technical skills. The testing and certification were considered to be issues for Malawi because currently there are no organizations or agents involved in testing and providing certificates of competence. As such, most companies in the industry are currently forced to outsource experts from South Africa to operate production plants or heavy machinery since it is a requirement by insurance companies for clients to only engage experts with certificate of competence. Malawi, hitherto does not have any competence certifying agents hence the gap.

The study results also indicate a serious outreach and extension gap in terms of industrial research laboratories with appropriate machinery and technology for testing energy technologies. About 68% of the organizations indicated that they lack proper research laboratories, showrooms and maker space for energy technologies. This includes displays of energy generating technologies or system models for each energy resource like solar, wind, hydro, biogas and biofuel among others. It was noted from the study that only Mzuzu University (MZUNI) has a Centre for energy testing and training. However, the Test and Training Centre for Renewable Energy Technologies at MZUNI (TCRET) is also not very fully equipped and hence, not very effective in addressing the pertinent issues in the sector.

Furthermore, results show that about 60% of the organizations indicated that they lack energy innovation and technology hubs or incubators. The issue of incubators was considered an impediment as individuals with potential ideas for innovations are unable to develop and commercialize their concepts due to lack of technical support, facilities and work space for trials and product development. Generally, as Malawi's population continues to grow rapidly year after year, it is likely that the demand for energy will also continue to increase. As such, there is need for Malawi to diversify energy generation to ensure that energy supply is over and above the current and future projected demand. Hence there is a need to seriously look into possibility of dealing with these gaps in the energy sector.

Overall Structural Transformation and Policy Gaps

Sustainable industrial development has been a major contributor to economic growth and poverty reduction over the past 50 years in most Asian countries. Developing countries have benefited from liberalization of markets for industrial goods, improvements in telecommunications, and reduced transportation costs. However, some countries have not shared in those benefits as a result of human capital deficits, poor infrastructure, weak government institutions and unfavorable investment climates, which continue to be key constraints. For such countries like Malawi, which continue to face the above highlighted constraints, there is need for both a robust industrial policy targeted at new exportable goods, and a supportive exchange-rate policy that promotes production of tradable goods across the board. According to Rodrik (2006) it is practically impossible to induce investment and entrepreneurship in tradable goods of any kind in the absence of a stable and competitive exchange rate and a more directly targeted industrial policy.

Industrial policy is not an effort by the government to select particular sectors and subsidize them through a range of instruments (directed credit, subsidies and tax incentives) as governments do not have adequate knowledge to pick winners. According to Rodrik (2006), industrial policy is more appropriately conceived as a process whereby the state, the academia or researchers and the private sector jointly arrive at diagnoses about the sources of blockage in new economic activities and propose solutions to them. Industrial policy therefore requires that governments build the public-private institutional arrangements whereby information on profitable activities and useful instruments of intervention can be elicited. It is however important to note that the findings from this study suggest that there are very limited platforms facilitating a linkage between the government, the academia/researcher, the industry and society. As such, the lack of joint efforts to solve problems causing stagnation of the industry is a major concern that requires structural transformation.

Needs Prioritization based on Respondents Importance Ratings

The respondents reported that technology needs and gaps were most urgent with an avergae priority scoring of 9.2 out of 10. This is mostly because the lack of efficient and advanced technologies is a major impediment on productivity for the industry. There is need therefore to engage in development of relevant and effcient technologies for a more vibrant agro-processing and energy sector. Training needs are also considered very critical with results indicating an average priority rating of 8.6 out of 10. This is mostly as result of lack of technical skills and knowldge for both the agro-processing and energy sectors. Research and outreach needs were considered moderately urgent with average priority ratings of 6.9 and 5.5 respectively. These priority ratings suggest that there is need to prioritize interventions targeted for industrial development with prior focus on technology development; followed by technical skills development and training; research volarization; and then, extension and outreach.

CONCLUSIONS

This study reveals a number of pertinent issues, challenges, research needs, training needs, technology needs and outreach and extension gaps that exist in the agro-processing, energy and industrial development sectors. Some of the key areas signaling the need for further research valorization and research capacity building in agro-processing sector include (i) development of improved storage or preservation technologies and innovations for agricultural produce and processed products; (ii) establishment of industrial research laboratories and workshops for industrial tests and experiments; and (iii) development of food safety management systems testing and certifying organizations or experts.

For the energy sector, some of the key existing research needs revealed by study include (i) the need for collection and storage (resource profiling) of relevant data on solar and wind resource availability across the country; (ii) the need for further research on improved and cheaper power storage technologies to replace the expensive and less durable batteries in solar system; (iii) the need for research on water harvesting and reserving technologies and innovations for sustainable hydro power generation throughout the year; (iv) research on development of better turbines that are efficient even in low water or wind speed; (v) the need for feasibility studies to evaluate the possibility of geothermal power generation in Malawi; (vi) development and adaptation of existing geothermal power generation technologies; (vii) development of efficient charcoal making technologies for maximum output per given input to improve on the indigenous charcoal making techniques; (viii) development of technologies for making waste biomass charcoal pellets or briquettes for cooking; and finally (ix) the need for research on development of efficient biofuels production technologies that also take up a variety of agricultural or forest wastes. Besides, based on the key issues and challenges raised in both sectors, these is also need for researchers to look into possibility of developing relevant research projects and programs that would address each of the challenges or the identified needs.

The study results show that some of the most significant knowledge gaps in the agro-processing sector include the lack of (i) awareness and training on HACCP practices and food safety management systems; (ii) technical skills in processing, products development and packaging; and (iii) finally, knowledge on IPR issues. Based on the respondents' importance ratings, the study revealed that the need for advancement of industrial workers' technical skills and training on food safety management systems and HACCP practices were the most pressing training needs in the agro-processing sector. However, for the energy sector, the key knowledge gaps were on issues of (i) safety and regulatory standards; (ii) advancement of technical skills sizing, installation and maintenance of energy technologies and also in the issues of IPR. As for the energy sector, results on importance ratings indicated that the main concern is on advancing the technical skills of industrial workers (through short courses trainings) in sizing, installation and maintenance of energy technologies and training on safety and regulatory standards or procedures for the various energy systems. Capacity building in these areas of need is essential as it would help provide the much needed knowledge and skills required for diversified power generation following the recent liberation of the sector.

In terms of technology needs, the study shows that there is (i) need for improved storage and preservation technologies for agricultural produce and products; (ii) need for more processing or value-addition technologies especially for products that are exported or sold as primary products without much value being added to increase returns; (iii) finally, need for improved harvesting technologies to reduce post-harvest losses in agro-processing sector.

As for the energy sector, the study also indicates that there is a significant technology gap hence the existing energy demand deficit. Some of the key technology gaps revealed in study include (i) the need for improved and durable power storage technologies for solar systems; (ii) the need for more efficient biogas technologies; (iii) the need for improved and efficient turbines that are adaptable under varying wind speeds; (iv) the need for water harvesting and reserving technologies for sustainable hydro power generation (and irrigation); (v) the need for more efficient biofuel production technologies or systems that can take up a variety of raw materials; (vi) the need for technologies for making waste biomass charcoal pellets or briquettes for cooking; and lastly, the need for efficient coal burning technologies. It is important to note that the study indicates that there is a huge technology gap in both the agro-processing and energy sectors hence the need for more investment in research and development towards development, adaptation, copying and reverse engineering of improved technologies for Malawi wherever possible in order to meet the technology needs in these two key industries.

According to the UN Department of Economics and Social Affairs, (2007) technological change for developing countries like Malawi often consists of adoption of technologies or marketing and organizational strategies, which are already well established in developed countries. Similarly, in Malawi's context, innovation is not so much a matter of pushing back the frontier of global knowledge, but more on the challenge of facilitating the first use of new technology in the domestic context. Innovations therefore should be considered broadly as improved products, processes, and business or organizational models. For successful industrial development in Malawi, there is need therefore to think not only of R&D and the creation of knowledge, but also attend to the details of technology and innovation acquisition, adaptation, dissemination, and use in diversified local settings.

In terms of outreach and extension gaps in line with industrial development and policy, the study generally reveals some significant gaps in terms of disconnection between the academia and industry. Some of the outreach and extension gaps include (i) lack of relevant exchange programs; (ii) lack of business and innovation incubators; (iii) lack of significant industrial attachment and apprenticeship programs; (iv) lack of marketing linkages and networks; and finally, lack of innovation and business award programs in both the in energy and agro-processing sector. However there is need to strengthen the linkage between the academia or researchers and Industry or society through outreach and extension programs or projects in these sectors. This will help to ensure functional innovation cycles where there is continuous engagement of industry, society and government in the research and development process to ensure development of need-driven programs, products and services towards solving the existing problems in industry towards economic growth. This would also involve outreach and extension programs that facilitate learning and linkage like exchange program, industrial internship, incubation and market linkages, networking program and innovation award programs.

There is need therefore for MUST through the Industrial Research Center to work with the priority objective of (i) designing and developing new models comparable with the latest available in the international market and pass on the knowhow to the industry for commercial exploitation through either short course programs, extension or outreach programs. (ii) Establishing and strengthening the testing and quality control research laboratories in order to make available experimental and testing facilities for all types of technologies in the agro-processing and energy sectors. (iii) re-enforcing the documentation of relevant technical data for Malawi by making available latest and detailed data on energy resources, new designs, energy system models, testing methods and international standards and specifications (iv) work on establishment of capacity building programs in terms of training, incubation, exchange programs and industrial attachments to enhance the technical skills and capacity of industrial workers, innovators and entrepreneurs towards industrial development.

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Factors Influencing Adoption of Off-grid Community-based Solar Photovoltaics in Chikwawa District, Malawi

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ABSTRACT

Solar PV diffusion policy has generally neglected demand-based factors, thereby limiting adoption rates. In Malawi, community solar photovoltaics (CSPV) have been used as the means for diffusing off-grid photovoltaics in rural areas, but the national energy policy is yet to incorporate a diffusion strategy aligned with user attitudes towards the technology. Rogers' Diffusion of Innovation technology-specific attributes of relative advantage, compatibility, complexity, trialability and observability were applied in determining factors influencing diffusion of CSPVs in Chikwawa, Malawi. A standard multiple regression model constructed from interview responses of 309 users revealed that observability of CSPV benefits and the technology's compatibility with user characteristics are the major factors influencing adoption. We conclude that the major factor influencing CSPV diffusion is observability followed by compatibility; and we find no evidence that complexity and trialability do influence diffusion among community users of Chikwawa. Ease of use and opportunity to try the CSPV therefore play no significant role in influencing adoption. Therefore, a policy for diffusion of PVs in rural Malawi must place particular emphasis on observable benefits and compatibility of the technology with potential user characteristics.

Keywords: Community solar photovoltaics, Roger's Model, adoption, off-grid, rural

INTRODUCTION

The energy industry is experiencing a significant transition due to a worldwide focus on reducing pollution that is going along with the need to meet increasing demand for electricity (Sommerfeld *et al.* 2017). In light of this, policies for deploying sustainable resources have driven both developed and developing countries to search for alternative renewable energies (REs) in order to sustain their economic development and growth (Sriwannawit 2015; Ondraczek 2014).

The motives for investing in renewable energies (REs) might differ between countries and between regions. For example, it can be noted that environmental concerns are mainly driving developed countries to take up REs; whereas, against a need to achieve economic growth and development, poor developing countries are finding it hard to expand their energy capacities without exploring alternative routes that should add on to fossils and hydroelectricity (see for example Sampaio and González 2017).

The decentralized off-grid systems have included wind, biomass, geothermal and solar. These have been supported by various researchers due to their flexibility, little to no carbon footprint, ease of mobilization, low running costs and renewability (Zerriffi 2011; Smith and Urpelainen 2014; Brass

et al. 2012). But, among these, solar photovoltaics (PV) are increasingly being seen as the leading alternative energy source for households and communities (Sampaio and González 2017).

The PV market has evidently grown over the past decade especially across Europe, Asia and America, and researchers such as Devabhaktuni *et al*. (2013) and Avrutin *et al.* (2011) expect further growth. Evidence of growth was demonstrated by Sampaio and González (2017) when they showed that there had been a 41% worldwide sales growth between years 2000 and 2015; and that China and Taiwan's markets had grown by 71% within the same period. But, unlike the European and Asian experience, PV uptake remains relatively low in Sub-Saharan Africa (Kebede *et al*. 2014; Bazilian *et al*. 2013; Ondraczek 2014).

Malawi is one of the countries in Sub-Saharan Africa with very low cross-country electrification. Hydroelectricity is the main electric energy source that is supplied solely by Escom. Nonetheless, by 2013, only 20% of urban households and 1% of rural households had hydroelectric supply with lengthy and daily load shedding (Tenthani *et al*. 2013). Faced with a growing population, energy demand is increasing, thereby putting more pressure on the existing grid (Kaonga *et al*. 2014).

Kerosene, fuelwood and charcoal are the primary energy sources for heating, lighting and cooking taking up to 90% of total energy consumption due to their affordability and accessibility (Currie *et al.* 2012; Jumbe and Angelsen 2011; Kambewa and Chiwaula 2010; Tchereni 2013).

The installed generation capacities of new renewables was less than 2MW (Zalengera *et al*. 2014), pushing the country to the bottom of comparative overall electrification with other countries (Deichmann *et al.* 2011; Onyeji *et al*. 2012). The government of Malawi (GoM) was expecting that by 2010, REs would reach 5.5% consumption but it was at a worrying 0.2% (GoM 2010).

PV Diffusion and the Case of Malawi

Different countries have adopted diverse mechanisms for ensuring diffusion of PVs. The most popular ones are feed-in-tariffs (FIT) adopted by a majority of European countries (Briguglioa and Formosa 2017; Jenner *et al*. 2013). Another mechanism employed by countries like Japan and the United States is that of renewable portfolio standards (RPS), whereby use of REs is mandatory by law (Sampaio and González 2017).

Nevertheless, as was observed by DeCicco *et al*. (2015), most diffusion programmes are push-based, to the neglect of the consumer. This neglect was highlighted by Sommerfeld *et al.* (2017) and Fleiß *et al.* (2016) as the leading cause of failure of policy initiatives for expansion of REs. They posited that citizen and consumer acceptance of a technology policy is a critical element in its diffusion since the consumers are expected to align themselves with the policy.

In Malawi, a specific RE policy is yet to be developed; and the current energy policy fails to specifically point out a diffusion strategy for REs (GoM 2003). PV diffusion in Malawi has observably been sporadic and uncoordinated. Agents of deployment have mostly been donors and the government (Girdis and Hoskote 2005). These government and donor-funded projects have been push-based community programmes, again without a proper study into the perceptions and attitudes of the target consumers towards the PV.

Bashiri and Alizade (2017) found that adoption of REs is dependent on political, market and social factors. The social element includes customer reaction and behavior towards the RE. Thus, the finding of Sommerfeld *et al.* (2017) that customer perceptions are not deeply considered is related to the social dimension of RE diffusion. In terms of customer perception, Rogers (2003) proposed technology-specific attributes that influence consumer rate of adoption of the technology. He

postulated that consumers are influenced by five factors for adoption, namely: relative advantage, observability, compatibility, trialability and complexity of the new technology.

The need for determining factors that influence users to accept and adopt community-based PVs, which is the mainstream PV deployment strategy in Malawi, prompted this study. Coupled with push factors, positive consumer attitudes tend to pull demand; and a determination of adoption pull factors about the technology itself is necessary for proper design of diffusion policy that is informed by an understanding of customer perceptions.

Our study therefore informs policy building by showing the diffusion factors that are critical to community acceptance of PVs. It applies the five elements proposed by Rogers (2003), being the widely applied theory in diffusion research and one that is user-centric (see, for example, Messier 2013; Sriwannawit 2015). This study therefore was conducted to determine factors that influencing adoption of community-based solar photovoltaics (CSPVs) among community users in Malawi, focusing on Chikwawa District.

MATERIALS AND METHODS

Diffusion attributes of Rogers' model were applied to design a Likert-type questionnaire for data collection in the villages of Gumbwa, Mikolongo, Chilongoma, Ndakwera and Chithumba where community solar PVs had been installed at a school and/or health centre. Using the standard questionnaire, quantitative data was collected using both self-administered and personal interview methods as some of the respondents could not write and read on their own.

Using Likert-type scales, respondents were required to indicate their level of agreement with particular statements, as follows: *Strongly Agree*, *Agree*, *Neutral*, *Disagree* and *Strongly Disagree*. The statements were items related to the dependent construct, adoption; and the independent constructs: relative advantage, observability, complexity, compatibility and trialability.

Cronbach's Alpha was used to test internal reliability and consistency of the construct scales. A score of less than 0.6 indicates a high level of independence between items, therefore at least 0.6 was deemed acceptable for scale reliability in this study (Manerikar and Manerikar 2015). Some items were deleted or rephrased in order to improve the Alpha, and the final results were as shown in Table 1.

Table 1: Construct Scale Reliability

Reliability Statistics			
	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Adoption	0.849	0.867	5
Trialability	0.751	0.77	4
Relative advantage	0.856	0.878	6
Compatibility	0.846	0.833	7
Observability	0.712	0.703	4
Complexity	0.652	0.628	4

Basing on local council demographic data, about 2100 households were deemed to be benefiting from the CSPVs in all 5 sites. The questionnaire was administered to a quota sample of 350 users, identified by site committee members and those found onsite and grouped according to installation site, age, occupation and sex. Actual responses were 309, achieving a response rate of 88.2%.

Quantitative data was analysed using SPSS 20.0 for determination of constructs, descriptive statistics, bivariate correlations between constructs and regression analysis. All constructs were together put into the regression model; and then other constructs were controlled for when their power of prediction was insignificant. The factor that had the highest prediction power was taken as the one that best influences variance in adoption.

RESULTS AND DISCUSSION

Objective i: To establish factors influencing CSPV adoption

Respondent descriptives are summarized in Table 3. The dependent variable, *adoption*, is shown first. 53.2% of respondents indicated to have adopted but 41.4% were neutral about it. On the independent variables, *observability* appeared to have been the highest indicated factor at 99.4%, followed by *relative advantage* at 91.4%, then *compatibility* at 63.7%.

Table 2: Adoption and influencing factor descriptives

Construct	Strongly Agree/Agree	Neutral	Strongly Disagree/Disagree	N	Mean score
Adoption	53.2	41.4	5.4	297	3.44
Observability	99.4	0.6	0.0	309	4.27
Relative advantage	91.7	8.3	0.0	300	4.16
Compatibility	63.7	30.7	5.5	309	3.71
Trialability	41.6	51.7	6.7	298	3.35
Complexity	13.0	39.6	47.4	309	2.66

Further correlation analysis was then undertaken to test the strength of relationship between the perceived level of CSPV adoption and each influencing factor. Table 3 shows the results.

Table 3: Correlation between each construct and adoption

		Adoption	Observability	Relative Advantage	Compatibility	Trialability	Complexity
Adoption	Pearson Correlation	1	.854*	.741*	.626*	.553**	-.174
	Sig. (2-tailed)		.037	.017	.029	.010	.204
	N	297	297	288	297	287	296

In Table 3, the strongest relationship with adoption was that of observability, which was positive at 0.854 and significant at 95% confidence level (p=0.037). Relative advantage correlation coefficient was strong at 0.741 (p=0.017), followed by compatibility at 0.626 (p=0.029); while the trialability coefficient was 0.553 (p=0.01). There was no significant correlation between adoption and complexity.

These results were generally consistent with the pattern of overall descriptive results for the constructs except for complexity. Similar to the descriptives, observability, relative advantage, compatibility and trialability followed each other in strength of correlation. We then developed a standard multiple regression model determine the major factor that influences adoption.

Determination of major factors influencing adoption
A regression analysis was done, and the results are shown in Table 5

Table 4: Regression model for adoption

		Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
Adoption (Constant)		3.911	0.555		7.048	0
Observability		0.397	0.09	**0.417**	8.256	0
Compatibility		0.323	0.064	0.399	4.295	0.002
Relative Advantage		0.18	0.083	0.152	5.718	0.005
Trialability		0.132	0.069	0.125	0.903	**0.058**
R^2	0.409					
Adjusted R^2	**0.366**					
Regression F (df = 4, 281)	39.402					
P	0.001					

Initially, the model included all the four factors, but *trialability* was shown not to be a significant factor in influencing adoption as shown in Table 4. Having taken off *trialability,* the second model with the remaining three factors explained 36.6% of the variance in adoption. With an ANOVA *F*-statistic of 39.4, our model was considered good for prediction.

We therefore conclude that there is a very high likelihood that 37% of the variation in adoption can be explained by the factors of *observability, relative advantage and compatibility.*

The results show further that observability was the major factor that uniquely explains the variance variance in adoption at 41.7%, followed by compatibility at 39.9% when other factors are controlled for. This shows that for the respondents in question, observability and compatibility played the strongest role in engendering the desire to adopt. Respondents had earlier indicated that they had used the CSPV after seeing the benefits their friends were experiencing.

Our findings suggest that visibility of technology benefits to potential users *(observability)* is the most important factor for Chikwawa users. They show that observability is of more relevance than the mere presence of benefits *(relative advantage)* if such benefits cannot be seen. Compatibility with respondent characteristics, e.g. occupation, is another major significant factor enhancing adoption. Thus, relative advantage is of more relevance when such advantage aligns with user characteristics.

These results corroborate earlier findings (Palm 2017; Richter 2014; Bashiri and Alizade 2017; Reinsberger *et al*. 2015) on importance of observability and compatibility to adoption. Our findings differ from previous research, however, because they compare the observability impact against other factors. In our case, the results have isolated *observability* and *compatibility* as the main determining factors of adoption against other factors in the case of Malawi.

The implications of these findings are that the visible benefits of PVs and the compatibility of use to which it is put should be emphasized when promoting diffusion of PVs. On the other hand, mere ease of use (*complexity*) and opportunities availed to potential users to test the CSPV (*trialability*) do not induce adoption.

CONCLUSIONS

The findings have shown that adoption of the CSPV is thus determined by perceived observability, compatibility and relative advantage of the CSPV. It has shown that *observability*, followed by *compatibility*, is the best factor influencing adoption. It is therefore recommend that a policy for diffusion of PVs in rural Malawi must place particular emphasis on observable benefits and compatibility of the technology with potential user characteristics.

The study has identified the significant factors influencing adoption in one part of Malawi, which can be applied when strategizing on promotion of photovoltaics in Malawi. Such information may assist project implementers and government when considering investing in similar communities; and may demonstrate points to enhance for easier and quicker adoption.

Further research should look at the adoption of solar home systems in the communities where CSPVs were installed and in their surrounding communities. Since studies have shown that observability effects stimulate purchase within a 1-mile radius (Richter, 2014), then further study should focus on relative increase of home systems in surrounding areas to the community.

The study is carried out among a single ethnic group, thereby limiting its generalizability to other ethnic groups. Furthermore, its findings are directly applicable on community photovoltaics, hence generalization to the home photovoltaic market is limited. Nevertheless, since community and home PV systems are similar, the study provides an insight into perceptions about the technology that can be extended to consumer perceptions about home systems.

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Consumer Choice and Willingness to Pay for Improved Cookstoves in Malawi: A Case of Chiradzulu District

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ABSTRACT

The Government of Malawi is championing the promotion of Improved Cookstoves (ICS) with a target to disseminate 2 million stoves by 2020. Although Non-Governmental Organizations (NGOs) have been promoting ICS in Malawi over the past 10 years, the adoption of such technologies has been low and slow. The study was therefore designed to assess the consumer choice and willingness to pay for Improved Cookstoves in Chiradzulu District. The understanding of consumers` choice and their willingness to pay for the ICS is crucial in order to design appropriate strategies to enhance their wider adoption. The ICS technologies considered in this study were Chitetezo Mbaula, Total Landcare Rocket Stove and Portable Rocket Stove. Data used in this research were collected from 404 households in Chiradzulu district using a contingent valuation questionnaire. The study found that distance to firewood source from home, monthly household expenditure, firewood collection frequency per week, number of adult females, type of firewood source, household head age, knowledge of negative environmental impact of Three-stone Firewood Stove and under-five children ratio were significant factors influencing the choice of ICS. The mean WTP for Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove were estimated as MK1586 ($2.22), MK2838 ($3.98) and MK12032 ($16.87), respectively. WTP for Chitetezo Mbaula was significantly influenced by number of firewood collection helpers in the household, sex of the household head, total time spent collecting firewood and number of adult female members in the households. While firewood source distance from home and age of the primary cooks significantly influenced TLC Rocket Stove`s WTP. Furthermore, WTP for Portable Rocket Stove was significantly influenced by firewood source distance from home and total time spent collecting firewood. These findings have important implications for designing strategies for up-scaling ICS to support government program of reaching two million households by 2020. The study therefore recommends ICS dissemination efforts to be extended to Chiradzulu District and that GoM and ICS dissemination partners should consider the socioeconomic differences that affect household`s choice and WTP for ICS.

Key words:

INTRODUCTION

Globally, biomass fuels are the common sources of fuels for cooking and heating. According to Adkins et al. (2010), between 2 and 2.4 billion people worldwide use wood, dung, charcoal and other biomass fuels for cooking and heating. In Malawi, biomass fuels particularly firewood and charcoal are important sources of energy used by 95 percent of the households (NSO, 2012). Of all biomass extraction activities, fuel wood accounts for 84 percent of total annual use and 70 percent of Malawian households living in the urban areas have no access to non-biomass fuels (Stanturf et

al., 2011). In fact, even households with electricity connection still depend on woodfuels due to high cost of electricity, appliances and unreliable supply of electricity (Jumbe and Angelsen, 2011). The dependence on biomass as a source of energy is associated with several environmental and health-related problems such as deforestation, carbon emissions and household air pollution (Sagbo, 2014). In Malawi, the recorded deforestation rate of 3.2 percent is among the highest in Africa (Malakini et al., 2014). Furthermore, the burning of biomass for cooking and heating on traditional three-stone firewood stove is often associated with greenhouse gas emissions (Wanjohi and Smyser, 2013). Apart from carbon dioxide emissions, soot from burning biomass fuels is considered the second largest contributor to anthropogenic climate change (Sagbo, 2014). In terms of health outcomes, household air pollution (HAP) is reported the second most vital risk factor after childhood underweight in sub-Saharan Africa with 13,000 annual deaths estimated in Malawi alone (Lim et al., 2012).

To reduce the health and environmental effects associated with cooking with biomass fuels, the Government of Malawi in partnership with some development partners and Non-Governmental Organizations have been promoting the use of improved cookstoves (ICS) in place of traditional three-stone (open-fire) cookstoves. These ICS are clean and energy efficient cooking technologies that allow a more complete combustion of firewood (Malinski, 2008). The complete combustion minimizes the emission of black carbon particles that are detrimental to human health and environment (Inayatullah, 2011). Increased combustion efficiency through the use of ICS reduces the frequencies of firewood collection and expenditures on firewood purchase by households (Malinski, 2008). Therefore, the reduction in the frequency of firewood collection releases labour that can be used for other household social and economic activities such as farming, businesses or leisure. The commonly promoted firewood ICS in Malawi are Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove. Chitetezo Mbaula is made from pottery clay and is moulded, cured and fired to produce the portable ceramic end product. TLC Rocket Stove is fixed and has metal pot rests and metal firewood stand. These metal features enhance durability and efficiency of the stove. However, the combustion chamber is made of burnt bricks and mud (MBAULA, 2014). Portable Rocket Stove is not fixed, as the name suggests, and is made of steel, aluminum and insulated bricks hence is the most durable stove compared to the Chitetezo Mbaula and TLC Rocket Stove.

Government of Malawi and other local and international organizations have been promoting ICS to Malawian households with a target to distribute 2 million stoves by 2020. Research has shown that despite such dissemination efforts and promotions, ICS adoption has been low and slow (Meyer et al. (2015), Jeuland et al. (2013) and Jueland et al. (2015)). This raises the questions as to whether consumer preferences for ICS are considered during such promotions. Furthermore, researchers and practitioners claim that ICS technologies are not widely adopted because they do not conform to user preferences and local cooking environment (Lewis and Pattanayak, 2012). Therefore, a thorough understanding of household choices for ICS is critical for the success of interventions aimed at promoting ICS. The current study was therefore designed to assess the consumer choice for ICS in Malawi. Specifically, the study aimed at determining factors that influence household choice of ICS using data collected from Chiradzulu District which is one of the districts targeted for ICS distribution. By addressing this question, the study has unraveled critical factors that need to be considered by government and other stakeholders involved in the up scaling and out scaling of ICS technologies. This study was conducted to to assess consumers` choice and WTP for ICS in Chiradzulu District. Specifically, the study achieved two objectives, namely; to determine factors that influence the choice of cookstoves among households in Chiradzulu District and to determine consumer WTP for ICS and its influencing factors in Chiradzulu District.

MATERIALS AND METHODS

The study was conducted in Chiradzulu District, in the southern region of Malawi. The district was chosen because it is one of the districts targeted for ICS promotion under the National Cookstove Program by GoM which aims at distributing 2 million ICS by 2020. Furthermore, the district is densely populated (304 people per km^2) with 90 percent of people living in rural areas (Kamanga *et al*., 2009). As such the district is not well endowed with forests. Therefore, the distribution of efficient cookstoves would help to reduce forest degradation in the district in addition to health benefits.

The study was a mixed design involving quantitative (household survey questionnaire interviews) and qualitative (key-informant interviews and focus group interviews) methods. The questionnaire collected information on socioeconomic and demographic characteristics of both household head and primary cook, characteristics of firewood sources and stove choice set. During the interview, the primary cook in the household was asked to choose his/her preferred stove among the three stoves, Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove. The questionnaire was presented with pictures of the three stoves along with the description of their associated features and attributes. The primary cook was then asked to choose from the pictures the stove he/she would prefer based on the description of each stove. After choosing the preferred stove, the respondent was asked to state his/her WTP through a discrete question. Given that bid prices reflects the real stove`s market prices, respondents were asked to state whether they are willing to pay for the chosen stove or not. In this regard, a respondent with WTP greater than the stated bid amount gives a `yes` response and is considered willing to pay for that particular stove. If WTP is less than the bid, the respondent is considered not willing to pay for the chosen stove. Data were entered, validated, cleaned and analyzed using SPSS and STATA. Determinants of ICS choice was analyzed using Multinomial Logit Model while WTP for ICS and it`s influencing factors was analyzed using single bounded contingent valuation model and probit model, respectively.

RESULTS AND DISCUSSION

Determinants of ICS Choice

Results in Table 2 in the appendix indicates that Chitetezo Mbaula was most preferred stove by the sampled households as followed by TLC Rocket Stove and Portable Rocket Stove with probabilities of 63 percent, 23 percent and 14 percent, respectively. Total monthly household income was found to significantly influence average probability of choosing Portable Rocket Stove by 6.7 percent while negatively influence the average probability of choosing Chitetezo Mbaula by 8.1 percent at 1 percent significant levels. The results imply that total monthly household income is positively associated with the probability of choosing metallic and durable ICS. Furthermore, Chitetezo Mbaula had a lower price bid of MK650 (or $0.91) as compared to Portable Rocket Stove (MK12, 000 or $16.83) and TLC Rocket Stove (MK3, 000 or $4.21), therefore the probability of choosing a more expensive stove is positively associated with income. These findings portray that as household income increases, households invest more on environmental conservation technologies such as buying expensive ICS and vice versa (Malla and Timinsina, 2014). Number of adult female members in the household was positively associated with the probability of choosing Chitetezo Mbaula but negatively influence the probability of choosing TLC Rocket Stove by 9.9 and 8.9 percent, respectively. The reason could be because adult female household members are usually the primary cooks in rural settings, therefore, increase in their number in the household reduces the burden of cooking and collecting firewood. Jagger and Jumbe (2016) also found the same results that households with a large labour force for fuel collection were less likely to adopt ICS.

Source of firewood significantly influences the probability of choosing TLC Rocket Stove and Portable Rocket Stove positively and negatively, respectively. The results show that sourcing firewood from the private land increases the average probability of choosing the fixed TLC Rocket Stove by 8.7 percent but decreases the average probability of choosing the Portable Rocket Stove by 9.3 percent. The reliance on private land for firewood may signal firewood abundance, so households are not conscious about fuel saving attribute of ICS. Furthermore, weekly firewood collection frequency significantly increases the average probability of choosing Chitetezo Mbaula, *ceteris paribus*. Results in table 3 show that increase in number of firewood collection trips (that a household takes per week) by 1 increases the probability of choosing Chitetezo Mbaula by 2.3 percent. Distance to firewood source from home positively determine the probability of choosing Chitetezo Mbaula but negatively determine TLC Rocket Stove choice, holding other things constant. This implies that households that take long distances to collect firewood are willing to pay for ICS that is portable. The findings agree with what Mobarak *et al*. (2012) found that in cases where the households have to take long and strenuous walks to collect firewood, ICS is preferred. The MNL results show that increase in the number of under-five children increases the probability of choosing Chitetezo Mbaula but decreases the average probability of choosing TLC Rocket Stove at 33 percent and 49 percent respectively. Results for Chitetezo Mbaula are similar with findings by Kooser (2004) who also found a positive relationship between increase in number of under-five children and choice of ICS. The negative relationship between TLC Rocket Stove choice and number of under-five children could be as a result of the fact that children are mostly carried by their mothers during cooking hence the mother may not want to restrict herself to stay in the kitchen (in using fixed TLC Rocket Stove) during cooking. Knowledge of negative environmental impact of using inefficient Three-stone Firewood Stove positively influences the choice of Chitetezo Mbaula but negatively influences the choice of fixed TLC Rocket Stove, ceteris paribus. During data collection, households admitted that cutting down trees for firewood was one of the leading causes of deforestation. It was also observed that some households planted trees in their homes so as to ease the burden of fetching firewood and also protect their houses from strong winds. Therefore, the choice of Chitetezo Mbaula which saves firewood about 60 percent could be to control the firewood demand hence reduce the pressure on trees.

The last determinant of ICS choice is household head age. Results show that increase in age of the household head negatively influences the probability of choosing TLC Rocket Stove, holding other things constant. There is marginal reduction in the probability of choosing fixed stove as household head gets old. The results can be attributed to the fact that TLC Rocket Stove is fixed and looks more complicated as it comprises both metal and clay components to improve its efficiency hence not attractive to older people. These results are similar to results by Nlom and Karimov (2015) who found that older individuals are resistant to change and they are less likely to make a switch from less complicated traditional cooking technologies as compared to younger ones.

Estimation of Mean WTP

Table 1 below shows the estimation results from single bounded model. The mean WTP for Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove are estimated at MK1586 ($2.22), MK2838 ($3.98) and MK12032 ($16.87), respectively. The mean WTP estimates are significant at 10 percent for Chitetezo Mbaula, 1 percent for TLC Rocket Stove and Portable Rocket Stove. Mean WTP value for Chitetezo Mbaula ($2.22) is far above the market price of the stove ($0.9). This implies that respondents are willing to pay for Chitetezo Mbaula even if market price rises by 144 percent. However, the estimated mean WTP for TLC Rocket Stove ($3.98) is slightly lower than the TLC Rocket Stove market price (MK3000 or $4). Portable Rocket Stove estimated mean WTP is slightly higher than its market price by MK20.34 ($0.03).

Table 1: Estimates of WTP

Stove Type	Coefficient	Std. Error	z-value	p-value
Chitetezo Mbaula	MK 1586.225	MK 853.996	1.86	0.063*
TLC Rocket Stove	MK 2838.06	MK 66.893	42.08	0.000***
Portable Rocket Stove	MK 12032.04	MK 43.663	275.57	0.000***

* Significant at 10 percent level ** significant at 5 percent level and *** significant at 1 percent level

Determinants of WTP

The study found that total number of adult female members in the household, sex of the household head, number of firewood collectors in the household and total time the household spend collecting firewood are the significant factors affecting WTP for Chitetezo Mbaula (Table 3 in the appendix). Total number of firewood collectors in the household was found to have a negative and significant relationship with the WTP for Chitetezo Mbaula. The results show that having one additional firewood collector in the household`s WTP for Chitetezo Mbaula, *ceteris paribus*. The results are similar with what other researchers found that the households with more labour on firewood collection cannot appreciate energy saving characteristics of ICS (Kooser, 2012). Total time spent collecting firewood by the household significantly increases the probability for willingness to pay for Chitetezo Mbaula, holding other things constant. The results imply that an hour increase in time spent travelling to and from firewood source and collecting firewood, increases the probability of WTP for Chitetezo Mbaula by 0.05 percent. The findings meet prior expectation that people who spend much time in sourcing firewood or those with firewood scarcity problem are willing to pay for ICS so as to save time through reduced firewood trips.

Sex of the household head significantly determine WTP for Chitetezo Mbaula. The results indicate that having a male household head positively influences the probability of WTP for Chitetezo Mbaula by 8.4 percent, holding other things constant. The results are similar to the findings from Concern Universal (2014) that men are supportive of ICS and about 78 percent of household heads managed to buy Chitetezo Mbaula without NGOs` persuasion. The last but not the least significant determinant of WTP for Chitetezo Mbaula is number of adult female members in the household. The increase in the number of adult female members positively affects the probability of WTP for Chitetezo Mbaula by 3.7 percent. The Positive relationship might be revealing the important aspect that presence of female members in the household enhances the understanding of ICS benefits because females are mostly involved in cooking. The adult female members` experience with inefficient traditional three-stone firewood stove can make them pay for ICS such as Chitetezo Mbaula.

TLC Rocket Stove`s WTP is influenced by firewood source distance from home, primary cook age, total number of female adults in the household, firewood collection frequency and monthly household income. Out of these determinants, firewood source distance from home and age of the primary cook are significant determinants of WTP for TLC Rocket Stove at 1 percent and 10 percent, respectively. Results in Table 3 further indicate that firewood source distance from home increases the probability of WTP for TLC Rocket Stove. The increase in distance to the firewood source from home by a Kilometer increases the probability of WTP for TLC Rocket Stove by 34 percent. The results are similar with findings from Mobarak et al. (2012), who found that households who take long and strenuous walks to collect firewood are willing to pay for firewood efficient cook stoves.

CONCLUSIONS

In conclusion, the study has proved that Chitetezo Mbaula is the most preferred ICS seconded by TLC Rocket Stove and lastly, Portable Rocket Stove, therefore, GoM and ICS dissemination partners should prioritize the distribution of Chitetezo Mbaula. The study further establishes that the choice of Chitetezo Mbaula is significantly influenced by household monthly income, distance to firewood source from home, presence of under-five children in the household, firewood collection frequency per week, number of adult females and knowledge of negative environmental impacts of using Three-stone cookstove. TLC Rocket Stove Choice is significantly influenced by household head age, distance to firewood source, presence of under-five children, knowledge of negative environmental impacts of using three-stone cookstove, number of adult females and type of firewood source. While Portable Rocket Stove choice is significantly influenced by household monthly income and type of firewood source. These findings signals the importance of considering differences in household characteristics and degree of heterogeneity among households when promoting ICS technologies. The findings call for GoM and ICS dissemination partners to consider promoting various designs of ICS so that households are given a chance to choose their preferred stove design. The study has also established a significant relationship between the choice of ICS and household knowledge of negative environmental impact of using three-stone firewood stove. Civic education and awareness campaigns on negative environmental impacts of using traditional Three-Stone cookstove are needed prior to ICS dissemination for wider adoption and sustained usage.

In addition, the study has proved that people value ICS and are willing to pay about the market price of the ICS and even more in Chiradzulu District. While there are programs that distribute ICS for free in Malawi, households would manage to buy ICS if they are informed about health and environmental benefits of using ICS. Therefore to ensure stove availability, GoM and ICS dissemination partners must consider training local artisans for sustained production of ICS. Furthermore, the study discovered that total distance to firewood source and total time taken to collect firewood increases the WTP for ICS in Chiradzulu District. This implies that ICS are appropriate technologies for areas with firewood scarcity, for instance, Chiradzulu District. Therefore, there is a need to extend and intensify the current ICS distribution efforts to all areas with firewood scarcity problem.

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APPENDIX

Table 2: Estimation Results for Choice of ICS from MNL Model

Variable name	Pr(ICS_choice==Chitetezo Mbaula) = 0.6294			Pr(ICS_choice==TLC Rocket Stove) = 0.2312			Pr(ICS_choice==Portable Rocket Stove) =0.1394		
	Marginal Effects	Std. Error	p-value	Marginal Effects	Std. Error	p-value	Marginal Effects	Std. Error	p-value
Household head age (years squared)	0.0000	0.0000	0.164	-0.0000**	0.0000	0.026	0.0000	0.0000	0.391
Household head gender	0.0351	0.0624	0.560	-0.0694	0.0561	0.217	0.0343	0.0400	0.392
Total monthly-household expenditure (MK)	-0.0814***	0.0301	0.007	0.0143	0.0258	0.580	0.0671***	0.0215	0.002
Firewood collection frequency (trips/week)	0.0226*	0.0131	0.084	-0.0185	0.0116	0.110	-0.0041	0.0086	0.634
Number of adult female in the household	0.0987**	0.0501	0.049	-0.0892*	0.0457	0.051	-0.0095	0.0325	0.769
Firewood source (1=Private land 0=otherwise)	0.0058	0.0579	0.920	0.0871*	0.0457	0.057	-0.0929**	0.0445	0.036
Cooking behavior (1=cooking on two places, 0=otherwise)	-0.0833	0.0845	0.324	-0.0067	0.0702	0.923	0.0901	0.0637	0.156
Firewood Source distance (Kilometers)	0.0350**	0.0144	0.015	-0.0206*	0.0121	0.089	-0.0144	0.0094	0.124
Under-five children ratio (Total number of under-five children/total household size)	0.3269*	0.1865	0.080	-0.4857***	0.1729	0.005	0.1588	0.1171	0.175
Household location (1=Chitera TA, 0=Likoswe TA)	0.0537	0.0531	0.312	-0.0065	0.0461	0.887	-0.0471	0.0359	0.189
Household assets value (MK)	-0.0322	0.0205	0.116	0.0242	0.0180	0.178	0.0080	0.0143	0.575
Knowledge of health impact of three-stone firewood use (1=know, 0=otherwise)	-0.0488	0.0558	0.381	0.0489	0.0474	0.302	-0.0001	0.0379	0.998
Knowledge of environmental impact of three-stone firewood use (1=know, 0=otherwise)	0.1040*	0.0617	0.092	-0.0973*	0.0555	0.080	-0.0067	0.0413	0.871

* Significant at 10 percent level; ** significant at 5 percent level; *** significant at 1 percent level.
Log likelihood = -348.00204
Number of observations = 403
LR ch2 (26) = 68.65
Prob > ch2 = 0.0000

Table 3: Determinants of WTP for ICS

Variable name	Chitetezo Mbaula (n=241)		TLC Rocket Stove (n=96)		Portable Rocket Stove (n=67)	
	Marginal Effects	Std. Error	Marginal Effects	Std. Error	Marginal Effects	Std. Error
Female adult in the household (number)	0.0382*	0.0210	0.0990	0.0851	-	-
Household head sex	0.0843**	0.0414	-	-	0.2534	0.1621
Monthly-household expenditure (ln)	-	-	0.0538	0.0456	-	-
Firewood collection help (number of people)	-0.0210**	0.0102	-	-	-	-
Firewood collection time (hours)	0.0283**	0.0121	-	-	-0.3589***	0.1005
Age of the primary cook	-	-	-0.0057*	0.0030	-	-
Firewood Collection Frequency (per week)	-	-	0.0281	0.0240	-	-
Firewood source distance (ln)	-	-	0.0823***	0.0219	0.1432***	0.0398
Monthly Fuelwood Expenditure	-	-	-	-	0.0000	0.0000
Location (1 =T.A Chitera 0= T.A Likoswe	-0.0359	0.0232	-	-	0.1568	0.1547
	Log likelihood= -44.20474		Log likelihood= -41.3750		Log likelihood= -32.830903	
	LR ch2(5)= 29.16		LR ch2(5)= 22.41		LR ch2(5)= 24.31	
	Prob>0.0000		Prob>0.0004		Prob>0.0002	

*Significant at 10 percent level *** significant at 5 percent level ** Significant at 1 percent level.

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Effect of Homogenization Stirring Speed on Mechanical and Water Barrier Properties of Gallic Acid Treated Zein-Oleic Acid Composite Films.

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ABSTRACT

In this study, the effect of different homogenization stirring speeds (10,000 rpm, 12,000 rpm, 14,000 rpm, 16,000 rpm, 18,000 rpm and 20,000 rpm) on mechanical and water barrier properties of gallic acid treated zein-oleic acid composite films was investigated. In addition, the effect of low and high homogenization speed on film microstructure with respect to speeds at 10,000 rpm and 20,000 rpm was also investigated. Results showed that homogenization stirring speed significantly ($p<0.05$) and diversely affected the mechanical and water barrier properties of the films. A higher tensile strength (TS) of 33.4MPa was registered in gallic acid treated zein-oleic acid composite containing 2% oleic acid homogenized at 12,000rpm while the lowest tensile strength of 10.9MPa was registered in gallic acid treated zein-oleic acid composite containing 2% homogenized at 10,000rpm. Overall, higher tensile strength values irrespective of film type were observed at homogenization stirring speeds of 12,000rpm, 16,000rpm and 18,000rpm. Lower water vapour permeability values (WVP) were obtained at homogenization stirring speeds of 10,000rpm, 12, 000rpm and 16,000rpm with the lowest value of 0.23 (g mm m^{-2} h^{-1} kPa^{-1}) registered in gallic acid treated sample homogenized at 10,000rpm. Results further revealed that WVP increased with increasing homogenization stirring speed especially in gallic acid treated zein films suggesting that the film matrix was being weakened as homogenization became more intense.

Keywords: homogenisation, Gallic acid, Zein – Oleic Acid, Permiability

INTRODUCTION

It is generally well recognized that biodegradable films are characterized by poor mechanical and water barrier properties. As such, various approaches such as enzymatic and chemical treatments as well as use of composites have extensively been used to address the limitations (Kolodziejska & Piotrowska, 2007; Makishi et al., 2013; Ahmad, Hani, Nirmal, Fazial, Mohtar, & Romli, 2015; Ghanbarzadeh & Oromiehi, 2008). However, despite the use of different approaches to improve film properties, there is still a growing realization that in most instances, some of the film properties are still negatively affected. Over the years, more alternatives continues to emerge where a combination of approaches are used in an attempt to significantly improve the mechanical and barrier properties of different biodegradable films produced from different hydrocolloids (Bae et al., 2009; Kolodziejska & Piotrowska, 2007; Di Pierro, Chico, Villalonga, Mariniello, Masi, & Porta, 2007). The use of composite films have been reported to produce films with superior properties as it combines the beneficial properties of the individual components involved in the film forming substances. Of particular interest, the use of hydrophobic compounds in composites such as

lipids have mainly been used to improve water barrier properties of films. However, apart from improving the water barrier properties, the use lipids have also been reported to improve mechanical properties owing to the favoured protein-protein interactions induced by the oil in the film matrix (Ma et al., 2012). With respect to the use of zein in development of biodegradable films, the classical brittleness exhibited by zein films is one of problems limiting applications of zein based films. In an attempt to address the poor water barrier properties and brittleness associated with zein based films, various researchers have previously applied different approaches (Ghanbarzadeh & Oromiehi, 2008; Arcan & Yemenicioglu, 2013; Alkan et al., 2011). For lipid based films, processing conditions such as stirring speed has been reported to be an important factor in obtaining homogeneous films which can subsequently influence the performance of the films (Garcia, Martino, Zaritzky, 2000). It is well known that different homogenization speeds are used in incorporating lipids in composite films. The homogenization speeds of 13,500 rpm followed by 20,500 rpm for 1 min and 3 min respectively have extensively been used by various researchers in incorporating lipids into composite films (Fabra, Talens, & Chiralt, 2008; Jimenez, Fabra, Talens, & Chiralt, 2013). From our previous unpublished work, we observed that tensile strength was progressively being reduced while permeability was being increased when oleic acid was incorporated into the gallic acid treated zein films. In view of such developments, preliminary work was carried out using different homogenization stirring speeds where a number of interesting observations were noted. Six homogenization stirring speeds were purposefully selected to be used in this current study. It is worth noting that the use of these six homogenization speeds should not be mistaken as a continuation of optimization process. This clarification on the presumed misconception is based on the fact that results from preliminary work revealed that film properties for different film types based on gallic acid treatment and oleic acid concentration were affected differently by the same homogenization speed. This therefore suggest that it might be difficult to identify a single homogenization speed where all the film properties are fully optimized hence the choice of a wide range of homogenization speeds to cater for the changes. The study was conductedto determine the effect of homogenization stirring speeds on mechanical properties (tensile strength and elongation at break of gallic acid treated zein-oleic acid composite films and on water vapour permeability of gallic acid treated zein-oleic acid composite films

MATERIALS AND METHODS

Materials

Zein (approx. molecular weight (35000), nitrogen content (13.1-17.0), fat (<2%), heavy metal (<0.002%) and lead (≤2ppm) were purchased from Hangzhou Showland Technology Company Limited, Hangzhou, People's Republic of China. All other chemicals and reagents used were of analytical grade.

Film preparation for control and gallic acid treated film samples without oleic acid.

6g of the zein was dissolved in 100ml heated (80^{o}C) 95% ethanol using a hot plate with magnetic stirrer for 30 min. After 30 min, ethylene glycol at 27% based on protein zein weight was added and the mixture was further heated for 30 min. For the control samples, the solutions were further heated to boiling point using a hot plate and were left to boil for 15-20 s. While still hot, the solutions were filtered using a polyester screen mesh with mesh opening size of 110 µm to remove any foreign materials and undissolved components. The filtered solutions were later homogenized using FJ 200-S homogenizer (Shanghai Biaoben Mould Factory Company, Shanghai, China) using the six homogenization stirring speeds (10,000rpm, 12,000rpm, 14,000rpm, 16,000rpm, 18,000rpm and 20,000rpm) for 4 min. The film forming solution was degassed using ultrasonic cleaning machine for 30 min and the solution was cast in square plastic plates (10cm by 10cm) by weighing 15g of the film forming solution. The films were dried for 36 h at 30^{o}C. The dried films were conditioned in a dessicator for 48 h at 53 % relative humidity and 25 ^{o}C using concentrated solution

of magnesium nitrate prior to further analysis. For the gallic acid treated samples, the same procedure as outlined for the control samples was followed. After 30 min from addition of plasticizer, the solution was left to cool at room temperature for 7-10 min before gallic acid (99% purity) at the concentration of 40mg/g zein was added to the film forming solution. The gallic acid was first dissolved using luke warm distilled water (50 ^{o}C). After stirring for 1-2 min using a magnetic stirrer, the gallic acid treated film forming solution was incubated at 50 ^{o}C for 30 min. After the incubation, the solutions were further heated to boiling point using a hot plate and were left to boil for 15-20 s and thereafter the same procedure as applied for control samples was followed.

Gallic acid- treated zein-oleic acid composite films: The same procedure as outlined for gallic acid treated samples without oleic acid was followed. Soon after the film solutions were filtered, the solutions were allowed to cool before different concentrations of oleic acid were added ((1%, 2%, 3% and 4.0% based on protein zein weight). The solutions were later homogenized using the six different homogenization stirring speeds (10,000 rpm, 12,000 rpm, 14,000 rpm, 16,000 rpm, 18,000 rpm and 20,000 rpm) for 4 min. Thereafter, the film solutions were degassed for 30 min using ultrasonic cleaning machine and the same procedure outlined for gallic acid treated films was followed.

Molecular weight distribution analysis

The molecular weight distribution analysis for the selected samples was carried out for two reasons. The first reason was to confirm cross linking by gallic acid and in this respect, the film forming solutions for the control and gallic acid treated samples were homogenized at 10,000rpm for 3 min. The second reason was to determine the effect of the low and high homogenization stirring speeds on molecular weight of the selected film forming solutions. This analysis was carried out after it was observed that results obtained from particle size determination to relate the particle size with film properties proved unsuccessful as there was no direct link among particle size, homogenization stirring speeds and trend of improvements in film properties. As such, results from particle size determination were not used. The molecular weight (MW) distribution profiles of the samples were estimated by high-performance gel-filtration chromatography. Waters 600 liquid chromatography system (Waters Co., Milford, MA, USA) equipped with 2487UV detector and Empower work station was used for this experiment. The column used was TSK gel 2000 SWXL7.8 i.d x 300 mm (Tosoh Co., Tokyo, Japan), while the mobile phase consisting of acetonitrile/water/trifluoroacetic acid (40/60/0.1, v/v/v) was delivered at a flow rate of 0.5 mL/min. The column temperature was 30 ^{o}C and 10 µL of sample was injected into the HPLC system. A MW calibration curve was obtained from the following standards from Sigma: cytochrome C (12,500Da), aprotinin (6,500Da), bacitracin (1,450Da), tetrapeptide GGYR (451Da), and tripeptide GGG (189Da). The results were obtained using UV detector (220nm), and data analysis was performed using gel-permeation chromatography software.

Mechanical properties

Tensile strength (TS) and percentage elongation at break (EAB) were performed in accordance with ASTM standard method D882 (ASTM, 1996) using a texturometer (Stable Microsystems, model TAXT2i, Surrey, UK) fitted with a 25kg load cell. The initial grip separation was set at 50mm and crosshead speed at 1 mm/s. The tested film strips were cut into 80 x 20mm sizes. Tensile strength was calculated by dividing maximum force with film cross-section (thickness x width) and percentage elongation at break was calculated by dividing the film elongation at rupture by initial gauge length or the difference in distance between the grips holding the film specimen before and after the break.

Water vapour permeability

Water vapour permeability tests were carried according to ASTM method E96-95 (1995) with minor modifications. Special bottles with a measured diameter of 2.7cm and a depth of 5cm were used to determine the WVP of the films. Films (4.5x4.5cm) were cut to ensure that they adequately cover the mouth area of the bottles (5.73cm^2). 10mL of distilled water was placed in the special bottles used and the films were mounted on to the bottles and subsequently sealed using super glue previously applied on the mouth to ensure that films firmly stuck to the bottles. A small load was placed on the films for 5-10 min to ensure a good seal is achieved as a result of the action of the applied super glue. The other portions of the sample extending beyond the mouth area of the bottles were carefully cut off to avoid errors resulting from sample or specimen area being larger than the exposed mouth area. The whole assembly was placed in a dessiccator containing silica and the water vapour transmission rate and water vapour permeability were calculated based on the equations (1) and (2):

WVTR= Slope/film area (g m^{-2} h^{-1}) (1)

$WVP = (WVTR \times L)/(PA_1 - PA_2)$ (g mm m^{-2} h^{-1} kPa^{-1}) (2)

PA_1 = Vapor partial pressure at film outer surface in the dessicator = 0 kPa

PA_2 = Vapor partial pressure at film inner surface in bottle = 3.169 kPa

ΔP = -3.169 kPa

L = The average film thickness (mm)

The dessicator containing the samples was thereafter placed in an incubator at 25^{o}C and the bottles (whole assembly, bottle with film sample) were first weighed every 2 h and then measurements were carried out every 12 h for two days. Water vapour transport was determined by weight changes of the bottle.

In addition, other parameters such as thickness of the films were calculated in order to help in calculation of water vapour permeability. Moisture content and solubility were also calculated although they have not been included in this work.

Statistical analysis

Statistical analysis was performed using IBM-SPSS Inc. software (version 16.0). One-way analysis of variance (ANOVA) was used to determine significant differences between means, with the significance level taken at ($p < 0.05$). Duncan multiple range test was used to analyse significant difference in different mean values and differences were considered to be significant at $p<0.05$.

RESULTS AND DISCUSSION

Mechanical properties

Results for tensile strength (TS) and elongation at break (EAB) are presented in Figures 1 and 2. TS was significantly and diversely affected by the homogenization stirring speeds. The highest TS value of 33.4 MPa was registered in the gallic treated film containing 2% oleic acid homogenized at 12,000rpm while the lowest TS value of 10.9MPa was registered in the gallic acid treated film containing 2% oleic acid homogenized at 10,000rpm. Although the changes in TS were variable, generally low homogenization stirring speed of 10,000 rpm irrespective of film type resulted in low TS values. Overall, high TS values irrespective of film type were registered at homogenization speeds of 12,000 rpm, 16,000 rpm although for some film types, relatively higher TS values were also registered at a homogenization speed of 18,000 rpm. In general, higher homogenization stirring speeds such as those exceeding 18,000 rpm especially in both gallic acid treated zein films as well as in gallic acid treated zein-oleic acid composite films. The decrease in TS was highly evident in gallic acid treated zein films where TS was reduced by 46% when homogenization speed was increased from 10,000 rpm to 20,000 rpm. However, the changes were highly variable

characterized by inconsistent trends in different film types and these observations are consistent with those reported by Bae et al (2009) who reported that TS of fish gelatin/montmorillonite nanocomposite films varied inconsistently when the shear rate was varied from 0-5000rpm. Consistent with our observations on the variability of the changes in TS. Other authors previously reported that mechanical changes in composite systems are highly variable. They attributed this to factors such as amounts and molecular properties of each constituent in the mixture, degree of their compatibility and interactions within the films (Arcan & Yemenicioglu, 2013). Results further revealed that in most film types irrespective of gallic acid treatment and oleic acid concentration, TS increased when homogenization speed increased from 10,000 rpm to as high as 16,000 rpm and this can be attributed to the enhanced protein-protein and protein-oleic acid interactions. The differences in these findings can be attributed to the different preparation conditions and treatments as well as film components involved in the development of films making comparisons from different studies relatively difficult.

Elongation at break was significantly affected by the homogenization stirring speed with the values characterized by inconsistent trends with marginal differences. The highest elongation at break value was 4.5% registered at 20,000 rpm homogenization speed in gallic acid treated films containing 1% oleic acid. On the hand, the lowest two values at 2.7% for each were registered at 16,000rpm and 18,000rpm homogenization stirring speeds for gallic acid treated films and gallic acid treated zein-oleic acid films containing 2% oleic acid respectively. From the results, it is evident that either the homogenization stirring speeds and oleic acid did not improve the inflexibility problems associated with zein based films.

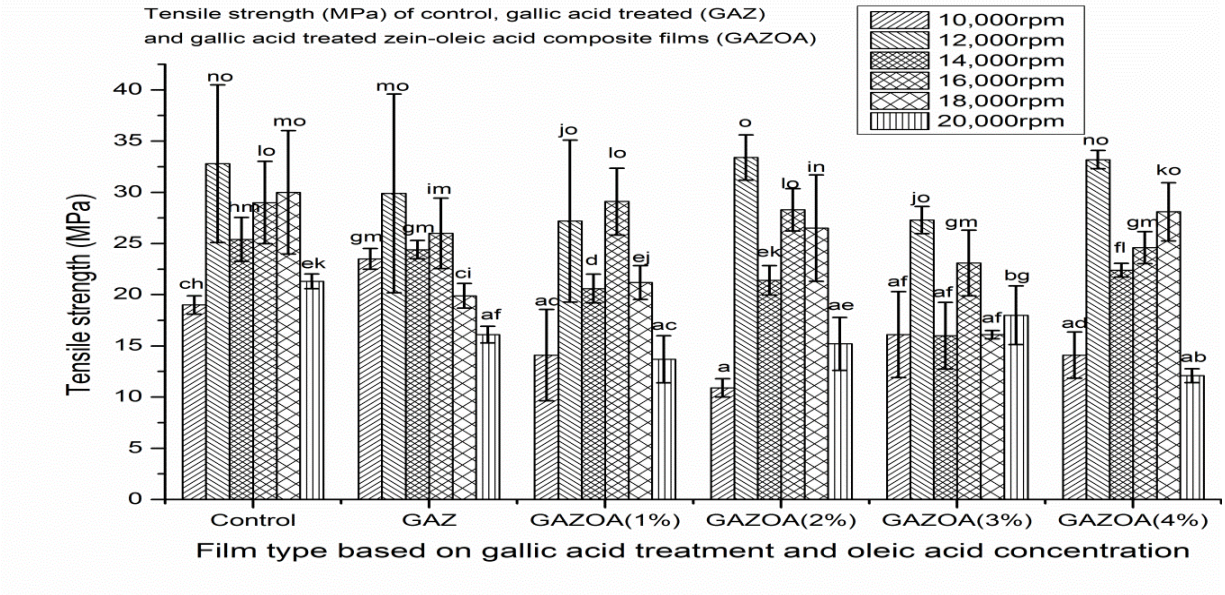

Figure 1: Tensile strength (Mpa) of various films

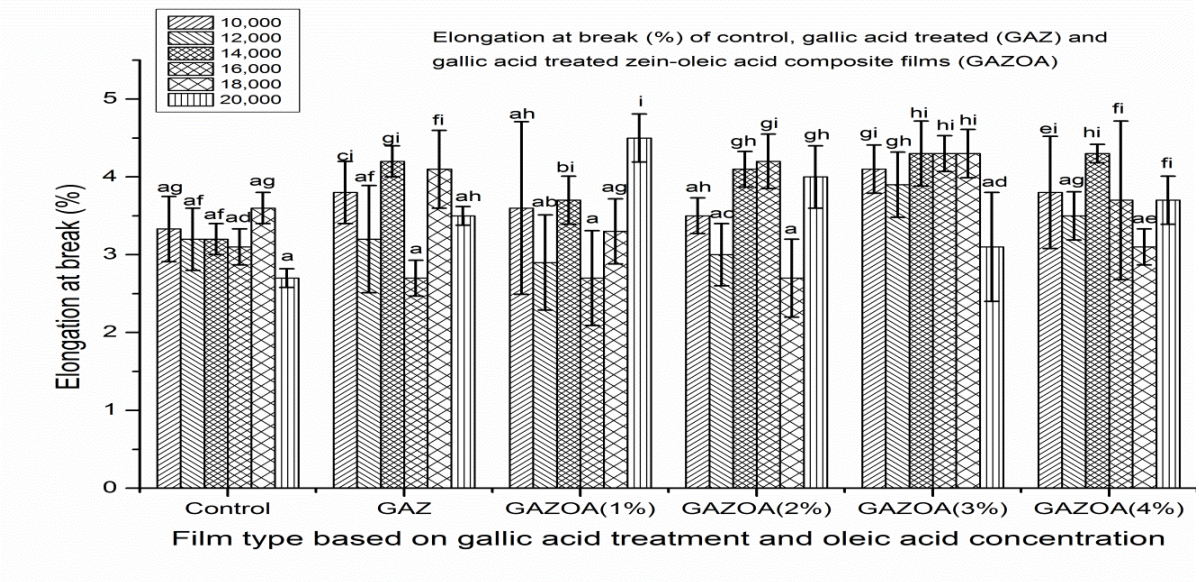

Figure 2: Elongation at break of various films.

Water vapour permeability

Results on water vapour permeability (WVP) are presented in Figure 2. WVP was significantly and diversely affected by homogenization stirring speed. In general, relatively low homogenization speeds at 10,000 rpm, 12,000 rpm and 16,000 rpm resulted in comparatively low water vapour permeability values. On the other hand, higher stirring speeds at 18,000 rpm and 20,000 rpm resulted in relatively higher permeability values although there were isolated incidences where lower permeability values were obtained even at high stirring speeds. However, this is inconsistent with findings previously reported by other authors who found out that WVP was decreasing with increasing homogenization stirring speed (Bae et al., 2009; Limpisophon, Tanaka, & Osako, 2010). The increase in permeability for gallic acid treated zein films when subjected to various homogenization speeds was very significant. WVP increased from 0.23 to 0.58 (g mm m^{-2} h^{-1} kPa^{-1}) at the homogenization speeds of 10,000 rpm and 20,000 rpm respectively representing an increase of 152% in permeability.

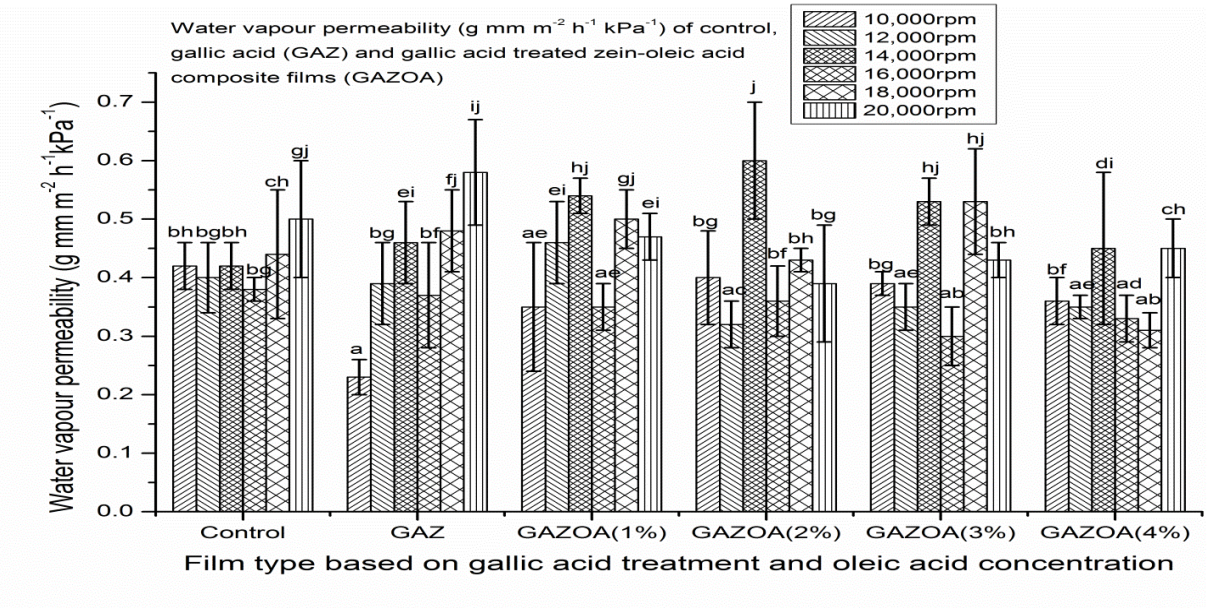

Figure 3: Water vapour vaporisation on various gallic and oleic acid concentration

This observation seemed to be in agreement with findings by other authors who reported that the formation of polymers with a high molecular weight in gelatin-calcium carbonate composite films induced by transglutaminase gave rise to the weakened water vapour permeability of treated films resulting in increased permeability values (Wang, Liu, Ye, Wang, & Li, 2015).

CONCLUSION AND RECOMMENDATIONS

The results of this study have shown that the mechanical properties and water vapour permeability of gallic acid treated zein-oleic acid composite films were significantly affected by the different homogenization stirring speeds used. For gallic acid treated zein-oleic acid composite films, it is recommended that homogenization stirring meant to incorporate the lipids in the films should not exceed 16,000 rpm because higher stirring speeds would weaken the film structure resulting in low tensile strength and higher water vapour permeability which is undesirable for films functionality.

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Potential of Improving Energy Efficiency in Water Works through Energy Audits: A Case Study of Mzuzu Water Supply

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ABSTRACT

Energy is prime mover of all economic sectors. However, there are many countries, including Malawi, that are in energy deficit. Efficient use of available energy is one of cost effective way of reducing demand and hence improve energy availability. Although energy efficiency principles and practices are well known, most industrial energy users in developing countries do not use energy efficient practices in their operations. The sector of interest in this study is the water sector where pumping systems are rated as the highest energy users in water supply. The study investigated energy efficiency practices at Mzuzu Water Supply (MWS) using a comprehensive energy audit. The energy audit involved four critical step: structured interviews involving management and staff to assess commitment, perception and knowledge; detailed technical assessment of the pumping system was done (flow charts, motor ratings, power factor, pumping outputs, electricity bills, condition of equipment); collected data was prepared for modelling purpose using Monitoring and Targeting Tool; and finally MWS system was modelled using Pumping System Assessment Tool (PSAT). The results of the study showed that management commitment, energy policy and budget were rated as the most critical factors in the implementation of energy efficiency measures. Using the model, pumping sub-systems that had highest potential for energy savings were identified. For sustainability, energy audits should not be implemented in isolation and as once-off activity but rather they should be in the job descriptions and be embedded in continuous improvement management practices of the organisation such as Plan-Do-Check-Act and Total Quality Management.

Key words: Energy efficiency, water supply, energy audit, Mzuzu Water Supply.

INTRODUCTION

Water and energy are vital for social and economic development as well as environmental sustainability. Water and energy are linked i.e. water-energy nexus (Copeland, 2014). Studies reveal that about 2-3 percent of the energy consumption in the world is used for pumping and water treatment for urban and industrial purposes but also energy consumption could be reduced by about 25 percent in most of water systems all over the world through performance improvements in the energy efficiency (Watergy, 2009). The availability of energy and water for use is challenged by increasing world population, massive industrialization and agricultural activities which demand large quantities of these resources. Water problems are aggravated by limited availability of energy. Malawi electricity generation capacity is at 351 MW against a demand of 354MW in 2015 and a projected demand of 798 MW in 2020 (MoFEP&D, 2014). Energy is a scarce and expensive resource, and therefore it contributes significantly to the cost of production of goods and services. Energy is the key element that must be managed to insure a company's profitability (Turner, 2005).

Energy efficiency is a measure of energy used for delivering a given service and improving energy efficiency means getting more from the energy that we use (EEDO, 2012). Energy management is the strategy of adjusting and optimising energy using systems and procedures so as to reduce energy requirements per unit output. The objective of energy management is to achieve and maintain load requirement, minimise the cost of energy and environmental effects (Lamba & Sanghi, 2015). Different treatment processes have varying energy requirements largely based on water source, facility age, treatment type, storage capacity, topography, and system size, which encompasses volume produced and service area (U.S.EPA., 2013).

Globally, water supply systems through pumping account for approximately 25 percent of the energy consumed by pumping units, and for about 20 percent to 60 percent of the total electricity usage in many industrial, water, and wastewater treatment facilities (Ferman et al, 2008; Europump and Hydraulic Institute, 2001). Studies indicate that energy accounts for one third of the operating budget for drinking water and wastewater systems (U.S.EPA., 2008) and that in water supply systems about 90 percent of energy is used for pumping (Grundfos, 2004; EPRI, 2002; Reinbold and Hart, 2011; Bunn & Reynolds, 2009). Available literature states various causes of energy inefficiency in water supply systems. Liu et al (2012) sites that energy efficiency challenges are due to sector governance issues, knowledge gaps and financing hurdles, Moreira (2012) outlines that inefficiencies in water systems are due to; old and outdated equipment, aged pipes, wrong maintenance and replacement policy, complexity in the supply network, lack of cross information between various departments that manage operations and absence of correct measuring and monitoring of main parameters that regulate the system, while Constantin and Smaranda (2005, p. 191) states that electrical energy expenditure depends on the specific character of the area, source, technology used, and the means by which the water is transported to the consumer.

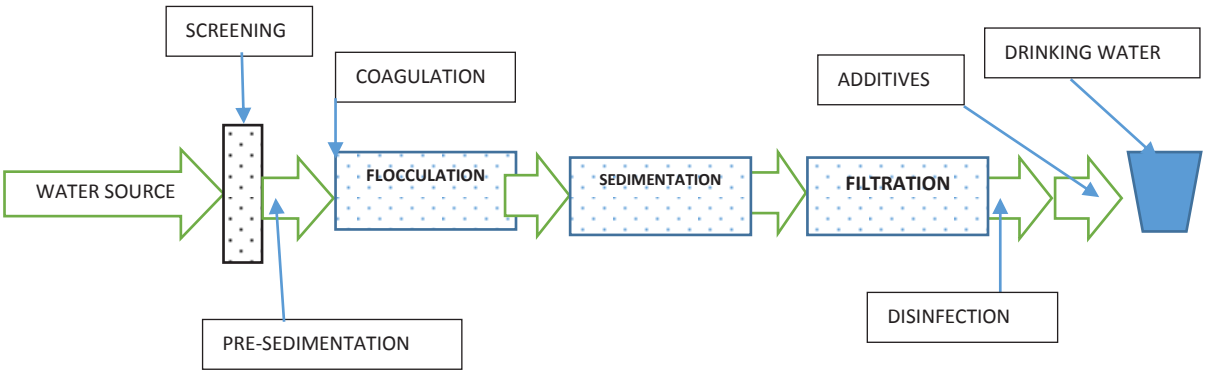

Figure 1: Generalised water treatment process (Hickey, 2008).

Understanding where energy is being consumed is critical to focusing resources where the greatest savings potential exist (Coleman et al. 2009, p. 15). There is evidence that EE improvements are possible; at Emfuleni in South Africa they realised 14 million KWh/year energy savings with 12000 tonnes GHG emissions avoided with a payback of less than 3 months, at Pune in India 3.8 million KWh/year energy savings with 38,000 tonnes/year CO2 emissions avoided was achieved (Barry, 2007). Energy efficiency and management improvements are possible when an energy audit in a facility is carried out which seeks to determine where, when, why and how energy is being used. A better understanding of the facilities that consume energy is necessary for a successful energy audit and this can be accomplished through plant surveys and system measurements. Water and wastewater facilities can often achieve a 20 to 30 percent reduction in energy use through energy efficiency upgrades and operational measures (U.S. EPA, 2010a; Leiby & Burke, 2011, p. 157).

The main objective of this study is to contribute towards operational cost reduction efforts through improvements in the energy utilization in MWS. Specifically, the study undertakes audit energy in

MWS system; assesses potential energy savings in MWS; and develops energy utilization model in MWS system.

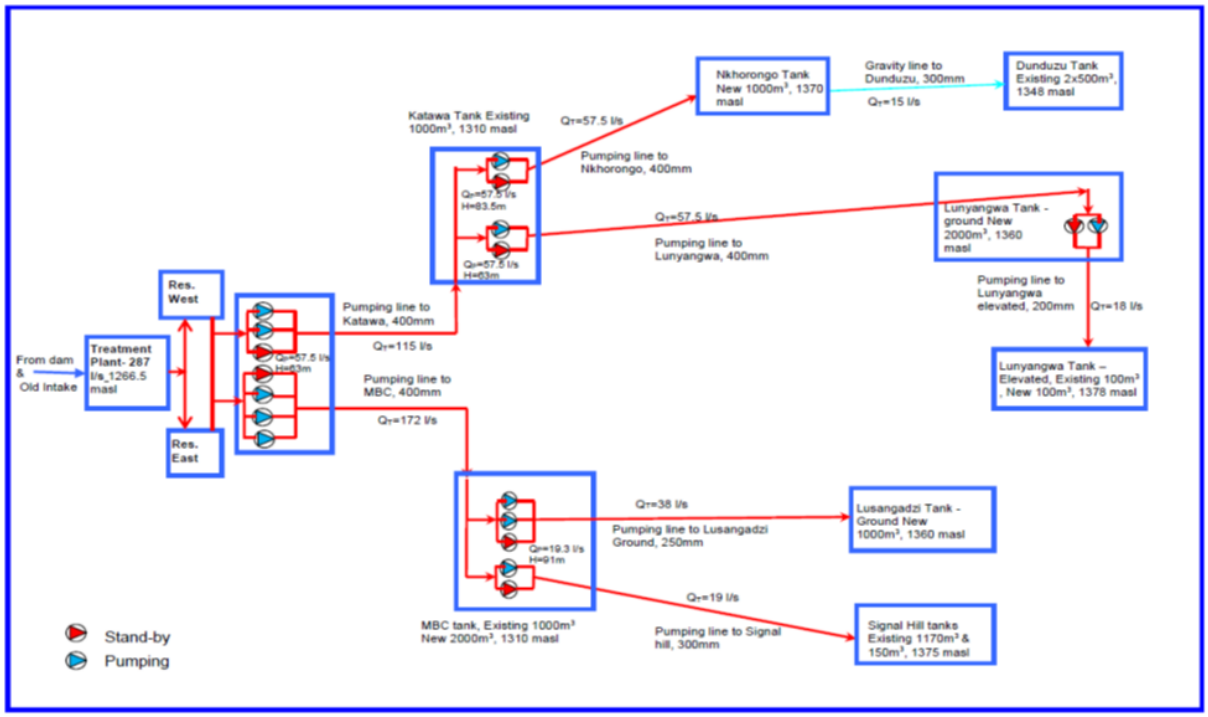

Figure 2: Schematic Layout of Mzuzu Water Supply Pumping System

Malawi and Northern Region Water Board

Water problems in Malawi are exacerbated by limited availability of energy i.e. hydro power generation capacity of only 351 MW against projected demand of over 700 MW (Taulo, Gondwe, & Sebitosi, 2015). According to studies done at Mzuzu University, energy savings are economically viable in Malawi (Krishnakumar & Dhungel, 2013). This study is located at MWS in the Northern Region Water Board (NRWB) which is wholly owned by the Government of Malawi. NRWB saves a population of 277,412 with 79 percent coverage and 35,565 customers. MWS is the largest of NRWB water supply systems producing about 18000m^3 of water per day (NRWB, 2015). The average energy intensity for the whole system is 0.37KW/m^3. MWS had a 38 percent contribution to the NRWB total expenditure of which 13 percent was due to energy cost (NRWB, 2015).

MATERIALS AND METHODS

Data collection

Data was collected through the use of a survey, energy audit and computerised pumping efficiency assessment tool.

Structured questionnaires were administered to NRWB employees to gather more data related to energy policies, energy efficiency and management practices in MWS. This was done to understand the context and operating perceptions that could have an impact on the adoption of energy efficiency and energy management policies and measures.

Then a preliminary energy audit was done at MWS using American Standard ASME/ANSI EA-2-2009 which provides detailed requirements for an assessment of the pumping systems (ASME EA-2-2009, 2009). The audit was done in order to identify the locations of energy use, the functions and the intensity of the energy for the particular equipment. The audit data was collected using a computerised tool, Pumping System Assessment Tool in combination with Energy Monitoring and

Targeting (M&T), to calculate potential energy and associated cost savings (Casada, 2007; CIPEC, 2002; Ferreira & Castanheira, 2005). The results of the questionnaire and energy M&T were both further analysed using excel sheets and SPSS.

RESULTS AND DISCUSSIONS

The results of this study are summarised in terms of the Survey, the outputs of the M&T and the output of the PSAT.

The Survey

A total of 100 questionnaires were administered and randomly distributed, 82 completed questionnaires were received at the end of the entire exercise. This could reflect the importance the respondents put to the research area.

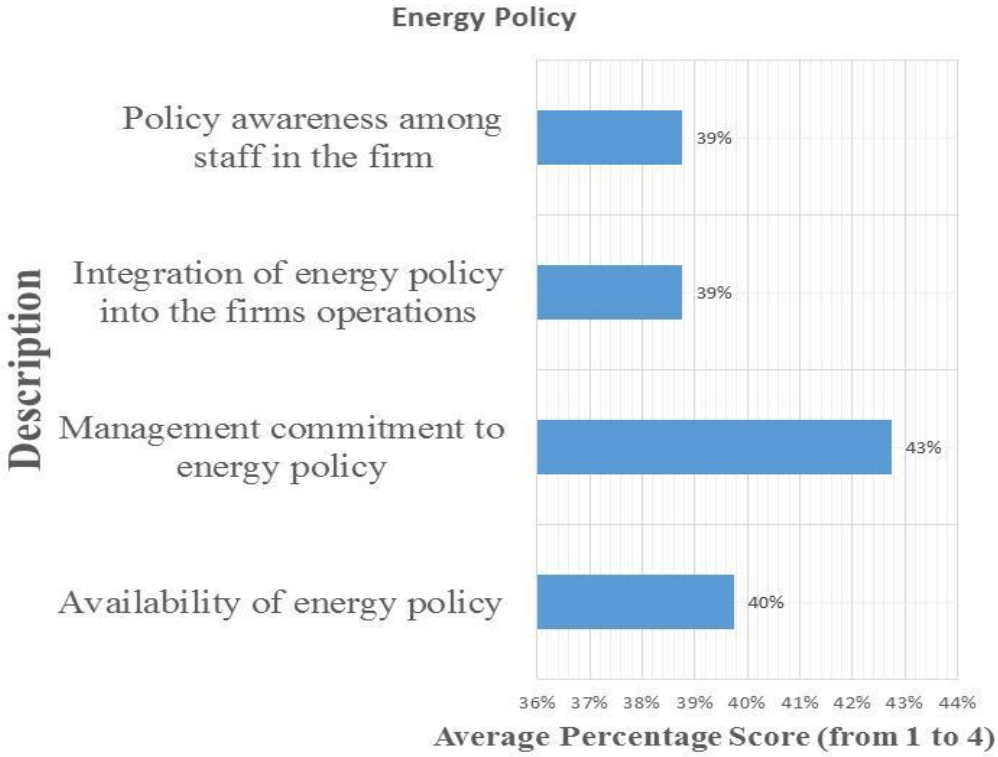

Figure 3: Average score percentage of the respondent rating of energy policy

The survey then assessed the area of energy policy. From the results, a 40 percent rating indicate that there is informal energy policy; 43 percent indicate that management has interest but not committed to energy management; 39 percent show that there is no energy policy integration into the firms operation; and 39 percent indicate that there is no energy policy awareness amongst members of staff (Figure 3).

The results from the perception of respondents imply that management commitment on EE needs improvements. As decision makers, managers are expected to champion EE policy and measures since management commitment to EE is one of the most critical factors for effective and sustained EE improvements; in addition, the lack of a general governance framework or institutional environment that demands good performance, specific EE efforts at the utility level are unsustainable (Liu, Ouedraogo, Manghee, & Danilenko, 2012; Thollander & Ottoson, 2008).

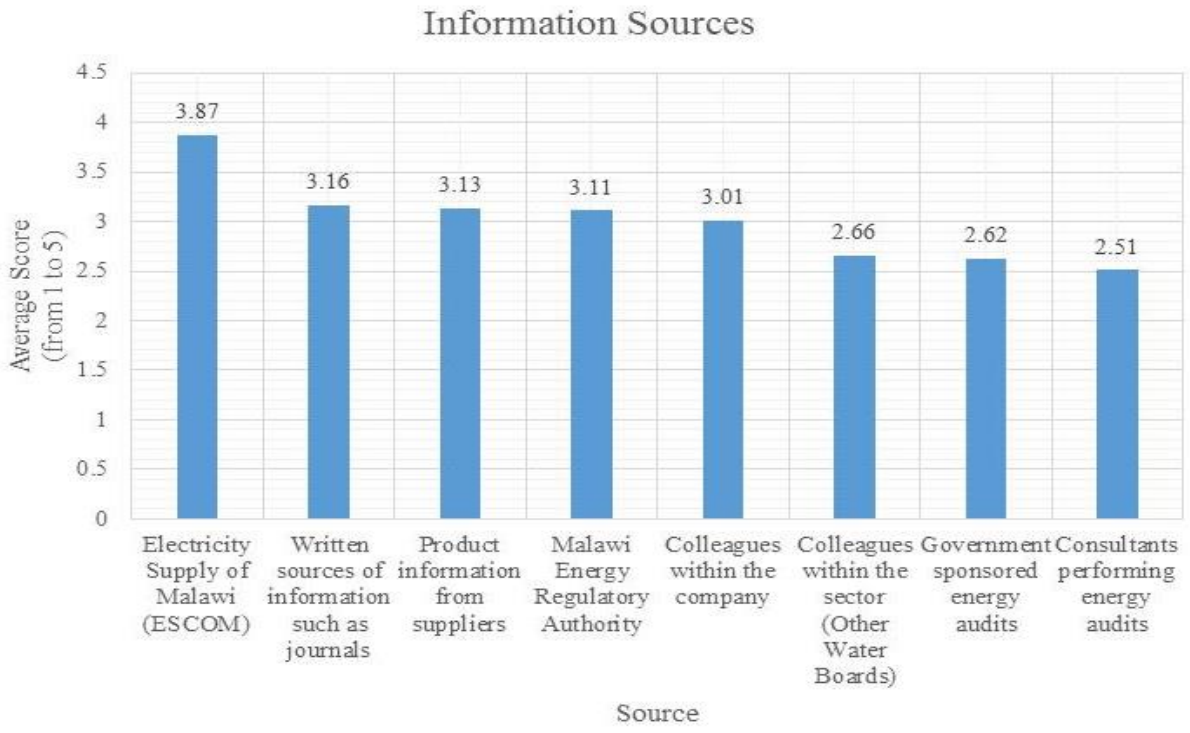

Figure 4: Scaled results of EE opportunities information sources.

For a successful implementation of water supply energy efficiency and energy management, there is need to access relevant information on energy. Therefore, information source must be credible and data be traceable. In the survey, the respondents of the survey were asked to rank the effectiveness of some official and unofficial information sources with regard to energy efficiency in NRWB. The results in Figure 4 show that information from ESCOM was ranked as the best source. These results are in line with EE and management studies done in Ghana (Apeaning, 2012).

The Survey then assessed the main energy consuming processes in MWS. There are six common energy consuming processes. The processes were ranked in a scale of 1 (low) to 5 (maximum). The results showed that clear water pumping consumes more energy than the rest in NRWB. These results agree with the studies which indicate that about 85% of energy consumption in water supply systems is through pumping globally (Grundfos, 2004; Reinbold and Hart, 2011).

In addition, the respondents of the survey were asked to assess the extent to which they have adopted 14 energy efficient technologies and measures in the study area, using a scale of 1 (not implemented) to 5 (extensively implemented). The results of the survey show that carrying out preventive maintenance works was best implemented in the study area seconded by proper pumping system design. These results are comparable to the EE studies done in Kenya (Tiony, 2012). Failure to adoption of EE technologies is associated with various barriers. In the study, the respondents ranked importance of 22 barriers to EE in a scale of 1 to 5, 1 for not important, 2 for rarely important, 3 for sometimes important, 4 for important and 5 for very important. The results of the study showed that lack of budget funding and access to capital were considered as the most important barriers followed by low priority given to energy management and then lack of staff awareness. These are in line with findings of the similar study in Ghana (Apeaning, 2012).

The Survey - Driving Forces for Energy Efficiency Improvement

The survey also investigated on drivers for implementing energy efficiency which forms a basis for decision makers to formulate strategies that can be employed to enhance implementation of energy efficiency measures and technologies. A total of 18 drivers were ranked on a scale of 1(least important) to 5 (most important). The results show that 'long term energy strategy' is ranked as the most important driver seconded by 'Environmental Management Systems (EMS)' which was closely followed by 'threats of rising energy prices. These results are in line with other studies similar studies in Ghana (Apeaning, 2012).

Energy Monitoring and Targeting (M&T)

Energy M&T is a conceptually simple and yet powerful energy management technique that deals with the analysis and interpretation of energy use in the form of time series data (Ferreira & Castanheira, 2005).

The following assumptions were used when performing correlation coefficient tests;

- The variables x and y are linearly related.
- The variables are random variables.
- The two variables have a bivariate normal distribution.

Energy Monitoring and Targeting: Main Treatment Plant

From the equation, the relationship has a coefficient of determination, $r^2 = 0.254$, and $r = 0.504$.

Testing the significance of the correlation coefficient, for $r = 0.504$, $n = 20$, critical values obtained in tables for a 2 tailed is ±2.104, test value $(t) = r\sqrt{\{(n-2)/(1-r^2)\}} = 2.47$, the test value falls in the critical region. It can be concluded that there is a significant relationship between volume produced and electrical consumption.

Energy Monitoring and Targeting: MBC Booster Station

From the equation, the relationship has a coefficient of determination, $r^2 = 0.643$, and 'r' = 0.80.

Testing the significance of the correlation coefficient, for $r = 0.8$, $n = 10$, critical values obtained in tables for a 2 tailed is ±2.306, test value $(t) = r\sqrt{\{(n-2)/(1-r^2)\}} = 3.77$, the test value falls in the critical region. It can be concluded that there is a significant relationship between volume produced and electrical consumption. We can use the equation to predict future energy cost as a result of increased volume of production.

Energy Monitoring and Targeting: Katawa Booster Station

From the trend line, the relationship has a coefficient of determination, $r^2 = 0.9035$, and 'r' = 0.951.

Testing the significance of the correlation coefficient, for $r = 0.951$, $n = 15$, critical values obtained in tables for a 2 tailed is ±2.16, test value $(t) = r\sqrt{\{(n-2)/(1-r^2)\}} = 3.77$, the test value falls in the critical region. It can be concluded that there is a significant relationship between volume produced and electrical consumption. We can use the equation to predict future energy cost as a result of increased volume of production at this station.

Table 1: Mzuzu Water Supply summarised PSAT results

Item	Pump Station	Pump Efficiency (percent)		Optimisation Rating (percent)		Annual Savings Potential (US$)
		Designed	Actual	Designed	Actual	Off Peak
1	MBC Feeders	78	55.3	98.3	69.2	12,600
2	Government Feeders	-	67.9	100.3	87.2	1,700
3	Katawa Feeders	76	52.1	103.7	67.4	8,800
4	Backwash Pumps	-	65.2	90.4	72.9	1,500
5	Signal Hill Feeder	75	49.7	71.83	64.7	2,600
6	Lusangazi Feeder	75	44.3	93.7	57.6	6,200
7	Lunyangwa Feeders	77	63.4	93.2	80.6	2,600
8	Nkhorongo Feeders	79	48.4	81.2	81.2	7,400

From summarised PSAT results in Table 1, the loss of efficiency on MBC and Katawa Feeders could be attributed to compromised maintenance strategies as captured during survey and audit where maintenance policy and plans were not available and this is also evident on worn-out impellers captured at this station, and possible wrong pumping configuration for the pumps running at the station. The loss of efficiency on Government Feeders and Backwash pumps could be attributed to poor maintenance strategies and age. These pump sets were planned for abandonment owing to system review (Metaferia, 2008). The loss of efficiency on Signal Hill, Lusangazi and Nkhorongo Feeders could be attributed to wrong design of pumps running at the station which may have happened as a result of poor demand estimate.

Energy Saving Opportunities

Changes in tariff effected by ESCOM on a 24-hr period has a 265 percent difference between on peak and off peak translating to similar energy cost saving opportunities once utilised (ESCOM, 2016). Power factor for the three station were below 0.90 (Main Plant 0.84, MBC 0.86 and Katawa 0.86) which attract a 30 percent surcharge, implementation of power factor correction on the three stations would avoid this energy expense. Correct demand estimate was not implemented in the three stations attracting a penalty from the energy supplier as punishment, a saving of US$ 10,000 annually, can be realised from these stations. Other energy saving opportunities are; procurement of efficient plant and equipment, energy efficient designs, effective plant and equipment maintenance, use of variable speed/frequency drives etc.

Energy Management

Sustaining energy savings in Mzuzu water supply demands a culture of continuous improvement. The Plan-Do-Check-Act (PDCA) model is pertinent in coming up with MWS management guidelines. The PDCA model is applicable because it facilitates an organizational culture of continuous improvement. The model is a circular evolving process that focuses on continual improvement over time (U.S.EPA., 2011).

CONCLUSIONS

NRWB has not implemented most of EE measures; this could be attributed to lack of knowledge on the available EE measures, insufficient funds for implementation, shortage of expertise in EE measures and low management commitment. ESCOM, a sole electricity supplier and MERA, an energy regulator, are expected from the study, to provide adequate information on EE measures.

Energy efficiency gaps have been identified in the study area and include knowledge and application of ESCOM tariff structure, effective equipment and plant maintenance and proper water supply designs. There is significant loss of pump efficiency in almost all pumping stations under study as observed from the PSAT results in Table 1 which show a remarkable difference between the designed and actual pump efficiencies.

Potentially, MWS through improved motor and pump efficiency from a summary of PSAT results can save US$ 43,400 annually on energy cost for an off peak tariff for Main Plant, MBC and Katawa pumping stations. This saving translates to 500 new water connections at the material time of the study with resultant effects of increased access to potable water in the supply areas and increased sales volume. A 265 percent energy saving potential can be realized in MWS system for each reduction in pumping during the on peak tariff though pumping and reservoir capacity pose a challenge to this opportunity. Annually, about US$ 10,000 energy reduction without investment can be realized through correct demand estimate in MWS.

Energy consumption in MWS is proportional to production. The test values for Mzuzu Main Plant, MBC and Katawa Stations fall in the critical regions with correlation coefficient, R, of 0.50, 0.80 and 0.95 respectively. The weak correlation at the Main Plant is due to submersible pumps which are not metered but share the same energy meter. The mathematical energy models emanating from Main Plant, MBC and Katawa Station can be used as baseline models for interpretation of energy use, monitoring variations, identifying causes, setting targets and monitoring results in MWS system.

Therefore, energy audit, supported by energy M&T and PSAT is critical as it exposes EE gaps in an organisation. The EE gaps once sealed forms part of energy cost saving opportunities. Finally, continuous achievement in EE improvements require institutional capacity, management commitment and employee buy-in, hence, EE initiatives should be embedded in continuous improvement management practices of the organisation such as Plan-Do-Check-Act and Total Quality Management.

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Community Transformation through Installation of Sustainable Renewable Energy Technologies

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ABSTRACT

The inadequate generation capacity from ESCOM hydropower and the geographic isolation of many of the Malawian communities present serious challenges for the equitable distribution of grid power to rural and remote areas. A major concern for these communities is the lack of access to electricity enjoyed by their city counterparts, particularly given the enormous educational, economic and social benefits to be derived from access to power. Projects funded by the Scottish Government International Development Fund, namely Malawi Renewable Energy Acceleration Programme (MREAP) and Sustainable Off Grid Electrification for Rural Villages (SOGERV) aim to provide rural communities with sustainable renewable energy (RE) technologies. Strategic community RE technologies have been deployed throughout Malawi to determine their sustainability. The deployment of strategic community RE technologies included due diligence in technical design, market assessments, needs assessments, procurement analysis of suppliers and contractors, and district engagement for implementation of the projects. A rigorous M&E system, coupled with an intelligent remote monitoring technology, has been deployed to gather key learning from these projects, resulting in a series of learning papers on the sustainability of a community energy approach. Results demonstrate that the approach to community renewable energy systems deployed in these projects significantly improve the long-term sustainability outlook. Investment in the technical, social, economic and organisational aspects of the project design is critical for a sustainable project. Previous efforts in community energy have focused on ownership and operation models where all responsibility lies either with the community, public entities, or a commercial entity. In the projects presented here, a holistic business model for community electrification has been developed that includes community, local government, and private enterprise contributions, roles and responsibilities. Early results indicate this model has the potential to scale up as a sustainable deployment model for off-grid electrification.

Keywords: Community Energy, Rural Electrification, Sustainable Renewable Energy Technology

INTRODUCTION

The inadequate generation capacity from ESCOM hydropower and the geographic isolation of many of the Malawian communities present serious challenges for the equitable distribution of grid power to rural and remote areas. A major concern for these communities is the lack of access to electricity enjoyed by their city counterparts, particularly given the enormous educational, economic and social benefits to be derived from access to power. Malawi currently supplies electricity to only 9% of its population overall and Malawi's rural electrification ranks relatively

low at only 5%[5]. For public institutions such as primary schools, the situation is also grim. UNESCO reported only 10% of primary schools had access to electricity in 2012[6]. The International Energy Agency (IEA) are expecting up to 70% of future energy access to come in the form of mini-grids and other off-grid systems[7]. With this level of emphasis, it is critical to ensure the sustainability of the new systems coming online and address weaknesses from existing projects. This paper describes the development of a novel approach to the design and deployment of off-grid PV systems in Malawi.

MATERIALS AND METHODS

Joss Vassen (2010) highlights the fact that a number of evaluations of distinct projects or country programs are recognized in the literature however, only very little studies evaluate small-scale community energy projects of less or equal to 100 kW in unindustrialized countries with regards to their influence on local living conditions and sustainability postinstallation.

The issue of how to effectively address sustainability of off-grid community energy projects in Malawi was a consistently recurring theme throughout The Malawi Renewable Energy Acceleration Programme (MREAP), a development Programme funded by the Scottish Government over 2012-2015. Previous community energy work in Malawi strongly identified community engagement and support mechanisms as a sustainability measure[8]. Building on this learning, MREAP's approach emphasized community engagement, capacity building, and support as elements deemed critical to a successful and sustainable community

Building on this learning, MREAP's approach emphasized community engagement, capacity [9]building, and support as elements deemed critical to a successful and sustainable community energy project. Focusing on MREAP systems, a subsequent sustainability study made the following recommendations for future projects:

- Ensuring the use of technically robust design standards and component choice is required for improved technical sustainability. Mechanisms to achieve this should be a priority for the sector.
- Project design should be based on a sustainability pillars approach. Best practice for all sustainability metrics should be referenced and used to justify a fully sustainable project design prior to implementation.
- Project designers to consider the role of district authorities in the sustainability of off grid PV systems.

Building on these recommendations, a current project funded by the Scottish Government International Development Fund (the Sustainable Off-Grid Electrification for Rural Villages - SOGERV) project aims to provide rural communities with sustainable renewable energy (RE) technologies. SOGERV has focused on due diligence in technical design, market assessments, needs assessments, procurement analysis of suppliers and contractors, and district engagement for implementation of the projects. A rigorous M&E system has been deployed to gather key learning from these projects, resulting in a series of learning papers on the sustainability of a community

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energy approach. The key methods developed during SOGERV for sustainable project design and deployment are described in the following section.

RESULTS

Technical Needs Assessment

A technical needs assessment (TNA) was conducted in four SOGERV sites by WASHTED technical team prior to the design of the installed systems. The idea was to solicit views from the end users and observe technical issues so that applications could be unfolded and an optimum system could be designed. The TNA gathered key information from all locations (such as Global Positioning System – GPS, and mobile network connectivity), and also undertook some measurement activities with the public facilities (such as room size and configuration, structural considerations, and potential security issues).

GPS coordinates were collected by using Garmin Etrex 30X Model. The WASHTED technical team interviewed key health and educational personnel to find out where critical solar PV system equipment could be positioned in order to improve system security. The goal of the interviews was to ensure that the key informants participate in the technical needs assessment and contribute to the process of system design. Twenty different people from different households were interviewed to generate information about the strength of the signal for three mobile service providers including TNM, Airtel and MTL in the area in readiness of remote monitoring installation. The team used mobile phones to verify mobile signal availability at each household around the selected villages.

The physical strength of the health and school walls was checked by verifying whether the walls were built using burnt bricks or cement blocks. The strength of the roofs were physically checked if the panel mounting structures weight would be carried and by asking the staff how long the roofs have been in existence with or without repairs. The building cross-sectional area was measured by using a measuring tape and length, width and height (up to truss horizontal members) were measured.

The sizing of the solar photovoltaic systems was based on using two IEEE standards which govern stand-alone PV sizing: IEEE 1013 and 1562 for lead acid batteries and solar PV array, respectively. The approach in IEEE 1562 was altered slightly as some systems would use MPPT controllers rather than PWM controllers as prescribed in the standard. The demand estimation approach involved estimation based on facility space measurements and interviews with users, where appropriate. Separate demand estimations were taken from the business model designs which were completed concurrently to the technical designs. Further research on energy-use appliances was informed by current market offerings and desk study of potential suppliers. The design team adjusted the days of autonomy to either 3 (most systems) or 4 (health systems) days from the standard approach (specifying between 6 and 14) due to prohibitively high cost of this level of reliability.

The technical sizing calculation uses an average daily load and minimum daily insolation as key inputs. Key characteristics for the solar panel array, batteries, charge controllers, inverters, and cable sizing was calculated through the sizing calculation. The team assumed any system which had an average daily demand of 500Wh or more uses a 24VDC nominal system voltage and use a MPPT controller to increase the overall efficiency of the system.

All other systems would be based on 12VDC nominal and use PWM controllers. The option to use 48VDC was avoided as this equipment is relatively less available. The TNA revealed that the schools and health facilities lacked proper security. Classrooms and health posts buildings had no doors and windows. Also where doors and windows were present, it was observed that the windows

and doors were either broken or not properly fixed. As such if solar PV installation would proceed in these buildings in the present state, the installed systems will be vulnerable to theft and vandalism. To mitigate on this challenge, the technical needs assessment team advised the responsible persons at the schools and health posts to fix doors and windows and install door protectors before deployment of solar PV systems. Following the TNA it was found out that the community had interest in having solar PV installed at schools and health facilities. Key informants at school and health facilities, and community representatives patronized the meetings to contribute towards the technical needs assessment and provide vital information such as where the critical solar PV system equipment would be installed in order to enhance system security.

The Health Surveillance Assistant (HSA) house is attached to the Madrande health post. The TNA team agreed that the HSA's house should be considered for solar PV installation as one way of promoting staff retention through provision of solar energy.

Technical Design

The University of Malawi – The Polytechnic (WASHTED) team in conjunction with University of Strathclyde team designed the solar PV systems for SOGERV and MREAP sites taking into account a number of factors as highlighted below that could enhance system sustainability.

Technical Design Parameters

The size of the solar PV system depends on the daily load demand. In the project we designed the rooms to have specific number of operating hours dependent on room use. For instance, the health centre, the maternity wing was given 24 hours of daily operation. As such the battery bank design capacity was to be realistic to reflect the daily load demand.

Equipment Life Expectancy

The WASHTED team inspected the solar PV specification on the electrical equipment and accessories to be installed. For example a life expectancy guarantee of 25 years for a PV module and with rated power output equal to or greater than 80 watts was taken to be good choice. Therefore, all the peripheral equipment was designed to match the chosen module specification. Some of the critical equipment considered in the design with their life expectancy are shown in Table 1:

Equipment	Life expectancy
Batteries	≥5 years
Modules	≥25 years
Module frame	≥25 years
Lamp dependent on use & technology	≥10,000 continuous operating hours
Switches	≥3 years

Security of Critical Components

A separate brick work compartment was constructed inside each classroom block where solar PV system was installed. The compartment comprised of a lockable door and housed caged battery bank, inverter and charge controller. The aim was to prevent theft and vandalism of the critical electrical components.

Roles and Responsibilities

A district engagement plan was put in place and the Terms of Reference (ToRs) were drawn. The district engagement plan was important because it defined the roles and responsibilities of each partner in the project (Fig 1). It was thought that if district engagement approach was not known, then there would be a risk to project sustainability. Therefore, the approach to sustainability for MREAP and SOGERV projects involved the Community, University of Malawi – The Polytechnic-WASHTED, District Office and University of Strathclyde (UoS). The Polytechnic-WASHTED was responsible for design solar PV systems and install Remote Monitoring system and to ensure that the systems function normally during and after project life span.

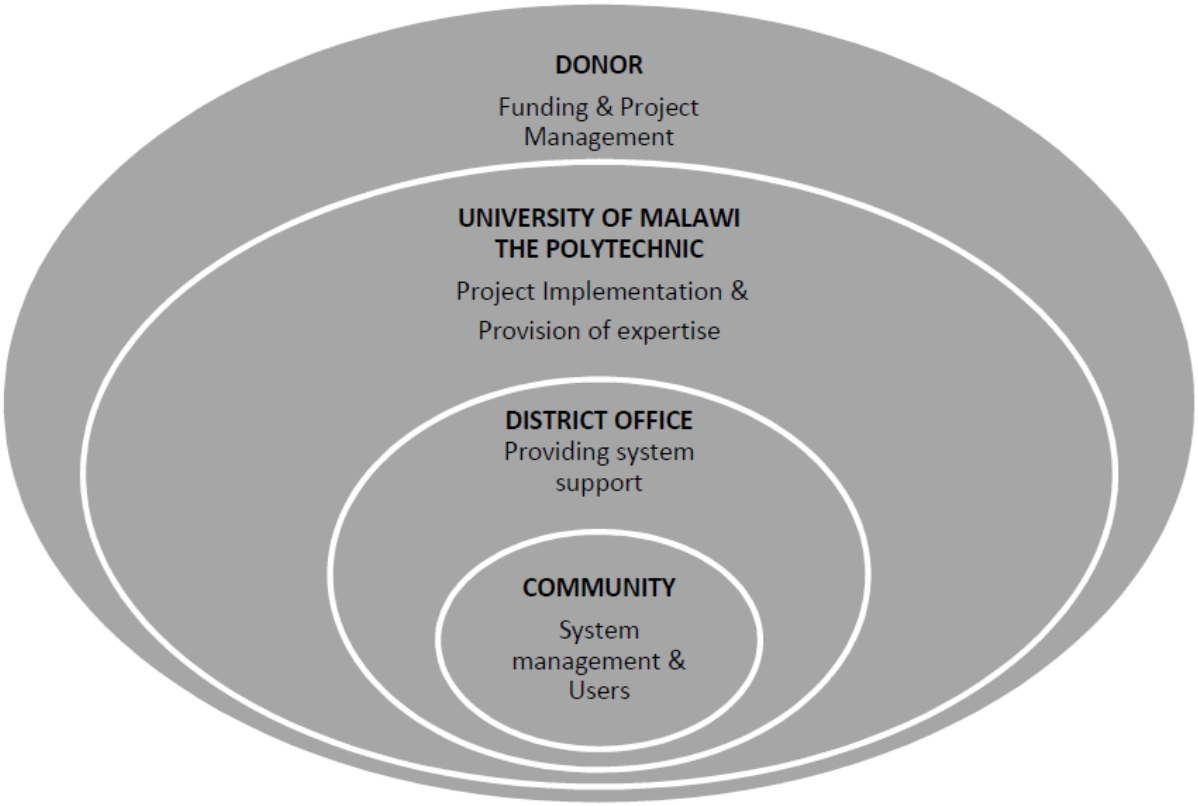

Figure 1: SOGERV Roles and Responsibilities

Furthermore, WASHTED were tasked to design a technical support process that would reinforce a high reliability of operation, an effective warranty and maintenance regime, and to be informed by remote monitoring. United Purpose (UP) was responsible for community engagement and capacity building, owning all equipment in the villages during the initial period, organizing the procurement, MOU, and installation of renewable energy systems at the village. UP will also continue to support the community with technical, financial and organizational training and guidance until end of the initial period. In addition the project team was tasked to develop a sustainable economic model and that would be operational for each community energy project. This involved development of Community Energy Business Plans to ensure highest level of community energy project success. The Community identified a suitable location within the main trading area and provided significant materials, labour and monetary contribution towards the building of a charging station house. Also the community is responsible for maintaining structures, as appropriate, at school and health facility so that they can hold the Solar PV System as well as routine maintenance of the buildings The District Office is responsible for providing support to the community mainly at Schools and Health Centres through regular communication, administrative oversight, and training.

Also to supply and maintain the working order of public facility appliances and equipment utilizing the installed power system, for example, refrigerator, microscopes, computers, specialized equipment, televisions, etc.

Business Model

A market assessment (MA) permitted the creation of a business model for the first two locations (Kandeu and Mandrade) which provided a 3-year detailed income forecast and a long-term (20-year) forecast (Fig 2). However, the MA results had shown very low willingness to pay by the community. Therefore, an effort was made to procure affordable smaller systems rather than larger solar PV standalone systems as was originally designed. It was believed that the small solar PV systems would be more sustainable/appropriate solution for the community. A Franchiser/Franchisee model was proposed and a commercial solar PV company engaged as the Franchiser.

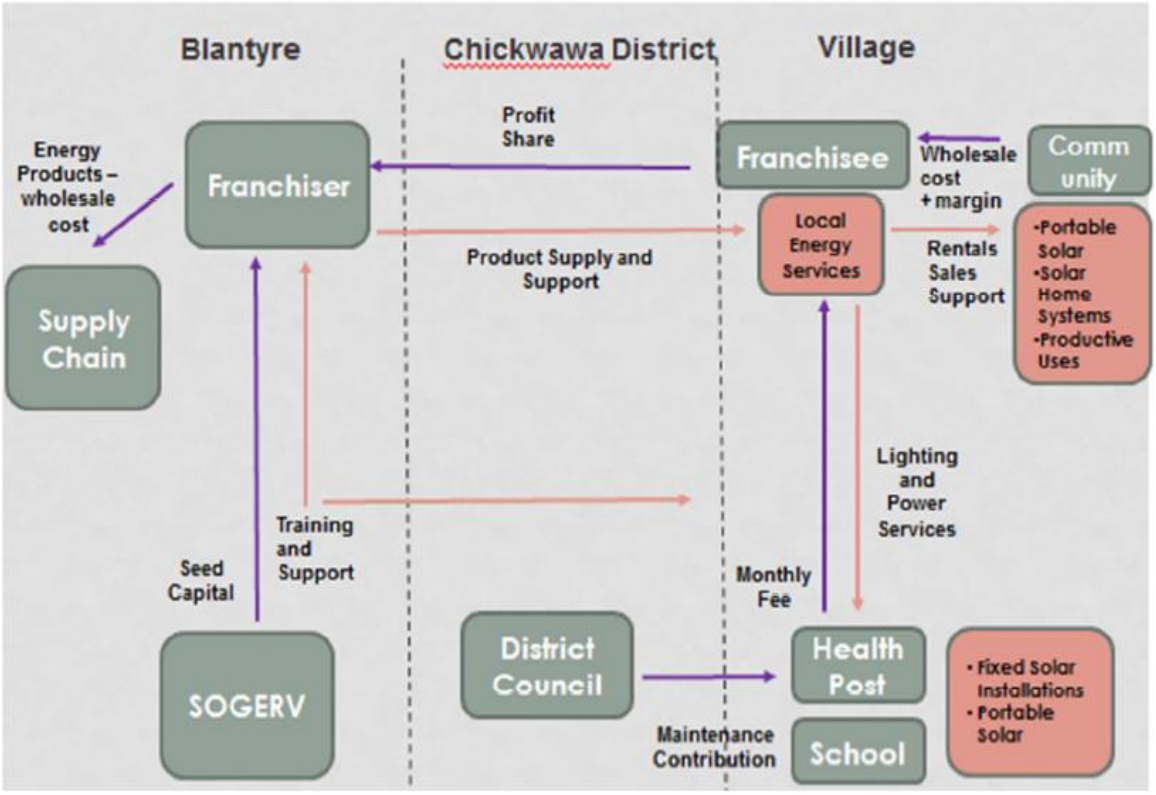

Figure 2: SOGERV Business Model

Memorandum of Understanding (MoU)

An official Memorandum of Understanding (MOU) was drawn up to define the terms and conditions of ownership and operation of the renewable energy business in the communities. The MoU was important to naturally mediate and figure out what was most important in moving toward with the project's objectives for the benefits of all sides.. The roles and responsibilities of various partners were described in detail. It was agreed that the MoU would remain in force from the signed date until March 31st 2021. After the Initial Period has expired, the SOGERV Partner Lead will automatically be removed from the MOU where the business is considered to be fully operational.

Remote Monitoring

Technically, the project has been designed to be supported by remote monitoring that assists in assessing the daily performance of the installed systems (i.e. M & E). The technical data is being

captured and analysed. This data advises the project designers whether the systems are operating as intended.

Capacity Building

WASHTED and UP conducted operational and maintenance workshops as a means of capacity building. Stakeholders (district, community, entrepreneurs) benefited through workshops in terms of acquiring relevant skills and knowledge for carrying out maintenance and repairs of solar PV systems. Energy committees were organized to support and engage with the installed systems. Entrepreneurs were engaged to manage the operation of the business and systems setup through the project. It is has been found that the approach has enhanced system ownership.

Monitoring and Evaluation

(UNICEF, 2003) defines evaluation as a process which determines as systematically and as objectively as possible the relevance, effectiveness, efficiency, sustainability and impact of activities in the light of a project / programme performance, focusing on the analysis of the progress made towards the achievement of the project objectives while on one hand monitoring is a process of tracking milestones and progress against expectations, for purposes of compliance and adjustment. For the SOGERV project financial logbooks had been deployed so that the Franchiser and Franchisee recorded income from sell of pico solar products, solar lantern rentals, battery and phone charging services. In terms of maintenance, the franchisee regularly inspected system wiring for damage and status of the charge controller LEDS to verify the healthiness of the system. Technical raw data was captured by remote monitoring for M&E. The data was synthesized, analyzed and used to support business decisions

CONCLUSIONS

Assessment of the SOGERV project has demonstrated the development of a process intended to establish Complete Good Practice. This builds on extensive knowledge and experience gained from past projects. Investment in the technical, social, economic and organisational aspects of the project design is critical for a sustainable project. Previous efforts in community energy have focused on ownership and operation models where all responsibility lies either with the community, public entities, or a commercial entity. In the projects presented here, a holistic model for sustainable community energy projects has been developed that includes community, local government, and private enterprise contributions. However, the deployments are still at an early stage and there is need to monitor and test the approach to system sustainability over time.

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INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) AND KNOWLEDGEMENT MANAGEMENT

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Security Services in Group Communication over Mobile Ad-Hoc and Wireless Sensor Networks Using Performance Analysis of Algorithms for Malawi

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ABSTRACT

Group communication in wireless networks has been facilitating many emerging applications that require packet delivery from one or more sender(s) to multiple receivers. Due to insecure wireless channels, group communication is susceptible to various kinds of attacks. Although a number of proposals have been reported to secure group communication using Group management key (GMK), provisioning security in group communication in wireless networks remain a critical and challenging issue. This article presents a survey of recent advances in security requirements and services in group communication in three types of wireless networks, and discusses challenges in designing secure group communication in these networks: wireless infrastructure networks, mobile ad hoc networks, and wireless sensor networks. This project presents a survey of recent advances in security requirements and services in group communication in three types of wireless networks, and discusses challenges in designing secure group communication in these networks: wireless infrastructure networks, mobile ad hoc networks, and wireless sensor networks.

Keywords: WSN, Security, communication, network, mobile

INTRODUCTION

Many Wireless Sensor Networks (WSNs) are being en-visage in military, emergency and surveillance applications today, where sensor nodes need to send sensed data to the sink. In many applications under hostile environment, sensor nodes cannot be deployed deterministically and thus are randomly deployed into the field. An important requirement in network management of many mission critical applications is to secure end to end sensor networks data from being eavesdropped by the attacker. While there have been many works devoted to hop by hop secure communications in WSNs, the issue of end to end secure communications is largely ignored. This is mainly due to the fact that there exist two intuitive approaches to provide a high degree of end to end secure communication. The study was conducted to determine mobile ad hoc networks are formed by a collection of, potentially mobile, wireless nodes; communication links form and disappear as nodes come into and go out of each other's communication range. Wireless networking has received a boost from the development of standards such as IEEE 802.11 and Bluetooth. Much of this activity has focused on the design of routing and medium access control protocols, since efficiency of these protocols can have a significant impact on performance. This project has a survey of recent advances in security requirements and services in group communication in three types of wireless networks on India during 2014-2016, which can promote good strength in Malawi communication field also.

MATERIALS AND METHODS

Group Communication

A group communication service forms an important building block for applications in dynamic distributed systems and is useful in many applications that involve collaboration among a group of people. The key features of a group communication service are:

(1) Maintaining information regarding group membership.

(2) Letting nodes within a group communicate with each other in an ordered manner. There has been significant research activity on group communication in traditional wired networks. The vast body of this research is an indicator of the significance of the group communication service paradigm.

Approaches Used for Total Ordered Node Delivery

Group communication services have been successfully used in the past as building blocks and abstractions for implementing distributed tasks. Past work on total ordering has yielded several approaches which use a token to implement the total order. These algorithms have two flavors: As exemplified by the algorithms, totally ordered message delivery is achieved by continually circulating a token through all the nodes of the network in a virtual ring.

Tokens Carrying Sequence Numbers

The token circulates around the virtual ring carrying a sequence number. When a node receives the token, it assigns sequence numbers (carried with the token) to its messages, and then multicasts the messages to the group members. The sequence number carried in the token is incremented once for each message sent by the node holding the token. Since the messages are assigned globally unique sequence numbers, total order can be achieved.

Tokens Carrying Messages

An alternative approach is to store the messages in the token itself – since the token visits all nodes in a virtual ring, the messages will eventually reach all the nodes, the order in which messages are added to the token determining the order in which they are delivered to the nodes. Both these approaches depend on the existence of a virtual ring in the network. But the prior work has not sufficiently addressed the issue of determining efficient embeddings of rings in networks with dynamically changing topology.

Static Vs Dynamic

The topology is said to be static, when there is no mobility. Whereas when there is mobility, the topology is said to be dynamic. There are several mechanisms for finding approximations to a virtual ring that change dynamically as the topology changes and that are efficient according to certain metrics. Since token circulation around a virtual ring is a useful component of many existing group communication mechanisms for wired networks, we will consider ways of improving the performance of such mechanisms in mobile ad hoc networks.

Group Key Management (GKM)

The fundamental security service in SGC is the provision of a shared key, the group key. The shared group key is used to encrypt a group message, sign the message, authenticate members and messages, and authorize access to traffic and group resources. Thus, the strength of SGC largely relies on the cryptographic strength of the keys and the key management protocol. A GKM scheme deployed in any secure group communication system should satisfy the following requirements:

# of shared keys	0	1	2	3	4
# of links increase	54%	−8%	−20%	−29%	−19%
# of shared keys	5	6	7	8	>8
# of links increase	−2%	25%	56%	183%	475%

Table-1 Increase of the Number of Links with Different Number of Shared Keys under Differentiated Key Pre-Distribution

- Key generation is secure.
- Imitation of the group key should be infeasible or computationally difficult.
- The group key is securely distributed and only the legitimate users can receive a valid group key.
- Revocation of the group key upon every membership change should be immediate.
- Every membership change must result in rekeying of associated keys.
- A rekeying of the key is secure.

Group authentication

In group communication (one-to-many and many-to-many), a member can be either the designated sender, the designated receiver, or both. Both users and messages should be authenticated to safeguard identity related attacks. In some systems a member certificate is issued by the trusted certificate issuing entity along with its validation period. In some systems the expired certificate is maintained for further verifications. Expired certificates are compiled into the revocation list, which is distributed to notify all members. Group authorization and access control: In any conventional access control mechanism, a member who holds a decrypting key can access full contents in a flow (or all flows in an aggregated stream). This is referred to as a single access privilege.

Group accounting and no repudiation

Any group operation executed or a record of resources utilized by a member should be available for tracking in order to detect any abusive usage of resources and operations. A no repudiation service can ensure that the identity of a member whose activities are in dispute can be fully and precisely determined by the designated entity. In general, the group signature and member certificate can be used to authenticate the source and message, and to provide proof of the source's activity in case of a dispute.

Group privacy and anonymity

Any information related to a group message, such as identities of a sender and a receiver, message length, and time, can be protected or hidden to preserve privacy and anonymity of members. An anonymous message refers to a message that carries no information about the senders and receivers.

Group message integrity and confidentiality

Message integrity should be preserved by ensuring that the message has not been fabricated (some or all portions of the message have not been added, deleted, or modified) or dropped by an unauthorized entity. This can be done by several means, including hashing and signing the message along with strong encryption keys.[1] In ad-hoc networks, group members may have different capabilities and protocols to perform different levels of encryption on group messages. Thus, some messages may be encrypted with strong encryption, while others with weak encryption are relatively easily breakable. In WSNs sensor nodes may have similar capabilities and protocols that are embedded before deployment. Confidentiality ensures that only authorized members can retrieve meaningful data from the message.

Group survivability and availability

An attacker can attack routing hosts (i.e., access points and base stations) to isolate some or all group members, or partition the group. Thus, all routing hosts must be protected to ensure group

survivability. However, the attacker can still target a joining procedure (i.e., by flooding the access point or base station in wireless infrastructure networks and WSNs), thus causing service unavailability to other legitimate users. [2]Group availability ensures that only authorized users can always communicate within the group by using restricted group resources, and any violation exceeding the limitation of group resources will be promptly detected. Thus, flooding packets would be dropped immediately once such an attack has been detected. Unauthorized routing update can be detected and prevented by the following services: authenticating both source and message to determine whether the routing update message is legitimate and originated by an authorized member; enforcing access control over a routing table; signing the routing update message such that message integrity is preserved and no attacker has falsely modified the message; encrypting all management packets (routing update requests and replies); and any loophole or sinkhole routing, which possibly leads to a denial of service, will be tested, detected, and fixed prior to actual deployment.

Routing Protocols in WSNs

Routing in wireless sensor networks has some differences from that in traditional wired and wireless ad-hoc networks due to resource constraints, faults/failures etc. [3] There are two main paradigms of routing protocols in WSNs: location-centric routing and data-centric routing. Other paradigms include hierarchical routing and security aware routing.

Location-centric routing

Greedy Perimeter Stateless Routing (GPSR) is a well-known location centric routing protocol. In GPSR, beacon messages are broadcast by each node to inform its neighbors of its position. (GPSR assumes that sensors can determine through separate means the location of the sink) revisit. Each node makes forwarding decisions based on the relative position of the sink and its neighbors. In general, the neighbor that is closest to the sink is chosen.

Data-centric routing

Directed diffusion is the most well-known data centric routing protocol, in which the sink sends queries to all nodes and waits for data from the nodes. Satisfying specific requirement check. In order to create a query, an interest is defined using a list of attribute-value pairs such as name of objects, geographical area, etc. [4]

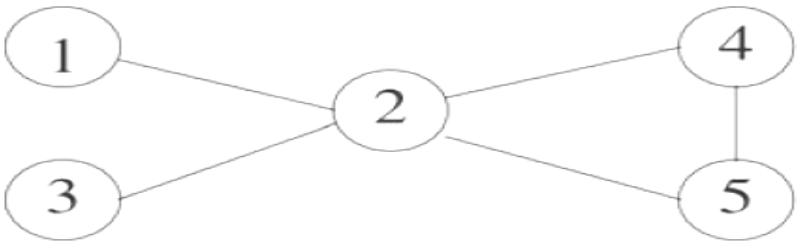

Figure 2: Data Centric Routing

The interest is broadcast through the network, and used by each node to compare with the data received. The interest entry also contains several gradient fields. A gradient is a reply link to a neighbor from which the interest was received. By utilizing interests and gradients, paths are established between sensors and the sink. Several paths may be established, and one of them is selected by reinforcement.

User Interface:

(Initially setup the network simulator model using java swing concepts. It will be displayed the number of nodes and regions in different colours for user reference.[5] GUI also displays the performance measurements, time, and speed and display graph also.)

V Local-Frequency (LF)

The Local-Frequency (LF) algorithm keeps track of how many times each node has been visited and sends the token to the least frequently visited neighbour of the token-holder. To implement this algorithm, the count, for each node, as stored in the token, contains the number of past token visits to that node. The token-holder may not have a precise knowledge of its neighbours; occasionally the chosen node may no longer be its neighbour. To protect against the potential loss of the token in such cases, we use a TCP connection to deliver the token. [6] There is no mobility and the topology is connected, then the LF algorithm ensures that every node is visited infinitely. i.e., there is no starvation. The LF algorithm has the unfortunate property that the round length can increase without bound in certain network topologies, even if there is no mobility.

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Performance Evaluation

In this section, we present performance evaluation based on both analysis and simulation. We first describe our simulation setup, and then report performance data and our observations.

Simulation Setup:

The network is circular with radius 500 *meters*, where 1000 nodes are uniformly deployed at random. The sink is at the center of the network. Unless otherwise specified, the default parameters are: $c = 2$, $n1 = 200$, $n2 = 800$, $k1 = 80$, $k2 = 30$, $k = 40$, $K = 10000$, $r = 100$ *meters*, $\alpha = 1$ and $Nc = 50$ The default values of $k1$, $k2$ and k are chosen such that $k1n1/(n1+n2)+k2n2/(n1+n2) = k$, which means the average number of keys disclosed to the attacker is the same in our differentiated key pre-distribution and the original *RKP* scheme for the same number of captured nodes.[8] Our communication model is one where sensors periodically transmit data to the sink. In the legend in all figures, *our GPSR* and *our minhop* refer to our protocols extending GPSR [45] and minimum hop [50] routing present. The legends *GPSR* and *minhop* refer to the traditional GPSR and minimum hop routing protocols following the uniform key pre-distribution respectively. Each point in the simulation data is the average of 100 runs based on independent random seeds.

Sensitivity of Pe2e to Attack Intensity:

First compare our differentiated key pre-distribution with the traditional uniform key pre-distribution (for both GPSR and minimum hop routing protocols) under different number of captured nodes *Nc*. We find that while the performance of all schemes degrades with increasing *Nc*, our schemes are consistently better than those of traditional schemes. We also find that the

improvement increases with larger values of *Nc*. This is because when the attacker captures more nodes, the resilience of highly resilient links in our schemes degrades at a much slower pace than those of the less resilient links in traditional schemes. Besides, we can also observe that the end to end security under minimum hop based protocols is better than their GPSR counterparts.

Sensitivity of Pe2e to Network Density:
We can compare our schemes and traditional schemes under different communication range *r*, which in turn corresponds to different network density (i.e., number of neighbours per node).

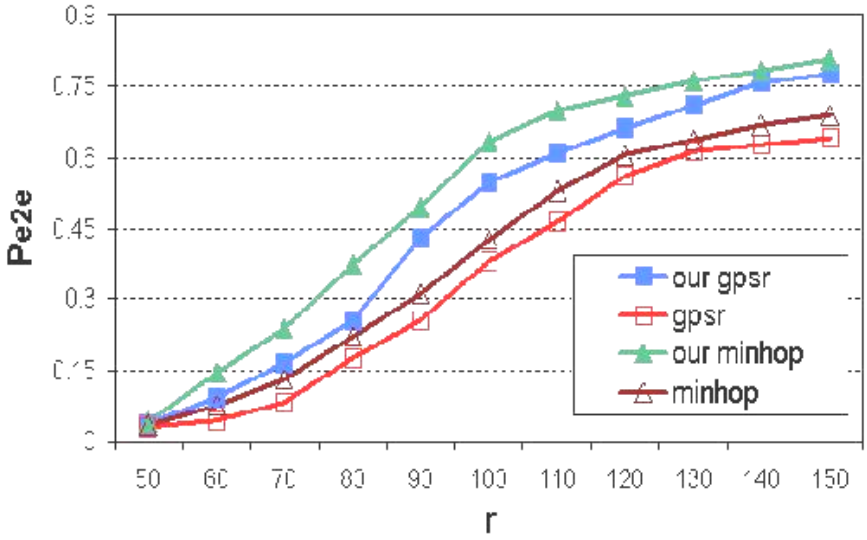

Figure 2: Sensitivity of P_{e2e} to communication range *r*.

When *r* is small, *Pe2e* is low due to both low connectivity (many nodes cannot find secure neighbours) and low resilience (fewer proxies resulting in fewer key paths for each link). When *r* increases, *Pe2e* increases correspondingly. For all values of *r*, our schemes perform consistently better.

Sensitivity of network lifetime to parameter α:
Recall that α is the *knob* that trades-off security with lifetime. we compare our schemes and the traditional schemes for different values of α. We define network lifetime as the time until when the first node has used up its energy. Since traditional schemes do not have weight assignment, they are insensitive to α. The lifetime in our schemes decreases with larger values of α. This is because a larger value of α means more priority is given to links with high resilience, thereby draining the corresponding neighbours more rapidly. We also observe that the extended GPSR has higher lifetime compared with extended minimum hop for smaller values of α, and the difference diminishes as α increases. This is because for smaller values of α, lifetime is mainly decided by total number of candidate forwarders of each node. In extended GPSR, each node usually can find more forwarders (secure neighbours closer to sink) than it can find in extended minimum hop protocol (secure neighbours on minimum hop secure path).

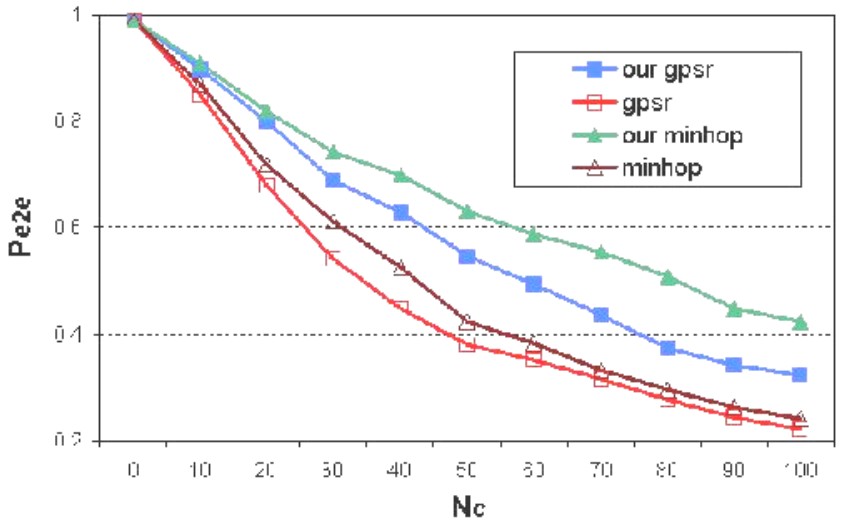

Figure 3: Sensitivity of P_{e2e} to number of captured nodes N_c.

When α increases, lifetime is mainly decided by the number of most secure neighbours of each node. This number is similar for both protocols, and hence they have similar lifetimes when α increases. We also observe that lifetime of traditional GPSR scheme is lower than that of traditional minimum hop scheme.

Sensitivity of Pe2e and network lifetime to number of class* 1 *nodes:
We compare the traditional schemes, our schemes with default parameters, and our schemes with optimal parameters. The optimal parameters are obtained via our analysis.

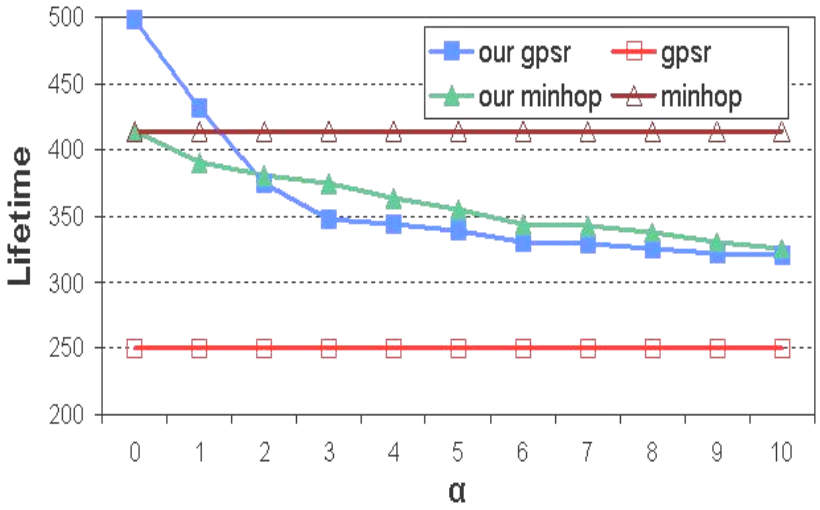

Figure 4: Sensitivity of lifetime to parameter.

The average number of keys pre-distributed per node is the same across all schemes for fairness of comparison. we find that traditional schemes are insensitive to $n1$ since all nodes are given same number of keys. Our schemes achieve much better performance under intermediate values of $n1$, while the performance of our schemes is close to that of traditional schemes for very small and very large values of $n1$. This is because when $n1$ approaches 0 or 1000, all nodes will be given same number of keys, and thus our schemes degrade to traditional schemes.

CONCLUSIONS

Nowadays, most of the network system is established in the mobile environments. Every mobile ad hoc system should be accessed with the better performance. In this proposed system "Distributed Token Ring circulation in mobile Ad-hoc Networks", to measure the performance of the local and global connectivity between the nodes. An important application of such algorithms is to ensure total order of message delivery in a group communication service. If the algorithms are gives different performance results for each group in the ad hoc network topology. When using a token circulation algorithm, a *round* is said to complete when every node has been visited at least once. Criteria for comparing the algorithms include the average time required to complete a round, number of bytes sent per round, and number of nodes visited per round.

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Integrating Information Communication and Technology (ICT) in Distance Education at Domasi College of Education

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ABSTRACT

Domasi College of Education introduced the Distance Education programme to offset the teacher shortage in Malawi. As a way of improving learner support in Distance Education, the College, with funding from African Development Fund (ADF), has embarked on a project to integrate information communication and technology (ICT) in its Distance Programme. It has established ten internet centres for use by the teacher-learners and staff. Considering that this is the first time ICT would be used in Distance Programme in the country, there are a number of issues to be addressed so as to ensure its success. In this regard a study was conducted, with its primary focus on the prospects and challenges, to find out how the college intends to use the internet sustainably in the Distance Education. Among its prospects, the study found out that the teacher-learners would be exposed to other resources apart from the modules and lecturers' handout notes. This would in turn benefit the College in reducing communication costs between lecturers and their teacher-learners. In terms of the foreseen challenges, the study found out that there is low computer literacy level among most of the targeted teacher-learners. Apart from that the College will find it difficult to fund the programme once the project is over. In order to address those envisaged challenges, the study recommends a joint venture approach whereby other institutions which are also involved in distance learning in Malawi should work together with Domasi College. In addition, there is also need for intervention from the Malawi Government to support the programme.

Keywords: Domasi College, Distance Education, African Development Fund (ADF), ICT, Teacher-Learner

INTRODUCTION

In 2000, Domasi College of Education (DCE) introduced a distance Education programme to train teachers up to degree level. The Distance Education Programme at DCE has two components. The first component is a two-month residential session, which runs from October to December. During the residential session, learners receive instruction materials in their respective subject areas, are introduced to the course work and given assignments for the whole academic year. The residential session is followed by a ten-month study by distance.

During the rest of the ten months, the learners continue to study on their own while teaching in their respective schools. The learners are expected to study course materials, write and submit assignments. It is also during this period that learners report to the College twice, one in each semester, for examinations. While in the field, the learners get academic support from Field Supervisors. For purposes of increasing learner support, DCE demarcated the country's six education divisions, into zones. There are 15 zones covering all the six divisions, each headed by a Field Supervisor. The supervisors also provide the link between the learners in the field and the

College facilitators. All supervisors are qualified teachers with vast experiences in the teaching profession. The number of learners varies from zone to zone and also from year to year.

Although Modern developments of innovative technologies have provided new possibilities to distance teaching professions, DCE has exclusively been using printed materials because it has not yet developed an ICT programme capable of communicating with ODL learners. Communication between the College and students in the filed has mainly been through surface mail. However, the increased enrollment of ODL learners made the College to begin thinking of how to use some ICT technologies to communicate with ODL learners.

In 2008, the College won a Project sponsored by the African Development Fund (ADF) to upgrade 400 under-qualified science and mathematics teachers to diploma in Education through distance mode. Under this Project, the College has established 15 internet centers throughout the country, with the main aim of integrating ICT into the Distance Education Programme.

Considering that this is the first time ICT in the form of internet would be use in the programme, it was felt necessary to explore the possible opportunities and challenges this initiative would present, so that informed decisions can be made in advance. It is against this background that we decided to embark on the study which titled "Integrating Information Communication and Technology (ICT) in the Distance Programme at DCE: Prospects and Challenges
Theoretical grounding

In this section, theoretical ideas drawn from relevant literature have placed much emphasis on the role of ICT in distance Education. The review of literature is therefore anchored on the fact that ICT plays a critical role in contemporary education system. As Hope and Guiton, (2006) explain, ICTs may be an integral or supplementary part of the course delivery system. They support the communication of information and interaction between learners and teachers. ICTs are also important to the establishment of sound management and administration systems that underpin effective distance education operatio**n.**

Information and communication technology, what it is. Information and communication technology (ICT) is a term that is defined in a number of ways, mostly depending on the context. However, a good way to think about ICT is to consider all the uses of digital technology that already exist to help individuals, businesses and organizations use information. (McCausland, H.,Wache, D. & Berk, M. (1999) defines ICT as any product that will store, retrieve, manipulate, transmit or receive information electronically in a digital form. For example, personal computers, digital television, email, robots, radio and cellular phones.

ICT is often categorized into two broad types of products; the traditional computer-based technologies and the digital communication technologies. The traditional computer-based technologies mostly refer to the basics application software used on the personal computers while digital communication technologies are for specialists. Cases which highlight innovative approaches of utilizing ICT including multimedia, LMS, mobile technology and e-books are introduced (www.openaguniversity.cgiar.org/Publications/wsrpt02.pdf).

Role of ICT in education
Technology is not new to education. However, contemporary computer technologies, such as the Internet, allow new types of teaching and learning experiences to flourish. As Morales-Gomez & Melesse, (1998) note the influence of the technology on supporting how students learn will continue to increase. A number of researches have shown that ICT plays a pivotal role in education:

ICT innovations have increased information literacy. One way in which emerging ICTs are impacting on the content of education curricula stems from the ways in which ICTs are dominating so much of contemporary life and work. As Blumenfeld, P et. al (1991) argue Many new technologies are interactive, making it easier to create environments in which students can learn by doing, receive feedback, and continually refine their understanding and build new knowledge. Access to the Internet gives unprecedented opportunities in terms of the availability of research material and information in general.

Supporting knowledge construction. The contemporary education psychology is putting much emphasis on constructivism. As Faye, (2000) notes, learning approaches using contemporary ICTs provide many opportunities for constructivist learning through their provision and support for resource-based, student centred settings and by enabling learning to be related to context and to practice. This idea is also supported by Morales-Gomez & Melesse, (1998) who argue that ICTs by their very nature are tools that encourage and support independent learning. Students using ICTs for learning purposes become immersed in the process of learning as more and more students use computers as information sources and cognitive tools.

ICT has had an impact on when and where students learn. In the past, educational institutions have provided little choice for students in terms of the method and manner in which programs have been delivered. The emergency of ICT applications provide many options and choices and many institutions are now creating competitive edges for themselves through the choices they are offering students. Moore & Kearsley, (1996) assert that students are starting to appreciate the capability to undertake education anywhere, anytime and anyplace. This flexibility has heightened the availability of just-in-time learning and provided learning opportunities for many more learners who previously were constrained by other commitments (Stephenson, 2001).

ICT has assisted in ensuring Competency and performance-based curricula: The moves to competency and performance-based curricula are well supported and encouraged by emerging instructional technologies. Beck and Wynn (1998) described the integration of technology in teacher preparation programs through a continuum that on one end there is a course separate from the teacher preparation program and on the other end technology is integrated throughout the program.

Key Challenges in Integrating ICTs in Education

Although valuable lessons may be learned from best practices around the world, there is no one formula for determining the optimal level of ICT integration in the educational system. There are significant challenges that policymakers and planners, educators, education administrators, and other stakeholders need to consider in order to ensure successful integration of ICT in the distance education system. Studies have revealed a number of challenges that affect the integration of ICT in education.

ICT Infrastructure.

Kumar, (2008) observed that the main challenge for ICT-enhanced education is the availability of information and communication technologies infrastructure. Before any ICT-based program is launched, policymakers and planners must ensure the availability of the followings: appropriate rooms or buildings to house the technology, computers as well as affordable Internet service for on line learning, and availability of electricity and telephony.

Lack of teachers equipped with ICT skills. Thompson *et.al* (1996) observed that the institutes where ICT is going to be integrated in education, should have teachers that are well trained about ICT tools in education. Before going to teach to students, teachers must know about how and when to use ICT tools to achieve particular purposes.

E. Leadership Integrating ICT in education is not an easy task, as it requires a wide range of support including higher management, and teachers (Kumar, 2008). Therefore it is necessary to properly convince them for their support, and for this task a leader is required. Leadership is necessary before, during and after project implementation (Grossman (1989, 1991)).

The review of the literature shows that before any project is initiated, leadership is needed in order to explain the model, the concept and create awareness; during the project, leadership is needed to manage change and support the project; and after the project, it is needed to pledge the required adaptability and flexibility of the initiative. It is in this understanding that the study was conducted the aim of exploring the key issues as far as the integration of ICT in education is concerned. ". This study was therefore aimed at exploring the possible prospects (opportunities) and challenges the integration of ICT would present. The results of the study would be communicated to the key stakeholders and would be expected to guide decision making. In addition, the results of the study would be presented in education conferences as a way of information sharing. It is also expected that the results of the survey would present opportunity for further studies.

MATERIALS METHODS

This paper is derived from a survey genre using both quantitative and qualitative methods. The quantitative inquiry was mainly used to get data on students' capacity to use computers in their studies since, as (Anderson, R.E., & Plomp, T., (2000) argue, for the integration of ICT to be successful, various competencies must be developed throughout the educational system. The quantitative data would therefore give an insight into learners' capacity to use the facility.

Since the goal in the study was to get information that would assist in effectively using the computer facilities for distance learning, the qualitative methods were used iteratively (Rossman & Rallis, 2003) to collect data that represented the perceptions, values, feelings and dispositions of the research participants as regards to the integration of ICT in the ODL programme. The qualitative approach was fundamental in this study because it gave detailed accounts and deeper understanding of events and processes of a phenomenon under investigation (Rossman & Rallis, 2003). Thus, the overall goal of the qualitative method was not for making generalizations, but to offer a critical inquiry that raises consciousness for possible steps for decision-making (Rossman & Rallis, 2003).

Participants in the study

The study targeted 200 distance learners, 8 lecturers 3 managers and 4 field supervisors.
The learners provided quantitative and qualitative data on the following issues;

- The extent to which the learners are conversant with the basic application software. In this context, the basic application software are M/S word, Excel, PowerPoint and Internet
- How frequently the learners use basic application software.
- The challenges they face in using the software packages.
- The extent to which they consider the internet facilities to be of use to their studies
- How the learners intend to use the computer facilities in their studies
- What they consider to be the ways of ensuring that the facilities are effectively used for distance education and

DCE managers provided qualitative data on:

- T he reason for the establishment of internet centres
- T he reason for the establishment of internet centres
- Capacity of the College to run the centres
- How ready the College is to sustain the centres
- Mechanisms the College has put in place to ensure that the intended objectives are achieved

- The envisaged benefits of the programme

DCE lecturers provided qualitative data on

- How the facilities would improve the provision of distance education in the College.
- How lecturers intend to use the facilities in handling distance education1`
- The envisaged benefits of the programme

Field supervisors provided information on the their experience as regards the issue of established internet centres

Instruments

For the quantitative design, the study used a structured questionnaire, purposely designed mainly to collect data on students' baseline skills in the use of computers and have an insight into how they intend to use the facilities. The open ended questionnaire and interview protocol were administered to college lecturers and College management respectively, to obtain qualitative data.

Data Collection

The structured questionnaires were administered to 200 students. 193 of them responded, representing a 96.5% return rate. The open ended questionnaires were administered to 8 lecturers, of which 6 responded, representing 75%. Face-face structured interviews were conducted on managers. Interviews with field supervisors were through telephone they stay far from the institution.

Data analysis

Qualitative data were analysed descriptively with a focus on the key issues demanded by the study. Quantitative data were mainly analysed graphically using Microsoft Excel.

Findings from the study

(a) The opportunities the integration of ICT might in the way distance program

As explained above during the 10 months distance period, learners are on their own in the field studying and writing assignments. However, most of the assignments learners are given require that they look for information from more sources and not the modules only. This therefore means that the learners have to look for information from libraries within their vicinity. However, as NCES (1998) notes, most students studying under distance education face the critical challenge of access to materials. Most of the distance learners in the College stay in remote areas where getting academic information of their level is a serious challenge. The libraries they have access to do not have materials relevant to their study. The interviews with management revealed that the College has instituted the internet centres with the aim of mitigating the shortage of resource materials for students.

The expectation from management is that:

- Students are going to access information from the websites since their school libraries do not meet their demand.
- This will improve communication between members of staff and students in the field. One of the managers made the following comment on the same.

Our vision is that when this is fully operational, the whole distance programme would undergo massive transformation as students would be sending their assignments through e-mails and lecturers would be giving feedback through the same. The issue of missing assignments would be a thing of the past. Apart from that, the system will reduce the costs we incur during the assignments turnaround.

- Additionally, management feels that the establishment of the centres will lead to the creation of the institution's website, where in addition to assignments, it will contain electronic library and lead to the creation of blog groups. One of the managers emphatically said;

We need to be vigilant on this. As in institutions in developed countries, we can make our programmes fully electronic. If we can create blog groups, it would be possible to conduct lecturers electronically, without necessarily meeting the students face-face.

On the part of lecturers, the study has shown that lecturers are quite optimistic about the role ICT is going to play in the distance education programme. Data from the questionnaire showed that lecturers believe that the integration of ICT would improve the quality of delivery of the distance pogramme in that:

- It will enable lecturers to provide additional information to learners and easily follow on the progress of the learners. One lecturer made the following comment

Facilitation would not be ending here [at DCE], it will be continuing while students are in their schools through the net. There will thus be an opportunity t for students to ask questions that would be answered by lecturers in good time.

This assertion is in agreement with what Moore & Kearsley,(1996) who claimed that in concert with geographical flexibility, technology-facilitated educational programs also remove many of the temporal constraints that face learners with special needs as students are starting to appreciate the capability to undertake education anywhere, anytime and anyplace.

- There will be speedy flow of information from the College to all teacher learners hence minimizing the communication gap that exists when learners are in the field.

How the students feel the integration of ICT would impact their studies:

One of the items in the questionnaire required students to rate how they feel the integration of ICT would impact their studies. They were to tick against one of the following guided responses No improvement, Very little improvement, At least some improvement and huge improvement. Figure1 below gives a summary of their responses:

It was observed that 82% of the learners are optimistic that the integration of ICT would their studies. On how they would utilize the ICT facilities for their studies, the learners' responses showed that they indeed have an idea of how best to use the facility.

Table 1 gives a summary of their responses.

Way of Using the Facility	**Number of respondents**	**%**
Search for information	162	90
Communication with lecturers	121	67
Sending assignments	77	43
Communication with classmates	78	43

As the table1 shows, 90% of the learners suggest they would use ICT for searching for information, while 67% suggest they would use the facility for communication with lecturers. These responses are in agreement with what most scholars purport. As McCausland, Wache & Berk, (1999) posit, ICT enhances the capacity to identify, issue, locate and evaluate relevant information in order to engage with it or to solve a problem arising from it.

(b) Perceived challenges in the integration of ICT

In exploring the perceived challenges of integrating ICT in distance education, the study categorized the challenges into three:

- Learners' capacity in using ICT
- Management of ICT facilities and
- Sustainability

To determine learners' capacity in making use of ICT facilities, learners were to indicate by ticking how conversant they are with each of the indicated software package, and how often they use each of the indicated software packages. Figures 2 and 3 give a summary of the learners' responses.

What this means is that their capacity to make maximum use of the ICT facilities is compromised. This therefore poses a critical challenge to the successful utilization of the resources. AS Morales-Gomez, D. and Melesse, M. (1998) note, teachers need to have up-to-date skills in ICT so as to easily adapt themselves in the swiftly evolving technological era. This therefore means that the lack of skills in using computer software will to some extent affect the programme.

Management of the ICT facility

Human capacity

Professional development in ICT should focus on particular applications; integration into existing curricula; curricular changes related to the use of ICT and skills development (http://en.wikibooks.org/wiki/ICT_in_Education/Key_Challenges_in_Integrating_ICTs_in). Ideally, these should be addressed in pre-service teacher training and built on and enhanced in-service. However, as the interview with the Management revealed, the College does not have deliberate ICT capacity building strategies. As such, it does not have officers on the ground to take technical charge of the facility. Even though the field supervisors will be entrusted with the responsibility to take care of the ICT facilities, they do not have skills to respond to technical issues.

Conflict with host institutions

The other challenge sited by management is the possible conflict between the host schools and the College students. Since the centres are in existing secondary schools, members of staff are also given access to the facilities. If not properly, sensitized, members of staff in the host schools might assume the ownership of the facilities hence denying the rightful owners of the facilities to benefit from them.

Sustainability challenge

Many teacher or student-initiated ICT projects have been undermined by lack of support from above (http://www.idrc.ca/en/ev-93060-201-1-DO_TOPIC.html). For ICT integration programs to be effective and sustainable, administrators themselves must be in full support of the initiative. The other key issue management pointed out was the support from Ministry of Education. College Management feels that the sustainability of the programme requires unflinching support from the policy makers. One of the managers made the following comment: *"Readiness of the Ministry to absorb the cost of the service after the end of the Project is over is needed. There is a need that the Ministry takes interest in the endeavor so that the dream of having fully integrating ICT in distance education is realized".*

Another manager lamented:

The problem with most donor funded programmes is that they die a natural death after the donors pull out. It is high time that we start owning these programmes. The comments from the managers indeed show that if there is no political will to support the initiative, the integration of ICT into the Distance Programme would be a failure.

Lack of connectivity:

The interview with some of the field supervisors revealed that in most centres in the rural areas, there is no internet connectivity due to the logistical challenges the service provider is facing. There is therefore a need to find quick solutions to the problem.

(c) Possible mitigation strategies

The study has explored a number of strategies that might be used to mitigate on the envisaged challenges.

Capacity of the learners:

One of the open ended questions on the questionnaire required the students state how they feel the deficiencies they have in ICT might be addressed. The majority of the learners suggested that

College should introduce ICT courses in the Distance Programme. In this, learners feel the College should treat the issue of ICT as one of the contemporary issues and hence incorporate them into the curriculum. This they argued would equip them with the relevant skills to use the ICT facilities. This suggestion is in concert with the argument put forward by Anderson, R.E., & Plomp, T., (2000) who assert that in order to function in the new world economy, students and their teachers have to acquire skills that would enable them to navigate large amounts of information, to analyse and make decisions, and to master new knowledge and to accomplish complex tasks collaboratively.

Management of the ICT

The responses from teachers, management and the field supervisors agreed on one thing that it would be necessary to train officers to take care of the ICT facilities. Most lecturers felt that since field supervisors are the ones currently taking charge of the centres, it would be proper to train them in the technical issues. This they argued would ensure continuity.

Sustainability issues

Management of the College felt that to sustain the Programme, it would be pertinent that the endeavour be a joint venture and not only a task for the College alone. One of them made the following comment: *"ICT should be a joint venture among institutions e.g Health, Education and so on…… Cooperation among institutions is needed. Institutions like Mzuzu University should also open internet centres where all should benefit.* This suggestion in agreement with what Moore & Kearsley, (1996) who argued that it is cheaper, and easier, to introduce a form of technology into education, and keep it working, where education is riding on the back of large-scale contributions by governments or the private sector. On the issue of involvement by the Ministry, Management suggested the need to involve the Ministry in the key activities of the Programme.

DISCUSSION

The study has shown that the College has indeed made strides in establishing ICT centres with the ultimate goal of integrating ICT into the distance Programme. There are a lot of opportunities the facility might bring to the programme. With full support, ICT promises to revolutionize the Distance Programme in College. Learners would have the unlimited access to recent information; they will be able to communicate with colleagues and lecturers easily. Above all, as (Brooks & Brooks, 1999) and (Magolda, 1999) posit, the use of ICT as a means of instruction increases the awareness and recognition of alternative theories for learning, which are founded on the premise that learning is achieved by the active construction of knowledge supported by various perspectives within meaningful contexts. What this means is that the integration of ICT would enhance independent learning. Students using ICTs for learning purposes become immersed in the process of learning and as more and more students use computers as information sources and cognitive tools the influence of the technology on supporting how students learn will continue to increase in education circles (Morales-Gomez & Melesse, 1998). It is therefore important that all stakeholders play their role so as to realize the dream of having a sustainable

CONCLUSION AND RECOMMENDATIONS.

The study has also revealed the challenges that are to be surmounted so as to have a successful implementation of the programme. The key challenges revealed in the study are inadequate capacity by the learners to use ICT, lack of capacity to manage the ICT facilities and sustainability issues. A sure way to overcome this challenge is to identify and involve key stakeholders in the programme. As Moore & Kearsley, (1996) note, Private sector-public sector partnerships to either pilot or fast track ICT-based projects is a strategy that has gained currency among Ministries of Education in developing countries. These partnerships take many forms, including private sector grants with government counterpart contributions, donations of equipment and education-related content by corporations to state-run schools, and the provision of technical assistance for planning, management, and strengthening human

resources at the grassroots level. It is therefore important that the College makes an effort to work in partnership with other stakeholders. The results of the study have compelled researchers to make the following recommendations:

- Introduce ICT courses to distance learners. Without ICT skills, learners will find it hard to make full use of the facilities. Different departments should come up with plans on how to accomplish this.
- Train officers to manage the facilities in the centres.
- Establish linkages with distance institutions which integrated ICT in their programmes.

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National Commission of Science and Technology (NCTS)
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Making Access to information on HIV and AIDS and Sexual Reproductive Health Cool for Young People: The Role of Short Messaging Services and Social Media

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ABSTRACT

Traditional messaging for behaviours change using information, education and communication materials has slowly become an old fashion. Young people are increasingly looking down than up and therefore difficult to find them. They are looking down on their mobile phones, IPAD and laptops to check emails and messages. Young people are members of various social media groups. Since the traditional communication structures is phasing away, youth in remote areas face a lot of problems due to lack of information being infected with HIV and STI's, getting unwanted pregnancies among other. Information communication technology offers an opportunity to reach out to young people on sexual and reproductive health (SRH&R), HIV and AIDS and behaviour change. YONECO SMS systems and Social media is a robust semi-automated system that is used to disseminate information on a number of issues that are affecting young people. YONECO utilizes social media as well as Short Messaging Services to provide access to services and information to young people and vulnerable groups. Through the use of mobile platforms, YONECO has developed android applications and mobi-sites with support from different partners. YONECO through the Helpline Services has been able to escalate and engage more young people on SRH&H as well as utilize these mobile technologies and reliable mapping platforms to disseminate SRH&H information which is at the finger tips and/or touch of a button by the youth. The paper therefore considers how research and ICT for development can enhance effective communication and behaviour change among the Malawian youth in the rural communities with use of ICT for development.

Keywords: Yoneco, Messaging, HIV and STI, Helpine

INTRODUCTION

Teenagers today are growing up in very different from that of their parents' and grandparents' youth. In developing countries, things are changing fast. Growth in mobile phone access in developing countries has grown exponentially, rising from a word-wide total of one billion mobile phone subscriptions in 2000 to six billion in 2012. Young people are more technology savvy than ever in the current setup and leveraging this aptitude and interest has great potential. The application of internet and mobile phone technology to health programmes – is a new and promising approach to increase access for young people. In fact technology has replaced the parenting and extended family systems in most families. Young people represent the highest

proportion of global consumers of mobile technology. Globally, more than 93% of the world's population is covered by mobile phone networks, and more than 87% of people living in the developing world are mobile phone subscribers (The World Bank; 2012. p. 246). Due to declining mobile phone costs and increasing reliance on mobile phones as essential commodities, mobile phone use is on the rise, even in the most resource-poor settings. Data on mobile phone penetration among younger populations is limited, but recent findings suggest that mobile phone ownership among youth in low-to-middle income countries (LMICs) is steadily increasing (Hightow-Wideman, Muessig, Bauermeister et al; 2015. p. 1–16). A 2014 survey of 24 emerging nations revealed that between 53 and 95% of people aged 18–29 owned mobile phones; the overall average was nearly 83% ownership among young people (Pew Research Center; 2014). Text messaging is found to be the most popular form of mobile phone communication, particularly among young people (I bid). A recent study of seven African countries (South Africa, Nigeria, Senegal, Kenya, Ghana, Tanzania, and Uganda) documented that texting was substantially more popular among individuals ages 18–34 than those 35 and older [4].

Traditional messaging for behaviour change using information, education and communication materials has slowly become an old fashion. Young people are increasingly looking down than up and therefore it has been difficult to find them. They are looking down on their mobile phones, iPads and laptops to check emails and messages as well as network with their peers through various social media groups. Since the traditional communication structures are phasing out, youth in remote areas face a lot of problems due to lack of information which in turn leads to them being infected with HIV and STI's, not accessing SRHR messages, and getting unwanted pregnancies among other. Information communication technology offers an opportunity to reach out to young people on Sexual Reproductive Health and Rights (SRH&R), HIV/AIDS and behaviour change. The use of mobile phones to transmit HIV/AIDS and SRHR messages and provide links to services to improve health behaviours among hard to reach populations has gained increasing attention in recent years.

It is estimated that about a million people globally acquire a sexually transmitted infection (STI) every day, including many who are infected with the human immunodeficiency virus (HIV) (World Health Organization. Global strategy for the prevention and control of sexually transmitted infections: 2006–2015. 2007; World Health Organization: Draft global health sector strategy on sexually transmitted infections, 2016–2021. 2015). In order to prevent STIs, minimize the effects among infected people, and to reduce the enormous burden that STIs represent for developed and developing countries, the World Health Organization (WHO) has published the Global Strategy for the Prevention and Control of Sexually Transmitted Infections, where the need for educating people on sexual health is emphasized (I bid). In order to achieve this educational goal, the WHO points to the importance of choosing the communication channels that most effectively reach the target population and usage of social media and SMS bulk tool is one of the effective tools when it comes to reaching out to the youth. The study was conducted to find means of increasing access to SRHR, HIV/AIDS, human rights and child protection information among community members in Malawi.

MATERIALS AND METHODS

A qualitative method is employed through means of observational approach to gathering data from the youth that YONECO is targeting in a number of districts where it is undertaking HIV/AIDS and SRHR programming. What this entails is that YONECO through its numerous district offices engages with the youth in their communities on a number of HIV/AIDS and SRHR interventions and from such engagement harvesting of contact details is done to enable sending of HIV/AIDS and SRHR messages to the youth through an SMS bulk tool stationed at YONECO head office. The SMS bulk tool was necessitated as appropriate having noted that not all phones have access to the

internet and that not all youth that have phones with internet access afford to stay online all the time citing the financial hardships they go through in their daily lives.

Focus Group Discussions are also conducted as a means of needs assessment of specific target groups of people that YONECO targets to reach with HIV/AIDS and SRHR interventions in the different districts where it is operating. Through the different themes that are crafted for the focus group discussions that are conducted, the findings that ensue inform the model of a specific SMS bulk tool platform. The same is for social media messages that are developed through creative workshops building also on the findings that come from the focus group discussions that are done with specific target groups.

To highlight, the social media platforms that are mainly used are WhatsApp, Facebook and Twitter through which YONECO pushes a number of messages to the thousands of youth that follow and liked the page and have access to updates as they are posted. Currently, YONECO Facebook page has 12, 828 "followers" and 12, 915 "who liked the page" (Youth Net & Counselling – YONECO). Further to this, YONECO has 938 of its Twitter account (@yoneco3). The social media platforms are manned by experienced YONECO staff on media issues and the platforms are designed in such a way that they are interactive with the target audience (the youth).

A snow-balling approach is also used to enable YONECO reach out to more youth with messages of SRHR and HIV/AIDS mitigation. Snow balling is a non-probability sampling technique where existing study subjects recruit future subjects from among their peers. This allows for more youth to be engaged and a lot of feedback collected for development of the targeted messages that are then designed for dissemination to a larger population for their benefit.

Innovation and Research: YONECO SMS systems and Social media is a robust semi-automated system that is used to disseminate information on a number of issues that are affecting young people. YONECO utilizes social media as well as Short Messaging Services to provide access to services and information to young people and vulnerable groups. Through the use of mobile platforms, YONECO has developed android applications and mobi-sites with support from different partners.

RESULTS AND DISCUSSIONS

Gathering of the results over the period 2014 - 2017 has been through means of a number of monitoring visits to the many districts where YONECO is implementing youth targeted SRHR interventions as well as through the Helpline and ICT systems that are housed within YONECO secretariat.

Findings reveal that there is increased uptake of SRHR services provided in the districts as the rural youth, through the information that they get from the SMS system and social media platforms that they use are able to access service providers from within their localities as the systems include mapping data of where the service providers are. Some YFHS coordinators in some of the districts like Mangochi where YONECO is operating have actually intimated that they feel the platforms used to provide information to the youth are just what the youth need in a developing country in a technology savvy era. Youth these days quickly relate to technological innovations hence these serve as a channel that bridges the communication gap with the youth on SRHR and HIV/AIDS.

Because the social media platforms used are interactive, there is increased traffic to the platforms where the youth are mainly seeking access to information that they feel shy about getting from both their parents and guardians. In the long run, this ensures that a lot of youth access the relevant

information with regards SRHR and HIV/AIDS basing on the assurance that they share their experiences with their peers in their communities. There has been very positive and encouraging feedback from the youth that YONECO is engaging on all the aforementioned platforms. Most of the youth cite that they find the messages resonating to their sexual reproductive needs that they may not be accessed through their parents and guardians.

CONCLUSION

All things being equal, YONECO through the above mentioned platforms has been able to escalate and engage more young people on HIV/AIDS and SRHR as well as utilize these mobile technologies and reliable mapping platforms to disseminate SRHR information which is at the finger tips and/or touch of a button by the youth. The SMS application is a growing database of over 14,000 contacts, disaggregated by district and it contains youth and various key stakeholders such as members of parliament and chiefs that are targeted with specific messages for advocacy purposes.

There is increased uptake of SRHR services provided in the districts as the youth are able to access service providers from within their localities as the systems include mapping data of where the service providers are based. YONECO GPS mapped around 400 services providers nationwide for referral services in child protection, HIV/AIDS and SRH&R. Through the social media as well as the SMS bulk tool, there is evidence of increased traffic to the platforms where the youth are mainly seeking access to information about SRHR and HIV/AIDS that they feel shy about getting from both their parents and guardians.

It has to be highlighted that linking tailor-made HIV prevention and SRHR policies to the ICT policies that the government of Malawi has in play would go a long way in improving the access of the youth to SRHR and HIV/AIDS. Going by the current practice, it is key to note that the policies currently are stand-alone policies hence cannot address issues in another policy.

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Adoption and Integration of Google Classroom in Teaching and Learning: A Case of a University College in Malawi

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ABSTRACT

Electronic technologies have proliferated to all parts of the world. Malawi, a developing nation in Africa has also experienced a thrust in this area. Although it may lag behind in a number of ways in as far as technology permeation and adoption is concerned, a lot is being done to ensure that University lecturers at a constituent college of the University of Malawi own and utilize such technologies for teaching and learning. One such endeavor was the introduction of Google Classroom as a learning management system at the university. After the introduction of this learning management system (LMS), the college administration through the ICT department, organized week long training sessions for academic members of staff with the hope that they would upload their courses on this platform and start using Google Classroom as a tool for teaching and learning. This study sought to find out if academic members of staff had started using the learning platform and identified factors that facilitated or hindered usage of the LMS. A survey questionnaire with structured and open-ended questions was sent out to all faculty members in in the School of Education. Results indicate that the lecturers had not yet started using the platform. Reasons for non-adoption were little familiarity with the LMS and lack of knowledge on the benefits of using the platform; limited access of students to computers and the Internet; and lack of students' exposure to the LMS. Some of the suggestions provided to improve usage of the platform, are; offering training for lecturers who did not take part in the initial trainings, and provision of house call services to lecturers right in their offices to help them with day to day issues in dealing with the learning platform; provision of orientation to students on how to use the platform and increasing computer and Internet access to students to enable them access the LMS.

Key Words: Adoption, Integration, ICT, Google Classroom, Learning Management System

INTRODUCTION

The use of technology in education is growing in all parts of the world (Anderson & Kanuka, 2003). While it may be expected that technology availability would result in corresponding utilization, the case may not necessarily be so (Nicolle, 2005). Administrators of universities have invested in computer technology and the Internet with the hope that easy accessibility of such technologies will prompt faculty members to not only use the technologies, but also integrate them in teaching and learning. Yet this does not seem to be the case.

Evidence exists that illuminates that investing in technologies does not always result in utilization and integration in teaching and learning (Keengwe, 2007). As a matter of fact, it has been further

found that universities are lagging behind as far as in-class use of instructional technologies is concerned. While developed countries are decades away from their developing counterparts in regards to technology availability and accessibility, results of studies regarding technology integration have tended to cut across cultures and borders. In the technologically rich environments, despite high accessibility of up-to-date technology and equipment, technology integration in teaching and learning is still an issue. This shows that there must be other factors which interact to influence the probability of technology adoption and integration (International Society for technology in Education, 2000).

Developing countries have lagged not just economically and socially, but more recently, technologically as well. Despite problems universities in these environments meet to balance basic needs of running the universities and the technological needs, immense efforts are underway to provide electronic technologies to faculty as a step towards enabling them use and apply the technologies in their teaching. Technology permeation into developing nations such as

Malawi is a welcome development which is likely to help bridge the information barrier between developed and developing nations. However, improved access to technology does not seem to result in improved utilization for instructional purposes (Bryant, 2000; Green, 2001; International Society for technology in Education, 2000; Keengwe, 2007). Malawi faces human and financial resource constraints as it pursues to develop the ICT sector (Isaacs, 2007). According to Isaacs, such constraints include underdeveloped ICT infrastructure, high cost of telecommunications and unstable and unreliable power. Similar results have been found in studies conducted elsewhere in Africa (E.g., Farrell, Glen & Isaacs, 2007; Kalanda & De Villiers, 2008).

Despite these constraints, efforts are underway to improve the ICT sector. This is evidenced by development of policies, legislation and programs that provide an enabling environment for further progress in this area. For instance, the Communications Act, the Science and technology Act, the removal of import duty on computers and printers and the adoption of a national ICT for development policy are some cases in point pointing to the fact that efforts are being made to improve the status of ICT in Malawi (Isaacs, 2007).

On their part, universities in Malawi and probably elsewhere in Africa have made a concerted effort to provide computers and internet facilities to staff including faculty members amidst overstretched resource bases (Farrell, Glen & Isaacs, 2007). Chancellor College, a University College in Malawi, has provided computers, laptops, the Internet and a Learning Management System called Google Classroom to its faculty members. In addition to ensuring that these technologies are available to members of faculty, week long training sessions were provided to Members of faculty to orient them on the use of the Google Classroom Platform as a Learning Management System. It remains to be investigated whether this technology have been integrated in teaching and learning in this University College.

Theoretical Framework

Rogers (2003) provides a framework for studying diffusion and adoption of instructional technology. Through his diffusion of innovations (DOI) theory, he explicates how innovations spread in a social system, factors that determine whether an innovation is adopted or not and the rate at which such innovations may be expected to spread. Prominent scholars in the area of instructional technology (e.g., Ely, 1999; Surry, 1997) have applied Rogers (1995) theory to come up with theories that are relevant to the field of instructional technology. Surry (1997) offers three reasons why the study of diffusion theory is valuable to the instructional technology (IT) field. He posits that instructional technologists need to know factors that influence adoption of innovations and apply that knowledge to explain, predict and account for factors that limit or enhance their diffusion; to be able to work effectively with clients and possible adopters and to come up with

systematic and prescriptive diffusion and adoption models that would culminate in innovations that are effective and pedagogically appropriate.

There has been a trend recently for innovation research to shift from diffusion and adoption to implementation and institutionalization (Surry & Ely, 2002). Klein and Knight (2005) refer to successful implementation as one in which organizational members use the new idea regularly, in a consistent and committed manner. It is during implementation phase that issues relating to the use of the innovation arise (Rogers, 2003). Failure to implement the innovation successfully has been the major reason for failure to derive optimal gains from the innovation rather than the innovation itself as it is mostly construed (Klein & Sorra, 1996).

A number of research studies have explored reasons for successful programs. This approach, though less common (Surry & Ely, 2002), seeks to identify factors that facilitated the adoption and implementation process of successful innovations. It also attempts to identify consistencies among those facilitating factors among varied innovations and contexts. Ely (1999) seems to provide a major framework for this kind of approach.

Ely's Conditions for Implementation

A series of studies conducted specifically to investigate facilitating factors for successful implementation of innovations helped uncover eight conditions that facilitate implementation of innovations. Following are the conditions identified by Ely (1993): Dissatisfaction with the status quo, existence of knowledge and skills, resource availability, availability of time, Rewards or incentives, participation, commitment and leadership.

According to Ely (1990b), these conditions are important for change to be implemented following diffusion and adoption of an innovation. If all these conditions are present, there would be high probability of sustained implementation. Conversely, if only few of these conditions are present, there would be low probability of sustained implementation. Although the conditions are listed independent of the others, they are interrelated and may support or undermine one another (Nawawi, Ayub, Ali, Yunus, & Tarmiz, 2005). For example availability of resources may be a reflection of the commitment of the leadership of the organization to support the implementation of the innovation. Similarly, provision of incentives and rewards to individuals that are utilizing the innovation reflects the willingness of the leadership of the organization to motivate the individuals that have committed to utilize the innovation.

The present study employed aspects of Ely's facilitating conditions to elicit information regarding adoption and implementation of Google Classroom LMS at a university in Malawi. . The study was conducted to to find out if members of university faculty in Malawi were integrating Google Classroom for teaching and learning and to identify factors affecting its adoption.

MATERIALS AND METHODS

A survey questionnaire was sent to all members of faculty in the School of Education at Chancellor College to elicit their experiences regarding the use of the Google Classroom Learning Management System following a training that was offered to all members of Academic Staff at the college. Structured and open-ended Survey questions were formulated by the researcher using some aspects of Ely's (1999) eight facilitating conditions. Open ended questions helped the researcher obtain deeper insights from the respondents on some issues. The return rate of the survey questionnaires was 50%.

RESULTS AND DISCUSSION

Major themes adopted from the research questions were: technology accessibility for faculty members and technology accessibility for students; extent of technological innovation adoption; factors hindering adoption, and use of technology; and ways of overcoming the challenges. In this section, results have been presented in a narrative form and discussion done in light of the theoretical framework that has informed the conduct of this study.

Technology Accessibility for Faculty Members

All the ten faculty members that were surveyed indicated that they had computers, laptops, access to the Internet and access to a Projector. Additionally, all of them used technology in one way or another. This finding is in agreement to Farrell, Glen and Isaacs' (2007) postulation that Universities in Malawi and elsewhere in Africa have made and continue to make a concerted effort to provide computers, the Internet and other related infrastructure amidst overstretched budgets. However, the case is different when you look at technology accessibility for students.

Technology Accessibility for Students

One question sought to find out if the faculty members thought that there were enough computers to cater for all students. Responses to this question showed that all the faculty members were of the opinion that the computers at the college were not enough to cater for the academic needs of all students. The results render evidence to suggest that while the college has progressed in the area of electronic technology provision for faculty members, provision of computers for students is still in infancy stages. This means that even if the faculty members were ready to use the Google Classroom LMS, they could be limited by the low uptake of the technology by the students due to inaccessibility since the LMS requires that students add themselves to a virtual class for them to access learning materials, submit assignments and engage in discussion boards-which they cannot do if they do not have access to computers and the Internet.

Extent of Technological Innovation Adoption

Amongst the ten lecturers, only four had attended the Google Classroom Training that was offered by the ICT Department of the College. Most of those who failed to attend said they were unable to attend because they were busy with other engagements. Only one person said they were not aware of the training. Amongst the four that had attended the training, none of them was using the LMS. Some of them were unable to adopt the technology because they had forgotten how to use the facility. One lecturer had this to say: "I have forgotten since I did not practice after the training". This means that it is one thing to be trained and another to implement what one has been trained in. This highlights the need for instructional technologists to be aware of factors that influence adoption of technologies so as to provide effective and efficient adoption models and advise clients appropriately as postulated by Surry (1997). Other factors that were highlighted as hindrances to adoption of the LMS technology were lack of access to computers and the Internet by students; lack of training amongst the students and large class sizes which in turn meant that only few students could access the Internet at any one given time. Conversely, all the lecturers who did not attend the training indicated lack of training as a major factor hindering them from using the LMS. However, from factors provided by those who had attended the training as hindrances, it is clear that training is not the only factor involved. Even after being trained, the lecturers met other hindrances that prevented them from using the facility.

The findings of this present study are similar in some respects to findings of studies conducted elsewhere such as those conducted by Baltaci,Goktalay and Huguet (2008); Del, Favero and Hinson (2007); Ensminger and Haab (2005); Ensminger and Surry (2008) who found that , lack of accessibility to available equipment, lack of knowledge and skills to use the technologies, lack of involvement in decisions making involving electronic technologies by faculty members, lack of

infrastructure to support the technologies, lack of technical, pedagogical and administrative support were some of the factors that hindered adoption and implementation of instructional technologies.

Ways of Overcoming the Challenges

Results from the study indicate that while lecturers who attended the Google Classroom Training suggested that training students and making computers and the Internet accessible to students would go a long way in reducing the challenges being encountered, those who did not attend suggested that being oriented in the use of Google Classroom would solve the problem.

From these two perspectives, it is clear that those who have been trained push the blame on either students' lack of knowledge and skills on how to use the LMS or lack of enough computers and related technology for the students while those who have not been trained blame it on their lack of knowledge and skills.

These findings can better be understood from Ely's perspective as he highlights that no one factor is sufficient to bring about the needed adoption in the implementation of instructional technologies. While training provides the needed knowledge and skills and is indeed a basic necessity towards adoption and implementation of instructional technologies, it is not sufficient on its own. Resource availability, time, rewards and incentives, commitment and leadership; and dissatisfaction with the status quo are all necessary for successful adoption and implementation. The linkage amongst these factors as postulated by Ely cannot be overlooked. Commitment of leadership of the college is reflected in the way resources are allocated; the way faculty members' efforts to use the technologies are rewarded and incentivized for instance.

This present study also finds a lot of relevance in similar studies conducted elsewhere. For example, a study that explored the diffusion of information and learning technology (ILT) among educators in Malaysia, it was shown that while faculty members appreciated the importance of ILT as vital in teaching, only few used it in actual teaching (Rashid & Gloeckner, 2008). Similarly, in the present study, although most faculty members were appreciative of the LMS' capability to aid in teaching and learning, their interaction with it and application for classroom was non-existent in as far as the sampled respondents were concerned.

CONCLUSIONS

The study has revealed that provision of technologies for teaching and learning is a positive move towards adoption and implementation of instructional technologies. Chancellor College, a University in Malawi, has made this important move and went further to provide training to all faculty members of the college. However, provision of the Learning Management System and training of staff in the use of the LMS are not the only factors to consider in ensuring adoption and implementation of the technologies for teaching and learning. Other conditions, as suggested by Ely also need to be made available, where possible, to ensure successful adoption and implementation. Such factors include dissatisfaction with the status quo, existence of knowledge and skills, resource availability, availability of time, rewards or incentives, participation, commitment and leadership.

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HEALTH AND POPULATION

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Susceptibility testing of some common pathogenic bacteria and fungi to *pterocarpus angolensis*

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ABSTRACT

The medicinal plants used to treat different ailments in Malawi, contain important phytochemicals which have bactericidal and anti-fungal properties. In this study, different organs of Pterocarpus angolensis, a medicinal plant which is locally used to treat skin diseases, were qualitatively screened for the presence of phytochemical constituents and quantitatively assayed for the antimicrobial activity to ascertain their pharmaceutical potential. The study revealed that P. angolensis contained tannins, flavonoids, saponins and terpenoids. The aqueous, dichloromethane and methanolic extracts of the leaves, stem-bark, fruits and roots of the plant were tested against Escherichia coli, Staphylococcus aureus, Streptococcus agalactiae and Candida krusei by the macro tube dilution method. All the extracts exhibited some activity against the test organisms. However, the activity of the extracts depended on concentration and microbial species. The minimum inhibition concentration (MIC) values of the extracts ranged from 0.166 g/ml to 0.01046 g/ml with the dichloromethane and methanolic extracts exhibiting more activity than the aqueous extracts. The minimum bactericidal concentration and minimum fungicidal concentration (MBC and MFC, respectively) values of the extracts ranged from 0.166 g/ml to 0.0417 g/ml. The results obtained indicate that Pterocarpus angolensis has both antibacterial and antifungal properties and could be used for the treatment of ring work and other ailments. Use of the isolated and purified compounds from P. angolensis could increase the susceptibility of the tested pathogenic microorganisms in this study.

Keywords: Medical plants, phytochemicals, sterm-bark, extracts

INTRODUCTION

The use of herbal supplements has drastically increased over the past 30 years with the World Health Organization estimating over 80% of the world's population using herbal medicines as part of their primary health care (WHO, 2010). Statistics show that treatment regimens have not been effective in treating diseases due to poor access to advanced medical facilities and scarcity of medicines in developing countries (WHO, 2013). Patients who cannot afford expensive modern hospital treatments; whose disease did not respond to modern medicines or for cultural reasons, often resort to traditional and complementary medicines because medicinal plants are relatively cheap and locally available compared to synthetic drugs. Often times they are effective in treating many conditions, such as asthma, eczema, premenstrual syndrome, rheumatoid arthritis, migraine,

menopausal symptoms, chronic fatigue, irritable bowel syndrome, and cancer, among others (Maroyi, 2013).

Like in many parts of the world, rural communities in Malawi use medicinal plants for fuel and treating different ailments. For example, the fruit of *Pterocarpus angolensis* is used to treat ring worm in Ntcheu district, central Malawi. Dependency on plants for fuel and medicine coupled with the growing interest in medicinal plants has resulted in over-harvesting of plants. Therefore, diversity of plant species are rapidly dwindling leading to their extinction and desertification (Maroyi, 2013; WHO, 2010). Furthermore, the prohibitive cost of synthetic drugs has compelled the indigenous populations to look for alternative sources of drugs so as to overcome their problems. Because of the problem of drug resistance, scientists have resorted to exploit plants as they contain different bioactive compounds, hence many plant-derived drugs can be produced from a single plant (Rana, 2014).

Research has shown that *P. angolensis* in tropical Africa is valued for its efficacy against a wide array of ailments and it is proving to be effective because of its high concentration of tannins and flavonoids (Maroyi, 2013; Luseba, 2007). In quest for alternative treatment modalities, it is of unquestionable significance to establish the efficacy and usefulness of *P. angolensis* used by locals for the treatment of bacterial as well as fungal infections.

Geographical distribution

P. angolensis is a medium-sized to large, deciduous tree that grows up to 30 metres tall and is native to southern Africa. It derives its name from Greek words ‘pteran’ meaning ‘a wing’ and ‘karpos’ meaning ‘fruit’ (Figure 1). The specific name angolensis means ‘from Angola’. The common name ‘kiaat’ is derived from ‘kajaten’, the Old Dutch name for teak, because the wood of the South African trees was thought to resemble teak. In Malawian Nyanja, it is called Mlombwa or Mlombe (Orwa, 2009).

Medicinal uses

Traditionally, herbal drugs are used as tinctures, poultices, powders and teas. They can be used as a single herb or a combination of herbs that work in synergy, therefore, each part of a medicinal plant can be deployed in treatment of different health problems. The bark of *P. angolensis*, has several uses. When it is heated in water and mixed with figs it is massaged on the breast to stimulate lactation; a plain cold infusion from the bark works against nettle rash, stomach disorders, headaches, blood in the urine, earache and mouth ulcers (Maroyi, 2013; Geldenhuys, 2013). A decoction of the bark is also taken orally for piles. Bark or roots of *P. angolensis*, boiled with fresh meat, facilitates the treatment of gonorrhoea (Maroyi, 2013; Geldenhuys, 2013). A decoction of its root alone is highly regarded to cure malaria and blackwater fever. Furthermore, an infusion made from the roots of *P. angolensis* is taken by mouth for the treatment of diarrhoea, bilharzia and abdominal pains (Maroyi, 2013; Geldenhuys, 2013). Its roots are burnt and the ash dissolved in water is taken orally to treat asthma and tuberculosis. A concentrated root sap obtained after soaking the roots of *P. angolensis* in water for 6 hours is used as eyewash to heal corneal ulcers (Orwa, 2009). In the follow-up treatment of corneal ulcers, flowers of *P. angolensis* are placed in boiling water over which the patient holds the face, allowing the steam to fill the eyes; dropping sap into the eyes treats cataracts and sore eyes (Orwa, 2009). The red fluid resulting from the boiled bark of *P. angolensis* is used in treating skin lesions and ringworm. *P. angolensis* ripe seeds are burnt and the ash is applied to inflamed areas of the skin and bleeding gums for curing. The sap is known to heal sores, including ringworm sores and stab wounds (Maroyi, 2013; Geldenhuys, 2013).

Known research findings on *Pterocarpus angolensis*

Pterocarpus angolensis is reported to yield high concentration of tannins, flavones and flavonoids (Maroyi, 2013; Luseba, 2007). In South Africa, *P. angolensis* was reported to exhibit anti-inflammatory activity and high inhibitory activity against *S. aureus, E.coli* and *Salmonella typhimurium* (Luseba, 2007). Although *P. angolensis* grows in many parts of Malawi, there is no substantive data on its chemistry and activity against pathogenic bacteria and fungi.

The study was conducted to evaluate the effectiveness of *Pterocarpus angolensis* against common pathogenic bacteria and fungi; and then determine the phytochemicals that are present in it.

MATERIALS AND METHODS

Sequential extraction of the stem-bark, leaf, root and fruit of *P.angolensis* was performed using non-polar, medium-polar and more-polar solvents i.e. n-Hexane, dichloromethane, Methanol and water respectively. *Staphylococcus aureus, Streptococcus agalactiae, Escherichia coli* and *Candida krusei* were then exposed to the different levels of concentration of the extracts to determine MIC, MBC and MFC of the crude extracts.

Collection and pretreatment of plant material

Fresh plant parts (leaves, bark, fruits and roots) were collected in September-October 2015 from trees free of disease along Nkhata-Bay Forest Reserve with the help of the National Herbarium and Botanic Gardens of Malawi (NHBM) plant taxonomist (Mzuzu office) who identified the plant. Herbarium specimens were deposited at the NHBM. Collected plant materials were washed and air-dried at room temperature under shade. Using a grinding machine, motor and pestel, each organ was ground to a uniform powder, sieved (#40 0.420mm) then stored in dark bottles and appropriately labelled with its respective organ name until use. Different parts of the plant were analysed separately.

Extraction of plant material

Extraction of the plant material was done sequentially as explained by Kamanula (2015) and Sukhdev Swami Handa (2008). Each powdered plant material (50 g) (Bark, Root, Fruit and Leaf) was macerated in 300 ml of sterile n-hexane. The contents were then shaken vigorously and left to stand at room temperature for 48 hours with occasional shaking. Using a well cleaned, dried Buchner flask and funnel, the contents were then filtered through a Whatman filter paper no. 1 (7.0 cm) with the aid of a pressure pump. To ensure total extraction, 100 ml of n-hexane was added to the residues and left to stand for 48 hours and then filtered. The n-hexane extracts were combined and dried on the rotary evaporator (50 °C). To the residues, 300 ml of sterile Dichloromethane was added. The contents were then shaken vigorously and left to stand at room temperature for 48 hours with occasional shaking. After filtration, the extraction process was repeated with methanol as a solvent. Dried extracts were kept in the refrigerator (4 °C) until when needed for efficacy testing. To another 50 g, of each plant material, 300 ml sterile distilled water was added and the mixture was shaken vigorously and left to stand for 48 hours at ambient temperature in the laboratory. The extract was filtered and the filtrate was kept in the refrigerator until when it was used. Water extracts were not dried on the rotary evaporator because it was difficult to dry all the water.

Preparation of serial dilution of test extracts

Distilled water (20 ml) water was added to the whole extract for emulsification and reconstitution. The final twofold dilutions of extracts was prepared volumetrically in the broth by transferring 2 ml of the solution from the stock extract solution to the first tube. Then 1ml from the first tube was pipetted to the second tube containing broth, followed by a third one and continued to make serial dilution until the entire range of 8 dilutions was covered. A panel contained 8 dilutions of an extract

and 2 control tubes. One tube as a positive growth control (broth plus inoculum), and the other served as a negative control (broth only). 4 panels of different extracts (Leaf, Stem-bark, Root and Fruit) were prepared and tested against each organism. A minimum final volume of 1 ml of each dilution was needed for the test.

Phytochemical screening

Qualitative analyses were carried out on the roots, bark, fruits and leaves of *P. angolensis*. Qualitative analyses included identification for the presence or absence of certain classes of compounds such as alkaloids, tannins, terpenoids, saponins, anthraquinones/quinines, flavonoids and anthocyanins, among others. Standard methods described by Harborne (1998), Sofowora (1993) and other authors were used for qualitative analyses. All reagents used were of Analytical Reagent (AR) grade. The experiments were done in Chemistry Laboratory, Mzuzu University and all Standard Operating Procedures were followed. The methods are described below:

Alkaloids

A test of Alkaloids was done using Dragendorff reagents.

Preparation of Dragendorff reagents

Solution A: 1.7 g basic bismuth nitrate in 100 ml water/acetic acid (4:1). Solution B: 40 g potassium iodide in 100 ml of water. Mix reagents together as follows: 5 ml A + 5 ml B + 20 ml acetic acid + 70 ml water.

Procedure

Each powdered plant material (5 g) (roots, fruits, stem-bark and leaves) was macerated in 5% (v/v) hydrochloric acid (aq) solution (50 ml) for 24 hours and filtered using a Whatman filter paper no. 1 (Wink *et al*., 1995). A portion of the filtrate (1 ml) was treated with 10 drops of Dragendorff reagent. Formation of red precipitate indicated the presence of alkaloids.

Terpenes/Terpenoids

Each powdered plant material (0.5 g) (roots, fruits, stem-bark and leaves) was macerated in 10 ml of Diethyl ether and left to stand for 24 hours. The contents were filtered using Whatman filter paper no. 1. To the filtrate (2 ml), 1 ml of acetic anhydride was added, followed by the addition of 2 ml of concentrated H_2SO_4 (Sulphuric acid). Formation of reddish violet colour indicated the presence of triterpenoids.

Saponins

To each 0.5 g of the powdered plant material in a test tube (roots, fruits, stem-bark and leaves), 10 ml of distilled water was added and left to stand for 24 hours. The contents were filtered using Whatman filter paper no. 1. The filtrate (2 ml) was shaken vigorously, and observed for a stable persistent froth. The froth was measured and later mixed with 3 drops of olive oil and shaken vigorously then observed for the formation of an emulsion.

Flavonoids

An infusion of each of the powdered plant material (5 g) in distilled water (50 ml) was prepared and left to stand for 24 hours. The contents were filtered using a Whatman filter paper no. 1. A solution consisting of hydrochloric acid, methanol and water (1:1:1) (0.5 ml) was added to the filtrate (1 ml) followed by some few magnesium turnings. The appearance of a pink or red colour was taken as an indication for the presence of flavonoids.

Tannins
About 0.5 g of each of the powdered plant material was boiled in 10 ml of distilled water in a test tube. The contents were left to stand for 24 hours at room temperature and filtered using Whatman filter paper no. 1. A few drops (5-10 drops) of 0.1% ferric chloride were added to the filtrate (2 ml) and the solution observed for brownish green or a blue-black coloration, which indicated the presence of tannins.

Anthraquinones
About 0.5 g of each of the powdered plant material was boiled with 10 ml of H_2SO_4 and filtered while hot. The filtrate was shaken with 5 ml of chloroform. The chloroform layer was pipetted into another test tube and 1ml of dilute ammonia was added. The resulting solution was observed for colour changes. Formation of rose-pink colour, indicated the presence of anthraquinones.

Anthocyanins
An infusion (5% w/v) was prepared by macerating each powdered plant material (1 g) in deionized water (20 ml). The contents were left to stand for 24 hours at room temperature and then filtered. Hydrochloric acid (aq) solution (2 M) (2 ml) was added to the filtrate (2 ml) and heated in a water bath for 30 minutes (Harborne, 1973). The colour change was recorded.

Preparation of culture media.
Aseptic technique was followed in preparation of culture media. Benches were decontaminated using freshly prepared 0.5 % bleach. The culture media was prepared according to manufacturer's instructions. Media included MacConkey Agar, Blood Agar, Brain Heart Infusion Broth, Muller Hinton Agar, Saboroud Dextrose Agar and Mast ID-Chromagar Candida.

Bacterial and Fungal Inoculum Preparation for Susceptibility Testing and Determination of Antimicrobial Activity against Selected Common Pathogenic Bacteria and Fungi

Microorganisms
Growth inhibitory effects of all fractions of extracts obtained from all parts of *P.angolensis* was tested against the following microorganisms: *Candida krusei, Staphylococcus aureus, Streptococcus agalactiae* and *Escherichia coli*. These were isolated from patient specimens submitted to Malamulo Mission Hospital Laboratory. They were sensitive and resistant to the following drugs respectively: *E. coli* was sensitive to Ceftriaxone, intermediate to Streptomycin but resistant to Sulphamethoxazole/Trimethoprim and Amoxycillin. *S. agalactiae* was sensitive to Penicillin, Streptomycin, Gentamycin and Ampicillin. It was resistant to none of the available drugs. *S. aureus* was sensitive to Streptomycin, Amoxycillin and Ampicillin, however, it was resistant to Penicillin while *C. krusei* was sensitive to Fluconazole.

Inoculum preparation
Four to five isolated colonies of each bacterium, of same morphological type were picked using an inoculating loop from overnight growth on agar medium (Oxoid, UK), and suspended in sterile saline (0.89%). This was agitated on a Vortex mixer and the turbidity of suspension matched with that of the 0.5 McFarland standard, by addition of saline or inoculum. The inoculum was conformed to be equivocal to that of 0.5 McFarland spectrophotometrically at 625 nm through a 1 cm cell path to give an absorbance of 0.08-0.10. This approach eliminated the time needed for growing the inoculum in broth (Testing, 2003).

Determination of antimicrobial activity against selected common pathogenic bacteria and fungi
Minimum Inhibitory Concentration (MIC), Minimum Bactericidal Concentration (MBC) and Minimum Fungicidal Concentration (MFC) were taken as measurement parameters to quantify the

effects of antimicrobial agents. MIC is the lowest concentration of an antimicrobial agent that inhibits growth as determined visually after a standard incubation period of 18-24 hours at 35-37 °C (Testing, 2003). The MBC and MFC is the lowest concentration of the agent that shows no growth after a subculture of all the dilutions that showed no growth in the MIC test.

RESULTS AND DISCUSSION

Table 1: Preliminary phytochemical screening of stem-bark, leaf, fruit and root of *Pterocarpus angolensis*

Components	Stem-Bark	Leaf	Fruit	Root
Flavonoids	-	++	-	-
Tannins	+++	+++	++	-
Saponins	++	-	-	+++
Anthraquinones	-	-	-	-
Alkaloids	-	-	-	-
Anthocyanins	-	-	-	-
Terpenes/Terpenoids	-	++	-	-

+++ = Appreciable amount
++ = Moderate amount
+ = Trace amount
- = Completely absence.

Table 2: Results of sensitivity testing of *S. aureus*, *S. agalactiae*, *E.coli* and *C. krusei* to *terocarpusangolensisextracts*

ORGAN	EXTRACTING SOLVENT	CONCENTRATION	S.aureus MIC	S.aureus MBC	S.agalactiae MIC	S.agalactiae MBC	E.coli MIC	E.coli MBC	C.krusei MIC	C.krusei MBC
Leaf	Water	0.166g/ml	Resistant		Resistant		Resistant		Sensitive	growth
Bark	Water	0.166g/ml	Sensitive	growth	Sensitive	growth	Resistant		Sensitive	growth
		0.0833g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
		0.04166g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
Fruit	Water	0.166g/ml	Resistant		Resistant		Resistant		Sensitive	growth
Root	Water	0.166g/ml	Resistant		Sensitive	growth	Resistant		Sensitive	growth
		0.0833g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
		0.04166g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
		0.0208g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
		0.01042g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
		0.005208g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
		0.0026g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
		0.0013g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
Leaf	Dichloromethane	0.166g/ml	Resistant		Sensitive	growth	Resistant		Sensitive	growth
		0.0833g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
		0.04166g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
Bark	Dichloromethane	0.166g/ml	Resistant		Sensitive	no growth	Resistant		Sensitive	growth
		0.0833g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
		0.04166g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
Fruit	Dichloromethane	0.166g/ml	Resistant		Sensitive	no growth	Resistant		Sensitive	growth
		0.0833g/ml	Resistant		Sensitive	no growth	Resistant		Resistant	
		0.04166g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
Root	Dichloromethane	0.166g/ml	Sensitive	growth	Sensitive	no growth	Resistant		Sensitive	no growth
		0.0833g/ml	Sensitive	growth	Sensitive	no growth	Resistant		Resistant	
		0.04166g/ml	Resistant		Sensitive	no growth	Resistant		Resistant	
		0.0208g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
		0.01042g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
Leaf	Methanol	0.166g/ml	Sensitive	no growth	Sensitive	no growth	Resistant		Sensitive	no growth
		0.0833g/ml	Sensitive	growth	Sensitive	no growth	Resistant		Resistant	
		0.04166g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
		0.0208g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
Bark	Methanol	0.166g/ml	Sensitive	growth	Sensitive	growth	Resistant		Sensitive	no growth
		0.0833g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
Fruit	Methanol	0.166g/ml	Sensitive	growth	Sensitive	no growth	Resistant		Sensitive	no growth
		0.0833g/ml	Resistant		Sensitive	growth	Resistant		Resistant	
Root	Methanol	0.166g/ml	Sensitive	no growth	Sensitive	no growth	Resistant		Sensitive	no growth
		0.0833g/ml	Sensitive	no growth	Sensitive	growth	Resistant		Resistant	

DISCUSSION OF THE RESULTS

The study demonstrated that antimicrobial activity varied with solvents used for extraction. Dichloromethane and methanolic extracts showed most activity compared to water extracts. Maximum inhibition was exhibited at a concentration of 0.166 g/ml for most extracts against *S. aureus, S. agalactiae* and *C. krusei*. However, minimum inhibition of dichloromethane root extract went as low as 0.01042 g/ml for *S. agalactiae* whereas leaf methanolic extracts inhibited the same organism at the least concentration of 0.0208 g/ml. Samie *et al.*, (2009) and Steenkampa *et al.*, (2004) documented the activity of *P. angolensis* against *S. aureus, S. pyogenes, E. coli* and *E. histolytica* while Luseba *et al.*, (2007) depicts that *P. angolensis* is rich in phytochemical compounds such as tannins which explains its antibacterial activity. Therefore the antibacterial and antifungal properties exhibited by the different extracts of *P. angolensis* in this study may be attributed to the presence of tannins, flavonoids and saponnins detected during phytochemical screening.

Dichloromethane extracts exhibited limited activity against *S. aureus*, but were better inhibitors than water extracts because they did not only inhibit some of the test organisms, rather they completely killed some of them which is not the case with water extracts. Although all extracts of *P. angolensis* did not exhibit activity against *E. coli* in this study, Samie *et al*., (2009) and Steenkampa *et al*., (2004) documented the activity of *P. angolensis* against *S. aureus, S. pyogenes, E. coli* and *E. histolytica*. Therefore, it is unsafe to conclude that this plant does not contain broad spectrum antimocrobial properties considering that it was only tested against a single strain of wild type gram negative bacteria. This might have had an effect as the organism used in the previuos studies were mutant species. Furthermore, crude extracts were used in this study hence due to lack of purity and probably antagonistic effect of other constituents reduced the effectiveness of the active compounds in the extracts.

Medicinal and healing properties of plants are closely related to their chemical components which are classified into some major groups like alkaloids, acids, essential oils, steroids, saponins, tannins etc. Getting these chemicals out into the herbal remedy depends upon the solubility of these compounds in various solvents. Against all the tested bacterial and fungal strains, methanolic and dichloromethane extracts of all the samples showed better antibacterial as well as antifungal activities compared to aqueous extracts. However, both rural and urban communities use water as a solvent for most of the herbs used in the treatment of ailments. This study therefore, provides substantive evidence that would substanciate the use of solvents that enhance more extraction and the best plant parts containing the highest concentration of active compounds for better efficacy in realiving man kind of the burden of disease. For example, adding locally brewed ethanol (Kachasu) to water that is used for extraction of *P. angolensis* would probably increase the efficacy of the plant extracts against particular microorganisms.

CONCLUSION AND RECOMMENDATIONS

Based on this study, *P. angolensis* crude extracts have great potential as antimicrobial agents against bacteria and fungi. The results obtained in this study suggest that *P. angolensis* could be used in the treatment of infectious diseases caused by resistant bacteria strains. Therefore, the antibacterial and antifungal properties shown in this study support the traditional use of the plant used in this study in the treatment of *S. aureas, S. agalactiae, E. coli* and *C. Krusei* infections. Because of the broad spectrum antimicrobial properties of the plant extracts, other microorganisms could also be susceptible.

A more detailed phytochemical analysis should be conducted in order to determine the bioactive compounds present in *P. angolensis*. Secondly, isolation of the active ingredients should be done. Thirdly, testing for the efficacy of *P. angolensis* extracts against a large number of other pathogenic microorganisms should be done to give a representative picture of the antimicrobial activity. Finally, sensitivity testing on the non-polar extracts (i.e. those extracted using n-Hexane) could be performed using DMSO (Dimethyl sulphoxide) to establish their efficacy. These, would result in more generalizable results on the antimicrobial activity of *P. angolensis*. Based on the results in this study, toxicological studies should be conducted on *P. angolensis* extracts in order to authenticate its safety for use in the treatment of infections. When such scientific data becomes available, *P. angolensis* can become an alternative to conventional antibiotics to which many microorganisms have become resistant. Since there are several active agents in *P. angolensis*, isolation and purification of these compounds could lead to the development of new synthetic antimicrobial agents, adding to the pool of antimicrobial agents on the market today.

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Prevalence and intensity of schistosomiasis in communities around water reservoirs in Malawi

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ABSTRACT

Although Schistosomiasis is endemic in Malawi, little is known on the epidemiology of the disease in communities around water reservoirs which use water from the surrounding reservoirs. A study was therefore conducted to determine the extent of infection by both S. haematobium and S. mansoni in communities around water reservoirs in malawi. The study was carried out during the wet and dry seasons in communities around three water reservoirs (Njala, Ukonde and Mlala) located in different ecological zones. A total of 1594 individuals with age range of 1 to 78 years were selected using systematic random sampling procedure. They provided stool and urine samples which were examined for schistosome eggs using kato katz and sedimentation methods respectively. Reagent strips were also used to compliment findings of the sedimentation method by testing the presence of haematuria in the urine. An overall prevalence of 47.4% was found with 42.9% for S. haematobium for and 9.5% for S. mansoni. Dry season registered a significantly higher prevalence (58.5%) than wet season (36.6%) (p=0.01). Prevalence for those living 0-2 km from the reservoir was significantly higher than that of those living >5km away (p=0.00). Furthermore, the prevalence at njala water reservoir (50.6%) was significantly higher than that at ukonde (43) reservoirs. Although, age groups of 6-15 and 29-30 years registered highest prevalence, there was no clear prevalence trend in age, as individuals aged ≥ 60 also recorded high prevalence implying that probably schistosomiasis transmission in communities around the water reservoirs is not a function of age. As for infection intensity, a maximum of 360epg and 192eggs per 10ml were recorded for S. mansoni and S. haematobium respectively. Ages of ≥ 50 years had no heavy S. mansoni infection and age group of 6-15 registered highest infection intensity for s. Mansoni. It is thought that the adults may have harbored the disease for ages and developed pseudo-tubercles and pseudo-papillae in the mucosa and sub-mucosa of the colon, which may be trapping the eggs.

Schistosomiasis is endemic in communities around water reservoirs in malawi. The current intervention measures that on the selective treatment of 'school children only approach' may not be the best option considering that adults recorded higher prevalence. In light of this, communities around dams in malawi may require annual mass drug administration, as the prevalence recorded was above the 50%, which is who threshold for launching mda.

Keywords: communal water reservoirs, schistosomiasis, prevalence, intensity, malawi

INTRODUCTION

Schistosomiasis, also known as bilharziasis (Muller, 2002) is a chronic parasitic diseases caused by digenetic trematodes of the genus *Schistosoma*. Humans acquire schistosomiasis through contact with cercariae infested freshwaters. It is endemic in 78 countries with an estimated 779 million people being at risk of contracting it worldwide, out of which 106 million live in irrigation schemes or in close proximity to large water reservoirs (Steinmann *et al.*, 2006; WHO, 2013). Worldwide, 243 million people are infected and over 192 million people of these live in Sub-Saharan Africa. The disease causes about 280,000 deaths worldwide annually (CDC, 2013).

Both urinary and intestinal schistosomiasis is endemic in Malawi. Studies have shown a varying (spatially) but increasing prevalence (Kapito-Tembo *et al.,* 2009). Although current prevalence as reported by the National Schistosomiasis Control Programme (GoM, 2001), stands at 40-50%, studies by Bowie (Bowie *et al.*, 2004) reported a national prevalence of 6.9%. Further more, localised studies in Blantyre (Chipeta *et al*., 2013) and Chikhwawa (Kapito-Tembo *et al.*, 2009) reported a *S. haematobium* prevalence of 10.4% and 14.2%, respectively. On the contrary, studies in Phalombe and along the Lakeshore area reported a prevalence of about 94% in children (GoM, 2001; Madsen *et al.*, 2011; Msyamboza *et al.*, 2010).

In Malawi, communal water reservoirs are open access facilities. As such, they are prone to many kinds of abuses, including faecal pollution as communities may dispose in them various substances. There are about 750 small to medium dams, with only 7 large dams mainly for municipal water supply (GoM, 2004). Most studies on schistosomiasis linked to large water bodies, have been conducted along the Lake (Madsen *et al.*, 2011). As a result, the distribution of schistosomiasis in Malawi is inadequately unwrapped, as a large proportion of freshwater bodies, including reservoirs, which serve a large proportion of the country's population, have not been adequately studied. In order to reveal the true picture of the disease in Malawi, it is important to establish the burden of the disease in all potential hotspot areas.

This study was conducted to solicit complementary information on prevalence of schistosomiasis in communal water reservoirs in Malawi and how they relate to snail infectivity and distribution. These findings will augment the existing information and provide a true picture of schistosomiasis prevalence in Malawi, which may trigger attention of health care providers to initiate control measures for the disease within these communal water reservoirs.

MATERIALS AND METHODS

Study site
The study was conducted in communities around water reservoirs in three different ecological zones. These were communities around;

Mlala water reservoir
Located in Nkhotakota district, about 70 km North of Nkhotakota district, near Dwangwa Trading centre in central region of Malawi between latitudes 13º0' and 13º35'S, and longitudes 33º51' and 42º25'E. The water reservoir is about 2 hectare big. It is used for washing, bathing, fishing, and soaking of cassava among other uses. It was constructed around 2002 by the Illovo Sugar Company to store water for irrigating sugarcane whilst it also benefits the community. It is surrounded by three villages, Mlala, Chimbaka and Kambale.

Njala water reservoir
Located in Zomba district, near Govala trading centre southern region of Malawi between latitudes 15° 52' 60S and longitudes 35° 47' 60E. The reservoir is about 10km East of Zomba Township.

The water reservoir is about 1 hectare big. It was built in the 70s by Government and rehabilitated in 2009 by Irrigation, Rural Livehoods and Agriculture Development Project (IRLAD). It is mostly used as a source of water for the rice irrigation scheme, washing, bathing, fishing and livestock among others. It is surrounded by two villages; Njala and Gelevulo.

Ukonde water reservoir

The reservoir is located about 36.5 kilometres south of Lilongwe city northeast of Kamphata Trading centre in the central region of Malawi. It is between latitudes 14°35'S and longitudes 33°50'E and covers and area of about 1 hectare. The water reservoir was constructed by the Malawi government in the 70s. It was then rehabilitated by Self-help organization in 2011 with the main purpose of supplying water for irrigation of crops. The reservoir is also used to provide water for bathing, swimming, fishing, as well as livestock drinking. It is boarded by Mzongo village to the North and Gonondo village to the southern part. It is about 0.8hactares.

Study design and sampling protocol

A total of 1594 individuals (at least 250 from each study area, in each season) were recruited for the study. This sample size was arrived at based on WHO recommendations of a minimum of 200 individuals per ecological zone to be recruited during an epidemiological study (WHO, 1998). The study population comprised adults, school children as well as non-school children with age ranging from 1 to 78 years organised in age groups in accordance to WHO (1998), GoM-NSO (2008), Agi and Okafor (2005), the number of participants in each age group was estimated in accordance to population distribution by age in the study areas as reported in (GoM-NSO, 2008).

Data Collection

Data on prevalence and infection intensity was obtained by examination of urine and stools for schistosome eggs. Beside this, urine strips were used to complement findings of the urine microscopic examination. The urine and stools samples were collected for two consecutive days from all individuals who had consented to participate in the study by signing the consent forms (appendix 1). The Kato-Katz faecal examination technique was used to examine the stools for *Schistosoma mansoni* eggs within 12 hours of collection. Infection intensity was determined by using number of eggs per gram of stool (epg) procedure and categorized as:

light (1-100 epg), moderate (101-399 epg), heavy (400-1000 epg) and very heavy (>1000 epg) (Katz *et al.*, 1972; Muller, 2002; WHO, 1993). As for *S. haematobium* examination, 10 ml sample of terminally void urine was collected in a properly labelled clean and sterilised container. The samples were collected between 10:00 and 14:00hr as the excretion of *S. haematobium* eggs follows a circadian rhythm, which peaks around noon (Doehring *et al.*, 1983; Doehring *et al.*, 1985). The samples were centrifuged and sedimented in accordance to WHO (2004) and examined under a microscope using x10 and x40 objectives for urinary schistosome eggs. The number of eggs examined were expressed as egg / 10 ml urine. Results from urine analysis were used to determine urinary schistosomiasis prevalence as well as infection intensity. The intensity was determined as the number of eggs per individual expressed as negative (0 egg / 10 ml urine), light (1-49 eggs / 10 ml urine) and heavy (≥ 50 eggs/10 ml urine). Prevalence was determined using the formula (WHO, 2004);

Prevalence (%) = $\frac{\text{Number of subjects tested positive x100}}{\text{Number of subjects investigated}}$

Numberofsubjectstestingpositivexdofsubjectsinvestigated

Additionally, a urinary reagent test strip (URS) which measures ten (10) urine-parameters manufactured by Cyress diagnostic, 3201 Langdorp – Belgium was dipped into each urine sample collected for less than 5 seconds to determine the presence of blood in the sample which was confirmed by change of colour of the strip.

Data analysis
Data were analyzed using IBM SPSS for Mackintosh version 22.0 (Armonk, NY: IBM Corp.). Descriptive statistics was used to determine prevalence and frequency. Chi-square was used to test association of prevalence and various demographic and ecological characteristics of the samples.

RESULTS

A total of 1594 individuals of age ranging from 1 to 78 years participated in this study. Whilst all individuals provided urine samples, only 1509 provided stool samples. The frequency of each characteristic is as in figure 1.

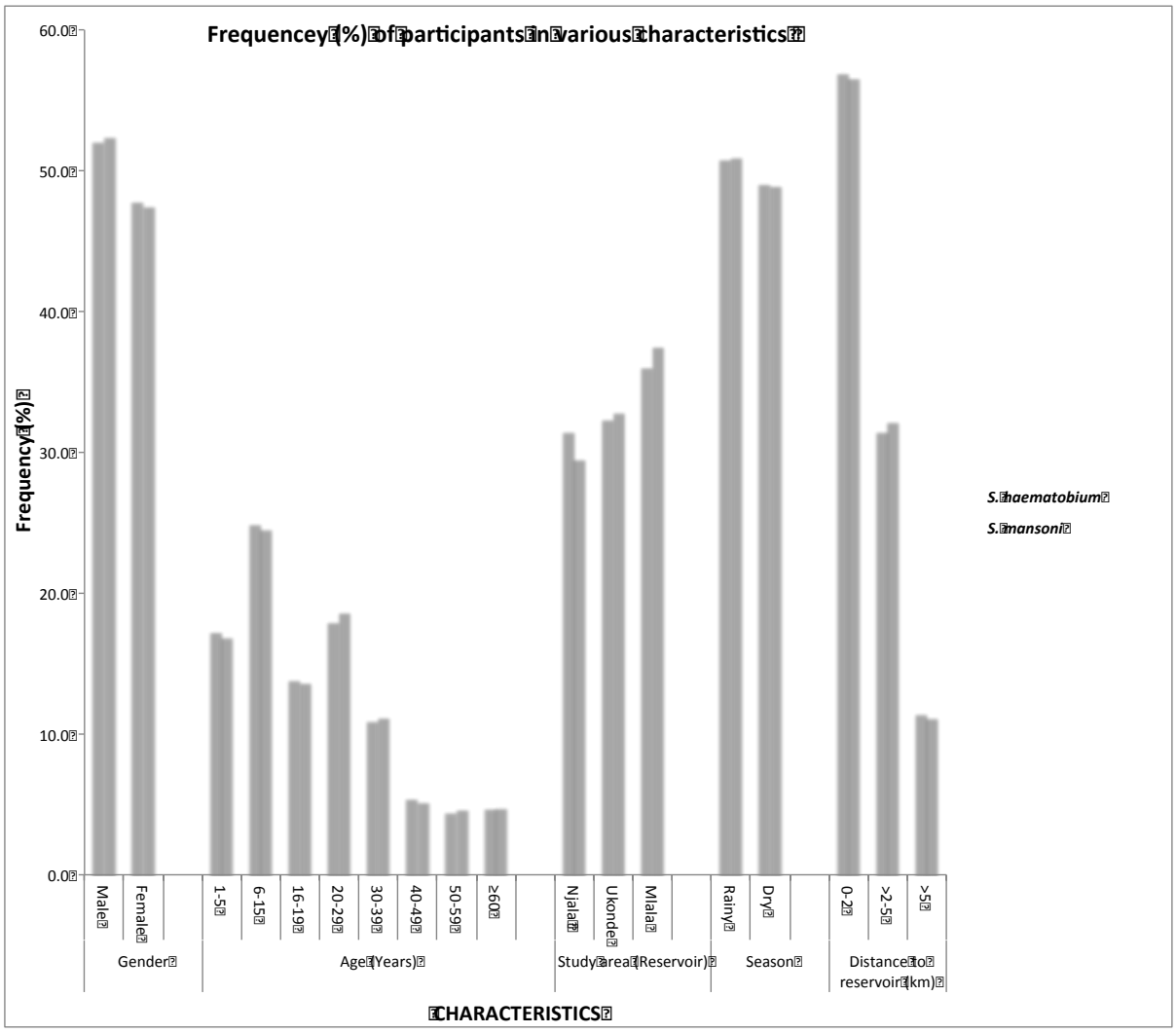

Figure 1: Characteristics of the study population.

There was variation in the frequency the characteristics. The highest number of participants was in age group of 6-15 and the lowest were from age groups of ≥ 60 and above. Similarly, highest number of participants came from those closest to the reservoir (0-2km) than those furthest from the reservoir (>5 km). Almost same number of individuals participated from Njala, Ukonde and Mlala dams communities (Figure 1). A total of 71 individuals (4.5%) did not return stool samples whilst a total of 22 (1.4%) participants did not return urine samples. Despite the noncompliance, the required sample size was achieved in each category hence the data analysis and interpretation was not affected. As for the noncompliant population, there were more males than females and more

youth in the age group of 20-29 and none from 50 years and above. There was highest non-compliance from Njala dam and lowest in Mlala dam.

Prevalence of schistosomiasis

The overall prevalence of schistosomiasis was 47.4%. The prevalence of *S. haematobium* was 42.9% and that of *S. mansoni* was 9.5%. The highest prevalence was 58.5 recorded in the dry season for *S. haematobium* and the lowest was 5.7% recorded in the age group of >60 years and above for *S. mansoni* (Figure 2). The prevalence of *S. haematobium* determined by

urinary reagent test strip (URS) was 37.6% and these results were used to complement the prevalence of *S. haematobium* determined by microscopic method.

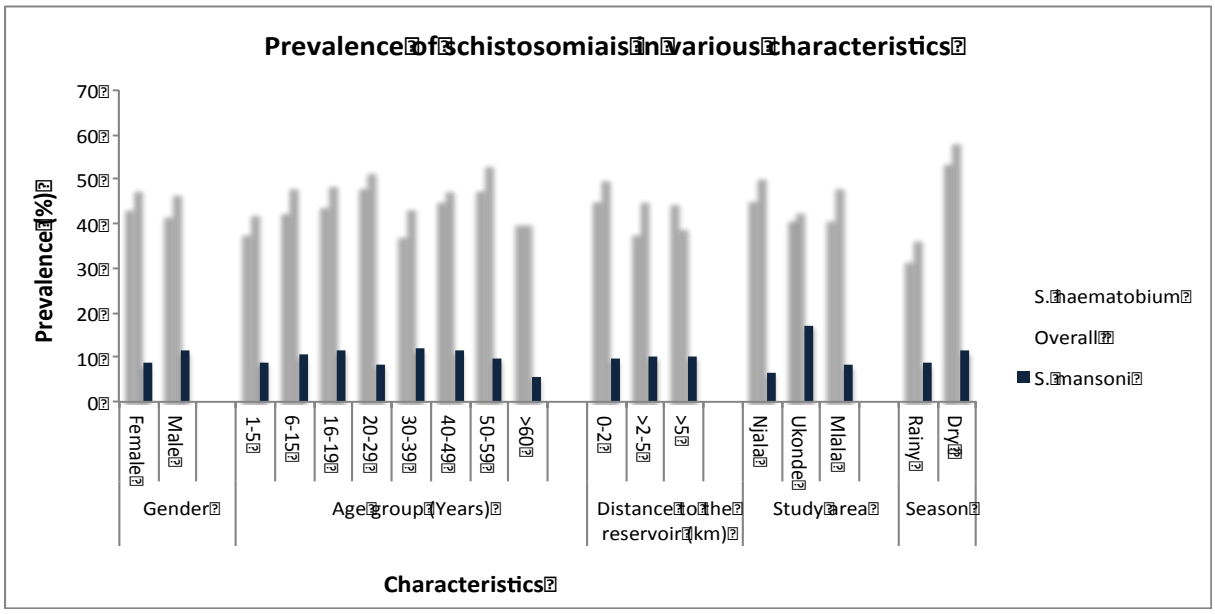

Figure 2: Prevalence of Schistosomiasis in communities around water reservoirs

Prevalence within various characteristics

An overall prevalence of 47.3% was recorded in this study. Furthermore, the prevalence of schistosomiasis in communities around Njala reservoir was highly significantly higher than that of Ukonde but not significantly different to that of Mlala. The prevalence unearthed during the dry season was significantly higher than that of the rainy season and the prevalence of the area located furthest (> 5km away) was significantly lower than that of the area closest to dam (0-2 km away). There was no significant difference in prevalence of schistosomiasis in males and females although the males' prevalence was higher. Similarly, there were no significant differences between different ages although the age group of 20-29 gave the highest prevalence.

Comparison of prevalence of *S. haematobium* and *S. mansoni schistosomiasis.*

Results showed that *S. haematobium* prevalence was significantly higher than the *S. mansoni* prevalence. Further more, the prevalence of *S. haematobium* was more than 3 times higher than that of S. mansoni in each of the demographic and ecological characteristics assesses. In both types of infections, the prevalence obtained during wet season was lower than that of the dry season. However, the prevalence of *S. mansoni* was significantly higher in communities at Ukonde than Njala and Mlala water reservoirs.

Prevalence of schistosomiasis in the three communities

The prevalence of *S. haematobium* in the three communal water reservoirs ranged from 38% to 45.6% with Ukonde community giving the lowest prevalence whilst *S. mansoni* was significantly higher in communities around Ukonde dam than in the other two communities.

Table 2: Prevalence of intensity of infection of *S. mansoni*

VARIABLE	No. of respondents	TEST RESULTS (%)		P- value (light infection)
		Light infection	Moderate infection	
Gender				
Male	792	35.5	6.6	
Female	717	36.7	7	0.62
Age (Years)				
0-5	256	8.6	0.4	
6-15	371	9.7	0.8	
16-19	207	10.1	1.4	
20-29	282	8.2	0.4	
30-39	170	9.4	2.4	
40-49	79	10.1	1.3	
50-59	71	9.9	0	
>60	73	6.8	0	
Site				
Njala	860	9.4	0.7	
Ukonde	475	10.9	0.8	
Mlala	174	7.4	1.1	0.76
Proximity to the reservoir (km)				
0-2	446	8.6	1.2	
>2-5	496	9.9	0.4	
>5	567	9.1	0.9	0.04
Season				
Wet	475	7.3	1.3	
Dry	174	11	0.4	0.03

Age and prevalence of intensity of infection for S. mansoni

There were no heavy (400-1000epg) and very heavy (>1000epg) infection intensity recorded in all the individuals examined. There was no moderate (101-399epg) infection intensity for ages of 50 years. However, all other age groups recorded light (0-100epg) and/or moderate (101-399epg) infection intensity. The prevalence of the moderate infection intensity ranged from 0-2.4% whilst the prevalence for light infection intensity from 6.8 – 10.1%.

Seasonality and infection intensity

Prevalence of light infection intensity for dry season was significantly higher than that of wet season. The prevalence of infection intensity in the rest of the characteristics (viz: proximity to the reservoir, site and gender) did not show any significant difference.

Table 3: Intensity of *S. haematobium* infection amongst selected variables

VARIABLE		No of respondents	TEST RESULTS (%)		P- VALUE (Light infection)
			Light infection	Heavy infection	
Gender					
	Male	763	36.7	7	
	Female	831	35.5	6.6	0.51
Age (Years)					
	1-5	275	31.3	7.3	
	6-15	399	35.5	7	
	16-19	221	40.3	3.6	
	20-29	287	40.1	8.7	
	30-39	176	30.7	6.8	
	40-49	88	38.6	6.8	
	50-59	71	39.4	7.0	
	>60	77	35.1	5.2	0.56
	Site				
	Njala	502	37.8	8.0	
	Ukonde	516	33.3	4.3	
	Mlala	576	37.2	8.0	0.01
Distance from the reservoir (km)					
	0-2	902	38.8	6.9	
	>2-5	514	34.0	7.2	
	>5	178	28.7	5.1	0.03
Season					
	Wet	811	23.9	8.1	
	Dry	783	48.8	5.2	0.00

Study site, distance to the reservoir and prevalence of intensity of infection

Njala and Mlala communities recorded a significantly higher prevalence of light and heavy infection intensity than Ukonde. In addition to this, the communities closer to the reservoir recorded significantly higher prevalence of light infection intensity than the furthest communities. The dry season recorded significantly higher prevalence for light infection intensity than the wet season.

DISCUSSION

The trend of prevalence in various characteristics

This study found an overall prevalence of 47.4% against a national prevalence of 50%. However, the current national prevalence of 50% was determined about 15 years ago (GoM, 2001), as such it might not be realistic as a number of disease interventions have been made over the years. More over, studies conducted _ENREF_2 about 10 years ago reported a national prevalence of 6.9 % (Bowie *et al.*, 2004). In light of the latter findings, the prevalence of schistosomiasis in the present study may be considered to be almost 7 times that of the national prevalence reported by Bowie *et al.* (2004). These findings may confirm the assertion that schistosomiasis is highly prevalent in communal water reservoirs (Steinmann *et al.*, 2006). This higher prevalence due to the presence of dams was also unveiled by Grosse (1993) who reported increase of schistosomiasis from 6 to 60%

after Aswan High dam in Egypt was completed in 1930, increase in schistosomiasis to 90% after lake Volta was completed in Ghana in 1966, increase to 70% after Lake Kariba in Zambia was completed in 1968, increase to 88% after Akosombo dam in Ghana was completed , increase from 30 to 60% after Sennar dam in Sudan was completed and increase to 85% in 25 years after Arusha Chini dam was completed (Grosse, 1993). High schistosomiasis prevalence were also reported in Zimbabwe dams before schistosomiasis control measure were instituted (Chimbari, 2012). Furthermore, Akinwale *et al.* (2010) found increased prevalence of schistosomiasis from 7 to 83.9% in communities around Oyan Reservoir in Nigeria and N'Goran *et al.* (1997) reported it in Ivory Coast around Kossou and Taabo dams from 0-73%. Whilst it is evidently expected that introduction water reservoirs into areas of bilharzia endemicity would be accompanied by upsurge in bilharziasis, the extent and process are not obvious for which this study has unveiled for Malawi.

The findings of this research found slightly lower prevalence than those reported for communities along Lake Malawi. These differences could be attribute to the selection of participants and methods of determination of schistosomiasis. The former studies purposively selected the susceptible and active age group of school children (Madsen *et al.*, 2011; Stauffer & Madsen, 2012) while this study used stratified and systematic sampling methods with age ranging from 1 to 78. Additionally, this study used the conventional microscopic method whilst the other studies include the use serological methods. Nonetheless, the study has provided impeccable information on the roles of dams in schistosomiasis infection in Malawi.

The findings from this study have shown that S. haematobium is more prevalent (54.8%) than S. mansoni (9.5%). Similar findings of differences in prevalence of the two schistosomiasis species have been reported by Bowie *et al.* (2004), Chipeta *et al.* (2013) and Msyamboza *et al.* (2010). These findings can be attributed to variation in the abundance of specific intermediate host snail population for the schistosome species. Studies by Madsen *et al.* (2001) along Lake found more *Bulinus* snails than *Biomphalaria*. However, the reasons for such variability have not been adequately explored and documented.

In terms of seasons, the prevalence of schistosomiasis in the dry season was significantly higher (58.5%) than that of the wet season (36.6%). Ivoke *et al.* (2014) and (Anto *et al.*, 2013) in their studies in Nigeria found similar trends although Bakuza (2012) in his study in Tanzania did not find any significant difference between seasons. Higher prevalence during the dry season than the wet season could be a reflection of increased water contact frequency. Studies by Anto *et al.* (2013) in Ghana showed that during the dry season water is scarce because many water points dry up. As results most of the activities that require water are conducted at the reservoir in turn increasing the water contact frequency. Additionally, dry season presents conducive environment for high snail production, which are intermediate host for the schistosome worms (Dida *et al.*, 2014). During this time, the water temperature, the water levels and water currents are within the favourable status unlike during the rainy season when the rains are heavy and wash away the some of snails (Madsen *et al.*, 2001; Muller, 2002; Slootweg *et al.*, 1993).

Remarkable results were also unveiled on effect of distance from the reservoir on prevalence. Prevalence of schistosomiasis in the communities closer to the reservoir (0-2km) was significantly higher than the communities further away (>5km). Zakhary (2010), Isa *et al.* (2015) and Grosse (1993) also reported increased infection closer to the reservoirs than in the distant communities. It is assumed that frequency of visit to the reservoirs by individuals from distant places (<5km) was low hence the low prevalence. Assuming all communities solely depend on the reservoir for their water needs, communities proximal to the reservoir may frequent the water body than those far away. The higher the water contact frequency the more the chances of getting infected by schistosomiasis (Paredes *et al.*, 2010; Yamana, 2004).

On the other hand, communities around Njala reservoir had a significantly higher prevalence of schistosomiasis that the other two communities furthermore, Ukonde had the lowest prevalence. The presence of the water reservoir may not be important in the transmission of schistosomiasis without the factors that support the accomplishment of this role. Kabatereine *et al.* (2004), Mazigo *et al.* (2010), Midzi *et al.* (2011) and Onyeneho *et al.* (2010) reported showed that acquisition of schistosomiasis is a function of several factors which may include water contact practices, knowledge, contamination by infected snails among others. It is assumed that there is variability in these the three communities hence the difference in prevalence. Equally important to facilitating transmission are the communities' occupation in each of these study areas. Communities around Njala reservoir are mostly irrigation farmers, growing rice in schemes. It therefore means that water contact frequency is higher with this type of occupation hence increased chances of contracting the schistosomiasis as also evidenced by Steinmann *et al.* (2006), Yamana (2004) and Grosse (1993) who reported more schistosomiasis prevalence in irrigational reservoirs than non-irrigational reservoirs.

As for prevalence of gender, there was no significant difference between male and female schistosomiasis prevalence. However, more females were infected than males. Bala *et al.* (2012); Mafiana *et al.* (2003); (Kapito-Tembo *et al.*, 2009)_ENREF_29; Mazigo *et al.* (2010); Midzi *et al.* (2011); Nour *et al.* (1990) and Dabo *et al.* (2011) in their studies found

similar results of non significance between males and female, however, on the contrary they found more males affected than females. This may be an indication of almost similar water contact frequency between for the male and females.

Similarly, prevalence between ages was not significantly different. This is in contrast to what has been reported in Mazigo *et al.* (2010)_ENREF_33; Mutapi *et al.* (2008); Deribe *et al.* (2011)_ENREF_29; _ENREF_16 who found that prevalence between age is significantly different with school children highly prevalent. This study further found small variations in prevalence between different ages although school children were among the top most infected. These findings may be an indication that all individuals around the communal water have the same risk regardless of age.

Infection intensity for *S. mansoni*

Infection intensity ranged from 24epg to 360epg. There was no record of moderate *S. mansoni* infection in all individuals aged 50 years and above and the age group registered the lowest egg count (with light infection intensity). Agi and Okafor (2005), Madsen *et al.* (2011) reported similar findings decreasing egg counts with increasing age. This can be attributed of number factors, which include reduced worm burden and low fecundity rate of the worms due to high immunity in the adults (Behnke, 2005; Chinwe & Agi, 2012), presence of pseudo-tubercles and pseudo-papillae in adults which develop as a result of harboring the disease for long time. These trap the already low number eggs in the mucosa and sub-mucosa of the colon leading to no or less eggs being released (Jordan P *et al.*, 1993; Muller, 2002; Ross *et al.*, 2002).

Children below 5 years of age gave startling results of infection intensity as 8.6% had egg loading of about between 101 to 360 epg (Table 1). This was unexpected considering that these are kids at a tender age. However, the results may be an indication that children accompany their mothers as well as siblings during washing, bathing, swimming and playing at the reservoirs as also observed by Chinwe and Agi (2012).

Even though the results of prevalence of infection intensity from communities around Ukonde reservoir were not significantly higher than those (GoM, 2001) of Mlala and Njala, they support findings by Bowie *et al.* (2004), GoM (2001), (Kapito-Tembo *et al.*, 2009) that *S. mansoni* is more prevalent in

Central region (represented by Ukonde in this study) than in the other two regions. This has also been shown by prevalence of *S. haematobium* infection intensity, which has registered lower infection intensity in communities around Ukonde reservoir.

Prevalence of light infection intensity for dry *season (S. haematobium)* was twice as higher and significantly different from the wet season infection. These findings concur with the overall schistosomiasis prevalence, which also found significantly higher prevalence during the dry season. The findings confirm the reports by Dennis *et al.* (1983); Ekwunife (2005) _ENREF_14 and _ENREF_13 Dawet *et al.* (2012) that the likelihood of being infected by schistosomiasis in dry season is higher than during the wet season as reflected in the infection intensity and prevalence.

CONCLUSION

Reservoirs in Malawi are schistosomiasis risk areas. Furthermore, there is no clear trend of infection in age, implying that selective treatment of 'school children only' may not be a best option for communities around water reservoirs as adults aged above 60 years also recorded high prevalence. Proximity to the water reservoir, ecological area and seasons are some of the factors that would increase the likelihood of acquiring schistosomiasis. In light of these findings, communities around water reservoirs in Malawi may require Mass Drug Administration (MDA) once every two years as the prevalence is within the WHO threshold of MDA of 50%.

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Ethical clearance
The research proposal and the informed consent forms were submitted to COMREC for review and approval. Literate participants were asked to read informed consent forms then sign whilst for the illiterate and participants below 18 years had the consent forms read in the presence of an impartial witness and or guardian after which the participants were asked to thumbprint the consent form. The consent forms were written in both Chichewa and English language. Only those who signed or thumbprinted the consent form were allowed to participate in the study.

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Tracking the Quality of Youth Friendly Health Services (YFHS) Using M-Health Tools: A Case for Mangochi

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ABSTRACT

Youth Friendly Health Services (YFHS) is within the Malawi Government's Health Strategy, however the availability, quality and uptake of these services still remains low. This is due to low awareness among young people, lack of youth participation in designing services, negative attitudes of providers and luck of resource allocation to ensure facilities and staff have adequate capacity to provide these services. To address this, the Malawi YFHS (2015-2020) identifies, among others, two key strategies to improve YFHS: 1) Youth Participation, to improve information provision and increase ownership 2) Use of emerging/appropriate m-health technologies. This paper discusses how young people in Mangochi used mobile technologies to track and rate the quality of YFHS in five target health centres in T/A Mpondasi and T/A Nankhumba. The one-year m-based research started December 2016 and is currently in its first phase. Leveraging on high level use of mobile phones among young people, a mobile scoring tool through GPS enabled phones and SMS was developed. Using these tools opinions of young people on different aspects of YFHS were collected. The first phase 112 youths from clubs took part followed by additional 74 youths from the communities. The preliminary opinions indicated low scoring in five health centers in services such as family planning, HIV services, condom use, STI, and antenatal services. Health centers registered 60% indicating not being satisfied with family planning and STI services while around 52.4% indicated that HIV services had a good rating in some health facilities. Issues of attitude by the service providers was rating poorly in most facilities. The preliminary findings in the first phase have been indicative of which YFHS are lacking among the targeted health facilities. These are reflective towards which components needs improvements in the targeted facilities. The finding also indicate that the majority of the young people are afraid to communicate to the duty bearers on the challenges and therefore the need to find alternative mechanisms for communicating the problems. Finally, there is need for effective monitoring of the health structures at district levels. It is therefore noted that the use of youth-oriented activities often provides a comprehensive overview of the challenges and shortfalls that youths meet when they are accessing YFHS. Nevertheless, it is these weaknesses in YFHS that have weaken the uptake of YFHS by the youth in Malawi.

Keywords: YONECO, Health Strategy, STI, HIV, SMS

INTRODUCTION

The Malawi Government considers Youth Friendly Health Services (YFHS) as a key component with its Health Strategy, however the strategy is faced by many problems such as availability, quality and uptake of these services which still remains very underutilized. There are so many reasons and factors however this can be attributed to low awareness among young people, lack of youth participation in designing health services and strategies as well as, negative attitudes of providers coupled with inadequate resource allocation to ensure facilities and staff which in turn may tender them to have inadequate capacity to provide these services. To address this, GOM strategy on YFHS (2015-2020) identifies, among others, two key points to improve YFHS: 1)

Youth Participation, to improve information provision and increase ownership 2) Use of emerging/appropriate m-health technologies. This entails YFHS is a key initiative that was operationalized in Malawi 2000 following the realization of the need to increase the uptake of health services for young people more especially Sexual and Reproductive Health. Despite a number of initiatives to promote YFHS, the fertility rate amongst adolescents and young people is increasing from 26% (MDHS 2010) to 26% (MDHS 2015/17). The increase can be attributed to the quality of services. A number of barriers contribute to the low uptake of services which include; long distances to health facilities; attitude of service providers towards young people; stock-outs of medical supplies and consumables; absence of recreational facilities; limited awareness on the availability of YFHS at the nearest health facility. In 2015, following the Evaluation of YFHS in Malawi, the Ministry of Health formulated national standards and guidelines on YFHS provision in an effort to sustain high quality of services. However, the next evaluation process will be done in long term yet the health facilities need robust information for timely intervention to improve the quality of service provision. In addition to this, young people need to be engaged in the tracking process on the quality of YFHS. Henceforth, young people; service providers and community leaders need to be informed on community scorecard processes on YFHS at selected health facilities using mobile technology by young people.

INTRODUCTION

Mangochi District has a large network youth clubs that are existing, these clubs are usually tied to youth networks that exist in most Traditional authorities. The project targeted young people who patronize youth clubs that are near the health facilities in the targeted T/As of Mpondasi and Namkhumba. Most of these youth corners span around 25 to 40 youths who are active and aware of YFHS services that are offered in these health facilities. Looking at the current situation there are the following issues identified. Only 50-75% of facilities report implementation of Youth Friendly Health Services (YFHS). An evaluation by the government showed that in most cases, the quality was low. Furthermore, less than one third of the youth had ever heard about YFHS; only 13% had ever used them; In Mangochi, youth indicated that the staff were very judgemental. This then led to rolling out of the programme dubbed Raising Voices for Better choices. This is an innovation challenge project by Packard that is led by SIMAVI that looks at empowering the youths in Mangochi to give them a voice to give their opinions on how they see the quality of YFHS as per guidelines of the Malawi Government Strategy on YFHS. Currently in its first phase of assessment using M-Health tools youths were able to rate the quality of YFHS in their respective health facilities. These opinions were then required and used to form basis to advocate for changes in the services at district level and health center level. The last assessment is expected to be done by the end of the year 2017 in the respective health centres

MATERIALS AND METHODS

Most young people in Mangochi has an access to smartphone. According to MACRA studies phone penetration is considerably higher in urban areas on the district and other rural areas as compared to other districts. This necessitated that young people used mobile technologies to track and rate the quality of YFHS in five target health centres in T/A Mpondasi and T/A Nankhumba. The one-year m-based research started December 2016 and is currently in its first phase. Leveraging on high level use of mobile phones among young people, a mobile scoring tool through GPS enabled phones and SMS was developed. The tools entailed training Peer educators who were able to conduct and collect opinions from youths within the catchments areas of the respective health centres in the two T/A. The groupings of young people were those who patronize these health facilities and to balance up the opinions some of the peer educators were from the communities. After this the youths in the respective health centres were interviewed and using these tools opinions of young people on different aspects and components of YFHS were collected. The first phase 112 youths from clubs

took part followed by additional 74 youths from the communities. The second phase consists of 150 youths from the 5 health centres that will provide additional opinions to follow up on the first phase. The second phase is currently scheduled to be undertaken at the end of the project.

Materials

Using the Malawi Government Strategy of YFHS peer educators that were trained in the guidelines of YFHS and using m-health tools. The opinions are collected on an open data kit tool that is configured on an android smartphone. The tool is linked with our main server where data is automatically synchronized when there is a proper internet. If the connection is not that good data is locally stored in the phone. The application is linked to an online tracking online system that visualizes the tracked opinions

RESULTS

This being a first stage on the study, the preliminary opinions that have been collected in the first phase indicated low scoring in the quality of YFHS in five health centers in various YFHS services such as family planning, HIV services, condom use, STI, and antenatal services. These were benchmarked against the standards of YFHS as attributed to by the Malawi Government Strategy on YFHS. These results in the five health centers registered 60% indicating not being satisfied with family planning and STI services while around 52.4% indicated that HIV services had a good rating. Issues of attitude by the service providers was rating poorly in most facilities, opening times, privacy. This was reflected in all health facilities. The opinions were reflective in the preliminary opinions on the improvements that young people needed to see improvements in the quality of YFHS.

DISCUSSION

Regardless of the study being in its first phase some of the preliminary findings have been indicative of which YFHS are lacking among the targeted health facilities. These are reflective towards which components needs improvements in the targeted facilities. The finding also indicate that the majority of the young people are afraid to communicate to the duty bearers on the challenges and therefore the need to find alternative mechanisms for communicating the problems. These have been reflected in that there is need for effective monitoring of the health structures at district levels. The use of mobile tools has indicated that there is need strengthen the available mechanisms. Most young people are not aware of the existing platforms they can use to track and provide feedback on the way YFHS are offered in the respective health facilities. This has been seen largely in that the issues arising from the communities are that young people are not patronizing these health facilities due to these issues identified. There is need to engage further with the health facilities on how best they can improve on issues that are considered short term.

CONCLUSIONS AND RECOMMENDATIONS

The Government of Malawi guidelines are key and particular about how a young person should be treated when it comes to issues of YFSH. The guidelines are clear on what young people should experience and one of the objectives being accessibility of quality YFHS amongst the youth. However, in as much as demand has been generate for the young people to access these services there have been other barriers that has made most young people shy away on accessing YFSH hence impacting on the uptake of YFHS amongst young people. Therefore, tracking quality of YFSH by the youths has been evidenced that by supporting youth engagement and participation there are high chances of providing genuine evidence that can easily be used to generate advocacy towards key stakeholders. This is so as the issues that are there such as staff attitude, privacy, insufficiency of information, waiting time, would be a thing of the past if most of these health

facilities are able to improve on these services. This entails that since young people are now empowered the will be able to demand the correct YFSH as there have the capacity to distinguish between good and poor standards of youth friendly health services. This thereby in principle has shown that the use and engagement of young people entails Government and all concerned Health providers can now easily be held accountable for their duties by the youths and the community. The process can therefore strengthen further the engagement and improvement of service by the providers in these health facilities as they will now be actively be involved hence dialogue would be easy to conduct on how quality of YFSH can be improved.

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Impact of food safety, Hygiene and sanitation Interventions using Health Food Market Concept in Rural markets of Chikwawa District, Southern Malawi

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ABSTRACT

This paper discuses findings from an evaluative study on the impact of food safety and hygiene promotion interventions using Healthy Food Market concept in Chikwawa District markets. The focus is on market hygiene and sanitation, coordination and participation of stakeholders in the promotion of food safety and the knowledge and practice of food handlers in food safety and hygiene in food markets. Results of two markets, pilot and control markets indicated improvement in market sanitation as well as food safety promotion activities with meagre improvement in food stakeholders' participation and food handlers' knowledge and practices in food safety. This suggest that the healthy food market concept provides a perfect basis for healthy food markets but require skillful implementation like improving on infrastructure, coordination and capacity building for it to be an efficient model.

Keywords: Food Safety, Hygiene, Saniation, Market

INTRODUCTION

A Healthy Food Market (HFM) is a setting in which all stakeholders involved in market chores collaborate to provide safe and nutritious food to consumers (Moy, 2006). A HFM is one that serves to improve the safety of food from farm-to-table continuum. The promotion of HFM in rural areas act as an approach for promoting food safety and related environmental health issues (WHO, 2006). The HFM concept was developed from the Health Cites Project (HCP) concept which was initiated in 1996 by the World Health Organization (Moy, 2006).

The overall strategy employed by the HCP initiative is to integrate health protection and health promotion activities in urban areas and transform priority health determinants like water supply, hygiene, sanitation and food safety for the better (WHO, 2006). It is from such an understanding that the Health Food Market (HFM) concept was started in 1996 (WHO, 2000). The HFM concept is buttressed by three basic principles that include: the provision of safe and nutritious food; the promotion of food safety from production to consumption; and the promotion of partnerships between traders, consumers, the Government and other development partners (WHO, 2006).

In Africa, the first pilot HFM was introduced in 1997, a year after its initiation in 1996, at Burugumi Market in Dar es Salaam, Tanzania under the Dar es Salaam HFM Project. It was successfully implemented and led to improvement in road access; construction of a solid waste

storage bay; construction of toilet and hand washing facilities; and development of a system for the collection and sorting of solid waste for subsequent disposal.(WHO, 2006).

Pilot HFM projects were also eventually initiated in other African countries like Botswana, Mozambique and Rwanda (WHO, 2007 & Tracy, 2014). In Malawi the HFM concept was introduced in 2014 on pilot basis in Chikwawa at Mfera and Dembo food markets under the Scotland Chikwawa Health Initiative (S-CHI) Project (Morse, 2014a). The intention of the S-CHI HFM project was to help in the improvement of the two pilot food markets in Malawi by applying the WHO concept of Healthy Food Markets (Morse, 2014).

In Malawi, according to Morse (2014) most of the local markets lack basic amenities for health such that the likelihood of poor food safety, poor sanitation and food contamination is very high. When the S-CHI project initiated the pilot HFM at Mfera and Dembo in Chikwawa in 2014, a situation analysis was done which indicated lack of comprehensive knowledge of food handlers in food safety and hygiene, poor market hygiene and sanitation, poor participation and coordination of stakeholders like the market committee, the District Health Office, the District Council in market development activities. (Morse, 2014). In response to this, market committees were revamped and a comprehensive food safety, hygiene, sanitation and market management training of market committees and vendors was conducted in the same year 2014 with support from the SCHI project. At the end of the training, action plans unfolding several interventions were laid down to be implemented with the participation of all concerned stakeholders. (Chidziwitsano, 2014, unpublished). The interventions were aimed at improving food safety, hygiene and sanitation standards in the two pilot HFM of Mfera and Dembo. (Morse, 2014). The study was conducted to assess the impact of food safety, hygiene and sanitation interventions in Chikwawa District food markets.

MATERIALS AND METHODS

Data was collection from 14th to 26th July 2016 in two markets of Dembo the pilot market with HFM interventions and Bereu as a control market. Bereu Market is located outside the S-CHI project area hence avoiding information diffusion from the HFM intervention market. Primary data was collected using Focus Group Discussions (FGD), Key Informant Interviews (KII), survey questionnaires and observation (using a checklist). Secondary data was collected through extensive literature review.

The target population for the study were all the 35,880 people from Dembo (17,374) and Bereu (18,506) markets catchment area. These included vendors, community leaders, extension workers and heads of Government Departments and Non-Governmental Organizations.

The sample size was 652 study units comprising of 510 customers and 142 vendors (Mobile= permanent =89). Sample size for permanent vendors, mobile vendors and customers was calculated using Yamane formula (1967) at 95% Confidence interval (CI) with 0.05 precision level. Systematic random sampling was used to select the 89 permanent vendors. Convenient sampling was also used to sample mobile vendors and customers. Key informants (n=14) composed of extension workers, councillors, market masters and heads of Government and Non-Governmental departments from Health, Agriculture, Water and Community Development.

Prior to use of the tools they were shared with the Environmental Health Department at Polytechnic and pretested at Thabwa Food Market located at Chikwawa District Headquarters to assess their applicability and understanding. Customers and traders, were interviewed face to face using a standard questionnaire which was uploaded in Android phones using software called *Magpi*. Responses were recorded directly in the phones and uploaded on website for further processing and

analysis using Excel and Statistical Package for Social Scientists (SPSS) computer packages. Key informants were given the questionnaires and were collected within the data collection period.

A total of four Focus group discussions (FGD) two at each market were conducted using FGD guide by the researcher and a Disease Control Assistant from the two markets. Observations were done by the researcher on hygiene and environmental sanitation practices related to food safety and hygiene using an observation checklist. Bias was addressed by the use of systematic random sampling of permanent vendors and use of enumerators from outside the study areas. Food safety experts from the Polytechnic under the S-CHI Project reviewed the questionnaire before final copy. Pre- testing also helped to ensure reliability of the results.

FGD and KII data was grouped and tabulated according to variables and thematic areas. Observational data was categorized or coded to facilitate statistical analysis. All numerical data was analysed using descriptive statistics while categorical data was analysed using frequencies. The significance of relationship ($p<0.05$) and Confidence interval (CI) of 95% to test the difference between proportions was used. Chi-Square test and Independent Paired t-test was used to test whether groups were significantly different while correlation was used to assess the strength of relationships between variables.

RESULTS AND DISCUSSIONS

Hygiene and Sanitation conditions in food markets

Several attributes were used to determine the sanitation and hygiene status of the markets like the availability and use of waste bins, waste disposal pits, water source and hand washing facilities.

At Dembo, the majority of respondents, 276 (96.8%) indicted availability of waste (5-8 bins) while at Bereu, only 107 (36.8%) indicated availability of waste bins (1-2 bins) in their markets and this was statistically significant (p=0.001). The waste bins were being covered in both markets Dembo 259 (93.8%) and Bereu 96 (89.7%) and this finding was statistically significant (p=0.001).The waste bins were also being emptied when necessary Dembo 267 (96.7%) and Bereu 104 (97.2%) and this was statically significant (p=0.001). Results from FGD and observations showed that the only waste bin at Bereu was not being covered, always full and not frequently emptied.

Poor sanitary conditions affect food quality (Obuobie et al 2006). Poor sanitation and unhygienic conditions in market threaten the safety of ready to eat foods (Granaham et al (2001) and CDC (2005) Waste bins prevent scattering of waste and harboring of disease vectors, pathogens and also acting as nuisance. This affects the safety and hygiene of food in the markets thereby enhancing spread of food borne diseases and sanitation related infections (Moore et. Al. 2002).

Waste bins in markets also require covering and emptying immediately they are full. This prevents multiplication of vectors, rodents, pathogens and production of foul smell which have a negative impact on food safety and hygiene in the markets. (Adewole, 2009)

On availability of waste disposal pits, respondents at Bereu 268 (92.1%) and Dembo 270 (94.8%) indicated their availability. It was encouraging to note that 91 (87.5%) and 243 (87.1%) of respondents from Dembo and Bereu respectively said that the waste bins were being emptied into the available waste disposal pits. This finding was not statistical significant (p=0.202). Observation results showed that disposal pits in both markets are poorly located within a distance of less than 200 meters from the market. This is undesirable as foul smell, scavengers and wind may blow the waste back to the market thereby exposing food to contaminants making it unsafe for human consummation (Adewole, 2009)

A greater number of respondents from both Bereu 259(89.0%) and Dembo 242(84.9%) disclosed the presence of latrines in the markets. This shows that latrines were available in both markets. Latrines play an important role for safe disposal of human excreta for the prevention of diarrhea infections through fecal contaminated of food. The toilets in both markets were very close to shops, less than 30 meters from the markets as indicated by 71.4% % and 63.2%% respondents from Bereu and Dembo respectively making it difficult for people to use them due to inadequate privacy. During FGD, it was learnt that the toilets at Bereu were built over five years ago by the council. At Dembo, there were two toilet structures, a newly constructed latrine (with support from SCHI through the Chikwawa District Council) and an old full latrine, locked and not in use.

At Dembo 99.6% indicated presence of borehole inside the market while at Bereu few respondents (27.5%) indicated availability of a borehole 200 metres away from the market. As such 35% of the respondents at Bereu use water from vendors for hand washing and cleaning food and food handling utensils and tools. The majority at Dembo 65.6% were using soap with only 45.5% at Bereu washing their hands with soap. This finding was statistically significant (p=0.001). This showed that use of soap for hand washing at Dembo was somehow better as compared with Bereu.

Participation of different stakeholders in FSH promotion activities in markets

Food markets in Malawi are managed by District councils using a Market Master and a Market cleaner with support of market committees. FSH promotion activities in markets include planning and review meetings, daily cleaning, general cleaning days, market inspection and awareness campaigns. Results show that 61.51% and 66.55% of the respondents indicated the presence of a market master, 56.84% and 78.35% knew the presence of a market cleaner while, 266 (91.41%) and 165 (57.89%) indicated availability of market committees in the markets of Bereu and Dembo respectively. One market cleaner is inadequate as a result Bereu and Dembo were not being fully cleaned on daily basis due to workload. Morocchini (2009) says that market cleaning services provided by the municipal sector are usually inadequate and sometimes not existing in markets.

On FSH promotion activities and stakeholders involved in the activities, Table 1 sows that the majority of committee members 278 (96.53%) extension workers 216 (75.00% and local leaders 214 (74.31%) at Bereu participated in review meetings. At Dembo the majority indicated only the participation of Market committee 252 (88.73%) and Extension workers 173 (60.92%) As for awareness campaigns, at Bereu it was extension workers 262 (90.97%),\and market committees 173(60.92%) while at Dembo it was mainly extension workers 225(79.23%) and market committee members 192(67.61%) that were participating in FSH awareness campaigns. For market cleaning days, at Bereu the market committee 228 (79.17%) market cleaner 227(78.72%) and market master 153(53.13%) featured high while at Dembo it was only the market committee that was mentioned by the majority 210(73.94%). As for market inspection, at Bereu, extension workers 233(80.90%) and market committees 157(54.51%) work together while at Dembo market inspection was almost equally done by Market Committee 181 (63.17%) and extension workers1984 (64.31%).

These FSH promotion activities cannot be conducted by only the market master, committee and cleaner. There is need for proper collaboration among stakeholders in the management of the market (Moy 2006). According to WHO (2006) these are supposed to take place in food markets more often which was not the case at Bereu. This was clearly evidenced by presence of piles and scattered waste in the market. Such waste harbor vectors and act as breeding places for pathogens that contaminate food items thereby putting consumers at risk of foodborne and food related infections. (King, 2013). Other studies carried in US in 2001 indicated that uninspected markets were more likely to have food-borne disease outbreaks (Miguel *et al.,* 2001).

Table 1: Participation of stakeholders in FSH promotion activities in food markets

Type of Stakeholder		Review Meeting		Awareness campaign		General Cleaning		Market Inspection	
		Bereu	Dembo	Bereu	Dembo	Bereu	Dembo	Bereu	Dembo
Market committee	Freq	278	252	174	192	228	210	157	181
	%	96.53%	88.73%	60.42%	67.61%	79.17%	73.94%	54.51%	63.73%
Vendors	Freq	30	25	9	16	42	28	0	9
	%	10.42%	8.80%	3.13%	5.63%	14.58%	9.86%	0.00%	3.17%
Market masters	Freq	128	73	95	49	153	80	105	74
	%	44.44%	25.70%	32.99%	17.25%	53.13%	28.17%	36.46%	26.06%
Market Cleaner	Freq	109	49	88	41	227	169	91	43
	%	37.85%	17.25%	30.56%	14.44%	78.82%	59.51%	31.60%	15.14%
Extension workers	Freq	216	173	262	225	99	103	233	194
	%	75.00%	60.92%	90.97%	79.23%	34.38%	36.27%	80.90%	68.31%
Heads of departments	Freq	92	38	77	26	72	23	97	34
	%	31.94%	13.38%	26.74%	9.15%	25.00%	8.10%	33.68%	11.97%
Customers	Freq	13	6	8	3	23	2	8	2
	%	4.51%	2.11%	2.78%	1.06%	7.99%	0.70%	2.78%	0.70%
Local leaders	Freq	214	99	135	56	104	64	34	17
	%	74.31%	34.86%	46.88%	19.72%	36.11%	22.54%	11.81%	5.99%
None of the above	Freq	5	0	12	6	26	3	134	70
	%	1.74%	0.00%	0.69%	1.76%	0.00%	0.70%	46.18%	24.65%
Total	Freq	261	239	267	210	236	152	224	148
	%	89.7%	84.2%	91.8%	73.1%	81.0%	53.5%	77.0%	52.1%

Food safety and hygiene knowledge and practices of food handlers

In both markets permanent vendors had have adequate knowledge only on keeping food clean and covered (Bereu 92.45% , Dembo 92.31%) over half of the respondents at Dembo had adequate knowledge as compared to less than half at Bereu having inadequate knowledge on thorough cooking, separation of cooked and raw food and use of potable water in cooking. This is in unison with a study by Monney (2013) which observed 55% of vendors covering their food. This is also similar to FAO and WHO (2001) recommendation that food should be adequately protected not to pose a threat to food safety. In a study by Nyamari (2013) it was realized that without actually observing the food handling behaviors, it is hard to determine that food handlers will implement safe food handling behaviors. Supporting this, Meers & Misner (2000) in their study also found that food safety knowledge scores had a small positive effect on food safety practices.

Considering tools and equipment used for picking and wrapping food items in markets, results indicate that at Bereu, a high proportion of mobile food handlers were using sticks/wires (54.72%) with mobile vendors using newspapers (52.78%). At Dembo, a greater proportion of permanent food handlers indicated using used newspapers, with 61.54% of mobile food handlers using fork and sticks/wires. This differs from findings by Muinde and Kuria (2004) in Nairobi who reported that 60% of street food vendors handled food with bare hands. According to Ferron et al. (2000*)* the hands of food vendors are usually the most critical means of transmitting pathogens.

Tools and equipment used for food handling needs to be cleaned and stored well covered in safe places to protect food from contamination as well as protecting consumers from food and food related infections (Hertzman and Bannash, 2007). Cleaning of utensils after use by every customer is highly practiced at Dembo (82.61%) as compared to only half at Bereu (56.08%). The problem at Bereu was that the utensils were reported being cleaned with water only without any disinfectant while at Dembo 82.6% of food handlers were using soap. In both markets, tools and equipment

after cleaning were being covered while in storage but it was only at Bereu where they were being kept 60cm above the ground. CDC (2005) stipulates that poor FSH practices and use of contaminated equipment and poor personal hygiene considerably contribute to the spread of food borne diseases. Proper food handling play a vital role in safety of food during preparation and storage (Lillquist et al, 2004) Pathogens may also be introduced into the food due to poor handling of the food specially RTE foods (Green et al, 2005).

Most of the food handlers, over three quarters in both markets had knowledge that a food handler has to wear clean clothes with sleeves. It was encouraging to realize that at least half of the food handlers at Dembo had knowledge on the wearing of aprons (49.15%) and hair covering (39.83%) and little knowledge on almost all the other requirements. This was different with Bereu as most of the food handlers had little or knowledge on wearing aprons (4.35%) no decorated hands (4.35%), no communicable disease (8.7%) with some having no knowledge at all on hair covering, picking food with forceps, no eating while preparing food and no handling of money while handling food. It was also worrisome to realize that Dembo food handlers from HFM pilot area, only 11.02% had knowledge on the requirement of regular hand washing the same way with11.9% of food handlers at Bereu without any FSH interventions. (Table 2)

According to Ferron *et al.* (2000) the hands of food vendors are frequently the supreme perilous means of transferring pathogens from contaminated areas and objects and could result in cross contamination upon contact with food and food items especially in situations where food vendors handle money from customers with the same hand. This can promote and exacerbate the condition due to possible accumulation of dirt on the money. CDC (2005) further says that poor FSH practices and poor personal hygiene contribute significantly to the spread of food borne diseases.

Table 2: Knowledge of food handlers on requirements of a Food Handler

Requirement	Bereu		Dembo	
	Frequency	Percent	Frequency	Percent
Wear clean clothes with sleeves	68	73.91	96	81.36
Wear aprons	4	4.35	58	49.15
Hair covered	0	0	47	39.83
No decorated hands	4	4.35	15	12.71
Short clean nails not coated	8	8.7	22	18.64
Use forceps or ladles to pick up ready-to-eat food	0	0	8	6.77
No communicable disease	8	8.7	16	13.55
Regularly hand washing	11	11.9	13	11.02
Don't handle money and then handle food	0	0	14	12.71
Don't eat while preparing food	0	0	25	21.19
Total	92	14.8	118	85.2

Medical checkup is also one of the prerequisites of a food handler but less than half know this with only 8.99% having gone only once for the checkup as compared to 15.73% at Bereu who know but nobody having undergone any medical checkup. All this was happening despite 41.03% of food handlers at Dembo and 26.97% of food handlers at Bereu having been trained in FSH. (Figure 1) Despite having knowledge on FSH, Food handlers in the market of Dembo and Bereu reported lack of safe practices indicating a gap between knowledge actual food safety practices. Another study by Roberts (2008) revealed that food handlers who had received training on food safety knowledge did not translate the knowledge into practice. This suggests that food FSH and hygiene information is not a new concept in the markets. Such findings are similar to findings from a report given by Minnesota Department of Health (2010) which observed a significant improvement in the

knowledge and awareness of food safety code of practice in many countries. On the other hand, findings by Azanza and Zamora-Luna (2005) showed a significant discrepancy between reported food safety knowledge and actual food safety practice. Regardless of this observation, Hertzman and Bannash (2007) recommended that food handlers must be knowledgeable enough and stick to hygiene and sanitation guidelines and practices. The same opinions were also echoed by King (2013) that formal trainings to food handlers is a prerequisite to ensure maximum required knowledge on FSH for all food handlers.

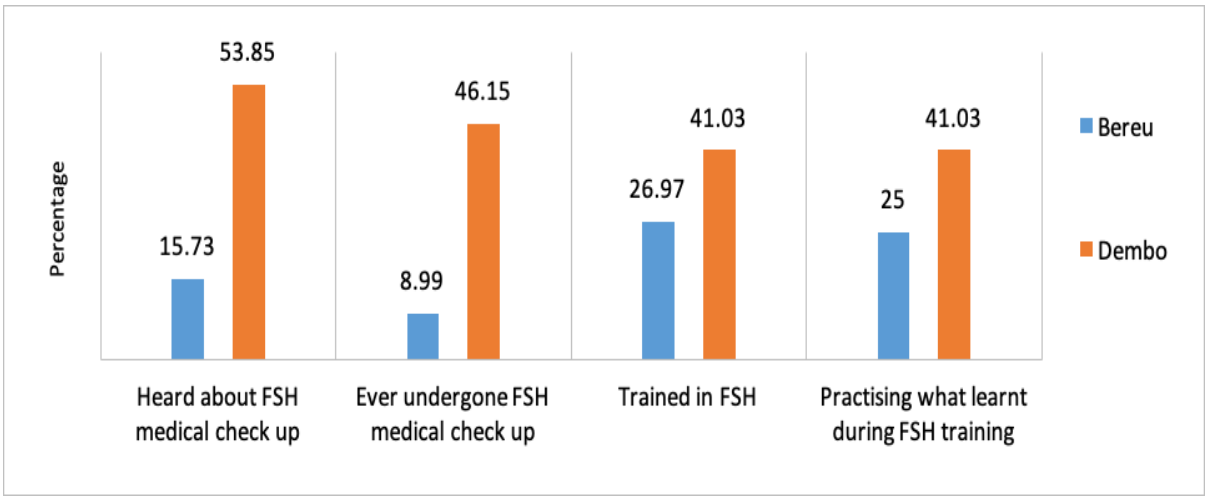

Figure 1: Food handlers' Training on FSH and Medical check up

CONCLUSION AND RECOMMENDATIONS

In conclusion, the HFM concept has brought some improvements to FSH and sanitation at Dembo Market, the pilot market. New sanitation facilities like waste bins (Dembo, 8 bins; Bereu, 1 bin) a waste disposal and a rehabilitated borehole have been made available. On food hygiene, food in both markets is handled using picking tools and wrapping materials. However food handlers in both markets have inadequate knowledge on the requirements of a food stall like having a hand washing facility (Dembo 49.24%, Bereu 4.34%)and placement of food 60cm above the ground during preparation or display (Dembo,19.70%, Bereu, 4.34%). They also don't have inadequate FSH knowledge as few were trained (Bereu 26.97%, Dembo 41.03%). Despite being trained, few food handlers in both markets practice what they learnt (Dembo 25.0%, Bereu 41.0%). This include medical checkup (Dembo 46.15%, Bereu 8.995%) regular hand washing with soap (Dembo 45.5%, Bereu 65.6%) wearing of aprons (Dembo 49.15%, Bereu 4.35%) indicating a gap between knowledge and actual food safety and hygiene practices.

The intervention market of Dembo is inefficient as compared with Bereu the control market in FSH promotion activities in the markets. Bereu is doing better in awareness campaign, (Dembo 73.1%, Bereu 91.8%), general cleaning days, (Dembo 53.5%, Bereu 81.0%) and market inspection (Dembo 52.1% Bereu 77.0%).

There is inadequate participation of stakeholders in FSH promotion activities in both markets. At Bereu, there is more participation in FSH planning and review meetings as well as awareness campaigns by Market committee, market master, local leaders and extension workers while at Dembo it is only extension workers and market committee that participate more in review meetings and awareness campaigns. One worrisome thing is the availability of only one market cleaner in both markets which make it difficult for him to clean the markets efficiently.

The HFM concept provides a perfect basis for HFM but require professionally implementation like improving on infrastructure, coordination and capacity building for it to be an efficient model.

Based on the findings the following recommendations are made:

- Chikwawa District Council should facilitate FSH knowledge heightening of market users through FSH awareness campaigns and FSH training.
- Chikwawa District Council should facilitate multisectoral collaboration in FSH promotion activities like market inspection, general cleaning days, to ensure provision of safe food.
- Chikwawa District Council to ensure that food markets have adequate sanitation facilities and staff like market cleaners to ensure adequate market cleaning and waste disposal. And also facilitate demolishing of the full toilets at Dembo and opening of the new one.
- Chikwawa District Health Office should Support medical ups for food handlers
- S-CHI should facilitate development and finalisation of toolkit to support extension workers for HFM implementation

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The use of maternity waiting home at Chiradzulu District Hospital, Southern Malawi

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ABSTRACT

In an effort to improve maternal and neonatal heath, maternity waiting home (MWH) was introduced at Chiradzulu District Hospital in 2012. Since then, no study has been conducted to examine the use of MWH at the district hospital. The study examined the use of MWH at Chiradzulu District Hospital by identifying the characteristics of pregnant women who used MWH and factors that influence use of MWH at the district hospital. A comparative cross section study was conducted at Chiradzulu District Hospital, postnatal ward. A total 266 mothers were enrolled in the study. These mothers were put into two groups depending on their usage of MWH, and each group had 133 mothers. A well-structured questionnaire was used to collect data through face to face interviews and review of client records. Data collection was done from June to October 2015. Data analysis was done quantitatively using SPSS version 16.0. Chi-square test at 5% level of significance was used to determine associations. There was no significant difference in demographic attributes of mothers who used MWH with those who did not use MWH (>0.05). Furthermore, results showed that both groups had pregnancy risk factors only that pregnant mothers that had malaria, severe anaemia as well as breech presentation were more likely to use MWH at Chiradzulu District Hospital (p<0.05). In contrast to studies done elsewhere, there was no significant difference in demographic attributes as well as pregnancy risk factors between of mothers who used MWH and those who did not use MWH at Chiradzulu District Hospital. This can be attributed to lack of admission protocols, standard operating procedures and inadequate midwifery skills among providers.

Key words: Maternity waiting home, skilled attendance, skilled birth attendant

INTRODUCTION

Pregnancy and childbirth is a life event experienced by millions of couples all over the world each year. Most often things go well but at times complications occur. The likelihood for a good outcome for the mother and the neonate following a complication depends on the place where the woman is giving birth. Out of all the data on health that World Health Organization monitors, maternal deaths show the greatest divide between the poor and the rich; the chance of a woman dying from complication related to childbirth is 100 times higher in resource-poor as compared to resource rich settings (van Lonkhuijzen 2011). This is the case because women from resource poor settings often lack enabling environment for safe motherhood and childbirth. An enabling environment for safe motherhood and childbirth depends on: the care and attention provided to pregnant women and newborns by the communities and families, the skilled attendance at birth, the acumen of skilled birth attendants, and the availability of adequate obstetric health care facilities (UNICEF 2008)

An estimated 303,000 women died from causes related to pregnancy and childbirth globally in 2015 (World Health Organization 2015). Ninety nine percent of these deaths occur in developing countries with sub Saharan Africa alone contributing more than 50% of the global total (UNICEF 2008). According to Malawi Demographic and Health Survey 2015-16, the pregnancy related mortality rate for Malawi is at 497/100,000 live births (National Statistical Office (NSO) & ICF 2017). Maternal deaths mostly occur around labour, delivery, and immediate postpartum period and a large proportion of these deaths take place in hospital. Neonatal deaths tend to follow the same geographic pattern as for maternal deaths. Like maternal deaths, 99% of neonatal deaths occur in developing countries, and sub Saharan Africa has the highest national rates (Lawn et al. 2005). Evidence shows that averting maternal and neonatal deaths often require implementing the same interventions. Maternity waiting home (MWH) is one of the interventions employed in developing countries, where most deaths occur due to delays in receiving appropriate care in an event of childbirth complication (Bhutta et al. 2009)

MWH is a residential facility located near or within a hospital or health centre that provides emergency obstetric care (EmOC). The aim is to improve access to skilled and facility based delivery for pregnant women from remote areas; thus, reducing morbidity and mortality of mothers and neonates should complications arise during labour and delivery. Pregnant women stay in the MWH at the end of their pregnancy and await labour. Once labour starts, women are advised to go to the labour ward, so that labour and delivery can be assisted by skilled attendants. It is mostly women with complications in pregnancy or those that live far away or face other geographic barriers, such as rivers during rainy seasons that are encouraged to stay at the end of their pregnancy (Satti et al. 2013). Various forms of MWHs have been documented in different countries and each appeared to be slightly different in terms of both its creation and services provided. For example, MWH in Mongolia in Cuba was established as a result of government initiative whereas the MWH in Colombia in Indonesia was established by academic and community groups. the positive aspect about the diversity is that countries are at liberty to implement this concept according to their local needs and available resources (World Health Organization 1996).

The World Health Organization highlighted the potential advantages of implementing MWH as part of the comprehensive package of essential obstetric services in 1991 (Wild et al. 2012). Since then, MWHs have been incorporated into ministry of health policy in many developing countries with support from United Nations (UN) agencies, World Bank and other local donors to improve access to skilled birth attendance (Satti et al. 2013; Republic of Malawi 2012; Wild et al. 2012). The Malawi Government adopted MWHs through the Presidential Initiative on Maternal Health and Safe Motherhood (PIMHSM) in 2012, in an effort to accelerate the reduction of maternal and neonatal mortality in order to achieve the MDGs number four and five (Republic of Malawi 2012). Likewise, the management of Chiradzulu District Hospital changed what used to be a nutritional rehabilitation ward into a MWH in the same year. Since the adoption of the MWH in the country, no study had been conducted to critically assess the use of MWH. This study therefore examined the use of MWH at Chiradzulu District Hospital, Southern Malawi.

This study was conducted to examine the use of MWH at Chiradzulu District Hospital. Specifcally, the study identified characteristics of pregnant women who used MWH. It also identified factors that influence use of MWH.

MATERIALS AND METHODS

Study design
A cross sectional study conducted in postnatal ward. The study participants were postnatal mothers who delivered at Chiradzulu District Hospital Labour Ward. These mothers were put into two groups based on the use of MWH. Mothers who used MWH were put in one group and those that did not use MWH were put in another group.

Setting
The study was conducted at Chiradzulu District Hospital, a government owned hospital in Chiradzulu District. Chiradzulu District is one of the 13 districts in the southern part of Malawi and occupies a total land area of 767km^2. The district has a projected population of 322,646. The district hospital serves as a referring hospital to 13 health centres. Chiradzulu District had one of the highest neonatal mortality rates in Malawi at 47/1000 live births, and the proportion of skilled birth attendants was at 49.9% (National Statistical Office & UNICEF 2008). According to Chiradzulu District Hospital HMIS records, 19% of women who delivered at Chiradzulu District Labour Ward were admitted at MWH during the period of January 2014 to February 2015.

Sample size
The study recruited 266 postnatal mothers and in each group there were 133 mothers. This sample size gave an 80% power to detect a significant difference between mothers who used a MWH and those who did not use a MWH.

Inclusion criteria
The study recruited postnatal mothers who delivered at the district hospital at term gestation and consented to participate in the study.

Sampling technique
The study used proportionate stratified random sampling method. The variables chosen for stratification were MWH use and non-MWH use. One stratum comprised women who used MWH to wait for the onset of labour and delivery and another stratum comprised women who reported directly from home to deliver at the district labour ward. Selection of participants in each stratum was done using systematic random sampling method.

Data collection
Data collection was done using a well structured questionnaire through face to face interviews and review of participant's records. The questionnaire was pre-tested on 10 randomly selected mothers at the same facility prior to main data collection. Data collection was done by the principal investigator only.

Data analysis
Data cleaning and analysis was done using the Statistical Package for Social Sciences (SPSS) version 16.0. Descriptive statistics were computed on demographic variables to determine the proportions and frequencies. Chi-square test at 5% level of significance was computed to investigate the associations.

Ethical considerations
Ethical approval of the study was granted by the College of Medicine Research and Ethics Committee (COMREC) on 25th May 2015. A written permission to conduct the study was obtained from the District Health Officer (DHO) for Chiradzulu District Hospital. Before data collection from participants, an information sheet containing information about the study was read out to participants and participants were giving the chance to freely decide whether to participate or not

without any form of coercion. Participants who gave verbal consent were then asked to sign a consent form.

Study limitation

This study has been conducted at a single site and that these results may reflect the pattern and practices unique to this single institution. Therefore, it is difficult to generalise the findings of this study to other site.

RESULTS AND DISCUSSION

Demographic characteristics

Table 1 summary of the demographic attributes of the 266 respondents who participated in the study. The results show that the demographic attributes of respondents who used MWH and the respondents who did not use MWH were basically similar and there was no significant association between demographic attributes and use of MWH.

Table 5: Demographic characteristics of participants who used MWH and those who did not use MWH

Variable	MWH (N=133)	Non-MWH (N=133)	P-value
Age (M,SD)	24.02 (6.34)	23.63(6.14)	.085
Age categories (N, %)			
≤19 years	40(30.1%)	45 (33.8%)	
20-24 years	33(24.8%)	35 (26.3%)	
25-29 years	31 (23.3%)	24 (18%)	
30-34 years	18 (13.5%)	18 (13.5%)	
35-39years	7 (5.3%)	9 (6.8%)	
40-44 years	4 (3%)	2 (1.5%)	
Marital status (N, %)			
Married	125 (94.7%)	125 (94%)	.643
In relationship	3 (2.3%)	5 (3.8%)	
Single	2 (1.5%)	0 (0%)	
Divorced	2 (1.5%)	3 (2.3%)	
Education level (N, %)			
Primary	100 (75.2%)	85 (64.4%)	.188
Secondary	26 (19.5%)	40 (30.3%)	
Never attended	6 (4.5%)	5 (3.8%)	
Tertiary	1 (0.8%)	2 (1.5%)	
Source of income			
None	54 (42.5%)	51 (39.5)	.988
Business	42 (33.1%)	44 (34.1)	
Farming	24 (18.9%)	27 (20.9)	
Employed	4 (3.1%)	4 (3.1%)	
Casual labour	3 (2.4%)	3 (2.3%)	
Source of income of the partner			
Employed	52 (41.9%)	56 (44.4%)	.508
Business	35 (28.2%)	24 (19.0%)	
Farming	22 (17.7%)	28 (22.2%)	
Casual labour	11 (8.9%)	14 (11.1%)	
Schooling	4 (3.2%)	4 (3.2%)	

Tribe			
Lomwe	83 (64.8%)	62 (47.7%)	.111
Yao	22 (17.2%)	35 (26.9%)	
Not sure	11 (8.6%)	10 (7.7%)	
Others	12 (9.4%)	23 (17.7%)	
Religion			
Christian	120 (91.6%)	121 (93.1%)	.830
Moslem	11 (8.4%)	9 (6.9%)	

Factors influencing use of MWH

The study showed that number of pregnancies the participant had in the past had no influence on the use of MWH at the district hospital (p=.413). The mean gravidity for participants who used MWH was 2.57 (SD 1.87) whilst the mean gravidity for participants who did not use MWH was 2.37 (SD 1.67). Thirty nine percent (n=51)of participants who used MWH and 44.4% (n=59) of participants who did not use MWH were primigravida; 35.6% (n=47) of participants who used MWH and 35.3% (n=47) of participants who did not use MWH were multigravida; and 23.5% (n = 31) of participants who used MWH and 18.8% (n=25) of participants who did not use MWH were grand multigravida and 2.3% (n=3) of participants who used MWH and 1.5% (n=2) of participants who did not use MWH were great grand multigravida.

The results showed that number of deliveries the participant had in the past had no influence on the use of MWH (p=.558). The mean parity for participants who used MWH was 2.41 (SD 1.75) while that of participants who did not use MWH was 2.20 (SD 1.55). Forty three percent (n=56) of participants who used MWH and 48.1% (n=64) of participants who did not use MWH were primipara, 33.6% (n=44) of participants who used MWH and 34.6% (n=46) of participants who did not use MWH were multipara (had two to four deliveries), 22.9% (n=30) of participants who used MWH and 16.5% (n=22) of participants who did not use MWH were grand multipara, and 0.8% (n=1) of participants who used MWH and 0.8% (n=1) of participants who did not use MWH were great grand multipara.

Outcome of the previous pregnancy was found to have no influence on the use of MWH at the district hospital (p=.541). Thirty nine percent (n=51) of participants who used MWH and 43.5% (n=57) of participants who did not use MWH were primigravidae hence they did not respond to this question. Fifty-one percent (n=66) of participants who used MWH and 44.3% (n=58) of participants who did not use MWH had a live birth during the previous pregnancy.

This study further showed that the place where the participant delivered during her previous pregnancy had no influence on the use of MWH (p=.760). Fifty two percent (n=68) of participants who used MWH and 47.3%. (n=62) of participants who did not use MWH delivered at a health facility during their previous pregnancy. Only, 4.6% (n=6) and 3.8 (n= 5) of participants who used MWH and 6.1% (n=8) and 3.1(n=4) of participants who did not use MWH delivered at home and TBAs during their previous pregnancy. The rest 39.2(n=51) of participants who used MWH and 43.5 % (n=57) of participants who did not use MWH were first time mothers.

Number of antenatal care visits (ANC) a participants had showed to have no influence on the use of MWH (p=.236). The mean ANC visits for participants who used MWH was 3.34 (SD=0.91) whilst the mean visits for participants who did not use MWH was 3.49 (SD=0.99). Forty percent (n=52) of participants who used MWH and 38.3% (n=51) of participants who did not use MWH had the recommended four visits. Almost 38% (n=49) of participants who used MWH and 36.1% (n=48) had three visits.

Participant's knowledge of the existence of MWH at the district hospital had no influence on the use of MWH (p=.089). Majority of the participants 88.5% (n=115) who used MWH and 80.5% (n=106) of participants who did not use MWH were informed during the ANC visit about the availability of MWH at the district hospital.

Presence of anaemia in pregnancy showed to have a significant influence on the use of a MWH at the district hospital (p=.013). Five percent (n=6) of participants who used MWH had anaemia in pregnancy whilst no participant from the group that did not use MWH had anaemia in pregnancy.

Malaria in pregnancy also appeared to have a significant influence on the use of MWH at the district hospital (p=.030). Thirty eight percent (n=48) of the participants who used MWH and 24.2% (n=31) of the participants who did not use MWH had malaria in pregnancy. Of these participants who reported having suffered malaria in pregnancy; 45.8% (n=22) of participants who used MWH and 48.4% (n=15) of participants who did not use MWH had malaria in second trimester, 42% (n=20) of participants who used MWH and 32.3% (n=10) of participants who did not use MWH had malaria in third trimester, and only 12.5% (n=6) participants who used MWH and 19.4% (n=6) of participants who did not use MWH had malaria in first trimester.

Furthermore, results showed that having breech presentation in pregnancy had a significant influence in the use of MWH at the district hospital (p=.042). Ten percent (n=13) of participants who used MWH had breech presentation whilst 3% (n=4) of participants who did not use MWH had breech presentation.

DISCUSSION

The results of this study showed that sociodemographic attributes of the participants who used MWH and those who did not use MWH were basically similar. This similarity in sociodemographic attributes of participants of the two groups is in line with the objectives of adopting the concept of MWH in Malawi. According to the Presidential Initiative on Maternal Health and Safe motherhood Strategic Plan 2012- 2016, MWHs provide accommodation for pregnant women who live in remote rural areas and at a district level MWHs provide a safe place for pregnant women with high risk pregnancies to await labour or to plan a caesarean section (Republic of Malawi 2012). This finding is consistent with the result of a study done by Kelly et al. (2010) that showed no differences in the sociodemographic characteristics of women who were admitted at the MWH and those who were not admitted at the MWH. However, a study that was conducted in rural Zambia on husbands' experiences and perceptions regarding the use of MWH revealed that financial constraints of spouses prevented pregnant women from using MWHs because husbands could not afford to buy food, cleaning materials, and clothes for the mother and neonate needed during and after labour (Sialubanje et al. 2016), but the financial status of spouses that managed to send their wives to MWH and those who failed to send them to the MWH was not compared.

In contrast to a study done by Kelly et al. (2016), this study showed no significant differences in parity between mothers who used MWH and those who did not use MWH. Kelly et al. found that both primiparous and younger mothers were more common amongst the group of women that were not admitted at MWH. This was the case because women were admitted based on either the previous history of problems or a risk factor identified during that current pregnancy. The differences in the findings of these two studies may be attributed to differences in admission protocols. Attat Mission Hospital, a place where Kelly et al. conducted their study, MWHs were mostly for mothers with actual or anticipated labour complication whilst at Chiradzulu District Hospital every pregnant woman is allowed as long as she is willing to stay at MWH.

This study has shown that outcome of the previous pregnancy had no influence on the use of MWH. This result is not consistent with results of other studies by Kelly et al. (2010), Nigussie et al. (2005), Zelalem-Ayele et al. (2014) that showed that mothers who experience abortions, stillbirths, and obstructed labour previously were better users of maternal healthcare services because they had a practical experience on the dangers associated with pregnancy and childbirth. This lack of significant differences in the proportion of pregnant women who used MWH and those who did not use the MWH in terms of stillbirths and neonatal deaths may be partly attributed to the quality of antenatal care given during ANC visit. If the messages given during ANC are not adequate, it is obvious that women cannot make a good decision to come and wait at the MWH.

In line with the findings from others studies by Kelly et al. (2010), van Lonkhuijzen et al. (2003), this study showed that mothers who used MWH had greater obstetric risk factors in terms of malaria in pregnancy, breech presentation and anaemia in pregnancy compared to mothers who did not use the MWH. All mothers attended antenatal care (ANC) clinics and most of them had knowledge about the existence of MWH because they were told during antenatal visits. However, a slightly higher proportion of mothers who used MWH had knowledge about the existence of MWH compared with mothers who did not use MWH. This is a good development that most mothers were told during ANC about the availability of MWH at the district; hence providing an opportunity for the promotion of the use of skilled attendance at birth. This finding differs with the findings of several studies by Mramba et al. (2010), Ruiz (2010), Shrestha et al. (2007) that had the majority of participants who were ignorant on the availability of MWHs in their areas. This could be partly attributed to the lack of incorporation of MWH information in ANC.

CONCLUSION

The study provides insight into the use of MWH at the district hospital. The results demonstrated that there are no differences in sociodemographic characteristics as well as pregnant risk status between pregnant women who use MWH and those who do not use MWH. However, significant association were observed between having malaria in pregnancy, anaemia in pregnancy and breech presentation and use of MWH. The lack of significant differences can be attributed to lack of admission protocols, standard operating procedures and inadequate midwifery skills among providers. These results can serve as a basis for designing protocols and other interventions to better improve utilization of the MWH at the district hospital and elsewhere.

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An examination of the management of infertility in Thyolo and Blantyre Districts

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ABSTRACT

The provision of infertility services is given a very low priority in many developing countries as it is mainly regarded as none life threatening and usually associated with high cost of treatment. In Malawi, infertility is one of the priority sexual and reproductive health (SRH) issues according to the national SRH and Rights policy (2009). However, little is documented on the availability and quality of infertility services in the country. This study therefore sets out to assess the type of infertility services provided at all levels of health service delivery by assessing health care providers (HCP) knowledge, practice, barriers to provision of services and client's satisfaction. This study was conducted between December 2015 and December 2016. It employed a cross section research design using a mixed method approach. Quantitative data was collected from 73 HCP through interviews and observation while qualitative data was collected through in-depth interviews with 27 clients receiving infertility services. Quantitative findings were analysed using SPSS version 16; qualitative data was analysed manually using thematic content analysis. Study results revealed a generalised lack of knowledge and good practice of infertility management among all HCP assessed. HCP cited lack of knowledge and skills (45.2%, n=33) as the main barrier to provision of infertility services. Clients cited long duration of receiving infertility services and failure to integrate male clients in the service as reasons for their dissatisfaction. A gap exists between policy and infertility management practice. To improve infertility service provision, there is need for Ministry of Health and policy makers to develop standard guidelines for training and provision of infertility services. Furthermore, there is need for integration of infertility services in already existing RH services in all levels of service provision.

Keywords: Infertility services, Health Services, Client, Blantyre

INTRODUCTION

Infertility is given very low priority in most developing countries because it is expensive to treat and is mainly regarded as none life threatening (Akinloye Truter, 2011). Most of these countries are highly populated and have high fertility rate. As a result, decreasing fertility growth among the population is considered to be more important and cost effective than treating infertility (Okanofua, 2009; Ombelet, 2009). In addition, these countries have a heavy burden of life-threatening conditions like HIV/AIDS, maternal and neonatal mortality; and the scarcity of health resources, hence it is understandable for their governments not to prioritize infertility services (Inhorn and Birenbaum-Carmeli, 2008; Okanofua, 2009; Ombelet, 2009).

However, unavailability of infertility preventive, investigative and treatment services in developing countries are known to aggravate the psychosocial problems that commonly accompany infertility (Ombelet, 2009). Such is the case as childlessness is associated with inadequacy and inability to

fulfil ones sexual and reproductive obligations since children are considered very important in most societies (Donkor & Sandall, 2007; Donkor, 2008). Therefore, setting infertility as a low priority problem has contributed to limitations in availability and/or access to infertility treatment thus contributing to many psychosocial problems (Akinloye & Truter, 2011; Ombelet, Cooke, Dyer, Serour, & Devroey, 2008b).

In Malawi, infertility is considered one of the priority Sexual and Reproductive Health (SRH) components (SRH and Rights policy, 2009; Malawi SRH Strategy, 2006). However, very little has been documented on the problem and more so regarding its management in public health facilities in Malawi. This study therefore examined the management of infertility in the primary, secondary and tertiary levels of health service delivery in Thyolo District Health Office (TDHO) and Queen Elizabeth Central Hospital (QECH). This study was conducted to assess the type of infertility services provided in all levels of health service delivery in TDHO and QECH.

MATERIALS AND METHODS

Design

This study deployed a cross section concurrent mixed method approach.

Setting

It was conducted in 16 health facilities in Thyolo district: 14 primary health facilities (Bvumbwe, Makungwa, Mangunda, Khonjeni, Chingazi, Chimaliro, Chisoka, Mikolongwe, Chimvuu, Thomas, Makandi, Miyanga, Satemwa and Didi), 2 secondary health facilities (Thyolo district and Malamulo Mission Hospitals) and Blantyre city (1 tertiary health facility- Queen Elizabeth central hospital).

Study period

It was conducted between December, 2015 and December 2016.

Population, sample and sampling

The quantitative study included 73 HCPs who at the time of the study were working in STI, FP Voluntary Medical Male Circumcision (VMMC) and gynaecology clinics in the17 participating health facilities. While the qualitative study included 27 clients in its post-service interviews (five of the interviews were couple interview while 17 were individual interviews).

Data collection tools

Data was collected using three study tools.

Questionnaire and checklist

These tools were used to collect quantitative data. The investigator developed them with reference to the SRH and rights policy (2009), the 2011-2016 reproductive health strategy (2011), Management of STI using syndromic management approach, a guide for service providers (2007), The association of Malawian gynaecologist and obstetrician, Densons' Diagnosing and managing infertility (2006) and Frey et al, 2004. The questionnaire included, section A: HCP demographic characteristics, section B: HCP knowledge on infertility management and section C: HCP's barriers to provision of infertility services. The checklist was used to observe HCP providing infertility services.

Interview guide

A Chichewa tool developed by the investigator based on literature and objective of the study. This tool had 2 sections, section A: demographic characteristics and section B: clients' satisfaction with infertility services provided by the HCP.

Data analysis

Data from the questionnaire and checklist was analysed using SPSS version 16. Descriptive statistics such as, mean and standard deviation were computed for the dataset. Furthermore, each section in the tools was scored and calculated into percentages and compared to the standard of 80% (indicative of best standard practice). This was adopted from the Infection Prevention and Reproductive health assessment tool. Qualitative data was transcribed and translated from Chichewa into English and then manually analysed using thematic content analysis.

Ethical consideration

Approval to conduct the study was obtained from the College of Medicine Research and Ethics Committee. Further permission was obtained from TDHO, Malamulo mission hospital and QECH. No coercion was used to recruit participants and consent was obtained from all participants. Participants were made aware that they were allowed to terminate participation at any time should they feel the need to. Anonymity and confidentiality was observed by using codes in place of names and conducting the interview and observation in privacy respectively.

RESULTS AND DISCUSSION

The results are presented in line with the study objectives.

Sociodemographic data (Health Care Providers)

Most of the participants were females (59%, n=43) only 41% (n=30) were males. The participant's ages ranged from 22 to 73 years with a mean age 39 years old. The majority (53.4%, n=39) of participants were nurses, 23.3% (n=17) were medical assistance, 13.7% (n=10) were clinical officers and 9.6% (n=7) were doctors. Nearly half of the participants (45.2%, n=33) were trained at certificate level, 42.5% (n=31) at Diploma level, 9.6% (n=7) at Bachelor's degree and only 2.7% (n=2) had Master's Degrees. Majority (50.7%, n=37) had 3or more years of work experience, while 34.2% (n=25) had less than a year experience and15.1% (n=11) had 1 to 2years experience. Majority (61.6%, n=45) of the participants were from the primary level of health service delivery, while secondary and tertiary levels had both 19.2% (n=14) each.

HCP Knowledge on infertility management

Majority (78.1%, n=57) of HCPs were not aware of infertility guidelines. Those who were aware of guidelines mentioned SRH Rights policy (6.25%, n=1), MST guideline (6.25%, n=1), Association of Malawian obstetrician and guidelines (50%, n=8), Syndromic management of STI guidelines (25%, n=4) and Integrated maternal and neonatal health guidelines (12.5%, n=2) and majority were from the tertiary. This is consistent with the findings in Aberdeen where usage of infertility guidelines was more pronounced at higher levels of service provision compared to primary health facilities (Morrison, Bhattacorya, Hamilton, Zempleton, & Smith , 2007).

To assess HCP knowledge on history taking a series of 15 questions were asked. Individual scores were calculated in percentages and compared to the standard score of 80%. All scores were below 80%, as they ranged from 0% to 73% with a mean score of 34.9% and a standard deviation (SD) of 1.06. Performance on individual questions was very poor (Table 1). Secondly, a series of 10 questions were asked to assess HCP knowledge of infertility investigative services. Scores ranged from 0% to 90% with a mean of 26.2% and a SD of 1.81. Only one scored above 80% showing that only one was knowledgeable of infertility investigative services. Five questions were asked to assess HCPs' knowledge on counselling. HCPs' scores ranged from 0% to 80%with a mean score of 26%, and a SD of 0.92. Only one scored 80% indicating knowledge of infertility counselling.

Table 1 shows HCP performance on each question. Finally, HCPs' individual scores on knowledge of infertility treatment ranged from 0% to 55% with a mean score of 17.18% and a SD of 1.36. None of the HCP scored above 80%. Performance on each question is displayed in Table 1.

Table 1: shows HCPs' knowledge on history taking.

Item	n	%
Knowledge on infertility guidelines	**57**	**78.1**
Knowledge on History taking		
Consults as partners then individuals	**4**	**5.5**
Schedules meeting with partner	**22**	**30.1**
Asks clients age	**14**	**19.2**
Review body systems/changes	**0**	**0**
Asks if any surgical problems	**14**	**19.2**
Reviews menstrual cycle	**40**	**54.8**
History of infertility treatment	**56**	**76.7**
Asks clients social history	**10**	**13.7**
Previous pregnancy	**56**	**76.7**
Ask medical history	**54**	**74**
Drugs history such as NSAID	**10**	**13.7**
Ask clients contraceptive history	**37**	**50.7**
Ask clients sexual frequency	**20**	**27.4**
Asks if any erectile dysfunction	**1**	**1.4**
Ask clients if any children	**56**	**76.7**
Knowledge on infertility investigative services		
Blood group and rhesus factor	**6**	**8.2**
Full blood count (FBC)	**6**	**8.2**
Pelvic Ultra Sound Scanning (USS)	**18**	**24.7**
Hormonal Assay	**5**	**6.8**
Hysterosalpingography (HSG)	**16**	**21.9**
Endometrial biopsy	**1**	**1.4**
TB culture	**0**	**0**
Urinalysis	**6**	**8.2**
VDRL	**61**	**83.6**
HIV	**47**	**63**
Knowledge on infertility counselling		
Timing of sexual intercourse coincide with ovulation	**32**	**43.8**
Advise on frequency of sexual intercourse	**18**	**24.7**
Modify social habits such as smoking/alcohol use	**4**	**5.5**
Advise on avoiding excess use of lubricant	**2**	**2.7**
Avoidance of stress and promotion of emotional	**41**	**56.2**
Knowledge on infertility counselling		
Preconceptual weight loss is a must	**4**	**5.5**
Life style modification i.e. cessation of smoking and alcohol use	**2**	**2.7**
Clomiphene citrate is the first line ovulation induction drug	**3**	**4.1**
Metformin should be used routinely with Clomiphene citrate	**2**	**2.7**
Identify high risk women i.e. early sexual debut/promiscuity	**10**	**13.7**
Start with screening and treating Chlamydia	**33**	**45.2**
Management of other STIs should be priority	**43**	**58.9**
Assessing tubal patency should be considered	**10**	**13.7**
Semen analysis as a primary investigation	**29**	**39.7**
Cessation of smoking	**1**	**1.4**
Use of PDE % inhibitor for men with premature ejaculation	**1**	**1.4**

HCP practice on infertility management

Fourteen areas were observed (Table 2) to assess HCP practice on history taking. General performance was poor with scores ranging from 7% to 60 % with a mean score of 31.53% and a SD of 1.92. On practice of physical assessments 10 areas were observed. HCPs' scores ranged from 0% to 40 % with a mean score of 10.73% and a SD of 1.18.Individual question performance on this section shown in Table 2. Furthermore, the results on investigative studies showed that practice scores ranged from 0% to 70% with a mean score of 15.06% and a SD of 1.73. Furthermore, 4 areas were observed to assess the practice of infertility counselling HCP's scores ranged from 0% to 75% with a mean score of 33.58% and a SD of 0.83. Finally, 12 areas observed on infertility treatment (Table 2). Score ranged from 0-100% with a mean score of 51.4%and SD of 1.24.Only one HCP scored above 80%.

Table 2: HCP practice on infertility management

Item	n	%
Practice on infertility history taking		
Consults as partners then individuals	4	5.8
Asks present complaint	69	100
Schedules meeting with partner	23	33.3
Review body systems/changes	5	7.2
Asks if any surgical problems	12	17.3
Reviews menstrual cycle	40	58
History of infertility treatment	29	34.8
Asks clients social history	4	5.8
Previous pregnancy	24	34.7
Ask medical history	45	65.2
Drugs history such as NSAID	10	14.5
Asks clients contraceptive history	40	58
Asks clients sexual frequency	28	34.8
Asks if any erectile dysfunction	6	8.7
Practice on physical assessments		
Female physical assessments		
Assess weight, height and Body Mass Index (BMI)	9	13
General exam	3	4.3
Breast exam for galactorrhea	6	8.7
Pelvic exam	23	33.3
Abdominal exam for masses and/or surgical scars	29	42
Male physical assessments		
Abdominal exam	1	1.4
Secondary sex characteristic	2	2.9
Undescended testis	1	1.4%
Genital exam size and shape	1	1.4%
Breast exam for gynaecomastia	0	0%
Investigative services		
Blood group and rhesus factor	23	33.3
Full blood count (FBC)	18	26.1
Pelvic Ultra Sound Scanning (USS)	18	26.1
Hormonal Assay	1	1.4
Hysterosalpingography (HSG)	11	15.9
Endometrial biopsy	1	1.4
TB culture	0	0
Urinalysis	5	5.8
VDRL	58	84.1

HIV	53	76.8
Practice on counselling		
Timing of sexual intercourse coincide with ovulation	23	33.3
Advise on frequency of sexual intercourse	7	10.1
Modify social habits such as smoking/alcohol use	10	14.5
Advise on avoiding excess use of lubricant	*	
Avoidance of stress and promotion of emotional	50	72.5
Practice on treatment		
Preconceptual weight loss is a must	2	2.9
Life style modification i.e. cessation of smoking and alcohol use	2	2.9
Clomiphene citrate is the first line ovulation induction drug	*	*
Metformin should be used routinely with Clomiphene citrate	*	*
Identify high risk women i.e. early sexual debut/promiscuity	*	*
Start with screening and treating Chlamydia	32	46.4
Management of other STIs should be priority.	32	46.4
Assessing tubal patency should be considered	11	15.9
Semen analysis as a primary investigation	5	7.3
Cessation of smoking	1	1.4
Use of PDE 5 inhibitor for men with premature ejaculation	*	*
Refers client to next level	61	91.3

Barriers to provision of infertility health services

Approximately half of the participants 45.2 % (n=33) cited lack of knowledge on infertility management as the main barrier to provision of infertility services. About 26% (n=19) mentioned lack of appropriate supplies while 5.5% (n=4) of the HCPs thought providing infertility services was time consuming. Individuals mentioned low client turnout, only women seeking services, lack of infertility services, limitation due to level of service delivery, considering infertility a low priority problem, difficulties in handling men and recurrent STIs in clients as barriers to service provision. While others mentioned HCP lack of effort to treat clients with HIV (2.7%, n=2), cancellation of nurses infertility clinic (2.7%, n=2), the expensive nature of some investigative services (5%, n=4) and finally, lack of community sensitisation on infertility services (2.7%, n=2).these findings are different from Widge (2008) findings in India were a majority of HCP cited high cost of treatment as a barrier to provision of infertility services, however, in this study clients associated high cost with frequent travels to the clinic as infertility treatment requires prolonged engagement.

Client's demographic characteristics

Majority (70%, n=20) of participants were female only 30% (n=7) were male. Respondent ages ranged from 25 to 55years old with a mean of 37 and a standard deviation of 7.97. About 48% (n=13) of the respondents had primary school education, 25% (n=7) secondary education, 7% (n=2) tertiary education and11% (n=3) had no education at all. Majority (86%, n=23) of the respondents were married while the rest (14%, n=4) were divorced. About half (44%, n= 12) were unemployed, 37% (n=10) owned small businesses and 19% (n=5) were employed. Majority (89%, n=24) had no living children, 4% (n=1) had one and 7% (n=2) had 3 children. The majority had secondary infertility (55%, n=15) while 45% (n=12) had primary infertility. Majority (52%, n=14) had no STIs while 48% (n=13) were found with an STI. About 45% (n=12) were HIV negative, 30% (n=8) were HIV positive while 25% (n=7) had unknown HIV status. Respondents interviewed were from primary (55%, n=15), secondary (15%, n=4) and tertiary (30%, n=8) level health facilities.

Clients' satisfaction

Study results revealed that there were variations in their satisfaction levels. This led to the emergence of two sub-themes which are: being satisfied or unsatisfied. Clients who were satisfied were as such because their expectations were met by HCP. Satisfaction was not dependent on the

successful outcome of the infertility treatment but on the various types of other services they received at the facility such as STI treatment and medications for other presenting problems. This is similar to Parrots (2014) observation in Karonga (Malawi) were clients looked at syndromic treatment of STI as effective treatment especially in the primary level. Some participants understood that various levels of service provision had limitations with regards to the extent to which they can offer certain services. For these clients, they were satisfied as long as management was done at an expected level. Even though other clients complained that they were not given adequate information by the HCPs and they had waited for a very long period to receive the service, they still expressed satisfaction with the care they received. This was particularly attributed to some investigations that were done such as HIV, VDRL, abdominal ultra sound scanning, pregnancy test and cervical cancer screening. This is what one participant had to say:

"I think I am mainly satisfied because I have been scanned and they have given me the pictures (Female 39 years old Q019)."

Despite receiving various investigative services some participants were somehow dissatisfied with the services. They complained that the services took a long period to be conducted. This is similar to Morrison et al (2007) study findings in Aberdeen that revealed that clients had problems with waiting for a long time for services. In this group, some gender differences were also observed. For those participants who came as a couple, the females were almost always satisfied with the services whilst men expressed some reservations. In some cases, the men felt that the infertility treatment was gender biased. Many investigations were targeting the female than the male client. This is how one participant/client explained:

"All I wanted was for the nurse to focus on me and give me a body cleaner like they do at the traditional healer. All she did was examine my wife and asked me a few questions (Couple/male 28 years old Q018)

Similarly male clients in South Africa also complained that HCP were not able to integrate males' needs in the infertility services which were biased towards women (Dyer, 2008). A similar observation was also made in the northern Malawi by Hemmings (2007).The National SRH policy (2009) acknowledges failure to meet needs of males in RH services in government sponsored health facilities as a major challenge. The lack of focus on male clients has also been reported among clients who seek infertility services from traditional healers (Parrott, 2014). Participants also disclosed that they were not satisfied because the HCP only asked questions without conducting any physical assessment. This was a common concern among men. Others were dissatisfied due to lack of proper explanation from the health care providers. They believed that at least HCP needed to explain the way forward even if all their tests come out negative. Participants who reported to the health facilities without their spouse were disappointed because they were sent back without any treatment by the health workers. This was commonly expressed by participants at primary and tertiary levels. These sentiments were equally shared by both males and females.

Limitations

This study had the following limitations (1) low turnout of clients affected HCP observations **(2)** Time was a significant constraint as the study was for academic purposes hence there was need for it to be completed within a specific period (3) There were only a few specialists (Gyneacologist) present at the Gynae clinic at QECH on days allocated for infertility treatment. This resulted in assessing a few specialists.

RECOMMENDATIONS

Based on the study findings the study concluded that (1) there is lack of knowledge of infertility management guidelines (2) there is universal low level of knowledge on management of infertility across the levels of services provision (3) Practices on management of infertility falls below standard across all levels of service provision (4) services provided are biased towards women. Hence the study recommends that **(1)** Ministry of health in corroboration with RHD and DHOs should develop a strategy for disseminating infertility guidelines to all HCPs. **(2)** TDHO and QECH to provide on-the-job training for its staff on management of infertility. **(3)** Integration of infertility services in already existing RH services in all levels of service provision. **(4)** HCPs to incorporate gender sensitive approaches in the provision of infertility services.

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Trends in Child Malnutrition Inequalities in Malawi: A Decomposition Approach

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ABSTRACT

The economic consequences of child malnutrition to individuals and households are well documented. It is also reported that child malnutrition is more prevalent among children from poor households, implying the existence of inequalities. This study therefore, aimed at decomposing the determinants of child malnutrition inequality in Malawi. Using concentration curves and concentration indices to examine the extent of child malnutrition inequality, the study further adopts the novel Recentered Influence Function regression based decomposition method, to decompose the determinants of child malnutrition inequality. Data from Malawi Demographic and Health Survey for 1992, 2000, 2004, 2010 and 2015-16 was used, and analyzed in Stata to answer the questions. The main results show there is a slow declining trend in child malnutrition inequalities in Malawi. In terms of decomposition, place of residence, household economic status, parental education and source of antenatal care were found to be the major factors contributing to child malnutrition inequalities in Malawi. Even so, the results indicate that a mother's higher education is vital in significantly reducing child malnutrition inequalities in Malawi since it was found to be the highest contributor. Policy-wise, since child malnutrition is more prevalent among the poor, child nutrition programs should continue to target the poor households. There is also need for income redistribution strategies, and education policies that do not only aim at achieving universal primary education, but also secondary and higher education for both males and females. Mobile skilled antenatal care services should be implemented to reduce child malnutrition prevalence and inequalities.

Keywords: Malnutrition, Households, Inequality, Households

INTRODUCTION

Unlike any other group in society, malnutrition gravely affects infants and children due to their high nutritional requirement for growth and development (Blössner & Onis 2005). Poor nutrition in childhood can have irreversible consequences that can affect them in their entire life as well as the economic growth of a nation. Child malnutrition, in Malawi is confirmed to incur huge economic losses due to its consequences on health, education and productivity. This loss is estimated at MK147 billion annually which is a 10.3 percent annual loss in GDP (MoF, 2012).

Child malnutrition is a major contributing factor to child morbidity and mortality in developing countries. In Malawi, 23 percent of child mortality incidents are linked to malnutrition, reducing the

workforce by 10.7 percent as of 2012 estimates (MoF, 2012). Stunting[10] in childhood also negatively impacts school performance thus contributing to grade repetitions (UNICEF 2013). 18 percent of all school year repetitions in the country are attributable to malnutrition (MoF, 2012). Consequently, lower school achievement due to childhood malnutrition leads to diminished income-earning capacity in adulthood (UNICEF 2013). The loss in productivity attributes 1.2 percent annual loss in GDP (MoF, 2012). Furthermore, Webb (2014) notes that the existence of malnutrition impedes the successful accomplishment of the Sustainable Development Goals (SDGs). Clearly, child malnutrition negatively affects the development potential of a nation.

Although Malawi has been able to reduce underweight prevalence in under-five children from 25 percent in 2000 to 17 percent in 2014, this was still above the 14 percent MDG target indicating the existence of chronic food and nutrition insecurity (GoM & NSO, 2014). In addition, results of the Malawi Demographic and Health Survey (MDHS) have consistently indicated that the prevalence of child malnutrition has been higher among children from the lowest wealth quintile as compared to those in the richer quintiles (NSO & ICF International, 2016; NSO & ORC Macro, 2005; NSO, ORC Macro, & ICF Macro, 2011). This implies there are persisting inequalities in child malnutrition in Malawi irrespective of the decline.

In corroboration to the situation in Malawi, some studies have indicated that reductions in the overall rate of malnutrition does not reduce malnutrition in all socioeconomic groups. Poel et al. (2008) and Bredenkamp et al. (2014) found evidence that such average improvements in nutritional status mask widening inequalities unfavorable to the. Other findings indicate these inequalities almost always disfavor the poor (Kumar et al., 2014; Kumari, 2013; Larrea & Freire, 2002; Novignon et al., 2015; Wagstaff & Watanabe, 2000, Mukherjee, 2015). Hence this puts a case to investigate the income related dimension of child malnutrition. In this regard, commitments to reduce malnutrition among the least affluent should be the goals and targets of nutrition policies.

Considering the burden child malnutrition poses on the development of a human being and the nation at large some studies have been conducted to analyze the contributing factors to child malnutrition by Chirwa & Ngalawa (2006), Sassi (2013), Chikhungu et al. (2014), Chikhungu & Madise (2014). More similar to this study are studies by Gondwe (2015), Mussa (2011a) Mussa (2011b), however, these studies were mean based and not full distributional analysis. Despite these studies, socioeconomic related inequalities in child malnutrition for the entire population distribution have not been explored. Understanding the whole distribution is important as mean based analysis misses important parameters at different points of a distribution (Firpo et al., 2009; Fortin et al., 2011; Heckley et al., 2016; Carrieri & Jones, 2016;). Studies on socioeconomic related inequalities in child malnutrition are of importance as they are necessary in delivering expedient, efficacious and sustainable solutions, and competently meeting the needs of the most vulnerable.

In extending the previous studies, this study investigated the causes of child malnutrition inequalities by decomposing the concentration index (CI) using the distributional decomposition method. With the main objective of assessing child malnutrition inequalities in Malawi.

This study is set to contribute to literature in three ways. Firstly, it is the first to use all waves of the MDHS data for 1992, 2000, 2004, 2010 and 2015-16 to explain child malnutrition inequalities in Malawi. Secondly, it adopts an evolutionary approach by examining trends and patterns of child malnutrition inequalities in Malawi to unravel whether the overall decline in child malnutrition has led to widening or a reduction in child malnutrition inequalities. Thirdly, it is the first to decompose

Stunting, underweight and wasting are the common indicators of child malnutrition. Stunting or shortness is expressed as low height relative to age and it is a result of slow skeletal growth caused by poor dietary intake over time and poor health conditions and reflects a failure to reach expected growth potential (Garcia 2012).

the causes and show change in the causes of child malnutrition inequalities across the entire population distribution by using RIF method which is a recent methodology in literature.

MATERIALS AND METHODS

The econometric analysis will be done in three steps; first concentration curves for the child malnutrition (stunting) will be constructed. Secondly, the concentration index will be computed to compliment the concentration curves. The final analysis will be to decompose the concentration indices to identify the factors that contribute to inequality in child malnutrition over time.

The concentration curve gives a pictorial view of the pattern and magnitude of inequality in child malnutrition. In a situation where there exists perfect equality in child malnutrition, the concentration curve will coincide with the line of equality (the 45^0 line). The curve would depict inequality against the favor of the poor if it lies above the line of equality and against the rich if it lies below the line of equality (O'Donnell et al, 2008a). Concentration index will complement the curve by giving the numerical measure of inequality in stunting (Kakwani et al, 1997). It lies between -1 and +1, a positive sign indicates malnutrition is concentrated among the rich and a negative sign indicates malnutrition is concentrated among the poor (de Onis & Blossner, 1997). This study uses an absolute CI, since child malnutrition is an unbounded variable.

A recentered influence function (RIF) regression based decomposition method is employed due to the advantages it has over the commonly used Wagstaff decomposition (WDW) of the CI method. RIF-regression based decomposition provides a simple way of performing a detailed decompositions for any distributional statistic for which an influence function can be computed (Fortin et al., 2011). Unlike the WDW method, RIF regression does not impose a rank *ignorability* assumption[11] or a weighting function *ignorability* assumption[12] as it explains inequalities by directly decomposing the weighted covariance of the socioeconomic rank and the health variable, the CI. Another benefit of the method is that the results are similar in interpretation as in OLS regression. The decomposition is done in two steps; an RIF of the CI is computed followed by a regression of the RIF on a set of covariates that give the marginal effects of the covariates on the CI.

RIF of the Concentration Index

The RIF regression based decomposition method is similar to the standard regression, only different that the dependent variable, is now the RIF of the statistic (Fortin et al. 2011), which in this study is the CI. The RIF of the absolute CI, is expressed as;

$$\mathrm{RIF}\,(\mathrm{h}, \mathrm{F_Y}(\mathrm{y});\ \nu^{\mathrm{AC}}) = \nu^{\mathrm{AC}}\left(\mathrm{F_{H,F_Y}}\right) + \mathrm{IF}\,(\mathrm{h}, \mathrm{F_Y}(\mathrm{y});\ \nu^{\mathrm{AC}}) \qquad (2)$$

Where h represent the child malnutrition variable (stunting) having a probability measure denoted as $\mathrm{F_H}$. Each individual is ranked by a random variable, socioeconomic status (wealth index), Y and $\mathrm{F_Y}$ is the fractional rank for each individual. $\mathrm{F_{H,F_Y}}$ denotes the joint distribution of the health variable, H and the fractional rank of an individual $\mathrm{F_Y}$ and ν^{AC} is the absolute CI. The estimated RIF of the CI yields empirical estimates of each individual's recentered influence on the index.

RIF Regression Decomposition

Since the RIF is a recentering of the influence function (IF) whose expectation in zero, the statistic, $\nu^{\mathrm{AC}}\left(\mathrm{F_{H,F_Y}}\right)$ can be expressed as the expected value of the RIF;

$$\nu^{\mathrm{AC}}\left(\mathrm{F_{H,F_Y}}\right) = \mathrm{E}[\mathrm{RIF}\,(\mathrm{H}, \mathrm{F_Y}; \nu^{\mathrm{AC}})] \qquad (3)$$

[11] Ignoring the association between rank and covariates by decomposing one part of the covariance (health). This assumes rank remains constant when the covariates change hence one-dimensional decomposition.

[12] The weighting function is not affected by a change in covariates. Implying can only decompose an absolute CI.

The method assumes a functional form linear in parameters with an additive error term in the regression model of the RIF of CI and the impact of X on the conditional mean of the RIF is estimated using OLS (RIF-I-OLS);

$$E[RIF\ (H, F_Y; \nu^{AC})|X = x] = X'\psi + \varepsilon \quad (4)$$

The coefficient ψ represents the marginal effect of a covariate, X on the distributional statistic ν^{AC}.

Variables and Data

This study takes height-for-age (stunting) as an indicator of child malnutrition as used in Adali & Tezcan (2015), Larrea & Freire (2002), Mukherjee (2015) and Wagstaff et al. (2001). This variable has been preferred to wasting and underweight as it has the highest prevalence in Malawi. In addition, Adali & Tezcan (2015) says that stunting is not as affected by seasonal fluctuations or temporary effects as much as wasting and underweight. It is expressed in the form of z-scores standard deviation (SD) from the median of the 2006 WHO International Reference Population and not as a binary variable as commonly used to better reflect the depth of malnutrition. For easy interpretation, the study uses the negative values of the z-scores as in Wagstaff et al. (2001).

Factors contributing to child malnutrition inequalities chosen for the analysis include; household economic status, mother's and father's level of education, source of antenatal care (skilled antenatal care), place of residence, birth order, size of child at birth, sex of child, age of child and mother's body mass index. The study uses data obtained from the five waves of the MDHS conducted in 1992, 2000, 2004, 2010 and 2015-16 by the National Statistical Office (NSO) which has been analyzed using a statistical software package called STATA version 13.0.

RESULTS AND DISCUSSIONS

Descriptive Statistics

Table 1 presents the descriptive statistics for the variables used in the analysis. Under-five stunting has for the first three years been below -2 standard deviations of the WHO reference population except for 2010 and 2015-16. This implies that the average under-five child in Malawi, was moderately malnourished, improving in 2010 and 2015-16. The statistics show a greater percentage of the sample being from the rural area than the urban area and also indicates an improvement in the level of parental education. The values of the body mass index variable shows that the average mother in Malawi is normal according to the WHO international classification of adult underweight, overweight and obesity according to BMI[13]. The number of women receiving skilled antenatal care has been increasing with the year 2015-16 having the highest percentage.

[13] http://apps.who.int/bmi/index.jsp?introPage=intro_3.html

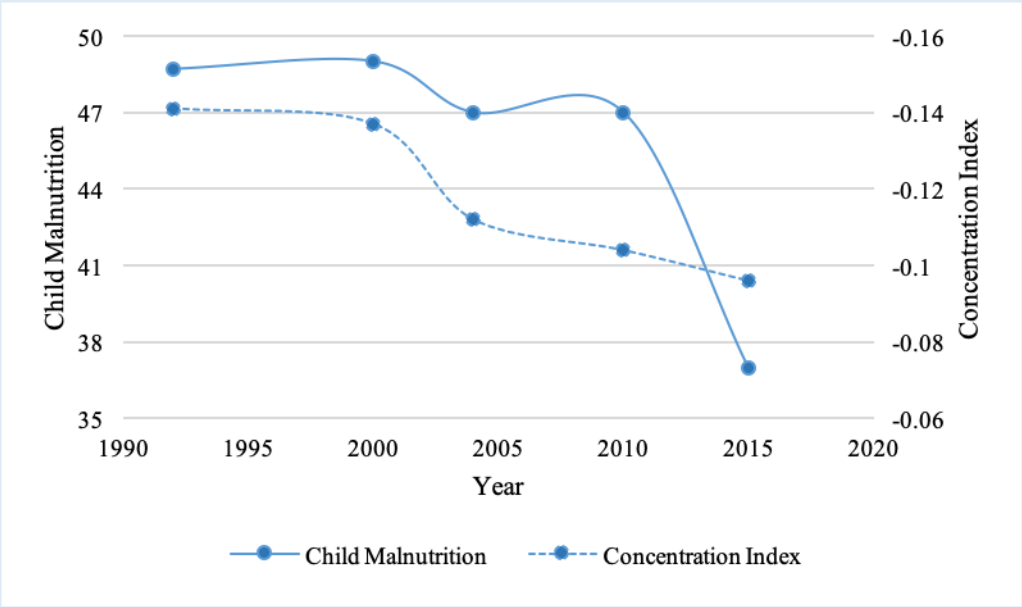
Table 1. Descriptive Statistics for 1992, 2000 2004, 2010 and 2015-16

Descriptive Statistics					
	1992	**2000**	**2004**	**2010**	**2015-16**
Variable	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**
Stunting	-2.108	-2.116	-2.118	-1.911	-1.619
Place of residence					
Urban	0.250	0.186	0.103	0.099	0.162
Rural	0.750	0.814	0.897	0.901	0.838
Wealth quintile					
Poorest	0.162	0.212	0.191	0.195	0.217
Poor	0.169	0.194	0.221	0.230	0.225
Middle	0.201	0.195	0.238	0.232	0.196
Rich	0.217	0.202	0.206	0.197	0.186
Richest	0.251	0.196	0.145	0.147	0.175
Mother's education					
No education	0.417	0.295	0.258	0.168	0.124
Primary	0.528	0.628	0.641	0.698	0.654
Secondary	0.053	0.076	0.098	0.130	0.206
Higher	0.002	0.001	0.002	0.005	0.016
Father's education					
No education	0.165	0.146	0.145	0.093	0.078
Primary	0.632	0.636	0.617	0.636	0.468
Secondary	0.161	0.190	0.204	0.233	0.257
Higher	0.009	0.006	0.010	0.017	0.037
Body mass index					
BMI	22.028	22.125	22.005	22.358	22.837
Antenatal care					
Skilled	0.632	0.659	0.652	0.672	0.762
Unskilled	0.020	0.083	0.060	0.070	0.002
Size at birth					
Small	0.031	0.034	0.032	0.032	0.041
Average	0.624	0.593	0.487	0.417	0.503
Large	0.038	0.085	0.095	0.119	0.079
Age					
Months age	26.808	27.116	27.793	29.378	28.993
Sex					
Male	0.500	0.493	0.499	0.496	0.494
Female	0.500	0.507	0.501	0.504	0.506
Birth order					
Birth order	4.250	3.606	3.536	3.684	3.171
Observations	3174	9188	8091	4586	5149

Source: Calculated by Author using MDHS

Prevalence of Child Malnutrition Inequalities in Malawi

With the aim of assessing prevalence of child malnutrition inequalities, figure 1 portrays the concentration curves for stunting for the years 1992, 2000, 2004, 2010 and 2015-16 in Malawi. All the concentration curves clearly lie above the line of inequality depicting that inequalities in child malnutrition have been against the favor of poor households. This was expected as it has been a common finding among most studies in developing countries. The magnitude of the curves suggest inequalities have been almost constant as there are no clear gaps between the curves.



Source: Calculated by Author using MDHS

Figure 1: Graph of Concentration Index and Average Prevalence of Stunting

Econometric Results

Trends in Child Malnutrition Inequalities in Malawi

Concentration indices were calculated to corroborate the concentration curves in the previous section. The concentration indices (mean RIF[14] in table 2) were found negative; -0.141, -0.137,-0.112, -0.104 and -0.096 in 1992, 2000, 2004, 2010 and 2015-16 respectively. This ascertains the findings from the concentration curves that child malnutrition has been persistently concentrated among the poor. However, the absolute value of the concentration indices depict a slow dying trend in inequalities, similar to findings by Adali & Tezcan (2015) in Turkey. Such changes may be explained by changes in prevalence of malnutrition among the different socioeconomic groups. Figure 2 further shows how the change in the CI (inequalities in child malnutrition) relates to the change in the average prevalence of malnutrition. Overall, it is clear that average child malnutrition prevalence has been declining together with its inequalities in Malawi.

[14] Recall in it was shown in methodology that the expectation of the RIF gives the value of the CI being decomposed.

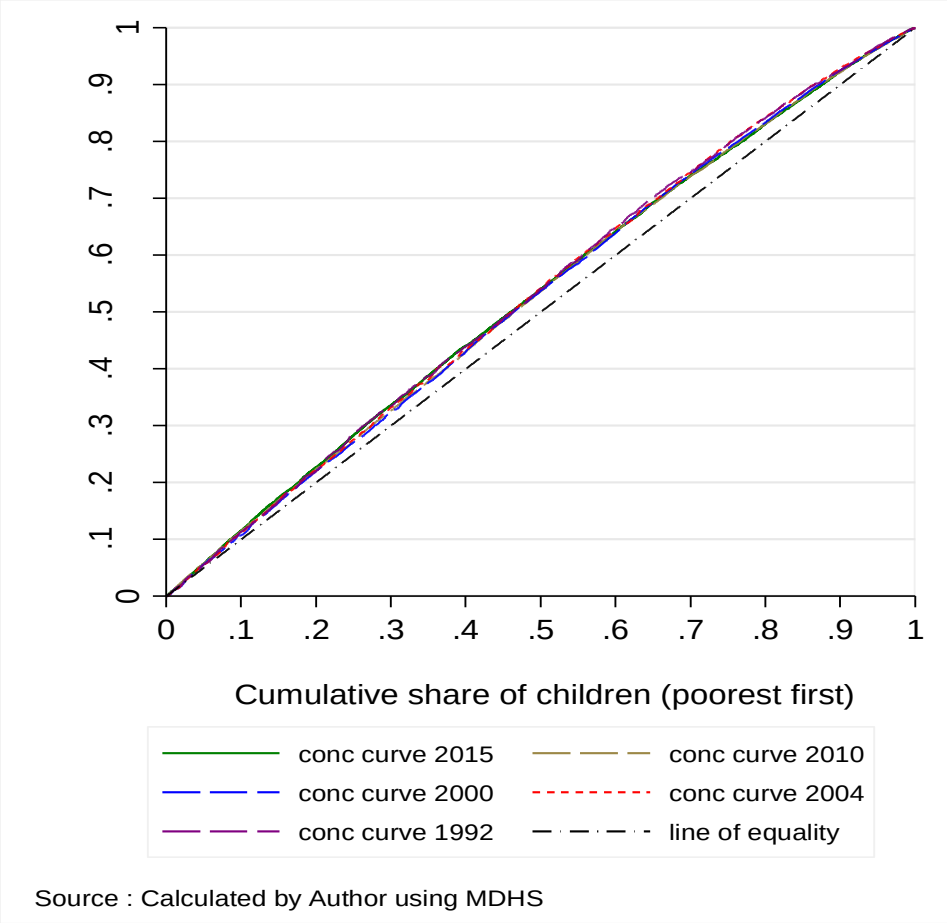


Figure 2: Concentration Curves for 1992, 2000, 2004, 2010 and 2015-16

Decomposition Results: Contributing Factors to Child Malnutrition Inequalities

Table 2 presents the results from decomposing the CI. It shows how the different socioeconomic and demographic variables contribute to child malnutrition inequalities and how these contributions have been changing over the time of the study period. Assuming regressors are exogenous, interpretation of the RIF-I-OLS coefficients is similar to that of Ordinary Least Squares (OLS) regression because the estimates of the mean of RIF-I-OLS are the same as the estimates of the mean of OLS regression[15] (Heckley et al. 2016). The contribution of a variable to inequality (negative or positive) in child malnutrition is through its relationship with child malnutrition and through its relationship with distribution across wealth status.

[15]The RIF-I-OLS coefficients are interpreted as how a marginal shift in the distribution of a covariate influences the inequality index.

Table 2: Results from decomposing the Child Inequalities

Large	-0.059	-0.021	0.033	0.041	0.024
	(0.074)	(0.030)	(0.028)	(0.037)	(0.037)

RIF Regression Results Continued					
Variable	1992	2000	2004	2010	2015-16
Male	0.012	-0.015	-0.005	0.025	-0.025
	(0.026)	(0.016)	(0.018)	(0.022)	(0.018)
Age	-0.002	-0.002***	-0.002***	-0.001	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Birth order	-0.004	-0.010***	-0.009**	0.001	-0.005
	(0.005)	(0.004)	(0.004)	(0.006)	(0.005)
_Cons	0.085	-0.039	0.009	-0.050	-0.010
	(0.125)	(0.074)	(0.080)	(0.096)	(0.080)
Mean of RIF	-0.141	-0.137	-0.112	-0.104	-0.096
Observations	3148	9128	8031	4536	5123
Prob>chi2	0.000	0.000	0.000	0.000	0.000

Source: Calculated by Author using MDHS
Bootstrap standard errors in parentheses
* *10% level of sign*

The combined effect of residing in urban area on child malnutrition and wealth distribution reduces inequalities. This may be because households living in urban areas have better access to health information and facilities as compared to those living in rural areas. However, the contribution of declined and then become insignificant possibly due to increasing urbanization in Malawi. For economic status, the contribution of the poor quintile is positive while that of the richest wealth quintile has narrowing effects on the CI. Households in richer quintiles have access to the best health facilities hence good health care and can afford a variety of nutritious food for their families.

Table *3*: Decomposition Results

RIF Regression Results					
Variable	1992	2000	2004	2010	2015-16
Place of residence					
Urban	-0.102***	-0.080***	-0.062*	0.025	-0.005
	(0.033)	(0.026)	(0.037)	(0.047)	(0.031)
Wealth quintile					
Poor	0.017	0.049*	0.074**	0.104***	0.059**
	(0.061)	(0.029)	(0.032)	(0.038)	(0.030)
Middle	0.129**	0.075***	0.066**	0.093***	0.089***
	(0.054)	(0.026)	(0.030)	(0.036)	(0.029)
Rich	0.101*	0.053*	-0.003	0.056	0.059*
	(0.055)	(0.030)	(0.035)	(0.042)	(0.033)
Richest	0.011	-0.138***	-0.190***	-0.100*	-0.019
	(0.067)	(0.039)	(0.050)	(0.056)	(0.046)
Mother's education					
Primary	0.055*	0.001	0.002	0.004	0.019
	(0.029)	(0.021)	(0.023)	(0.032)	(0.030)
Secondary	-0.253***	-0.221***	-0.064	-0.087*	-0.006
	(0.079)	(0.045)	(0.044)	(0.049)	(0.038)
Higher	-0.377	-1.490***	-0.066	-0.559**	-0.205**
	(0.309)	(0.144)	(0.282)	(0.266)	(0.104)
Father's education					
Primary	-0.056	0.049**	0.049*	0.026	0.024
	(0.036)	(0.024)	(0.026)	(0.034)	(0.025)
Secondary	-0.172***	0.033	0.020	0.013	0.018
	(0.052)	(0.031)	(0.033)	(0.040)	(0.027)
Higher	-0.435**	-0.338***	0.067	0.023	-0.126*
	(0.173)	(0.129)	(0.149)	(0.124)	(0.071)
Antenatal Care					
Skilled	0.014	-0.008	-0.022	0.035	0.063***
	(0.036)	(0.022)	(0.023)	(0.028)	(0.024)
Body mass index					
BMI	-0.008*	-0.001	-0.002	-0.006*	-0.007***
	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)
Birth size					
Small	0.069	0.021	0.058	-0.018	-0.058
	(0.085)	(0.048)	(0.053)	(0.063)	(0.050)
Average	0.027	0.015	0.006	0.015	0.019
	(0.029)	(0.019)	(0.019)	(0.023)	(0.020)

Whereas children whose mothers have primary education has no association with inequalities in child malnutrition, those with more secondary and higher education have a negative association with child malnutrition inequalities. While a child's father having primary education increased inequalities in 2000, those having secondary education reduced inequalities in 1992 and 2000. The positive relationship with primary education may be explained by lower income earning potential of the father, who is likely employed in the informal sector where earnings are poor. Hence access to nutritious food and health care services utilization is a challenge. Generally, rising parental education negatively influences inequalities due to its impact on income generation, good sanitation

practices and increased awareness on health practices. However, this impact has been decreasing over the years through nutrition interventions that target rural and poor households.

Receiving antenatal care from a skilled health personnel had a positive impact on child malnutrition inequalities in 2015-16. This is a similar finding to that of Novignon et al. (2015) in Ghana and Kumar & Singh (2013) in Indian. This implies that women from richer households are more advantaged to access skilled antenatal care as compared to those from poorer households in Malawi. The poor are disadvantaged due to high cost of transport or lack of awareness on health promotion behavior leading to detrimental effects on child nutrition thus widened inequalities.

CONCLUSION AND RECOMMENDATIONS

This study was intended to explore the nature and levels of child malnutrition inequalities in Malawi and the factors contributing to the inequalities through a decomposition. Stunting was used as a measure of childhood malnutrition and malnutrition inequalities across the distribution of wealth index was measured by a CI. Using the MDHS survey data, the analysis showed child malnutrition is more prevalent among the poor but there is a slow dying trend in inequalities. Residing in urban areas, having high socioeconomic status and higher levels of parental education are associated with low levels of child malnutrition inequalities while receiving skilled antenatal care is associated with higher levels of child malnutrition inequalities in Malawi.

The study findings suggest several implications for the design of child malnutrition reduction strategies in Malawi. Since child malnutrition inequalities have been consistently against the favor of the poor, of a special importance child nutrition programs should mainly target the poor for effective reduction in child malnutrition in Malawi. Secondly, in addition to poverty reduction strategies there is need for income redistribution strategies like increase in minimum wage[16], progressive taxation and expansion of earned income tax[17] and investment in education[18]. Indirectly transferring income from the richest to the poor up to a point where income sustainably improves health for all is an effective strategy since such a transfer raises the health of the poorer individual by more than it reduces the health of the richer individual according to the absolute income health hypothesis.

Thirdly, parental education is an important policy tool for reducing inequalities in child malnutrition in Malawi. Different from primary education, only secondary and higher education significantly reduces inequalities in malnutrition. This implies understanding and acting upon messages of nutrition require more than having basic primary education. Therefore, there is need for policies that promote not only universal primary education, but also secondary and higher education attainment for both males and females but more especially the females. Finally, mobile antenatal services like Medic Mobile can be implemented in communities to ensure equal access to the minimum recommended number of skilled antenatal visits especially among the poor.

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[16] Higher wages for the lowest paid laborers has the potential to move people out of poverty.

[17] Where the resources can be used to provide support for the poor, this can pull more children out of poverty

[18] This increases economic mobility, increases productivity and decreases inequalities

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Knowledge and Practices about Cervical Cancer Screening Among Married Men in Traditional Authority Nkhumba, Phalombe District

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ABSTRACT

Cancer of the cervix is still causing deaths of women worldwide and Malawi has not been spared. Of the 16 countries with the highest incidence of cervical cancer in Africa, Malawi has the highest, with an incidence of 75.9. Being a reproductive disease, male involvement is critical as men control approximately 95% of sexual relationships in Malawi, but their role in cervical cancer prevention is not known. This study was carried out to investigate the knowledge and practices of married men regarding cervical cancer and screening. A cross-sectional study recruited 396 married men. Collected data were analyzed by using SPSS for Windows version 20. Majority of participants were not knowledgeable about cervical cancer as 84.1% did not know the cause. Only 4% knew the risk factors. On prevention, 76.5% had no knowledge, and 68.2% had some knowledge on treatment. Almost all participants (99%) said would encourage their spouses to undergo screening, and 71.7% said that men are responsible for deciding whether their spouse should access screening services or not. Men demonstrated interest in taking part in cervical cancer prevention. This is a window of opportunity that the Ministry of Health can use to develop strategies that are tailored toward men to participate fully in cervical cancer prevention to reduce its burden.

Key words: Cervical cancer, Malawi, Male involvement, Knowledge

INTRODUCTION

Cancer of the cervix remains a burden and a major public health concern in Malawi and most of the developing countries in the world. It is the second common cancer among all cancers in Malawi (Msyamboza et al., 2012) and highly contributes to mortality rate (Anorlu, 2008). With early detection, cervical cancer is preventable and curable. In the presence of a vibrant screening program that ensures effective coverage, quality and proper follow up of clients, the incidence of cervical cancer can be reduced by 80 % (Sangwa-Lugoma et al., 2006).Countries all over the world including Malawi offer cervical cancer screening to assist with early detection of precancerous lesions though the services are largely underutilized. The underperformance of cervical cancer screening program has been attributed to both individual and health systems factors (Maseko et al., 2015).

Recently, there has been a turn of events whereby men are being encouraged to champion access to reproductive health services. This is in contrast with the 1990s where almost all reproductive programs were targeting women as the sole players (Green et al., 2009).It was in 1994 at the ICPD meeting in Cairo that nations decided to involve men as key players in reproductive health issues considering that they make most of the decisions at household level. Since then more programs that

focus on men have emerged with the purpose of improving maternal outcome. Despite such efforts by nations and developmental partners, it seems men still lack knowledge in various issues of reproductive health including cervical cancer (De Bocanegra, et al., 2009; Williams& Amoateng, 2012; Asuzu et al., 2014) thereby limiting their participation in such matters. This study therefore was aimed at understanding men's knowledge and participation in cervical cancer and screening program.

MATERIALS AND METHODS

Design
Across-sectional descriptive design was used. This design enabled the researcher to examine the relationship between cervical cancer and some variables of interest of the study participants.

Setting
The study was conducted in 6 villages of Chiopsya, Sakhome, Mariko, Nalingula 1, Chibwana and Sakwedwa in Phalombe District. Villages were sampled randomly. These villages are under Phalombe Health center catchment area. The facility has a catchment population of 42,477 and 19 villages. These sites were suitable for the study because Phalombe Health Centre offers cervical cancer screening for women in the district.

Recruitment
Systematic random sampling was used to recruit study participants where every 16^{th} participant was recruited. This was obtained by dividing the total population of married men (6,526) by the sample (396). A list of households for each participating village was obtained from the Village head man with assistance from the Health Surveillance Assistant (HSAs). There was 100% response rate.

Data Collection
The data collectors did face to face interview with the participants and information was filled on the questionnaire. The interviews were done in the participant's homes and lasted for 20 – 30 minutes

Ethical Consideration
Approval was sought from the College of Medicine Research and Ethics Committee (COMREC). Further approval was sought from the District Commissioner for Phalombe district including concerned village heads. Ethical issues such as informed consent, voluntary participation, privacy and confidentiality and protection from harm were highly observed. Completed data collection tools were kept in a lockable safe, all electronic information was kept in a computer with a password.

RESULTS AND DISCUSSION

Table 1: Demographics

Variable	Frequency	Percentage
	Age	
20-30	188	47.5
31-40	133	33.6
41-50	75	18.9
	Education	
None	28	7.1
Primary	237	59.8
Secondary	126	31.8
Tertiary	5	1.3
	Employment	
Self employed	243	61.4
Farming	103	26
Formal employment	50	10.4

Knowledge about Cervical Cancer and Screening

Majority of the participants, 87.9% (n=348) have ever heard of cervical cancer as a disease that affect women but not in full details. Radio was the most common source of information on cervical cancer and screening followed by health workers. This finding is consistent with a study that was conducted by Nyirenda and colleagues (2016) on public engagement in Malawi through a health-talk radio programme which found that men's participation from the rural area was greater than that of women. This might be attributed to the fact that many people in rural areas especially men rely on the radio for information on different development programmes (NSO ICF, 2011). It might be possible that those who had mentioned health workers as their source of information might have acquired the information at VMMC as 97.7% had gone through the procedure**.**

Knowledge on cervical cancer cause and risk factors

Majority of the Participants 84.1% (n=333) in the study did not know that cervical cancer is caused by Human Papilloma virus which is sexually transmitted. Similarly 75.5% had no knowledge on risk factors. This might be due to lack of awareness of the disease in the general population as well as illiteracy level as 66.1% of the participants had either not attended school or dropped out in primary school. HPV being sexually transmitted is a cause for concern because if married men are engaged in extramarital affairs, spreading of the virus would be rampant and this might increase the risk of HPV infection to their spouse and then consequently cervical cancer.

Knowledge on prevention.

More than half of the participants 76.3% had no knowledge regarding prevention. This low knowledge on prevention has a negative implication on access to cervical cancer screening by women. This is so because if the men do not know how to prevent it, then they would not be in a position to engage themselves in preventive measures that would protect their spouse. Neither would they share correct preventive information with their spouses, friends or families that could positively contribute to the reduction in incidence of cervical cancer. In Malawi, routine health checkups and other screening interventions are underutilized. Majority tend to seek health care when they have a problem (Munthali et al., 2015). WHO (2005) suggests that effective prevention of cervical cancer largely depends on the screening coverage which is not consistent with these

findings. Therefore as much as the Malawi government has included cancer in its essential health package, the prevention aspect needs to be expounded. Information on preventive measures need to trickle down to the most remote areas where there are many at risk groups of women.

Knowledge on treatment.

The public health sector offers free services for all in Malawi. As a result, majority of the people report to these facilities most of the times when faced with health problems trusting that the health personnel have solutions for their problem (Fort, 2012). Findings of the study revealed that most of the participants (68.2%) mentioned that they would be treated at a heath facility with either surgery or drugs. Despite that majority of the participants being unknowledgeable about the disease, they had a belief that the health sector has treatment for cervical cancer. These findings are consistent with other findings from Mwake et al., (2015) where participants said cervical cancer can be treated if diagnosed early. These findings depict that health care in Malawi is more focused on the curative aspect than preventive just as in many developing countries (Munthali et al., 2015).

Participation in Cervical Cancer Screening Services

Majority of men felt they have an obligation in cervical cancer prevention because they are equally affected sexually, as husbands as 71.5 % said they are decision makers. Furthermore 99 % of the participants said they would encourage their spouses to be screened. This realization offers a turn from the traditional ways of thinking that reproductive health services are mainly for women. Furthermore it opens up an opportunity to reach out to the men and involve them fully in reproductive health issues including cervical cancer. Current evidence shows that men's support is the center point in increasing coverage to cervical cancer screening and treatment for women (Winkler et al., 2008; Airhihenbuwa, 2008; Greene et al., 2009) and lack of it is a barrier to screening opportunity (Al-Naggar et al., 2010; Oon et al., 2011).

Factors that Affect Screening

Gender of the screening personnel has also been highlighted as a factor that affects uptake of screening services by women (Nene et al, 2007; Ansink et al., 2008; Williams & Amoteng, 2012). The study found that majority of the participants 73.5% said anyone who is qualified to do the screening regardless of gender can do it. The men's unbiased attitude towards the gender of the screening personnel provides another window of opportunity that can positively affect scaling up of cervical cancer screening services. However some studies have reported that a female provider is preferred due to embarrassment suffered considering that screening is done on a preventive basis (Nene et al, 2007; Ansink et al., 2008; Williams & Amoteng, 2012). Some men mentioned that they should be taught what to look for during cervical cancer screening other than having another male provider visualizing their spouses' private parts (Williams & Amoteng, 2012). Munthali et al., (2015) also found that male health workers negatively affect screening practices. Some of the participants in that study were from Mangochi district which is largely inhabited by Muslims. Evidence shows that Muslims have a strong belief that their wives nakedness is strictly to be seen by their husbands as such a male provider would not be ideal to perform cervical cancer screening (Modibbo et al., 2015).

RECOMMENDATIONS

Preventive measures are not well known by the participants; therefore it is essential that preventive interventions be promoted. This approach is also cost effective because the cost of cervical cancer screening is way lower than treating cervical cancer. Specific interventions that are tailor made for men that give them full participation in reproductive health issues should be considered by the Ministry of Health. This can be achieved by introducing men's wellness clinics in the public health facilities. Health professionals in various facilities should utilize various avenues like health talks,

meetings with influential local leaders and men to discuss about cervical cancer whenever they have the opportunity. Health talks in areas where men gather like outpatient departments (OPD), Art Clinics as well as NCD clinics should be utilized to talk with men about cervical cancer. The health sector has a considerable number of Health Surveillance Assistant (HSAs) who are supposed to work at community level. These can be empowered to tackle issues at community level and inform communities about cervical cancer and screening.

CONCLUSION

It is clear that married men in Phalombe are not knowledgeable about cervical cancer. Such low knowledge level poses a threat to women's access to reproductive health services including cervical cancer screening. Despite the availability of literature on the importance of male involvement in reproductive health services, majority of men are still lagging behind. Men themselves are eager to learn more about the disease and take part in preventive efforts as well as encouraging their spouses to get screened. As such, the Ministry of Health's obligation is to strengthen preventive health services in Malawi as they are cost effective.

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Assessing Health System Responsiveness to Vulnerable and Children with Disabilities: Results from 'Aiming Higher in Malawi' Project Survey

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ABSTRACT

Studies have shown that persons with disabilities do face challenges in accessing health services because of their disabilities and dependency on others. However, not much is known about the health system and provider related factors that might be contributing to the same. The objective of the study was to explore health system and provider related factors that influence disabled and vulnerable children access to health services and propose evidence - based means to which health system could respond to the needs of people with disabilities. We conducted a cross-sectional study involving 403 guardians of disadvantaged children with different disabilities and their families in rural villages in Thyolo and Mulanje. Multi methods approach composed of both quantitative and qualitative studies was adopted. We also conducted ten focus group discussions with community members and 12 key informant interviews. Findings of our quantitative study show that disabled and vulnerable children are usually hidden and locked away, discriminated against, hence fail to access health services. Most guardians reported that disabled and vulnerable children lack the health services they want such as rehabilitative and physiotherapy services as they are not available in their local communities, and do not access even the general services available even in times of need. Apart from the outside factors, which obstruct disabled and vulnerable children from seeking care, service providers and the health system in general also play a crucial role. While disabled and vulnerable children needs are evident, most health systems are too slow to respond to their concerns. We recommend a shift from provider to people-centred health systems.

Keywords: Health systems, vulnerability, disability, physiotherapy

INTRODUCTION

In 2007 World Health Organisation came up with a framework that would assist governments in strengthening health systems. The framework consists of six building blocks namely; health service, health workforce, health financing, health information system, medical products, vaccines and technologies, leadership and governance (WHO 2007). As governments are aiming at providing quality health services in an effective and efficient manner to its citizen people with disabilities are to be considered. Disability is an umbrella term, covering impairments, activity limitations, and participation restrictions. An impairment is a problem in body function or structure, an activity limitation is a difficulty encountered by an individual in executing a task or action; while a participation restriction is a problem experienced by an individual in involvement in life situations (WHO 2016).

World Health Organisation WHO (2011) estimated that about 15% of the world population lives with a form of disability. Munthali (2011) in his study "*Situation analysis of persons with disabilities in Malawi"* estimated that 12.97% of Malawi's population is composed of people with disabilities. He further said that the majority are in rural areas that in urban. In 2013 UNICEF stated that about 1 in 20 children have a disability worldwide. Plan (2016) in "*Protect us! Inclusion of children with disabilities in child protection"* indicated that children with disabilities are 5-10 times likely not to go to school, and more likely to experience poor health and violence. Mulanje is one of the districts in the rural.

Aiming Higher in Malawi is a project in Mulanje particularly in Traditional Authority Ntiramanja with about four hundred and twenty eight (428) Children with Disabilities (CWD's). Most of these children are coming from poverty stricken homes. The projects' main aim is to improve the quality of life of vulnerable CWD's. The project achieves the quality of life through; Provision of transport to CWD's to access rehabilitation services at Queen Elizabeth Central Hospital, Improving nutrition status of CWD's by conducting nutrition assessments, Developing mother support groups to be doing gardening with an aim of sustaining nutrition status of CWD's. Studies have shown that persons with disabilities do face challenges in accessing health services because of their disabilities and dependency on others (WHO 2011). Every person including people with disabilities have right to access health services. It is government responsibility to provide health services. Munthali (2011) reports that people with disabilities do not have equal access to health care and do not receive disability related services that they require. However much is not known about health system and provider related factors that might contribute to these challenges. The study was conducted to assess health system and provider related factors that influence vulnerable children with disabilities access to health services. And the results may be used in planning health system that could respond to the needs of people with disabilities.

MATERIALS AND METHODS

Study design and setting

It was a cross-sectional descriptive study employing mixed methods. The study was carried out in 2016 in T/A Mtiramanja in Mulanje and Thyolo within Aiming Higher project catchment area, southern Malawi. All children with disabilities registered with the project as at November 2016 and they were well involved in this study. Mothers/guardians of children with disabilities. A total of 403 children with disabilities were identified to participate.

Data Collection and collection tools

Questionnaire and interview guide were used to collect data. Face validation was used to ensure validity of the questionnaire and interview guide. We collected both quantitative and qualitative data, Secondary data population demographics, earnings per day, distance to nearest health care centre. The data was collected from project's data base. Qualitatively, 12 Key informant interviews, 5 Focus group discussions were done on selected guardians of children with disability. A total of 50 mothers/guardians were identified to forming 10 focus groups.

RESULTS AND DISCUSSION

Demographic details

The study found 403 children who had full detailed information. It showed that 55% Males and 45% Females with an age ranging from 6months to 16 years. Distance from home to Chonde health centre range from 0.5 to 11 Kms. 90% of these children get 1 meal a day.

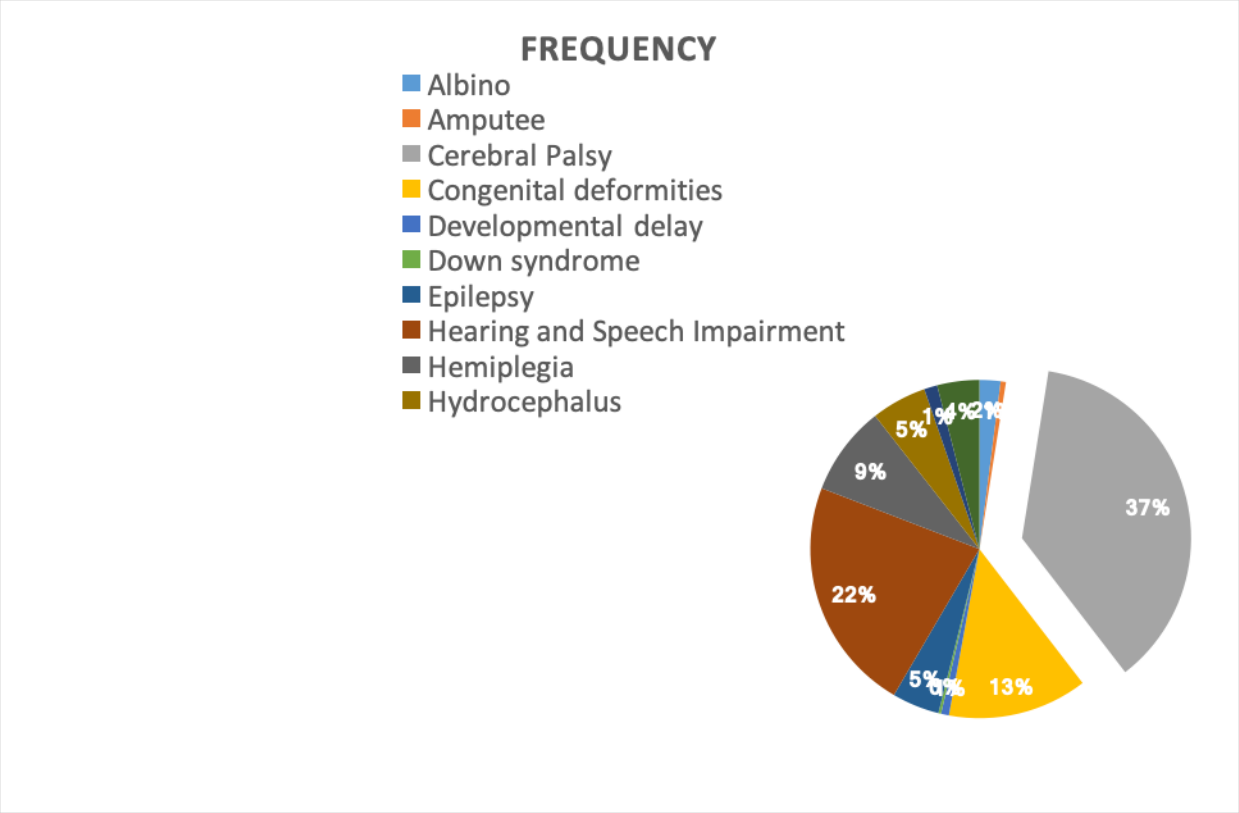

Figure 1: Disability frequency

Providers factors affecting service delivery

No rehabilitation services

The study found out that rehabilitation services not available at Mulanje DHO.

"*I tell them to go to QECH, unfortunately most of them don't due to lack of money for transport*." **KII1**.

"*I appreciate what Aiming higher is doing to these CWD's, but they come in large numbers to be seen in one day. This compromise the quality of rehabilitation service.*" **KII2**

Lack of knowledge

Some community members were unable to differentiate clinical and rehabilitation services. They thought that every doctor can provide rehabilitation services.

*"I believe that they get help at the health centre. Doctors are there to help them"***KII7**

Looking at the above findings, it shows that rehabilitation services are not available at Mulanje district hospital, which is not in line with what the government commitment to provide health services to all citizens including people with disabilities. Rehabilitation is one of the four components of primary health care but the study has shown than government is slow in responding to the special needs (rehabilitation) of people with disabilities.

Economic factors affecting mothers/guardians of children with disabilities to access rehabilitation services

Lack of money for transport
CWD's need health services almost every month. "*We spend MK2000 on average going QECH. It is very costly on our side. If only the services were available in our district*." **Participant 1**
"*Rehabilitation is not a priority comparing to finding food for children including the one with disability to eat."* **participant 7**

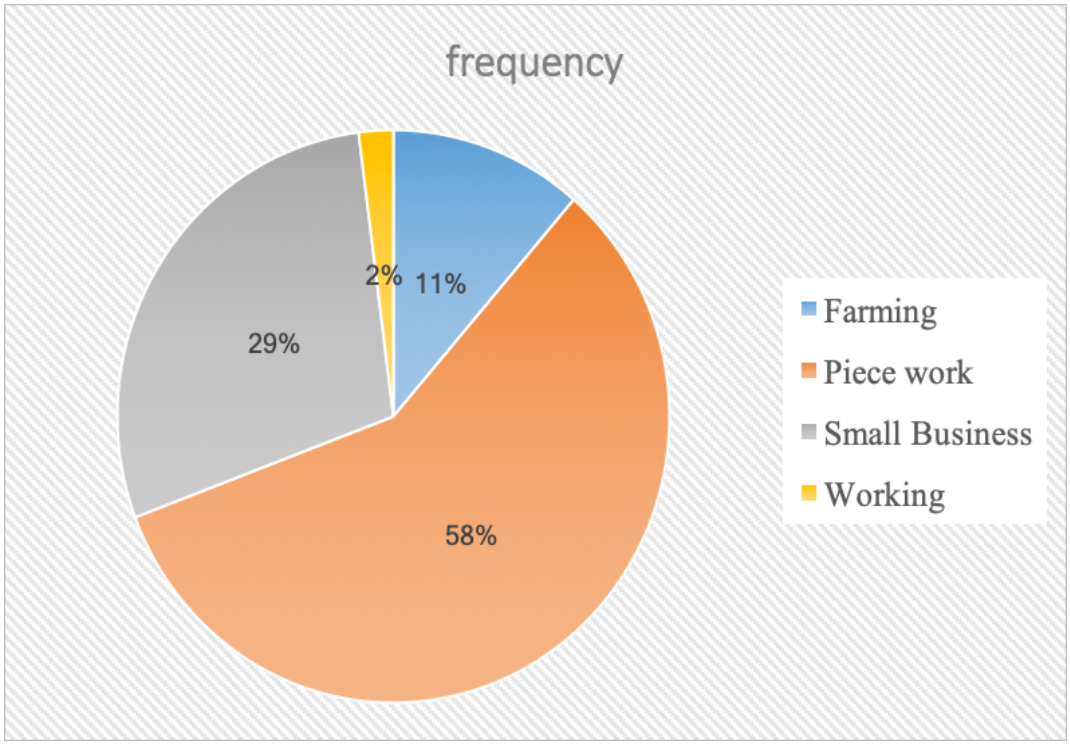

Figure 2: How they earn a living

In addition to travelling long distance and spending that much to access rehabilitation services, they spend almost the whole day at the hospital. This has an impact in their finances. It is like a day spend without doing an income generating activity. Most of them rely on piece work to find money to feed the family and transport. According to (WHO 2007) well-functioning health system must protect its citizens from financial catastrophe. Despite our health system providing health services for free; children with disabilities are facing challenges in accessing them since they are not available within their community. This is creating a vicious circle of poverty. Most families can afford a meal a day. This leads to malnutrition and delayed development.

Social factors affecting mothers/guardians of children with disabilities to access rehabilitation services

Curse:
A belief that having a child with disability is associated with witchcraft. One participant from **FGD4** narrated a situation where 3 boys in one family are disabled. Their father passed on and the relatives and community at large are not helping the lady. She has developed mental disorder and the boys are left on there on. The community believes that they did not follow what the traditional doctor told them.

Discrimination

They feel ashamed to carry a child with disabilities. People discuss about their children.

"*My child has hydrocephalus. When I take her to the hospital we become the topic of discussion by other patients."* **FDG 1**

Mothers of CWD's are overburdened to take the child to hospital. They must do everything at home on top of taking care of the children.

"*Most of us are divorced. Our husbands left us because we have CWD's. We have to take care of everything at home by ourselves. Having a CWD's is a burden."* **FDG 2**

It is a shame to see people discriminating children with disabilities. This shows lack of knowledge and understanding on disability issues in the community. Discrimination is compromising the quality of life of children with disabilities. Every person including children with disabilities have a right to access health care.

CONCLUSION

From the study it has shown that disability – a cross cutting issue can be addressed better through multi-sector approach. Health sector alone cannot address the needs of children with disabilities. The community shows lack of knowledge and understanding disability issues a factor that affect parents or guardians' health seeking behaviours for children with disabilities. Lack of rehabilitation services in primary and secondary care centres has caused congestion in tertiary care centres consequently affecting quality of care given to the children with disabling conditions.

RECOMMENDATIONS

1. Government to consider providing rehabilitation services as part of the primary health care component at all health care delivery levels; primary, secondary and tertiary levels.
2. There is need to decentralize government efforts in managing child disability issues as a cross cutting issue between health and other government sectors, this can be done through expanding rehabilitation services as indicated in 1 above.
3. Cerebral palsy has been recognised as a highly prevalent cause of child disability, reasonable efforts need to be made to manage children irrespective of their location and socio economic status to access medical and rehabilitation services.
4. A situation analysis within the ministry of health strategic direction should be done to assess government response to disability health.

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How Do Diets of Infants and Young Children Aged 6-23 Months Whose Care Givers Are In Care Groups Differ From Other Infants? A Case of T/A Kalumo, Ntchisi, Malawi

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ABSTRACT

Malawi adopted the care group model to foster dietary diversity and appropriate feeding practices among the under five children through nutrition education to caregivers, thus reduce malnutrition, a problem of public health concern. Through the model, 10 to 15 households receive information and counselling through volunteers. A study was conducted to assess the effectiveness of this approach in infant and young child feeding practices. Purposive and simple random sampling was used to select 70 women (35 Care group, and 35 non-care group). Additional information was collected through focus group discussions and key informant interviews. Although 54.3% of the children whose care givers were in care groups and 42.9% in the non-care groups, achieved minimum dietary diversity, and 80% and 71.4% achieved minimum meal frequency in the same order, differences were not significant. About a quarter of the children achieved the minimum acceptable diet in the non-care group compared to 34.3% in care groups. Whether or not one belongs to care group does not matter and there is need to consider an extensive evaluation of the model to inform practice for what will work best for community nutrition and health.

Key words: Care Group, Non-Care group, Diets, Infants and Young Children.

INTRODUCTION

Malnutrition remains a major challenge in Malawi. It contributes to high morbidity and mortality rates among children under five years and other vulnerable groups such as pregnant and lactating women (Mw Govt., 2012). Nutritional well-being of a population is the reflection of the performance of its social and economic sectors, and to a large extent an indicator of the efficiency of national resource allocation (FAO/WHO, 1992). Good nutrition in early childhood is essential for the normal growth and development of a child (Neumegen, 2008). The effect of under-nutrition on young children can be devastating and enduring. It can impede behavioral and cognitive development, educability and reproductive health, thereby undermining future work productivity (Martorell, 1996). An estimated 6% of under-five deaths can be prevented by ensuring optimal complementary feeding among which dietary diversity and meal frequency are most important ones, significantly contributing to the realization of Millennium Development Goal 4 (Savy, *et al*., 2013).

While economic and contextual factors are strong determinants of child nutritional status, immediate causes such as dietary diversity and meal frequency are associated with nutritional outcomes particularly stunting, independent of socio-economic determinants. The first two years of life are a critical window for ensuring optimal child growth and development (WHO, 2008), because even with optimum breast feeding, children will become stunted if they do not receive sufficient dietary diversity and meal frequency after 6 months of

age (Beyene *et al.,* 2015). Poor child feeding practices and high rates of infections have a detrimental effect on health and growth of children less than two years of age. The transition period from exclusive breastfeeding to two years is critical window for optimal growth and development of the child. During this period, appropriate, safe, adequately nourished and frequent feeding is essential. For vulnerable infants and young children, the problem is particularly critical because they need energy and nutrient dense foods to grow and develop both physically, mentally, and to live a healthy life (Arimond, 2004).

The major measures of under-nutrition in developing countries include stunting, wasting and micronutrient deficiency (Black et al., 2008). Children aged 6–23 months are at a greater risk to suffer from under nutrition. It is during this period that a child moves from breast milk to family diet and most poor children growth falter due to combination of illness and inadequate diet. When introduced to solid foods, the child may suffer from indigestion, infection, insufficient food or a combination of these. This can result in childhood under nutrition (Hober, 2012). Dietary diversity refers to an increase in the variety of foods across and within food groups (WHO/FAO, 1996) capable of ensuring adequate intake of essential nutrients that can promote good health (Ruel, 2002). Since no single food can contain all nutrients, Labadarios (2011) noted that the more food groups included in daily diet, the greater the likelihood of meeting nutrient requirements. Dietary diversity is crucial to the supply of a broad variety of micro-and macronutrients. It has long been recognized by nutritionists as a key element of high quality diets. Increasing the variety of foods across and within food groups is recommended in most dietary guidelines internationally (Ruel, 2003; Kennedy *et al*., 2007).

The care group model was adopted to foster dietary diversity and appropriate meal preparation through nutrition education to caregivers. This is aimed at reducing stunting in under-five children at community level with lessons covering household behaviors to promote maternal and child health (Davis, 2011). Through the use of volunteers at the household level, rather than paid promoters, the Care Group model presents a low cost approach for program delivery. The Care Group model was developed by World Relief, an international NGO based in Baltimore and its child survival staff working in Gaza Province, Mozambique in the late 1990s (CORE Group *et al.,* 2014). The Care Group model approach involves the formation of mothers' groups of approximately 10 Care Group volunteers, each responsible for visiting on average 10 households closest to their home (Davis 2011). A facilitator visits a Care Group every 2–4 weeks to teach the volunteers 1–3 new key messages to share with their neighbors. Household visits by Care Group volunteers are conducted every 2 weeks.

This study sought to find out differences in diets between infants and young children whose caregivers are in Care Group and those not in Care Groups to assess the effectiveness of the model in a rural set up. Child malnutrition contributes to stuntedness, mental and physical growth retardation world-wide, and to the death of many children under five years old. Over 50% of 13 million child deaths each year are due to combination of illnesses and malnutrition (NSO, 2015).
Even though NGOs and the government are implementing nutrition interventions using the Care Group model in some of the areas including Ntchisi district, malnutrition seems to be on a higher side reaching 39.5% as indicated by MDHS 2015-2016. Knowledge on infant and young child feeding is now being imparted to caregivers through the Care Group model. However, it is not clear whether this model is working since no studies that compare children whose care givers belong to care groups and those not in care groups are scanty. Such a gap makes it difficult to promote Care Groups for improved maternal, infant and young child feeding. It is for this reason why this study was conducted to assess if the model is really helping to foster dietary diversity practices among infants and young children. The study findings provide evidence to government and its stakeholders on the role of Care Groups in improving infant and young child feeding practices, thus a basis for decision making around its promotion of use in nutrition and health programming.

MATERIALS AND METHODS

Study area
The study was conducted in Traditional Authority Kalumo, one of the T/As where Care Groups were established by World Relief Malawi in Ntchisi district. The area, located 4 Kilometers from the District Council, was purposively selected because it has well-structured Care Groups and also has villages where Care Groups have not yet been introduced, making it suitable for the study.

Study design
A community based cross-sectional study design was used.

Study participants
Participants were caregivers of infants and young children aged 6-23 months living in TA Kalumo area in Ntchisi district.

Sampling
Selection of Subjects
Subjects were selected using purposive sampling and simple random sampling. Health registers from the area, were used to purposively draw the list of households with infants and young children aged between 6-23 months. Out of 120 households with children under two years, 35 households whose caregivers were in Care Groups were sampled using simple random sampling. On the other hand, out of 73 households with under two children, 35 households whose caregivers were not in Care Groups were also sampled. Caregivers were adequately briefed about the study and gave verbal consent to participate in the study.

Sample size
The study recruited a total of 70 households (35 households whose caregivers belong to Care Groups, and 35 households not in Care Groups).

Data collection
Quantitative data was collected using questionnaires which were administered to the care givers while checklists were used to interview key informants (staff responsible for care groups and care group volunteers) in order to acquire qualitative information related to the care groups being implemented in T/A Kalumo. A focus group discussion guide was developed and used to get caregivers perceptions of care groups including perceived benefits.

Data Analysis
Data collected was entered and analyzed using the Statistical Packaging for Social Scientists (SPSS) version 21, where descriptive statistics (means, frequencies and cross tabulation) were generated. Excel was used to analyze qualitative data which was collected from key informants and focus group discussion where common similarities and differences among responses were summarized and discussed.

RESULTS AND DISCUSSION

Socio-demographic characteristics of participants
The results in Table 1, show the socio-demographic characteristics of the caregivers. Most of the households interviewed were headed by men (60) representing 85.7%, and only 10 (14.3%) were headed by females. There were significant differences in household head by gender (P= 0.041). Most of the household heads and caregivers, were in the age range of 26-35 years, and there were significant differences in care givers age (P= 0.001) with most care group care givers (20) being older than non-care group care givers (15). About 86% of the household heads left school at

primary level but only 3 people had never attended school. Among caregivers attending Care Groups, the majority (68.6%) had been in Care Groups for more than 5 years.

Table 1: Socio-demographic characteristics of participants

Characteristic	CG		NCG		P-Value
	n	%	n	%	
Sex of House hold Head					
Males	33	94.3	27	77.1	0.
Female	2	5.7	8	22.9	0.004
Age (years)					
26-35	15	42.9	15	4	
36-45	15	42.9	8	2	
46-55	4	11.4	2	5.7	
Highest Education					
Primary	30	85.7	33	94.3	
Secondary	4	11.4		0	
None	1	2.9	2	5.7	
Age of Care givers (years)					
15-25	4	11.4	16	45.7	0.001
26-35	20	57.1	15	42.9	
36-45	9	25.8	4	11.4	
46-55	2	5.7	0	0	
Duration in Care Group among care givers in care groups					
1-2 years	7	20.0	N/A		
3-4 years	4	11.4	N/A		
5 years or more	24	68.6	N/A		

Characteristics of the sampled Children

In Table 2 below, results show that 41.4% of the children were males while 58.6% were females. About 32% were in the age range of 6-8 months, 45.8% were in the age range of 9-12 months and the majority were aged between 12 and 24 months. There was a significant difference in terms of children's age both in care groups and in non-care groups (P= 0.001).

Table 2: Characteristics of the sampled children

Characteristic	CG		NCG		P-Value
	n	%	n	%	
Sex of House hold Head					
Males	16	22.9	13	18.5	0.
Female	19	27.1	22	31.5	0.004
Age (Months)					
6-8	3	8.8	8	22.8	0.001
9-12	6	17.1	10	28.7	
12-24	26	74.3	17	28.8	

Child feeding Practices

Breastfeeding practices

All the 70 children reported to have ever been breastfed and 88.6% of the children were still being breast fed while 11.4% stopped breastfeeding before two years. It was observed that 22.9% of the children whose caregivers attend Care Groups stopped breast feeding earlier than those children whose caregivers were not attending Care Groups. This means that, in terms of breast feeding continuity, the number of non-care group care givers was significantly more than care group care givers (P=0.05).

Table 3: Infant and young children breast feeding practices

Characteristic	CG		NCG		P-Value
	n	%	n	%	
Breast feeding Practices					
Ever breastfed	35	100	35	100	0.
Still breastfeeding	27	77.1	35	100	0.004
Stopped breastfed	8	22.9	0	22.9	0.001

Types of food groups consumed by children.

Data was collected on types of foods consumed by children 24 hours preceding the survey. Results showed that all the children (100%) had consumed foods from staples. Vegetables were consumed by 85.7% of the children whose care givers were attending care groups and 88.6% of the children whose care givers were not attending care groups. Children whose mothers were in care groups ate more fruits (48% versus 34.3%), food from animals (51.4% versus 25.7%), legumes (48.6 versus 37.1) as well as fats and oils (85.7 versus 57.1). Statistical comparison showed that differences were not significant in consumption of staples (P= 0.382), Vegetables (P= 0.231), fruits (P= 0.341), food from animals (P=0.726) and legumes (P=0.27). However, a significant difference was observed in consumption of food cooked with fats and oils (P=0.08) between the two categories. As shown in Figure 4.1, more care givers in care group, were giving children foods cooked with cooking oil than those not in care groups.

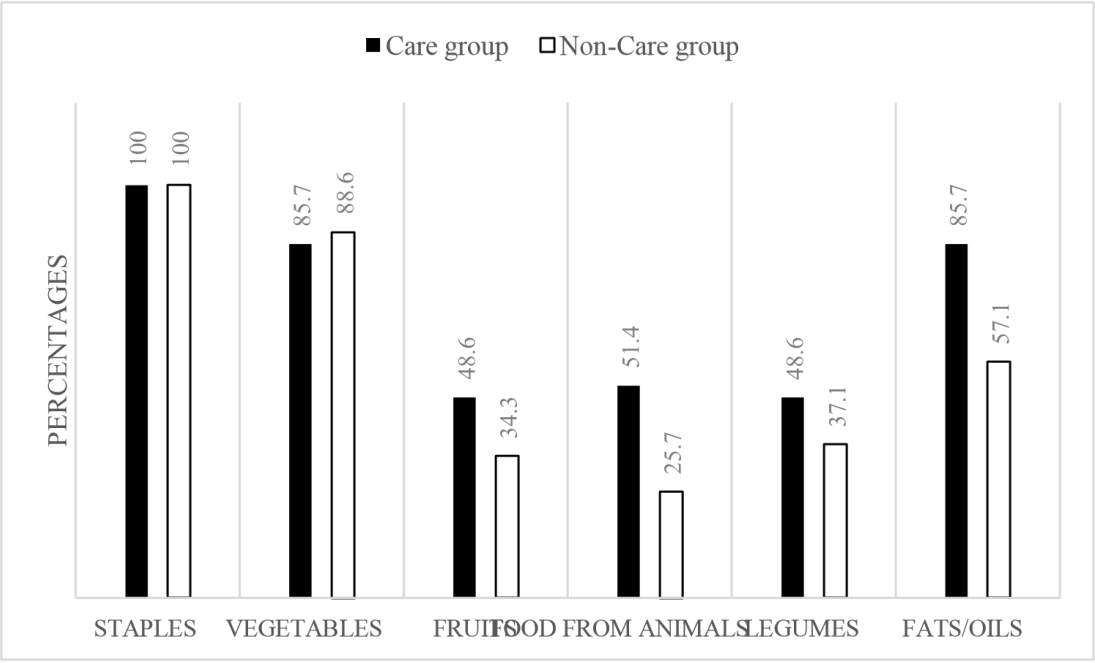

Figure 1: Types of food groups consumed by children previous day

Dietary diversity.

Minimum dietary diversity was determined by the proportion of children 6–23 months of age who received foods from 4 or more food groups. A cut-off of at least four out of the Malawi six food groups is associated with better quality diets for both breastfed and non-breastfed children (MDHS, 2015/2016). Comparing the two groups, 54.3% of the children whose care givers were attending care groups achieved minimum dietary diversity while only 42.9% achieved minimum dietary diversity in the other group. However, from statistical comparison, there was no significant difference in dietary diversity among the children in these two groups (p=0.281).

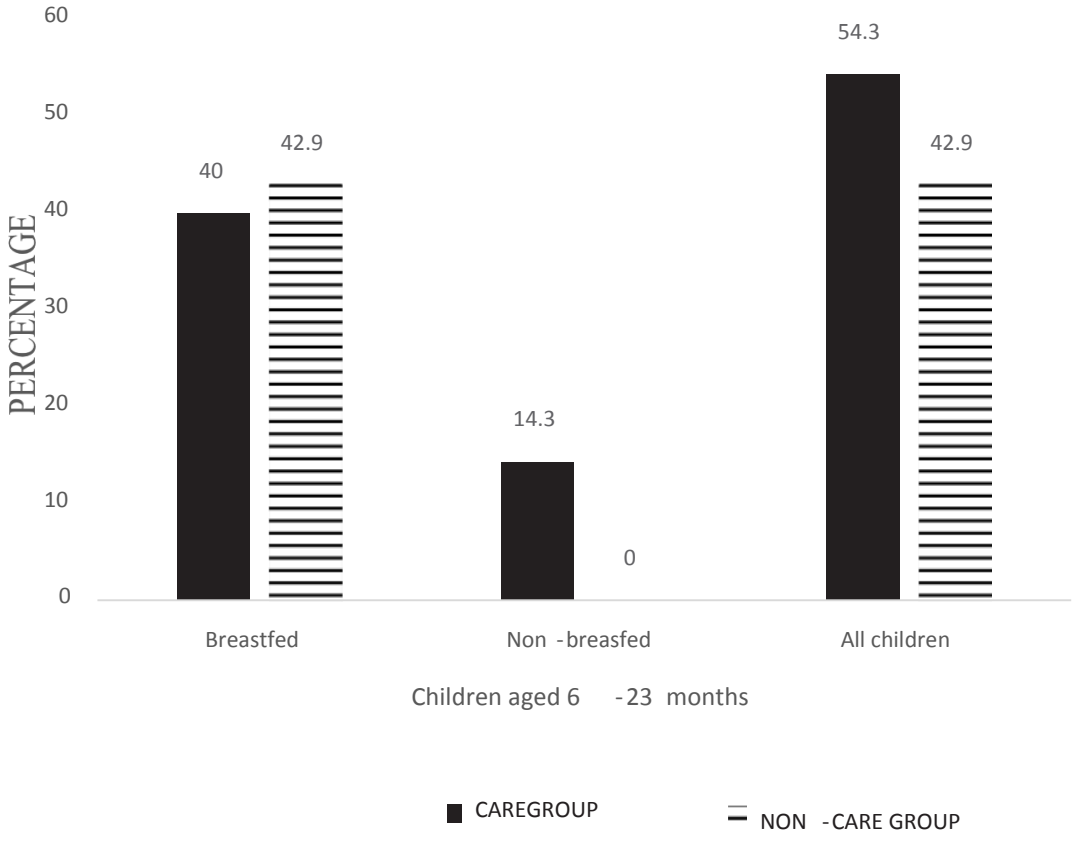

Figure 2: Proportion of children meeting minimum dietary diversity by group.

Minimum meal frequency

Minimum meal frequency was determined by the proportion of children 6–23 months of age who ate foods 3 times or more per day. Figure 3 shows that 62.9% breastfed and 17.1% non-breastfed children whose caregivers were attending care groups achieved minimum meal frequency while 71.4% children whose care givers were not attending care groups achieved minimum meal frequency. However, independent-samples t-test showed no significant difference in meal frequency between care group and non-care group children (p=0.346).

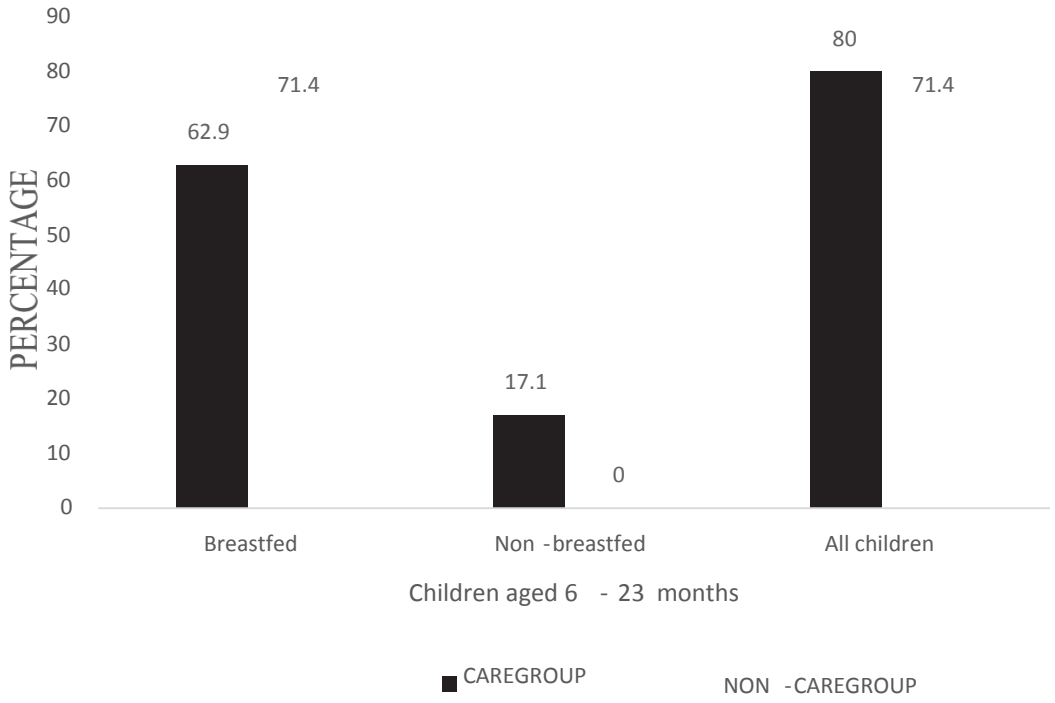

Figure 3: Meal frequency among infants and young children.

Reported practice on feeding times and quantity

Infant and Young Child Feeding recommendations in terms of frequency and quantity by Scaling Up Nutrition (SUN), explains that a child less than 6 months should be exclusively breastfed at least 8 times per day and on demand every day. For children who are 6-8 months should be fed ½ cup/meal and 3 times a day, 9-12 months, ½ -2/3 cup/meal + 1 snack and 4 times a day while children between 12 to 24 months should eat a quantity of ¾ cup meal and 5 times a day.

In terms of reported practice, similar number of care givers were practicing as recommended on feeding frequency (24 versus 35) for both groups. However, there were higher proportion following right practices among care givers in the care group than those not in care groups. Within age categories, for example, all care givers (100%) with children aged 6-8 months were following the recommended practices compared to 87.5% in non-care group. Interestingly, there were slightly more care givers of children aged 9-12 months in the non-care groups following recommended practices compared to those in care groups although the difference was 70% versus 66%. Within the age category of 12-24 months, 65% of the care givers in care groups, were following the recommended practice compared to 58% of non-care group care givers. It was observed that as the age of the child increases, the number of care givers following the right practice on feeding frequency was decreasing in both groups and this may lead malnutrition because as the child is growing, the nutritional needs required by body also increases. Statistically, there were no significant differences in proportion of mothers following the recommended practice in feeding times among those in care groups and those not in care across all age categories as follows; 6-8 months (P= 0.568), 9-12 months (P= 0.898) and 12-24 months (P=0.672).

Table 4: Proportion following recommended practice on feeding frequency by age group

Age (Months)	Recommended feeding frequency	Proportion following recommended practices				Pvalue
		Care group		Non-care group		
		n	%	n	%	
6-8	3 times/day	3	100	7	87.5	0.568
9-12	4 times/day	4	66	7	70	0.898
12-24	5 times/day	17	65	10	58	0.672

Results in Table 5, show that all (100%) care group care givers with children aged 6-8 months were following the recommended practice in feeding quantity compared to 62.5% of non-care group care givers. There were more (60%) care givers not in care groups following the recommended practice than care givers in care groups (33.3%) within the age category of 9-12 months. Within the age category of 12-24 months, 56% of care group care givers were following the recommended practice in feeding quantities as compared 58% of non-care group care givers. It was also observed that as the age of the child increased, the proportion following recommended feeding quantity decreased. This may have an implication on the child because it may lead to malnutrition due to inadequate dietary intake. From statistical comparison, there were no significant differences in proportion of mothers following the recommended practice in feeding quantities among those in care groups and those not in care groups at all ages such as 6-8 months (P=0.256), 9-12 months (P= 0.334) and 12-24 months (P= 0.672).

Table 5: Proportion following recommended practice on feeding quantity by age group

Age (Months)	Recommended practices quantity	Proportion following recommended				feeding	P-value
		Care group		Non-care group			
		n	%	n	%		
6-8	½ cup/ meal	3	100	5	62.5		0.256
9-12	½ -2/3 cup/meal + 1 snack	2	33.3	6	60		0.334
12-24	¾ cup/meal + 2 snacks	17	65	10	58		0.672

Type of porridge and snacks provided to children aged 6-23 months

Care group care givers (65.7%), provided mixed porridge to their children whereby some nutritious foods like pulses and nuts, animal source foods, green leafy vegetable, energy rich foods and Vitamin A rich foods were added to the child's porridge. It was found that the majority (43%) added pulses and nuts, 19.8% added green leafy vegetables and energy rich foods and about 3% added Vitamin A rich foods to the porridge. Almost half (45.7%) of the non-care group care givers

provided plain porridge to their children. Only 29% provided mixed porridge to their children with 25% adding pulses and nuts to the porridge and 2.9% adding animal source foods to the porridge. All the care givers who attended care groups, expressed that they feel confident in preparing foods for their children since they acquire the knowledge from care groups and participate in cooking demonstrations conducted during some of their meetings. Unlike the care group care givers, some of the non-care group care givers said that they do not feel confident in preparing foods for their children due to lack of knowledge and lack of a variety of foods to add in their children's porridge. It is recommended to provide snacks between meals to children aged 6-23 months for growth and good health. About 97% of the care group care givers, provided snacks to their children, and the majority (94.3%) expressed that it is important because it promotes children's good health. However, it was found that only 22.9% non-care group care givers were providing snacks to their children even though 85.7% of the care givers knew that it was important to provide snacks to children for good health and growth. As reported by the care givers on the types of foods given to children as snacks, more mothers (24 out of 35) in care groups provide fruits to their children than those not in care groups (5 out 35).

Proportion of children meeting the minimum acceptable diet.

To determine minimum acceptable diet, number of children who achieved both minimum meal frequency and minimum dietary diversity were recorded. The feeding practices of 34.3% (12) children whose care givers were in care groups and 25.7% (9) children whose care givers were not in care groups met the requirement for minimum acceptable diet. However, independent-samples t-test showed no significant difference in minimum acceptable diet between the two categories (p=0.441).

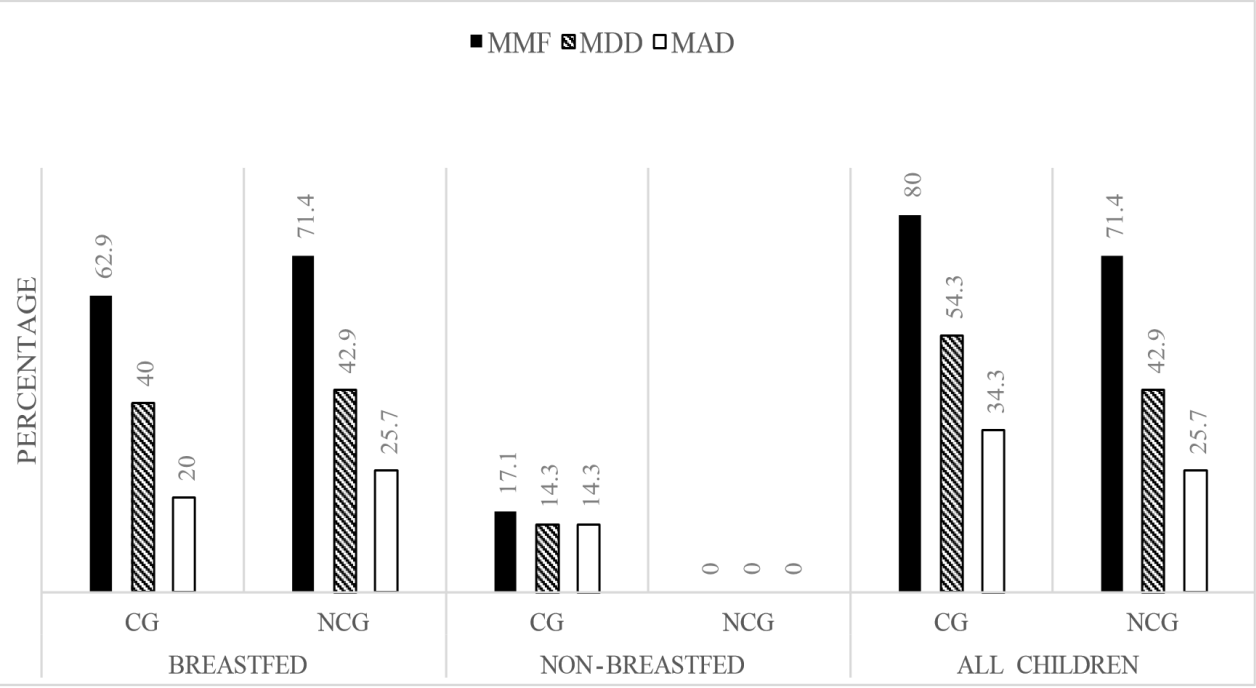

Figure 4.4: Proportion of children meeting the minimum meal frequency, dietary diversity and acceptable diet by group.

Age appropriate knowledge of feeding

There are no statistical differences in knowledge on appropriate feeding times in relation to child age among care group and non-care group members. Table 6 shows that 54.2% care group care givers against 42.8% non-care group care givers have knowledge in feeding times (breastfeeding) of children less than 6 months (P= 0.346). At 6-8 months, 65.7% versus 42.8% (P= 0.349) care group and non-care group care givers respectively, have knowledge on feeding times. Figures are higher

in terms of knowledge in both care groups and non-care groups members (85.7% versus 74.2%) at the age of 9-12 months though statistical differences are still not different (P= 0.239). Interestingly, the percentages are the same (54.2%) in both groups on knowledge on feeding times at 12-24 months with P=1.0. However, it was observed that as the age of the child increased, the knowledge proportion in feeding frequencies also increased.

Table 6: Proportion of knowledge about feeding frequencies

Age category (months)	Recommended practice	Care group		Non-care group		Pvalue
		n	%	n	%	
Less than 6	At least 8-12 times/day (Breastfeeding)	19	54.2	15	42.8	0.346
6-8	3 times/day	23	65.7	20	57.1	0.349
9-12	4 times/day	30	85.7	26	74.2	0.239
12-24	5 times/day	19	54.2	19	54.2	1.0

Table 7 shows that all care givers in care groups (100%) and 97.1% non-care group care givers have knowledge in feeding quantities at less than 6 months. There are no significant differences at this age between the two groups (P= 0.321). At 6-8 months, 71.4% versus 60% (P= 0.798) care group and non-care group care givers respectively, have knowledge on feeding quantities. In terms of knowledge in both care groups and non-care group members at the age of 9-12 months, it was 74.2% versus 51.4% with P=0.209 which is non-significant different. The percentages at 12-24 months were 74.2 and 45.7 among the care group and non-care group members with P= 0.142 which reflect a non-significant difference between the two groups. However, the percentages in knowledge about feeding quantities were the same (74.2%) at 9-12 and 12-24 months of age among the care group care givers and they were decreasing with increasing age of children among the non-care group care givers.

Table 7: Proportion of knowledge about feeding quantities

Age category (months)	Recommended practice	Care group		Non-care group		Pvalue
		n	%	n	%	
Less than 6	On demand (Breast feeding	35	100	34	97.1	0.321
6-8	½ cup/meal	25	71.4	21	60	0.798
9-12	½-2/3 cup/meal + 1 snack	26	74.2	18	51.4	0.209
12-24	2/4 cup/meal + 2 snacks	25	74.2	16	45.7	0.142

Knowledge on introduction of complementary foods

Care givers who were attending care groups (100%) and those who were not attending care groups (83%,) reported to have knowledge on the right age when should infants and young children must

be introduced to complementary foods, but results showed that a number of care givers were failing to practice the reported behaviors. Some reasons cited were the child was crying too much or being advised to do otherwise by mothers or relatives. These reasons forced the care givers to introduce complementary foods earlier to their children (before 6 months). Some women indicated that when a child is crying too much, it is an indication that the milk alone is not enough for the baby therefore must be introduced to complementary foods. Early introduction of complementary foods, including water, has been associated with increased morbidity from diarrheal disease (Popkin et *al*., 1990), linear growth faltering (Caulfied et *al*., 1996) and increased risk of mother to child HIV transmission (Coutsoudis et *al*., 2001). In Malawi infection rates in the first year of life are considered high and are associated with significant post neonatal mortality (Verhoeff et *al*., 2004), and there are low rates of exclusive breastfeeding.

Table 8 shows ages when different foods were introduced to children, and it was found that most children whose care givers did not attend care groups, were introduced to different complementary foods before 6 months as compared to those children whose care givers attended care groups. In both groups care givers introduced complementary foods to their children following advice from health personnel although child crying was frequently reported as a reason for early introduction of foods by care givers not in care groups. Other reasons were following advice from mother and other relative. However, in terms of introduction of complementary foods, there is a significant difference between care group care givers and non-care group care givers (P= 0.001). Non-care group care givers introduce most of the complementary foods to their children before 6 months. It was also found that non-care group care givers never introduced some complementary foods such as infant formula, tinned milk and juices to their children not because of nutrition related reasons but they reported that because they could not afford these.

Table 8: Introduction of complementary foods by group.

Food item	**Before 6 months**		**>6 months**		**Never introduced**		
	CG	**NCG**	**CG**	**NCG**	**CG**	**NCG**	**P-value**
Water	8	16	27	19	0	0	0.001
	7	6	27	19	0	14	0.001
Infant formula							
Tinned milk	8	11	17	21	10	3	0.001
Juices	3	16	31	18	1	1	0.001
Yoghurt	3	14	32	20	0	1	0.001
	5	17	30	18	0	0	0.001
Thin porridge							
Other liquids	5	15	30	20	30	20	0.001

Information sources.

Figure 5 shows that 25 out of 35 care group care givers (71.4%), reported care group as their main source of messages, while 27 out of 35 non-care group (77.1%) reported that a hospital was their main source of information. There were fewer caregivers who reported that mobile clinic and radios were their main source of childcare messages. This shows that there is still a gap on access

to information that needs to be filled by empowering extension workers both from health and agricultural sectors including NGO's since they directly work with the communities in order to make these messages widely accessible to caregivers.

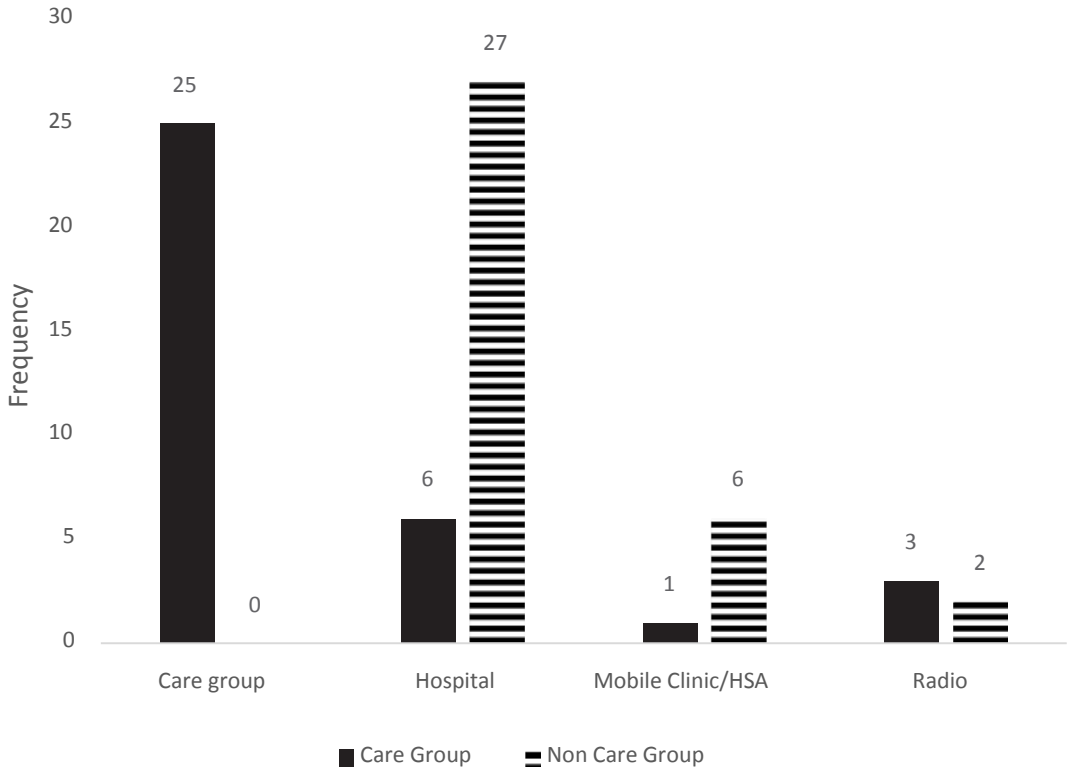

Figure 5: Main source of information

Benefits of the care group model

All 35 care givers that were attending care groups, reported that care group model was beneficial to them. 34.3% of the caregivers reported that improved food preparation methods was the key benefit and the least (8.6%) reported improved feeding practices (Table 9).

Table 9: Reported key benefits of care group

Key benefits	Number of care givers	Percentage (%)
Improved food preparations methods	12	34.3
Improved hygiene and sanitation practices	11	31.4
Improved child nutrition	5	14.3
Improved child health	4	11.4
Improved feeding practices	3	8.6

However, care givers reported to have made specific changes in child feeding practices. 15 out of the 35, changed in food preparation methods, 12 changing in food diversification, 6 in frequency of feeding their children and 4 changed in their hygiene and sanitation practices.

Figure 6, shows the information obtained through care groups. It was found that exclusive breast feeding and feeding during lactation were the information mostly acquired by many caregivers and the least acquired was information on diarrhoea prevention and dietary diversity. However, there was none reported to have acquired information on dietary diversity as shown in Figure 6. This might be because most of the times dietary diversity is incorporated in a number of topics such as complementary feeding, feeding during pregnancy and lactation whenever one is conducting nutrition education sessions. These topics cannot be delivered without mentioning dietary diversity and that is why caregivers hardly mentioned as a stand-alone topic.

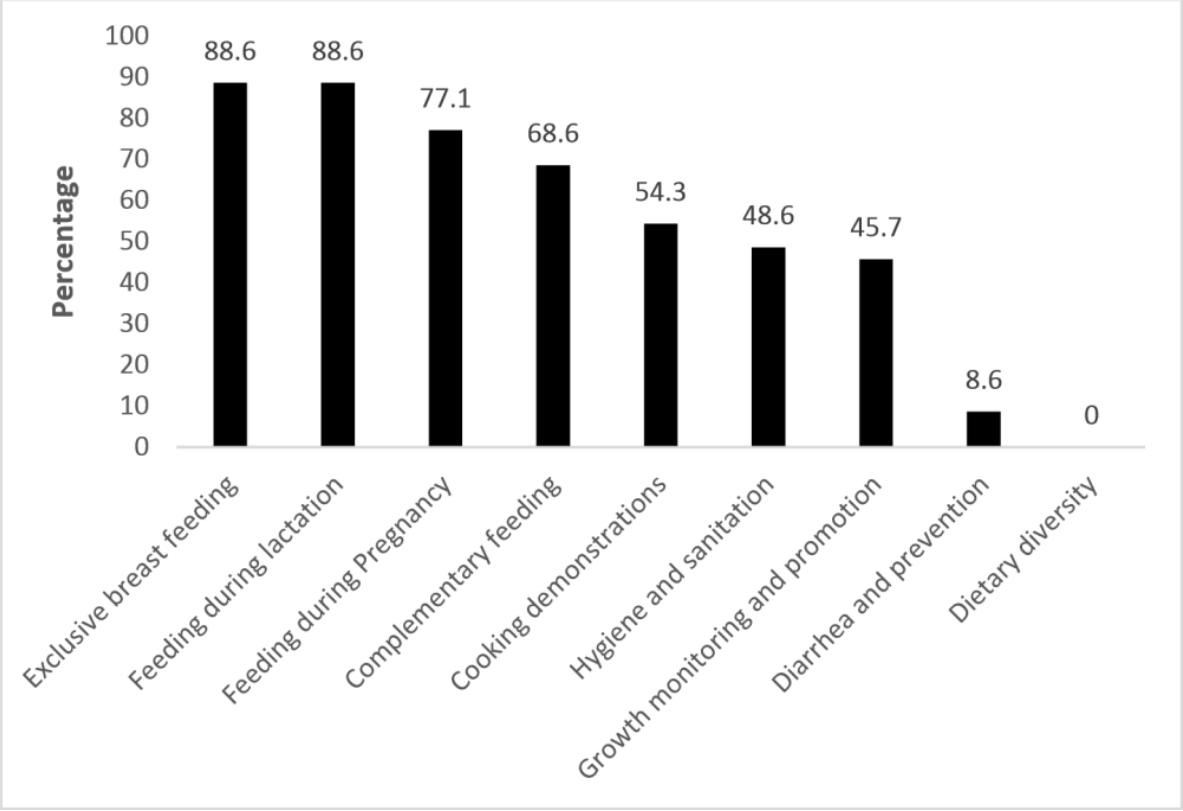

Figure 6: Main Information acquired through care groups

Benefits and sustainability

Perceived benefits

There were similarities which were reported by the key informants and focus group discussion participants on the perceived benefits of care groups. It was reported that care group model is a cheaper way of disseminating information since the lead mothers work on voluntary basis, the promoter operates from within the area, and resources that are used (for example during cooking demonstrations) are those that are locally found in the communities. In addition, it reduces the facilitator's and promoter's work load, and promotes a sense of ownership to the members since they plan programs and activities on their own and there is flexibility in choosing what should be done.

Actual benefits

It was reported that people have improved on sanitation and hygiene practices, dietary diversification, exclusive breast feeding and improved food preparation methods. The facilitator and the promoter confirmed to have observed these benefits in the care givers households during follow up visits. Care givers themselves, reported that at first, they did not care about their children and other household members foods from the six food groups and were just cooking foods for their

children anyhow. Breast feeding babies less than 6 months exclusively, constructing toilets, hand washing facilities, bathrooms and rubbish pits was also rare, but after learning these, they started implementing them in their households and have seen benefits like reduced diseases which has led to improved health status of their children and other household members. It was reported that the model is a sustainable approach since operations are possible with limited external support as compared to other models which rely much on external support. Care givers also learnt tactics of feeding their children who were "*fussy"* eaters by playing with them, singing for them, eating together with them among others. Through care groups, they have learnt to prioritize food for consumption and not for sale which has made the diversification simpler than before.

Sustainability

Challenges and recommendations

There are a number of challenges that care groups face during its operations such as; low turn up during meetings, inadequate trainings to the promoters, poor understanding of care group model among the cluster leaders upon introduction which initially led to withdraw of some members from the care groups when they realized that their expectations of receiving incentives was not achieved and cluster leaders not visiting all the assigned households as required.

Stakeholders recommended capacity building trainings to care group members including promoters; giving care group members incentives such as small livestock, t-shirts, bicycles as well as zitenje as part of motivation despite them being volunteers, and conducting training visits or field tours to other care groups to learn from others. It was also recommended that implementers should frequently visit the care groups to hear the volunteers challenges and address them, and that stakeholders adopting the model should follow the right criteria for care group implementation at all levels. The care group implementation criteria includes the following steps; community mobilization, household registration, cluster formation, selection of leaders, formation of care groups, selection of promoters, capacity building for care group promoters and cluster leaders begin household visits first interventions.

CONCLUSIONS AND RECOMMENDATIONS

It was observed that care group members fed their children better than non-care group members in terms of feeding frequency, dietary diversity and minimum acceptable diet. However, there are no significant differences in minimum dietary diversity, minimum meal frequency and minimum acceptable diet in children aged 6 to 23 months between the two categories. Therefore, whether or not one belongs to care group does not matter and there is need to consider an extensive evaluation of the model to inform practice for what will work best for community nutrition and health**.**

Recommendations

- Based on the findings from this study, the following recommendations could be of help to relevant stakeholders;
- Education around dietary diversity must be strengthened.
- The study should be repeated with lager sample size in another district in Malawi, where interventions are implemented using care group model to further strengthen the evidence and knowledge around care groups.
- Because of the potential for improved infant and young child feeding, more efforts and actions are needed to address existing challenges particularly around volunteer motivation.

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AGRICULTURE, IRRIGATION AND FOOD SECURITY

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Problems of Farmers in connection with Status of Irrigation Facilities in Agricultural Sector: A special reference to-of Mangochi District

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ABSTRACT

This paper focuses on the Problems of "Irrigation facilities for Agricultural Sector in Chiwawula sub-region in Mangochi District". The poverty and seasonal agricultural un-employment are the major problems of this study area in Mangochi District. Even though, most of the people have own agricultural land and cultivate agricultural products such as corn, sugarcane, cotton, potatoes, tomato, several people along with cattle and goats, there is no sufficient growth in agriculture, due to lack of facilities and supportive policy to sustainable development in Agriculture, especially the irrigation facilities. The population of the study consist farmers of eight villages of Chiwawula Sub-region in Mangochi District of Malawi. Study was conducted with the objectives to ***i)*** *describe the Socio- economic background of the farmers in these villages, the nature and type of cultivation in their agricultural field ii) understand the problems of farmers with respect to in-adequate Irrigation system, scientific methods adopted in agriculture iii) suggest the implementation of proper Irrigation and Scientific method in Agriculture for green revolution. A sample size 40 was achieved through adopting the non-probability /purposive sampling method with a decision of selecting 5 farmers from each village, to collect the pertinent primary data. Relevant secondary data were collected from the library books, Journals, newspapers, magazines, and websites. The primary data were collected through Interview and unstructured observations to understand socio- economic background of the farmers, nature and type of cultivation in their agricultural field, and problems faced by farmers specially of in-adequate Irrigation. Reference period for data collection was 1-29 June 2017. Results show that mostly, farmers are very poor as an outcome of helplessness, lack of supportive policy, lack of access to development, and require competency to market their Agricultural products. Farmers require more awareness on efficient irrigation management. As the rain fed agriculture is vulnerable to changes, irrigation agriculture to be intensified in Mangochi district through increased awareness on land and irrigation management with the help of technological development. Policies and funding should be properly implemented.*

Keywords: irrigation, agriculture, farmers, Mangochi

INTRODUCTION

This paper focuses on the Problems of farmers in connection with status of irrigation facilities in Agricultural Sector in Chiwaula sub-area in Mangochi District. It is a southern most district of Malawi; Malawi is a sub-Saharan African country located to the south of the equator. It shares borders with Tanzania in the north and north east, Mozambique to the east, south and southwest, and Zambia to the north and northwest. It has a population of about slightly over than seventeen million people. Divided into three regions of the North, Centre and South, The Malawi population is predominantly rural, with estimates suggesting that 86 percent of Malawians live in rural areas. The poverty and seasonal agricultural un-employment are the major problems of this country, particularly in this study area in Mangochi District. Even though, most of the people have own agricultural land and cultivate crops such as Maize, sugarcane, groundnut, tomato, sweet potato, beans, carrot and banana etc, several people along with cattle and goats. The natural resources like fertilized agricultural land and ground water facilities are available in this area, because it is surrounded by largest river connecting three countries Malawi, Zambia and Mozambique. There is no sufficient growth in agriculture, due to lack of financial facilities and supportive policy to sustain development in Agriculture, especially the proper irrigation facilities.

Malawi is a member of several international organizations including the Commonwealth, the UN and some of its child agencies especially like UNICEF, the IMF, the World Bank, the African Union and the World Health organization. Malawi is among the worlds -least developed countries. The economy is heavily based in agriculture. Malawi government faces a number of challenges among which are the following/-

1) Proper Irrigation and technological input in Agriculture
2) In building and expanding the economy,
3) Improving education,
4) Healthcare,
5) Environmental protection
6) Struggling in financial independent.

Status of Agriculture and Industries in Malawi

The main agricultural products of Malawi include tobacco, sugarcane, cotton, tea, corn, potatoes, sorghum, panama and some vegetables most of the people along with cattle and goats. The main industries are tobacco, tea and sugar processing, sawmill products, cement and consumer goods. World Health Organization moves against the particular type of tobacco that Malawi produces burley leaf. It is seen to be more harmful to human health than other tobacco products. There are some factors that affect the farmers in their socio-economic and their cultivation of agricultural products. The two major factors also noted here i) Socio-economic factors, ii) Scientific factors

Generally, there are some factors that affect the farmers in their socio-economic and their cultivation of agricultural products in Malawi, particularly in Mangochi District. The two major factors also noted here are: -

i) Socio-economic factors,
ii) Scientific factors

I) Socio-economic factors

The socio-economic characteristics of the people of this study area also been homogeneous. i.e. Socio-economic background is very poor. The poverty and un-employment are the major problems in Mangochi District, especially this study area. Because most of the farmers they have small land holdings and only poor yield in their agricultural field. They have holdings of two acres or less,

which does not allow the use of mechanized method of cultivation. The fragmented and small size of holding is an important factor of low agricultural productivity. There is no sufficient development in agricultural field. Most of the farmers are very poor as a result of helplessness, lack of supportive policy, lack of access to inputs, lack of financial support, in-competent market to their Agricultural-products and lack of road networks for transportation of the agricultural products.

II) Scientific factors

a) Lack of irrigation facilities

Lack of Irrigation services also play a crucial role in failure of agriculture and generate the poverty in Malawi, particularly in Mangochi District. There are no adequate functional facilities to the farmers adopt proper irrigation facilities in their land, because lack of electricity and inadequate supply of loans from institutional credits are mostly not able to adopt proper irrigation facilities. Most of the farmers practicing the old method of irrigation facilities in their land and unable to purchase of modern inputs of agriculture in particular time. These are the major problems of seasonal un-employment and poverty among the people.

b) Lack of mechanization

The use of mechanization was introduced in Malawi, yet most of the villages include this study areas do not access these new modern technologies. Old farming practices are still being used in agriculture.

c) Inadequate supply of input

The supply of modern inputs like improve seeds, organic fertilizer, pesticides and mechanization are not only costly, but also inadequate and irregular. The inadequate availability of the modern inputs at the time and prices is also a problem in the expansion of agricultural production

d) Inadequate Agricultural research

Due to lack of sufficient fund allocated for particularly in agricultural research, the innovation of new varieties of crops, organic fertilizers, pesticide, farm machinery and animal health services remains slow.

e) Lack of extension service program

In order to raise farm productivity, the extension service program needs to be extended in the rural areas. There is need to increase number of extension workers to educate farmers for the adoption of agriculture technology with proper irrigation is an enormous work and has to be carried out systematically and efficiently. The lack of funds again is a problem in the proper implementation of this programme. The result is slow growth in agricultural production.

g) Climate change

Climate change is also one of the elements that are leading to poor or low yield of production in agriculture. In-sufficient rainfall pattern might be experience in a year which could not be enough crops to mature. Sometimes rain might come in abandoned which could in turn produce runoff and washing away crops and humus in the soil. The people have a great impact that contributes to climate change such as deforestation, poor farming and soil tillage.

Research Methodology

The Universe of the study is the Chiwaula sub-area consists of several villages like Chiwaula, Steven, Miseu, Nsamu, Namasano, Mbuluwata and Sawasahaa etc in Chimwala Traditional Authority, Mangochi District of Malawi. This paper focuses on the *Problems of Farmers in connection with Status of Irrigation Facilities in Agricultural Sector.* The poverty and seasonal agricultural un-employment are the major problems of this study areas. Even though, most of the

farmers have own agricultural land and cultivate agricultural products such as maize, sugarcane, groundnut, tomato, sweet potato, beans, carrot and banana, a sizeable number of farmers along with livestock.

Objectives of the Study

1. To describe the Socio- economic background of the farmers in this study area
2. To analyze the nature and type of cultivation in their agricultural field.
3. To understand the problems of farmers with respect to in-adequate Irrigation system, scientific methods adopted in agriculture
4. To suggest the implementation of proper Irrigation and Scientific method in Agriculture for green revolution

Sampling

A sample size of 40 was achieved through adopting the non-probability -purposive sampling method with a decision of selecting 5 farmers from each village, to collect the pertinent primary data.

Secondary Data

Relevant secondary data were collected from the library books, Journals, newspapers, magazines, and websites.

Primary data

The primary data were collected from the selected farmers through Interview and unstructured observations to understand socio- economic background of the farmers, nature and type of cultivation in their agricultural field, and problems faced by farmers especially of in-adequate Irrigation farming.

Period of Study

Reference period for data collection was 1-29 June 2017.

RESULTS AND DISCUSSIONS

All the farmers of this study area are homogeneous characteristics of their socio-economic background is very low. Among the total population of this villages, nearly eighty percent of them depend on the agriculture, most of them are own agricultural land and only few of them lease or rental agricultural land. Among the total population of the farmers in these villages, the educational background of the farmers reveals that nearly sixty five percent of them are illiterates, while, nearly thirty percent of the farmers completed primary education up to VIIIth Standard, and few of them run the small-scale business-like chips stall, Potato stall, Tomato stall, etc.

There are no-sufficient basic amenities and infrastructural facilities like safe drinking water, proper concrete road, public toilet, electricity, government primary health Centre. Mal-nutrition problem is one of the major problems among the people, particularly in farmers; it's also leads to form of some diseases like Measles, pneumonia, anemia, particularly affects the pregnancy women and born children's due to mal-nutrition problems.

Nearly ninety five percent of them have own house but in dilapidated condition, rest of them living in rental house. Religious wise distribution of the respondents reveals that most of them belongs to the Christians, particularly in Roman Catholic, rest of them belongs to different tribes like Yao (Islamic), remaining of them are one type of Christian, they are only followers of Jesus Christ, but they do not follow any Christian organizations like Roman Catholic, Assembly of God, Pentecostal

mission. No caste system among these people in these villages, the socio-economic status also determined their status as lower or middle class.

Most of the people they have own a small size of agricultural land i.e. they have holdings two acres or less than two acres, they are also cultivate some agricultural products such as maize, sugarcane, groundnut, tomato, sweet potato, beans, carrot and banana, etc, few of them along with livestock's, The fragmented and small size of land holding is an important factors of insufficient development in the agriculture.

Few of them are do not have own agricultural land. But they are also cultivating some crops in lease or rental agricultural land. Among the total population of the farmers, nearly fifty percent of them only seasonal cultivation in rain season from the month of November to April. Rest of them also cultivates some crops all the season, because they can easily access water sources for their small pieces of land. Because, the ground water sources also nearest from the bottom of the land only a few feet as the area is close to Lake Malombe. They are also practicing the old method of cultivation and irrigation facilities like using treadle pump. They are also cultivating some crops like vegetables, sweet potato, paddy and maize, etc.

As the rain fed agriculture is vulnerable to changes in present, Climate change also one of the reasons of reduce the yield in the field in the way that increase of rain upturn the runoff which washing away crops and humus in the soil. The people have a great impact that contributes to climate change such as deforestation, poor farming and soil tillage.

No scientific method adopted in their cultivation, the use of mechanization not fully adopted in the entire country, most of them practices old method of cultivation and still being used for agriculture. Modern inputs like improve seeds, fertilizer and pesticides are available. But there are inadequate supplies of loans from institutional credits, the people are mostly not able to purchase the fertilizers and pesticides in particular time which result in low productivity.

These are contributing to seasonal un-employment problem in agricultural sectors. In these factors also lead those to going for fishing work in nearest Lake, Molambe. Some people migrate to South Africa to get the employment opportunities in industrial and commercial sectors. Most of them have holding natural resources like natural fertilized agricultural land and sufficient ground water facilities. But there is no sufficient economic power to get the proper irrigation facilities mean ground water in their agricultural land.

The entire farmers are poor and also, they don't have electricity facilities, not only in their houses but also in their agricultural sectors. Because, electricity facilities are very essential to farm the irrigation and scientific method of cultivation in Agriculture. The major problems of the failure of agriculture are lack of infrastructural facilities like farm to market, roads and shortage of transport facilities, etc.

This study reviews that people in this study area are poor and practices the local irrigation farming. To improve their life's there is need to assist them with modern irrigation farming technologies such as modern machineries, proper electricity, capacity buildings like agricultural extension services and enough financial support from international funding agencies to assist them procure farm inputs.

CONCLUSION AND RECOMMENDATIONS

Most of the developing countries have sustainable development in cultivation of agricultural products, by the innovative and scientific methods like proper irrigation facilities and adopted the mechanization in agriculture sector. There have been numerous attempts to introduce the successful concepts from the Mexican and Indian projects into African countries although with less successful efforts. Reasons cited for their failures include lack of financial support and policy, insecurity, lack of infrastructure, and lack of will power on the part of the farmers. In the most basic sense, the Green Revolution was a product of globalization as evidenced in the creation of international agricultural research centers that shared information, and with transnational funding from groups like the Rockefeller Foundation, Ford Foundation, and United States Agency for International Development (USAID).

The Green Revolution was a research establishment in Mexico and the Philippines that were funded by the governments of those nations and international donor organizations. Similar work is still being carried out by a network of institutes around the world. Proponents of the Green Revolution argued that it contributed to environmental preservation because it improved the productivity of land already in agricultural production and thus saved millions of acres that would otherwise have been put into agricultural use. These factors permitted these countries to diffuse both the new seeds and technology and to bring the products to market in an effective manner. Africa benefited far less from the Green Revolution than Asian countries and is still threatened periodically with famine. Therefore, it is right time to make the new policies for implement the scientific method of cultivation with proper irrigation facilities in Agriculture through International Agricultural Research and funding from the aforesaid international funding agencies and support from the World Bank.

The activities outlined by the network research could benefit countries like Malawi especially people of Chiwaula area in Mangochi District which the study in this project was carried out. It is envisaged that Malawi as a nation, located in the sub Saharan Africa is one of the countries where Green revolution is taking place, majority of people are poor and could be assisted in the activities and their by improving their economic status and uplifting living standards.

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Economic Analysis of Small-scale Fish Farming in Bunda, Lilongwe, Malawi

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ABSTRACT

The study to determine economic returns of small-scale fish farming in Malawi was carried out in Bunda area, Lilongwe. Thirty-two small-scale fish farmers were purposively sampled and interviewed using a structured questionnaire. Data collected were analyzed using descriptive statistics, budgetary analysis and multiple linear regression. Descriptive analysis revealed that both the males (68.8%) and the females (31.3%) are involved in fish farming. The average age of farmers was 43.87 years and the majority of fish farmers were aged between 41 and 50 years (34.4%). Cost and returns analysis per harvest showed the gross margin of MK7, 378.12. Regression analysis showed that costs of fingerlings, costs of labour, respondent's total area of land, and costs of manure and fertilizer were significant factors affecting respondent's total revenue. The major problems faced by fish farmers were high cost of input, predators, inadequate extension visit and fluctuation of pond water. The study concluded that small-scale fish farming is a profitable enterprise, especially when there is proper management, absence of predators, and when farmers has access to extension.

Key words: Economic analysis, small-scale, fish farming, revenue, Malawi

INTRODUCTION

Aquaculture in Malawi contributes to food security in terms of increased access to food, increased food production, improved household capacity to acquire food and improved utilization of farmland for food production (Jamu and Chimatiro, 2004). Aquaculture supplies fish to most upland areas which are not easily accessible to fish from the lakes and rivers. Fisheries resources contribute 4 percent to the nation's GDP. Aquaculture accounts for about 2 percent of the nation's fish production. It also contributes between approximately one and 17 percent of overall household income, depending on the fish farming activities involved (SSC, 2005). In southern Malawi, where most aquaculture is concentrated, farmers are able to generate US$ 199 from 1 to 3 ponds of average pond sizes of 151 m^2 (Andrew et al., 2003). Malawian agriculture is dependent on rainfall from November to April, leaving the remaining months dry and idle in terms of agricultural production. Aquaculture enables farmers to continue producing food in those idle dry months. Fish farming also plays a crucial role in turning marginal wetlands into productive land for crop production such as vegetables. In other areas, aquaculture is carried out in communal ponds and

irrigated dams, thereby diversifying income through the sale of fish and the provision of nutrition to poor households.

In Malawi a typical small-holder fish farmer has one or two small ponds about $200m^2$ or less usually located in close proximity to a seasonal wetland (dambo). The number of these small holder farmers has increased recently and the National Aquaculture Centre at Domasi estimated that there were approximately 6,010 fish farms in 2012 and that the numbers had increased to 6,230 farmers with 10,000 ponds in 2013 (GoM, 2014).

Fish production from small holder farmers has steadily increased from 1,600 tonnes in the 2008 to 2,500 tonnes in 2010. This production comprised 93 per cent tilapia (*Oreochromis shiranus*, *Tilapia rendalli*, *Oreochromis mossambicus* and *Oreochromis karongae*), 5 per cent catfish (*Clarias gariepinus*) and 2% exotic species of common carp (*Carpio cyprinus*) and rainbow trout (*Onchorhynchus mykiss*) (GoM, 2011).

In a detailed survey carried out in Malawi, it was reported that most fish farmers recognize that aquaculture provides an opportunity for farm diversification and improved income (ADiM, 2005). However, most were dissatisfied with their performance. The main reasons for dissatisfaction in all groups currently engaged in fish farming were the slow growth rate of fish (35 percent), small pond size (25 percent) and the lack of technical support (8 percent), although all farmers were satisfied with the market and the price of fish. The results of the survey showed that 8 percent of farmers had abandoned aquaculture in recent years, the main reason being lack of water. All of these reasons indicate a poor understanding of the critical requirements for successful fish farming.

On the other hand in Nigeria, studies by By Olaoye et al. (2013) and Adewuyi et al. (2010), reported that there is a considerable level of profitability in fish farming and also showed that fish output is significantly determined by pond size, labour used, cost of feeds, cost of lime and cost of fingerlings. This study was conducted to determine the economic returns of fish farming in Bunda, Lilongwe, Malawi.

Justification

Most Malawi's capture fisheries have reached their maximum sustainable yields yet demand for fish is significantly high. Since increasing fish supply from capture fisheries is unlikely, aquaculture provides a viable alternative for increasing fish production (Schmidt, 1977, Balarin, 1984). Much as aquaculture is viewed as a viable alternative means of increasing fish supply to inland areas, most fish farmers lack information on how to assess the profitability of their farms. This has partly hampered aquaculture development in the country and has led to potential farmers not opting into fish farming and even others becoming inactive because the profitability of aquaculture has not been demonstrated to them. However, studies to determine the economic returns as well as factors that affect profitability of fish farming in Malawi are scanty. This paper therefore examines the economic returns and factors influencing profitability of fish farming in Bunda, Lilongwe, Malawi with a view to determine its viability or otherwise.

METHODOLOGY

Study area and sampling procedure

This study was conducted in Bunda area, Lilongwe, Malawi. The area is located within the coordinates, 14.10^0S, 33.47^0E, with an altitude of 1200m above sea level. A total of 42 fish farmers that were supported by a local Non-Governmental Organization (NGO), Kawjo foundation with funding from Global Environment Facility Small Grants in the study area were purposively selected for the interview. The study ended up with data from 32 farmers where farmers were dropped during the study due to a shortfall of data as they did not harvest their farms. The Global

Environment Facility Small Grants programs aimed at, ‘‘scaling up adaptive capacity of rural communities to climate change through innovative integrated agriculture aquaculture for improved rural livelihoods’’.

Data collection
Primary data were collected using a questionnaire that was based on the objectives of the study. Secondary data were sourced from publications, textbooks and other unpublished literature.

Data analysis
The collected data was analyzed using descriptive statistics, the budgetary technique and the regression analysis. The means, frequency and percentages were used as descriptive statistics.

The Budgetary Technique
The budgetary technique involves the costs and revenue (Adewuyi *et al.*, 2010) which is simply the gross margin. The difference between the total revenue (TC) and the variable costs (VC) gives the gross margin (GM). Gross margin is expressed as;

GM = TR- VC…… (i)
TR= PQ…….... (ii)
Where;
GM = Gross Margin (MK)
TR=Total revenue (MK)
VC= Variable Cost (MK)
P= Unit price of output (MK)
Q= Total quantity of output (Kg)

The Regression Model
The multiple regression model was employed to examine the factors affecting revenue from fish farming. According to Agboola, 2011 this is a statistical tool that measures the relationship between independent variables (regressors) and the dependent variable (regressand). The model is specified as follows;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \varepsilon \ldots\ldots \quad (iii)$$

Where; the dependent variable Y= Total income (MK), and the independent variables are; X_1 = Feed costs (MK), X_2 = Labour costs (MK), X_3 = Fingerling costs (MK), X_4=Manure and fertilizer costs (MK), X_6 = Respondent total land size (ha), X_7 = Farm size (m^2), X_8= Age of farmers (years), X_9 =Education level of the household head (level), X_{10} = Household size (Number of individuals in a family), e = Error term

RESULTS AND DISCUSSION

Socio-economic characteristics of fish farmers
Table 1 shows results of the analysis of the socio-economic characteristics of fish farmers in the study area. Age of the household head is very critical in understanding most production decisions made on the farm. The results revealed that most of the household heads, accounting for 34.4 percent were between the age group of 41 to 50 years and this indicates that the farmers still have the strength to run the business.

The results in table 1 also show that both the males (68.8%) and the females (31.3%) are involved in fish farming in the area. Most respondents reported that they were married. This is evidenced by 93.8 percent prevalence for married where the widower and single had 3.1% each. This means that the majority of the farmers are in a better position of making better production decisions through consultations with their spouses.

Agboola, 2011 indicated that education is an important factor influencing management and the adoption of any technology. As shown in table 1, about 81.3 percent of the respondents comprising of 71.9 percent for primary education and 9.4 percent for secondary education at least claim to acquire some formal education, and the results also revealed that 18.8 percent had no formal education.

Main occupation is an indicator of the household source of income. All the respondents interviewed rely on farming as their main occupation. This may have significant influence in the level of commitment to fish farming since all the respondents relies mainly on farming as their primary economic activity.

Table 1: Socio-economic characteristics of respondents

Variable	Frequency	Percentage
Age		
<30	3	9.4
30-40	10	31.3
41-50	11	34.4
51-60	2	6.3
61-70	4	12.5
71-80	2	6.3
Total	32	100
Sex		
Male	22	68.8
Female	10	31.3
Total	32	100
Marital status		
Single	1	3.1
Married	30	93.8
Widowed	1	3.1
Total	32	100
Education background		
None	6	18.8
Primary education	23	71.9
Secondary education	3	9.4
Total	32	100
Household size of respondent		
1-3	2	6.3
4-6	14	43.8
7-10	16	50
Total	32	100
Access to extension		
Yes	12	37.5
No	20	62.5
Total	32	100
Main occupation		
Farmers	32	100
Land allocated to fish farming		
150 m^2	13	40.6
200 m^2	19	59.4
Total	32	100

Source: Field survey, 2015.

Access to extension services exposes fish farmers to new innovations and better technologies for improved production and Kapanda et al. (2003) reported that uptake of new technologies is influenced by contact between extension staff and farmers due to information flow. The results on access to extension services indicate that the majority of the respondents (62.5%) had no access to extension and a minority of the respondents (37.5%) had access to extension.

Cost and returns analysis per production cycle

Harvesting is carried out twice in a year, in a six months interval according to the respondents. The analysis below is done based on per cropping operation. The average values for the thirty-two respondents were used. From the analysis, it was discovered that most of the incurred by the fish farmers were in form of the fixed costs.

Table 1: Gross margin analysis of fish farming in the study areas

				Unit	Amount
1.	**Gross Income (GI)**				
	Average yied			Kg	18.56
	Price/kg			MK	1,600
	Gross Income (GI)			**MK**	**29,692.50**
2.	**Variable costs (VC):**				
	Fingerlings			MK	9609.38
	Feed			MK	7362.50
	Labour			MK	2118.75
	Fertilizer and manure			MK	3223.75
	Total variable costs (TVC)			MK	**22314.38**
3.	**Fixed costs:**	Quantity	Unit price (MK)		
	Hoes	4	1300	MK	5200.00
	Shovels	2	1800	MK	3600.00
	Buckets	3	600	MK	1800.00
	Slashers	1	1300	MK	1300.00
	Land			MK	7000.00
	Pond construction (Labour)			MK	36600.00
	Total fixed costs (TFC)			MK	**55500.00**
4.	**Total costs (TC) (2+3)**			MK	**77814.38**
5.	**Gross Margin (GM) (1-2)**			MK	**7378.12**
6.	**Net Farm Income (NFI) (5-3) or (1-4)**			MK	**-70436.26**

Source: Field survey and data analysis

Profitability and Viability Estimate of Fish Farming in the Study Area

Profitability ratio is a class of financial metrics that helps investors assess a business's ability to generate earning compared with its expenses and other relevant costs incurred during a specific period (By Olaoye *et al*., 2013).

The analysis of ratios in table 2 reveals that the Benefit cost ratio (BCR) was less than one. This ratio is one of the concepts of discount method of project evaluation. As a rule of thumb, any business with benefit cost ratio greater than one, equal to one or less than one indicates profit, break-even or loss respectively (Olagunju et al., 2007). This is different from the work of By Olaoye et al., (2013) who reported the Benefit cost ratio of fish farming of 1.69. Since the ratio (BCR = 0.38) it implies that fish farming in Bunda is not profitable.

Table 2: Profitability ratios

Ratio	Values
Benefit Cost Ratio	0.38

Results of the multiple linear regression analysis

Results of a multiple linear regression model that was run to establish the factors that influences the gross margin (profitability) of fish farming in the study area are as presented in table 3. Having an R^2=0.578 means that 57.8 percent of variations in output were explained by the explanatory variables included in the model. The standard error of the estimate was 0.76. F-value of 3.563 was significant at 1 percent which implies that the functional form and model specifications were correct. Five out of ten variables, which include age of respondent, costs of fingerlings, costs of labour, costs of feed, and costs of manure and fertilizer significantly affected gross margin. Costs of fingerlings, costs of labour, costs of feed, and costs of manure and fertilizer were significant at $p<0.05$ while age of respondent was significant at $p<0.1$. Costs of fingerlings, and costs of manure and fertilizer were positively related to gross margin. This suggests that these are the key factors influencing gross margin in the study area. Age of respondent, costs of labour, and costs of feed were negatively related to gross margin. The negativity indicated that the variables and revenue move in opposite directions.

Table 3: The regression results of the determinants of fish output in the study area

Variable	Coefficients	B	T	Sig.
Constant	12405.081	_	.908	.374
Age of respondent	-2403.669	-.343	-2.025	.056**
Education level	2285.014	.126	.784	.442
Household size of respondent	1825.629	.118	.798	.434
Respondent's total area of land	2902.865	.338	1.977	.610
Land allocated to fish farming	6441.244	.335	1.687	.106
Costs of fingerlings	2.311	.430	2.163	.042*
Costs of labour	-1.131	-.374	-2.423	.025*
Costs of feed	-.424	-.238	-1.465	.015*
Costs of manure and fertilizer	1.815	.495	2.822	.010*
Costs of pond construction	-.014	-.021	-.115	.910
R^2=0.578 F Stat = 3.563				

**significant at p<0.05, **significant at p<0.1, None = Not significant*

Problems faced by fish farmers in the study area

It is clearly shown from table 4 that fish farmers face serious problems in the course of their production activities. The major ones include high cost of input, predators, inadequate extension visit and fluctuation of pond water. According to the respondents, high inputs and predators accounted for 100 percent prevalence each, 24% and 11% accounted for inadequate extension and theft respectively, and fluctuation of water level accounted for 17%. This is in agreement of what Oladejo (2006) reported that the major problems faced by the catfish farmers were predators, high cost of inputs and finance.

Table 4: Problems faced by fish farmers

Problem	Frequency	Percentage
High input costs	32	100
Predators	32	100
Inadequate extension visits	24	75
Theft	11	34.4
Fluctuation of water level	17	53.1

Source: Field survey, 2015.
* Percentage greater than 100 due to multiple responses

CONCLUSION AND RECOMMENDATIONS

Based on the findings it was observed that, on average, a gross margin of about MK 7,378.12 and a net farm income of MK-70,436.26 were realized from fish farming in the study area. The major problems and constrains of fish farming in the study area include high cost of input, predators, inadequate extension visit and fluctuation of pond water. Factors that significantly affected revenue in the study area were age of respondent, costs of fingerlings, costs of labour, costs of feed, and costs of manure and fertilizer. This study concluded that small-scale fish farming in the area is not economically rewarding and profitable, but it can be economically viable when there is proper management, absence of predators, and when farmers has access to extension.

Based on the findings, the following recommendations were made; high input cost was observed as one of the major constraints to fish farming in the area. To combat this problem, farmers should make use of their clubs to purchase inputs in bulk for the use of members so as to increase their bargaining power and reduce cost of production, the government through the department of fisheries should consider allocating extension workers who are specialists in the field of aquaculture since the majority of the farmers had zero knowledge of fish farm management and had no access to extension agents, and there is need for the establishment of the formulated fish feed depot in the study area because most feed used by farmers are the maize bran.

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Productivity Impact of Drought Tolerant Maize Varieties under Rainfall Stress in Malawi

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ABSTRACT

Drought tolerant (DT) maize variety is a technology developed to boost maize productivity under rainfall stress. We examine the impact of this variety on maize productivity among female and male-headed households in Malawi using correlated random effects tobit models with a control function approach. The results show higher maize yield on households that grew DT maize than those that grew other varieties. On average, maize yield is 70% higher on plots with DT and 48% less with local maize relative to other improved maize varieties. The impact is greater on plots for female-headed households (105%) than those cultivated by male-headed households (82%). These results show that DT varieties offer yield advantage over other maize varieties under rainfall stress. This could be evidence that the poor harvests that have characterized most smallholder farmers in Malawi under rainfall stress, is largely due to lack of appropriate technologies. While, alternative climate-smart agriculture technologies such as irrigation, inorganic fertilizer and organic manure are expensive and labor intensive, availability of technologies such as DT maize variety can offer smallholder farmers, female-headed households in particular, an option to hedge against drought-related poor yields. There is a need however to address input access gap in complementary technologies between female and male-headed households.

Key words: Drought tolerant maize, rainfall stress, maize yield, correlated random effects, Malawi

INTRODUCTION

Maize is a single most important food crop in Malawi whose availability equates to food security (Smale, 1993). Annual consumption per capita is one of the highest in Africa estimated at 129 kilograms and makes approximately 90% and 54% of total cereals and caloric per capita intake, respectively (Derlagen, 2012). Production takes over 90% of productive land under cereals and is dominated by smallholder farmers where nearly 97% of them grow maize (Denning et al., 2009). The crop is heavily dependent on rain-fed during a single rainy season which covers at most five months from November to March, and therefore greatly affected by the country's erratic and unpredictable rainfall (Kassie et al., 2015b). The rainfall uncertainty in frequency and distribution coupled with frequent dry spells reduces maize productivity by more than half and hence exacerbates the country's food insecurity problems (Fisher et al., 2015, Tesfaye et al., 2016).

In a country characterized by poor and/or missing markets for credits, insurance and off-farm income, investing in agricultural technologies that reduce vulnerability and risks of yield loss due to weather related shocks is a more realistic option (Davies et al., 2009, Pangapanga et al., 2012, Kassie et al., 2015a). Drought tolerant (DT) maize variety is one potential technology that has been developed to help smallholder farmers cope with drought and drought-related constraints. It is estimated that DT maize can produce up to 30% of their potential yield after six weeks of water stress, before and during flowering and grain-filling (Magorokosho et al., 2009). On-farm field

experiments conducted across several countries in Southern Africa indicate that DT maize varieties can give a yield advantage of up to 40% over other maize varieties under severe drought environments (Tesfaye et al., 2016). It is also projected that full adoption of DT maize varieties can result in both production and economic gains with significant number of producers and consumers out of poverty (La Rovere et al., 2014).

Given potential relevance of this technology to Malawi and other countries in the Sub-Saharan Africa (SSA) region, empirical evidence beyond ex ante analysis and on-farm and on-station experiments is of particular importance. This paper adds to the body of literature by examining the impact of drought tolerant maize varieties on maize productivity on female-headed and male-headed households. There have been some studies on this subject across countries in SSA and the results are mixed. Holden and Fisher (2015) and Fekadu and Endeshaw (2016) for example, found insignificant yield advantage of DT maize over other improved maize varieties but local. On the other hand, other authors show positive impact of DT maize on maize production, yield and food security across all other varieties in Nigeria (Idrisa et al., 2014, Radda, 2015, Awotide et al., 2016), Zimbabwe (Makate et al., 2017, Lunduka et al., 2017) and SSA (Cenacchi and Koo, 2011). We attribute this inconsistency to use of cross section data that may not fully captured heterogeneity effects and variability of rainfall. DT may not have yield advantage over other improved maize varieties under normal rainfall and this may lead to underestimation of impact.

We address this inconsistence in this paper by using a three-round panel data spanning six years from 2009 to 2015 that controls for unobserved heterogeneity and captures rainfall variability. This data set is of interest to this particular study as it captures three different rainfall scenarios, namely, normal rainfall in 2009, early droughts in 2012, and early floods and late droughts in 2015. The paper addresses the following hypotheses: (1) adoption of drought tolerant maize enhances maize productivity under rainfall stress, and (2) female-headed households benefit more from adoption of drought tolerant maize varieties. The extension of the analysis to female-headed and male-headed households is another value addition of this paper. Apart from Awotide et al. (2016) in Nigeria, no other study to the best of our knowledge has brought gender dimension to the impact of DT maize.

MATERIALS AND METHODS

Study areas

The data in this paper comes from household panel surveys from six districts in Malawi, namely, Lilongwe, Kasungu, Chiradzulu, Machinga, Thyolo and Zomba. The districts are in different agro-ecological zones and receive different amounts of rainfall. Machinga for example is partly located in a drought prone zone (Mangisoni et al., 2011, Katengeza et al., 2012) with Thyolo lying in the high plateau and hilly areas. The first round of the survey took place in 2006 where an initial sample of 450 households was drawn using a simple random sampling technique following the 2004 Integrated Household Survey Two (IHS2) (Lunduka, 2009). Data collection used a semi-structured questionnaire on household and plot level characteristics with detailed plot-level information that include area measurements using GSP. 378 of the households were resurveyed in 2009, 350 in 2012 and 2015 giving a four-round unbalanced household panel data. Our paper uses three of the four-rounds (**Error! Reference source not found.**).

Table 2: Study areas

District	2009		2012		2015		Total	
	HHs	Plots	HHs	Plots	HHs	Plots	HHs	Plots
Thyolo	51	133	47	112	47	150	145	395
Zomba	84	125	76	109	79	243	239	477
Chiradzulu	35	102	37	86	34	123	106	311
Machinga	49	133	47	150	45	128	141	411
Kasungu	88	286	82	248	80	291	250	825
Lilongwe	71	162	61	90	65	201	197	453
Total	378	941	350	795	350	1,136	1078	2872

Adoption of drought tolerant maize varieties

Smallholder farmers in Malawi adopt a portfolio of maize varieties given different production and consumption attributes of the varieties (Lunduka et al., 2012). While DT maize is preferred for drought tolerant traits, other improved hybrids are high yielding under normal rainfall while local varieties possess preferred processing and consumption characteristics. We therefore measure adoption equal to one if DT maize variety was planted on a given plot and zero otherwise. Adoption is given as total share of plots allocated to DT maize production. There is an increase on plot allocation to drought tolerant maize varieties from 2% in 2006 (Katengeza et al., 2017) to 43% in 2015 (**Error! Reference source not found.**). Plot size under drought tolerant maize increased from 0.08ha in 2009 to 0.25ha in 2012 but decreased to 0.20ha in 2015. Correspondingly, other improved maize decreased from 0.25ha in 2009 to 0.20ha in 2012 but increased to 0.23ha in 2015, but there is a consistent decrease in plot size for local maize varieties.

Table 3: Adoption of maize varieties by year

Variable	2009		2012		2015		Total	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
DT maize (1=yes)	0.21	0.40	0.48	0.50	0.47	0.50	0.38	0.49
Local maize (1=yes)	0.40	0.49	0.21	0.41	0.16	0.37	0.25	0.44
Other improved maize (1=yes)	0.39	0.49	0.31	0.46	0.37	0.48	0.36	0.48
Plot size in hectares	0.41	0.52	0.51	0.50	0.40	0.45	0.43	0.49
Plot size under DT (ha)	0.08	0.19	0.25	0.46	0.20	0.40	0.17	0.37
Plot size under LM (ha)	0.19	0.51	0.10	0.23	0.06	0.18	0.11	0.34
Plot size under OIM (ha)	0.25	0.39	0.20	0.35	0.23	0.40	0.23	0.38

Descriptive statistics of explanatory variables used in the analysis

Error! Reference source not found. presents summary statistics of the explanatory variables used in this paper. We include dummy variables for DT maize and local maize varieties with other improved maize as base variety. Access to FISP is measured on whether household accessed seed subsidy and/or fertilizer subsidy. We notice that seed subsidy access increased from 36% in 2009 to 64% in 2015 but there is a decrease from 2012 to 2015 for fertilizer subsidy. The drop-in fertilizer subsidy access may affect maize yield via reduced fertilizer use. The household endowment variables include quantity of fertilizer use per hectare (Kg/ha), organic manure (Kg/ha), asset value in Malawi Kwacha (MK) and Tropical Livestock Unit (TLU). Fertilizer use intensity decreased from 2009 to 2012 but increased in 2015 and there is a similar trend with organic manure and asset value. We proxy asset value and TLU for wealthy and we assume that ownership of these livestock and physical assets will enhance access to and use of inorganic fertilizer. Livestock also provide organic manure and an increase of TLU would increase application of organic manure. There is consistent decrease however for TLU from 2009 to 2015. We have also included distance to agricultural market as a supply factor likely to influence access to drought tolerant maize seed and inorganic fertilizer.

Household heterogeneity is controlled by the inclusion of household level factors such as age (years), education (years) and sex of household head, household size, whether household head is

married or not, male and female family labor and *ganyu* (off-farm) labor. Plot-specific variables include plot size (ha), plot distance (KM), perceived soil fertility, slope, and soil type. These variables control for observable plot heterogeneity. We also include drought and rainfall stress variables constructed using daily rainfall data from the Department of Climate Change and Meteorological Services under the Ministry of Natural Resources, Energy and Mining. We include longest period of a dry spell (days) and four-year mean rainfall in mm. A dry spell is defined as a period of 10 – 15 days with a total rainfall of less than 20 mm following a rainy day of at least 20 mm (Katengeza et al., 2017). We identify how long in days there was a dry spell early in the season (December – early January) and later in the season (February – early March). We define these as early dry spells and late dry spells, respectively. On average, the longest early dry spell lasted 14 days in 2009 while the longest late dry spell of 18 days was reported in 2015.

Table 4: Definitions and summary statistics of variables by year

Variable	2009	2012	2015	Total
Maize type: Base-Hybrid maize				
DT maize (1=yes)	0.21	0.48	0.47	0.38
Local maize (1=yes)	0.40	0.21	0.16	0.25
FISP				
Household accessed maize seed subsidy (1=yes)	0.36	0.57	0.64	0.53
Household accessed fertilizer subsidy (1=yes)	0.54	0.70	0.52	0.57
Household endowments				
Fertilizer quantity (Kg/ha)	238	162	220	210
Organic manure (Kg/ha)	1181	559	794	856
Asset value (Malawi kwacha)	4808	2597	5985	4661
Tropical Livestock Unit	1.40	1.34	0.60	1.06
Distance to agricultural market (Km)	4.29	4.24	4.23	4.25
Household characteristics				
Age of household head (years)	46.30	51.24	49.10	48.77
Sex of household head (1=male)	0.81	0.78	0.61	0.72
Household size (# of persons)	5.64	5.42	5.68	5.59
Household residence (1=wife's village)	0.48	0.25	0.00	0.23
Household head married (1=yes)	0.77	0.72	0.67	0.72
Male household labor (adult equivalent/ha)	3.26	3.20	3.73	3.43
Female household labor (adult equivalent/ha)	3.01	2.86	3.37	3.11
Ganyu labor (# of adults)	0.25	0.40	0.25	0.29
Plot Characteristics				
Plot size in ha	0.41	0.51	0.40	0.43
Plot distance (Km)	2.89	2.78	3.38	3.06
Land tenure (1=own plot)	0.91	0.92	0.93	0.92
Sandy soil (dummy)	0.24	0.25	0.21	0.23
Loam soil (dummy)	0.49	0.47	0.67	0.56
Clay soil (dummy)	0.27	0.28	0.12	0.21
Flats slope (dummy)	0.59	0.61	0.52	0.57
Moderate slope (dummy)	0.35	0.35	0.42	0.38
Steep slope (dummy)	0.05	0.04	0.07	0.05
High soil fertility (dummy)	0.18	0.17	0.09	0.14
Medium soil fertility (dummy)	0.62	0.63	0.70	0.65
Low soil fertility (dummy)	0.20	0.19	0.21	0.20
Drought and rainfall variables				
Four year average rainfall (mm)	5.88	5.68	5.80	5.80
Longest early dry spell (days)	14.00	8.00	7.00	14.00
Longest late dry spell (days)	9.00	13.00	18.00	18.00

Empirical model specification and estimation strategy

Let us assume the deterministic Cobb-Douglas production function given as:

$$lnY_{ipt} = \alpha_0 + \alpha_1 DT_{ipt} + \alpha_2 LM_{ipt} + \alpha_{ix} lnX_{ipt}, + \alpha_{iz} Z_{it} + \varepsilon_i \quad 1$$

where Y_{ipt} is (log of) maize yield for farmer i on plot p in year t measured in kilograms per hectare (Kg/ha). DT_{ipt} is a dummy on whether household i grew drought tolerant maize or not while LM_{ipt}controls for local maize varieties. $X_{ipt}$is a set of production inputs in natural log (i.e. inorganic fertilizer, organic manure, labor, and land) while Z_{it} represents household and plot characteristics, access to input subsidies and rainfall stress variables. Our main interest is to examine how DT maize seed affects maize yield and this is given by α_1. The expectation is that α_1 should be positive and significant while α_2 should be negative and significant. This suggests that adoption of DT gives yield advantage over OIM and LM but OIM is better than LM.

Estimation of equation (1) uses non-linear correlated random effects (CRE) tobit models with a control function (CF) approach. This strategy addresses unobserved heterogeneity challenge associated with adoption of DT varieties. Failure to control for unobserved heterogeneity can result in biased estimates if the unobserved heterogeneity is correlated with the decision to adopt (Ricker-Gilbert and Jones, 2015). Fortunately, the correlated random effects models an extension of a Mundlak–Chamberlin (MC) device allows control for unobserved heterogeneity in unbalanced data (Wooldridge, 2009a). Unobserved heterogeneity is allowed to correlate with observed covariates and sample selection. This is an alternative to household fixed effects. Unlike other approaches, the CRE methods also identify average partial effects, avoid incidental parameters problem and can be combined with the control function (CF) approach in non-linear models with heterogeneity and endogeneity (Wooldridge, 2009b). We express the CRE model as follows:

$$Y_{ipt} = \alpha_0 + \alpha_1 DTM_{ipt} + \alpha_2 LM_{it} + \alpha_3 {F^c}_{ipt} + \alpha_4 P_{ipt} + \alpha_5 M_{ipt} + \alpha_6 L_{ipt} + \alpha_7 {F^s}_{it} + \alpha_8 {S^s}_{it} + \alpha_9 \bar{H}_{it} + \alpha_{10} {P^c}_{ipt} + \alpha_{11} {D^m}_{it} + \alpha_{12} R_{dt} + \alpha_{13} D_{it} + \alpha_{14} T_t + \alpha_i + \varepsilon_{ipt} \quad 2$$

where Y_{ipt}, DT_{ipt} and LM_{it} are as define in equation (1). ${F^c}_{ipt}$ is (log of) commercial fertilizer use (Kg/ha), P_{ipt} is (log of) plot size (ha), $M_{ipt}$is (log of) of organic manure (Kg/ha) while L_{ipt} is (log of) male and female family labor and off-farm labor (adult equivalent/ha). $F^s$is a dummy for access to subsidy fertilizer while $S^s$is a dummy for seed subsidy. $\bar{H}_{it}$ represents time-averages of observed time-varying farm household characteristics. These variables include sex of household head (1=male), household size (number of persons), age (years) and education (years) of household head, and plot distance (KM). ${P^c}_{ipt}$ controls for observable farm plot characteristics such as soil type, slope and soil fertility as reported by the farmer while ${D^m}_{it}$ is average distance to agricultural market (Km). R_{dt} is a vector of rainfall stress variables (longest early and late dry spells (days) and four-year average rainfall (mm)). D_{it} controls for location variables (survey districts) while T_t denotes year-specific dummies. α_i captures time-invariant unobservable characteristics of households and farms such as managerial ability and unobservable land quality while $\varepsilon_{ipt}$is normally distributed error term representing time-varying unobservable characteristics.

We also control for the problem of endogeneity of some covariates such as access to farm input subsidies, adoption of DT maize and use of inorganic fertilizer by combining the CRE methods with the control function (CF) approach. We use the observed variables, economic theory and targeting criteria of the farm input subsidy program to compute controls for the dependence between endogenous variables and the error. We first identify IVs that are correlated with access to farm input subsidy program using the targeting criteria of the program where resource poor and

vulnerable households (e.g. physically challenged, female and child-headed) and households with many dependants are targeted (Lunduka et al., 2013). Suggested IVs are age and age squared of household head, number of children residing in the family, whether household head is married or not (marital status), tropical livestock unit (TLU), asset value in Malawi Kwacha (MK) and distance to agricultural markets. We estimate three separate reduced form equations for the three PEVs and compute control functions (μ_{ipt}). The control functions are included in structural form equation with the CRE tobit models for maize yield together with the PEVs. The final equation is given as:

$$Y_{ipt} = \alpha_0 + \alpha_1 DT_{ipt} + \alpha_2 LM_{it} + \alpha_3 F^c{}_{ipt} + \alpha_4 P_{ipt} + \alpha_5 M_{ipt} + \alpha_6 L_{ipt} + \alpha_7 F^s{}_{it} + \alpha_8 S^s{}_{it} + \alpha_9 \overline{H}_{it} + \alpha_{10} P^c{}_{ipt} + \alpha_{11} R_{dt} + \alpha_{12} D_{it} + \alpha_{13} T_t + \alpha_i + \alpha_{14} \mu_{ipt} + \varepsilon_{ipt} \quad (3)$$

Results for reduced form equations (not reported to save space) show that the IVs are jointly statistically significant at 5% level or lower in all the three reduced form models. Thus, the PEVs are identified. Having ascertained the relevance and validity of the IVs in the first stage, we compute control functions (residuals/errors) for each of the three PEVs.

RESULTS AND DISCUSSION

Error! Reference source not found. presents results of (log of) maize yield using the Cobb-Douglas functional form. The first column is for full sample, followed by female-headed household in column two and male-headed households in third column. All residuals are significant in full sample and male-headed households while in female-headed household only residual from DT maize adoption is significant. The significance of residuals indicates endogeneity of DT maize adoption, fertilizer use intensity and fertilizer subsidy access hence the CF approach is appropriate. The results for full sample show that maize yield is positively correlated with drought tolerant maize varieties and commercial fertilizer use intensity but there is a negative correlation with local maize. We interpret coefficients on DT maize and LM dummies as semi-elasticities of maize yield with respect to the varieties while the coefficient on (log of) fertilizer use intensity is interpreted as elasticity of maize yield with respect to fertilizer (Wooldridge, 2014; p155). Using the CF approach, we find that given other improved maize varieties as base, adoption of DT maize increases maize yield by 70% while local maize reduces maize yield by 48%. On the other hand, a one percent increase in fertilizer use intensity increases maize yield by 0.72%.

Our results overall are consistent with on-station and on-farm trials where drought tolerant maize is superior to other improved maize variety under rainfall stress (Tesfaye et al., 2016, Setimela et al., 2013, Kostandini et al., 2015, La Rovere et al., 2010). DT maize is superior to other improved maize varieties when faced with droughts during grain formation as they are developed to withstand dry spells. The results however contradict Holden and Fisher (2015) in Malawi and Fekadu and Endeshaw (2016) in Uganda who observed insignificant yield advantage of DT over OIM varieties but LM. As noted, Holden and Fisher (2015) and Fekadu and Endeshaw (2016) reported results from data of a single season that does not capture full heterogeneity effects and rainfall variability. DT maize does not outperform OIM without drought but during rainfall stress conditions (Magorokosho et al., 2009).

The findings also concur with Radda (2015) and Awotide et al. (2016) in Nigeria, Makate et al. (2017) and Lunduka et al. (2017) in Zimbabwe and Cenacchi and Koo (2011) who also reported positive impact of DT maize adoption on maize yield. While these studies used cross sectional data, our use of the panel data authenticate the empirical conclusion that DT maize varieties have potential to increase maize productivity during rainfall stress growth conditions. The significance of these results to smallholder farmers in Malawi and the SSA region who are consistently exposed to dry spells is that, the poor harvests most of them get when dry spells occur can be largely attributed

to poor technologies they use as opposed to rainfall related effects. Thus, with proper use of agricultural technologies such as DT and other climate-smart agriculture practices, farmers should be able to realize bumper yields even if a bad state of drought occurs. Such technologies could be complements or alternatives to other technologies with hedging effect against drought stress such as irrigation when such are not available or expensive to the farmer.

With respect to gender differentials, maize yield is 21% higher on male-headed households than on female-headed households. This shows a yield gap between female-headed and male-headed households. This could be a result of limited access to male household labor and inorganic fertilizer by female-headed households (Minot et al., 2000 in FAO 2011, Gilbert et al., 2002). However, when we estimate separate models for male-headed and female-headed households, growing DT maize increases maize yield by 82% on male-headed households and 105% on female-headed households. There are also positive and significant effects for inorganic fertilizer and fertilizer subsidy on male-headed households, but insignificant on female-headed households. On the other hand, seed subsidy is insignificant on male-headed households but positive and significant on female-headed households.

These results show that the impact of DT on maize yield is higher on plots for female-headed households than those plots cultivated by male-headed households. Female-headed households however do not benefit much from inorganic fertilizer and fertilizer subsidy but seed subsidy. The results could mean that the yield gap between female-headed and male-headed households is largely a result of access gap to vital complementary technologies such as inorganic fertilizer and improved seed–in this case drought tolerant seed. Given that inorganic fertilizer is a major production factor and complementary technology to drought tolerant maize seed, equal access to these by female-headed households can result in comparable maize productivity levels with male-headed households despite having limited male household labor (Gilbert et al., 2002, in FAO, 2011).

These results could also suggest that female-headed households have not benefited enough from the fertilizer subsidy program in terms of enhanced maize productivity despite the program being in place for over 10 years. One reason is targeting errors (Holden and Lunduka, 2013, Ricker-Gilbert et al., 2011) in the program where vulnerable groups such as female-headed households are disadvantaged. The other possible reason is that due to few fertilizer coupons distributed, the beneficiaries share the package among many households such that others use less than one-50Kg bag of fertilizer (Mason and Ricker-Gilbert, 2013). With limited access to cash and input credit to purchase extra inorganic fertilizer, this is the only amount of fertilizer used by most female-headed households on maize plots. With the desire to cover larger maize land with inorganic fertilizer, the small quantities from fertilizer subsidies are applied below minimum requirements and this effectively reduces nitrogen input per hectare and result in poor maize response.

Table 5: Maize yield impact results with CRE models with CF approach

Variable	Full sample	Female-headed households	Male-headed households
Maize type: Base-Hybrid maize			
DT maize (1=yes)	0.698**	1.048*	0.820**
	(0.28)	*(0.58)*	*(0.36)*
Local maize (1=yes)	-0.477****	-0.696**	-0.318**
	(0.11)	*(0.28)*	*(0.13)*
Ln(fertilizer use -Kg/ha)	0.715****	0.077	1.262****
	(0.21)	*(0.56)*	*(0.25)*
Seed subsidy (1=yes)	0.088	0.451*	-0.152
	(0.12)	*(0.25)*	*(0.12)*
Fertilizer subsidy (1=yes)	0.744***	-0.036	1.306****
	(0.28)	*(0.66)*	*(0.35)*
Ln(organic manure -Kg/ha)	-0.039**	-0.008	-0.061***
	(0.02)	*(0.03)*	*(0.02)*
Ln(male labor -adult equiv./ha)	-0.237	-0.032	-0.414
	(0.33)	*(0.64)*	*(0.43)*
Ln(female labor -adult equiv./ha)	0.452	0.977	0.24
	(0.41)	*(0.75)*	*(0.54)*
Ln(plot size -ha)	-1.362****	0.221	-2.262****
	(0.36)	*(0.91)*	*(0.43)*
Four-year average rainfall (mm)	-0.075	0.729	0.278
	(0.35)	*(1.38)*	*(0.36)*
Longest early dry spell (days)	0.114*	-0.02	0.219***
	(0.06)	*(0.16)*	*(0.07)*
Longest late dry spell (days)	-0.054*	0.038	-0.125****
	(0.03)	*(0.08)*	*(0.04)*
Sex of household head (1=male)	0.187*		
	(0.10)		
Year 2012	0.354	-0.356	0.897**
	(0.35)	*(0.81)*	*(0.38)*
Year 2015	2.129**	-0.831	4.619****
	(0.93)	*(2.30)*	*(1.09)*
Error from DT adoption	-0.501*	-0.944*	-0.535
	(0.29)	*(0.56)*	*(0.37)*
Error from fertilizer use	-0.610***	-0.012	-1.139****
	(0.22)	*(0.56)*	*(0.25)*
Error from fertilizer subsidy	-0.661**	0.067	-1.231****
	(0.26)	*(0.67)*	*(0.33)*
Constant	3.598	2.921	-1.997
	(2.89)	*(10.23)*	*(3.24)*
Prob > chi2	0.000	0.000	0.000
Rho	0.012	0.000	0.000
Observations	2864	792	2072

Significance levels: *10%, **5%, ***1%, ****0.1%. The mean household endowments, plot characteristics, and district dummies are left out to save space. Standard errors in parentheses are bootstrapped with 400 replications.

CONCLUSION AND RECOMMENDATIONS

Drought tolerant maize is one potential technology to minimize the grinding impact of drought exposure. In recent times, several drought tolerant maize varieties have been developed and disseminated in Malawi and several countries in SSA. Examining the impact of this technology in reducing the impact of drought is increasingly becoming important. Following the work of Holden

and Fisher (2015) this paper has used correlated random effects tobit models with a control function approach to understand the impact of DT maize in Malawi under rainfall stress. The data is from farm households in six districts collected in three-year intervals from 2009 to 2015. The paper has found strong evidence suggesting that maize yield is positively and significantly affected by adoption of DT varieties that perform significantly higher than both local and other improved maize. Yield is 70% higher for drought tolerant maize than other varieties under rainfall stress conditions. On gender disaggregation, the paper has found that DT maize has a higher impact on female-headed households' plots than those cultivated by male-headed households, but female-headed households do not benefit from inorganic fertilizer and fertilizer subsidy.

Our findings could be evidence that poor harvests amongst most smallholder farmers in Malawi under rainfall stress conditions are largely a result of poor technology adoption. Thus, despite persistent dry spells, with good and proper packaged technologies, farmers can still get good harvests. In a country where smallholder farmers heavily rely on rain-fed agriculture in a single rainy season and alternative climate-smart agriculture technologies such as irrigation are seldom due to high investment and maintenance costs, DT maize and similar technologies could offer an option for better yields. The paper therefore recommends support on programs that promote development, packaging, promotion and availability of good technologies such as DT to allow smallholder farmers hedge against rainfall deficiency related poor harvests. DT maize however requires significant investment in complementary inputs such as inorganic fertilizer.

On gender differentials, giving female-headed households equal access to complementary technologies such as inorganic fertilizer and drought tolerant seed would minimize the yield gap between female and male-headed households. Female-headed households have not benefited from the subsidized fertilizer but seed subsidy despite being the primary target of the program. The country therefore needs deliberate efforts to increase access to complementary inputs specifically to female-headed households if the long-term objective of sustainable food security is to be achieved. The significant impact of seed subsidy, a seed that is either distributed freely or very cheap can be a starting point to assist female-headed households.

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Adoption of Integrated Soil Fertility Management Technologies in Malawi: Impact of Drought Exposure

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ABSTRACT

Integrated soil fertility management (ISFM) technologies may potentially protect against climate risks, reduce nutrient depletion and enhance food security. In this paper, we study impact of drought exposure on adoption and adoption intensity of ISFM technologies, specifically, focusing on maize-legume intercropping and organic manure. The paper uses four-round panel data collected from six districts in Malawi over a period of nine years and we use correlated random effects models with a control function approach for data analysis. Results show an increase in adoption rates from 33% in 2006 to 76% in 2015 for maize-legume intercropping and from 30% (2006) to 53% (2015) for organic manure. Regression results reveal that exposure to early and late dry spells increases the likelihood of adoption and adoption intensity of maize-legume intercropping with late droughts also having a positive impact on adoption and adoption intensity of organic manure. We also find positive effects of fertilizer use intensity and fertilizer price on adoption and adoption intensity of both intercropping and organic manure.

Key words: Drought exposure, maize-legume intercropping, organic manure, adoption, Malawi

INTRODUCTION

In Malawi, a country heavily dependent on rain-fed agriculture, the twin problems of drought and low levels of nitrogen use are major causes of low crop productivity resulting in persistent food insecurity (Weber et al., 2012). Efforts to enhance crop productivity through increased nutrient application, nutrient maintenance, and drought resilience are thus important to achieve sustainable food security. Such efforts require complementary investments in organic and inorganic integrated soil fertility management (ISFM) technologies and high yielding and drought tolerant crop varieties. ISFM technologies increase nutrient intake, protect the soils, minimize nutrient depletion through enhanced soil organic matter and biological activity and eventually increase crop yields and yield stability (Weidmann and Kilcher, 2011). ISFM ensures nutrient balance and efficient management of soil fertility through combinations of inorganic fertilizer, organic manure, soil and water conservation technologies and crop diversification that include maize-legume intercropping.

In this paper, we use a four-wave panel dataset for central and southern Malawi to examine adoption and adoption intensity of two ISFM technologies – organic manure and maize-legume intercropping – and how drought exposure influences farmer uptake. Organic manure and maize-legume intercropping are popular technologies among smallholder farmers in Malawi and our dataset allows us to gain an improved understanding of their adoption pattern over a close to 10-year period. In this period the sample farmers have been exposed to several climate shocks in the

form of late and early droughts and have also had varying access to input subsidies that indirectly may have affected the adoption of these technologies. In the same period the Government of Malawi (GoM) has enhanced efforts to promote adoption of climate-smart agriculture (CSA) technologies that includes organic manure and maize-legume intercropping through programs such as the Agriculture Sector Wide Approach (ASWAp) (Government of Malawi, 2011).

Previous research examined the determinants of farmers' investment decisions in maize-legume intercropping and organic manure in Malawi. Findings suggest that adoption of organic manure increases with inorganic fertilizer use and fertilizer price (Holden and Lunduka, 2012), tenure security (Kassie et al., 2015), knowledge of manure making (Kilcher, 2007, Mustafa-Msukwa et al., 2011) and household labor availability (Snapp et al., 2002, Mustafa-Msukwa et al., 2011, Chatsika, 2016). The probability of adopting maize-legume intercropping has been shown to be limited by the yield advantage of maize over legumes, pest susceptibility, and a lack of appropriate legume genotypes (Kerr et al., 2007, Ortega et al., 2016). Other factors shown to influence maize-legume intercropping are market access, output prices, availability and cost of improved legume seeds, farm size and exposure to weather shocks (Kerr et al., 2007, Kilcher, 2007, Ortega et al., 2016, Kassie et al., 2015, Asfaw et al., 2014).

Our paper builds on these studies by testing a number of hypotheses. First, the paper tests the hypothesis that exposure to drought shocks increases the likelihood of adopting maize-legume intercropping and organic manure. The paper makes a new contribution on this hypothesis by providing new evidence on how early and late dry spells affect adoption of maize-legume intercropping and organic manure. It is reported that sustainable conservation agriculture practices can minimize drought sensitivity of crop yields (Makate et al., 2017b, Muzari et al., 2012, Makate et al., 2017a, Kilcher, 2007). However, whether farmers respond to previous exposure to droughts by adopting maize-legume intercropping and organic manure, and how early and late dry spells affect adoption, remains largely unexplored in the literature. This analysis, therefore, reveals farmers' responses to drought shocks during the nine-year period our data covers. An increase in adoption over the years in response to drought shocks would suggest that farmers have experienced the advantages of these technologies under drought growth conditions.

Second, we test the hypothesis that an increase in inorganic fertilizer price is associated with higher likelihood of adopting organic manure and maize-legume intercropping. We extend this hypothesis by testing how fertilizer use intensity and fertilizer subsidy crowds out these technologies. We build on the findings of Holden and Lunduka (2012) to get robust evidence on impact of inorganic fertilizer price and fertilizer use intensity on adoption of organic manure. Holden and Lunduka reported positive impact of inorganic fertilizer price and fertilizer use intensity on uptake of organic manure. We extend the empirical analysis by including maize-legume intercropping technology. This hypothesis is of policy relevance in Malawi given the ongoing Farm Input Subsidy Program (FISP) that significantly affects inorganic fertilizer price as well as use intensity of inorganic fertilizer.

Third, we hypothesize that an increase in population density drives adoption of potentially land-saving technologies such as maize-legume intercropping. The evidence on how population growth affects adoption of maize-legume intercropping and organic manure is very important in Malawi given the country has one of the highest population densities in sub-Saharan Africa (SSA) (Holden and Lunduka, 2012). While researchers argue that population growth in Malawi pushes farmers to adopt maize-legume intercropping intensification and organic matter-based technologies (Snapp et al., 2002), to our knowledge this has not been examined econometrically.

MATERIALS AND METHODS

Data

We use four waves of panel data collected through household surveys conducted between 2006 and 2015 in central and southern Malawi. The first round in 2006 drew a random sample of 450 households using a simple random sampling technique following the second integrated household survey of 2004 (IHS2) (Lunduka, 2009). Of these 450 households, 378 were resurveyed in 2009, 350 in 2012 and 353 in 2015, resulting in four rounds of unbalanced panel data. The data show an increase in adoption from 30% in 2006 to 53% in 2015 for organic manure and from 33% to 76% for maize-legume intercropping (**Error! Reference source not found.**). On intensity, the data show a decrease for organic manure use between 2006 (2182 kg/ha) and 2015 (1456 kg/ha), but there is an increase in the share of farmed area allocated to maize-legume intercropping from 27% (2006) to 37% (2015).

Table 6: Adoption of organic manure and maize-legume intercropping

Technology	2006	2009	2012	2015	Total
Applied manure (1=yes)	0.30	0.43	0.49	0.53	0.43
Manure quantity (Kg/ha) for adopters	2182	1616	1526	1456	1724
Maize-legume intercropping (1=yes)	0.33	0.45	0.53	0.76	0.51
Farm size share of maize-legume intercropping (adopters)	0.27	0.25	0.34	0.37	0.30

Summary statistics of independent variables by year

Error! Reference source not found. presents summary statistics (means and proportions) for the explanatory variables used in this paper for each panel round. The data show considerable variation over time in exposure to early and late droughts. For example 2006 has the longest previous early dry spells lasting an average of 7.9 days and the longest one-year lagged late dry spell with 12.6 days. The fertilizer real price has increased from 60 Malawi Kwacha (MK)/Kg in 2006 to MK127/Kg in 2015. The data also shows that the quantity of inorganic fertilizer applied per hectare of land increased between 2006 and 2009 but has been decreasing since then. This trend could reflect the scale of FISP, which has been scaled back in recent years. In 2006, the program supplied 166000 metric tons (MT) of fertilizer, 195000 MT in 2009, 140000 MT in 2012 and 150000 MT in 2015.

Table 2 also reports changes in output prices. For example, the one-year lag of maize grain real price was higher in 2009 than in 2006, was lower in 2012 than in 2009, and increased between 2012 and 2015. Some of the observed price variations could be explained by policy and weather changes. The combined effect of availability of fertilizer through FISP and good rains, for example, enhances output supply, which also affects output price. We expect these factors affect farmers' investment decisions in organic manure and maize-legume intercropping. The data also suggest that there has not been a significant change in owned farm size from 2006 to 2015, but household size increased from 5.3 to 5.6. These changes present potential driving forces for adoption of organic manure and maize-legume intercropping technologies.

Table 7: Summary statistics of independent variables by year

Variable	2006	2009	2012	2015	Total
1 year lag longest early dry spell (days)	7.90	6.46	5.71	4.93	6.35
1 year lag longest late dry spell (days)	12.61	11.42	10.62	6.22	10.38
Fertilizer price (MK[a]/kg)	60.35	76.72	116.79	126.69	92.99
Fertilizer quantity (Kg/ha)	150.32	223.53	186.76	149.53	176.51
Annual average maize price - 1 year lag (MK[a]/Kg)	38.07	53.24	26.98	45.48	40.99
Annual average legume price - 1 year lag (MK[a]/Kg)	103.65	70.87	120.90	139.98	107.92
Distance to agricultural markets (Km)	4.41	4.30	4.19	4.20	4.28
Population density (household size/ha)	4.68	4.62	4.62	4.61	4.64
Southern region (1=yes)	0.57	0.58	0.59	0.58	0.58
Maize seed subsidy (1=yes)	0.35	0.33	0.56	0.64	0.46
Fertilizer subsidy (1=yes)	0.35	0.54	0.73	0.54	0.53
Tropical livestock unit	1.08	1.49	1.11	0.50	1.05
Asset value (MK)	3364	4123	2438	5918	3931
Farm size (ha)	1.22	1.18	1.20	1.23	1.21
Plot distance (Km)	0.96	3.00	3.78	3.22	2.63
Household head sex (1=male)	0.25	0.24	0.26	0.34	0.27
Household size	5.28	5.30	5.29	5.61	5.36
Off-farm labor (# of adults)	0.14	0.21	0.35	0.25	0.23
Male labor (adult equivalent/ha)	3.64	3.76	3.54	4.12	3.76
Female labor (adult equivalent/ha)	3.51	3.56	3.20	3.76	3.51

[a]Values in Malawi Kwacha (MK) are deflated with consumer price indices (CPI) using 2010 prices

Model specification and estimation strategy

We use the correlated random effects (CRE) model for data analysis specified as follows:

$$C_{it} = \beta_0 + \beta_1 W_{dt} + \beta_2 P^f_{it} + \beta_3 F_{it} + \beta_4 Pd_{ivt} + \beta_5 D_{it} + \beta_6 P^y_{dt} + \beta_7 R_{it} + \beta_8 H_{it} + \beta_9 \bar{H}_i + \beta_{10} T_t + \beta_{11} S_{it} + \alpha_i + \varepsilon_{it} \quad (1)$$

C_{it} is the dependent variable and takes different values for adoption and intensity of adoption? In adoption estimation, $C_{it}$is a dummy, equal to one if household *i* used organic manure (maize-legume intercropping) in year *t*, and equal to zero otherwise. For intensity of organic manure use, C_{it} is measured as quantity of organic manure applied in kilograms per hectare (kg/ha) and is log transformed. For maize-legume intercropping adoption intensity, C_{it} is defined as the share of total cultivated land under intercropping.

W_{dt} is a vector of previous (one-year lagged dry spells (e.g. length of longest early and late dry spells measured in days). $P^f_{it}$is fertilizer[19] real price including both commercial and subsidized fertilizer prices. F_{it} is (log of) fertilizer (including both commercial and subsidy) used (kg/ha) by household *i* at time *t* while Pd_{ivt} is (log of) population density in household *i*'s village *v*. $D_{it}$is average distance to the market in km (a proxy for market access); P^y_{dt} is a vector of annual average real output prices (maize and legume grain) in district *d* at time *t* while R_{it} is a dummy variable for the southern region. H_{it} and $\bar{H}_i$ is a vector of household and time-averages of household endowments, respectively. These variables include (log of) farm size (ha), distance to the farm (km), (log of) male and female labor endowment (adult equivalent/ha), (log of) livestock endowment (livestock tropical unit), and (log of) asset value in Malawi Kwacha (MK). T_t are year dummies (2006 is the reference) which control for price variation across years, while S_{it} indicates that a seed subsidy coupon was received. α_i captures individual time-invariant household fixed effects, while ε_{it} is the error

[19] Fertilizer price is at household level while output price is at district level. We use household level price for fertilizer to capture variations in final price paid by the farmer considering farmers access commercial and subsidized fertilizer.

term. By using CRE method, we are able to control for unobserved heterogeneity across households that is time invariant.

Sample selection and endogeneity

Estimation of equation one could suffer from sample selection bias due to farmers having non-random access to the Farm Input Subsidy Program and endogeneity bias of fertilizer use as it is a choice variable. To control for sample selection and endogeneity bias, we use a two-step control function (CF) approach (Wooldridge, 2011, Petrin and Train, 2010). The first step involves estimating two separate selection equations. We estimate a probit selection model for receipt of the seed subsidy including as explanatory variables the exogenous variables defined in equation (8) plus several identifying instruments: age and age squared of household head and a binary variable for whether the household resides in the wife's home village. The residual ($\bar{\lambda}_{it}$) from this regression is then computed. We also estimate a Tobit selection model of fertilizer use intensity with the same set of explanatory variables as in the seed subsidy model plus number of children (for household dependants) and physical asset endowments (wealth level) and obtain the residual ($\bar{\mu}_{it}$). The set of instruments controls for endogeneity related to the fertilizer subsidy access variable in the fertilizer demand equation, an approach adopted from Holden and Lunduka (2012).

Selection of the identifying instruments is based on previous studies, theory and FISP targeting criteria which seek to reach village-resident households who are resource poor and headed by a child, orphan, or female. Holden and Lunduka (2012) used age and age squared of household head on the assumption that access to FISP could be influenced by one's position in the village. In rural Malawi, social position is often a function of age, but this position may diminish as one grows older and less involved in village affairs. While FISP was meant to target resource poor households, Holden and Lunduka (2013) found targeting errors where in essence it is the powerful that benefit more from the program and this includes the wealthier. We therefore include wealth level on the assumption that such households should access more of inorganic fertilizer. However, despite the program targeting errors, we hypothesize that household residence in wife's village and household dependants would increase access. However, these variables are expected to not directly affect adoption of organic manure and maize-legume intercropping. The residuals from these regressions are included in the second step as additional regressors, while the instruments are excluded.

RESULTS AND DISCUSSIONS

Error! Reference source not found. presents results for adoption and adoption intensity of organic manure and maize-legume intercropping. The first two columns are for adoption and adoption intensity of organic manure while adoption and adoption intensity of maize-legume intercropping are respectively, in the third and fourth columns. Fertilizer demand and access to seed subsidy endogeneity is controlled for by including residuals from first-stage regressions, as described earlier. Results from reduced form equations are not presented to save space but available upon request. The instruments are jointly significant in the fertilizer demand and seed subsidy equations. The error component from the inorganic fertilizer use intensity model is significant in structural models in **Error! Reference source not found.** for adoption and adoption intensity for both organic manure and maize-legume intercropping, but the residual from seed subsidy is insignificant. We therefore re-estimated the maize-legume intercropping models presented in **Error! Reference source not found.** excluding seed subsidy residual (Mason and Ricker-Gilbert, 2013). Significance of residuals suggests endogeneity of fertilizer use intensity.

The first hypothesis the paper tests is that exposure to drought shocks increases the likelihood of adopting maize-legume intercropping and organic manure. The results in Table 3 show that we cannot reject this hypothesis and show a positive and significant relationship between previous

exposure to late dry spells and adoption and adoption intensity of organic manure. For maize-legume intercropping, adoption and adoption intensity are positively correlated with both early and late dry spells. These results suggest that farmers are aware of climatic shocks and their negative consequences and one of the ways they try to adapt, i.e. hedge against production losses, is by adopting these technologies. Research indicates that occurrence of climatic shocks creates fear and worry among smallholder farmers of a reoccurrence and leads to increased investments in adaptive mechanisms that hedge against resulting losses (Van Den Berg et al., 2009). Increased adoption of these technologies over time in response to drought exposure could be evidence that farmers are able to observe the impact of these technologies on yield and yield stability under drought growth conditions.

Our results also show that late droughts stimulate adoption of both maize-legume intercropping and organic manure, while exposure to early droughts appears to only stimulate more adoption of maize-legume intercropping. Crop production, maize in particular, which dominates in Malawi, is susceptible to early and late droughts and farmers are willing to invest in technologies that minimize the impacts. While irrigation technology is an option, the high investment and maintenance costs in SSA (Inocencio, 2007, Woodhouse et al., 2017) limit most smallholder farmers from adoption of this technology. Organic manure and maize-legume intercropping offer farmers an option to hedge against late droughts in particular by conserving soil moisture through organic matter and soil cover. Furthermore, some legumes (e.g. pigeon peas) are late drought tolerant hence more likely to be intercropped with maize in areas where late droughts are frequent. The positive significance of early droughts on maize-legume intercropping could be related to farmers' need for short duration crops that fit into a short season when an early drought occurs. Maize-legume intercropping allows farmers to plant short duration legumes in maize plots such as beans and soybeans.

The second hypothesis we test is that an increase in inorganic fertilizer price is associated with higher likelihood of adopting organic manure and maize-legume intercropping. This was extended to test how fertilizer use intensity (including both commercial and subsidy) affects adoption of these technologies. The results indicate that we cannot reject the hypothesis that price of commercial fertilizer affects adoption and adoption intensity of organic manure and maize-legume intercropping positively. An increase in fertilizer price of MK1000/Kg is associated with a 21% increase in quantity of organic manure use (Kg/ha) and 1% increase in farm size allocation to maize-legume intercropping. Results for the fertilizer demand equation (**Error! Reference source not found.**) suggest that an increase in the fertilizer price of MK1000/Kg reduces fertilizer demand by 9%. As an increase in fertilizer price reduces demand for fertilizer, farmers make a systematic tradeoff by investing more in organic manure and maize-legume intercropping. In our theoretical framework, farmers' decisions to adopt organic manure is not only influenced by its marginal productivity but also the price of inorganic fertilizer.

Fertilizer subsidy is insignificant on all adoption models suggesting no evidence of crowding out effect but there is evidence that commercial fertilizer use intensity has a positive and significant effect on adoption of both organic manure and maize-legume intercropping. A 1% increase in commercial fertilizer use intensity is associated with a 2.18% increase in organic manure use intensity. These findings concur with Holden and Lunduka (2012) who reported a 0.6-1.9% effect on organic manure of a 1% increase in fertilizer use intensity. The positive relationship between inorganic fertilizer use and organic manure use intensity suggests the two inputs are complements. The consistency of our findings with Holden and Lunduka (2012) provides additional evidence that inorganic fertilizer crowds in organic manure. There is also a positive and significant relationship between inorganic fertilizer use intensity and both adoption and adoption intensity of maize-legume intercropping. A 1% increase in fertilizer use intensity increases farmland share under intercropping by 0.12%.

The third hypothesis is that an increase in population density drives adoption of potentially land-saving technologies such as maize-legume intercropping. Our results do not allow us to reject the hypothesis as higher population density is associated with higher adoption and adoption intensity of organic manure and adoption intensity of maize-legume intercropping. These results provide more empirical evidence to support the claim by Snapp et al. (2002) that population growth has potential to drive smallholder farmers to adopt maize-legume intensification and organic matter-based technologies. Related to this we find that adoption and adoption intensity of maize-legume intercropping is higher in Malawi's Southern Region than in the Central Region. This is as expected because maize-legume intercropping is a land-saving technology. Compared to the Central Region, the Southern Region has small land holdings and high population density.

Controlling for market access and output prices, the results show positive and significant correlation between one-year lag of legume prices and adoption of organic manure as well as adoption and adoption intensity of maize-legume intercropping. But there is a negative correlation between adoption intensity of organic manure and lagged maize prices. There is also positive effect of distance to agricultural markets on adoption and adoption intensity of maize-legume intercropping. These results suggest that farmers are somewhat price and market responsive. However, while legume price presents an incentive potential for farmers to adopt soil fertility management technologies, maize price appears to demotivate farmers from adopting organic manure. We hypothesized in our theoretical framework that adoption of organic manure and maize-legume intercropping would be affected by their marginal productivity which is a function of output and input prices. Relative to the opportunity cost for labor, a higher and significant output price signifies higher expected profits and increases the probability of adopting the technologies. With greater profits, farmers are more able to afford the new technologies.

Table 8: Regression results on adoption of organic manure and maize-legume intercropping

Variable	Organic Manure		Maize-legume intercropping	
	Adoption (1=yes)	Log Manure (Kg/ha)	Adoption (1=yes)	Farm size share
Early dry spell (1-year lag)	-0.007	-0.135	0.039*	0.015**
	(0.018)	*(0.091)*	*(0.022)*	*(0.007)*
Late dry spell (1-year lag)	0.020**	0.132**	0.035***	0.015***
	(0.010)	*(0.053)*	*(0.011)*	*(0.004)*
Log-commercial fertilizer (Kg/ha)	0.348***	2.176***	0.391***	0.115***
	(0.120)	*(0.556)*	*(0.134)*	*(0.044)*
Log-subsidized fertilizer (Kg/ha)	0.032	0.147	-0.009	-0.001
	(0.034)	*(0.164)*	*(0.036)*	*(0.013)*
Price commercial fertilizer (Mk/Kg)	0.004***	0.021***	0.003**	0.001**
	(0.001)	*(0.006)*	*(0.001)*	*0.000*
Price subsidized fertilizer (Mk/Kg)	-0.002	-0.010	-0.002	-0.001
	(0.002)	*(0.011)*	*(0.002)*	*(0.001)*
1-year lag legume price (Mk/Kg)	0.003***	0.006	0.003**	0.001***
	(0.001)	*(0.005)*	*(0.001)*	*0.000*
1-year lag maize price (Mk/Kg)	-0.005	-0.121**	-0.014	-0.007
	(0.013)	*(0.061)*	*(0.016)*	*(0.005)*
Distance to market (km)	-0.039	-0.180	0.049*	0.023***
	(0.025)	*(0.117)*	*(0.028)*	*(0.009)*
Log-population density	1.524***	6.132**	0.368	0.434**
	(0.542)	*(2.794)*	*(0.622)*	*(0.211)*
Southern region dummy	-0.208	-0.408	1.246***	0.520***
	(0.161)	*(0.843)*	*(0.199)*	*(0.064)*

Household head sex (1=female)	-0.005	0.040	0.303**	0.103***
	(0.122)	*(0.564)*	*(0.147)*	*(0.038)*
Log-male labor (adult equivalent/ha)	0.083	0.722	-0.411*	-0.149*
	(0.186)	*(0.849)*	*(0.230)*	*(0.087)*
Log-female labor (adult equivalent/ha)	-0.040	0.376	0.146	0.068
	(0.193)	*(0.885)*	*(0.247)*	*(0.089)*
Log-farm size (ha)	0.099	-0.411	0.276	-0.048
	(0.218)	*(0.995)*	*(0.235)*	*(0.074)*
Seed subsidy dummy			-0.018	-0.012
			(0.118)	*(0.036)*
Error from fertilizer equation	-0.332***	-2.054***	-0.374***	-0.111**
	(0.122)	*(0.566)*	*(0.132)*	*(0.043)*
Constant	-4.215***	-12.350**	-3.110***	-1.361***
	(1.070)	*(5.217)*	*(1.074)*	*(0.364)*
Prob > chi2	0.000	0.000	0.000	0.000
Rho	0.208	0.146	0.212	0.148
Number of observations	1490	1490	1475	1475

Significance levels: ∗10%, ∗∗5%, ∗∗∗1%. Household and mean household endowments and year dummies are left out of the table to save space. The standard errors are bootstrapped with 400 replications, resampling households.

CONCLUSIONS AND POLICY IMPLICATIONS

Using four waves of panel data for nine years, this paper finds an increase in adoption from 33% in 2006 to 76% in 2015 for maize-legume intercropping and for organic manure increasing from 30% in 2006 and 53% in 2015. Our results demonstrate that adoption and adoption intensity of maize-legume intercropping are positively associated with exposure to early and late dry spells. Exposure to late dry spell in the previous year also appeared to stimulate adoption intensity of organic manure. The positive impact of dry spells on adoption of maize-legume intercropping and organic manure implies that farmers respond to occurrence and risks associated with dry spells and may perceive that maize-legume intercropping and organic manure help them to hedge against resulting production losses. We leave for future research to investigate how efficient these technologies are in achieving this. With the Government of Malawi taking an active role in promoting these technologies, there is need for collective and coordinated efforts to ensure that appropriate climate-smart agriculture technologies are available and disseminated to the farmers. While irrigation technology is an expensive option due to high investment and maintenance costs, organic manure and maize-legume intercropping offer smallholder farmers lower-cost options to hedge against late droughts by conserving soil moisture.

Second, our findings show that subsidies for inorganic fertilizer do not necessarily crowd out organic manures nor maize-legume intercropping. Although there is a significant positive effect of fertilizer price on use of these technologies this is compensated by the positive and significant (complementary) relationship between inorganic fertilizer use and use of organic manure and maize-legume intercropping. It may be possible to further enhance such complementarities through extension efforts. Promotion of ISFM can facilitate further extraction of such synergistic effects. Vanlauwe et al. (2011) showed that Nitrogen use efficiency can be enhanced in maize-based systems by combining moderate amounts of organic manures with inorganic N fertilizers.

Third, the positive correlation between adoption of maize-legume intercropping and population density and residence in Southern Region (the region with highest population density) indicates that intensification takes place on small farms through adoption of land-saving technologies as population growth continues putting pressure on land. Maize-legume intercropping is a land-saving

technology as it maximizes output per unit land. Promotion of legumes such as pigeon peas and soya beans can facilitate such intensification.

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Microbial quality assessment of open sun and solar tent dried Barbus paludinosus in Lake Chilwa Basin

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ABSTRACT

This study assessed the effects of two processing methods; open sun drying and solar tent drying on microbial quality of Barbus paludinosus, (straight fin barb locally known as Matemba), a species of ray-finned fish in the family Cyprinidae that supports a significant fishery sector in Malawi.

Barbus paludinosus (Matemba) were dried using open sun drying and solar tent driers. Samples were collected in newly bought polythene bags, well labelled and collected in cooler boxes transported ready for laboratory analysis. One-gram (1g) representative sample was obtained aseptically from the muscle of the fresh and dried the straight fin barb (Matemba) samples. The samples were grounded and serial dilutions (10-1 to 10-4) of the homogenized samples were made using sterile distilled water.

Fish samples were analysed for total plate count (TPC), Total fungal count (TFC), E. coli counts and for pathogenic organisms (Salmonella) following the methods prescribed by (AOAC, 2000). Each analysis was carried out in triplicates.

There were significant differences (p = 0.05), with respect to total viable bacterial counts between open sun dried and solar tent dried B. paludinosus (1.6 x 10^6cfu/g, 1.4 x 10^6cfu/g, respectively). Open sun-dried B. paludinosus harboured significantly higher total viable counts as well as a higher population of Escherichia coli compared to solar tent dried Barbus paludinosus. However, open sun-dried B. paludinosus harboured undetectable levels of Salmonella typhi, a microbe of public health importance. Overall, bacterial populations were not above acceptable norms (10^8cfu/g) for both processing methods implying that the two methods can be deployable without public health concerns.

Keywords: Barbus paludinosus, fisheries, Salmonella typhi, Malawi

INTRODUCTION

Fishing has been regarded as very significant to Malawi as it contributes to the livelihood of Malawians. The fishing industry contributes about 4% to the Gross Domestic Product (GDP) for Malawi and employs about 60000 fishers and indirectly employ over half a million Malawians through processing, fish marketing and boat building and repair. Many of these employees are rural women in involved fish processing and marketing (Government of Malawi, 2012).

In Malawi, fisheries are an important part of food security as fish is a reliable source of food and nutritional security. Fish accounted for 70% of animal protein intake and 40% of total protein consumed by the Malawian population in the 1970s. The trend has however changed as there has been a decline in fish landings and increase in population over time during the past thirty years. This has led to the decline of per capita fish consumption from 14 kg per person per year in the 1970s to about 5.6 kg in 2011 (Government of Malawi, 2012).

The fish landings in the Lake Chilwa have been declining over the years with mean total landings for period 2000- 2009 pegged at 7537 tonnes per year which are lower than the peak of 12000 tonnes per year in the 1990s (EAD, 2004). The decline in the fish landings brings to light the need to preserve the harvested fish to reduce post-harvest losses which are estimated at 30% of the fish landings (Jamu, Botha and Luhanga, 2012). Thus, adoption of processing technologies offers an opportunity to the processors to preserve as much fish as possible.

In spite of fish being a highly nutritious and economically viable food, it is also one of the most perishable because of its suitable medium for growth of microbes after harvest. Spoilage and deterioration are much faster amongst tropical fish species because of high ambient temperature prevalent in the tropics. Most tropical fish species could become unfit for consumption within 12–20 h of capture unless it is subjected to some of processing (Aberoumand, 2013; ECA., 1984; Ames, Clucas and Paul, 1999) which include preservation by drying. Various factors such as fish health status, parasites, wounds and bruises, mode of capture, handling, and preservation after capture are responsible for fish spoilage (Akinneye, Amoo and Arannilewa, 2007; Tawari and Abowei, 2011). Chemical, microbial, and enzymatic actions on captured fish bring about spoilage with resultant deterioration in the flesh, body tissues, and organs of the fish through physical and biochemical changes (Ghaly, Dave, Budge and Brooks, 2010). *Barbus paludinosus* (Matemba) a small fish which is endemic to the Lake Chilwa and is widely consumed in Malawi as a common relish and liked by many. Considering the importance of this fish and its distribution, it was necessary to study the drying processes of the fish and the effect of the drying methods has on the microbial quality of fish.

According to Kapute (2008), fish processing methods in Malawi include drying, smoking, boiling, and pan roasting. In order to reduce post-harvest losses fish processers in the Lake Chilwa basin use different processing methods to preserve the fish before the fish is sold to wholesalers, retailers and consumers. Matemba are commonly dried using open sun drying methods on raised drying racks.

Mustapha et al, (2014), have reported that sun drying of fish is one of the traditional methods used to preserve fish in many sub-Saharan African countries because of the richness in availability of high solar radiance for a greater part of the year. Sun drying helps to remove water from the fish by evaporation (Eyo, 2001) and this reduces water activity of the fish which results in the slowdown of autolytic activity, enzymatic reactions, and microbial activities. Sun drying of fish which is usually done in the open exposes fish to contaminants such as dust, insect, pest, bird and animal attack. The fish are also vulnerable to infection by microorganisms, enzymatic reaction which leads to poor quality and spoilage of preserved fish. As a way of overcoming the shortfalls associated with sun drying, solar driers have been introduced and adopted as a way of drying fish and these have shown resulted in speeding up drying of fish resulting in high quality products with a longer shelf-life (Mustapha et al, 2014; Oparaku, 2010).

Objectives
To assess the effects of processing methods (open sun drying and solar tent driers) on *Barbus palidunosus*

METHODOLOGY

Study sites
The study was carried out in Zomba District at Mchenga beach in the Lake Chilwa basin where a CultiAf project funded by International Development Research Centre (IDRC) and Australian Centre for International Agriculture Research (ACIAR) was being implemented.

Study design
A completely randomised design was used when samples were collected from fish processors after processing for microbial analysis. All the samples were collected from fish processors soon after processing; 2 kg for each processing method (fresh fish, open sun dried and solar tent drier dried). The fresh fish after being collected from the landing sites were was before being open sun dried and solar tent dried on the raised drying racks. The samples were put in new polythene bags, labelled and collected in cooler boxes transported ready for laboratory analysis. Fresh samples were immediately put on ice before being taken to the laboratory while other samples were processed and collected immediately after and transported to the laboratory. Both the fresh and processed samples were collected from the same batch after purchase. At the laboratory samples were composited from each batch for subsequent analysis.

Solar tent drier description
The Solar tent drier was made up of a UV treated polythene 200 μm sheet worn over a wooden frame (Figure 2). Its dimensions were 12 m × 5 m × 5.5 m (length × width × height at the centre). The height at the side was 2.5 m. The solar tent drier has an inlet air vent on the bottom with a dimension of 30 cm × 30 cm and outlet vents up on both sides of the vertex with a dimension of 40 cm × 40 cm. The vents provided circulation of air to speed up drying process through convection current and these were sealed with galvanized fine meshed gauze wire to check entry of flies. Inside the solar tent drier are drying racks used to dry fish which were 11 m × 1 m (length × width).

Figure 1: Open sun drying of fish

Figure 2: Solar tent drier in Mchenga beach, Lake Chilwa

Microbiological Analyses

One gram (1 g) representative sample was obtained aseptically from the muscle of each of the smoked and dried samples. The samples were grounded and serial dilutions (10^{-1}- 10^{-4}) of the homogenized samples were made using sterile distilled water. Each analysis was carried out in triplicates. The fish samples were analyzed for total plate count, total coliforms, E. coli and pathogenic microorganisms (*Salmonella*). All microbial analyses were done following the methods prescribed by (AOAC, 2000). The results were reported in cfu/g.

Aliquots of suitable dilutions were transferred separately to plates count agar for total plate count, Salmonella-Shigella agar for salmonellae count, MacConkey agar for *E. coli* count and Violet Red Bile agar for total coliforms count.

Data analysis

All analyses were done using the SPSS software for Windows (version 16) (SPSS Inc., 2006, Chicago, IL. One-way analysis of variance (ANOVA) where $P < 0.05$ was applied to the different sample values obtained.

RESULTS AND DISCUSSION

Table 1: Microbial quality of smoked Barbus paludinosus in cfu/g

SAMPLE ID	Total Plate Counts	Total Coliforms	E. coli	Salmonella
Fresh *Barbus paludinosus*	7.7×10^5	1.5×10^5	1.0×10^6	2.9×10^4
Open sun dried *Barbus paludinosus*	1.6×10^6	2.1×10^6	9.6×10^5	3.5×10^4
Solar tent dried *Barbus paludinosus*	1.4×10^6	4.8×10^4	0	0

The study showed that highest total viable counts were observed in open sun-dried fish (1.6×10^6 cfu/g) as compared to solar tent dried fish (1.4×10^6 cfu/g) and these results were different significantly ($p= 0.05$) (Table 1). The bacteria that were also isolated from the open sun dried and solar tent dried fish were total coliforms (2.1×10^6 and 4.8×10^4 cfu/g), *E. coli* (9.6×10^5 and 0 cfu/g) and *Salmonella* (3.5×10^4 and 0) respectively.

Table 2: Moisture content of dried fish and temperatures during drying

Fish treatment	Moisture content %	Temperature
Fresh *Barbus paludinosus*	77.6±0.9[a]	
Open sun dried *Barbus paludinosus*	30.4±2.0[b]	23.6°C
Solar tent dried *Barbus paludinosus*	23.3±1.1[c]	31.8°C

Solar tent dried *Barbus paludinosus* had low moisture content than open sun dried. Fish spoilage has shown to be a function of moisture content. Patterson and Ranjitha (2009) have reported that high total plate counts, *E. coli* were recorded in processed fish which had high moisture content. Fish that have been dried to moisture levels of 6 to 8% have retarded rate of microbial spoilage because of low water activity which in turn increases the shelf life. The higher temperatures recorded during drying of the fish in the solar tent drier helped to remove more water from the fish though in this study the moisture content was still higher than the recommended moisture for dried fish. This was so because the study used the fish in the normal way fish processors dry the fish. This resulted in the higher moisture content which might have encouraged microbial growth as shown by the results. However, the study has shown that solar tent driers were more efficient in drying the fish and also reducing the microbial load in the dried fish.

Solar tent dried fish did not have *E. coli* and Salmonella which were found in the open sun-dried fish. Both these pathogens are associated with food borne illnesses and are an indicator of poor hygiene (Banda et al., 2017). Salmonella is a pathogen of public health as such it is important to look at source of contamination and encourage proper and hygienic handling of fish during processing.

Table 3: Free fatty acid values of fish samples

Sample	**Free fatty acid %**
Fresh Barbus paludinosus	0.034±0.005
Open sundried *Barbus paludinosus*	0.058±0.001
Solar tent dried *Barbus paludinosus*	0.017±0.000

The study also showed that the free fatty acid, which is a tertiary product of rancidity and increases during storage was lower in the solar tent dried fish than open sun-dried fish (Table 3). According to Eyo (1993) rancidity in fish oils becomes evident when the free fatty acid which is calculated as oleic acid is between 0.5 and 1.5 and in this research all the samples were below this limit. This means that the fish were of good quality and that the microorganisms that were found during the study may have been due to handling and might have been on the fish before processing.

Adegunwa, Adebowale, Olisa and Bakare (2013) previously reported that the International Commission on Microbiological Specification for Food, (ICMSF) has set the maximum recommended bacteria count for good quality fish products at 5.0×10^5 cfu/g and 1 x 10^7 cfu/g as the maximum for marginally acceptable quality products and for Listeria monocytogenes and Salmonella spp., the level in the presence of organism is zero tolerance. This calls for more sensitization on hygienic practices for all processors and fishers during handling and processing of fish.

CONCLUSION

The study findings have shown that solar tent drier would help in processing of small fish and having them processed in high quality. The solar tent driers would consolidate the fisheries value chain especially where fish processed dry the fish to recommended levels of moisture content. The

solar tent driers have an advantage also over open sun drying in that fish is dried even during adverse weather conditions and the fish is also protected from dust, flies and other predators.

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Microbiological quality of traditional and improved kiln smoked catfish (*Clarias gariepinus*) in Lake Chilwa Basin

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ABSTRACT

Microbiological quality of smoked catfish (Clarias gariepinus) was assessed in this study where traditional and improved smoking kiln were used to smoke fish. Catfish is common fish caught in abundance in the Lake Chilwa basin and the fish is usually smoked to reduce post-harvest losses and increase shelf life. Samples were collected in newly bought polythene bags, well labelled and collected in cooler boxes transported ready for laboratory analysis. One-gram (1g) representative sample was obtained aseptically from the muscle of the fresh and smoked catfish (Mlamba) samples. The samples were grounded and serial dilutions (10^{-1} to 10^{-4}) of the homogenized samples were made using sterile distilled water. Fish samples were analysed for total plate count (TPC), Total fungal count (TFC), E. coli counts and for pathogenic organisms (Salmonella) following the methods prescribed by (AOAC, 2000). Each analysis was carried out in triplicates. There were significant differences ($p = 0.05$), with respect to total viable bacterial counts between traditional kiln smoked and improved kiln smoked catfish (5.6×10^6 CFU/g, 1.9×10^6 CFU/g, respectively). Traditional kiln smoked catfish harboured significantly higher total viable counts as well as a higher population of Escherichia coli compared to improved kiln smoked catfish. However, for both types of smoking kilns there were detected levels of pathogenic bacteria Salmonella with traditional kiln smoked catfish containing 2.1×10^4 CFU/g which were significantly higher than amount found in improved kiln smoked catfish (1.5×10^4 CFU/g). Salmonella is a microbe of public health importance and has implications on the handling and source of the fish. Overall, bacterial populations were not above acceptable norms (10^8cfu/g) for both processing methods implying that the two methods can be deployable without public health concerns.

Keywords: Salmonella, Escherichia coli, catfish, Lake Chilwa

INTRODUCTION

Considerable quantity losses in the fish that is caught occur because fish is highly perishable commodity. It has been recorded that no other food other food provides so much observed evidence of serious loss from harvest to consumption and so little documentation of the overall proportion of losses from fish production (Aberoumand, Impact of freezing on nutritional composition of some

less known selected fresh fishes in Iran , 2013 ; ECA., 1984). Post-harvest losses of fish take place in the fish value in various degrees or extent. According to Signa, (2014) post-harvest losses (PHL) can be defined as the decrease in quantity, or quality or monetary value of fish in the supply or value chain. The losses will generally result in the loss of income to the people involved in the value chain and also loss in the availability of fish as food hence they represent a major food security concern in Africa, where many people are food insecure.

In Malawi about 30% of fish caught in Malawi is lost through post-harvest losses due to poor processing, packaging and transportation (Jamu et al., 2012). Fish after being caught is very susceptible to deterioration if not preserved and processed (Okonta & Ekelemu, 2005). The deterioration that sets in when fish dies is both physiological and microbial; these invariably degrade the quality of fish (Eyo, 2001). Chemical breakdown of protein content, fat content (agent of rancidity and off-flavour) and the water content/water activity contribute to quick spoilage of fish. These physiological and microbial activities make the fish unfit for human consumption within about one day of capture, unless it is subjected to some form of processing or preservation. According to Mutungi and Affognon (2013), in Malawi almost 90% of the fish from capture fisheries is preserved before being sold. Smoking accounts for 40% and sun-drying takes up 50% of the fish preservation methods whereas only 10% is handled and sold as fresh, chilled and frozen. There are a number of processing facilities that are used which include the traditional type, like dug-out smoking ovens and drying racks made of reeds and mats, improved facilities have also been adopted in some areas such as Bena kiln (improved Ivory Coast kiln) and wire drying racks.

In trying to reduce post-harvest losses fish processers in the Lake Chilwa basin use different processing methods to preserve the fish before the fish is sold to wholesalers, retailers and consumers. The fish processing methods include sun drying, solar drying, smoking and frying.

MATERIALS AND METHODS

Study sites

The study was carried out in Zomba District at Mchenga beach in the Lake Chilwa basin where a CultiAf project funded by International Development Research Centre (IDRC) and Australian Centre for International Agriculture Research (ACIAR) was being implemented.

Study design

A completely randomised design was used when samples were collected from fish processors after processing for microbial analysis. All the samples were collected from fish processors soon after processing; a total of 50 samples for each processing method. The samples were put in new polythene bags, labelled and collected in cooler boxes transported ready for laboratory analysis. Fresh samples were immediately put on ice before being taken to the laboratory while other samples were processed and collected immediately after and transported to the laboratory. Both the fresh and processed samples were collected from the same batch after purchase. At the laboratory samples were composited from each batch for subsequent analysis.

Microbiological Analyses

One gram (1 g) representative sample was obtained aseptically from the muscle of each of the smoked and dried samples. The samples were grounded and serial dilutions (10^{-1}- 10^{-4}) of the homogenized samples were made using sterile distilled water. Each analysis was carried out in triplicates. The fish samples were analysed for total plate count, total coliforms, E. coli and pathogenic microorganisms (*Salmonella*). All microbial analyses were done following the methods prescribed by (AOAC, 2000). The results were reported in cfu/g. Aliquots of suitable dilutions were transferred separately to plates count agar for total plate count, Salmonella-Shigella agar for

salmonellae count, MacConkey agar for E. coli count and Violet Red Bile agar for total coliforms count.

Data analysis

All analyses were done using the SPSS software for Windows (version 16) (SPSS Inc., 2006, Chicago, IL). One-way analysis of variance (ANOVA) where $P < 0.05$ was applied to the different sample values obtained.

Figure 1: Improved smoking kiln with doors open with catfish being smoked

Figure 2: Traditional smoking kiln with catfish being smoked

Figure 3: A fish processor in Lake Chilwa Basin showing the fish smoking process using improved smoking kiln

RESULTS AND DISCUSSION

Table 1 showed the microbial populations in fresh and smoked *Clarias gariepinus*. Total plate count (TPC), *Salmonella*, total coliforms and *E. coli* in colony forming units (CFU)/g of fresh and smoked *Clarias gariepinus* samples plated on selective and non-selective media. The highest mean total viable count of 5.656 x 10^6 was found in traditional kiln smoked *Clarias gariepinus*. The study has shown that traditional kiln smoked *Clarias gariepinus* had the higher microbial counts registered than the improved kiln smoked Clarias gariepinus as shown in Table 1. The study has shown that smoking reduces the amount of Salmonella, total coliforms and *E.coli* found in the *Clarias gariepinus* fish as highest figures were found in fresh samples 3.575 x 10^4, 1.80 x 10^5, and 4.00 x 10^4 cfu/g respectively. In improved kiln smoking fish is also hygienically handled and fish is in an enclosure which reduces infestation of microbes which is in agreement with Immaculate *et al.*, (2012).

Table 1: Mean microbial counts (cfu/g) in smoked *Clarias gariepinus*

Sample id	Total plate counts	Salmonella	Total coliforms	E. coli
Fresh Clarias	1.344 x 10^6	3.575 x 10^4	1.80 x 10^5	4.00 x 10^4
Traditional kiln whole smoked Clarias	5.656 x 10^6	2.100 x 10^4	4.53 x 10^4	6.67 x 10^2
Improved kiln whole smoked Clarias	1.936 x 10^6	1.550 x 10^4	2.00 x 10^4	0

Though total coliforms were found in the improved kiln smoked samples as shown in Table 1, it was noted however that these samples had lower amounts of coliforms and *E.coli* found in them (2.00×10^4 and 0 cfu/g) respectively as compared to traditional kiln smoked samples (4.53×10^4 and 6.67×10^2cfu/g). The results may be attributed to handling practices during smoking by the fish processors as the fish is handled with hands during and after processing which may introduce bacteria on the fish after processing. Smoking of the fish was also at variable temperatures because of the amount of fire available during the smoking period which meant that microorganisms were not exposed to the same amount of heat that would kill them completely. Daniel, Ugwueze and Igbegu (2013); Abolagba and Iyeru, (1998) have reported that varying microbial load in smoked fish would result from lack of proper smoking and hygienic handling of the smoked fish.

Table 2: Moisture and protein content of *Clarias* species

Fish type	Moisture %	Crude protein %
Clarias (Mlamba)fresh	$77.44^{a}\pm0.30$	$18.34^{b}\pm0.17$
Split open Clarias traditional kiln smoked	$30.15^{b}\pm3.60$	$53.16^{a}\pm1.39$
Split open Clarias improved kiln smoked	$33.51^{b}\pm0.56$	$58.22^{a}\pm1.51$

It has been shown in this research as shown in Table 2 that moisture content of the smoked fish was high which would still encourage microbial growth despite the number of microorganisms being reduced during smoking. It was observed during the research that the smoked fish were spread in the open on wire mesh to cool after smoking which was exposing the fish to the environment which was somehow humid and this may have encouraged the smoked fish to increase in moisture by absorbing it from the environment. This increase in moisture may have increased activity of microorganisms. Eyo (2001) stated that smoked fish samples may have a relatively high water activity which would encourage microbial growth. Akinwumi and Adegbehingbe, (2015) has recorded that smoking at high temperatures has potential to control fish microbial contamination, although the heat used may not suffice to kill all the microbial contaminants. Temperatures as high as >600°C when used in smoking would result in inactivating vegetative microorganisms, but this may bring in concerns on the sensory quality of the smoked fish.

CONCLUSION AND RECOMMENDATIONS

The study findings have shown that improved smoking kilns are more effective in reducing microbial load of the processed fish and that more fish are processed per unit time as compared to traditional smoking kilns. The improved smoking kilns will also help save the environment as the use 30 % lesser fuel wood during processing. It is being recommended that the fish be dried to lesser moisture content to reduce microbial growth due to low water activity.

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Nutrient use efficiency of maize in Central Malawi

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ABSTRACT

On-station and on-farm field trials were conducted at Chitala in Salima district and at Bunda Campus in Lilongwe district to determine maize yield response, nutrient use efficiency and the economically optimum N, P and K rates for maize production in central Malawi. Sixteen treatments consisting of N, P and K rates and a diagnostic treatment were laid in RCBD. The data were subjected to ANOVA and fertilizer optimization tool for the calculation of the economically optimum rates (EOR). Grain yields, agronomic use efficiency of N, P and K and value cost ratios (VCR) significantly differed with treatment in both districts. There was a 300% yield increase at both sites when the rate of 120 kg N plus 15 kg P/ha was applied compared to the control. The VCR values were all higher than the minimum required value of 2, with largest profits in applied N or P obtained for maize at both sites when the rate of 30 N kg/ha or 15 kg/ha of P alone was applied. VCR was above 4 even at 90 kg/ha N and 22.5 kg/ha P, indicating that fertilizer application is highly profitable at both sites. Values of EOR were similar to the fertilizer recommended rates for N. However, EOR for P (30; 24) were higher than the currently recommended rates of 3 to18 in Salima and Lilongwe. The EORs for K (2) were three times lower than the recommended rates for Salima (6 kg/ha K) and Lilongwe (8 kg/ha K) for maize production. The results demonstrated the practicality of increasing profit margins with minimal investments for the financially constrained smallholder farmers based on choice of the best fertilizer types and combinations.

Key words: *maize; nutrient use efficiency; fertilizer; economically optimum rates; agronomic use efficiency; value cost ratio.*

INTRODUCTION

Maize is a major staple food crop for most Malawians "maize is life" (Smale and Heisey, 1997), occupying 70% of arable land and predominantly grown by smallholder farmers with an estimated average yield of 2 t/ha (IFDC, 2013). The yield of maize remains low in Malawi due to a number of

factors, but the decline in soil fertility due to continuous cultivation and little addition of inputs ranks highly (Sanchez, 2002; Waddington *et al.*, 2004). Poor crop stand resulting from low seedling establishment, limited moisture regimes, poor agronomic practices all contribute to poor yields in maize production (Kamanga *et al.*, 2014; Whitebread e*t al.*, 2013). Nutrient losses through erosion are common, and annual losses are estimated at 30 kg/ha of N in Malawi (Mughogho, 1992; Stoorvogel *et al.*, 1993; Smaling, 1998). Consequently, there is need to replace these lost nutrients by use of fertilizers if any meaningful yields can be obtained from this region.

In Malawi, for the past decades, research efforts have managed to formulate many fertilizer recommendations made for different crops and agro-ecological zones where they are grown. However, the recommendations are mainly based on the assumption that farmers have no financial constraints as such they would manage to apply the full rates of fertilizer recommendations. Many farmers are financially constrained and cannot afford to apply all the full amounts of the recommended fertilizer rates. Estimates indicate that less than 50% of smallholders in the country use any fertiliser, and about 70% use less than 50 kg/ha (Kanyama *et al.*, 2000). Efforts are required to help such financially constrained smallholder farmers to make best use of their little available resources by increasing or maximizing profits in maize grain yield production. This can be achieved with proper nutrient use efficiency knowledge based on fertilizer optimization decision making tools. However, in Malawi there are no fertilizer optimization tools for nutrient use efficiency (Snapp *et al.*, 2014) that can be used to advise farmers on which types of fertilizer to buy and in what quantities to apply based on their available limited financial resources. This research work was carried out to address existing gaps in optimizing fertilizer recommendations that are economical. The objectives of the study were: a) to determine variability in maize yield response due to differential nutrient levels; b) to determine nutrient use efficiency in relation to maize grain yield production; c) to determine the economically optimum N, P and K rates for maize grain yield production.

MATERIALS AND METHODS

Soil and climatic characteristics of the trial sites

On-station and on-farm trials were implemented in two different agro-ecological zones (AEZ), i.e. Lilongwe and Salima districts located in central region of Malawi. Lilongwe falls under the mid-elevation, upland plateau AEZ, lies between 760 and 1300 m asl. It has sub-humid climate with monthly rainfall range of 1 to 221 mm; and minimum and maximum mean temperatures range of 8 to 17 and 24 to 30 ^{o}C, (Peel et al., 2007) respectively. The escarpment soils are predominantly shallow Leptosols. Soils higher in the plateau catenas are deep well drained Leptosols and poorly drained sand and clay soils are dominate in the valleys, locally called dambos. Other important soil groups include Luvisols, Ferrasols, Lixisols Cambisols and Gleysols (Jones et al., 2013).

Salima falls under the lakeshore, middle and upper Shire Valley AEZ of 200 to 760 m asl which is generally flat to gently undulating, with deep Fluvisol soils in the valleys and the shore lands of Lake Malawi. The soils at Bunda College are described as Luvisols (Jones et al., 2013). The climate is sub-humid with monthly rainfall ranges from 0 to 339 mm, and mean monthly minimum and maximum temperatures range from 16 to 22 and 26 to 33 ^{o}C, respectively. Important food crops include maize, rice, cassava, sorghum, and millet. The analysed initial data for the physical and chemical properties of the soil for the two study districts are given in Table 1.

Table 1. Soil analytical data for the two trial agro-ecological sites (Salima and Lilongwe) in Malawi

Location	Texture	pH	SOC^{+} g kg^{-1}	P	K	Mg	S	Zn	B
				mg kg^{-1}					
Lilongwe	SC*	5.64	1.53	13.31	0.29	1.15	10.08	2.73	0.13
Salima	SCL**	6.43	0.98	10.67	0.40	2.35	9.06	1.94	0.17

*SC = Sandy Clay; **SCL = Sandy Clay Loam; $^{+}$Soil Organic carbon.

Agronomic field trials and experimental designs

The on-station and on-farm field trials were mounted with 3 and 5 replications, respectively. For the on-farm trials, each farm was treated as a single replication and in total there were 5 farms. Each plot comprised of 6 ridges each 6 m in length spaced at 0.7 m. The maize seeds were planted on the ridges one seed per planting station spaced at 25 cm apart as per existing recommendations. The trial plots were enclosed with 4 border rows to control the external sources of variations.

A total of 16 treatment combinations made of at least 4 levels of the major nutrients were included in each replicate as follows:

0P0K versus 0N; 30N; 60N; 90N; 120N
15P,0K versus 0N; 30N; 60N; 90N; 120N
90N,0K versus 7.5P; 22.5P
90N,15P versus 10K; 20K; 30K
Diagnostic trial comprised of 90N,15P,20K,15S,2.5Zn,10Mg,0.5B

The experimental design was incomplete factorial design. It is assumed that N is the most limiting nutrient for maize crops followed by P, and then K. Other nutrients such as S and Zn are also expected to be limiting. On each site, a diagnostic treatment was included to determine the combined effect of other nutrients once N, P, K.

Data collection

Soil sampling

Initial bulk soil samples were collected from the sites before land preparation at 0 – 20 cm and 20 – 50 cm depth. Soil samples were taken from 8 points across the field along each of the blocks (replicates) to form a composite sample. Another soil sampling was done during crop harvest. A composite sample made of 3 sub samples was collected at 0 – 20 cm depth of soil done in the 0N-0P-0K(or S), 90N-0P-0K(or S) (the treatment with the second highest from highest N or P rate), and 90N-15P-0K(or S) (the treatment with the second highest N and P rate) plots in each replicate. In addition, one sub-soil sample was collected at a depth of 20 – 50 cm consisting of 6 sub samples per trial. All the samples were air dried, sieved through a 2 mm sieve and analyzed for particle size distribution, pH, organic carbon (OC), total N, available P, exchangeable bases, cation exchange capacity (CEC), exchangeable K, Ca, Mg; Na, and Zinc using infra-red spectrometry at ICRAF soil laboratory in Nairobi, Kenya.

Collection of agronomic data

Data collected included grain yield, total plant biomass per hectare, stand count at harvest, cost of inputs, crop prices, and rainfall. These were used to compute for maize-nutrient response data, nutrient use efficiency, value cost ratios considering variation in maize response due to agro-ecological zones, soil properties, previous crop, and yield level. To estimate maize yield, the crop was harvested from a net plot of four ridges each 4 m in length. The maize cobs were de-husked, and the seeds were collected by hand shelling. The 100 seeds were dried in an oven at 70 – 80°C for 24 hours to determine moisture content. Grain moisture content was adjusted to 12.5°C and yields were calculated on a per hectare basis.

Data Analysis

Analysis of variance (ANOVA) was used to determine variation in yield due to different levels of N, P and K inputs by site-year and combined across site-years. The effect of N, P and K fertilizer and their interactions were the primary focus of the analysis. The changes or differences in yield variables were considered significant when $P \leq 0.05$. Post-hoc comparisons of means were done using Dunnett's test at P value = 0.05.

When significant effects of N rate by P rate did not occur, asymptotic regression was fitted to the yield data in order to determine response to N. The asymptotic function is given as yield (Mg ha^{-1}) $y = a–bc^N$, where *a* is yield at the plateau (*i.e.* expected maximum), *b* is the amplitude (the gain in yield due to nutrient application), *c* is a curvature coefficient and *N* is the nutrient rate applied. The regression analyses for N rate effects included treatments with and without P separately. The economically optimum rates (EORs) were calculated using the OFRA fertilizer optimization tool developed by University of Nebraska, Lincoln in USA.

Nutrient use efficiency by crop maize was assessed focusing on the agronomic efficiency of N (AEN) at fixed P rates and agronomic efficiency P (AEP) at fixed K rates. AEP was calculated as a ratio of the increased crop output to the amount of P applied. AEN was calculated in the same manner as AEP.

Returns to fertilizer use were assessed using the value-cost ratio (VCR) because it is commonly used when assessing the profitability of fertilizer use, especially in the absence of data on full production costs. Hence, VCR was calculated as a ratio of value of increased crop output to the cost of fertilizer applied. A VCR ≥ 2 represents 100% return on the money invested in fertilizer and is sufficient to warrant investment in fertilizer (Kihara *et al.*, 2016). Therefore, in this analysis VCR$\geq$2 was considered as a reasonable threshold for risk coverage against investment in fertilizer at the scale of smallholder farms.

All analyses were done using the Statistics 10 (Analytical Software. Tallahassee. FL).

RESULTS

Grain Yield Responses

Grain yields response to different nutrient application rates indicate that at both Chitala and Bunda there was an increase in maize grain yields with addition of nutrients. The lowest maize grain yields obtained were 1954 and 1347 kg/ha at Bunda and Chitala respectively in the control treatment where no N, P and K nutrients were applied. The highest grain yield responses at Bunda (7101 kg/ha) and Chitala (6606 kg/ha) were recorded with the application of 120 N, 15 P and 0 K kg/ha.

Nutrient Use Efficiency

Agronomic use efficiency of nitrogen (AEN)

Table 2 gives nitrogen use efficiency (AEN) for the two sites. There were significant differences in AEN between the two sites. From the rate of 30 to 60 kg N/ha at Bunda AEN increased and then became constant from 60 to 120 Kg N/ha with increasing amount of applied N rates. In case of Chitala, the AEN did not change significantly (P=0.856) with increasing the amount of applied N rates (Table 2). Increase in N application rates at Bunda improved AEN while at Chitala N was less efficiently used with increasing N rate.

Table 2: Agronomic efficiency of nitrogen (AEN) and change in AEN (Change) relative to the lowest N application rate at Chitala in Salima and Bunda in Lilongwe Districts

N rate (kg/ha)	AEN (kg/kg N)			
	Lilongwe (Bunda)		Salima (Chitala)	
	Mean	Change	Mean	Change
30	38.00	0.00	25.79	0.00
60	43.97	5.97	24.16	-1.63
90	41.62	3.62	22.62	-3.17
120	41.53	3.53	25.62	-0.17
CV (%)	48.81		23.81	
P (rate)	0.973		0.856	
P (site)	0.002			

Values of Change followed by * indicate that the mean yield is significantly different from the control according to Dunnett's test.

Agronomic use efficiency of phosphorus (AEP)

AEP significantly differed between the sites (P=0.002) and among the P rates (P=0.005). The AEP values were higher at Bunda than at Chitala for all fertilizer levels of applied P rates. The AEP values decreased with increasing amounts of applied P. The highest AEP of 473 and 249 kg/kg P were obtained at Bunda and Chitala, respectively when 7 kg/ha P was applied. The calculated differences in AEP value between the treatment and the lowest P level were negative at both sites (Table 3) above the rate of 7 kg P/ha. The negative values above the rate of 7 kg P/ha indicate that P will be used by the crop less efficiently with increase in P rate.

Table 3: Agronomic efficiency of phosphorus (AEP) and change in AEP (Change) relative to the lowest P application rate at Chitala in Salima and Bunda in Lilongwe District

P rate (kg/ha)	Sites			
	Lilongwe (Bunda)		Salima (Chitala)	
	Mean	Change	Mean	Change
7	473.37	0.00	249.71	0.00
15	211.08	-262.29*	154.71	-95.00
22	143.31	-330.06*	95.90	-153.81*
CV (%)	51.08		48.52	
P (rate)	0.005		0.0313	
P (site)	0.002			

Values of Change followed by * indicate that the mean yield is significantly different from the control according to Dunnett's test.

Value Cost Ratio (VCR)

Analysis of returns to fertilizer use in terms of VCR in Lilongwe and Salima are given in Table 4. Significant differences were observed among the treatments (P=0.0002) in VCR values at Bunda and Chitala. The highest VCR values of 11.40 and 8.7 were obtained at Bunda and Chitala, respectively for the treatment where 0 P, 0 K and 30 N kg/ha was applied to maize. The lowest VCR values of 4.14 and 3.03 were obtained at Bunda and Chitala, respectively for the treatment where 90 N, 0 K and 22.5 P kg/ha was applied to maize. It should be pointed out that the VCR values decreased with increased amounts of applied nutrients along the treatments. The largest profits in applied N was obtained for maize at both Salima (VCR=8.7) and Lilongwe (VCR=11.4) when the rate of 30 N kg/ha was applied while for P the largest was obtained for maize at both Salima (VCR=7.24) and Lilongwe (VCR=7.76) when the rate of 15 kg/ha of P alone was applied.

Table 4: Value cost ratios (VCR) and change in VCR (Change) relative to the lowest N, P and K application rate at Chitala in Salima and Bunda in Lilongwe District

Nutrient Rates (kg/ha)	Sites			
	Lilongwe (Bunda)		Salima (Chitala)	
	Mean	Change	Mean	Change
0P, 0K, 30N	11.40	0.00	8.70	0.00
0P, 0K, 60N	8.46	-2.94*	5.60	-3.11*
0P, 0K, 90N	7.00	-4.40*	4.45	-4.25*
0P, 0K, 120N	6.39	-5.01*	4.29	-4.41*
15P, 0K, 0N	7.76	-3.64*	7.24	-1.46
15P, 0K, 30N	5.54	-5.86*	4.93	-3.77*
15P, 0K, 60N	5.18	-6.22*	4.30	-4.41*
15P, 0K, 90N	5.05	-6.35*	3.75	-4.95*
15P, 0K, 120N	5.19	-6.21*	4.55	-4.15*
90N, 0K, 7,5P	5.70	-5.70*	3.62	-5.08*
90N, 0K, 22.5P	4.14	-7.26*	3.03	-5.67*
90N, 15P, 10K	4.40	-6.99*	3.23	-5.47*
90N, 15P, 20K	4.27	-7.13*	3.46	-5.24*
90N, 15P, 30K	4.16	-7.24*	3.05	-5.65*
90N, 15P, 20K, 2.5Zn	4.50	-6.90*	3.24	-5.46*
CV (%)	17.31		17.1	
P value	0.0000		0.0002	

Values of Change followed by * indicate that the mean yield is significantly different from the control according to Dunnett's test.

Also, very important to the financially constrained farmer is the relative profit potential associated with specific nutrients applied to specific crops, that is, of the crop-nutrient choice.

Maize response functions in Salima and Lilongwe

Maize yield response functions to nutrient applications are given in Table 5. The coefficients a, b, and c are given in columns 3-5, changes in yield increments due to nutrient rates are given in columns 6-9 and economically optimum rates (EOR) are given in columns 10 and 11. The EOR values were calculated based on the agronomic (recommended elemental nutrient application rates) and economic field research data. The results indicate that in both sites Salima and Lilongwe, maize grain yields responded well to applied N, P and K. The maize yields responded profitably to N, P and K. Values of EOR were similar to the currently recommended fertilizer rates. However, EOR for P were higher than the recommended rates in Salima and Lilongwe while for K they were three times lower than the recommended rates in Salima and Lilongwe.

Table 5: Response functions, expected yield increases (t/ha) for crop-nutrients, and OFRA economically optimal rate (EOR) to maximize profit per hectare compared to current or recent (REC) recommendations P_2O_5 = P x 2.29; K_2O = K x 1.2.

Site	Response coefficients, Yield = a – bc^r ; r = elemental nutrient rate				Yield increases due to incremental increases in elemental nutrient rate (kg/ha)				Recommended nutrient rate	
	Nutrient	a	b	c	30	60	90	120	EOR	Rec
		t/ha			Yield increase, kg/ha				kg/ha	
Salima	N	4.90	2.57	0.98	1.08	0.63	0.36	0.21	87	69-92
Lilongwe	N	4.90	2.57	0.98	1.08	0.62	0.36	0.21	78	69-92
					0-5	**5-10**	**10-15**	**15-20**		
Salima	P	2.85	1.79	0.97	0.23	0.21	0.18	0.16	30	3-18
Lilongwe	P	2.85	1.79	0.97	0.24	0.20	0.18	0.16	24	3-18
Salima	K	4.08	0.10	0.90	0.04	0.02	0.01	0.01	2	6-8
Lilongwe	K	4.08	0.10	0.9	0.04	0.02	0.01	0.01	2	6-8

DISCUSSION

The results demonstrated positive maize grain yield responses to nutrient application at both sites. This implies that the applied nutrients were limiting and not available in adequate amounts in the soil. The maize grain yields also indicate that N was the most limiting nutrient in maize grain yield production followed by P. The differences in grain yield between the two districts indicate that the maize grain yield response to nutrient between the two sites was different. The maize grain yield response was higher in Lilongwe than in Salima. This could be due to differences in soils (Fluvisol which are more fertile in Salima than Luvisol in Lilongwe) and abiotic factors between the two districts. However, on both sites there were positive yield responses to nutrient application rates.

The respective positive and negative AEN values (relative to the lowest nutrient rate) obtained at Bunda and Chitala could be well explained by the differences in soils and climate in the two agro-ecological zones. Chitala contains fertile Fluvisols and dominated by traditional agroforestry using *Falderbia albida*. That is probably why it has improved levels of soil nutrients while Bunda contains Luvisols which are normally low in N levels (Jones *et al.*, 2013). The negative AEN values imply that at Chitala there was no need to apply N fertilizer except for the rate of 30 kg N/ha. The values probably show that there were adequate amounts of N in the soil and addition of more N may lead to less efficient use of the applied nutrient. Therefore, addition of about 30 kg N/ha may be adequate to optimize the nitrogen use efficiency by maize crop in grain yields. In case of Lilongwe the higher positive AEN values indicate that the soils are low in N levels limiting crop production. Addition of N controlled N as a limiting factor and this significantly led to improved values of AEN in maize for grain yield production.

Negative AEP values for maize grain yields at both sites Chitala and Bunda suggest that the soil P levels were adequate and there was no need to apply P levels of greater than 7 kg P/ha. The negative values above the rate of 7 kg P/ha also indicate that P will be used by the crop less efficiently with increase in P rate. The levels were enough to supplement the required soil P levels to offset the limiting maize grain yield production. The soils at Bunda have high affinity for phosphorous which result in P fixation (Batjes, 2011). This possibly resulted in most of the applied P unavailable for maize crop uptake and hence low response of maize grain yield to P application.

The VCR values are all higher than the minimum value of 2 required. In high risk environments, a VCR >4 has also been suggested in order to accommodate price and climatic risks. In this study, all the VCR values are larger than 4 indicating that fertilizer application is highly profitable at both

sites. The values were different due to differences in maize yield responses to different nutrient types and amounts of nutrients applied to maize. The maize grain yield responses were higher in some applied rates than others which in turn resulted in variations in amounts of profits among the treatments. Thus, some nutrient rate combinations gave much more profits in maize than others. In this case, for the resource constrained smallholder farmers, they can take advantage of this trend and capitalize on focusing on those nutrient combinations that gives highest returns on investment in fertilizer *i.e.* take advantage of the best profit opportunities according to their ability. In turn they can build upon the generated profits to gradually improve their worthiness and eventually improve their fertilizer application rates to all maize for profit maximization per unit area.

Furthermore, the calculated values of response coefficients (a, b, and c), maize grain yield increase due to increase in elemental nutrient rate, EOR imply that financially resource constrained farmers can achieve high profits from fertilizer use. This was also echoed by a related research in Uganda where they found fertilizer N use very profitable, with high NUE (Kaizzi *et al.*, 2012). As the amount applied of elemental nutrient increases up to 60 kg/ha for N, 20 kg/ha for P, the maize grain yield increase at a decreasing rate. That's the region of profit maximization is up to the region where the curves reach a peak and becomes flat, *i.e.* the point of maximum profit per hectare is reached. This region is where financially constrained farmers can take advantage and choose the crop-nutrient combinations that will give optimized yield and net returns on their limited available investment. The current recommendation for producing maize for home consumption in Malawi is to apply 92 kg/ha N, 21 kg/ha P_2O_5, 0 kg/ha K_2O and 4 kg/ha S. When growing maize for the market, the general recommendation is to apply 35 kg/ha N, 10 kg/ha P_2O_5 ha and 2 kg/ha S (Benson 1999). Therefore, the financially constrained farmers can take advantage of the best profit opportunities if maize is produced for market sale. On the other hand, if maize is produced for home consumption, applying 100% of the recommended N and P rate may be deemed more beneficial to the household (Benson 1999; Jama *et al.*, 2017). This is supported by the fact that the money used to buy fertilizer by smallholders did not come from commercial credit but from other cash sources of the household or government subsidies ((Benson 1999; Denning *et al.*, 2009). Suggestions from other quarters indicate that under such scenario, the household benefits by applying 100% or more of the recommended N rate as this eliminates the likelihood of paying the costlier consumer price on open market which is exacerbated by transport costs surpassing adding a little more fertilizer to own maize (Jama *et al.*, 2017).

CONCLUSIONS

Fertilizer application significantly increased maize grain yields on all the sites. The increase was due to improved N and P use efficiency in maize grain yield production in Central Malawi. The analysis of returns to fertilizer use has also shown that investment in fertilizers is profitable even at smallholder level. The economically optimum N, and P rates were higher than the current recommendations of N, P for maize grain yield production, while that of K was lower than the recommended rates. The results also provide an opportunity for the financial constrained farmers on how to choose the best nutrient combination in order to maximize profit on their little investment capital and to apply fertilizer to more of their land.

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Actors of Baobab Trade and Their Relationships along the Value Chain in Malawi

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ABSTRACT

There is very little information on the basic market functioning and actors involved in baobab product trade of baobab products which has predominantly remained informal with limited commercialization. A study was carried out to identify actors of baobab trade and map their relationships. Purposive sampling was used to select the districts while snow balling technique was used in selecting the actors of baobab trade. Mapping was carried out to assess actors involved in the baobab trade and map their relationships. Six categories of actors of baobab trade were identified, namely; harvesters, wholesalers, processors, retailers, consumers, and exporters. Three types of relationships exist between baobab actors in Malawi, namely; spot market relationship, persistent network relationship, and horizontal integration relationship. Baobab actors should develop chain relationships which are strong to agree upon a shared vision and a joint action plan to strengthen the whole value chain. Actors need to be coordinated and have horizontal integration relationships to increase their bargaining power, sell value added products with high quality and have access to market information to increase their gains.
Kewords:

INTRODUCTION

One crucial point to note is that promoting commercialization of plant species without clear understanding of their value chains has been reported to result in heavily distorted and biased markets (Agea et al., 2011). Many authors (El-Siddig et al., 2006; Jaenicke, 2010; Sidibe & Williams, 2002) have concluded that there is a total lack of socio-economic research at all levels along the production-to-consumption chain of NTFPs. According to Gibbon & Ponte (2005), the use of the term value chain suggests a focus on relationships between buyers and suppliers, and the movement of goods or services from producer to consumer. The concept of value chain encompasses issues of organization and coordination of different actors (dealing with baobab in this case) in the chain (Humphrey & Schmitz, 2000). Conducting a value chain analysis requires thorough investigation of what is going on between the actors in the chain, what keeps these actors together, what information is shared, and how relationships between actors are evolving (Kaplinsky & Morris, 2001).

This is where now the International Centre for Research in Agroforestry (ICRAF, the World Agroforestry Centre) has initiated a worldwide programme to domesticate the species identified by local people as their priority for cultivation in agroforestry systems (Tchoundjeu et al., 2010) and Adansonia digitata L. (baobab) was one of them (Akinnifesi et al., 2006). Baobab is regarded as the highest earner of all NTFPs in the Southern Region of Africa, with projections suggesting annual

incomes of up to US$1 billion for producer countries (Regional Trade Facilitation Program [RTFP], 2007). Baobab trade has the potential to be a billion-dollar industry for the continent of Africa and could employ over 2.5 million households, if fully commercialized (Vassiliou, 2008). Recently, baobab fruit pulp has been approved for sale in the European Union (EU) (2008/575/EC) and United States of America (USA) (GRAS Notice No. GRN 000273), and has thus entered the formal international food market offering opportunities for income generation for African farmers (EU, 2008). The most important EU importers of baobab fruit powder are Germany, France, and The Netherlands, while the most important exporters of baobab products are France, Germany and the United Kingdom (UK) (Gruenwald & Galizia, 2005). In the EU in 2003, the import value of baobab pulp grew by 13% while the export value grew by 11% (Baigonti, 2004).

Research in Benin has found more than 300 uses for different baobab tree parts (Buchmann et al., 2010). Malawi is one of the key producers of baobab pulp through TreeCrops Limited, a subsidiary of PhytoTrade Africa (PhytoTrade Africa, 2008). An estimated 80% of Malawians depend on baobab for subsistence and household income (Government of Malawi [GoM], 2011). A study done by Munthali (2012) found that baobab is extremely important for the livelihood of rural Malawians such that both rural and urban communities use most parts of the tree.

Akinnifesi et al. (2005) highlighted that in general, indigenous fruit commercialization is poorly developed in Malawi. Despite the socio-economic importance of baobab in Malawi, very little information is available on the commercialization of the species (Sanchez, 2011). This study, therefore, aims at filling the gap identified by the aforementioned authors in the studies they conducted on the marketing of baobab fruit products.

Objective of the study

To identify actors of baobab trade and their relationships along the value chain in Malawi

MATERIALS AND METHODS

Study area

The study was conducted in Karonga, Salima, and Mangochi districts. Following the baobab value chain, additional data for baobab companies, retailers, and wholesalers was collected in Lilongwe, Blantyre, and Mzuzu (in Mzimba district) cities as shown in Figure 1. The study areas were selected because of the abundance of baobab trees and active trade in baobab products (Munthali, 2012).

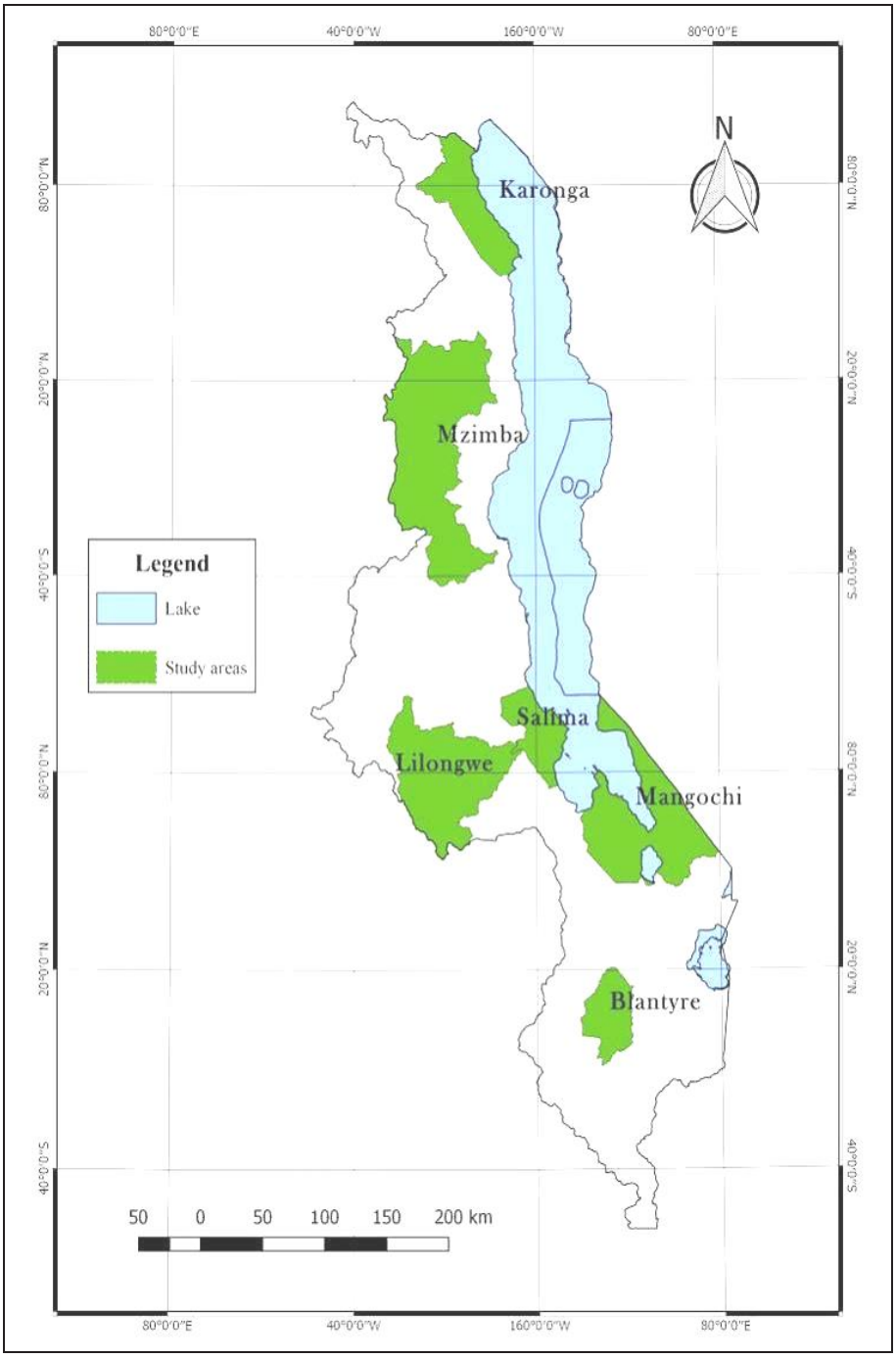


Figure 1: Study sites

Research design and sampling procedure

This research study adopted a qualitative design and also employed two qualitative sampling procedures. The sampling procedures were purposive and snow-balling techniques. Purposive sampling is a non-probability sampling method that occurs when elements selected for the sample are chosen by the researchers' judgment (Godambe, 1982). According to (Tongco, 2007), the snow-balling technique (also known as chain-referral sampling) is also a non-probability sampling method used when characteristics to be sampled are rare and difficult to find. It was also relevant to use this sampling technique because as we move up the chain, few actors are observed (Ferris *et al*., 2006). Respondents (actors) were interviewed if they had shown willingness to do so.

Data collection

Data was collected in February 2016 and in February and March 2017. Data was collected in different villages as shown in Table 1. A questionnaire was used when conducting individual interviews while a checklist was used when carrying out Focus Group Discussions (FGDs) as well as key informant (KI) interviews. For individual interviews, at least three actors at each stage of the chain per district were conducted for the actor types which were available (da Silva & de Souza Filho, 2007; Ferris *et al.*, 2006). In total 70 individuals, five retailers and six companies were interviewed in this study (Tables 1 and 2). Data collected were, type of actor, household characteristics, sources of baobab products, use of baobab products, product availability period, location of buyers, who buys the products and supporters of baobab trade.

Table 1: Districts, villages and number of interviews per baobab chain actor

District	Village	Number of Harvesters	Number of Wholesalers	Number of Household processors	Number of Consumers
Karonga	Lupembe	-	3	2	3
	Mpata	3	2	1	-
Salima	Lifidzi	2	3	-	1
	Lumwira	3	1	1	2
Mangochi	Madeco	2	3	3	3
	Mbwadzulu	3	1	-	-
Lilongwe	Nchesi	-	8	3	3
Blantyre	Blantyre	-	8	3	3
TOTAL		**13**	**29**	**13**	**15**

Source: Field survey (2016-2017)

Table 2: Districts, number of interviews for retailers, KIs, companies and FGDs

District	Retailers	Key Informants	Companies	Focus Group Discussions
Karonga	-	2	-	1 (8 participants)
Salima	-	1	-	2 (26 participants)
Mangochi	1	2	-	2 (31participants)
Mzuzu	-	-	-	1 (11 participants)
Lilongwe	3	3	4	-
Blantyre	1	2	2	-
TOTAL	**5**	**10**	**6**	**6 (76 participants)**

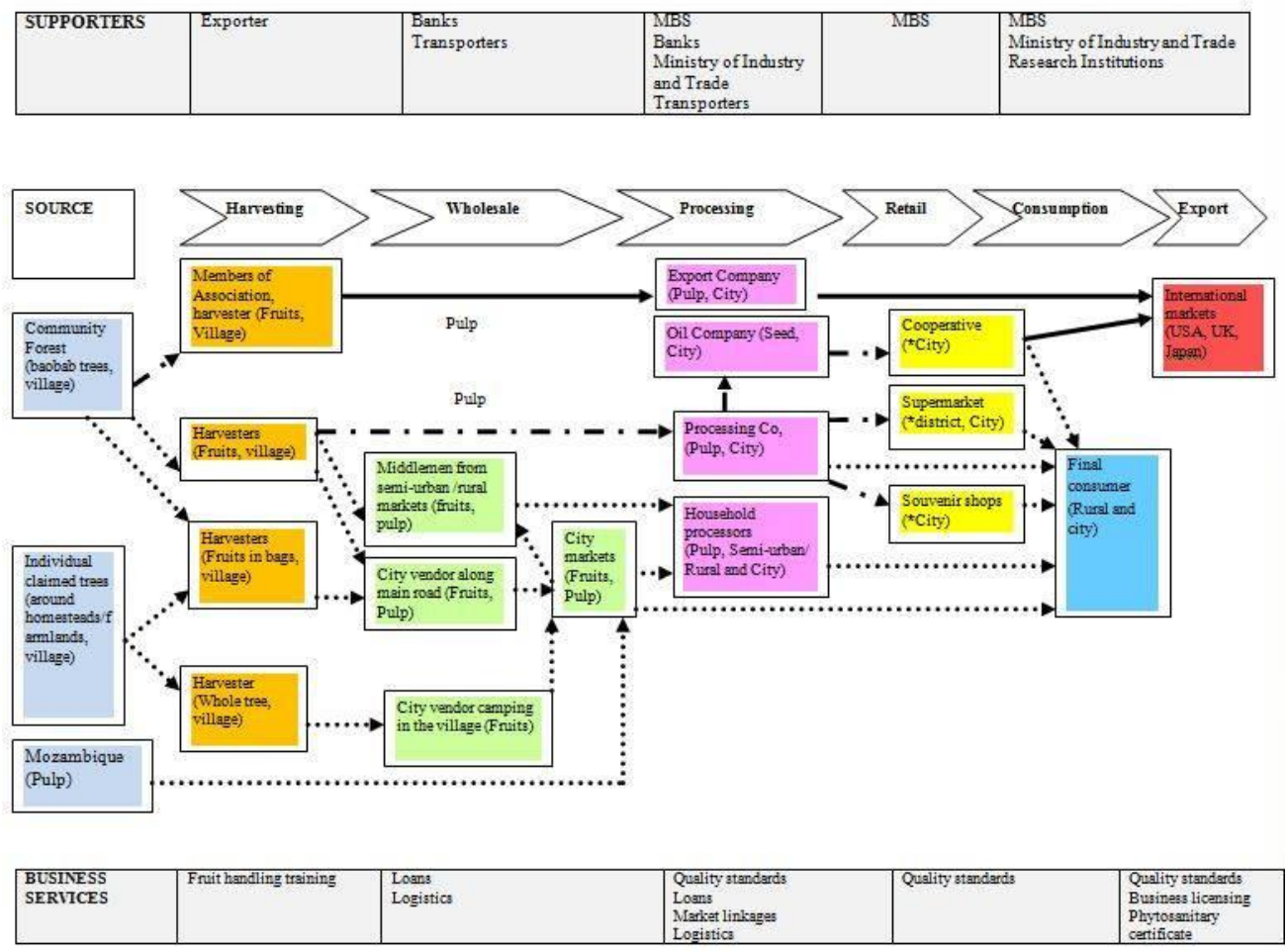
Source: Field survey (2016-2017)

Data Analysis

Value chain mapping was used to analyze the data using guidelines provided by M4P (2008). Quantitative data from questionnaires was coded and then entered into Statistical Package for Social Sciences (SPSS) version 19.0 data sheet. Thereafter data was verified by checking the categories of all variables for correction. The next step was to run SPSS to analyze the data as descriptive statistics. Value chain map was used to present the results.

RESULTS AND DISCUSSION

Six core processes and respective actors were identified through the M4P (2008) procedure (Figure 2). These actors are harvesters, wholesalers, processors, retailers, consumers and exporters.



*assorted processed baobab products

Key:

Horizontal relationship
Persistent network relationship
Spot market relationship

Figure 2: Value chain map for baobab products in Malawi

De Caluwe (2011) reported that different actors are involved in moving a product from the source to the final consumer and each actor has different abilities to influence the chain (Marshall *et al*., 2006). Harvesters get their baobab fruits from both community forests and individually claimed trees found around the households or farmlands and generate income. The current study concurs with Akinnifesi *et al*., (2005) that despite baobab trees growing in the rural areas, both the rural and urban communities benefit from them through consumption and trade (Figure 2).

Wholesalers of baobab products buy in bulk and transport them to semi-urban or city markets where they re-package in both small and big quantities, convenient to household processors, middle-men and final consumers. De Caluwe (2011) reported about petty traders packaging baobab and tamarind products in small quantities convenient to consumers in Mali and Benin. It was also observed that wholesalers sell any type of fruits which are in season there-by having a flow of income all year round. With the flow of income, wholesalers are able to access loans from banks

(Figure 2). This, therefore, makes the wholesalers to be able to meet high costs in their business like transportation, food and accommodation and overcome some challenges. Wholesalers of baobab products in this study pointed out that the supply of baobab raw materials (fruits and pulp) only lasts for two months and this is not enough as the demand for the products is all year round. This makes the wholesalers to import baobab pulp from neighboring countries like Mozambique. One point to note is that despite wholesalers having a supply of baobab pulp all year round, they only rely on household processers and few individuals to buy from them and none of the company processors buy from them because of quality issues.

The reason why women dominate the household processing of baobab products (31% men, 69% women) is that men prefer wholesaling (11% women, 89% men)as it fetches a lot of profit (KIT & IIRR, 2008). Akinnifesi *et al*. (2008); Awono *et al*. (2002) documented that women dominate the retail trade, while men concentrate on wholesale. The other reason is that this processing at household level requires less capital of MK2750 (US$3.5) which most women can afford as they use household equipment like kitchen utensils and a refrigerator.

Despite having many baobab products processed in Malawi (Appendix A) only three (oil, powder, and soap) are exported. Baobab powder is exported to USA and UK while oil and soap are exported to Japan. This implies that few companies are competing on international markets and have the required international standards accepted. The reasons why only two companies are exporting their baobab products is that some processors do not have financial muscle to buy the recommended packaging materials for international markets which are not produced in Malawi but are imported from Kenya. Abeyrathne & Jaenicke (2006) reported that the cost of packaging materials was one of the major challenges that small-scale processors are facing. Again Hishe *et al.* (2016) outlined that export oriented marketing is particularly demanding, requiring detailed information about specific markets, product specifications and standards which not all actors along the value chain can meet but comes with benefits. To increase export of baobab products, therefore, there is a need for baobab actors (processors) to be linked with Malawi Investment and Trade Centre (MITC) as its objective is to promote investment and exports in Malawi.

According to consumers, baobab products in Malawi are consumed daily and all year round. Buchmann *et al.* (2010) and Maranz *et al.* (2008) reported that baobab products in West Africa are available all year round and are consumed every day. Consumers purchase different processed baobab products from retailers or company processors. Despite many products processed in Malawi, not all consumers seemed to have an idea about other products like baobab soap, oil, jam and coffee. This shows that there is less advertisement and marketing of the processed products by companies in Malawi. Sabbe *et al*. (2009) reported that in developed countries, numerous tropical fruits and their derived products are quite unknown to many consumers and are likely to remain so, unless consumers' acceptance of these products followed by successful market introduction occurs. There is a need for processors to conduct product awareness campaigns for consumers to know and buy their products, which will consequently translate into making more profits.

Three types of relationships existing between actors in baobab trade in Malawi were identified during the mapping exercise (Figure 2) namely, spot market relationship also known as arm's length or adhoc relationship. Spot market relationship was observed when consumers were not choosing a particular supplier for the baobab products they want to purchase. Consumers buy baobab products from retailers, processors, and wholesalers (Figure 2). If they do not find that type of a product from one actor or they do not agree with the price they go to another actor, do all the transactions and leave. For example this type of relationship was observed when consumers are buying both processed and unprocessed baobab products in both formal and informal markets. Spot market relationship was also observed between wholesalers and harvesters. In this type of relationship, one is not bound to have a choice to transact with anyone he/she wants. This relationship gives room for variety of sellers to choose from, provided the buyer is satisfied with the

price, quality, and quantity of the product. KIT & IIRR (2008), documented adhoc relationships existing between traders and farmers of tomato business in Ghana whereby there is no organization between the two actors and business is done the moment they see each other. According to KIT & IIRR (2008), adhoc relationships do not come with trust between actors and it encourages cheating on quality, quantity and even exaggerates prices because actors do not know each other well. Because of the above reasons, this study discourages such type of relationships between baobab actors.

Persistent network relationships exist between company processors and harvesters whereby company processors mentioned of having some harvesters who supply them with baobab pulp time and time again. Processors agree with harvesters how they want the raw materials to be handled or processed. Through frequent communications actors develop mutual understanding of the business which may result in more cooperation and lower risks (KIT & IIRR, 2008). Persistent network relationship was observed between retailers and company processors. The contract can be signed or not, it all depends on how the actors agree (KIT & IIRR, 2008). In Abaca value chain a long-term relationship called "suki" system was also reported wherein a farmer regularly sells their produce to the same buyer, and where their relationships have been built in years without any contracts signed (Daly *et al*., 2016).

Horizontal integration relationship exists between powder exporting company and baobab association supplying the company with baobab pulp. The formation of this association was facilitated by the exporting company to be supplied with high quality raw materials. The export company has an agreement with local leaders for its association to be collecting baobab fruits from registered community forests in the communities. Horizontal integration relationship also exists between the exporting companies and their buyers in international markets (Figure 2). They have signed contracts on the standards of the baobab products to be followed, volumes, and price. Horizontal contractualization leads to better coordination among producers in aggregating products, maintaining quality standards, accessing inputs, and improving bargaining power (Riisgaard *et al*., 2010). This type of relationship is encouraged by KIT & IIRR (2008) because both market institutions and chain relations are stronger thereby there is value addition, quality is improved, and risks are reduced. Horizontal integration improves the overall efficiency of the aromatic and medicinal plant value chain in Madagascar by allowing some economy of scale and increasing the competitiveness (Juliard *et al*., 2006). Despite horizontal integration relationship coming with long processes like the legal requirements, it should not scare actors of baobab trade, in fact it must assure them that both parties will be abiding by those requirements and have a transparent business.

CONCLUSIONS AND RECOMMENDATION

From the study six categories of actors in baobab trade were identified in this study namely; harvesters, wholesalers, processors, retailers, consumers, and exporters. First actors in baobab trade in Malawi are harvesters who harvest fruits from both communal trees with open access rights and individually claimed trees with strict ownership rights. Despite community forests being open access traditional leaders need to develop and enforce strict by-laws on when and how to harvest the fruits for the trade to have high quality raw materials. Three types of relationships exist between actors of baobab trade namely, spot market relationship, persistent network relationship and horizontal integration relationship. Spot market relation is the common type of relationship between actors of baobab trade though horizontal integration relation is the one recommended by this study as it comes with trust and selling of high quality products. Harvesters need to be working in associations to increase their bargaining power, sell value added products, learn about product demands and gain access to finance. There is a need for processors to promote their products to enhance awareness of the many baobab products in Malawi. Baobab actors should work hand-in-hand with MITC to increase export of baobab products.

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APPENDICES

Appendix A: Multiple baobab products produced in Malawi

Key: 1=Jam 2= Oil 3=Coffee 4=Powder 5=Soap 6=Lip balm

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Students' Attitudes towards Science Subjects in Community Day Secondary Schools: Case of Three Schools in Blantyre, Malawi

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ABSTRACT

The investigation of students' attitudes towards studying science has been an essential feature within the science education research community for the past years. However the study of Students' Attitudes towards Science Subjects (SATSS) in Malawi appears sparse. Most Community Day Secondary Schools (CDSSs) register high failure rates in science subjects during national examinations and the trend could be attributed to students' attitudes towards science among other factors since without positive attitudes, students have little chance of learning proficiently. The study used a 130-item questionnaire (α = 0.893) to measure students' attitudes towards science subjects in CDSSs in Malawi. The data were obtained from 273 CDSS students in Blantyre, Malawi. A sample of 160 boys and 113 girls sampled based on stratified randoming using Taro Yamane's formula was used to collect the data. Results show that over 54.9% of the students (n = 273) in CDSSs have a positive attitude towards science subjects. Results of the study also showed that gender had a significant effect on students' attitudes towards science subjects. Girls [Mean = 2.53, and SD = 0.983] had significantly higher attitudes towards science subjects than boys [Mean = 2.28 and SD = 0.883] on total attitude scale and on all sub-scales of the questionnaire. This is perhaps because of girl child education campaign in CDSSs that is encouraging girls to like science and aspire to undertake scientific careers. The following were the underlying factors influencing SATSS: Self-efficacy (SE), Science Learning Value (SLV), Stimulating Learning Environment (SLE), Teacher Factors (TF), and Active Learning Strategies (ALS). However, Self-efficacy, Science Learning Value, and Stimulating Learning Environment were noted as predominant factors influencing SATSS since they had higher percentage of the total variance explained than the rest of the factors. This is because the SLV has the power to determine students' motivation and readiness to learn whereas the SLE have a direct impact on the learner and the learning process. Finally, findings reveal a significant positive relationship between SATSS and performance/academic achievement (r = 0.720 and p = 0.001). This means that students with positive attitude levels towards science subjects registered high levels of achievement in science. The findings have wide implications on learning of science.

Key terms: SATSS, attitude, gender, Self-efficacy, Teacher factors, stimulating learning environments, active learning strategies, science learning value, academic achievement.

INTRODUCTION

The Education Sector Implementation Plan (ESIP) in line with the Malawi Growth and Development Strategy (MGDS) endorse the vision for education as a catalyst for socio-economic development, industrial growth and an instrument for empowering the poor, the weak and the voiceless. Education enhances group solidarity, national consciousness and tolerance of diversity. It

facilitates the development of a culture of peace which is conducive and critical for socio-economic, political and industrial development. Hence, education is critical and necessary for economic and industrial growth and development. (MoEST, 2009 pg 20).

In line with such a declaration, the government, in cooperation with various donor organizations and the African Development Bank, is currently working to get the quality of community day schools up to par with conventional schools. It should be outlined that Community Day Secondary Schools (CDSSs) formerly known as "District Education Centres" most of which face critical shortage of resources enrols 46% of the students' population at the secondary level, which is 71% of the students' population in the government run schools (Al-Samarrai & Zaman, 2007).

Despite the government efforts to increase access to education by introducing more CDSSs and improving them, quality of the education in CDSSs remain challenged. Examination results, taken as one of the standard measurements of quality in education, reveal that the overall students' performance in science subjects is poor in CDSSs (Lungu, 2009; MANEB, 2013d, 2013g; Mlangeni & Chiotha, 2015). For instance, in the 2013 JCE Physical Science examinations, a bulk of students over 58% scored 10% and below, whereas over 35% of the students scored between 10%-30%, representing 7% of the students getting above 30% (MANEB, 2013d).

This has been largely linked with critical shortage of resources in CDSSs like teaching and learning materials, inadequate number of teachers and unavailability of library and laboratory facilities. As a result, academic accomplishment levels are extremely low. Furthermore, Kadzamira (2003) observed that very few CDSS students pass the MSCE, with a bigger magnitude of failures recorded in science subjects. However, studies to relate the students' attitudes towards science subjects and the higher failure rates in CDSSs seems sparse. The work was done in order to measure SATSS in CDSSs, explore factors that influence SATSS in CDSSs, assess if gender influences SATSS, relate student's attitudes towards science subjects and academic achievement.

RESEARCH METHODOLOGY

This study employed a descriptive quantitative survey research design. The study was cross-sectional in nature since it surveyed a specific population at a given point in time. Thus, a 'snapshot' approach was used where the data were collected at one point in time. Positivism paradigm was adopted for this study to clarify the structure of inquiry, the nature of knowledge and methodological choices. This is so because the study assumed that there is only one view of reality on SATSS. That is, the measurement would either reflect positive or negative SATSS. This is why the study was also underpinned by the objectivism as its epistemological viewpoint.

Population and study site

The study was done at three schools in Blantyre, Malawi namely; Chimwankhunda CDSS, Joshua CDSS and Lirangwe CDSS. Chimwankhunda CDSS had 321 students, Lirangwe CDSS had a total of 285 students while Joshua CDSS had 260 students. As such, the population for the study was 866 students.

Sampling

The sample size for this study was a total of 273 students from Chimwankhunda CDSS, Lirangwe CDSS and Joshua CDSS as based on Yamane's (1967:886) formula:

$$n = \frac{N}{1 + N(e)^2}$$

Where n is the sample size, N is the population size, and e is the margin error. A 95% confidence level and P = 0.05 were used for the sample size calculation.

The study used stratified simple random probability sampling because the population was partitioned into groups, called strata based on school, class level, and gender, and sampling was performed separately within each stratum using simple random probability sampling. This sampling technique was ideal because each student of the each subpopulation had the same chance of being selected as other members in the same group.

Data collection

This study used 273 questionnaires to collect the data needed to measure SATSS. Respondents were offered a choice of five point ordinal Likert scale which allowed the participants to express how much they agreed or disagreed with a particular statement. The subjects were also provided with open questions for more detailed individual answers. This was to ensure that answers were written by the respondents. To overcome inadequacies of Likert scale, rank-order attitude scale was used as an additional attitude scale. This is where the students were required to rank the four subjects-Mathematics, Physical science, Biology and computer studies, listing from the most preferable to the least preferable. Preference ranking was simple to use and the results of such research were easily presented, analysed and interpreted.

Data analysis

Data were analysed using descriptive statistics, factor analysis and ANOVA. Mean scores of items on Likert scale were calculated to measure SATSS. Factor analysis was performed using the Principal Component Analysis (PCA) method of extraction as well as both Varimax and Oblimin rotation with Kaiser Normalization to determine the underlying factors of SATSS. The Oblimin rotation would not be ignored as the interdependency (correlation) among the factors cannot be ruled out. Bartlett's test of sphericity, which tests the overall significance of all the correlations within the correlation matrix, was significant across all subjects (biology: $\chi 2$ (253) = 1001.820, p<0.000: physical science: $\chi 2$ (351) = 1271.504, p<0.000: Mathematics: $\chi 2$ (378) = 1398.290, p<0.000), indicating that it was appropriate to use the factor analytic model on this set of data. The Kaiser-Meyer-Olkin measure of sampling adequacy indicated that the strength of the relationships among variables was high (Biology KMO = 0.667; Physical science KMO = 0.662 and Mathematics KMO = 0.611), thus it was acceptable to proceed with the analysis.

Analysis of Variance (ANOVA) test was used to test any statistical significant differences in attitude levels among boys and girls. Subject preference inventory was also adopted to distinguish attitude difference across the subjects. Attitude was obtained by asking students to rank science subjects in order of their decreasing preference. The subject [biology] with highest number of preference indicated students' positive attitude whereas that with least level of preference indicated negative attitude towards science subjects.

RESULTS AND DISCUSSION

This study investigated students' attitudes towards science subjects (Biology, Physical Science, Mathematics and Computer Studies) from CDSSs in Malawi. Below are the key findings:

SATSS in CDSSs.

The results revealed that students in CDSSs have positive attitudes towards science subjects. Specifically, students showed more positive attitudes towards biology than the rest of the subjects. Table 1 shows the results of the measure of SATSS in CDSSs. The measure showed 54.9% of students (n = 273) in CDSSs to have a positive Attitude towards Science Subjects whereas 11.4% have a very strong positive attitude towards science subjects.

Table 1: Percentage of the measure of SATSS.

Item	Percentage
Strongly Agree	11.4
Agree	54.9
Undecided	22.3
Disagree	7
Strongly Disagree	4.4
Total	100

It can be concluded that 54.9% of the total sample had positive attitudes towards science subjects where as 11.4% had a very strong positive attitude towards science subjects. Hence, cumulatively, majority (66.3%) of the students in CDSSs have a positive SATSS.

Factors that influence SATSS in CDSSs.

Initially, 11 factors with eigenvalues greater than one were extracted representing 65% of the total variance. A series of factor analyses were conducted which indicated that seven factors gave the most interpretable solution An Oblimin rotation was performed since factors were expected to be correlated.

Table 2: Interpretable factor loadings.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.508	16.097	16.097	4.508	16.097	16.097	4.165
2	3.751	13.281	29.378	3.751	13.281	29.378	3.899
3	3.357	11.989	41.367	3.357	11.989	41.367	3.675
4	3.104	11.084	52.451	3.104	11.084	52.451	3.645
5	1.309	4.673	57.124	1.309	4.673	57.124	1.954
6	1.186	4.235	61.359	1.186	4.235	61.359	1.720
7	1.140	4.072	65.431	1.140	4.072	65.431	1.458

Extraction Method: Principal Component Analysis.

When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

Two items loaded onto Factor 1 whose total eigenvalue is 4.508 representing 16.097% of the total variance. It is clear from the structure table that these two items all relate to students' belief in their own abilities in science subjects. This factor loads onto reported level of easiness in understanding scientific concepts and interpreting assignment questions in science subjects. This factor was labelled, "Self-efficacy (SE) towards science subjects". Seven items load onto a second factor related to students' inclinations of science learning value. The eigenvalue of factor 2 is 3.751 with variance as 13.281% of the total variance. This is related to students' eagerness to learn more about sciences, to get a job that needs sciences and their belief on the importance of science subjects for their country, belief that science makes most things work better, students' time to read science related materials, and their rate on general importance of science subjects. This factor was labelled, "Science Learning Value (SLV)". The five items that load onto Factor 3 (eigenvalue 3.357 and 11.989% of the total variance) relate to the conducive learning environment for science subjects. This factor was labelled, "Stimulating Learning Environment (SLE)". This incorporates learning

environment where students do not misbehave in a science class, everyone feels loved in the science class, and noise free science classrooms. The two items that load onto Factor 4 identify the effective learning strategies in science subjects that includes; discussions, peer teaching and discovery learning and group work. This was labelled, "Active learning Strategies". Items loaded for Factor 5 (eigenvalue 1.309 and variance 4.673%) related to teacher attributes that influence students' attitudes towards science subjects. This was labelled, "Teacher Factors (TF)". Factor 6 had items related to gender. As such items loaded to factor 6 were named "Gender". In total all the factor loadings shared a cumulative total variance of 65%.

Gender versus SATSS.
Using ANOVA a comparison was made between students' gender and their attitude toward science subjects.

Table 3: Descriptives carried out to find out any significant differences of SATSS by gender.

Descriptives								
SATSS								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Male	160	2.28	.883	.070	2.14	2.41	1	5
Female	113	2.53	.983	.092	2.35	2.71	1	5
Total	273	2.38	.932	.056	2.27	2.49	1	5

Table 4: ANOVA statistics carried out to find out any significant differences of SATSS

ANOVA					
SATSS					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	4.339	1	4.339	5.068	.025
Within Groups	232.042	271	.856		
Total	236.381	272			

As seen from the Table 4, the results showed that there is a statistical significant difference between female and male students in terms of their attitudes toward science subjects ($P = 0.025 < 0.05$). Mean of female students' scores [Mean = 2.53, and SD = 0.983] was higher than male students' [Mean = 2.28 and SD = 0.883]. In other words, female students had more positive attitudes than male students towards science subjects in CDSSs.

SATSS and Academic Achievement.
To explore possible relationship between SATSS and Academic achievement, Pearson's correlation was adopted and the results were recorded as shown in Table 5:

Table 5: Relationship between SATSS and performance/academic achievement.

Correlations			
		SATSS	Performance
SATSS	Pearson Correlation	1	.720**
	Sig. (2-tailed)		.000
	N	273	273
Performance	Pearson Correlation	.720**	1
	Sig. (2-tailed)	.000	
	N	273	273
**. Correlation is significant at the 0.01 level (2-tailed).			

As seen, results in the table showed a statistical significant positive relationship between SATSS and performance/academic achievement. This means that students with more positive attitude levels towards science subjects registered high levels of achievement in science. Similar results were also obtained in the other studies (Abu-Hola, 2005; Mata, Monteiro, & Peixoto, 2012; Semukono, Orobia, & Arinaitwe, 2013; Simpson & Oliver, 1985; Weinburgh, 1995). In the light of these results, it can be suggested that students with high science achievement develops more positive attitudes towards science as well. However, the direction of impact was not examined. This is to say whether high attitude causes high performance or high performance causing high attitude levels. This may be considered as an area for further research in the recommendations as most of the results are inconclusive (Aydeniz & Kotowski, 2014).

Figure 1 shows a summary of the key findings on the underlying factors of SATSS.

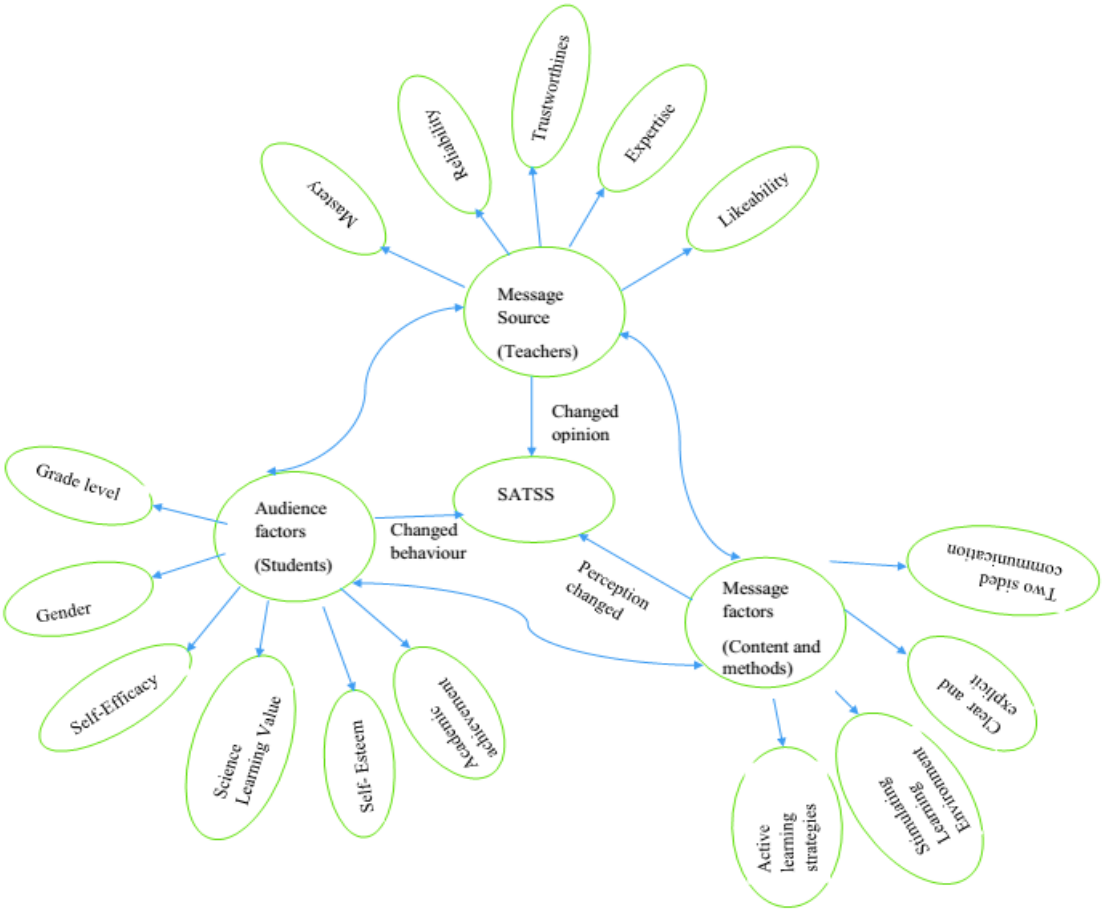

Figure 1: The underlying factors of SATSS reflecting Yale attitude change model

This is in agreement with social cognitive theory that views both internal and external factors as pivotal to learning. Environmental events, personal factors, and behaviours all operate together as interactive determinants or causes of each other in what Bandura (1997) calls the self-system (Harris & Sanborn, 2013; Pajares, 2000). This interlocking system shows that personal factors (beliefs, expectations, attitudes, and knowledge), the physical and social environment (resources, consequences of actions, other people and physical settings), and behaviour (individual actions, choices and verbal statements) all influence and are influenced by each other. As such, the individuality of the variables in influencing SATSS cannot be overemphasized at the expense of their interdependency. The bi-directional arrows show that teacher factors influence audience factors, audience factors influences message factors whilst message factors also influence the audience factors and lastly, teacher factors and the message factors also influence each other. The factors are linked showing their interdependency in influencing SATSS. This interaction among teacher factors, audience factors and message factors brings about changed opinions in the learner, changed perception and changed behaviour which is collectively termed changed attitudes.

Analysis of the relationship between academic achievement and attitude exposed a positive relationship. This stipulates that, students with high academic achievement in science subjects have high attitude towards science subjects and those with low academic achievement have low attitude towards science subjects. Increasingly, the study had other findings though not listed in the objectives. Firstly, examination of SATSS on the basis of class, it was observed that student attitudes tended to decline while class level increased. Some studies on attitude and grade level have also produced similar results (Geroge, 2006; Külçe, 2005; Weinburg 2000). The reasons behind this decline can be students decrease in self-efficacy, challenging science curriculum, ineffective teaching methods and techniques, teachers' inefficiencies in delivery of the curriculum, lack of teaching aids, students' stress and anxiety of the national examinations as most students perceive science subjects as difficult. These factors will gradually dwindle the SATSS with increase in the class level. Secondly, it should be explained that there was no statistical significant difference in students' attitude across the subjects as most of the students gave the same score for an item measuring same variable in biology, mathematics, and Physical science except Computer studies where majority of the students were undecided on the choice to score. However, when the students were asked to rank the subjects in order of their preference in decreasing order, the results were as shown in Figure 2.

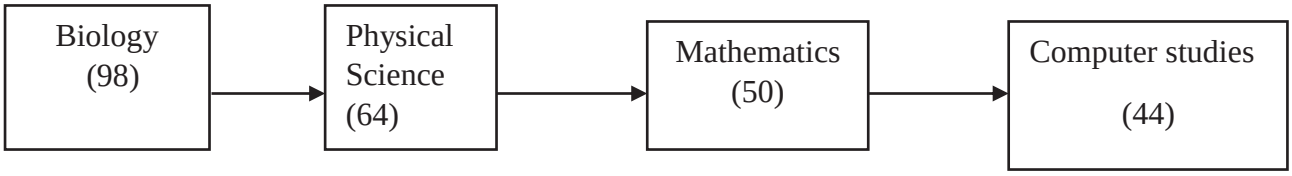

Figure 2: Subject preference rank order

showed that biology is highly preferred seconded by physical science whereas mathematics came third on the list and computer studies had the least preference by many students perhaps because it is not offered to all students in many schools. In their justification of preference most students said "biology and physical science explain real life things and more of biology explain living things how they behave and adapt". This increases their interest in these subjects. When asked what hinders them from learning science subjects effectively, students mentioned the following problems: few equipment in the laboratories, other students failed to understand why they learn particular subject, teachers' failure to motivate the students and teachers' inadequacies in handling science subjects.

CONCLUSION AND RECOMMENDATIONS

Contrary to the expected results, the study showed that students in CDSSs have positive attitudes towards science subjects. However, results of the study illustrated a significant effect of gender on SATSS. Girls had significantly more positive levels of attitude towards science than boys on total scale and on all sub-scales of questionnaire. In terms of underlying factors of SATSS, results showed that the following: self-efficacy, teacher factors, gender, stimulating learning environment, science learning value, performance, and active learning strategies deployed in the teaching and learning of science subjects in CDSSs. It should also be known that some other unexpected factors influenced SATSS. These are: grade level and locality of the school. It was shown that SATSS decreased with increase in grade level of the student. Thus form four students had fewer positive attitudes than form one students. This could be attributed to lowering of interest levels in sciences due to increase in difficulty levels of science subjects and fear of national examinations. Students in urban schools have more SATSS than those in rural areas. This is perhaps due to more exposure to role models to those in urban.

Following the results, the following recommendations were made to improve SATSS and the teaching and the learning process as a whole;

Recommendations to Teachers

- Must use active learning strategies that stimulate interest in students to learn science subjects like problem solving, study circles, discussion, group work, field visits, experiments, peer teaching, and discovery learning. Also teachers must explain real life examples and day to day applicability of the lesson.
- Must show great level of mastery of knowledge related to science subjects. This direct impact on learners' attitudes.
- Rationale of the science subjects must be well explained to learners to increase their SLV. Hence their attitudes change.
- Must be friendly and welcoming, so that the students feel free and encouraged to ask them challenging scientific and mathematical concepts. Hence improved attitudes.
- Must also take an initiative to help and scaffold those students struggling to understand science subjects.

Recommendations to students

- Must develop a culture of research. This is to read on topics of science and understand the real life examples and be able to apply in their everyday life. This increases the science learning value. Hence more positive SATSS.
- Must learn to work in groups and discuss with friends. This gives a good platform for students to learn from each other and have their self-efficacy level increased.
- Must respect teachers at the expense of his/her inadequacies. This creates a mutual respectful relationship between the teacher and the students. Hence easy flow of lesson and the student is free to ask whatsoever is challenging.

Recommendations on areas for further research

- The influence of laboratory instruction on science achievement and SATSS in Malawian secondary schools
- The impact of relevant material resources and qualified teachers on SATSS in secondary schools in Malawi.
- The teaching of science subjects in CDSSs and conventional secondary schools in Malawi.

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Experiences of English teachers when teaching learners with hearing impairment reading comprehension

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ABSTRACT

Information in the literature indicates that children who have hearing impairment (HI) often struggle with reading comprehension. HI students also struggle with the acquisition of crucial literacy skills and/or the attainment of reading abilities. It is therefore a challenge for hearing impaired learners to learn effectively in both primary and secondary schools. Information in the literature also points out that teachers encounter several challenges when teaching hearing impaired students. However, most of the studies in these areas have been carried out in African countries such as Tanzania and Kenya. In addition, the studies have focused on challenges faced when teaching in general without specifically looking at an individual subject. This study is therefore unique because its main purpose was to examine the experiences of English teachers when teaching learners with hearing impairment reading comprehension. In order to collect detailed information, interviews and focus group discussions were conducted with a total of eleven informants from three secondary schools in the northern region of Malawi (Nkhorongo Community Day Secondary School, Luwinga and Mzimba Secondary Schools). The results reveal that most hearing impaired students manage to predict the content of a written text from a title and answer comprehension questions. However, the results indicate that hearing impaired students have problems in explaining key terms and central ideas. Other challenges identified in this study include lack of teaching and learning materials suitable for hearing impaired students, lack of hearing aids, inadequate staff and large classes that prevent teachers to give a one-on-one assistance to students who require help. Among other things, the study recommends the need for teachers to be trained so that they are competent to teach hearing impaired students. The study also stresses the importance for schools to be supplied with the necessary teaching and learning materials to improve the poor learning environment of hearing impaired students.

Key works:

INTRODUCTION

Hearing impairment, according to Muiti (2010:12), is a "general term used to describe all levels of hearing losses ranging from mild to profound". According to Muiti (2010:13), in accordance with education guidelines, hearing impairment is divided into two groups namely, hard of hearing and deaf. Muiti states that the hard of hearing is especially used to refer to those people whose hearing loss fluctuates from mild to moderate. In this study, the term hearing impairment also applies to all levels of hearing losses as described by Muiti.

It is a challenge for hearing impaired learners to learn effectively in both primary and secondary schools. Several studies have been conducted regarding challenges that teachers encounter when

teaching hearing impaired students. Other studies have investigated hindrances to effective learning of pupils with hearing impairment. However, most of these studies have been carried out in African countries such as Tanzania and Kenya. In addition, the studies have focused on challenges faced when teaching in general without specifically looking at an individual subject. This study is therefore unique because it examines the experiences of English teachers when teaching learners with hearing impairment reading comprehension.

This study was conducted to examine the experiences of English teachers when teaching learners with hearing impairment (HI) reading comprehension.

Reading comprehension skills of HI students

There are certain factors that play a role in the comprehension skills of hearing impaired students. These factors include vocabulary knowledge, phonology, mode of acquisition, and syntactic knowledge. However, the discussion in this section mainly focuses on vocabulary.

Several studies have documented that hearing impaired learners have limited vocabularies (see Luckner & Cooke 2010). Other studies have also revealed that hearing impaired learners perform poorly in tests on vocabulary knowledge compared to their hearing counterparts (see Convertino, Borgna, Marschark & Durkin 2014). In particular, Dockery (2013) investigated the reading comprehension levels of grade 4 to 12 Jamaican hearing impaired students who enrolled in a sign-bilingual programme. Additionally, the study also sought to examine the predictive power that some selected variables including receptive vocabulary knowledge have on the reading comprehension levels of Jamaican hearing impaired students. The results reveal that receptive vocabulary knowledge was one of the important predictors of reading comprehension hence an important strong correlation between vocabulary knowledge and reading comprehension.

Text comprehension strategies for hearing impaired students

This section focuses on some of the strategies that could be used prior to reading, during reading and after reading. Some of the strategies that could be used fall under the following categories: prior to reading (e.g. pre-teaching/pre-learning vocabulary and grammar), during reading (e.g. making inferences and asking questions) and after reading (e.g. retelling and summarizing) (McAnally & Rose 1999); Rose, McAnally & Quigley 2003).

Benedict (2012), reports that "three decades' worth of research has shown that providing instruction in higher-order cognitive thinking skills (for instance, activating prior knowledge, making predictions, drawing inferences, and summarizing) improves students' reading comprehension". Overall, this means that, as pointed out by Fielding and Pearson (1994), the process of learning to read for understanding involves knowledge, experience, thinking, and teaching.

Challenges that teachers encounter when teaching hearing impaired students

The review presently focuses on studies that examined challenges that teachers encounter when teaching hearing impaired students. In the first place, a study that was conducted in Zimbabwe by Mpofu and Chimhenga (2013) highlights the following language related challenges: language use, vocabulary development, speaking, academic achievement and social functioning. In particular, their results reveal that most hearing impaired students have difficulties in expressing themselves. In addition, these students find it difficult to "develop the vocabulary of the English language since they hardly hear when other people are communicating" (Mpofu & Chimhenga 2013:72).

A study conducted by Muiti (2010) who investigated hindrances to effective learning of pupils with hearing impairment reported the following challenges: difficult in explaining abstract concept, communication barriers, lack of learning resources and hearing aids, too much work load, sharing of one class by learners at different levels, lack of support by parents, short attention span of pupils,

inadequate training of teachers in colleges and regular absenteeism.

Ways of overcoming challenges

Teachers can provide relevant cues that aid comprehension. Teachers can also encourage hearing students to be supportive whenever hearing impaired students require further explanations of what the teacher covers in class. Additionally, in order to overcome communication barriers, Mpofu and Chimhenga (2013) further advise teachers to make sure that hearing impaired students do not have unobstructed view of the teacher. Above all, in a study conducted by Udoba (2014), it was noted that some of these challenges may be resolved by a community that works together, a community that accepts people with disabilities as human beings. If they are thus accepted, we will realise that they need our help throughout their lives. In doing so, we will do everything possible to show them that they are loved and safe.

MATERIALS AND METHOD

The purpose of this section is to provide information concerning the data collection procedures that were followed. The focus is therefore on the following: research design, geographical area of the study, participants, data collection techniques and tools, data analysis and ethical consideration.

Research design

This study used a qualitative research design. According to Bailey, Hennink and Hutter (2011), qualitative research allows a researcher to examine people's experience in detail using methods such as in-depth interviews and focus group discussions. Furthermore, qualitative research enables a researcher to collect data that can be coded and categorized into themes.

Geographical area of the study

Data for this study was collected from three schools that are located in Mzuzu city and Mzimba district respectively as follows: Nkhorongo Community Day Secondary School (CDSS), Luwinga Secondary School and Mzimba Secondary School.

Participants

The researchers interviewed and had a focus group discussion with a total of eleven informants from the three secondary schools; three teachers from Nkhorongo CDSS, two teachers from Luwinga Secondary School, two teachers from Mzimba Secondary School, two specialist teachers from Luwinga Secondary School and two resource persons from Mzimba Secondary School.

Data collection techniques and tools

This study used the following data collection methods: interview and focus group discussion. Interview was considered as the main method of data collection while focus group discussion was a supplementary one. Below is the detailed description of each method.

Interviews

In general, this study involved semi-structured interviews. In particular, open-ended questions were used. The interviews were conducted with every teacher selected to participate in the study. Each interview lasted about thirty minutes. The purpose of this study and the specific objectives formed the basis for the interview questions. All the interviews were audio recorded in order to maintain the original data. Audio recordings are crucial because they provide a complete verbal record which can be studied much more thoroughly. Besides, audio recordings speed up the interview process (Gall, Gall & Borg 2007).

Focus group discussions
In this study, the researchers conducted two focus group discussions with English teachers, resource persons and specialist teachers. One focus group discussion took place at Luwinga Secondary School. The participants in the first focus group discussion were two English teachers and two specialist teachers in other subjects such as Bible Knowledge and Social Studies. Another focus group discussion took place in Mzimba in which the following were the participants, two teachers and two resource persons.

Data analysis
All the raw data collected in this study were transcribed. Thereafter, thematic analysis was used to organise the transcribed data.

Ethical consideration
In the first place, all the respondents were informed of the purpose of the study. They were also assured that their views and opinions would be treated with maximum confidentiality. They were also assured that the study findings would be for academic purposes only.

RESULTS

This section presents the findings of this study. The findings are organised and presented according to the themes corresponding to each specific objective. The specific objectives were achieved using information collected through interviews and focus group discussions.

Whether or not students with hearing and visual impairment are able to do the six specified tasks
The results reveal that most hearing impaired students manage to predict the content of a written text from a title. They also manage to answer comprehension questions. The teachers revealed that hearing impaired students are able to answer comprehension questions especially when they are encouraged to read a passage over and over again in order to fully understand it. However, they indicated in their responses that hearing impaired students struggle to do the following: identify key words that signal central idea, define or explain key words that signal central idea, identify central idea from the title of the written text and explain central idea.

Text comprehension strategies that are used when teaching reading comprehension
The focus in this section is on text comprehension strategies that teachers use when teaching learners with hearing impairment reading comprehension. Table 1 below presents a list of the strategies that the researchers obtained from the teachers that were interviewed.

Table 1: Text comprehension strategies that are used when teaching reading comprehension

Nkhorongo	Pre-reading activities, frequent exercises that enhance their reading comprehension skills, assigning group members to be assisting HI students, predictions from titles or pictures, skimming and scanning
Luwinga	Group work, pair work, explanation, whole class discussion, individual work, demonstration and use of gestures, silent reading and individual reading
Mzimba	The use of textbooks and a variety of passages for comprehension exercises, repetition and reading a passage several times, writing new words on the board and providing their meanings where necessary

Challenges that teachers encounter when teaching the six specified tasks
There were several challenges that the teachers raised during the interviews as well as focus group discussions. The discussion in this section only focuses on the main challenges. In the first place, the teachers pointed out that most of the teachers at the three schools are not trained to teach

learners with hearing impairment. Furthermore, the teachers pointed out that hearing impaired students rely on facial expressions and lip reading for them to understand what the teacher is talking about. However, facial expression may sometimes be misinterpreted. In addition to that, they also stated that lip movement may be misleading especially when producing words such as 'man' and 'mad'. The teachers therefore stressed the importance of using appropriate facial expressions and pronunciations.

Some teachers also complained about the low performance in English for some of these students. This low performance may be attributed to the fact that some of these students find it difficult to develop the vocabulary of the English language since they hardly hear when other people are communicating. Furthermore, it is a requirement for secondary school students to know how to summarise a passage because the national examinations in their final year of secondary education assess them in this area. However, writing summaries is considered as one of the difficult tasks for hearing impaired students according to the responses from the teachers.

Table 2: Challenges that teachers from the three schools encounter when teaching English subject

Nkhorongo	Lack of resources in terms of text books, insufficient staffing & large classes hence inability to give a one-on-one assistance to students who require help, students are not ready to tell the teacher that they are lost, failure to understand comprehension passages, group work problem, emphasis is required when instructing students
Luwinga	Lack of teaching and learning materials suitable for hearing impaired students, lack of hearing aids, lack of analytical skills, lack of interest and motivation, inability to get what is taught when sitting in a position far away from the teacher
Mzimba	Problems only when students are not given a passage in advance, problems with vocabulary, being absent minded when attention is required, failure to lip read correctly due to shortage of books

Other challenges that teachers raised concern the fact that hearing impaired students are easily distracted. These students specifically complain that there are usually a lot of distractions when doing group work. Other challenges that the teachers raised are given in Table 2.

Solutions to the challenges

In this section, the researchers reveal views and suggestions from teachers on how the challenges identified in the above section can be resolved. To begin with, it is important to point out that the teachers were of the view that it is not only a one man's job for these challenges to be resolved. They therefore stated that there is a need for teachers to collaborate with students and their families, specialists, their communities as well as the government. The rest of the solutions are presented in Table 3 below.

Table 3: Solutions to the challenges outlined in section 4.3

Nkhorongo	Provision or procurement of more teaching materials, students should be supervised when doing group work, encourage students to read widely, encourage students to speak English all the time when at school, supplementing what is available by photocopying passages from text books and other sources e.g. newspaper, HI students should be sitting in the front row all the time, fellow students can help HI students by clarifying certain points in their own free time
Luwinga	Sitting in the front row and the teacher should be closer all the time, sourcing hearing aids, improvisation in case of shortage of teaching and learning materials, using different strategies when teaching, making lesson interesting by using a variety of teaching and learning aids, using group work
Mzimba	Repeating what is said is important, encouraging them to read widely to increase their vocabulary knowledge, using the best and correct pronunciation in order for the students to lip read correctly, providing passages for transcription in advance

DISCUSSION

The results have revealed that hearing impaired students are able to predict the content of a written text from a title as well as answer comprehension questions. On the contrary, the results demonstrate that hearing impaired students struggle to identify key words that signal central idea, define or explain key words that signal central idea, identify central idea from the title of the written text and explain central idea. These results have proved that these students cannot do the six specified tasks if they struggle with their vocabulary.

These results are supported by what Mpofu and Chimhenga (2013) found. Their results reveal that hearing impaired students struggle to develop English vocabulary because of their inability to hear when other people are communicating. Mtuli (2015) also reports that hearing impaired students do not have normal language abilities and as a result they find it hard to communicate in inclusive education classes which do not capitalise on the use of sign language.

Similarly, Bickham's (2015) findings indicate that vocabulary is one of the main sources of difficulty for hearing impaired students in as far as reading comprehension is concerned. Information in the literature also reveals that their problems with vocabulary are attributed to the fact that these students do not have opportunities to acquire vocabulary as well as syntax from an early age (see Mpofu & Chimhenga 2013). Additionally, Dockery's (2013) findings also reveal an important strong correlation between vocabulary knowledge and reading comprehension.

Difficulties in vocabulary eventually lead to poor performance in English and other subjects. It is reported by Mpofu and Chimhenga (2013) that students with hearing impairment have difficulty with all areas of academic achievement, especially reading and mathematical concepts. They also report that the gap in academic achievement between children with normal hearing and those with hearing impairment usually widens as they progress through school.

When it comes to text comprehension strategies, it is important to mention that some strategies that were found to be useful in the literature were not mentioned by the teachers in this study. These strategies include the use of graphic and semantic organizers, question generation and inferencing. The teachers who participated in this study indicated that they tend to ask students questions after reading a passage but they do not encourage them to generate their own questions from the passage that they were reading. They also do not encourage the use of graphic and semantic organizers. This is where a student can be provided with meanings of difficult vocabulary as well as an outline of main ideas from a passage but in a graphic format. Finally, the teachers are fond of asking explicit questions; hence they do not encourage students to make inferences as they ask questions whose answers are readily present in the passage.

Regarding challenges, the results have revealed that teachers complained about insufficient staffing and large classes. They also indicated that most teachers are not skilled to teach hearing impaired students. Similarly, in a study that Mtuli (2015) conducted, he found that in Tanzania there was lack of in service training for the teachers of special education. He also found that there was lack of information to facilitate learning of hearing impaired students in inclusive education. This implies that if teachers are properly trained, they would be able to teach an inclusive class effectively.

The results also reveal that there is lack of teaching and learning materials suitable for hearing impaired students. Apart from this challenge, the students also do not have hearing aids. The problem of lack of resources appears to be common in most African countries. Mtuli (2015), Muiti (2010) and Udoba (2014) who conducted their studies in Tanzania and Kenya respectively report similar findings. It is an outcry for many teachers to have more advanced teaching materials such as audio and TV for teaching (Udoba 2014). Other teaching and learning materials include visual

media especially overhead projectors or PowerPoint (Mpofu & Chimhenga 2013). According to Mpofu and Chimhenga, these are effective tools because they enhance the learning process for the hearing impaired pupils.

Regarding solutions, the teachers mentioned that hearing impaired students need to be provided with adequate teaching and learning materials. This would however be possible if the teachers worked hand in hand with the government and non-governmental organisations (NGOs) because of financial complications. According to Udoba (2014), many teachers would like to be using modern teaching and learning materials as opposed to the locally available materials because the latter do not motivate the learning process during lessons. Udoba also points out that teachers may not be able to utilise appropriate teaching methods and approaches when modern teaching and learning materials are not available.

Furthermore, another solution that the teachers mentioned involves the need for fellow students to help hearing impaired students by clarifying certain points in their own free time. Regarding this, Mpofu and Chimhenga (2013) point out that it is important for teachers to use every opportunity to teach other students about hearing loss and what can be done to support hearing impaired children in class. There is also a need for parents and other relations to be supportive.

Collaboration with parents is crucial because parents know their children better than the teachers.

As alluded to earlier on in this section, the teachers in this study pointed out that hearing impaired students have problems with vocabulary. As a solution to this challenge, the teachers stressed the importance of encouraging students to read widely. Furthermore, it is important that teachers frequently check hearing impaired students to see if they are following the lesson or not. If they are not, other strategies may be used to enhance their understanding.

There were several ways that were offered in this study that would help to overcome communication barriers. In view of this, Mpofu and Chimhenga (2013) advise teachers to make sure that hearing impaired students do not have unobstructed view of the teacher so that they are able to lip read what the teacher says throughout the lesson. Mpofu and Chimhenga also stress the importance of repeating questions and comments uttered by other students in class who may not be in the range of vision of the hearing impaired student. Repeating what is said was also viewed as one of the important solutions in cases where students did not understand a lesson.

Besides the solutions outlined in Table 3, it was found out in this study that the challenges that the teachers pointed out cannot be completely avoided. What is important to most teachers is to find the best ways to minimise them. According to Udoba (2014), the best way to minimise these challenges is to make sure that learners are not affected to a great extent. Above all, what is important is to make sure that students are attending school as many of the challenges explained in section 4.3 may not have immediate solutions.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

The focus in this section is to provide a summary of the main findings. This section also makes recommendations for the enhancement of effective learning of students with hearing impairment.

Summary of findings

This study aimed at examining the experiences of English teachers when teaching learners with hearing impairment reading comprehension. The results reveal that most hearing impaired students manage to do the following: predict the content of a written text from a title and answer comprehension questions. The results also demonstrate that hearing impaired students are able to

answer comprehension questions especially when they are encouraged to read a passage several times. However, the results indicate that hearing impaired students struggle to identify key words that signal central idea, define or explain key words that signal central idea, identify central idea from the title of the written text and explain central idea.

The results also reveal that teachers make use of several strategies such as predictions from titles or pictures, skimming and scanning. The study also indicates that teachers encounter several challenges such as lack of teaching and learning materials suitable for hearing impaired students, lack of hearing aids, inadequate staff and large classes that prevent teachers to give a one-on-one assistance to students who require help. The results have also revealed that hearing impaired students struggle with vocabulary and writing summaries.

Furthermore, the study has revealed that the government and NGOs should provide teachers with the required resources in order to resolve some of the challenges that the teachers mentioned. Besides this, teachers are encouraged to be improvising when the required teaching and learning materials are not available. Finally, it was noted that the best way to minimise these challenges is to make sure that learners are not affected to a great extent.

Recommendations

This study makes the following recommendations:

1. Teachers need to be trained so that they are competent to teach hearing impaired students.
2. There is a need for the provision of resource persons because some schools do not have resource persons to support the learning of hearing impaired students.
3. Schools should be supplied with the necessary teaching and learning materials to improve the poor learning environment of hearing impaired students.
4. There is a need for collaboration between teachers and parents. Collaboration with parents is crucial because parents know their children better than the teachers.
5. Students should be sensitized on the importance of supporting hearing impaired students and also students with other categories of disability.

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Using the Theory of Transactional Distance to access open and distance education in Malawi

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ABSTRACT

Slowly but surely, Open and Distance Learning (ODL) programmes are being regarded as one of the most practical ways that universities across the globe are encouraged to adopt in order to increase access to higher education. Mzuzu University (MZUNI) is not spared from this ODL lure and it set up the Centre for Open and Distance Learning (CODL) to oversee the running of these programmes since 2011. In this study, we adopted the Transactional Distance Theory (Moore, 1997) to investigate the modes of instructional systems, benefits or opportunities and the challenges associated with the delivery of ODL programmes at MZUNI. By self-administering a questionnaire to 350 ODL students and nine Heads of Department in the Faculty of Education whose programmes are offered through ODL, we found that mainly, instructions are delivered to students through print-based instructional materials. The major benefits noted include increased access to quality higher education, affordable tuition fees and flexibility in payment of fees. However, we established some challenges which need to be addressed by the University. These include delayed feedback of assignments and release of end of semester examination results, absence of information for courses of study, poor communication between the Centre and departments and poor remuneration for lecturers.

Key Words: Higher Education, Malawi, Mzuzu University, Open and Distance Learning, Students.

INTRODUCTION

An expression 'education is key to success' is commonly said or quoted by many educational experts and researchers. It thus follows that education is supposed to be accessible by everyone regardless of their economic situation. To this end, Article 26 of the United Nations (1948), proclaims that "higher education shall be equally accessible to all on the basis of merit". Similarly, Article 13 of the United Nations (1966) stipulates that "higher education shall be made equally accessible to all, on the basis of capacity, by every appropriate means, in particular by the progressive introduction of free education". However, developing countries including Malawi are far from making higher education accessible to everyone who deserves by merit. A group of researchers (Badat, 2004; Bekhradnia, 2004; Brennan, 2004; Smith & Casserly, 2006) have all independently observed that inequalities of access to higher education, still exist around the world. In Africa, especially Southern Africa, the Southern Africa Regional Universities Association (2011) reports that access to higher education is said to be so low and disturbing. The Southern Africa Regional Universities Association (2011) highlights a range of challenges that are directly responsible for the poor status of higher education in Southern Africa. The challenges include reduced funding by governments to public universities and other institutions of higher learning which are deemed to be more affordable than private universities; rise in competition for donor

funding amongst private and public universities, increase in the number of students needing university education, and inefficiency in the use of the available resources by higher education institutions. Maybe because of the aforementioned factors, the Commonwealth of Learning (2002) reports that "none of the countries in Sub-Saharan Africa have fulfilled the promise of providing education to the entire population through the conventional education system" (p.5). In other words, universities in Southern Africa including Malawi, are unable to admit all deserving individuals on a campus-face-to face or residential basis. To ensure that they remain relevant and survive in the torrent environment in which they operate, Wilson (2008) observes that most universities have resorted to introducing ODL programmes which are believed to be helping them reduce the pressure of the growing number of students. Through ODL, "colleges, universities, businesses, and organisations worldwide now offer their students fully accredited online degree, vocational, and continuing education programmes in abundance" (Mbatha & Naidoo, 2010, p.68).

According to Garrison (2000) and United Nations Educational, Scientific and Cultural Organisation (UNESCO) (2003), two principal interlocking factors are directly responsible for the flourishing of ODL. They include the desire by individuals to upgrade their skills and current qualification and the unparalleled innovation and advancements in technologies which have effectively cleared the road blocks impeding access to education which previously, was only accessible through classroom based-learning. Most ODL learners have professional responsibilities (jobs), social responsibilities (families), are interested in part time studies, lack of access to on-campus based studies or are away from formal education (Akintayo & Bunza, 2000) and ODL becomes the readily available option for them to upgrade their qualifications. Realising the promises that come along with ODL, MZUNI is one of the institutions of higher education in Southern Africa which runs ODL programmes. Thus, with specific focus at MZUNI, this study sets out to investigate the opportunities and challenges associated with the implementation of ODL at this institution.

Problem statement and research questions

Since independence from Britain some 50 years ago, the Malawi Government has made sound initiatives to develop human capacity through the establishment of a number of vocational and tertiary educational institutions which include, teacher training, technical, nursing, agricultural colleges and more importantly, universities. However, it is understood that access to tertiary education in Malawi remains very low due to acute shortage of teaching and learning resources inadequate classrooms and library spaces, and shortage of human capacity. Some well deserving students are commonly not admitted into universities due to the aforementioned factors. For example, in 2008, public universities in Malawi (Mzuzu University and University of Malawi) then, admitted only 0.03% of the eligible school leavers using the face-to-face and residential delivery mode (Mzuzu University, 2014). Such developments seem to have stimulated MZUNI to introduce ODL programmes. MZUNI envisaged that the Open and Distance Learning delivery mode could provide an opportunity for people to study while working. For example, under-qualified teachers who are already employed in secondary schools would get a chance to upgrade their academic and professional qualification through the open and distance learning mode. The possible challenges for ODL delivery, especially in resource-challenged countries such as Malawi may include (i) provision of support to students during home-based study and (ii) the distance between students' homes and MZUNI for face-to-face delivery of courses and examinations, which may place financial burden on students. One wonders how the university has been fairing since the inauguration of the ODL programmes as it seems there has not been any empirical study to shed light about the successes or challenges of the open and distance learning mode at MZUNI. Although the Centre is considerably new, it is possible to speculate that the University has registered some successes and possibly, some challenges. In this study, we investigate these possible opportunities and challenges. To achieve this, the study answers the following questions:

- What are the modes of instructional systems of ODL programmes at Mzuzu University?

- What are the benefits or opportunities associated with the introduction of ODL programmes at Mzuzu University?
- What are the challenges associated with delivery of ODL programmes at Mzuzu University

Theoretical Framework: The Transactional Distance Theory

The study is underpinned by the Transactional Distance Theory (TDT) (Moore, 1997). In the TDT, the focus is on the cognitive space that exists between instructors and learners in any educational environment. Moore (1980) sees distance education not just as a geographical separation but rather a pedagogical concept. That is to say what is commonly or widely perceived as a problem that a learner faces is the geographical issue yet pedagogical issue, is the most important one. There are three elements that interplay to shorten the distance between an instructor and a learner (Martindale, 2002) and they include the structure of instructional programmes, the interaction between learners and teachers, and the nature and degree of self-directness of the learner.

MATERIAL METHODS

This case study design which employed a mixed methods approach was conducted between January and February, 2015 at MZUNI. The target population that provided data for this study included registered ODL students at MZUNI and Heads of Department in the Faculty of Education. At the moment, MZUNI runs four ODL programmes; Bachelor of Arts (Education), and Bachelor of Science (Education), Diploma of Arts (Education) and Diploma of Science (Education). During the time of collecting data, there were no students in Level One implying that the current 750 registered ODL students (Mzuzu University, 2014) are those in levels two, three and four. The data collected from respondents were organised in order to facilitate analysis by coding quantitative data into numeric data. To achieve this, the Statistical Package for the Social Sciences (SPSS) was used to determine frequencies and percentages. Some frequencies and percentages were imported from SPSS to Microsoft Excel to produce charts and figures. Frequency distributions were depicted in tables and charts. Qualitative data were analysed thematically. Thematic analysis is a method for identifying, analysing, and reporting patterns (themes) within data (Braun & Clarke, 2006). In this study, thematic analysis was achieved by identifying commonly recurring and prevalent themes which assisted in answering the research questions.

Data Analysis and Discussion of Results

In total, we sent a questionnaire to 350 students and 233 (66.5%) responded to the questionnaire. Of these, 191 (82%) were males and 42 (18%) were females.

Chawinga (2017), Chawinga (2016), Chawinga (2016), Chawinga and Zinn (2016), Chawinga and Zinn (2015), Chawinga and Ngwira (2015), Chawinga and Zozie (2016) and Chawinga and Zozie (2016b) have all observed that historically, universities in Malawi enrol more males than females mainly because of culture which dictates that females are supposed to get married as soon as they reach the puberty stage. In contrast, males are regarded as breadwinners and are encouraged to work hard in school so that they can support their wives and families. Likewise, of the nine Heads of Department to whom we sent a questionnaire, five responded of whom two were females and three males. Findings showed that most students are studying a Bachelor of Arts (Education). Elsewhere, Kritpracha, Kaosaiyaporn, and Atisabda (2015) find that more students were studying arts subjects with a score of 42 (21.0%) as compared to science subjects which had a score of 35 (17.5%). From the results, it is clear that arts subjects remain the most dominant subjects offered through ODL.

Modes of Instruction and Assessment

Upon establishing ODL, MZUNI indicated that it could adopt various modes of instructional media to deliver content to its students. However, findings from students which are displayed in Figure 1 suggest that the University is yet to adopt technologies such as Internet which are used to deliver lessons to ODL students as is the case at the UK Open University which according to Gourley and

Lane (2009) has used the radio, TV and Internet to reach out to its ODL students. Rather, MZUNI heavily uses print instructional materials with a score of 222 (95.3%) followed by the Internet technologies with a score of 57 (24.5%). Students' results are well corroborated by those of Heads of Department where, all indicated that they mainly use print based particularly, instructional modules to deliver lessons to students. For example, one lecturer commented that "lecturers usually provide print modules and assignments to students when they come for orientation or to write end of semester examinations." Since the TDT by Moore (1997) informing this study suggests that the learner may never meet the instructor, the situation is different at MZUNI where the results show that students spend some weeks on campus for three main reasons: to register, for orientation and to write end of semester examinations.

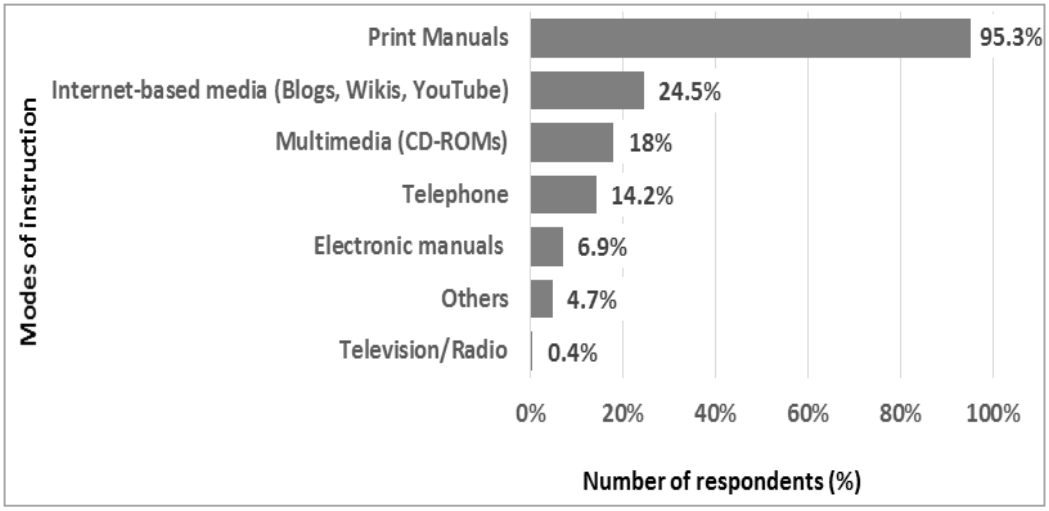

Figure : Modes of instruction

Findings further show that 203 (86.6%) students preferred university learning manuals (instructional modules) mainly because of three reasons: they are cheap to access, they are comprehensive and one does not need electricity to use them. Some verbatim from student respondents include: "we read even at our home in remote areas", "they are easily accessible and less expensive", "I am living in a very rural area where there is no electricity so it becomes convenient using print media", and I am able to read at my own pace and the records are permanent". Historically, print materials have remained the most popular learning materials in Malawi. This confirms what the TDT by Moore (1997) informing this study espouses by emphasising that taking into account that the learner may not meet the instructor, it is essential that courses should be well designed as if they are offered in a face-to-face environment. Thus, the fact that results show that students prefer print manuals because they are compressive signals that these learning manuals are well structured. Clarity and comprehensiveness of the learning print manual is a welcome development at MZUNI because Petroman and Petroman (2013) suggest that ODL materials should be structured in such a way that they completely replace the presence of the teacher, except for the final assessment and marking. Despite the popularisation of Internet and other electronic media in the past decade in Malawi (Chaputula, 2010), problems of electricity especially in rural areas where most of these students live, and the exorbitant prices stymie the use of these digital media. The situation is however, different in Russia where Kudryavtseva (2014 reports that "effective and successful methods of self-study of a foreign language was attributed to many tutorials and special electronic educational resources delivered via the Internet" (p. 1217).

Benefits of ODL

Items in this section sought to establish the benefits of ODL programmes from students' and lecturers' perspective. All students indicated they had benefitted from the programme because it had

accorded them an opportunity to access higher education which is affordable and flexible. As discussed in some of the previous sections, most of the students are currently working with the Ministry of Education, Science and Technology as Primary School Teachers. The Ministry would not want to see its employees stay away from work for a long period of time (usually, they get disciplined or dismissed if they do) and this arrangement offers these students an opportunity to study while working. Students seem to be very excited to have accessed university education so much so that most of them provided many similar comments as follows: "it has made me access university education after being left out by all universities in Malawi despite my good grades" and another one who agreed said "with this programme, I am able to continue working, look after my family while doing my university education".

Benefits mentioned by students were well supported by lecturers. For example some statements coming from the Heads of Department included "[ODL] students study and work at the same time; they do not need study leave since most are teachers and are required on campus during recess", "It [ODL] promotes the right to education as some people who had no chance to attain university education can do so now" and "with unpredictable funding from Government, this is an ideal programme to bring education to most Malawians". Another lecturer commented that "students are usually in control of their learning activities as they decide when to study, write assignments and prepare for examinations; they are actually independent learners". Such moments uphold observations by Rékaa, et al. (2015) that distance learners have higher levels of autonomy, competence and relatedness than full time learners. To this end, Kudryavtseva (2014) concluded that "it should be noted that distance learning is a process of self-education based on stand-alone courses, which do not involve regular interaction with the teacher (p. 1217). This is what Moore (1997) refers to as self-directness or autonomy, i.e. "the extent to which in the teaching/learning relationship, the learner rather than the teacher determines the goals, the learning experiences, and the evaluation decisions of the learning programme" (Moore, 1997).

The findings deepen what was observed some 13 years ago by the Commonwealth of Learning (2003) that open and distance learning has the potential to expand the limited number of places available for campus-based institutions which are few in numbers and have stringent entrance requirements. The findings also echo sentiments by Kudryavtseva (2014) who says distance learning offers opportunities for education outside the conventional system by providing flexibility in pursuing courses and taking examinations. Although Al-Arimi (2014:85) argues that distance education can be costly for students in some ways, findings of the current study show opposite results. According to students, tuition is affordable and the University offers a flexible way of paying such that some students responded that "making payments through instalments makes it easier for us who have lower levels of income", "to be honest, these fees are far much affordable as compared to what other colleagues pay in other universities", and another who agreed said "I have enough time to sort out financial issues while I am at home". Other students were of the view that studying as ODL students made them improve their teaching skills as evidenced by the following statement which represents many similar others: "as a secondary school teacher, I have improved in my delivery of lessons as I am able to explain some concepts which were difficult to explain before".

Challenges Faced

Although ODL programmes come along with various benefits as discussed in the preceding section, it is faced with a number of challenges. Thus, we asked participants to mention the challenges confronting the operations of ODL at MZUNI. According to Zirnkle (2001), most challenges emerge from three particular levels of, individual student, instructional and institutional. As presented in Figure 2 below, most individual problems that students face include financial bad perception of ODL programmes, balancing family affairs with studying and unfriendly study environments at home. Although MZUNI offers affordable fees to these students, it still becomes

difficult for them to pay because most of them have extended families to look after. Worth noting is that these students do not get any loans from government for their tuition and this is probably the reason some of them claim that they lack support from their employers (see Figure 2 below). Some Heads of Department also cited the problem of bad perception of ODL programmes especially by the general public such that one of them commented that "some people think that ODL students are half-baked just because they study on their own at home". The problem of bad perception of ODL has been reported in other studies such as those by Sherritt (1996), Commonwealth of Learning (2002), Wilson (2008) and Valentine (2002) who have all independently observed that some administrators, who are key decision makers, perceive ODL as second grade programmes. However looking at the number of applications that the University receives, this is not a worrying problem especially considering that the degree programmes offered are fully accredited by the Malawi Government.

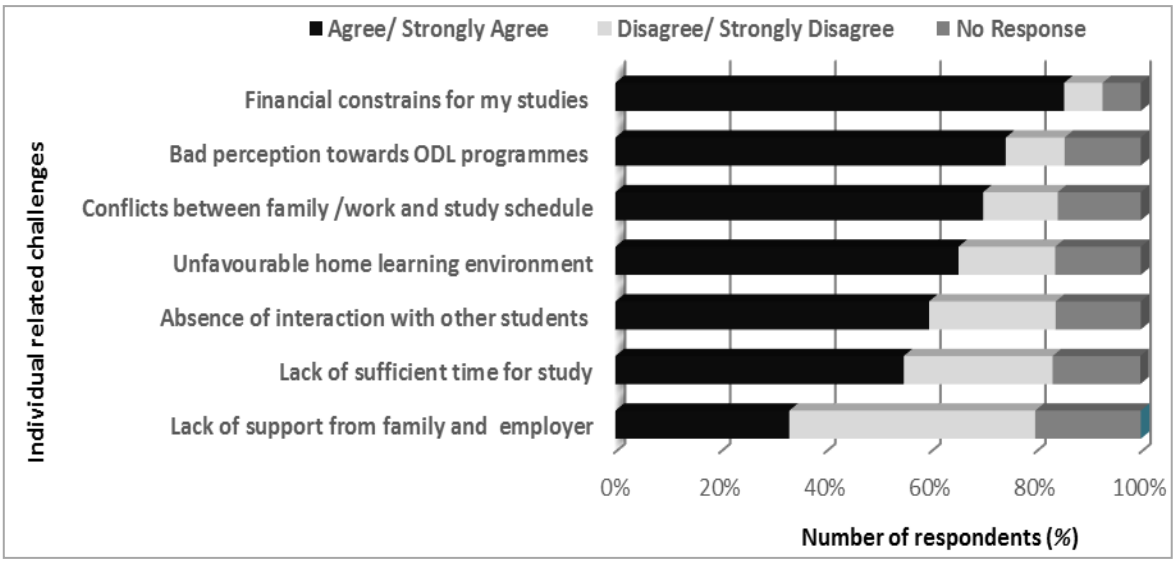

Figure 2. Challenges faced

Instructional problems result from the fact that generally, ODL programmes are based on indirect teaching relationships between the lecturer and the learner who is a self-learner (Juma, 2005). As can be seen in Table 1 below, it is clear that the main problems include lack of academic support, delayed end of semester examination results, delayed feedback from instructors and failure on the part of students to find information for their studies. Most students were so saddened with the perpetual delays in receiving end of semester examination results by the University and no wonder some made the following statements: "I wonder why the University decides to commence the next semester before releasing results of the previous semester" and another one who concurred said "It becomes devastating to learn you have been withdrawn from the University because of failing a course offered in the previous semester when you are already registered in the new semester; this demotivates us". From the Heads of Department perspectives, the study established three main problems: poor communication between CODL and departments, prolonged registration of students and poor remuneration for lecturers. The problem of poor communication was highlighted by all Heads of Department such that one of them commented that "communication between CODL and departments is not properly made; sometimes we learn things from students and we are forced to verify with the Centre".

The fact that only few students complained about poor learning materials or modules implies that the structure of instructional materials is flexible and the designers took into account that learners could be learning without the intervention of instructors according to the Transactional Distance Theory (Moore, 1997). Delayed feedback from instructors is one of the aspects that is likely to

affect the performance of ODL students according to Transactional Distance Theory (Moore, 1997). In this context, interpreting the results through the lens of Moore's (1997) s Transactional Distance Theory, there is lack of interaction between learners and teachers or dialogue and this leads to negative effects on teaching/learning experiences. Using the Transactional Distance Theory (Moor, 1997) to measure how student interactions in online and blended learning environments impacted student learning outcomes, Ekwunife-Orakwue and Teng (2014) report similar findings that interaction with content is the core of distance learning, "which is why learner content interaction may be contributing to its exponential growth and the proliferation of open education movements" (Ekwunife-Orakwue & Teng, 2014, p. 425). These findings substantiate observations by Kritpracha, Kaosaiyaporn, and Atisabda (2015) who place emphasis on the need to provide a learning platform that allows instructors and students to communicate without upheavals.

Table 1: output of instruction related challenges

Instructional Related Challenges

Instructional related challenges	**Agree/ Strongly Agree**		**Disagree/ Strongly Disagree**		**No Response**	
	f	***%***	***f***	***%***	***f***	***%***
Lack of academic support	181	77.6	24	10.3		12.0
Delayed end of semester examination results	176	75.5	25	10.8	32	13.7
Class too large	173	74.3	26	11.2	34	14.6
Delayed feedback from instructors	169	72.6	28	12	36	15.5
Failure to find relevant information for studies	156	67	47	20.1	30	12.9
Poor learning materials/manuals	77	33.1	109	46.8	47	20.2
Lost assignments and grades	163	70	37	15.9	33	14.2

In view of the problems highlighted in the preceding, several suggestions were provided by students on how MZUNI can address them. Between 156 (67%) and 210 (90.1%) respondents are of the view that the University should set up satellite centres in each district, should liaise with Government to offer soft loans to students, timely release of examination results and immediate feedback of assignments, the Centre should employ its own lecturers, offer accommodation to ODL students when they come for orientation, advertise the ODL programmes using more media outlets other than just relying on newspapers. Most of the Heads of Department suggested that the University should recruit tutors and improve communication to the Departments. The study established that there is strong need to recruit tutors for Science courses as evidenced by a statement from one of the Heads of Department that reads: "ODL has the potential to reduce shortage of teachers but needs to be handled with care by recruiting tutors who can help students in carrying out experiments which are a must in Science related courses". These tutors could travel to the proposed satellite centres. The need for satellite centres has been emphasised before by Al-Arimi (2014:85) who argues that "distance education often requires establishment of regional centres". The satellite centres should be based on recommendation made by some researchers such as Mbatha and Naidoo (2010) who argue that such "centres should be equipped with technological resources such computers and Internet" (p.66).

CONCLUSIONS AND RECOMMENDATIONS

Our case study has demonstrated the potential of ODL programmes towards achieving universal access to higher education in Malawi, not just to the working group but to other many Malawians who cannot access it through campus-based learning. This is made a reality due to flexibility of the programme whereby students are allowed to study while working, and more importantly, tuition is fairy affordable in addition to being paid through instalments. In a nut shell, the study finds that

over the years, MZUNI has admitted quite a number of Malawians. Despite successes registered and benefits associated with the introduction of ODL programmes at MZUNI, the programmes are not short of challenges. Our study finds that delayed feedback from lecturers, delays in releasing end of semester results, scarcity of study materials are the key instructional challenges that students cited. On the part of Heads of Department, challenges cited include poor communication from the Centre, poor remuneration and prolonged registration of students when they come on campus. In light of the findings of the study, the researchers urge MZUNI to: release end of semester examinations on time to avoid inconveniencing learners, offer incentives to lecturers to motivate them provide feedback to learners on time, and to set up satellite learning centres in the three geographical regions of Malawi where students can access information materials, particularly electronic resources and where they can meet and interact with their colleagues and lecturers or tutors. We further urge MZUNI to improve communication between the Centre and lecturers, to offer competitive numeration to lecturers involved in teaching ODL students and to speed up the process of registration for ODL students.

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Investigating the Role of History of Mathematical Concepts in Learning Mathematics in Upper Secondary School Level in Malawi

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ABSTRACT

Many learners perceive mathematics as difficult subject and lack motivation to study it in future. Many educationalists in Malawi have tried various ways of motivating learners in order to enhance their mathematical concept understanding. However, history of some mathematical concepts in mathematics teaching and learning has not been used as a motivating factor. Therefore, the purpose of this study was to explore the role of using history of mathematical concepts in teaching and learning mathematics in upper secondary school level in Malawi. The study used a qualitative case study approach in which 50 Form Three learners and their Mathematics teacher from one of the schools in Zomba city were conveniently sampled to participate. Data were generated through classroom observation, face to face interviews and questionnaires. Data were analysed qualitatively by coding, transcribing and classifying the data into themes guided by the research objectives. The findings of this study have revealed that using history of mathematical concepts in teaching and learning mathematics increase motivation and learners' learning as it enhance learners' mathematical concept understanding, enhance their activeness in mathematics learning, enable learners to engage in different learning strategies and enable learners to easily recall some concepts and make references to various historical information. The findings have also indicated that learners develop positive attitude towards mathematics. The study concluded that there are many benefits learners and the teacher would gain if historical information of some mathematical concepts is used in the teaching and learning mathematics compared to the challenges they may encounter in the process. The study recommends that history should be incorporated in mathematics classrooms if teaching and learning process is to be enhanced and to motivate some learners to learn and understand many mathematical concepts better.

INTRODUCTION

Mathematics is as one of the oldest fields of study in the history of mankind. It contains some of the most vital components of human thought that have existed for centuries. Mathematics sharpens the human mind, develops their logical thinking, and enhances their reasoning ability (Siu, 2000). In addition, science and technological developments in the world are enhanced by the use of mathematical ideas (Mapotse & Gumbo, 2015). Basing on the importance of mathematics in everyday activities and its application in various disciplines, mathematical ideas and concepts are taught at different levels of an individual's development, be it at kindergarten, primary, secondary or tertiary. Learners at different educational levels learn various mathematical concepts in Algebra, Arithmetic, and Geometry. However, most of the primary and secondary school learners have insufficient knowledge about how these concepts came into existence, where they were developed and why some were adopted and others were not since the secondary school mathematics curriculum does not incorporate the history of mathematics.

There are different factors that affect how learners learn mathematics and motivation is considered as one of the factors that allow learners to enjoy learning mathematics but one would ask "what motivates learners?" Fauvel and van Maanen (2002) suggest that using history of mathematical concepts in the mathematics classroom could motivate learners because they could see the relevance of learning mathematics basing on the past trends and the applications of mathematical ideas in various fields. On the other hand, other scholars argue that integrating the history of mathematical concepts into classroom activities does not automatically change learners' motivation but it can lead learners to view mathematics from another perspective that would enable them to think that mathematics is a human work (e.g. Avital, 1995; Fauvel, 1991). In addition, Burns (2010) pointed that learning mathematics is influenced by the conception of the mathematics itself and this does not depend only on the mathematical content knowledge of the teacher but also on the meaningful mathematical content base (knowing the reasons and ways/means of teaching and learning mathematics). So, the study of history of mathematical concepts could enable learners to understand the reasons and ways of mathematics (Jankvist, 2009).

Therefore, this study aimed at finding some benefits of incorporating the history of some mathematical concepts from the chosen mathematics topic in Malawian context on learners' understanding and reasoning skills as well as how history might be implemented in the mathematics classroom. The study also sought to understand some of the challenges of incorporating history of mathematical concepts in mathematics learning.

Theoretical Framework

There are different arguments for using history in the mathematics education. These arguments have been categorised into two: arguments referring to history as a tool and arguments referring to history as a goal (e.g. Jankvist, 2009). Jankvist (2011, 2009) theoretically suggests that using history-as-a-tool arguments concerns with learners learning of the inner-issues in mathematics (mathematical ideas, concepts, theorems, arguments, proof techniques and methods). Inner-issues relate to mathematical content or subject matter of a specific teaching module given to the learners.

According to Jankvist (2011, 2009) four useful ways that concern the use of history as a tool include: (a) an aid in the teaching and learning of mathematics inner–issues. In this case, history is considered as a vehicle for teaching and learning of inner-issues in mathematics, (b) a motivational or affective tool. In this respect, history helps to sustain learners' interest and excitement in the subject and historical knowledge of the concepts may give mathematics a more human face and perhaps make it less frightening (c) a cognitive tool. The cognitive tool deals with the provision of different points of view of mathematics or the mode of presentation of different mathematical ideas or concepts. Jankvist (2009) argues that history cannot only help to identify problems learners encounter in understanding the concepts or ideas but also to help overcome them by providing essential clues which may specify the nature of the knowledge to be taught and learnt and explore different ways of access to that knowledge. and (d) an evolutionary argument (the recapitulation argument or historical parallelism). The evolutionary argument concerns with the claim that there can be no learning and teaching of mathematics without its history. On the other hand, using history of mathematical concepts as a goal is concerned with showing learners:hat mathematics exists and evolves in time and space, that it is a discipline that has undergone an evolution over millennia, that human beings have taken part in the evolution, that many different cultures throughout history have contributed to the development of mathematics, and that these cultures have had an influence on the shaping of mathematics as well as vice versa (Jankvist, 2011:348).

In addition, there are different essentially distinct approaches of incorporating history of a mathematical concept in the classroom. For example, illumination approaches and the module approaches (Jankvist, 2009, 2010, 2011). In an illumination approaches, teaching and learning of existing mathematical concepts is supplemented or spiced up by the historical information of the

concepts. The information could be on the names of mathematicians, the dates on which the concepts were developed, famous works and events, time charts, biographies, famous problems and questions (Jankvist, 2009). In the module approaches, instructional units are devoted to history and, quite often, they are based on cases. These may vary in size and scope, from small modules closely tied to an existing curriculum and longer modules less tied to curriculum content to full courses on the history of mathematics within a mathematics program (Jankvist, 2011). The study was therefore conducted to investigate possible benefits of using history of mathematical concepts to support the understanding of concepts in mathematics among learners, to find out if using history of mathematical concepts in classroom has the potential to influence learners' attitude towards mathematics in general, find out when and how history of mathematical concepts could be incorporated in mathematics classrooms and investigate challenges of implementing the history of mathematical concepts in mathematics classroom.

MATERIALS AND METHODS

The study was qualitative in nature and a case study approach to research was considered. The case study was considered because it enables the researcher to explore/investigate, describe and explain a phenomenon (Cohen et al. 2007) in this case, the issue of using the history of a mathematical concept in mathematics classroom. In addition, "the case(s) is/are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time" (Creswell, 2009:227). The study was restricted to time allocated to a topic chosen to be taught to fifty Form Three learners at one of the Public Day Secondary School in Zomba city and the data generation procedures were observation, questionnaires and face to face interviews. Open-ended questions were used with the aim of generating data on the learners' and teacher's perceptions about using history of the mathematical concept in mathematics classroom. Out of fifty learners that responded to a questionnaire, ten learners were selected for focus group discussion to represent the opinions of fellow learners. The teacher and the researcher discussed what historical information was to be used in the classroom before the learners were taught the concepts from the chosen mathematics topic. The qualitative data generated demanded inductive qualitative data analysis (Creswell, 2012) and involved "coding, categorising, and interpreting data to provide explanations of a single phenomenon of interest" (Moyo, 2014:32). Qualitative data were categorised into themes (themes generated from the research objectives).

RESULTS AND DISCUSSION

This section presents the results of the study and their discussions. Results and discussions of research findings are presented in thematic sections basing on the research objectives.

Benefits of using history of mathematical concepts in developing mathematical concepts in learners.

(a) Mathematics development (evolution) and concept understanding.

The study revealed that using history of mathematical concepts in mathematics classroom provides useful background knowledge on the development of mathematical concept itself. For instance, 35 out of 50 learners indicated that history of mathematical concept would help to highlight some important information on the development of the concept. For instance, one of the learners said *it simply reminds us that mathematics has been there since in the past and we should focus on it.* Learners' responses also indicated that learners would use the knowledge and skills of ancient mathematicians to sharpen and develop their own reasoning skills and become critical thinkers. These learners would emulate what ancient mathematicians have been doing and would also be able to construct meanings from the concepts. For instance, one of the learners said *by using the history of mathematics helps to acquire some knowledge or skills that other people used.* The teacher also

pointed out that if the history of some mathematical concepts is incorporated into the lessons, then some learners would borrow the ideas and use them for their learning and knowledge construction and the teacher said *some learners have borrowed a leaf on working hard till they get correct solutions (a slight change on their mindset towards positive)*

(b) History of mathematical concept and learners' activeness in mathematics learning.
The learners' responses indicated a belief that using historical information of a mathematical concept in classroom would help them become active in the mathematics learning processes. In this case, learners would be able to analyse how the mathematical ideas have been coordinated and this would enable them to advance the mathematical concepts. It is then believed that this use of historical information of mathematical concept would enable learners to be actively involved in mathematics classrooms in knowledge construction (Charalambous et al. 2008).

(c) History of mathematical concept and the use of different learning strategies.
The analysis of learners' responses indicated that half of the learners suggested that historical information would help them to look for different learning strategies in mathematics. This indicates that understanding of mathematical ideas requires the use of different learning strategies as different learners understand mathematical concepts differently. The concept understanding is enhanced if individual learners are able to identify and use different learning strategies in mathematics (Clark 2012; Goktepe & Ozdemir 2013; Kaphesi, 2015) since mathematical knowledge construction requires different skills obtained from different sources. Therefore, history of the mathematical concept would play that role of enhancing understanding of concepts (Jankvist, 2011) as it illuminates learners to look for alternative ways of doing mathematics. Learners would also come across different activities from different mathematicians as they were developing and improving the concepts and the variety of skills they used. For instance, some of the learners said:

> *I can link what people did in the past with todays and apply them in solving mathematical problems. For example, if I fail solving mathematics with today's methods I can use what people did in the past and come up with the answer to the problems;*
> *It will also help people to find alternative ways of discovering the concepts than those were using in the past;*

(d) History of mathematical concept acts as a reminder or reference in mathematics learning.
It has been found that both learners and the teacher considered the use of history of the mathematical concepts to act as a reminder or a term of reference in mathematics learning. Learners are subjected to a lot of concepts in mathematics and other subjects, therefore, they can easily forget them if they come back to them sometime later and/or during examinations. In addition, if learners are not clear on some areas in mathematics, they may refer back to the original sources or changes that have taken place in mathematics for further understanding of the concept. So, it is believed that learners' memory could be ignited if they recall either the names of mathematicians or stories behind them or any historical aspect on the concept (Burns, 2010). This is also true as some theorems and topics are named in honour of some people involved in their development, for instance, Pythagoras' Theorem and Cartesian plane from Descartes. One of the learners said:

> *Ngati pali mayina vuto likabwera timakumbukira mwachangu ndipo timakumbukiranso njira (if there are names of inventors/discoverers, then when a problem comes we can easily remember the concept in consideration that time and even the method of solving the problems);*

On the other hand, the teacher agreed with the learners' suggestions that using history of the mathematical concept would *act as term of reference when solving certain problems.*

History of mathematical concept and attitude towards mathematics learning

Analysis of data indicated that incorporating history of the mathematical concept in mathematics learning plays a vital role in changing learners' attitudes toward mathematics learning. It was observed during the time the teacher was introducing the topic that accompanied its historical information that learners were so interested upon hearing what had happened during the concept development and who did what. It was also observed that the learners' behaviour was positive towards using history of mathematical concept in classroom. In addition, the analysis of learners' responses from their questionnaire revealed that 40 of the 50 learners involved in the study perceived mathematics as any other subject. This means that they considered mathematics doable as the concepts contained in it were discovered by people like them. This implies that to some extent historical information is one of the factors that could enable them to develop positive attitude towards the mathematics. In addition, learners' responses have also indicated that some learners initially lacked a motivating factor to learning mathematics. So, using history of mathematical concepts could motivate them as they are able to understand and know the processes involved in the concept development (Siu, 2000) and this is in line with using history as a tool in teaching and learning mathematics (Jankvist, 2009). For instance, one of the learners said

> *I was not understanding mathematics very well because I had so many questions like who discovered mathematics or who brought solution to mathematics problems;*

The teacher also suggested that incorporating history would enable learners to realise that mathematical concept development is an ongoing process and different ideas are being incorporated to make it learnable and meaningful. This also means that history would enable learners to understand that mathematics is not static but dynamic (Mac an Bhaird, 2009) because of the developments that have taken place so far and this could enable learners to have determined goals in life. In this case, the teacher pointed out that,

> *The learners will appreciate that mathematicians had problems too in discovering and proving the theorems and concepts but did not give up. Therefore, this should instill in the learners the spirit of hardworking and perseverance*

Incorporating history of mathematical concept in mathematics classroom

In the classroom, the researcher observed that incorporating history in the classroom covered few minutes. For instance, in day one, the historical information the teacher highlighted to learners in the classroom took about five (5) minutes. This means that teaching and learning mathematical concepts through its history does not necessarily require additional time (Clark, 2012). The allocated time on the topic is enough for the inclusion of historical information in the classroom. This could be done at any point in the classroom either when introducing a new topic in classroom (Burns, 2010). It was also observed from the interview that learners preferred to be told the history of a mathematical concept every time the teacher introduces new concepts in class. Learners pointed out that they would be interested to know how the concepts were developed, what skills were used and which ideas they can learn from them. For instance, one of the learners from the focus group discussion had this to say:

Learner A: Iwowo akamayamba, akamakoza kuti topic ikubwerayi mesa iyeyu ndi mphunzitsi azipanga study. Akumayenera kupangiratu kumenekoko chifukwa poyamba (inaudible) pazikhala pachiyambi pa topic yakeyo azikatiuza mclass. (The teacher decides the topic to teach, so before coming to class to teach he or she should find its history and what exactly to tell the learners from history. This should be done at the beginning of the topic)

Challenges of implementing the history of mathematical concepts in mathematics classroom

It was observed that if the teacher uses all the information regarding the development of a concept, then this has a possibility that it might "confuse learners by taking what is being said as important

not the mathematics" (Teacher's belief from the interview) and they might forget to capture the intended objectives of the lesson. For instance, the teacher pointed out that,

> *Some learners may think that the history of mathematics is among the specific objectives to be examined during the examinations hence compromise the intended outcome from the syllabus*.

The other challenge that was observed from both the teacher and the learners was lack of time. The teacher suggested that he might be spending a reasonable amount of time on the teaching of history instead of using that time on the actual content that is examinable. On the other hand, some learners during the interview argued that including history of mathematical concept in mathematics classroom might not allow them to learn a lot of mathematics because the other time might be spent on historical stories and not on the mathematical content. For instance, some of the learners' from the interview said;

Learner D: *Komanso ndikuwona ngati zizidya nthawi azikhala ndi tsiku loti period imodzi azikamba zoti history ka nthawi kazikhala ngati kakudyeka limodzi ndi zimene amafuna atiphunzitse tsiku limenelo. (But I think this will be using our time a lot. The teacher should have a special day for talking about history of mathematics because this will be consuming time for the day's lesson if the teacher combines these two).*

Learner E: *Inde akamapanga daily inde tizikumbukira koma sitimaphunzira masamu ambiri. (If this is done on daily basis, yes we might be able to remember a lot, however, we will not be learning a lot of mathematics).*

CONCLUSIONS AND RECOMMENDATIONS

The present study investigated the role of using history of mathematical concepts in the mathematics classroom. The findings revealed that using history as a tool and as a goal in the classroom is beneficial to the learners because it enables them to enrich the teaching and learning process, enhance individual learners' mathematical knowledge construction, actively participate in the learning of mathematics by finding alternative ways of doing mathematics and easily remember ideas previously learnt. It was also observed that learners' motivation is increased towards learning mathematics that increases the learners' learning of mathematics. It was also observed that history of any mathematical concept could act as a catalyst to the mathematics learning process, hence aiding understanding of the mathematical concepts. The challenges that were encountered in the implementation could be a platform for finding solutions to them.

Based on the findings of the present study, I recommend that the history of the selected mathematical concepts and topics be incorporated in the mathematics classrooms. The following studies could also be conducted to increase the knowledge base: Exploring teachers' attitudes toward using history in teaching secondary school mathematics. Exploring the benefits of listening to historical sources and the process of teaching secondary school mathematics.

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The Irony of Nutrition Extension Education: Knowledge of Agriculture Extension Development Officers (AEDOs) in Mitundu-Lilongwe

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ABSTRACT

Nutrition education is defined as instruction or training intended to lead to acquired nutrition-related knowledge and skills provided in an individual or any combination of education strategies designed to facilitate voluntary adoption of food choices and other food and nutrition related behaviors conducive to health and wellbeing. Agriculture Extension Development Officers (AEDOs) are mandated to disseminate nutrition messages among other messages like agriculture, HIV and AIDS to the community, as such they are assumed to be more knowledgeable. Assessing nutrition extension knowledge and determining specific nutrition knowledge gaps among AEDOs was conducted using a structured questionnaire where basic nutrition information based on Scaling up Nutrition(SUN) 1000 special days, like knowledge in infant and young child feeding, six food groups and some micro nutrients of public health concern was obtained. SPSS version 16 was used for data analysis where frequencies and graphs were obtained. A guideline for assessing nutrition-related knowledge, attitudes and practices developed by FAO was used to determine nutrition knowledge levels of each participant. Results from the findings indicated that 36 (95%) out of 38 AEDOs were not knowledgeable on the basic nutrition education. 2 (5%) of them need support and none was knowledgeable. Most of them had knowledge on infant and young child feeding and very little knowledge on micronutrients such as folate, iron, iodine and vitamin A. In view of this, there is need for intervention like nutrition education to help increase nutrition knowledge and also in particular, messages on micronutrients as deficiency of these micronutrients have negative and irreversible effects on development of the child. Deployment of their own nutrition staff in the field by the Department of Nutrition, HIV and AIDS will also ease the workload of AEDOs.

Keywords:

INTRODUCTION

Nutrition education is defined as instruction or training intended to lead to acquired nutrition-related knowledge and /or nutrition-related skills, and be provided in individual or any combination of education strategies designed to facilitate voluntary adoption of food choices and other food and nutrition related behaviors, conducive to health and wellbeing (Isobel and Contento, 2010). Extension education in regard to nutrition is institutionalized so as to disseminate nutrition messages to the communities that will help to promote good health at the same time reduce malnutrition. In view of improving nutrition, the Government of Malawi (GoM) represents a significant policy priority in both the health and agricultural sectors as demonstrated by the establishment of the Department of Nutrition, HIV and AIDS (DNHA) (Sigman, Rhoe, Peters, Banda and Malindi, 2014). DNHA does not have its own staff at the field level but rather works through Agriculture Extension Development Officers(AEDOs) who are typically generalists hence

more workload and also more time is given to food production as their ministry's priority than food utilization. Agriculture Extension Development Officers (AEDOs) are frontline workers under Ministry of Agriculture whose primary responsibility is to disseminate different agriculture messages. They are also mandated to disseminate other information such as HIV and AIDS and nutrition to farmers. They are of different levels of qualification, some are diploma holders, some have certificates and some are degree holders. However, they have different field of specialization such as Agronomy, Horticulture, Nutrition and Agribusiness. They are typically the largest, and most agriculturally experienced group of workers who directly engage with rural population such as farmers, their families, and others who derive their livelihood from agriculture; hence, their involvement in the delivery of nutrition sensitive agriculture interventions (Sigman, 2015). Extension workers such as AEDOs need to be more capable in knowledge and skills in nutrition messages to help disseminate correct information and improve efficiency of the delivered information (Mbuya, Menon, Habicht, Pelto and Ruel, 2013). The study therefore aimed at establishing the knowledge gap in basic nutrition among extension workers at Mitundu and Chitsime Extension Planning Areas under Lilongwe Agriculture Development Division in Lilongwe district. Agriculture Extension Development Officers (AEDOs) are directly engaged with rural people. These communities derive their livelihood mainly from agriculture. Adequate knowledge in nutrition is important as this would help communities to be able to prepare nutritious food and have good health as well as reduce the prevalence of undernutrition (Sigman et al, 2014). Communities however rely on AEDOs to give them food and nutrition information. Despite availability of AEDOs, there is evidence of low agricultural productivity, low food intake due to lack of effective opportunity to produce or purchase nutritious foods, poor food utilization due to knowledge/skill inadequacies related to food choices, dietary diversification and child feeding practices, poor nutrition education and in adequate knowledge/skills/technologies around food preparation, processing, preservation and weak capacity of institutions to implement nutrition programs(Sigman et al, 2014). In Malawi, 85% of the population derives its livelihood from agriculture and the alarming fact is that 37% of the children under five are stunted (NSO, 2016). According to NSO,2017, the percentage of children exclusively breastfed decreases sharply with age from 81 percent of infants age 0-1 month to 69 percent of infants age 2-3 months and, further, to 34 percent of infants age 4-5 months, 3 percent of infants under age 6 months are fed using a bottle with a nipple, a practice that is discouraged because of the risk of illness to the child. AEDOs being pluralists have a lot of workload and more emphasis is on food production as their ministry's priority (sigman et.al.,2014). Since nutrition education is key to promoting good health, establishing knowledge gaps in basic nutrition among AEDOs was necessary.

Knowledge

Conducting a capacity analysis is a fundamental element of capacity building. Practitioners need to identify and respect the pre-existing skills, structures, partnerships and resources before beginning to build capacity within public health interventions. One of the most obvious capacity determinants (or resources) in any community is the health workforce. Up-skilling health and community-based professionals in nutrition (workforce development) is one of the most common capacity building strategies used in public health nutrition (Hughes, 2008). In order to assess the quality of nutrition and physical activity guidance and identify continuing education (CE) needs, a study by Hughes, (2008) on primary health practitioners conducted at a local health district level of West Bengal captured a range of primary care system professional groups including medical and nursing. This health workforce sample has regular contact and provides advice to women with infants in the growing years period but have varying degrees of confidence regarding the accuracy of their advice. This study identified gaps in the guidance knowledge base and a range of opportunities and preferences for CE at a local level. The data had been used to develop local health service workforce development strategies (Hughes, Black and Kennedy, 2008).

Infant and Young Child Feeding Practices

Poor child feeding practices are caused by a myriad of factors like cultural factors that may create local tendencies toward selection of low quality complementary foods (FAO,2010). Social factors including caregivers' poor knowledge on nutrition and lack of knowledge on food diversity in their environment may correlate with poor feeding practices. Such factors may result in low dietary diversity, low feeding frequency, and low food and energy intake for children (FAO,2010). Care givers' nutrition education can help to clear cultural and tradition-based misconceptions and improve their general nutrition knowledge. Feeding practices can thus be improved if knowledgeable health workers treat and counsel caregivers on proper feeding practices and monitor their progress closely. Study by Sunguya et.al., (2013) found that nutrition counseling from well knowledgeable frontline health workers had been proven effective even in areas of limited food availability.

Facilitating behaviour change among caregivers through increased awareness, skill building and effective counseling was seen as an important pathway to address the problem of inappropriate improved infant and young child feeding practices. Results from a study by Chaturvedi and colleagues showed that apart from socio-economic, cultural and environmental factors, adoption of appropriate improved infant and young child feeding practices is also strongly influenced by the community health workers' level of knowledge and skills (Chaturvedi, Nakkeerann, Dosh, Patel and Bhagwat, 2014).

Nutrition Extension Education

Extension education in regard to nutrition is institutionalized in Malawi so as to disseminate nutrition messages to communities to promote good nutrition and improve health (DNHA,2016). In view of improving nutrition, the Government of Malawi (GoM) represents a significant policy priority in both the health and agricultural sectors as demonstrated by the establishment of the Department of Nutrition, HIV and AIDS (DNHA) (Sigman, Rhoe, Peters, Banda and Malindi, 2014). DNHA is mandated to provide strategic policy direction, guidance, oversight, coordination, technical support, highest level policy advocacy, resource mobilization, capacity building, monitoring and evaluation of Nutrition issues in the country (DNHA, 2016).

AEDOs are frequently seen as a country's prime resource for delivery of nutrition sensitive agriculture. They are typically the largest, and most agriculturally experienced group of workers who directly engage with rural population such as farmers, their families, and others who derive their livelihood from agriculture hence, their involvement in the delivery of nutrition-sensitive agriculture interventions is crucial (Sigman, 2015).

Extension workers such as AEDOs need to be more knowledgeable and skilled in nutrition education to help disseminate correct information and improve efficiency of delivered information (Mbuya, Menon, Habicht, Pelto and Ruel, 2013).

NSO, (2017) found that only 8% of the children aged 6 to 23months had met criteria for a minimum acceptable diet in respect to Infant and young child feeding practices. More than 63% of children 6 to 23 months had some degree of anaemia and 33% of women aged 15 to 49 years were anaemic. According to micronutrient survey,2016 anaemia prevalence was 28%, vitamin A prevalence was 36% and iron prevalence was 22%.

Most agriculture extension workers in the Ministry of Agriculture and Food Security (MoAFS) had only rudimentary training in nutrition, and negligible skills in communicating nutrition information to farmers and families in rural areas(FAO,2010). Nutrition was not their major subject and therefore they found it difficult to provide nutrition education (FAO, 2010). AEDOs are considered generalists and are relied on for work across multiple Agriculture Extension topics like HIV/AIDS, and Nutrition. Their available time and capacity shapes the focus of the

extension services they provide on the ground. Considering that AEDOs are of different acquired skills; for example, some are specialized in Agribusiness, some in Agronomy, some in Nutrition, the study aimed at establishing the gap in basic nutrition knowledge among AEDOs. The study was therefore conducted to assess level of basic nutrition knowledge among AEDOs in Mitundu and Chitsime and establish specific knowledge gaps in basic nutrition knowledge among AEDOs in Mitundu and Chitsime EPAs.

MATERIALS AND METHODS

Study Area

The study was conducted in Mitundu and Chitsime Extension Planning Areas (EPAs) under Lilongwe Agriculture Development Division, south west of Lilongwe District. Mitundu EPA had 21, 293 farming families and covers a total area of 28780.2 Ha. Non-arable land covered 6555.4 Ha, smallholder land covered 21250.4 Ha and estate land covered 974.4 Ha. It had 26 members of staff of which 18 were AEDOs, 2 veterinary officers and 6 support staff. Chitsime EPA had 20,887 farming families and covered a total of 26 980.4 hectares. Non-arable land covered 5670.1 Ha, smallholder land covered 20,756.2 Ha and estate land covered 554.1 Ha. It had 27 members of staff; 20 AEDOs, 3 veterinary officers and 4 support staff. These EPAs were chosen for convenience and also because they are in Mitundu area which is one of bread baskets of Lilongwe city.

Sampling Method

All the Agriculture Extension Development Officers (AEDOs) from the two EPAs were selected. In total 20 AEDOs were selected from Chitsime and 18 were selected from Mitundu, adding up to a sample size of 38.

Data Collection Method

Quantitative data was collected using a questionnaire that was administered to individual participants to assess their basic nutrition knowledge. The questionnaire included basic information on nutrition such as the six food groups, infant and young child feeding practices, sources and functions of some micronutrients of concern and consequences of lack of some micronutrients. The questionnaire was pretested among mature student AEDOs to check if the responses would give the required information.

Data Analysis

Data was analyzed using SPSS version 16, where frequencies and tables were generated. Nutrition knowledge was indicated by scores which were 1 for a correct response and 2 for an incorrect response. The total scores were calculated for each individual and converted into a percentage score. Correct responses for any participant were summed and divided by total responses, multiplied by one hundred. Then the percentage scores were compared to the cut off values for the different levels of knowledge according to a guideline for assessing nutrition-related knowledge, attitudes and practices (FAO, 2014). To identify specific knowledge gaps, analysis was undertaken on each question to find out which questions were answered consistently correct or incorrect. The scores were categorized as follows:

The scores of $\geq$ 90% were classified as knowledgeable about basic nutrition knowledge, scores between 70-89% were classified as knowledgeable but need support and score range of $\leq$ 70% were classified as not knowledgeable and need for nutrition education as an intervention.

Ethical Consideration

Ethical approval to conduct the study was obtained from The National Health Science Research Committee (NHSRC) and approval number was 1733. Permission was obtained from the Agriculture Extension Development Coordinators (AEDCs) from Mitundu and Chitsime EPAs. Informed consent was obtained from each participant prior to their involvement in the study.

RESULTS AND DISCUSSION

Demographic Characteristics of AEDOs

As shown in Table 1, more of the participants were females (n=29) and males were (n = 9). The results also showed that more AEDOs were in the age range of 25 to 30 years seconded by those in 31 to 35 years age range this could be because most of the older AEDOs left government sector and joined other Non-Governmental Organizations in anticipation for higher earnings. In terms of qualifications, the results showed that 33 AEDOs were diploma holders, this is because the government of Malawi is upgrading all AEDOs from certificate to diploma level and the certificate programme is no longer being offered at Malawi's local colleges like Natural Resources College. 20 AEDOs specialized in Agriculture, 2 AEDOs specialized in Horticulture, 2 AEDOs specialized in Agribusiness and 9 AEDOs specialized in Agronomy hence formal education did not equip them efficiently in the field of nutrition resulting in knowledge gap which had a negative bearing on their performance. 2 of the 38 AEDOs had certificates and these were of retiring age (55years) such that they did not see any need to upgrade to diploma level and 3 were first degree holders but in different areas of specialization namely; Gender and Development, Human science and Community Services and Nutrition and Food Science.

Table 1: Demographic Characteristics of AEDOs

Characteristics		Frequency (n=38)
Sex	Male	9
	Female	29
Age(years)	25-30	19
	31-35	12
	40-45	1
	46-50	2
	51-55	4
Education level		
	Certificate	2
	Diploma	33
	Degree	3

Knowledge on Infant and Young Child Feeding

The results in Table 2 showed that almost all AEDOs had knowledge in infant feeding as most of the questions were correctly answered by all. All of them (n=38) had knowledge about breast milk being the first food for a new born baby and also introduction of complementary food to a baby after six months. This could be because there had been more emphasis by Ministry of Health through health talks in clinics and radios. On whether a mother should express breast milk due to sickness or when she is not with the baby for long time, 29AEDOs had knowledge about it. This could be because some thought that it's a taboo and unhygienic and others thought that breasts cannot produce enough milk through expressing to satisfy baby's hunger. NSO, (2016) found out that the percentage of children that are exclusively breastfed decreases sharply with age. That is, from 81% of infants age 0-1 month to 69% of infants age 2-3 months and 3% of infants under age 6

months are fed using a bottle with a nipple, a practice that is discouraged because of the risk of infection to the baby associated with it when proper hygiene practices are not followed.

Table 2: Knowledge on Infant and Young Child Feeding

Knowledge on Feeding Practices	Yes (n=38)
Knowledge on Breast milk as first food for baby	38
Knowledge on exclusive breast milk	37
Knowledge on when to express breast milk	29
Knowledge on (6 months old) best time for complementary food	38
Knowledge on importance of complementary feeding	35
Knowledge on porridge as example of complementary food	36
Knowledge on fruit as an example of complementary food	27
Knowledge on diet diversity	33

Knowledge on Six Food Group

The results in figure1 show that some AEDOs did not know all the six food groups, 24 AEDOs knew the six food groups and 14 AEDOs did not know all food groups. Some of them had knowledge of the previous 3 food groups, hence need to emphasize on the importance of each food group and educating them on the six food groups. Inadequate knowledge in basic nutrition by AEDOs meant that they were disseminating incomplete information, this may affect the effectiveness of the message, hence caregivers let alone their siblings may not eat from six food group leading to malnutrition. These findings are similar to those by Chaturvedi et al., (2014), where they found that behaviour change in young child feeding among caregivers was influenced by the quality and level of knowledge of the frontline workers. More knowledgeable frontline workers had positive influence in changing feeding behaviour of caregivers.

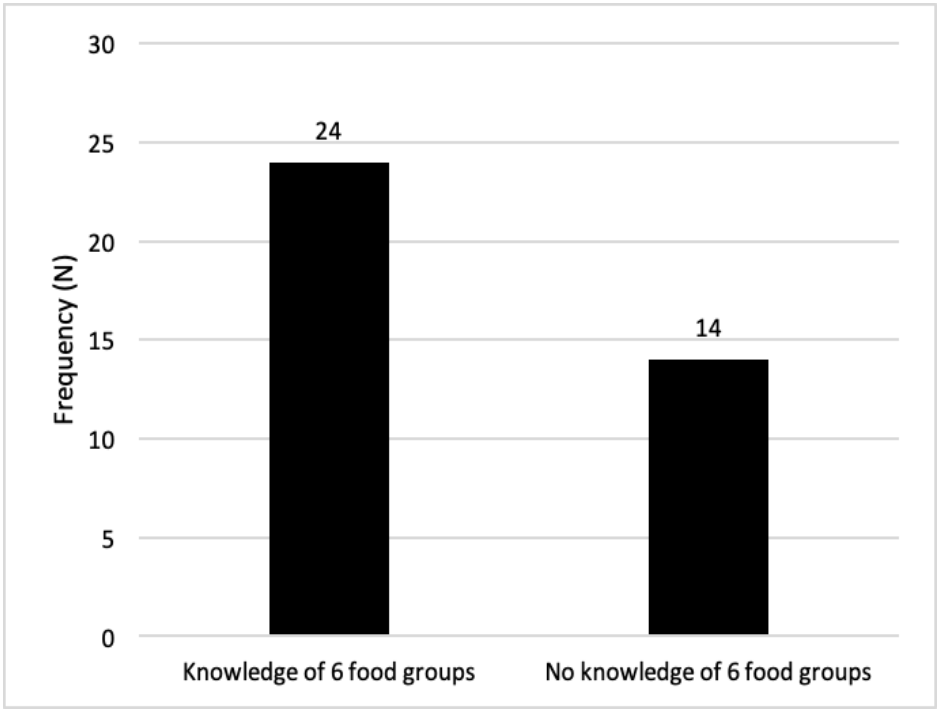

Figure 1: Knowledge of AEDOs on Six Food Groups

Knowledge on Vitamin A

Results in figure 2 showed that 36 AEDOs were knowledgeable on proper vision as a function of Vitamin A, whereas on strengthening Immune system and proper growth 10 and 4 AEDOs respectively had knowledge about it. On sources; dark green vegetables, animal source and yellow fruits had 25, 11 and 15 AEDOs respectively who were knowledgeable. This showed that more AEDOs did not have enough knowledge on vitamin A. Inadequate knowledge in vitamin A may result in mothers and children eating insufficient amount hence many disorders like night blindness, as well as frequent illnesses among children due to weak immune system may arise.

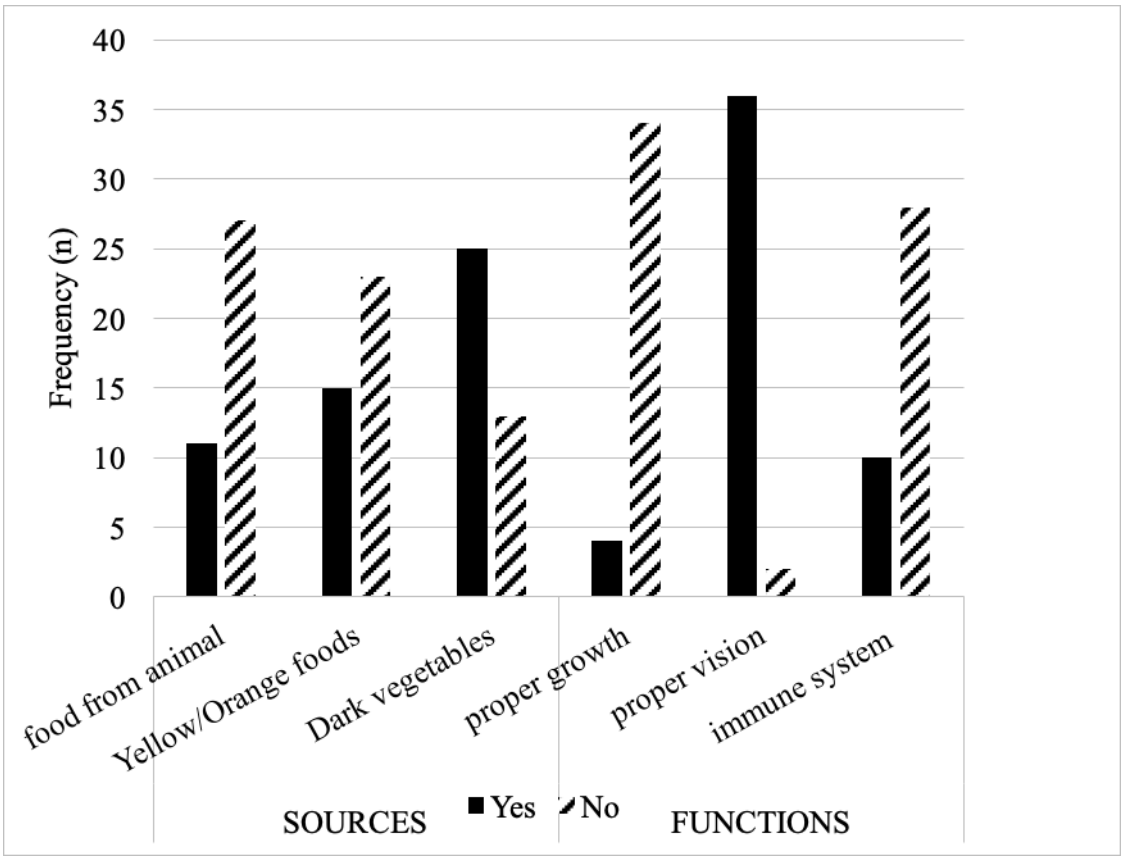

Figure 2: Knowledge of AEDOs on Vitamin A

Knowledge on Iodine

Results in figure 3 showed that 37 AEDOs were knowledgeable that iodized salt was the source of iodine while only 6 had knowledge that crops grown on soil containing iodine also were sources. On consequences of iodine deficiency, 36 AEDOS were knowledgeable that goiter is caused by iodine deficiency while 9 and 6 AEDOs had knowledge in growth retardation and poor school performance respectively. The results showed that AEDOs from Mitundu and Chitsime had insufficient knowledge on iodine; as their mandate to disseminate information to the community that meant community may in turn receive inadequate information pertaining to the importance of Iodine uptake. This may risk the children to disorders like cretinism which is a permanent and irreversible situation and goiter.

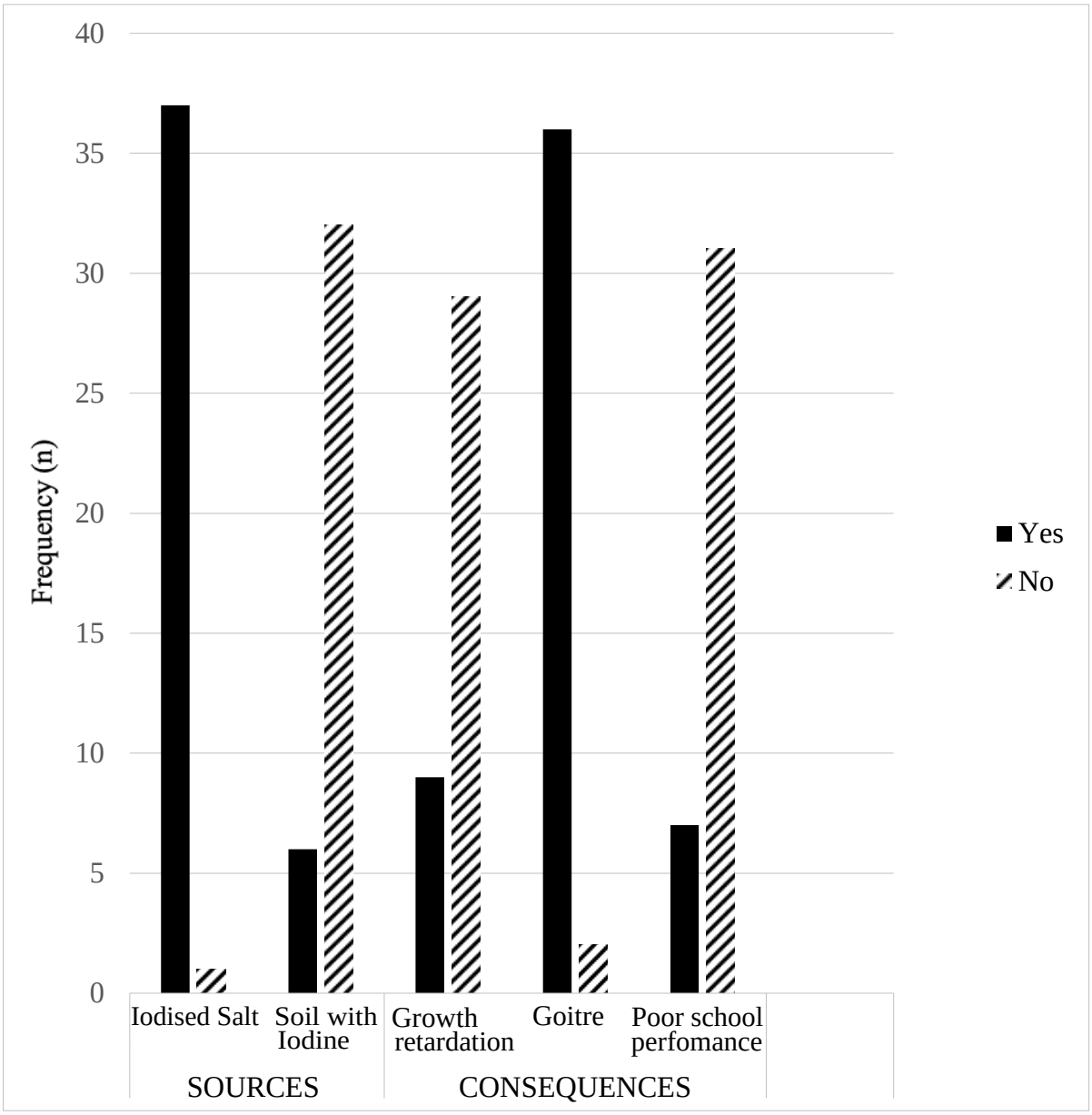

Figure 3: Knowledge AEDO on Iodine

Knowledge on Iron

As shown in figure 4, 26 AEDOs were knowledgeable that food from animals are sources of iron. About dark green vegetable, legumes and Iron supplement being sources of Iron, 17, 6 and 6 AEDOs respectively were knowledgeable while on functions of Iron such as; formation of red blood cells, 35 AEDOs were knowledgeable and on immune system strengthening, nervous system development and fetal development and growth, 4, 1 and 5 AEDOs respectively were knowledgeable. This also showed that more AEDOs had inadequate knowledge in iron. Prevalence of anaemia was 63% among children aged 6 to 59 months and 33% of mothers aged 15 to 49 years (NSO, 2015/16), which might partly be contributed by AEDOs inadequate knowledge in Iron. Iron is very important as it plays a crucial role during pregnancy especially in transporting oxygen to the baby and also as nutrient for normal fetal growth. Pregnant mothers also need enough iron as they lose a lot of blood during delivery and in addition, inadequate iron weakens immune system which may subject the body to infections, hence puts mothers and unborn babies at risk of losing their lives.

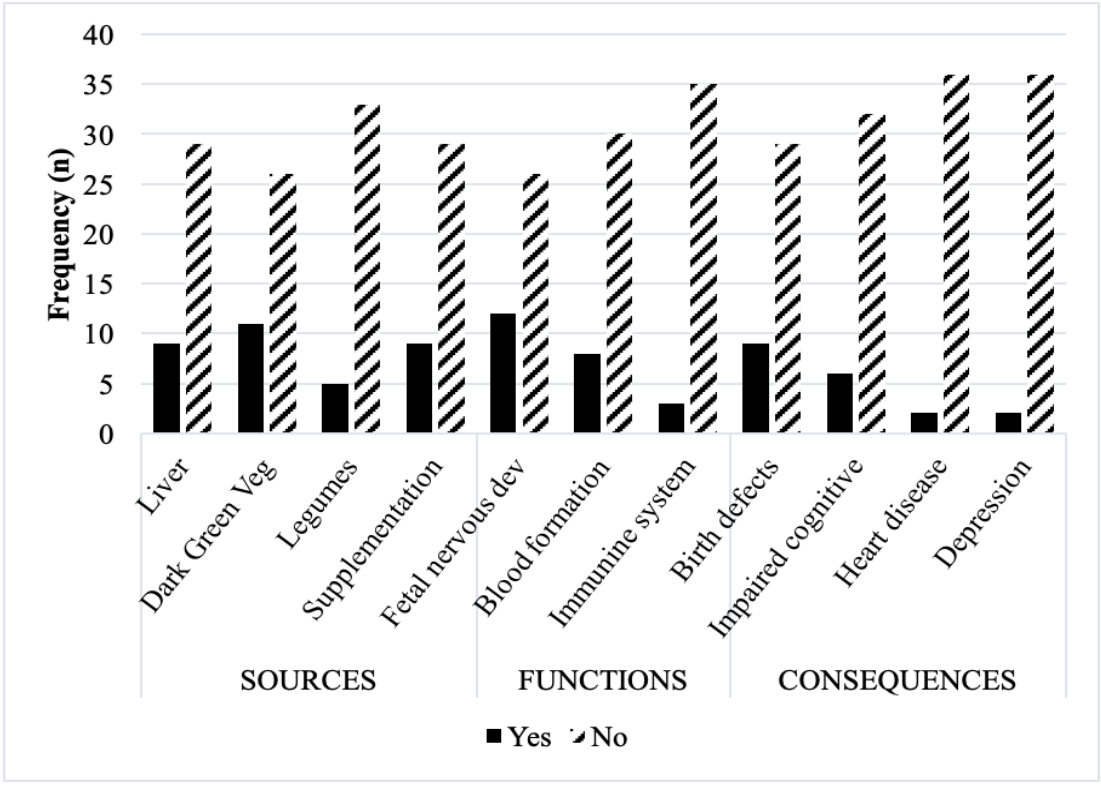

Figure 4: Knowledge of AEDO on Iron

Knowledge on folate

Results in figure 5 showed that most AEDOs had very little or no knowledge on folate. Most of them did not give correct answers or they did not know at all. On sources, only 9 AEDOs were knowledgeable on liver as source of folate, 11 knew green leafy vegetable as source of folate, while on functions, only 12 AEDOs were knowledgeable that development of fetus and nervous system were functions of folate and on formation of red blood cells and strengthening immunity, 8 and 3 AEDOs respectively were knowledgeable. On consequences of folate deficiency; only 9 were knowledgeable that it causes birth defects and 6 were knowledgeable that it causes impaired cognitive development while heart disease and depression had 2 AEDOs each who were knowledgeable. This showed that there was knowledge gap on folate among AEDOs. Folate is a vital micronutrient responsible for proper development of the fetus. Lack of knowledge in folate may result in pregnant mothers not taking enough resulting into some birth defects like spinal bifida and cleft mouth. Results indicate that there is need for immediate intervention in nutrition education in general and also much emphasis should specifically be put on folate intake. There is need to sensitize pregnant mothers to take iron tablet which contain both folic acid and iron. This would help reduce prevalence of malnutrition which is still high and also reduce the birth defects that may occur due to insufficient folic acid in the body.

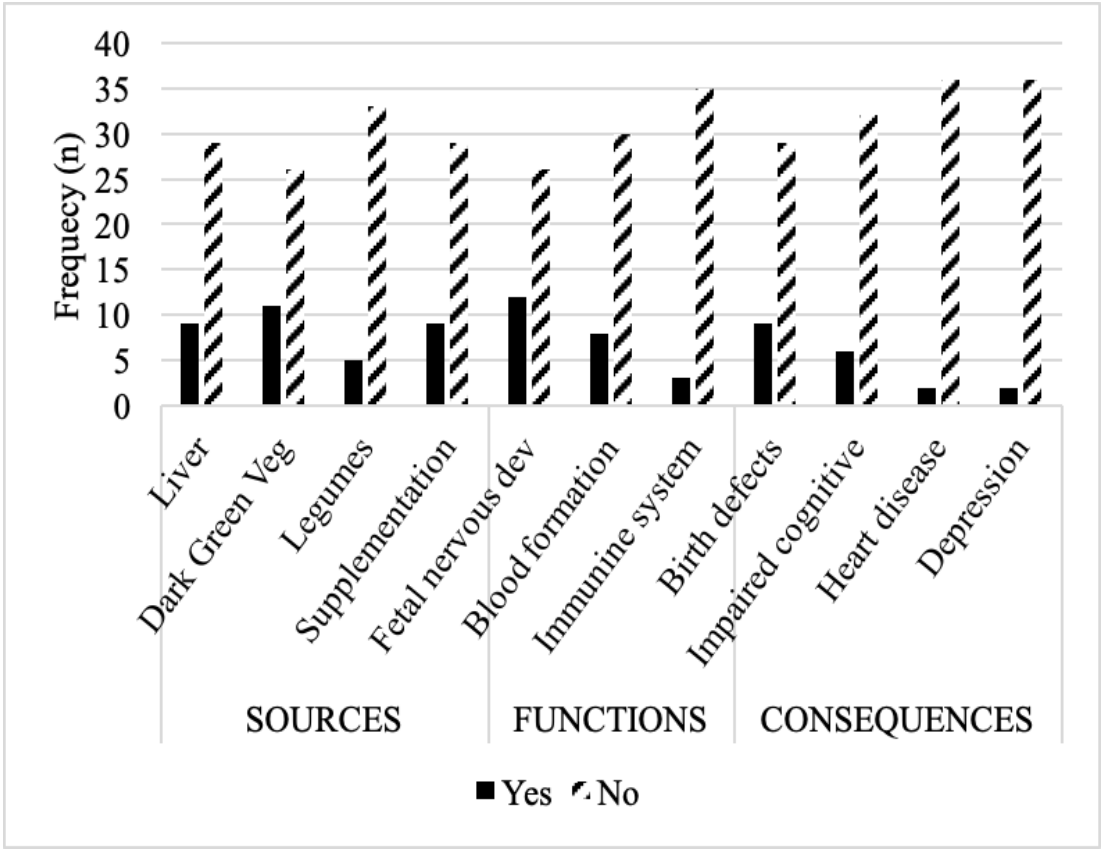

Figure 5: Knowledge of AEDOs on Folate

Knowledge on Basic Nutrition among AEDOs

The results from this study in figure 6 showed that 36 AEDOs had little knowledge and only 2 AEDOs had knowledge but need support and non was knowledgeable, this is according to guideline manual for assessing nutrition-related knowledge, attitude and practices scale (FAO, 2014) which states that an individual who score ≤ 70% out of the total scores has little knowledge on nutrition, between 71% -89% has knowledge but still need support and ≥ 90% shows that an individual has knowledge in nutrition education. Lack of adequate knowledge in basic nutrition education among AEDOs had a great impact as they directly interact with rural people and are the ones who are mandated to disseminate nutrition messages. This meant that the communities too would have inadequate nutrition knowledge which in turn would result in poor practices in food preparation and utilization, hence, undernutrition would still persist in the communities. The results of this study were consistent with the findings of Sunguya et al, (2013) where nutrition counselling done by well knowledgeable frontline health workers proved to change the behavior of caregivers in child feeding practices resulting in improved feeding practices, hence improved nutritional status of children.

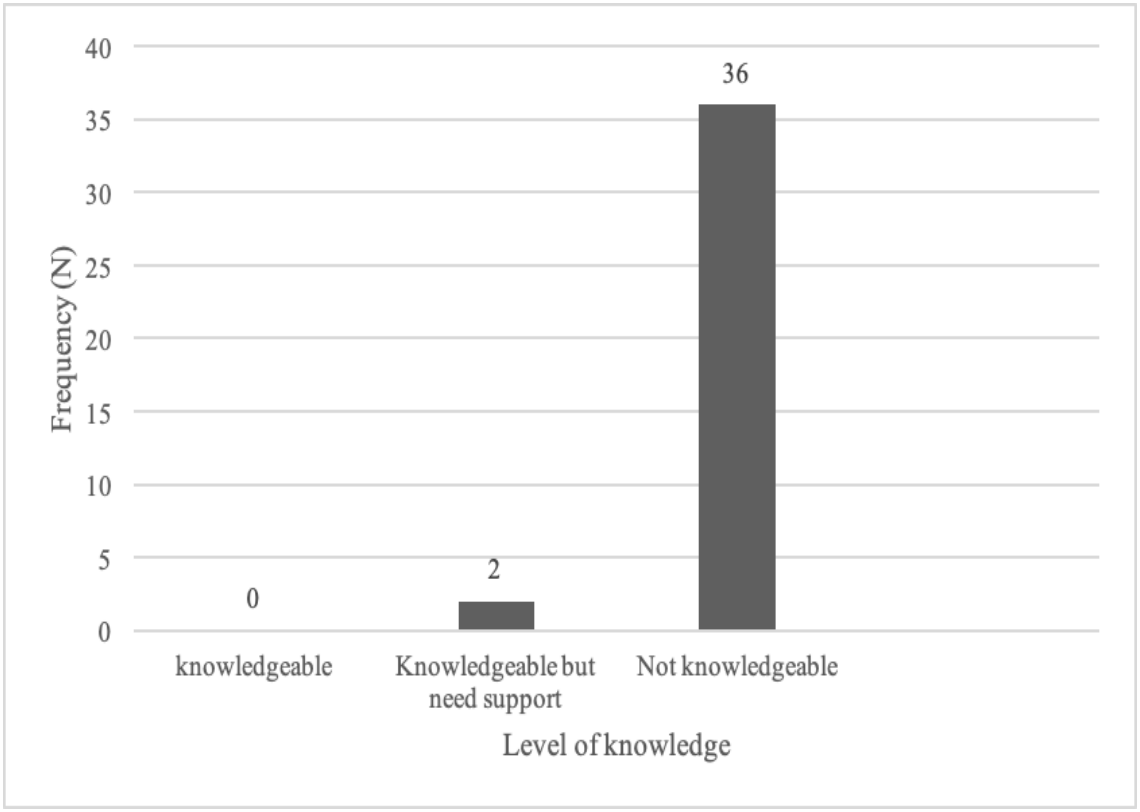

Figure 6: Performance of AEDOs on Basic Knowledge on Nutrition

CONCLUSION AND RECOMMENDATION

From the study, it can be concluded that most AEDOs in Chitsime and Mitundu EPAs had substantial knowledge gap and levels in basic nutrition. They were more knowledgeable on infant feeding, especially on breast milk as first food for a new born baby and introduction of complementary food at six months. On the other hand, the AEDOs had very little knowledge on micro nutrient, especially iron, iodine, vitamin A and folate rendering to their insignificant contribution towards curbing nutrition deficiency related ailments in communities of Chitsime and Mitundu EPAs.

Recommendations

There is need for immediate intervention through nutrition education for AEDOs on basic nutrition knowledge in general and should put much emphasis on information about micronutrients. The government should consider Department of Nutrition, HIV and AIDS having their own nutrition frontline staff deployed in the field in order to have effective results since the extension officers under ministry of agriculture have a lot of work load and are more engaged in their production work, hence little time to disseminate nutrition messages.

Ministry of Agriculture and other stakeholders should consider giving refresher courses or/ and on job trainings to the AEDOs since new researches and findings are being done so as to keep them updated with new findings. A larger study in various settings is warranted for wider representation.

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Estimating Risk Factors for Severity of Motor Vehicle Accident in Malawi with Gologit, Ordered Multinomial Logit and Bayesian Ordered Multinomial Logit Models

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ABSTRACT

Malawi is among the low- income countries in which citizens are dying from preventable and treatable causes such as road traffic accidents. Efforts to reduce severe road accidents have been done. However, more safety studies that use sophisticated statistical data analysis techniques and whose aim is to identify risk factors associated with severity of road accidents are recommended. We used the 1995 to 2007 motor vehicle accident secondary data from the National Road Safety Council of Malawi to demonstrate analysis of accidents data using generalised ordered, multinomial logit and Bayesian multinomial logit models. A better model was achieved through assessment of R^2, through test of significance and through comparison of variable estimates. Risk factors were drawn from significant variables. Surroundings and accident type were the only variables which were significant in OMNL ($P < 0.05$, CI that exclude a 1; (-1.2212, -0.8779), (-0.5263, -0.2066)) and in BOMNL ($P < 0.05$, and 2.5% quartiles that exclude a 1 (-1.2370, -0.8791) and (-0.5399, -0.2002)). The greatest effect of the two variables was to decrease the likelihood that the accident will be severe. BOMNL produced improved estimates. Drunk driving and risk taking behaviours are the risk factors suspected to increase severity.

Key words: Motor vehicles; Accident risk factors; Severity; Bayesian; Ordered Multinomial logit model.

INTRODUCTION

Malawi is among the low - and middle income countries in which citizens are dying mostly from causes that are preventable and treatable. Factors such as road traffic accidents, complications during pregnancy and child birth, suicide, violence, HIV/AIDS and tuberculosis (TB) are preventable and have been reported as major causes of mortality to citizens of low - and middle income countries (WHO, 2009).

Rampant increase of road traffic accidents annually are particularly a major worry to low - and middle income countries. According to Ghee, Silcock, Astrop and Jacobs (1997) half a million of road accident fatalities are estimated each year worldwide and about 70% of these occur in the developing world. Ghee *et al* (1997) stated that while a general decline in the numbers of fatalities in industrialised countries was observed over the years but an increase was observed in developing countries. Further to that, developing countries such as Malawi registered fatality rates of 10 to 20 times higher than the rest, thus, taking into account the levels of motorisation found by expressing accident statistics as rate per registered vehicle.

Malawi is also among the Southern African developing countries with rampant road traffic accidents in the recent years. This is partly due to the fact that roads are major form of transportation system in Malawi. Severity of road traffic accidents in Malawi range from those that are considered minor to those that are considered fatal. Data collected in Malawian roads show higher percentages of occurrence of minor accidents followed by serious severity accidents and fatal accidents are the least reported.

Although the National Roads Safety Council of Malawi (NRSCM, 2006) documented a decreased occurrence of road accidents during the years 1995 to 2005, rates of occurrence of road traffic accidents are high and remain as one leading cause of death in Malawi. The NRSCM document indicated that 5,195 road accidents were reported to the Malawi Police in 2006 as compared to 7,191 road accidents reported in 2005, representing a 28% decrease. A corresponding decrease of 23% and 11% of road accidents as well as fatalities due to accidents respectively, were also reported in the year 2005 and 2006. The report pointed out the following as major reasons for the decrease of road accidents; the proactive approach in effective enforcement and civic education by Malawi Police Service (MPS), NRSCM and Road Traffic Directorate (RTD); the role played by NRA in road maintenance and rehabilitation; Government support and commitment to the promotion of road safety through increased funding to its institutions dealing in traffic management as well as community participation in road safety. In addition, many people who survived road accidents sustained serious body deformations or huge scars from serious and minor injuries respectively (NRSCM, 2006).

Recently, road traffic accidents are on the rise despite putting measures in place to minimise occurrence of road traffic accidents in Malawi. Either the measures that are in place to check on risk factors and associated severity of the causes of road traffic accidents are inadequate or ineffective. Perhaps there is laxity of the people in the ministries responsible for providing safety to citizens. For instance, lack of implementation of timely and proper measures to rescue and treat road traffic accident victims has resulted in loss of life for survivors of road traffic accidents due to minor or serious injuries. Lack of ambulances, inadequate medical facilities, lack of proper medical care, inadequacy of medical personnel such as nurses and negligence could be challenges facing Malawi and many such low - and middle income countries for this campaign (Ghee C. *et al*, 1997). With a total population of more than 15 million (2010 estimate), only 19.8 percent of which is urban, Malawi is one of the least urbanised countries in Africa. Its urban growth rate, however, is one of the highest on the continent (5.19 percent between 2005-2010). The high fertility rate and rural-urban migration, which occurs as a result of droughts, decreasing rural land-holdings, limited off-farm economic activities, and rural environmental degradation, are the main reasons behind the high urbanisation rates (UN-HABITAT, 2009). Urban centres such as cities and towns have large volumes of motor vehicles which citizens use for different reasons including commuting to work, for business or for pleasure. The high volumes of motor vehicles in urban centres pose a great risk of road traffic accidents to the urban population. In some cases, regular commuting through motor vehicles from rural areas to nearby towns for various reasons exposes the majority of citizens to road traffic accidents (Dobson, 1999).

High incident rates of road traffic accidents in Malawi have also been attributed to poor standards of the road transportation system. The condition of all road types, especially the tarmac roads are not good. Some of the tarmac roads are characterised with potholes whilst other road types, for instance those made of gravel and earth are in need of constant maintenance as their condition is constantly compromised by adverse weather conditions such as strong winds and heavy rains. Further, human factors have also been attributed to severe road accidents in the country (NRSCM, 2006). These factors constitute variables of driver's characteristics, including under qualified drivers who use fake driving licences, careless driving, driving under the influence of alcohol, no use of sit belt, and overloading or use of motor vehicles that are not roadworthy. With such factors holding true, probability of severe road accidents shall always be high (Aljanahi, 2009 and Assum, 1998).

According to (Assum, 1998), there is a chain of causes ranging from the inadequately controlled forces bringing about each accident, to the institutional, political, economic, and social reasons behind this inadequacy. Assum further reported that accident level and the societal level are the two important levels of causation of road accidents such that for every single accident, one factor or a combination of factors may be established as a cause. The causes or factors usually pertain to the road, the vehicle, or the road user. Much as road accidents are difficult to do away with, but their occurrence and severity can be reduced. Such efforts have been undertaken and significant results have been realised. Some important evidence of efforts to reduce road accidents is obtained from activities of Malawi Traffic Police Service (MTPS) and NRSCM. These institutions manage to collaborate in collection of road accident data. The NRSCM analyses the collected data and produce reports of risk factors associated with the occurrence of road accidents as well as its severity. Based on the findings of data analysis by NRSCM, sensitisation campaigns to urban and rural masses on road safety are organised and conducted. While Governments and other stake holders are doing 4 their best to reduce general loss of life, there is more that needs to be done to rescue productive citizens of Malawi from deaths that can be prevented or treated.

Huge amount of data on fatalities and injuries from car crash is collected from Malawian roads every year as case reports. However, the data appears it is captured without a proper recording and notification system. This is a common problem to many countries and it leads to under-reporting and loss of crucial variables. This creates a problem related to identification and estimation of risk factors from such datasets (Takala, 2005). Inference from analysis of such inconsistence datasets can be faulty. However, inference from such datasets can be improved not only by systematically recording it but also by subjecting data to proper and more robust statistical analysis such as modelling techniques (Tarko, 2009). Modelling techniques provide for a deeper statistical analysis that may yield robust estimates and statistics. However, no literature is available about the use of such techniques on Malawian road traffic accident datasets. Hence, reasonable risk factors contributing to occurrence and severity of road traffic accidents to recommend for better safety measures are always difficult to come by. With modelling, assumptions cannot be ignored. Data is thoroughly cleaned and augmented to yield parameter estimates that are reliable and which can inform better decision making. Hence there is need to step up efforts to use better tools such as more statistical modelling techniques on analysis of monthly or annual road accidents data from the country's roads.

MATERIALS AND METHODS

Data source and description

To investigate severity of motor vehicle accidents based particularly on levels of motor vehicle damages and/ or whether an accident was fatal as well as on severity of occupants' injury, road accident data from Malawi collected from 1995 to 2007 by NRSC was used. Crash records related to all types of vehicles were considered and comprised a total of 16, 474 out of 28, 127 total records of all types of accidents available in the dataset, representing 58.6%. The dependent variable, accident severity, had five categories based on the recorded degree of injury involved and damages incurred. These include: fatal, serious injury, minor injury, damages only or animals only. However, the study only considered categories of; fatal, serious injury and minor injury, in that order. From the 11 years of data, 4.1% accidents were classified as fatal, 5.0% as serious severe, 19.6% as minor and 71.4% as no injury accidents.

Classification of an accident to a particular level of severity was based on the worst condition sustained among the casualties (Rifaat and Chin, 2005). In this case, an accident was considered as fatal or of serious severity if it resulted to death or serious injuries to a driver and/ or occupant of the motor vehicle involved in an accident. Information on the actual criteria used to classify an injury, and the body that decides on category of the injuries in the dataset were not available.

However the study used one injury classification criterion which stipulates that a casualty is considered fatal if the person was killed within 30 days of the accident. In addition, a severely-injured casualty is the one who had suffered some kind of fracture, concussion, internal lesions, crushing, severe cuts and laceration or severe general shock requiring hospitalization or other forms of bodily pain requiring at least 7 days of medical leave. On the other hand, a person is considered to have a minor injury if the victim had suffered from other forms of injury requiring conveyance from the accident scene to hospital by an ambulance or otherwise, the medical treatment requiring medical leave of at least 3 days (Rifaat and Chin, 2005).

The dataset contained more than 30 independent variables which were available for use to explain the injury severity of drivers and passengers (occupants). The variables appear in nine factors, and are observed to fall under the major physical factor categories of crash characteristics, road characteristics, environmental characteristics and surroundings. It was noticed that the dataset contained no variables related to the human factors, which captures such records as variables of driver or occupants characteristics including alcohol or drug usage. With such important variables missing, risk factors sometimes become very difficult to come by.

Statistical Analysis

The analysis considered eight variables from the dataset to fit Ordered Logit, Generalised Ordered Logit and Multinomial Logit Models to identify risk factors associated with severity of accidents during the study period. The variables considered are given in table 2.The first to be fitted was the Ordered Logit model. The model assumes the variables meet the *parallel lines* or *proportional odds* assumption. The *parallel lines* assumption was examined for all the variables used in the study. Otherwise, failure to achieve the assumption would lead to fitting a generalised ordered logit model that introduces constraints on the variables that fail to meet the parallel lines assumption. The parallel lines model used in the study is given as:

$$P(Y_i > j) = g(X\beta) = \frac{\exp(\alpha_j + X_i\beta)}{1+[\exp(\alpha_j + X_i\beta)]}, j = 2,3 \quad (1)$$

Fitting of the Partial Proportional Odds Logit Model was the first alternative to a Parallel Lines Model. The model was considered advantageous as compared to the fitted Ordered Logit since it provided additional information on deviations of the variables from the Parallel Lines assumption which were given as gammas. The partial proportional odds model considered in the study was specified as:

$$P(Y_i > j) = \frac{\exp(\alpha_j + X1_i\beta1 + X2_i\beta2+,...,+X8_i\beta8)}{1+[\exp(\alpha_j + X1_i\beta2 + X2_i\beta2+,...,+X8_i\beta8)]}, j = 2,3 \quad (2)$$

A Multinomial Logit or a Generalised Ordered Logit model analysis might lead to similar conclusions as Partial Proportional Odds Model but there would be many more parameters to look at. The increased number of parameters could cause some effects to become statistically insignificant. The Generalised Ordered Logit Model considered in the study was specified as follows:

$$P(Y_i > j) = g(X\beta_j) = \frac{\exp(\alpha_j + X_i\beta_j)}{1+[\exp(\alpha_j + X_i\beta_j)]}, j = 2,3 \quad (3)$$

When performing the Partial Proportional Odds Model or a Generalised Ordered Logit Model on this study, a backwards stepwise selection procedure was employed, starting with the least parsimonious model and gradually imposing constraints. The backwards stepwise selection procedure provides an empirical means of identifying areas where assumptions are violated, although the procedure can also capitalise on chance just like other stepwise procedures (Williams,

2006). The backwards stepwise selection procedure was done using a *0.5* level of significance to have confidence in the final model.

The Multinomial Logit Model, though considered complicated in interpretation of the coefficient estimates of the variables, was then implemented. Just like the generalised ordered logit model, it relaxed the Parallel Lines assumption and does not impose any constraints to the variables. When fitting the Multinomial Logit Model on the accident dataset, one of the response categories was nominated as a baseline or reference cell, calculated log-odds for all other categories relative to the baseline, and then let the log-odds be a linear function of the predictors. The highest category (category 3, fatal accident) was picked from which odds that i^{th} accident falls in category j as opposed to the baseline as p_{i1}/p_{iJ} were calculated.

The coefficient estimates from the OMNL and BOMNL models were compared. However, comparison of the two models in terms of goodness of fit was not performed due to limitations brought about by the statistical software used to fit the two models. That is, the limitation resulted into the two Ordered Multinomial Logit Models reporting different fitting information criterion. Bayesian platform reported Bayesian Information Criterion (BIC) while the maximum likelihood platform reported residual.

Statistical Modelling

The variables were recoded and dummy variables computed for meaningful interpretation of coefficient estimates of the factors used in fitting the models Table 1. The dummies were then set to their most default forms (zero) and one variable (variable set to one) was used as a benchmark for comparison with other variables in the factor within which it was extracted. The underlining hypothesis on which the models were fitted and interpreted was that all coefficient estimates of independent variables (dummy variables) are zeros.

Table 1: Dummy variables created from variables in the dataset

Variable type	Variable name	Variable Label	Description
Dependent	Severity	Accident Severity	1 = Minor, 2 = Serious, 3 = Fatal
Independent	Weather cond	Weather condition	0 = Adverse conditions, 1 = Dry
	roadsurface	Road surface	0 = Gravel_earth, 1 = Bitumen
	roadgeom	Road geometry	0 = Elsewhere, 1 = Straight road
	surroundings	Road surroundings	0 = Rural, 1 = Urban
	lightcond	Light condition	0 = Night, 1 = daylight
	roadcond	Road condition	0 = Poor, 1 = better
	acc_type	Accident type	0 = Rollover, 1 = Collision
	obstruction	Obstruction	0 = Other object, 1 = Stationary vehicle

The estimated coefficients (β) of dummies in both the Bayesian and Maximum Likelihood Multinomial Logit Models were expected to differ in their signs. The positive value of the estimated coefficient (β) indicated an increase in motor vehicle accident severity whereas the negative values signified a decrease in motor vehicle accident severity. As the value of the independent variables increases, the effect of the identified factors on accident severity in the fitted models was studied by examining the injury odds ratios against the reference case. The significant variables within the factors were mainly identified using *p*-values and confidence intervals of test statistics as well as its importance to assist explaining severity of motor vehicle accidents. The interpretation of the effect of independent variables on the levels of accident severity was followed by suggestions for precautionary measures to be taken to enhance safety as well as suggestions for future research. The response variable (Y_i) considered was severity of a particular accident with $J = 3$ as the number of categories of Y_i, namely: "1" = fatal, "2" = serious and "3" = minor. β_0 represented the intercept while $\beta_p X_p$ described a set of independent variables and its corresponding coefficient estimate

extracted from factors of road geometry, road surface, surroundings, road conditions, weather, time period of the day, accident type and obstruction. That is, X_p represented a particular predictor variable of accident severity, and β_p was the coefficient of a particular predictor. Stata (version 10), *R*-project (version 2.13.0) and SPSS (version 16) were also employed in modelling and data transformation.

Model Evaluation

Evaluation of goodness-of-fit of the Ordered Multinomial Logit Models was achieved through considering the likelihood ratio index (LRI) or the McFadden's pseudo R^2. These ratios have been useful in most studies of this nature. For instance, they have been useful in evaluating discrete choice or classification models. However, goodness-of-fit for Bayesian models was achieved through considering deviance information criterion (DIC).

RESULTS AND DISCUSSION

Data Descriptive

Table 2: Measure of association of accident severity with different input variables in the study

Input Variable		Categories of dependent variable (accident severity)			P-Value
		Fatal	Serious	Minor	
Road geometry	Straight road	750	750	2, 635	
	Otherwise	106	160	627	<0.001**
Road condition	Good/Fair	3,363	2,793	9,216	
	Potholes	111	72	270	
	Corrugated	77	71	226	0.156
	Slippery	20	32	70	
Road surface	Bitumen	3,192	2,626	8,883	
	Gravel	51	48	154	0.005*
	Earth	353	300	810	
Surroundings	Rural	631	552	1,544	
	Urban	139	286	1,463	<0.001**
	Peri-urban	102	93	346	
	Farm,	23	15	55	
Compound					
District	Cities	2,475	1,540	3,826	
	Others	1,130	1,446	6,057	<0.001**
Weather	Dry	853	906	3,245	
	Rainy	0	2	3	0.551
	Others	3	2	14	
Accident type	Head on car crash	243	351	1,567	
	Rollover	423	393	1,100	<0.001**
	Collision	231	205	747	
Lighting condition	Daylight	3,465	68.91	68.91	
	Night	1,448	28.80	97.71	0.108
	Dawn/Dusk	115	2.29	100.0	
Time of the day	Day time	1,216	1,182	4,064	
	Night hours	2,389	1,804	5,819	<0.001**

It was observed from table 2 that six out of nine variables that were available for use to explain accident severity in the study period passed a chi-square test of significance at set alpha level of *0.05* ($P < 0.05$). The variables of road geometry, place of residence (surroundings), district, accident type and time period of day of accident were highly significant ($P < 0.001$), and only

variable of road surface being marginally significant (*P = 0.005*). However, the variables of road condition, weather condition and lighting condition of the accident time failed the chi-square test of significance by having their probability values greater than the set critical alpha value (*P > 0.05*).

Despite some variables failing the chi-square test of significance, the study utilised all the variables available. This was justified on the basis that all the covariates would still assist to explain severity of accidents on the roads of Malawi and lead to identification of risk factors. The result of the test was however useful to explain the behavioural changes of variables when fitted in the models.

Results from the Parallel Lines and Partial Proportional Odds Models

The Ordered Logit Model performed three iterations using *5140* observations. The third iteration produced a *-4448.31* log likelihood and a Pseudo R^2 of *0.027* on a likelihood ratio chi-square of *248.45*. The Pseudo R^2 implies that the model covariates were only able to explain about 2.7% of the total variation in the model. However, the model was significant (*Prob > chi^2 = 0.001*). This means that the final model fitted the data well as compared to the null model. Nevertheless, analysis of the final model shows that only three variables were significantly associated with accident severity during the study period (table 3). The variables were *surroundings*, *lighting condition* and *accident type.*

Table 3. Adjusted odds ratios across accident severity panels through O*logit*

Variable	AOR (95% CI)	p-value
Weather condition		
Adverse	1.00 (ref)	
Dry	0.93 (0.80, 1.08)	0.346
Road surface		
Gravel	1.00 (ref)	
Bitumen	0.93 (0.78, 1.11)	0.422
Road geometry		
Straight	1.00 (ref)	
Elsewhere	0.97 (0.86 1.09)	0.610
Surroundings		
Urban	1.00 (ref)	
Rural	2.18 (1.93, 2.47)	<0.001
Light condition		
Daylight	1.00 (ref)	
Night	1.28 (1.13, 1.44)	<0.001
Road condition		
Poor	1.00 (ref)	
Better	1.02 (0.77, 1.36)	0.885
Accident type		
Collision	1.00 (ref)	
Roll over	1.37 (1.21, 1.54)	<0.001
Presence of obstruction		
Stationery vehicle	1.00 (ref)	
Other	0.89 (0.63, 1.27)	0.529
/cut1	-1.15 (-1.61, -0.69)	
/cut2	-0.14 (-0.60, 0.32)	

Checking with the odds ratio of the significant variables, it is clear that the odds of severe accidents were *2.18* higher in rural settings compared to urban settings (*AOR = 2.18, 95% CI = (1.93, 2.47)*). Also, the odds of severe accidents were higher during night hours compared to day time (*AOR = 1.28, 95% CI (1.13, 1.44)*). However, this model could not be used for interpretation of results. This was so because of a significant test statistic (*P > chi^2 = 0.026*) of *brant* test which provided evidence that the parallel regression assumption was violated, but the main problem seems to be with the variable surroundings (*P > chi^2 = 0.05*). Since the assumptions of the parallel lines model

are violated, using the model can lead to incorrect, incomplete, or misleading results (Williams, 2007). Alternative models were fitted and their goodness of fit was assessed. Generalised Ordered Logit was first option. It relaxed the variables from restrictive parallel lines assumption but had variable coefficients difficult to interpret. A better alternative was the Partial Proportional Odds Model, which constrained only some variables to meet parallel regression assumption.

The restricted Generalised Ordered Logistic Model (table 4) imposed constraints on variables that did not meet the Parallel Lines assumption thereby making the results more easily interpretable. The model imposed constraints on majority (seven out of eight) of the variables in the study except on the variable of *surroundings*. This had an effect especially on changing the interpretation of the meaning attached to the coefficients of the variables which had constraints imposed on them. This also could compromise validity of the results.

Table 4. Adjusted odds ratios across accident severity through a restricted *Gologit*

Variable	Serious severity AOR (95% CI)	p-value	Serious+Fatal severity AOR (95% CI)	p-value
Weather condition				
Adverse	1.00 (ref)		1.00 (ref)	
Dry	0.93 (0.80 1.08)	0.346	0.93 (0.80 1.08)	0.352
Road surface				
Gravel	1.00 (ref)		1.00 (ref)	
Bitumen	0.93 (0.78, 1.11)	0.422	0.93 (0.78 1.11)	0.435
Road geometry				
Straight	1.00 (ref)		1.00 (ref)	
Elsewhere	0.97 (0.86, 1.09)	0.610	0.97 (0.86 1.09)	0.597
Surroundings				
Urban	1.00 (ref)		1.00 (ref)	
Rural	2.56 (2.17, 3.03)	<0.001	2.10 (1.85 2.38)	<0.001
Light condition				
Daylight	1.00 (ref)		1.00 (ref)	
Night	1.28 (1.13, 1.45)	<0.001	1.28 (1.13 1.45)	<0.001
Road condition				
Poor	1.00 (ref)		1.00 (ref)	
Better	1.02 (0.77 1.36)	0.885	1.02 (0.77 1.36)	0.897
Accident type				
Collision	1.00 (ref)		1.00 (ref)	
Roll over	1.37 (1.21 1.54)	<0.001	1.37 (1.21 1.54)	<0.001
Presence of obstruction				
Stationery vehicle	1.00 (ref)		1.00 (ref)	
Other	0.89 (0.63 1.27)	0.529	0.89 (0.63 1.27)	0.540
Minor = base outcome				

The Wald test of Parallel Lines assumption for the final model shows an insignificant test statistic (*Prob > chi^2 = 0.1665*). This indicates that the final model (table 4) did not violate the Parallel Lines assumption. The restricted *Gologit* model is significant (*Prob > chi^2 = 0.0001*) with a log likelihood of *-4443.79* and a pseudo *R^2* of *0.0282*. The *R^2* shows that only about *2.8%* of the variation in the model is explained by the variables used to fit the model. Therefore, there is little evidence suggesting a better model fit. However, this model only slightly improved fitting as compared to the Parallel Lines Model with a pseudo R^2 of *2.8%*.

Taking lighting condition of accident place on the minor severity panel for example, the odds of severe accidents are *1.28* higher during night hours as compared to accidents occurring during daytime, and the association is significant *(p < 0.001, 95% CI (1.13, 1.45)*. A similar interpretation of the input variable lighting condition applies on the serious severity panel. This is because both panels have *1.28* as odds ratio to be contrasted with the base outcome (fatal accidents). However,

since variable of *surroundings* has different odds ratios on the panels of minor and serious severity, a one unit increase in the severity panel is observed to decrease odds of severe accidents with respect to fatal accident as a base outcome. That is, the odds of severe accidents were *2.56* higher in rural settings as compared to urban settings with respect minor severity category. However, taking consideration of the serious severity category, the odds of severe accidents were *2.10* higher in rural settings as compared to urban settings. Generally, accidents that occurred in *urban surroundings* tended to become less severe than those that occurred in *rural surroundings* during the study period. Therefore, the strongest effect of *surrounding* variable was associated with less severe accidents in the study period.

Results from the Ordered Multinomial Logit Model

Similar to the Parallel Lines Model, *Mlogit* performed three iterations and resulted in the log likelihood estimate of *-4439.63*. The results show that the model has likelihood ratio chi-square (16) of *265.80* and the model is significant (*Prob > chi*^{2} *= 0.0001*). The goodness-of-fit of *Mlogit* assessment is given by pseudo R^2 of *0.0291*. Therefore the variables help to explain about *2.9%* of the variations in the model. There is a slight improvement in model fitting with the Multinomial Logit Model as compared to *Ologit* and *Gologit* models estimated in this study. The Ordered Multinomial Logit Model shows that three covariates were significantly associated with more severe (fatal) road accidents during the study period. The covariates include location of accident (*surroundings*), *lighting condition* of the time of accident and *accident type*.

Considering *surrounding* variable, the risk of fatal accidents was significantly higher than that of serious and minor severe accidents in rural settings compared to urban settings. The odds of severe accidents were *0.35* higher in rural settings as compared to urban settings with respect to minor severity category (*P < 0.001, 95% CI (0.29, 0 .42)*). However, considering serious severity category, the odds of severe accidents were *0.62* higher in rural settings as compared to urban settings (*P < 0.001, 95% CI (0.53, 0.72))*. With respect to *lighting condition*, accident severity risk was higher with accident occurring at night than those occurring during daytime. Comparing fatal and minor severity accidents, the odds of fatal accidents were *0.71* higher during night hours compared to daytime (*P < 0.001, 95% CI (0 .60, 0.83)*). Considering a contrast of fatal and serious severity accidents, the odds of fatal accidents were *0.90* higher than that of serious accidents particularly during night hours compared to daytime

Considering the significant variable of accident type, relative risk ratio was also increasing with increase in severity of accidents. The relative risk ratio of fatal accidents was significantly higher than that of serious and minor severe accidents. However, the accident severity risk was higher with rollover accidents compared to collision accidents. The odds of more severe (fatal) accidents were 0.69 higher than that of minor accidents particularly with rollover accidents compared to collision accidents (P < 0.001, 95% CI (0 .59, 0 .81)). However, the odds of fatal accidents were 1.37 higher than that of minor accidents with rollover accidents compared to collision accidents (P < 0.001, 95% CI (0.65, 0.89))

Results from the Bayesian Ordered Multinomial Logit Model

Similar to an OMNL regression model (table 9), the Bayesian Multinomial Logit (BOMNL) regression model in table 10 was fitted with consideration of category 3 (fatal accidents) as the base outcome. However, through MCMC estimation techniques, using 12,000 iterations, BOMNL model produced posterior mean estimates of each variable unlike the *Gologit* and the *Mlogit* models which reported odds ratio estimates and the model was significant. However, examination of the estimates from BOMNL reveal similar story to that of *Gologit* and *Mlogit*.

The BOMNL model slightly improved the parameter estimates as compared to results provided by the maximum likelihood Multinomial Logit Model, OMNL. This is particularly suggested by comparing the coefficient estimates of the intercepts of the two models. Analysis of the parameter

estimates and intercepts in BOMNL shows that they tended to be more positive than those of the OMNL.

Table 5. Severity posterior means through a Bayesian Ordered Multinomial Logit

Variable	Minor severity Mean (2.5%, 97.5% Quant)	Median	Serious severity Mean (2.5%, 97.5% Quant)	Median
Weather condition				
Adverse	1.00 (ref)		1.00 (ref)	
Dry	-0.10 (-0.31, -0.10)	-011	-0.09 (-0.32, 0.16)	-0.09
Road surface				
Gravel	1.00 (ref)		1.00 (ref)	
Bitumen-	-0.11 (-0.32, 0.11)	-0.11	-0.07 (-0.35, 0.20)	-0.07
Road geometry				
Straight	1.00 (ref)		1.00 (ref)	
Elsewhere	-0.11 (-0.27, 0.06)	-0.11	-0.18 (-0.39, 0.02)	-0.18
Surroundings				
Urban	1.00 (ref)		1.00 (ref)	
Rural	1.05 (0.88, 1.22)	1.05	0.56 (0.36, 0.76)	0.56
Light condition				
Daylight	1.00 (ref)		1.00 (ref)	
Night	0.34 (0.17, 0.50)	0.35	0.24 (0.05, 0.43)	0.24
Road condition				
Poor	1.00 (ref)		1.00 (ref)	
Better	0.15 (-0.19, 0.46)	0.14	0.40 (-0.07, 0.88)	0.40
Accident type				
Collision	1.00 (ref)		1.00 (ref)	
Roll over	0.37 (0.22, 0.53)	0.37	0.10 (-0.11, 0.29)	0.10
Presence of obstruction	1.00 (ref)		1.00 (ref)	
Stationery vehicle	-0.11 (-0.55, 0.34)	-0.10	0.06 (0.48, 0.60)	0.06
Other				
Fatal = base outcome				

Despite the improvements on parameter estimates, the BOMNL however did not adjust the variables that were insignificant in the OMNL and *Gologit* models to be significant. Just like in Parallel Lines, Partial Proportional Odds and in OMNL models, *Surroundings, lighting condition* and *accident type* were the only variables which are significant in BOMNL model. The significance is shown by their credible intervals given by 2.5% and 97.5% in the model. The implication was that, driving in *urban surroundings*, during *daytime* and occurrence of accidents of *collision type* was more risky since severity of accidents was significantly associated with such conditions. Since coefficient estimates of the intercepts are bearing negative signs, generally, the greatest effect of the significant covariates were to decrease the likelihood that the accident will belong to higher severity categories.

Results from OMNL and BOMNL suggest that cautious driving and fewer incidents of risky behaviours such as careless overtaking of vehicles on the road might have led to less number of severe road accidents during *day time* especially with *collision* accident type and driving in urban *surroundings*. This is suspected from examination of odds ratio and coefficient estimates of the covariates of *surroundings* of accident spot, *lighting condition* of time of day of accident and *accident type* which are significant and generally seem to decrease with increase in accident severity. That is, they are more associated with less severe accidents.

Urban surroundings are generally densely populated with increased motor vehicle volumes and road activities. These include more traffic on the road, more pedestrian movements and vending along the roads. Also, urban roads are usually highly and constantly patrolled by traffic police. As a result, drivers of motor vehicles are usually alert and drive carefully on urban roads. Such caution driving behaviours might have assisted to prevent collision accident as most of such accidents are bound to occur in instances of over-taking which is unlikely in urban surroundings due to busy roads. Nevertheless, urban surroundings in Malawi are still severe accident prone areas. Most roads in urban surroundings are covered in tarmac and majority of them have lived past their life span. Most of these roads are not in good condition as evidenced by potholes. Hence careless driving in surroundings consisting of high motor vehicle volume with bad road conditions can result in more severe accidents. The residual deviances reported by models listed in table 12 are huge, implying the Bayesian models fit the data well. This is additional evidence that BOMNL has better parameter estimates than the OMNL model.

The models considered in the study were observed to have picked similar variables which are significant. These are variables of *surroundings, lighting condition* and *accident type* (table 11). The selected variables also had similar impact in decreasing severity of accidents in the study period. This was indicated by analysing the positive and negative signs of the coefficient of the variables. This is despite the fact that some models improved the estimates to more positive.

Table 6. Model fitting criterion information

Maximum Likelihood Estimation Models	**Pseudo R^2**	
Ordered logit Model	0.0272	
Generalised Ordered Logit	0.0292	
Generalised Ordered Logit (with constraints)	0.0282	
Ordered Multinomial Logit	0.0291	
Bayesian Models	**DIC based on Saturated Deviance**	
Bayesian Ordered Multinomial Logit	Deviance (bar_mu):	8879.32
	pD:	17.91
	DIC:	8915.14

CONCLUSION AND RECOMMENDATIONS

Modelling accident data can be more advantages over other data analysis techniques like chi-square and frequencies. Although modelling is rigorous and tedious since it involves paying attention to model assumptions which might be violated and lead to models that do not fit the data well, however it has capacity and can be trusted to inform better decisions on road safety.

Chi-square and frequency tables correlate only a few variables at a time, they report association of individual factors with the response variables and only assist in revealing trend or distribution of a response variable. On the contrary, modelling has capacity to establish association of various factors with the response variable at once. For instance, a Pearson chi-square test of association employed in this study only assisted to establish association of accident severity with each of the eight independent variables. However, when data was modelled, the association was given at an individual input variable level as well as at a level of collective impact of the eight variables on frequencies and severity of accidents on the roads of Malawi.

For an instant look at distribution but also in order to account for descriptive analysis, frequencies and chi-square techniques can be very useful tools. For instance, the two techniques were useful during data exploration before implementation of modelling in this study. That is, modelling itself does not exist and operate alone but in collaboration with other techniques in order to achieve its

objective. Chi-square has capacity to inform models on which factors to consider taking on board based on their individual significant association with the response variable. On the other hand, frequency can give clues of most likely distribution of the response variable. This can assist with choice of a type of model to implement, or assist with the measures to be taken to manipulate the response variable so that a choice model can still be implemented.

Simple statistical analysis techniques normally produce simple estimates of statistics that are often easy and straight forward to interpret. Such estimates usually do not inform much on their impact to the response variable since they often lack a reliable measure of significance, as is the case of frequencies, or may rely only on a single measure of significance such as a probability value as is the case with chi-square tests. With modelling, significant variables may be required from a test of association. Then models are run in search of a better model explaining the data from which the magnitude of association of input and response variables is determined by the significant estimates. During modelling, significance is normally decided based on two techniques including the probability value as well as through the reported credible intervals.

Use of modelling techniques in data analysis not only can provide for a solution to unreliable estimates but also bring in more accurate statistical tools for testing data. This is due to the fact that modelling takes data through a deliberate and useful process of cleansing, augmentation and assumption checking. As a result, parameter estimates that are reliable and which can inform better decision making are always likely to come by. The risk factors obtained by analysing significant estimates from modelling can have a better story to tell on how Malawians should interact with motor vehicles and the road network as was observed in this study as follows. .

Generally, there was estimation improvement of intercept and variable coefficients to more positive with fitting of BOMNL model. The model however picked similar variables to those picked by Parallel Lines, Partial Proportional Odds and Multinomial Logit Models as significantly associated with severity of accidents. These included accident location (*surroundings*), *lighting condition* of time of accident and *accident type*. Examination of the model fitting information, *Pseudo* R^2 of the *Ologit*, *Partial Proportional Odds* and *Mlogit* Models suggested that *Mlogit* reported a bigger *Pseudo* R^2. However the difference in the magnitude of the *Pseudo* R^2 among the models was just very tiny to endorse the *Mlogit* as a better model as compared to its counterparts.

Overall, it could be stated confidently that due to incorporation of normal (informative) priors when fitting Bayesian models, the parameter estimates realised in BOMNL model were more reasonable than those in OMNL. However, it is clear from the model that driving in dry weather conditions, in better road conditions especially of bitumen surfaces and straight road geometries had resulted to severe accidents in the study period.

On the contrary, driving in urban surroundings, occurrence of accidents of collision type and driving during daytime significantly impacted “less severe accidents” since they contributed to less number of fatal accidents during the study period.

The risk factors associated with variables that had a positive impact in causing more severe accidents include careless driving in straight roads with bitumen surfaces as well as in good weather and better road conditions. Therefore, road improvements are required to cover for the potholed conditions.

In addition, it is suggested that substance abuse by drivers, cell phone use during driving may result to carelessness and risk taking behaviours when driving. Substances like alcohol when taken in excess amounts reduce the control and driving capabilities of the driver hence more prone to severe accidents (Beckett, 1998). Cell phone use can disturb driver attention and concentration when

driving even in better roads or in good weather conditions. However, caution driving tendencies in urban surroundings, in which car volumes are greater and with increased road use activities than other surroundings may have resulted in less severe accidents in the study period.

According to Xie *et al* (2009), drunken driving, carelessness or risk taking behaviours on the roads are highly associated with the youth than any age group. Hence there is a need to step up the efforts of discouraging drunken driving, carelessness or risk taking behaviours particularly amongst the youth through information dissemination of their dangers.

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Experiences of English teachers when teaching learners with hearing impairment reading comprehension

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ABSTRACT

Information in the literature indicates that children who have hearing impairment (HI) often struggle with reading comprehension. HI students also struggle with the acquisition of crucial literacy skills and/or the attainment of reading abilities. It is therefore a challenge for hearing impaired learners to learn effectively in both primary and secondary schools. Information in the literature also points out that teachers encounter several challenges when teaching hearing impaired students. However, most of the studies in these areas have been carried out in African countries such as Tanzania and Kenya. In addition, the studies have focused on challenges faced when teaching in general without specifically looking at an individual subject. This study is therefore unique because its main purpose was to examine the experiences of English teachers when teaching learners with hearing impairment reading comprehension. In order to collect detailed information, interviews and focus group discussions were conducted with a total of eleven informants from three secondary schools in the northern region of Malawi (Nkhorongo Community Day Secondary School, Luwinga and Mzimba Secondary Schools). The results reveal that most hearing impaired students manage to predict the content of a written text from a title and answer comprehension questions. However, the results indicate that hearing impaired students have problems in explaining key terms and central ideas. Other challenges identified in this study include lack of teaching and learning materials suitable for hearing impaired students, lack of hearing aids, inadequate staff and large classes that prevent teachers to give a one-on-one assistance to students who require help. Among other things, the study recommends the need for teachers to be trained so that they are competent to teach hearing impaired students. The study also stresses the importance for schools to be supplied with the necessary teaching and learning materials to improve the poor learning environment of hearing impaired students.

Key words:

INTRODUCTION

Hearing impairment, according to Muiti (2010:12), is a "general term used to describe all levels of hearing losses ranging from mild to profound". According to Muiti (2010:13), in accordance with education guidelines, hearing impairment is divided into two groups namely, hard of hearing and deaf. Muiti states that the hard of hearing is especially used to refer to those people whose hearing loss fluctuates from mild to moderate. In this study, the term hearing impairment also applies to all levels of hearing losses as described by Muiti. It is a challenge for hearing impaired learners to learn effectively in both primary and secondary schools. Several studies have been conducted regarding challenges that teachers encounter when teaching hearing impaired students. Other studies have investigated hindrances to effective learning of pupils with hearing impairment. However, most of these studies have been carried out in African countries such as Tanzania and Kenya. In addition,

the studies have focused on challenges faced when teaching in general without specifically looking at an individual subject..

Reading comprehension skills of HI students

There are certain factors that play a role in the comprehension skills of hearing impaired students. These factors include vocabulary knowledge, phonology, mode of acquisition, and syntactic knowledge. However, the discussion in this section mainly focuses on vocabulary. Several studies have documented that hearing impaired learners have limited vocabularies (see Luckner & Cooke 2010). Other studies have also revealed that hearing impaired learners perform poorly in tests on vocabulary knowledge compared to their hearing counterparts (see Convertino, Borgna, Marschark & Durkin 2014). In particular, Dockery (2013) investigated the reading comprehension levels of grade 4 to 12 Jamaican hearing impaired students who enrolled in a sign-bilingual programme. Additionally, the study also sought to examine the predictive power that some selected variables including receptive vocabulary knowledge have on the reading comprehension levels of Jamaican hearing impaired students. The results reveal that receptive vocabulary knowledge was one of the important predictors of reading comprehension hence an important strong correlation between vocabulary knowledge and reading comprehension.

Text comprehension strategies for hearing impaired students

This section focuses on some of the strategies that could be used prior to reading, during reading and after reading. Some of the strategies that could be used fall under the following categories: prior to reading (e.g. pre-teaching/pre-learning vocabulary and grammar), during reading (e.g. making inferences and asking questions) and after reading (e.g. retelling and summarizing) (McAnally & Rose 1999); Rose, McAnally & Quigley 2003). Benedict (2012), reports that "three decades' worth of research has shown that providing instruction in higher-order cognitive thinking skills (for instance, activating prior knowledge, making predictions, drawing inferences, and summarizing) improves students' reading comprehension". Overall, this means that, as pointed out by Fielding and Pearson (1994), the process of learning to read for understanding involves knowledge, experience, thinking, and teaching.

Challenges that teachers encounter when teaching hearing impaired students

The review presently focuses on studies that examined challenges that teachers encounter when teaching hearing impaired students. In the first place, a study that was conducted in Zimbabwe by Mpofu and Chimhenga (2013) highlights the following language related challenges: language use, vocabulary development, speaking, academic achievement and social functioning. In particular, their results reveal that most hearing impaired students have difficulties in expressing themselves. In addition, these students find it difficult to "develop the vocabulary of the English language since they hardly hear when other people are communicating" (Mpofu & Chimhenga 2013:72).

A study conducted by Muiti (2010) who investigated hindrances to effective learning of pupils with hearing impairment reported the following challenges: difficult in explaining abstract concept, communication barriers, lack of learning resources and hearing aids, too much work load, sharing of one class by learners at different levels, lack of support by parents, short attention span of pupils, inadequate training of teachers in colleges and regular absenteeism.

Ways of overcoming challenges

Teachers can provide relevant cues that aid comprehension. Teachers can also encourage hearing students to be supportive whenever hearing impaired students require further explanations of what the teacher covers in class. Additionally, in order to overcome communication barriers, Mpofu and Chimhenga (2013) further advise teachers to make sure that hearing impaired students do not have unobstructed view of the teacher. Above all, in a study conducted by Udoba (2014), it was noted that some of these challenges may be resolved by a community that works together, a community

that accepts people with disabilities as human beings. If they are thus accepted, we will realise that they need our help throughout their lives. In doing so, we will do everything possible to show them that they are loved and safe. The study was conducted to investigate text comprehension strategies that teachers use when teaching learners with hearing impairment reading comprehension, identify challenges that teachers encounter when teaching the areas and obtain views and suggestions from teachers on how the challenges can be resolved.

MATERIALS AND METHODS

The purpose of this section is to provide information concerning the data collection procedures that were followed. The focus is therefore on the following: research design, geographical area of the study, participants, data collection techniques and tools, data analysis and ethical consideration.

Research design

This study used a qualitative research design. According to Bailey, Hennink and Hutter (2011), qualitative research allows a researcher to examine people's experience in detail using methods such as in-depth interviews and focus group discussions. Furthermore, qualitative research enables a researcher to collect data that can be coded and categorized into themes.

Geographical area of the study

Data for this study was collected from three schools that are located in Mzuzu city and Mzimba district respectively as follows: Nkhorongo Community Day Secondary School (CDSS), Luwinga Secondary School and Mzimba Secondary School. Data for this study was collected from 3rd January, 2017 to 7th April, 2017

Participants

The researchers interviewed and had a focus group discussion with a total of eleven informants from the three secondary schools; three teachers from Nkhorongo CDSS, two teachers from Luwinga Secondary School, two teachers from Mzimba Secondary School, two specialist teachers from Luwinga Secondary School and two resource persons from Mzimba Secondary School.

Data collection techniques and tools

This study used the following data collection methods: interview and focus group discussion. Interview was considered as the main method of data collection while focus group discussion was a supplementary one. Below is the detailed description of each method.

Interviews

In general, this study involved semi-structured interviews. In particular, open-ended questions were used. The interviews were conducted with every teacher selected to participate in the study. Each interview lasted about thirty minutes. The purpose of this study and the specific objectives formed the basis for the interview questions. All the interviews were audio recorded in order to maintain the original data. Audio recordings are crucial because they provide a complete verbal record which can be studied much more thoroughly. Besides, audio recordings speed up the interview process (Gall, Gall & Borg 2007).

Focus group discussions

In this study, the researchers conducted two focus group discussions with English teachers, resource persons and specialist teachers. One focus group discussion took place at Luwinga Secondary School. The participants in the first focus group discussion were two English teachers and two specialist teachers in other subjects such as Bible Knowledge and Social Studies. Another focus group discussion took place in Mzimba in which the following were the participants, two teachers and two resource persons.

Ethical consideration
In the first place, all the respondents were informed of the purpose of the study. They were also assured that their views and opinions would be treated with maximum confidentiality. They were also assured that the study findings would be for academic purposes only.

Data analysis
All the raw data collected in this study were transcribed. Thereafter, thematic analysis was used to organise the transcribed data.

RESULTS

This section presents the findings of this study. The findings are organised and presented according to the themes corresponding to each specific objective. The specific objectives were achieved using information collected through interviews and focus group discussions.

Whether or not students with hearing and visual impairment are able to do the specified tasks
The results reveal that most hearing impaired students manage to predict the content of a written text from a title. They also manage to answer comprehension questions. The teachers revealed that hearing impaired students are able to answer comprehension questions especially when they are encouraged to read a passage over and over again in order to fully understand it. However, they indicated in their responses that hearing impaired students struggle to do the following: identify key words that signal central idea, define or explain key words that signal central idea, identify central idea from the title of the written text and explain central idea.

Text comprehension strategies that are used when teaching reading comprehension
The focus in this section is on text comprehension strategies that teachers use when teaching learners with hearing impairment reading comprehension. Table 1 below presents a list of the strategies that the researchers obtained from the teachers that were interviewed.

Table 1: Text comprehension strategies that are used when teaching reading comprehension

Nkhorongo	Pre-reading activities, frequent exercises that enhance their reading comprehension skills, assigning group members to be assisting HI students, predictions from titles or pictures, skimming and scanning
Luwinga	Group work, pair work, explanation, whole class discussion, individual work, demonstration and use of gestures, silent reading and individual reading
Mzimba	The use of textbooks and a variety of passages for comprehension exercises, repetition and reading a passage several times, writing new words on the board and providing their meanings where necessary

Challenges that teachers encounter when teaching the six specified tasks
There were several challenges that the teachers raised during the interviews as well as focus group discussions. The discussion in this section only focuses on the main challenges. In the first place, the teachers pointed out that most of the teachers at the three schools are not trained to teach learners with hearing impairment. Furthermore, the teachers pointed out that hearing impaired students rely on facial expressions and lip reading for them to understand what the teacher is talking about. However, facial expression may sometimes be misinterpreted. In addition to that, they also stated that lip movement may be misleading especially when producing words such as ‘man’ and ‘mad’. The teachers therefore stressed the importance of using appropriate facial expressions and

pronunciations.

Some teachers also complained about the low performance in English for some of these students. This low performance may be attributed to the fact that some of these students find it difficult to develop the vocabulary of the English language since they hardly hear when other people are communicating. Furthermore, it is a requirement for secondary school students to know how to summarise a passage because the national examinations in their final year of secondary education assess them in this area. However, writing summaries is considered as one of the difficult tasks for hearing impaired students according to the responses from the teachers.

Table 2: Challenges that teachers from the three schools encounter when teaching English subject

Nkhorongo	Lack of resources in terms of text books, insufficient staffing & large classes hence inability to give a one-on-one assistance to students who require help, students are not ready to tell the teacher that they are lost, failure to understand comprehension passages, group work problem, emphasis is required when instructing students
Luwinga	Lack of teaching and learning materials suitable for hearing impaired students, lack of hearing aids, lack of analytical skills, lack of interest and motivation, inability to get what is taught when sitting in a position far away from the teacher
Mzimba	Problems only when students are not given a passage in advance, problems with vocabulary, being absent minded when attention is required, failure to lip read correctly due to shortage of books

Other challenges that teachers raised concern the fact that hearing impaired students are easily distracted. These students specifically complain that there are usually a lot of distractions when doing group work. Other challenges that the teachers raised are given in Table 2.

Solutions to the challenges outlined in section 4.3

In this section, the researchers reveal views and suggestions from teachers on how the challenges identified in the above section can be resolved. To begin with, it is important to point out that the teachers were of the view that it is not only a one man's job for these challenges to be resolved. They therefore stated that there is a need for teachers to collaborate with students and their families, specialists, their communities as well as the government. The rest of the solutions are presented in Table 3 below.

Table 3: Solutions to the challenges outlined in section 4.3

Nkhorongo	Provision or procurement of more teaching materials, students should be supervised when doing group work, encourage students to read widely, encourage students to speak English all the time when at school, supplementing what is available by photocopying passages from text books and other sources e.g. newspaper, HI students should be sitting in the front row all the time, fellow students can help HI students by clarifying certain points in their own free time
Luwinga	Sitting in the front row and the teacher should be closer all the time, sourcing hearing aids, improvisation in case of shortage of teaching and learning materials, using different strategies when teaching, making lesson interesting by using a variety of teaching and learning aids, using group work
Mzimba	Repeating what is said is important, encouraging them to read widely to increase their vocabulary knowledge, using the best and correct pronunciation in order for the students to lip read correctly, providing passages for transcription in advance

DISCUSSION

The results have revealed that hearing impaired students are able to predict the content of a written text from a title as well as answer comprehension questions. On the contrary, the results demonstrate that hearing impaired students struggle to identify key words that signal central idea, define or explain key words that signal central idea, identify central idea from the title of the written text and explain central idea. These results have proved that these students cannot do the six specified tasks if they struggle with their vocabulary.

These results are supported by what Mpofu and Chimhenga (2013) found. Their results reveal that hearing impaired students struggle to develop English vocabulary because of their inability to hear when other people are communicating. Mtuli (2015) also reports that hearing impaired students do not have normal language abilities and as a result they find it hard to communicate in inclusive education classes which do not capitalise on the use of sign language.

Similarly, Bickham's (2015) findings indicate that vocabulary is one of the main sources of difficulty for hearing impaired students in as far as reading comprehension is concerned. Information in the literature also reveals that their problems with vocabulary are attributed to the fact that these students do not have opportunities to acquire vocabulary as well as syntax from an early age (see Mpofu & Chimhenga 2013). Additionally, Dockery's (2013) findings also reveal an important strong correlation between vocabulary knowledge and reading comprehension.

Difficulties in vocabulary eventually lead to poor performance in English and other subjects. It is reported by Mpofu and Chimhenga (2013) that students with hearing impairment have difficulty with all areas of academic achievement, especially reading and mathematical concepts. They also report that the gap in academic achievement between children with normal hearing and those with hearing impairment usually widens as they progress through school.

When it comes to text comprehension strategies, it is important to mention that some strategies that were found to be useful in the literature were not mentioned by the teachers in this study. These strategies include the use of graphic and semantic organizers, question generation and inferencing. The teachers who participated in this study indicated that they tend to ask students questions after reading a passage but they do not encourage them to generate their own questions from the passage that they were reading. They also do not encourage the use of graphic and semantic organizers. This is where a student can be provided with meanings of difficult vocabulary as well as an outline of main ideas from a passage but in a graphic format. Finally, the teachers are fond of asking explicit questions; hence they do not encourage students to make inferences as they ask questions whose answers are readily present in the passage.

Regarding challenges, the results have revealed that teachers complained about insufficient staffing and large classes. They also indicated that most teachers are not skilled to teach hearing impaired students. Similarly, in a study that Mtuli (2015) conducted, he found that in Tanzania there was lack of in service training for the teachers of special education. He also found that there was lack of information to facilitate learning of hearing impaired students in inclusive education. This implies that if teachers are properly trained, they would be able to teach an inclusive class effectively.

The results also reveal that there is lack of teaching and learning materials suitable for hearing impaired students. Apart from this challenge, the students also do not have hearing aids. The problem of lack of resources appears to be common in most African countries. Mtuli (2015), Muiti (2010) and Udoba (2014) who conducted their studies in Tanzania and Kenya respectively report similar findings. It is an outcry for many teachers to have more advanced teaching materials such as audio and TV for teaching (Udoba 2014). Other teaching and learning materials include visual

media especially overhead projectors or PowerPoint (Mpofu & Chimhenga 2013). According to Mpofu and Chimhenga, these are effective tools because they enhance the learning process for the hearing impaired pupils.

Regarding solutions, the teachers mentioned that hearing impaired students need to be provided with adequate teaching and learning materials. This would however be possible if the teachers worked hand in hand with the government and non-governmental organisations (NGOs) because of financial complications. According to Udoba (2014), many teachers would like to be using modern teaching and learning materials as opposed to the locally available materials because the latter do not motivate the learning process during lessons. Udoba also points out that teachers may not be able to utilise appropriate teaching methods and approaches when modern teaching and learning materials are not available.

Furthermore, another solution that the teachers mentioned involves the need for fellow students to help hearing impaired students by clarifying certain points in their own free time. Regarding this, Mpofu and Chimhenga (2013) point out that it is important for teachers to use every opportunity to teach other students about hearing loss and what can be done to support hearing impaired children in class. There is also a need for parents and other relations to be supportive. Collaboration with parents is crucial because parents know their children better than the teachers.
As alluded to earlier on in this section, the teachers in this study pointed out that hearing impaired students have problems with vocabulary. As a solution to this challenge, the teachers stressed the importance of encouraging students to read widely. Furthermore, it is important that teachers frequently check hearing impaired students to see if they are following the lesson or not. If they are not, other strategies may be used to enhance their understanding.

There were several ways that were offered in this study that would help to overcome communication barriers. In view of this, Mpofu and Chimhenga (2013) advise teachers to make sure that hearing impaired students do not have unobstructed view of the teacher so that they are able to lip read what the teacher says throughout the lesson. Mpofu and Chimhenga also stress the importance of repeating questions and comments uttered by other students in class who may not be in the range of vision of the hearing impaired student. Repeating what is said was also viewed as one of the important solutions in cases where students did not understand a lesson.

Besides the solutions outlined in Table 3, it was found out in this study that the challenges that the teachers pointed out cannot be completely avoided. What is important to most teachers is to find the best ways to minimise them. According to Udoba (2014), the best way to minimise these challenges is to make sure that learners are not affected to a great extent. Above all, what is important is to make sure that students are attending school as many of the challenges explained in section 4.3 may not have immediate solutions.

COCLUSIONS

This study aimed at examining the experiences of English teachers when teaching learners with hearing impairment reading comprehension. The results reveal that most hearing impaired students manage to do the following: predict the content of a written text from a title and answer comprehension questions. The results also demonstrate that hearing impaired students are able to answer comprehension questions especially when they are encouraged to read a passage several times. However, the results indicate that hearing impaired students struggle to identify key words that signal central idea, define or explain key words that signal central idea, identify central idea from the title of the written text and explain central idea.

The results also reveal that teachers make use of several strategies such as predictions from titles or pictures, skimming and scanning. The study also indicates that teachers encounter several challenges such as lack of teaching and learning materials suitable for hearing impaired students, lack of hearing aids, inadequate staff and large classes that prevent teachers to give a one-on-one assistance to students who require help. The results have also revealed that hearing impaired students struggle with vocabulary and writing summaries.

Furthermore, the study has revealed that the government and NGOs should provide teachers with the required resources in order to resolve some of the challenges that the teachers mentioned. Besides this, teachers are encouraged to be improvising when the required teaching and learning materials are not available. Finally, it was noted that the best way to minimise these challenges is to make sure that learners are not affected to a great extent.

Recommendations

1. This study makes the following recommendations:
2. Teachers need to be trained so that they are competent to teach hearing impaired students.
3. There is a need for the provision of resource persons because some schools do not have resource persons to support the learning of hearing impaired students.
4. Schools should be supplied with the necessary teaching and learning materials to improve the poor learning environment of hearing impaired students.
5. There is a need for collaboration between teachers and parents. Collaboration with parents is crucial because parents know their children better than the teachers.
6. Students should be sensitized on the importance of supporting hearing impaired students and also students with other categories of disability.

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Female Fandom: Identity, Sexism and Football in Malawi

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ABSTRACT

In this article I consider women's relationship to football culture, showing how women sometimes downplay their gender identities to reinforce their fan identities. Domination of men's football spaces by men makes stadiums hostile environments for women who are often physically and verbally abused. This paper provides a nuanced analysis of female fans' responses to the masculine nature of the football stadium. This research in Malawi brings to the fore the voices of female fans and how they construct the stadium experience. To accomplish this I interviewed 38 female fans at Super League football matches and analysed their responses to abusive or insulting behavior by male fans. The paper highlights how women react, negotiate and respond to misogynistic and vulgar songs and chants, and the threat of violence from male fans. The qualitative data was analysed using the grounded theory approach. Women used three strategies to respond to sexism and homophobia. First, they expressed disgust at abuse, sometimes redefining fandom to exclude abusers. Second, they downplayed sexism. Their third strategy was to embrace gender stereotypes, arguing that femininity was inconsistent with "authentic" fandom and that abuse was a fundamental part of football. The findings are analysed in light of the hegemonic masculinity and dominant femininity theories. In the end, the strategies used by women to respond to sexism in the football stadia was in line with the established theories that women will most likely join in the sexist and abusive singing, remaining oblivious, sitting in quieter parts of the stadium and responding to abusers.

Key words:

INTRODUCTION

Background

The presence of women in largely male-dominated spaces such as football stadiums offers interesting questions about the paradoxical nature of female fandom. This paper focuses on part of the female fan experience in football stadium using women who attend matches in Blantyre and Lilongwe, Malawi. Scholars (Agnew 2006; Gosling 2007; Jones 2008) from across the world have shown how football stadiums are punctuated by abusive, misogynistic and phallocentric images. As such they are highly female unfriendly, yet the number of female fans is increasing across the world. Using a sample of 38 purposively sampled fans, and 273 surveyed female fans, this paper offers an exploratory endeavour into understanding how female fans respond to masculine cultures that dominate football stadiums.

The research begins from the standpoint that female fans are not a homogeneous or special group. They are differentiated in the same manner as male fans and are attracted to football for varied reasons. This study thus avoids essentialising the female fan or depicting them as anything other

than ordinary fans. In this paper, I highlight how they negotiate stadium spaces which are intrinsically sexist. There are many female fandoms which explains why women respond to sexism within the stadium in different ways. The importance of this paper is that it highlights the need for a serious analysis of stadiums in Malawi to ensure that teams attract more fans and provide an environment that makes football accessible to everyone.

Playing football and watching the game in the fan zone are considered as "gender performances". From a constructivist perspective, gender is embedded in social structures and institutions, integrated into individuals' identities and performed in social interactions. Gender is something we do, and by doing gender we create differences between men and women. Drawing on constructivist concepts, football can be understood as a gendered system and as a field in which individuals act according to gendered expectations, thus contributing to a continuation of the gender hierarchy in this sport.

Feminist approaches to gender tend to have a focus on women and to emphasise the hierarchical relations between women and men, but they often neglect the inequalities among men and among women. This perspective is taken up by Connell's (1995) early work, which explores and describes masculinity constructions, in particular "hegemonic masculinity". The football stadium provides various opportunities for doing gender, in particular for men, who can stage different forms of masculinity in an environment which is considered a male domain. In this "arena of masculinity" men behave according to society's expectations and play their "serious games" (Bourdieu, 1997; 2012) on the pitch as well as on the stadium's terraces. However, the findings of the fan studies presented above reveal that women can be football supporters, but have to negotiate and balance doing fandom and presenting femininity. In the football stadium not only the players but also the fans form communities, demonstrate abilities, accumulate capital and compete for recognition (Bourdieu, 1997; 2012). Sport-related capital has different values and meanings for both genders as the football stadium is a space where men, both the players and spectators, can be real men acquiring and demonstrating their capital on the field and in the stands. Women can also gain fan capital, but not to the same extent as men since they do not compete with men (neither on the field nor in the fan zone) and cannot participate in the "serious games", where women act merely as "flattering mirrors" (Bourdieu, 1997, 2012). The study was conducted to unveil information on how women socialized into football fandom and how they develop their identity as football fans, and how women respond to the abusive and denigrating atmosphere regularly experienced at football stadiums.

MATERIALS AND METHODS

The main sources used for this article are in-depth interviews with 38 female fans, and observations in the fan stands. However, in the findings part of the paper I also draw on the quantitative data which I collected from 273 female fans.

INTERVIEWS

In in-depth, problem-centred interviews 38 women shared with me their aims, activities and experiences as dedicated football fans. Problem-centred interviews combine deductive and inductive approaches by utilising different interviewing techniques. They provide answers to specific questions but also generate insights and understanding by promoting narrations (Witzel, 2000). I used an interview guideline derived from the theoretical approaches and results of the other studies outlined above. The questions referred in particular to the experiences of the interviewees: their opportunities and challenges as fans, their gender constructions and negotiations as women and football supporters, as well as the doing of gender of both male and female fans in the stadium. The fans also had the opportunity of sharing with me memories, problems, wishes and ideas. In addition, the interviewees filled in a short questionnaire on their demographic background which

was completed after the interview (Flick, 2006, p.163).

The interviews were taped, transcribed and processed using the techniques of qualitative content analysis proposed by Mayring (2003). As a first step, the transcriptions were coded according to the research questions and carefully revised within the process of analysis (feedback loops). In addition, new topics and categories which emerged inductively were included in the analysis and interpretation (Mayring, 2000, p.10).

To gain insights into different fan scenes, female fans of three important clubs playing in the Super League of Malawi - Big Bullets FC, Telecom Wanderers FC and Silver Strikers FC - were recruited for the interviews. A snowball sampling process was used. For the quantitative data, I approach female fans at the Kamuzu Stadium and Silver Stadium. When Bingu National Stadium opened in 2017, I attended some games there as well approaching female fans to complete my questionnaire for the quantitative aspect.

Because of the women's different forms of commitment and affiliation to different fan scenes, the interviews provide an insight into the various forms of fandom and allow different perspectives on female fans.

RESULTS AND DISCUSSION

Socialisation into Soccer Fandom

In answering the first research question, I simply asked the respondents in this study how they became fans. In short, the questionnaire simply asked them to explain how they grew to love the sport of soccer. With the qualitative approach, I simply asked my respondents to narrate how they grew to love soccer. Then I attempted to critically analyse the findings on the basis of previous research especially coming out of the global north. Drawing from the findings of the quantitative aspect of the study, several routes into soccer fandom were identified. The most prevalent routes included through close friends, through a male acquaintances (including spouse, fiancée, boyfriend, close male relative including fathers, brothers or brothers in law). Table One below ranks the most prevalent routes into soccer fandoms for the female fans responding to this study.

The findings above were confirmed through indepth interviews. Of the 273 respondents to the in-depth interview aspect of the study, seventy-four became soccer fans due to the influence of a close female friend who was already a fan. The process of bonding with a female friend always proved to the catalyst that brought someone into fandom. Witness the remarks from some respondents in the qualitative aspect of the study:

> My friend is football-mad . . . she would have the radio on whenever Wanderers were playing and I would be doing my house chores. I just wanted to find out why she was hopping around and cheering whenever Wanderers scored. She took me to Kamuzu Stadium one day . . . and that was the beginning for me. Now I am more football than she is (NM/23-04-15/15:49).

An examination of the same indicates that most of the respondents who became fans of soccer through the influence of a female friend or a boyfriend were all in the low income, self employed category (See Table One below). Thus, has will be noted later, it is safe to assume that socialization and the type of fan that a respondent became was dependent on socioeconomic status. In-depth interviews also reveal the particular ways that led to such recruitment. Witness the following remarks from the in-depth interviews:

> I used to sell zindasi close to at MDC stadium on match days . . . One to the young men who watched football there was interested in me and used to urge me to watch with him. But I did not have money. He paid for me one day, and from that point I love

> football (translated from Chichewa to English) (EP/15-03-15/10:28).

Thus, as female friends sought to bond with one another, an interest in soccer – innate or otherwise, was discovered and nurtured. Malawi seems to be unique in this respect since the literature search did not reveal such higher levels of socialization into fandom through such means.

The nuances of the first group are that the socialization into fandom is clearly based on friendship. However, a closer examination of Table One shows fans recruited in this way are of a lower socio-economic status. Most of these recruited in this way can be found in the menial employed, self-employed (lower bracket) and the domestic employed brackets.
Of course, it may not be an issue of social status; it could be an issue of age as women in the other brackets tended to be older and better educated. What is however clear here is that female fandom of football is cutting across all the age groups and socio-economic brackets observed here.

Close male relatives also played a hugely important role in the socialization of female fans into the game of soccer. However, this was more likely to happen with women who earned a lot more money or had a higher socio-economic status. Relative who were instrumental in bringing female fans into the game were mostly fathers and husbands.

As you will note from Table One above, these women tended to earn more money and hold professional jobs. Further, they are older than the brackets. However, the most important question is why boyfriends are more successful at recruiting women into soccer fandom than these close male relatives. The answer may be obtained from the findings of the qualitative aspect. Two particular findings were quite illustrative (even though not very surprising. Witness the following:

> I don't think that there is any husband who would want his wife to go and watch a soccer. Only a casual boyfriend would tolerate that . . . . No self-respecting husband would want to expose his wife to the disrespect and abuse at football games (translated from Chichewa to English) (BK/07-11-15/14:23).

Thus, Chiweshe (2014) notes, it is not just safety issues that are of concern to close male relatives. Husbands and close male relative do not want to expose there female folk to the male-centric and misogynistic atmosphere that prevails at soccer.

Women who claimed to have been recruited into football fandom by their fathers were noted that this happened when they were in pre-adolescence. This may have been an attempt by young girls to bond with their fathers by adopting their fathers' interests.

Table 1: Routes of Socialization into Football Fandom

Fan or spouse occupation and income	Close friend	Boyfriend	Husband	Father or Brother	Radio	Television	Totals
Self-employed (K300000 and above per month)	2	2	9	4	2	11	30
Self-employed (K150000 to 299000 per month)	7	15	7	8	0	13	50
Self-employed (K30000 to 150000 per month)	29	19	9	3	2	6	68
Domestic employment	18	11	0	0	9	0	38
Menial employment (K20000 to 74999 per month)	15	9	0	0	11	0	35
Clerical and technical (K75000 & above per month)	3	4	3	0	7	4	21
Professional (300000 and above per month)	0	2	13	7	0	9	31
	74 (27.1%)	62 (22.7%)	41 (15%)	22 (8.1%)	31(11.4%)	43 (15.8%)	273

In such cases, the fathers reciprocated their daughters' interests thus initiating them into female fandom of local football.

These relatives being either father or husband held powerful sway over what the women could do or could not do. In the African context women cede to the power of their fathers. These relatives being either father or husband held powerful sway over what the women could do or could not do. In the African context women cede to the power of their fathers and husbands. Thus even though our respondents fathers and husbands were primarily responsible for wetting the football appetites of their womenfolk, they assumed the oppositional role of being the gatekeeper who initially kept them away from the game of football.

Clearly, there are two reasons why these male relatives kept their wives and daughters out of the game of football. The first is safety; the second is gender roles. These two can all be placed under the overarching aspect of male hegemony. The assumption here is that football is an arena were men do masculinity; therefore, women are not supposed to attend a football game. As Heide (1978) argues, men dominate football grounds and unconsciously exercise misogyny. This makes women aliens in the football arena. Further, the exercise of masculinity in the football arena includes activities that can be deemed as unsuitable for respectable women including sexist chanting and hooliganism. Further, as Chiweshe (2014) notes, fans in the football arena will be in close and sometimes uncomfortable physical proximity. Thus, in African cultures which demand social distance between unmarried men and women, football grounds become unsuitable arenas for women. Husbands and fathers are then constrained by both culture and protective instincts to keep their women folk from football arenas (Morrell, Jewkes, and Lindegger, 2012).

As may have been noted above, a few of the respondents in this study were propelled into football fandom by the all pervading influence of mass media in particular radio and television. The foregoing quotation from an older respondent is an example of mass media acting as an influence. It is important to note that television more than radio tended to influence women into football fandom. Further, it is important to note from Table One that television tended to recruit women with high levels of income and holding a professional job. It is easy to speculate that the influence of European leagues on television such GOTv and SuperSport play an important role.

Matchday Experience

Apart from identifying the process of socialization and identity into football fandom, the study also intended to locate and analyse the matchday experience of female fans of football in Malawi. Right from the outset, it is important to note that I do not attempt to make any assumptions of the universal application of the research findings. Using theories of hegemonic masculinity and dominant femininity, I examine the stadium culture and experience through the lens of my respondents.

As noted earlier, football is essentially a male arena in which masculinity is performed to the exclusion of women. When women attempt to enter into such an arena, they have to negotiate their positioning in the stadium. The options include subsuming a male identity (which essentially means surrendering their female identity), or negotiating a compromise that permits them to perform fandom while keeping they feminine identity in place. Another position would be to use a counter-hegemonic femininity that permits them to perform fandom.

Negative Gendered Behaviour

The respondents commented on people's behavior in the stands during match day. The findings suggest that this behavior differs based on gender. One of the most important behaviours is that men were prone to drinking during games and were rowdy and on the edge of violence. Further, female fans noted that male fans were far much louder than female fans in the stands. Donahue & Wann (2009) confirm that young male fans are most likely to be dysfunctional in the stands. The respondents expressed concern that alcohol acts like fuel to fire in a competitive atmosphere which is already highly charged due to the competition.

Other behaviours that threaten the matchday experience for female fans is the use of abusive language in chants. The respondents in this study reported experiencing verbal abuse directed towards them. This happens mostly in the open stands. Respondents have been called 'mahule' (prostitutes), 'akazi opanda pake' (useless women), and 'chili pamuna, paakazi chiopa ndeu', (essentially cowardly women who are poorly socialized and unable to relate to other women, and hiding among men).

Apart from the rowdy male fans and the verbal abuse, other behavior that threatens fan females experience on match days is violence both during and after matches. Opposing fans have been known to use firecrackers to either celebrate a goal or to disrupt a match. This can, at times, result in chaos and stampedes. Violence has also been known to erupt after matches. Even female fans who watch from the VIP stands have to live with potential threat of violence.

In addition to violence, verbal abuse and general rowdy behavior, female fans also complained about physical harassment in the stands. The respondents reported unwanted physical attention including fondling. This kind of behavior is common during highly competitive games when crowds fill up the football stands. Thus, the matchday experience for women can be threatened by other fans especially men who view the stadium stands as place to perform masculinity.

My observations and the statements of my interviewees leave no doubt about the relatively high measure of misogyny at Malawian football arenas. The fan stands seem to be a "refuge of masculinity" (Marschik, 2003) and a space with its own set of values, norms and rules, where men celebrate dominance and power (Bourdieu, 2012) while women are considered intruders (Jones, 2008). Here, the principles of gender equality do not apply; rather, various forms of sexism and traditional forms of hegemonic masculinity (Connell, 1995; Connell & Messerschmidt, 2005). These findings are in line with the results of studies undertaken in other European countries and some African countries such as Zimbabwe and South Africa (Chiweshe, 2014; Daimon, 2010).

Countering Negative Masculine Behaviour

Women football fans tend to use some measures to counter negative masculine behave in order to enhance their football watching experience. The first weapon is to adopt the same behavior exhibited by men. These type of female fans tend to be just as aggressive and rowdy as the male fans. Obviously, these type of fans are the young women. These female fans believe that language and culture of football fandom was defined effectively in the past by male fan behaviour. In this respect, other female fans who cannot adapt and adopt to this culture tend to be viewed as less than true football fans and should stop attending games.

Women who incorporate masculine behavior to counter negative masculine behaviour are very much part of the hardcore fan groups of different teams. There are also in the lower socioeconomic status groups. They are not at all disturbed by male fans rowdy behavior and verbal abuse. In fact, they join in the male fans verbal abuse and rowdy form of supporting their team. Thus, as Chiweshe (2014) argues, this type of fans has taken up the role of football fan and immersed in the masculine nature of football fandom. Caudwell (2002) argues that these type of female fans subvert the accepted societal norm that prescribes more sedate roles to women. These women then employ a stance that is counter to the dominant femininity by adopting and practicing masculinities.

Female Fans who have Abandoned the Stadium for the Television

Another way of dealing with the misogyny in football stadiums was to stay away completely from the stadium. These women still love football but can no longer deal with the violence and misogyny. This type of fan is generally older or socioeconomically advanced. In in-depth interviews, the respondents noted the following:

> You only have one life . . . it was clear to me that going to the games made me vulnerable to violence.
> FAM and SULOM have failed women . . . . The stadiums are filled with hooligans and nobody cares. I do not even think that the police have will or ability to impose security in the stadiums.

Such fans prefer to watch football on television or listen to the radio. Staying away form stadiums is silent protest in which these women withhold their money depriving football of much needed cash. Whether football administrators will listen to this protest is yet to be seen.
Staying away from games has thus done very little for women who wish to change fan cultures. What is clear is that misogynistic language has been accepted as part of football culture. It is engrained within the psyche of male fans (Chiweshe 2014, 18):

> Women who love football are forced to suffer on in silence. Complaining is met by accusations of being 'fake fans' by male counterparts. To be accepted female fans have to accept masculine norms within stadiums. Boycotting the stadium is thus the only option for women who cannot ignore or participate in fan cultures.

CONCLUSION

Two key strands can be examined from the findings presented in this study. First, when women subsume masculinities when doing fandom, they trivialize sexism. As Bourdieu (1997; 2012) argues, the trivialisation of sexism by female fans is surrendering to the emblematic power of hegemonic masculinity. It is this power, which presents them from being football fans unless they accept the misogyny and violence which are an integrating part of football culture in the stands. These female fans have unconsciously incorporated the structures of male domination which are seen as the natural order in the stadium. Women then internalize the male hegemony position. Male hegemon is part of the socialization process into football fandom. Male hegemon acts as a gatekeeper to female football fandom. Those who accept the dominant power position of masculinity are socialized into fandom while those resist are either kept out or kicked out of the stadium which are the arenas for the performance of masculinities.

In keeping with this power relationship, the women fans accept misogyny and violence in order gain football fandom. Thus, they either participate in actual or symbolic violence in order to establish authentic fandom for themselves. This act means that female fans actually become accomplices in their oppression by a misogynistic male fan base.

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Factors Affecting the Participation of Girls in Technical Colleges in Malawi: Case of Don Bosco Youth Institute

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ABSTRACT

Technical Education, Vocational and Entrepreneurship Training Authority (TEVETA) in Malawi promotes equitable technical, entrepreneurial and vocational training programmes to all learners by among other things ensuring that conditions are attractive to girls' participation in TEVET programmes. Despite several efforts by the Malawi Government and other developmental stakeholders, the participation of women in automobile mechanics remains relatively low. The aim of the study was to explore factors that contribute to low participation of girls in technical and vocational education in Malawi, case of Don Bosco Technical Youth Institute especially in Automobile Mechanics course. The study used qualitative research methodology; the design is a case study, which was held at Don Bosco Technical Youth Institute, at Auto-mobile mechanics department. Data was collected using in-depth interviews (IDI) which was conducted to instructors in Auto-mobile Mechanics department. Semi-structured questionnaires were administered to collect data from students studying Automobile Mechanics and review of prescribed text books in Auto-mobile mechanics, and non-probability sampling technique was implored. It was guided by the "Holland's career choice Theory".The study revealed that the girls' participation in automobile mechanics at the institution is low. The overall girls' participation was 13 out of 131 auto-mechanics students representing 10%. The study identified several factors that hindered girls' participation in Automobile Mechanics which included negative peer pressure, stereotyping perception against automobile mechanics that women cannot participate in the course. Lack of motivation from the institution as there are no incentives for girls pursing automobile mechanics, lack of career guidance and counseling as well as lack of female role models contributed to low girls' participation in automobile mechanics. The study further revealed that all instructors have never attended training in pedagogy and that only 25% of the instructors are female in Automobile mechanics department. Some textbooks were promoting males than females in terms of appearance, for effective teaching and learning to take place the teaching and learning materials have to be gender responsive

.

The study therefore recommended for public sensitization campaigns to change the stakeholders' perception, encourage career guidance to girls, use of role models starting from secondary schools.

Keywords: Pedagogy; Gender-sensitive; Gender; Gender stereotype; Feminism; Career choice; Empowerment.

INTRODUCTION

Education is the hub of development in each and every country. The current vision of the education sector in Malawi, as outlined in the National Education Sector Plan (NESP), 2008-2017 is to be a catalyst for socio-economic development, industrial growth and instrument for empowering the poor, the weak and the voiceless. In terms of equity and access, the goal of education sector in Malawi is to improve the participation of girls and women, children with special needs and other

disadvantaged youths. Similarly, one of the pillars of Technical, Vocational, Education and Training (TEVET) in Malawi is to ensure access and equity in technical education in Malawi according to TEVETA annual report 2014-2015, the total enrolment for 2013 was 947 of which 936 (77.7%) were boys and 211 (22.3%) were girls. In 2014, the total enrolment was 1283 of which 889 (69.3%) were boys against 394 (31.7%) girls. While in 2015, of the total enrolment of 1084, 780 (72%) were boys and 304 (28%) were girls to TEVETA strategic plan 2013-2018. However the number girls enrolling in technical colleges are relatively lower than boys (TEVETA, 2013). The reasons for underrepresentation of girls in technical subjects are related to gender responsiveness. Gender responsiveness refers to taking action to correct gender bias so as to ensure gender equity and equality (Mlama, 2005). A gender responsive school is one in which the academic, social and physical environment and its surrounding community take into account the specific needs of both girls and boys. Chemba (2008) concurred that gender-responsiveness strengthens the life skills-based educational processes by making participatory teaching and learning methods more complex and equitable to both boys and girls.

A study conducted among senior secondary school students in Benin, Edo state, in Nigeria found that sex, parental, peer influences, social and cultural stereotyping were the major factors affecting gender inequity in the choice of careers in science and technology. The study found that less than 40% of the girls indicated interest in science and technology subjects even though they had the ability compared to 60 % of boys. (Oduh & Okanigbuan, 2014)

Hoffmann-Barthes (1999) observed that the nature of the job market is changing, and women and girls can no longer rely on the traditional, limited range of occupations. With the increase in the number of technical occupations, women will continue to suffer from unemployment, unless they have the ability to access them.

THEORETICAL FRAMEWORK

According to the Holland career choice theory, career choice is an expression of one's personality, members of an occupation have similar personalities and similar histories, where these remembrances are mounted to the six personality types, namely Realistic, Investigative, Artistic, Social, Enterprising and Conventional (Holland, 1997) . Each personality type has characteristics set of attitudes and skills to use in response to problems encountered in the environment. Theses encompasses preferences for vocational and leisure activities, life goals and values, beliefs about one self, and problem solving style. These develop as a product of characteristic interaction among a variety of cultural, personal forces including peers, biological heredity, parents, social class, culture, and physical environment. Thereafter, these experiences lead to an individual prefers some activities over others, the preferences then develop into strong interests, which lead to related competencies. These individual's competencies form specific disposition that allows the individual to think, perceive, and act in special ways, (Holland, 1997). Krumboltz (1994) identified Genetic endowment, race, gender, physical appearance and characteristics of an individual as some of the things which are taken into consideration when one is choosing a career. The other factors he cited is includes social, cultural, political, economic forces natural forces and natural resources that surround an individual and that the person has no control over them. He further observed that unique history of learning experiences by an individual doesaffect their occupational choice. They often don't remember the specific character or sequence of these learning experiences, but rather they remember general conclusions from them for instance, "I love animals" or "I love working with children". One of the pillars of TEVET in Malawi is to ensure access and equity in technical education in Malawi according to TEVETA strategic plan 20013-2018. (TEVETA, 2013) among other things provide conditions attractive to girl participation in TEVET programmes. However, the girl participation in technical and vocation training in Malawi remains low. From the TEVETA annual report 2014-2015, the total enrolment for 2013 was 947 of which 936 (77.7%) were boys

and 211 (22.3%) were girls. In 2014, the total enrolment was 1283 of which 889 (69.3%) were boys against 394 (31.7%) girls. While in 2015, of the total enrolment of 1084, 780 (72%) were boys and 304 (28%) were girls. Generally, the gender disparity is worse mainly in Mathematics and Science related subjects where men are more enrolled than women. For example in 2015, of the total 103 automobile students enrolled, 77 (74.7%) were boys and 26 (25.3%) were girls. Of the total 16 vehicle body repair students enrolled 14 (87.5 %) were boys and 2 (12.5%) were girls. Of the total 142 administrative students enrolled majority were girls 95 (67%) while boys were 47 (33%). Despite all the efforts from the government and stakeholders, the representation of girls and women in technical and vocational courses remains low. The researcher wanted to find out if the pedagogy used in our technical colleges has a hand in the low participation of girls and women in Auto-mobile Mechanics course. The study was conducted in order to establish female enrolment trends in Automobile and Mechanics Course at Don Bosco Youth Institute, establish factors those contribute to female low participation in Auto-mobile Mechanics at Don Bosco Youth Institute and identify strategies on what can be done to encourage girls participation in Auto-mobile at Don Bosco Youth Institute.

THE STUDY METHODOLOGY

The study employed qualitative strategy with a case study approach. The study was conducted at Don Bosco Youth Technical Institute, a TEVETA accredited institution located in Lilongwe, Malawi. Semi-structured interview guide, structured document review tool and semi-structured questionnaire were used for collecting data. The in depth interviews to deeply explore the point of view, feelings and perspectives of four instructors teaching in Auto-mobile Mechanics. All students, both male and female participating in auto-mobile mechanics were interviewed responded questionnaires. Four automobile text books were reviewed to find out if they were gender sensitive.

The study used purposive sampling technique. All the students studying Auto-mobile Mechanics and four instructors in Auto-mobile Mechanics Department during the time of the study were included in the study. All in-depth interviews for the four instructors were recorded. Qualitative data was transcribed into text. Themes and categories were subsequently generated. The girls interviews data was entered in excel database and pivoted table was produced. The findings were presented in tables and graphs. The automobile mechanics text books were reviewed. Each book was reviewed page by page to identify gender portrayed words and pictures. These were entered in the excel sheet Microsoft 2007 and analysed as female and male portrayed.

RESULTS

A total 131 students were enrolled for automobile mechanics at the time of study of which 118 were male and 13 female. There were 131 questionnaires which was dispatched for respondents, 125 were dully filled and returned representing 95% return rate. The gender of the respondents was sought since its findings would assist the study categorize respondents based on gender. Students were asked to indicate their sex, age and the level of their studies. The questionnaires were completed by 125 students with 114 male and 11 female who are pursuing auto-mobile mechanics in all the three levels of the course at the institution. There were 64 students (60 male and 4 female) in first year, 42 students (36 male and 6 female) were in second year and 19 students (18 male and 1 female) were in third year. These students were aged between 17 and 30. The ages were categorized as 17- 20 years with 63 responses (50%), 21-25 years with 35 responses (28%) and 26-30 with 27 responses representing 22%. The study found four instructors in auto-mobile mechanics department. Of the four, two teachers had Diploma in automobile mechanics, one had Diploma in Mechatronics and the other had Diploma in auto crafts. None of the teachers had a qualification in education let alone having training in pedagogy of education. Subjects being offered in automobile mechanics included the following; Mathematics, Technology, Entrepreneurship and Technical drawing.

What encouraged students to study Auto Mobile Mechanics?

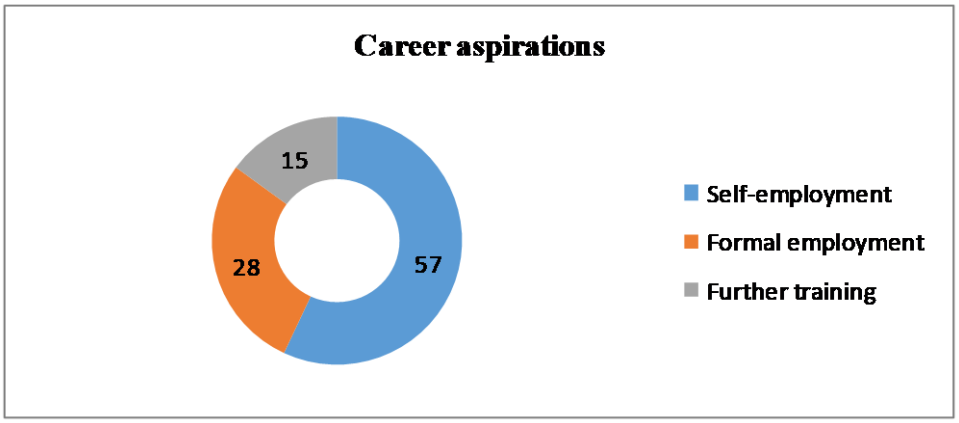
Table 1: below shows who encouraged the students to study automobile mechanics

Variable	No.	%
Friend	50	40
Teacher	24	19
Parent/guardian	35	28
Own interest	16	13

Table 1 shows that majority of the students 50 out of 125 representing 40% were encouraged by friends to study automobile mechanics. 35 (28%) of the respondents indicated that they were encouraged by either parents or guardians. 24 (19%) of the respondents were encouraged by teachers whilst the other 16 (13%) joined the courses on their own interest.

Career aspirations of students

Figure 1: below career aspirations of students in percentages



The figure 1 above shows that 71 out of 125 respondents representing 57% choose entrepreneurship as their second step after successfully completing their course at Don Bosco. 35 respondents indicated that they want to get employed after completion of their course; this is representing 28% of the respondents. The remaining 18 respondents' dream of continuing with their training may be to degree level, this had 18% representation.

What are some of the factors that hinder the participation of girls in Auto Mobile Mechanics?

Table 2: below shows factors that hinder the participation of girls in automobile mechanics

Factor	No.	%
Traditionally for men	60	48
It is tiresome	58	46
Negative peer pressure	71	57
Lack of learning materials	2	2
Lack of career guidance talk in secondary schools	32	26
Women not allowed to work in some companies	5	4
Girls inferiority	76	61
Husbands resistances	1	1

Table 2 above shows that majority of the respondents 60 (48%) thought that girls do not participate in automobile mechanics / technical courses due to the belief that automobile mechanics or technical courses are traditionally for men. Most respondents 58 (46%) also attributed low participation in technical courses or automobile mechanics to the fact that the course it is tiresome as it involves manual work which makes them to feel the course is masculine. A female respondent said that studying automobile mechanics is challenging to girls in a such way that pursuing Automobile mechanics needs extra time sometime she hardly finds time for her hair, make-up and not to talk of manicure and pedicure. She mentioned that she grew up playing with dolls and bright colours but this is not found in the Auto mobile mechanics where all she thinks and dreams about is tools box, workshop and being dirty. Another 32 (26%) respondents mentioned that lack of career guidance talk in secondary school is also contributing to the low female participation in automobile mechanics. One of the respondents said that there is no career talk in most of the secondary school as such most students leave secondary school without knowing what to do next. 71 respondents (57%) indicated that negative peer pressure also contribute to low participation of girls in automobile mechanics or technical courses. A good number of the respondents 76 (61%) mentioned girls' inferiority as a reason for low girls' participation in the course. The least factors that were identified by the respondents included women not allowed to work in some companies was mentioned by 2 respondents representing 2%, and 1 respondent mentioned that some husbands restrict their wives to join the profession with a representation of 1%.

The in depth interview of the instructors revealed that low participation of girls in automobile mechanics is attributed due to belief by parents and girls that automobile mechanics (technical courses) are for boys not girls. The other factor that came out very strongly was that girls do not take science subjects or do not work hard in science subjects at secondary school level which are usually pre-requisite to enroll and do better in automobile and technical courses. Lack of encouragement by school to motivate girls to purse automobile / technical courses was also mentioned by most of the teachers. Other instructors also attributed low participation of girls to technical courses to lack of incentives for girls to motivate them to pursue automobile mechanics. Some instructors also thought that selection criterion into technical courses favours men that women and there is no deliberately effort to select more girls.

What can be done to promote girls participation in automobile mechanics?

Table 3 below shows suggestions from the respondents of what can be done to promote the participation of girls in automobile mechanics.

Suggestion	**No**	**%**
Put women in high positions		18
Provide motivation such as allowances/sponsorship	72	55
Liaise with companies to employ more women in Auto Mobile	47	36
Community sensitization / carrier guide	96	73

Table 9 above shows that majority of students 96 out of the 125 representing 73% indicated that girl's participation in technical courses/ automobile mechanics can be increased by providing career guide to girls while in secondary or primary schools. The other strategy which was suggested was by provision of motivation incentives in the form of sponsorship or awards to girls studying the course; this was nominated by 72 respondents representing 55%. Whilst 47 respondents representing 36% mentioned that liaising with companies to employ more women from auto mobile mechanics could also increase access and participation of girls in technical courses / automobile mechanics. Some 24 students representing 18% suggested that girls participation in automobile mechanics can be increased by putting women in high positions related to automobile mechanics could inspire many girls to participate in the course as role models**.**

Gender-imbalance portrayed pictures, characters and occupations

The textbooks showed the first male character on the third page in technology book and first female character appeared on page 7. While in Entrepreneurship book first male character appeared on page 2 and female character appeared on page 6. No male and female characters are mentioned in mathematics and technical drawing books. The books further showed more and powerful male characters occupations and activities included manufacturer, tractor maker, motoring, floor cleaning, clean and store, panel beating, weight lifting and painting in technology and fish selling for female character in technology. The male occupations which were identified in entrepreneurship included decision making, technological, inspector, baby caretaker and receptionist, athlete, beautician, baby caretaker for female occupation and activities. There were 22 pictures which portrayed male characters and only one picture portrayed a female character in Technology book. In the technology book the woman was shown as a receptionist of a business directors office and male characters was shown as doing some mechanical works, fire fighters, manufacturer, Tractor maker, Motoring, Panel beating, Weight lifting, inspectors, technological, executive managers and painting, While in Entrepreneurship book there were 169 pictures for male and 33 for female. The pictures portraying female character in entrepreneurship book was showing a woman in a kitchen putting on an apron, selling fish, baby caretaker, beautician and decorator while those for male characters were showing men in serious business meeting and some pictures showing men as directors of big business entities. There was no picture portraying male and female character in Technical Drawing and Mathematics.

DISCUSSION

The study found that there was low number of girls participating in automobile mechanics at Don Bosco Youth institute. The results further showed the low representation of girls at the institution is even wider as you go up the classes of study. From the in depth interview with teachers, most of them graded the performance of girls as mostly average and at times below average. The study also noted lack of capacity of automobile instructors in pedagogical training as none was trained as teachers. This might have a negative impact on the instructors' ability to apply gender sensitive pedagogic skills to motivate girls' participation.

The major findings on the factors contributing to the low participation of girls in automobile Mechanics from the girls interview were the belief that automobile mechanic is for men not women and career guidance, peer pressure. Mustapha (2008) reported that demand of high physical and mental ability and peer pressure as factors that hinder female students from taking certain technical fields.

The other factors that were identified by this study-included woman not allowed working in some companies and husbands resistances to allow their wives study automobile mechanics. These results complement first major finding of negative believes that automobile mechanics is mainly for men. Some companies believe that women cannot demonstrate desired skills to meet company's demands and expectations. Mgaru (1999) identified negative attitude of industrial managers towards trainees and qualified females in practical attachments and job recruitment demotivate girls from participating in technical courses. This stereotyping behavior is hazardous to the development of girls' education. This will lead to girl student developing low self-esteem as to development of skills to perform the desired work. This can even have an indirect negative impact to instructors as they may undermine girls' capabilities in the end affecting classroom management.

Our study found some gender imbalance in both Entrepreneurship and Technology textbooks. The study that they were more male characters than female characters in in both Entrepreneurship and Technology textbooks. Technology textbook showed that first male characters appeared on third page compared to 7th page of first female character. The Technology text book had also more

pictures depicted male characters (15) compared to pictures depicted female characters (1). This agreed with Mlama et al. (2005) who explained that personality attributes portrayed in textbooks are consistent with traditional societal notions of male superiority and authority.

One of this study major finding from the teachers' interviews was that female student's participation in automobile mechanics can be improved by providing career guide right away from secondary or even primary school. Career guide aiming at encouraging girls to work hard in mathematics and science subjects will help to make sure that more girls quality and participate in automobile mechanics. The other strategy that was identified was provision of incentives / sponsorship to girls participating in automobile mechanics to motivate them. The institution management system is not gender-responsive, this was evidenced by lack of encouragement by school for girls to participate in automobile mechanics as there is nothing assigned to girls motivation. Even the instructors are not trained in gender responsive pedagogy as such there might be a gap on how well to handle gender issues at the institution or during classes. Putting women in high positions related to technical field was also mentioned as another strategy. These women could be row models to girls; however, the institution had only one female instructor in the auto mobile mechanics department which cements the gender blindness the institution has. One of the teachers also suggested that making curriculum gender sensitive could be one way of improving female student's participation in automobile mechanics. As evidenced by the text books reviewed the curriculum of automobile mechanics is full of pictures and occupations promoting stereotype. If the curriculum could be reviewed and make it gender sensitive that could motivate female students.

CONCLUSION

It is very clear that low participation of girls in technical colleges in Malawi is contributed mainly by general negative stereotype about girls attributed by girls themselves, parents, general public and even corporate partners, they believe that technical courses /automobile are traditionally for men and there is need to change the perception through sensitization campaigns and career talks. The other recommendation was that there is need for career talks and career guidance campaigns from secondary school where most students make career choice decisions. The corporate world should also be sensitized that female students are as good as male students; it is very demotivating for some companies to be shunning away from recruiting female interns for practical. The government should also consider introducing some awards and scholarships for female students pursing automobile mechanics. This might attract more female students and will support increased participation in automobile mechanics / technical training.

There is need to review teaching and learning materials to make them gender sensitive so that they motivate all categories of people. The books should have pictures which represent male and female characters equally. The occupations mentioned in the books should portray balanced occupations. Some of the books which were reviewed portrayed were gender imbalance as more paying occupations were associated with male characters for example executive managers, manufacturers and fire fighters whilst females characters were portrayed as fish sellers and receptionists. There is need to mix up these characters and harmonize on the characters and pictures portrayed.

Developmental partners have also a task to promote girls participation in automobile mechanics through support post training employment support services for girls graduated from automobile mechanics/ technical training. Deliberate efforts may attract more girls to take up automobile mechanics. The corporate world can also support gender related capacity building to technical college instructors and college management staff financially. This may enable teacher to become qualified through capacity building trainings in pedagogical studies for effective teaching and classroom management which will in turn/ motivate girls to enroll in automobile mechanics. Help to identify and support disseminating best practices aiming at motivating girls' participation in automobile mechanics/ technical training. The

corporate world can also support TEVET advocacy initiatives and motivation campaigns to encourage girls' participation in automobile mechanics / technical training.

Colleges should provide opportunities for industrial attachment and internship for girl's trainees and support them to acquire the desired skills to compete effectively on the labour market. The girls should be encouraged by recruiting them and provide them with opportunities for higher positions to act as role models. This might encourage more girls to enroll into automobile mechanics.

Institutions and instructors also have a role to play to promote girls participation in automobile mechanics. This could be by providing deliberate efforts to motivate girls to participate in automobile mechanics/ technical training for instance provision of awards or scholarship to good performing females in automobile mechanics.

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Assessment of informal cross border fish trade in the Southern African Region: A Case of Malawi and Zambia

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ABSTRACT

Intra-regional fish trade has the potential to addressing the region's food and nutrition insecurity, and poverty reduction through wealth creation. It has however, been overlooked and neglected in national and regional policy thereby leading to rampant informal fish trade. This paper examines cross boarder informal fish trade in Malawi and Zambia, unlocking the demographics of the 1068 informal traders along the borders and analyzing the factors influencing decision to practice informal trade and use informal trade channels. The study also identifies the fish species traded informally with their associated volumes and value and lastly analyses the socio-economic and institutional factors influencing trader's decisions to use informal trade routes. The results of the study show that the key species involved in informal cross-border trade are the small pelagics, the unawareness about the policies guiding the cross-border trade makes traders use informal routes and also the traders were put off by the cross-border trade regulations. The study recommends that there is need to for countries in the SADC region to regularize and formalize cross-border trade in small pelagic fish species since this species plays a great role in the livelihoods and food and nutrition security of many people in the region, especially the rural and urban poor. It is also important for governments to support processors and traders to improve the quality of fish being traded; enhance access of traders to cross border fish market information; decentralize issuing of the import/export certificates and other cross-border support documents; and enhance informal trade monitoring systems to adequately quantify the volumes and trade flows.

Key words: Informal trade, fish, small pelagic species, Malawi, Zambia

INTRODUCTION

Africa's participation in the global fish trade is fairly limited and represents approximately 4.9% of total value of commodities traded. By value, Africa was a net exporter since 1985 (except 2011), reflecting the lower unit value of imports mainly for small pelagic species (FAO, 2016). In addition to limited global participation, Africa's capacity for intra-regional trade is also low. As a result, official intra-African trade was just 11% of the continent's total trade between 2007 and 2011 (UNCTAD 2013[20]). While Africa is losing shares in the global markets, and trading relatively less with itself, intra-regional trade in fish is encouraging, reported to be 24% between 2010 and 2012

[20] United Nations. 2013. Economic Development in Africa Report 2013: Intra-African trade, unlocking private sector dynamism

(FAO, 2014). Consequently, fish was reported to be the second most traded agricultural commodity intra-regionally, after sugar (UNCTA, 2013); and recently, WTO[21] cited cotton, coffee and fish to be among agricultural commodities with export potential. Despite the potential of intra-regional fish trade in addressing the region's food and nutrition insecurity, as well as poverty reduction through wealth creation, this type of trade is often overlooked and neglected in national and regional policy. While the last 50 years has seen an increase in the role of marketed surplus from artisanal fisheries within capitalist economies, the inherent complexity of artisanal fisheries makes it difficult to understand their specific relevance to an area's livelihoods and food Security (Abbott et. al, 2015). As a result, intra-regional fish trade has largely remained informal, with low volumes traded by artisanal and small – medium enterprises, most of which are headed by women.

Concerned about the low level of intra-regional trade, the African Union Heads of State and Government, during their 23rd Ordinary Summit in Malabo, Equatorial Guinea in June 2014 (also known as Malabo Declaration)[22], committed themselves to triple, by the year 2025, intra-African trade in agricultural commodities (including fish) and services. With regard to fisheries, the Heads of State further expressed their concern "over the limited value addition in fisheries and aquaculture coupled with the high level of post-harvest losses especially in small scales fisheries, and the absence of specific financial mechanism to support SMEs". Subsequently, part of the Malabo Declaration included endorsement of the AU Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa; and committed themselves to "accelerate trade by developing fish value chains, promoting responsible and equitable fish trade and marketing in order to significantly harness the benefits of Africa's fisheries and aquaculture endowments".

Fish and fishery products are ranked among the most traded food commodities globally, with developing countries accounting for the bulk of the world's fish exports[23]. Fish and fishery products exported from developing countries comprise 20% of all agricultural and food processing exports. According to the FAO "State of the World's Fisheries and Aquaculture", it is estimated that world trade in fish and fishery products has grown significantly also in value terms, with exports rising from US$8 billion in 1976 to US$148 billion in 2014, at an annual growth rate of 8 percent in nominal terms and 4.6 percent in real terms (FAO, 2016). In 2014, fishery exports from developing countries were valued at US$80 billion, and their fishery net-export revenues (exports minus imports) reached US$42 billion, higher than other major agricultural commodities (such as meat, tobacco, rice and sugar) combined (FAO 2016).On the whole, it has been observed that the global demand for fish is increasing (Shortte, 2013).

Information on the informal cross border fish trade is scanty (Kachere, 2011, Dec, 2008) though trade in fish and fish products is becoming increasingly important for most country's food security and economic development. However, informal fish trade, just like all informal economic activities, has been overlooked and neglected in many national and regional policies, leading to obscurity of such an important part of the fisheries sector. Due to lack of information on the value of informal fish trade it is hard to quantify the total real value of trade as a result the value of fish trade is overlooked and neglected in national policies leading to less attention to the sector as figures are way less than actual situation on the ground. The study therefore, tried to examine the situation in the cross boarder informal fish trade in Malawi and Zambia with neighbouring countries to understand the traders' demography and also to uncover unfilled demand in the cross-border markets, quantify the amount of fish going informally and outline the factors influencing traders to use informal trade channels for policy support. The study is part of the *Improving Food Security and Reducing Poverty through intra-regional Fish Trade in sub-Saharan Africa (Fish Trade*

[21] World Trade Organization. 2014. World Trade Report 2014.
[22] African Union Commission. 2014. Malabo Declaration on accelerated agricultural growth and transformation for shared prosperity and improved livelihoods. Doc. Assembly/AU/2(XXIII).
[23] Food and Agriculture Organization, State of World Fisheries and Aquaculture, 2012

Program), being implemented jointly by WorldFish, two African Union institutions (AU-IBAR and NEPAD Agency). The program was funded by the European Union (EU), following the Malabo Declaration.

MATERIALS AND METHODS

The trade survey targeted 1068 respondents comprising both men and women across seven formal border posts for both Malawi[24] and four for Zambia[25]. These border sites were selected mainly because of their relative importance in fish trade activities and they are the official border posts for Malawi and Zambia with their neighbouring countries. Both quantitative and qualitative data were collected through household interviews with the informal traders, and key informant interviews with the border post fish inspection and revenue collection officers. Snowball technique was used in sampling out the informal fish traders within the border posts as proposed by Cornelius (1982). The advantage of this sampling method is that it is appropriate to use when the members of a population are difficult to locate where it allows reaching populations that are inaccessible or hard to find (Ama *et.*, al, 2013). In this case the few members of the informal fish traders were located and interviewed, and then those were relied to provide information needed to locate informal trade routes (channels) used and other fish traders that use informal channels whom they know. The local people were engaged in data collection since they have the contacts with informants which gave an opportunity to establish the confidence of informants, and also the locals were perceived to possess rich information on the political context of the area as suggested by Ellis and MacGaffey (1996.

Data analysis was done using SPSS (version 22) and Microsoft Excel. Descriptive statistics such as percentages, frequencies and means were used for summarising and presenting data from informal cross border fish trader's surveys. Probit regression model was used to assess socio-economic and institution factors influencing the motive for fish traders to participate in the informal cross border fish trade. The model was specified as follows;

$$y = \beta_0 + \beta_1 X_i + \varepsilon_i$$

Where; $\boldsymbol{y}$ is binary; 1 (participate) and 0 (otherwise), $\boldsymbol{X}$ is a vector of explanatory variables (Occupation, age, gender, source of fish, form of fish, transport mode across border, price of fish in cross border markets, time period, operational cost, knowledge of policies guiding informal trade, political dynamics between two countries), $\boldsymbol{\beta}$ is a vector of coefficients to be estimated, and $\boldsymbol{\varepsilon}$ is a random error.
Annual trade volumes and values were estimated by using the following formula suggested by Ackello-Ogutu, (1996);

$$ATV = M\,N \left[\sum_{i=1}^{n} Qd\,i\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

$$ADTV = {\left[\sum_{i=1}^{n} Qd\,i\right]}\Big/{J} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

$$AV = M\,N \left[\sum_{i=1}^{n} Qd\,i\right] P \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (iii)$$

[24]Target border posts in Malawi: Malawi-Mozambique border (Nsanje, Muloza, Mwanza, Mangochi), Malawi-Mozambique border transit to South Africa (Dedza), Malawi-Zambia (Mchinji), and Malawi-Tanzania (Songwe)
[25]Target border posts in Zambia: Zambia-DRC border (Kasumbalesa); Zambia - Namibia border (Katimamulilo); Zambia -Tanzania border (Nakonde); and Zambia/Mozambique/Zimbabwe border (Luangwa)

Where; ***N*** is the days in a month a trader exported or imported fish from or to the market; ***M*** is the number of months in a year during which a trader exported or imported fish; Q_d is the quantity of fish exported or imported per day; ***J*** is the total number of day's data was collected; P is the average price of fish per unit; ***ADTV*** is average daily trade volume; ***ATV*** is annual trade volume; ***AV*** is annual trade value; and ***i*** is the trader index

RESULTS AND DISCUSSIONS

Demographics of the informal traders shows that both the youth and elders take part in informal fish trade with the minimum reported age of 15 years and maximum of 72 years a clear indication that fisheries and aquaculture sector plays an important role in providing a source of livelihood to all age groups in Malawi. In both Malawi and Zambia, informal fish trade was dominated by female traders accounting for 65.7% and 52.1% respectively. This is an indication that women plays a major role in informal fish trade in the two countries conforming the figures reported by Economic Commission for Africa, (2010) where in Benin, women accounts for 80% of those involved in informal trade and also the figures were reported to reach 95% for informal marketing of unprocessed goods and also the United Nations Development Fund for Women (UNDFW) report, which reported that, in the SADC region, women constitute about 70 percent of the informal cross border traders and nearly 60 percent of informal traders in the Western and Central parts of Africa (UNDFW, (2009); (Afrika and Ajumbo 2012). Informal traders from three distinct nations were interviewed in Malawi where 93.7%, 6% and 0.3 were Malawians, Mozambicans, and Tanzanians respectively. For Zambia, traders involved in informal fish trade were Zambians (79%), Namibians (11.5%), Congolese (7%), Zimbabweans (1.7%) and South Africans (0.7%) (Table 1).

Table 1: Demographics of informal fish traders

	Variable	Zambia (n=286)		Malawi (n=782)	
		Frequency	**Percent**	**Frequency**	**Percent**
Age	15-29	31	10.8	201	25.7
	30-39	197	68.9	422	54.0
	40-49	41	14.3	128	16.4
	50 above	17	5.9	31	4.0
Gender	Male	137	47.9	268	34.3
	Female	149	52.1	514	65.7
Nationality of traders	Malawi	-	-	733	93.7
	Mozambique	-	-	47	6.0
	Tanzania	-	-	2	0.3
	Zambia	226	79.0	-	-
	DRC	20	7.0	-	-
	Namibia	33	11.5	-	-
	South Africa	2	0.7	-	-
	Zimbabwe	1	0.3	-	-
	Non response	4	1.4	-	-

''-''Denotes Not Applicable

Malawi informally trade fish with its immediate neighbouring Mozambique, Zambia and Tanzania Between 2015 and 2016, annual informal fish exports from Malawi to these countries was estimated at 24,115.68 metric tonnes valued at 41.6 million dollars which outstrips informal imports by 9,633.84 metric tonnes. By destination, Mozambique was the major importing country which informally imported 16,584.48 metric tonnes with the same period valued at 28.8 million dollars. Zambia comes second importing an estimated 11,399.20 metric tonnes valued at 21.6 million dollars and Tanzania imported 2,820 metric tonnes informally valued at 8.2 million dollars.

Amongst the fish species exported informally, Usipa (*Engraulicypris sardella)* a small pelagic species from Lake Malawi was the most traded fish species where an estimated 20,923.84 metric tonnes valued at 37.9 million dollars was exported was exported to all the three neighbouring countries (Mozambique, Zambia and Tanzania). This phenomenon correlates with the production levels for Usipa which accounts for 70% of the catches from Lake Malawi (GoM, 2014). The other fish species informally between Malawi and her neighbouring countries were Matemba *(Barbus paludinosus),* Utaka (*Copadichromis species),* Chambo (*Oreochromis spp.),* Mlamba (*Clarias gariepinus),* Ncheni (*Rhamphochromis spp),* Mbaba (*Buccochromis spp.),* Njole (*Labeo altivelis),* and Makakana (*Oreochromis mossambicus,* Bakayawo (Unidentified), Chikowa (Unidentified), Jamison (*Diplotaxodon argenteus),* Carapau (*Scomber* spp.), and Prawns (*Penaeus monodon*). The findings shows how important the small pelagic fish species are to the ever growing population of the sub-Saharan Africa suggesting the immediate needs to sustainably manage the small pelagics in our water bodies.

For the case of Zambia, from the four border posts where the fish trade survey and border monitoring were undertaken for 2015/2016 an estimated 102,263.9 metric tons of fish valued at 3.3 million dollars were informally traded between Zambia and her neighbours. Of the 102,263.9 metric tonnes of fish, 95% (97,119.06 metric tons) with an estimated value of 3.1 million dollars were informally exported to DRC through Kasumbalesa border (Zambia/DRC) (Table 6) and the possible explanation to that is the escalation of civil conflict in DRC which has severely damaged local livelihood systems including farming resulting in high demand for food items hence providing opportunities for trade according to FEWS (2015). The official national statistics show that Zambia is a net importer of fish commodities. For example, in 2015, statistics show that Zambia imported 77,199.2 tons of fish while exported 334.3 tons (ZRA, 2015). However, fish trade study findings indicates that Zambia imports fish which is then re-exported to neighboring countries and mostly through the informal trade channels. Despite huge quantities of fresh sea fish is landed in Zambia every year, almost 99% of it ends up in the DC Congo by informal trading through Kasumbalesa border post. This situation has arisen due to political instability in the DR Congo in the past few years of which most traders are not willing to take the risk (Department of Fisheries, 2017).

Among the fish species traded informally in Zambia are Tilapia (*Tilapia spp.*), Baibai, Bottle fish (*Mormyrus longirostris*), Buka-buka (*Lates stappersii),* Catfish (*Clarias gariepinus),* Horse mackerel, Popa (*Haplochromis spp.*), Tiger fish (Hydrocynus vittatus*),* Kapenta (*Clupeids species),* Makombo (*Serranochromis spp.),* Tomso, and Chinyonge (smoked *Lates stappersii).* Again Dagaa (*Rastrineobola argentea),* a Lake Tanganyika pelagic species was the most traded fish species. It was learnt from the fish trade survey that Tilapia is imported from China which lands in Zambia as its final destination, however, the fish is then re-exported to other countries mostly through informal trade routes.

Figure 1: Some of the fish species traded informally; Salted and sundried Kapenta (left), and Frozen Chinese Tilapia (right)

Results of a probit model that was run to examine the factors influencing the trader's decision to either participate or not in the informal cross border fish trade reveals that knowledge of policy regarding informal trade and number of people involved in the fish supply chain were the significant factors influencing fish traders in Zambia to use informal fish trade routes. Both factors had a negative coefficient implying a reduction in participation in informal trade in the occurrence of those factors. In Zambia, traders preferred to use informal trade routes because most of them claim to have not aware of the policies guiding the cross-border trade. Therefore, it might be deduced that once fish traders are made aware of the policies regarding cross-border fish trade, they are less likely to use informal border crossings. Also the traders are less likely to participate in the informal trade when the number of people involved in the fish supply chain increases. The likely interpretation of the inverse relationship between number of people and informal trade could be that increase in number of people involved in cross-border trade leads to increase in number of people employed in the chain, and hence indirectly increase the operation costs, leading to reduced revenue generated. Alternatively, this could also mean that large traders involved in the trade flood the markets and depress the prices, and again leading to reduced revenues. Abbot et al (2015) also reported that the rise in the number of fish vendors at Katimamulilo market (border between Zambia and Namibia), further reduced the potential profit. An analysis of socio-economic and institutional factors indicates that trading informally between Zambia and DRC have a positive coefficient which indicates that informal fish trading is more concentrated around Kasumbalesa (Zambia-DRC) border. This may indicate that Kasumbalesa is the most porous border in Zambia.

Environmental and socio-economic forces are said to shape artisanal fishery marketing channels in many ways, including growing urban demand, local decline in fish biomass which favour large-scale aggregators and imports (Abbot et al 2015). Abbot et al (2015), further reported that global demand for primary commodities such as copper, which is the main export commodity for both Zambia and DR Congo, has led to economic growth, in turn, has created centres of prosperity, and hence an increased demand for animal protein. Therefore, centres of prosperity in DR Congo across the Kasumbalesa border could be one of the key factors behind the push for informal flow of fish products from Zambia to DR Congo. Although mode of transport did not show significant effect in the model (Table 2), improvement of transport network between Zambia and DR Congo could also have contributed to large volume of informal trade between the two countries through. Abbot et al (2015) reported bundles of fish being carried by lorries to Kasumbalesa, where the fish is traded further north to feed mine laborers within the DRC. It is important to note that DRC is also the main

destination of fish from Lake Vitoria; as reported by Medard et al (2014), that DRC is the major recipient of Nile perch by-products from Kirumba market, accounting for 70-80% of sales.

In Malawi, gender, form of fish, mode of transport cross border, operation costs, period of time it take to gather fish, price of fish in cross border markets, knowledge of policy regarding informal trade, political dynamics and trading between Malawi and Mozambique were found to be significant factors influencing fish traders to use informal trade routes (Table 2). Form of fish, knowledge of policy regarding informal trade, price of fish in cross border markets and trading between Mozambique had positive coefficients implying that these were the factors influencing more participation in informal cross border trade. Gender, mode of transport, period of time to gather fish before taking to cross border markets, operation costs, and unfavorable political environment had negative coefficient. This shows that females were less likely to participate in informal trade whereas males were more likely to participate, increase in time taken to gather fish and operation costs makes traders less likely to participate in informal trade. The findings agree with studies in work preference which have shown that men are more likely than women to seek jobs in which competition with coworkers affects pay rates (Harms, 2011).

The study further revealed some of the reasons why traders use informal trade channels. It emerged from focus group discussions with informal fish traders and key informants interviews with border post fish inspection and revenue collection officials across the seven formal border posts of Malawi that traders are put off by the cross-border regulations that are restrictive which agrees with the findings by Chinya, 2010. In order to export or import fish, traders are required to possess a sanitary certificate, export and import permit, COMESA Simplified Trade Regime and all these documents demand processing fee, and duty stamp fees which most traders reported that they couldn't afford. Traders perceived that they were being double taxed on both sides of the borders and that some unscrupulous officials were corrupt and demanded bribes agreeing to the study conducted by Makombe (2011).

Table 2: Factors influencing decision of traders to participate in informal fish trade in Malawi and Zambia

	Malawi			Zambia		
Variable	**Coefficients**	**Std. Err.**	**P>z**	**Coefficients**	**Std. Err.**	**P>z**
Age	0.0027384	0.00557	0.623	-0.0024763	0.00212	0.243
Gender	-0.234529	0.06112	0.000***	-0.0343937	0.03041	0.258
Source	-0.2650314	0.39318	0.5	0.1152703	0.09715	0.235
Form of fish	0.3586229	0.1617	0.027**	0.0073176	0.04753	0.878
Mode of transport	-0.3284891	0.07266	0.000***	0.051594	0.0487	0.289
Number of people involved in the chain	-0.0051101	0.00336	0.128	-0.0002245	0.00006	0.00***
Volumes of fish traded	-0.0004726	0.00038	0.218	0.0237946	0.04414	0.59
Time period	-0.0221076	0.0077	0.004***	0.0237946	0.04414	0.59
Cost	-1.88E-07	0	0.736	-0.0659826	0.02761	0.017**
Knowledge of policies regarding informal trade	0.1635838	0.07471	0.029**	-0.0110833	0.03573	0.756
Influence Political dynamics	-0.160409	0.10764	0.136	-0.0138736	0.01087	0.202
Price	0.0000497	0.00003	0.076	0.0217723	0.04153	0.6

Dummy-Mozambique	.8400503	0.05563	0.000***	-	-	-
Dummy-DRC	-	-	-	-0.0002245	0.00006	0.00***
LR chi2(13)	257.61			45.82		
Prob> chi2	0.000			0.0000		
Pseudo R2	0.6299			0.2730		
Log likelihood	-75.683476			-61.020401		

***significant at p<0.05, ***significant at p<0.01, None = Not significant, ‘‘-’’Denotes Not Applicable*

CONCLUSION AND RECOMMENDATIONS

In summary, the small pelagic fish species are the most traded in both Malawi and Zambia and there is a great market potential for small fishes trade as they are affordable to the low income household hence demanding the much need attention to develop a sustainable management regime for these fish species in order to maximize benefits out of it for both the traders and final consumers. Also this calls for the need to regularise trade in small pelagic fish species involving artisanal traders since it plays a great role in their livelihood and also food and nutrition security. Fish traders uses informal trade routes due to unscrupulous policies guiding the cross-border trade and also the traders were put off by the cross-border trade regulations.

Therefore, on the basis of the study, it is important for countries in the SADC region to regularize and formalize cross-border trade in small pelagic fish species since this species plays a great role in the livelihoods and food and nutrition security of many people in the region, especially the rural and urban poor. It is also important for governments to support processors and traders to improve the quality of fish being traded; enhance access of traders to cross border fish market information; decentralize issuing of the import/export certificates and other cross-border support documents; and enhance informal trade monitoring systems to adequately quantify the volumes and trade flows.

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APPENDIXES

Appendix 1: Magnitude of informal fish trade in Malawi

Trade partner	Border post recorded	Imports (tons)	Exports (tons)	Total (tons)	Value (MWK)	Value (US$)
Mozambique	▪ Muloza ▪ Marka, ▪ Mwanza, ▪ Dedza ▪ Chiponde	14,481.84	16,584.48	31,066.32	37,703,524,068.68	52,366,005.64
Zambia	▪ Mchinji	-	11,399.20	11,399.20	15,542,982,056.00	21,587,475.07
Tanzania	▪ Songwe	-	2,820.00	2,820.00	5,895,568,695.65	8,188,289.85
Total		14,481.84	30,803.68	45,285.52	59,142,074,820.33	2,141,770.56 8

‘‘-’’Denotes Not Applicable

Appendix 2: Magnitude of informal fish trade in Zambia

Trade partner	Border post recorded	Imports (tons)	Exports (tons)	Total (tons)	Value (ZMW)	Value (US$)
Mozambique	Luangwa	3,228.59	-	3,228.59	968,577.27	103,040.14
Tanzania	Nakonde	1,642.50	-	1,642.50	492,750.00	52,420.21
Namibia	Katimamulilo	273.75	-	273.75	82,125.00	8,736.70
DRC	Kasumba Lesa	-	97,119.06	97,119.06	29,135,718	3,099,544.47
Total		5,144.84	97,119.06	102,263.90	30,679,170.27	3,263,741.52

‘‘-’’Denotes Not Applicable

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2017 Research Dissemination Conference Proceedings

An Analysis of knowledge and skills Acquisition in Home Economics in Integrated Science and Technology Curriculum in Selected Teachers' Training Colleges in Malawi

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ABSTRACT

This thesis is an interpretive analysis of knowledge and skill acquisition in Home Economics in the integrated Science and Technology curriculum in the Teachers' Training Colleges in Malawi. The study was situated within the interpretive paradigm and constructivism theory. The research design which guided this study was mixed method but biased towards qualitative paradigm with the critical research question as: How has the introduction of the Integrated Science and Technology curriculum affected the acquisition of knowledge and skills in Home Economics? Five methods were used to collect data which include: document analysis, questionnaires, classroom observations, face- face interviews and FGDs. The research sites were the two TTCs (Kasungu and Lilongwe). The sites had a sample of ten lecturers and twenty students currently teaching and learning integrated Science and Technology. The results have revealed that there is less knowledge and skill acquisition in Home Economics while integrated in Science and Technology curriculum among learners. What was observed was theoretical teaching and assessment without or with few resources. Less challenging activities were carried out which were attributed to lack of subject substantive dimensions from lecturers. These were attributed to: background factors as a result of inadequate training at the university colleges, as well as, teaching colleges in inform of CPDs and Curriculum structure factors. The study proposes that teaching of Home Economics can be improved if subject integration begins from university colleges. Home Economics to be taught as a separate subject and the lecturers should receive enough financial and administrative support.

Key words:

INTRODUCTION

This chapter is an outline of the background information on the teaching of Home Economics in public Teachers' Training colleges in Malawi. The chapter also contains research questions and objectives which were used to carry out the study.

Musset (2010) ; Malawi Institute of Education (MIE,2004) ; Banda (1982) observe that the education systems worldwide for so many years have been affected by several challenges which still exist to date. Among some notable ones include; low performances, low knowledge and skill acquisition, absenteeism, high dropout rates in schools, curriculum overload and shortage of teachers who can competently handle the science subjects like Home Economics. In relation to this development, there has been dramatic decline in a number of teacher preparation programmes. Splitting of subjects into different disciplines like Home Economics to be splited into Human

Ecology and family science serves as an example among the changes in the teacher preparation programmes.

On this regard Smith and Leah de Zwart (2010); Mchanzime (2003) noted that the governments globally have resorted to employing or sometimes hiring teachers qualified in other focus areas, as well as, changing the curriculum. This development has not spared the government of Malawi in Particular the Teachers' Training Colleges in the education sector. In Malawi, Home Economics is no longer a single subject but has been incorporated into other science subjects like Science and Technology.

Since 1964 to 2006 the Primary Teachers Training colleges in Malawi had a fifteen subject area curriculum where Home Economics was taught as a separate subject. During this period, the entire Teachers' Training programme in Malawi followed the same curriculum (Hauya, 1992; MIE, 2004). From 2006, the Teacher Training Colleges stopped the fifteen subject areas curriculum, where Home Economics was taught as a separate subject and replaced it with the Initial Primary Teacher Education (IPTE) curriculum of ten subject areas of study, and two professional areas, which are Foundation studies and Teaching Practice. Since 1964 to 2006, the areas of study were categorized into five departments.

Meanwhile the content and methodology are integrated in the subject areas, while Foundation Studies has been incorporated with Teaching Practice but as a separate learning area.

The new curriculum for teacher training has still maintained the five departments with the same learning areas. But there is a slight change in the Mathematics and Science Department where Home Economics now has been integrated in Science and Technology as a new learning area. This learning area is composed of the following disciplines; Biology, Physical Science, Chemistry and Home Economics. This meant a shift from handling of Home Economics as a subject and handling it as component in integrated Science and Technology. Home Economics does not have its own experts and it does not appear as a separate subject on the time table in the Science Department (Ministry of Education, 2006).

It is against this background where Home Economics has been integrated in Science and Technology curriculum (S/Tec) as a science subject which raises a great concern to whether or not the curriculum really prepares the student teachers with reasonable and desired knowledge, skills, and attitudes in Home Economics in the Teachers' Training colleges in Malawi. For the purpose of this study, the integrated curriculum is defined as a type of curriculum using a multidisciplinary approach which combines different subject parts so that they are taught together to form one single subject. This curriculum approach purposefully draws together knowledge, skills, attitude and values from within or across subject areas to develop a more powerful understanding of ideas (Contardi, et al. 2000). Hence, this study examined the knowledge and skills acquisition in Home Economics in the integrated S/Tec curriculum. The study was conducted to study aimed at finding out how the introduction of the Integrated Science and Technology curriculum has affected the acquisition of knowledge and skills in Home Economics.

MATERIALS AND METHODS

As outlined in the first chapter of this thesis the drift for this study arose from the reseacher's own teaching experiences as Home Economics teacher now teaching Science and Technology as an integrated subject. The researcher had a lot of doubts to whether all the components in the curriculum receive equal attention that can allow enough knowledge and skill aqcusition. In this study, the researcher wanted to find out the postion of Home Economics with regard to knowledge and skill acqcisition in the Integrated Science and Technology curriculum. Therefore, the study

focused on examining documents, teaching and learning context, lecturers' and learners' experiences currently teaching Science and Technology.

Research Paradigm
The study used mixed methods research design but with a bias to qualitative research design and was framed within the interpretive paradigm. Constructivism theoretical frame works by Vygotsky and conceptual frames works forms of multidisciplinary integrated curriculum guided the study.

Research Site
The study was conducted in Kasungu and Lilongwe as well St Joseph Training College as a pilot site.

Population Sample and sampling Techniques
The study used simple random sampling and purposive sampling to come up with the population sample of thirty participants. Each college had a population sample of fifteen participants, of which five were lecturers from the Science Department who are currently teaching Integrated Science and Technology and ten were learners from those classes of the sampled lecturers as a target sample. Among the ten lecturers one participant was a Head of Department (HOD) Science from each college.

Data Collection Methods and Instruments
The study particularly used questionnaires, Document analysis, classroom observation, face-face unstructured interviews and Focus Group Discussions (FGDs) as data collection techniques.

Discussions and Results
The generated data provided a deeper understanding on factors which might have compromised quality in Home Economics with regard to knowledge and skills acquisition. To begin with, majority of lecturers joined the college in 2010 when the curriculum was already in progress with different subject majors. But were not adequately trained in the college and also on job. This implies that lecturers who joined earlier plus those who joined later are lacking adequate knowledge in teaching the subjects, in particular Home Economics.

The results have revealed that Home Economics is averagely weighted, but it is not effectively taught due to time factors not being adequate, overloaded topics, profession background of lectures leading selection of topics in the curriculum and inadequate resources. This implies that lecturers are affected on lesson preparation and delivery. Hence, less knowledge and skills acquisition in HEC. Again, strategies used could not allow knowledge and skill transfer since the lesson were theory dominated. Head of Departments, lecturers and learners revealed less chances of Home Economics to be taught in primary schools because it is receiving less attention while integrated in Science and Technology

CONCLUSION

Lecturers have not been fully trained to teach HEC while in Int.S/Tec. Very few lecturers have been trained in Home Economics. Those few lecturers who have been trained in HEC have not been fully trained in all aspects of HEC, hence there is knowledge gap. HEC content not adequately presented in the Int.S/Tech.

Time allocated to HEC concepts is not enough as compared to the topics and methodologies outlined in the syllabus. Methodology used to teach HEC could not allow learners develop critical

thinking, it's more of theory than practical. A good number of learners have not learnt HEC affecting how they can understand the subject. Hence, it can be assumed that there less knowledge and skills acquisition in HEC while integrated in S/Tec.

- Int S/Tech curriculum is overloaded needs to be restructured to fit one year program
- HEC receives less attention while integrated in S/Tech. Hence, needs to be taught as separate subjects
- Lecturers teaching HEC while integrated not adequately trained. Hence, integration of subjects including HEC should start right away from training college.
- Inadequate resources to teach HEC practically. Hence, need for adequate funding in colleges
- Inadequate CPDs while on job, hence, needs adequate CPDs to fill knowledge gap
- On long term government to train more science teachers especially HEC and deploy the in TTCs

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Exploring Participatory Teaching and Learning Methods as a Means for Implementing Education for Sustainability: The Case of Chilanga Community Day Secondary School

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ABSTRACT

The research explored participatory teaching and learning methods (PT/LM) as a means for implementing Education for Sustainability (EFS). It investigated the efficacy of PT/LM integrated with linking lesson content to community contexts (LLCCC) with an overarching theme of empowering learners to be sustainability agents. The research had three major outcomes which were adoption of learner centred pedagogy by teachers, positive attitude change and innovation of club activities by learners which were achieved to a large extent. The research focused on establishing the influence of PT/LM on learners towards possible actions that would bring positive change at school and in community. The aim was to see learners dealing with EFS issues which are a result of human activity emanating from behaviour and lifestyles. The conceptual framework relates the research to EFS core themes of environment and society, and values and participation because it is about the interdependence of social behaviour and environment impact as well as values held and traditions practiced. It was carried out as an intervention guided by the adopted description of PT/LM. They enable the learner to explore a situation, identify a problem, describe, analyse, interpret, appreciate the problem and make a decision to solve it. The approach was mentoring teachers on effective use of PT/LM. A case study methodology guided the inquiry and the methods used to collect data were scrutiny of teaching and learning (T/L) records, questionnaires, lesson observation, and interviews. Limited learner ability to express themselves in English and misinterpretation of statements in questionnaires by teachers as well as learners affected data accuracy. Data coding and analysis was done manually. The methodology feature that shaped the research design is qualitative because of eliciting and explaining views about learner centred pedagogy. The intervention approach of mentoring teachers was a process of understanding and explanation that had implications for action. It was therefore underpinned by the epistemology of critical theory paradigm, which necessitated the choice of case study for in-depth enquiry. The intervention involved lesson observation of Life Skills and English, which were associated with Mama ye and Debate clubs respectively, because the outcome of the influence of PT/LM on learners was to be observed through innovation of clubs' activities. The findings showed that teachers adopted other PT/LM and LLCCC. Both teachers and learners demonstrated increased awareness of EFS issues by explaining links between lesson content and community issues of concern. The development is an indication of the influence of PT/LM on learners, which shows that PT/LM can be used as a means for implementing EFS. Innovation of club activities that focus on addressing EFS issues was however not established, because clubs held only one meeting instead of the planned four. The reduced research period contributed to the situation.

Keywords: participatory learning, sustainability, Malawi

INTRODUCTION

The research explored PT/LM as a means for implementing EFS. It investigated the efficacy of PT/LM integrated with LLCCC in empowering learners to be sustainability agents in communities where they live. It was carried out as a case study at Chilanga Community Day Secondary School (CDSS). The anticipated outcomes were adoption of learner centred pedagogy by teachers, positive attitude change and innovation of club activities by learners. The research was derived from a weakness in curriculum delivery. Inspection reports indicated that teachers neither used a variety of PT/LM during lesson delivery nor used the methods effectively. Teachers also did not LLCCC. An intervention was introduced that involved mentoring teachers on the effective use of PT/LM and LLCCC because the EFA report (2014) stipulates that evidence shows that education quality improves when teachers are supported and unlocking their potential is essential to enhancing the quality of learning. The intervention involved lesson observation of Life Skills and English, which were associated with Mama ye and Debate clubs respectively.

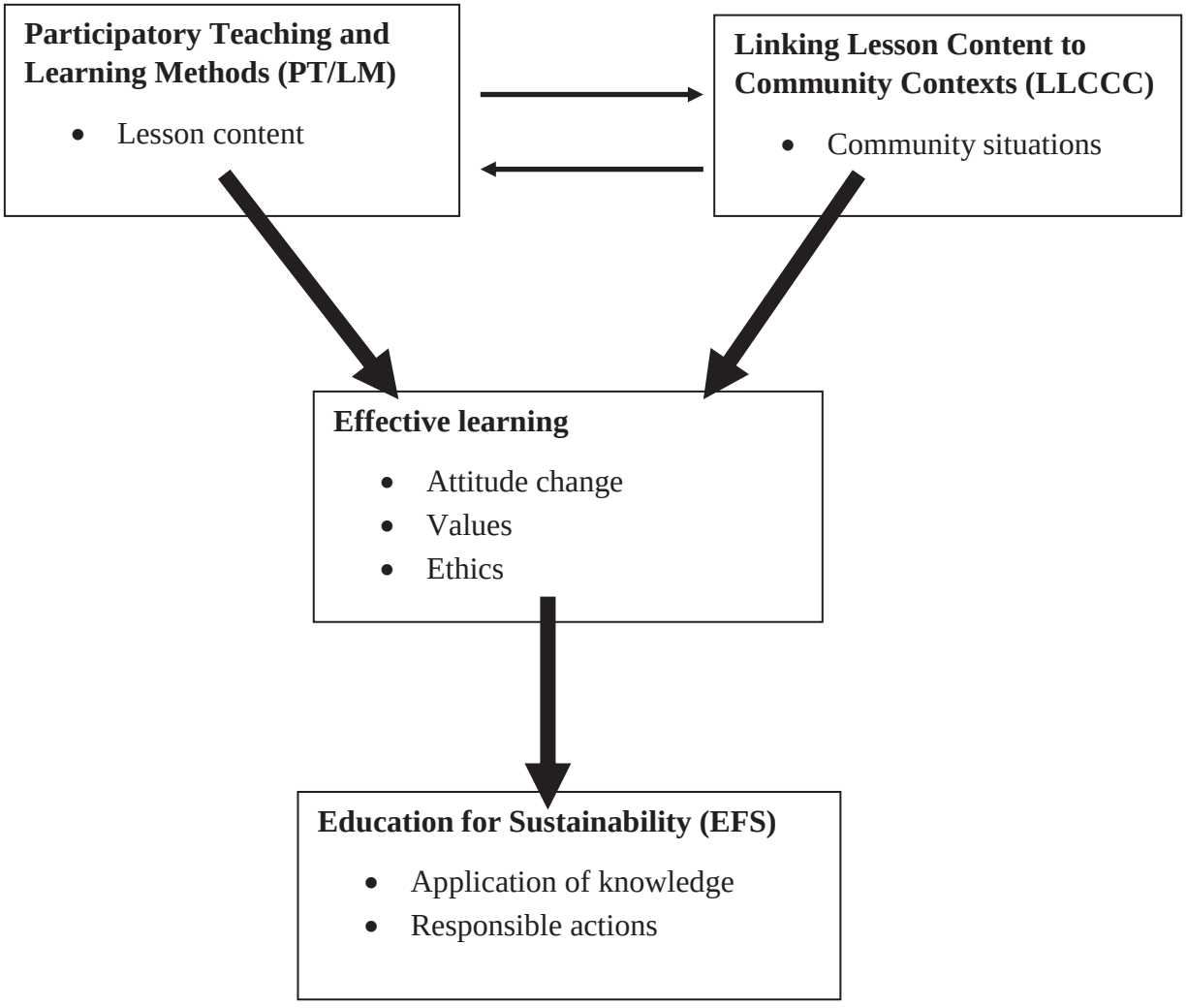
Okado (2004:87) defines EFS as a process of learning which aims to improve the quality of living by promoting thinking that leads to sustainable lifestyles for future citizens. The definition is adopted in the research because of its concern on the quality of living and reorienting thinking on lifestyles, which is about empowering people. PT/LM are believed to empower people because people feel more satisfied and achieve more when they can actively contribute to the process of learning (UNESCO 2012:25). PT/LM are encouraged because they are believed to ensure high quality education since learners are actively engaged. Musoko (2010:1) asserts that PT/LM "enable the learner to explore a situation, identify a problem, describe, analyse, interpret, appreciate the problem and make a decision to solve it".

Empowerment in this research implies increased consciousness through knowledge, which is more than forced change of power. Nanette Page and Cheryl Czuba define empowerment as a process that helps people to gain control over their own lives, their communities and society by acting on issues they define as important (in: Urenje 2013:11). LLCCC is believed to facilitate easy application of knowledge to situations and can therefore effectively enable increasing consciousness. The primary intention of the research was to investigate how use of PT/LM, where teachers LLCCC could help learners to gain knowledge that would influence responsible actions on issues of concern in the community where they live because of the belief that the relevance of PT/LM comes in when collaborative learning is linked to problem solving relevant to community contexts.

The research was motivated by my passion to explore ways in which the provision of quality and relevant education can be practical. It was based on the belief that PT/LM would influence learners to use knowledge to take responsible actions on EFS issues such as inappropriate farming practices, deforestation, environmental degradation, waste disposal, sanitation, pollution, water and electricity use which are a result of human activity emanating from behaviour and lifestyles. The concept relates to the EFS theme of environment and society because it explores the interdependence of social behaviour and environmental impact. The intention is positive because it proposes that responsible social behaviour can regenerate and protect environments and people, which is one of the principal aims of EFS as stated by Plant (2005:4). My thinking was informed and influenced by my experience as inspector and the assertion by Schumacher that if education is to save us, it has to be education that takes us into the depth of things and produces wisdom (in: Sterling 2010:17).

Since the impact of learning often comes many years after learning it may be very difficult to measure within a month, which was the research period. Impact in the study was interpreted as what people become after learning. The researcher therefore decided to assess impact by observing the outcomes of the influence of PT/LM on learners through club activities. Clubs were appropriate, because they consist of a group of learners with shared interests who come up with objectives that they identify with and carry out activities regularly to achieve their set objectives.

Diagrammatic representation of the conceptual framework



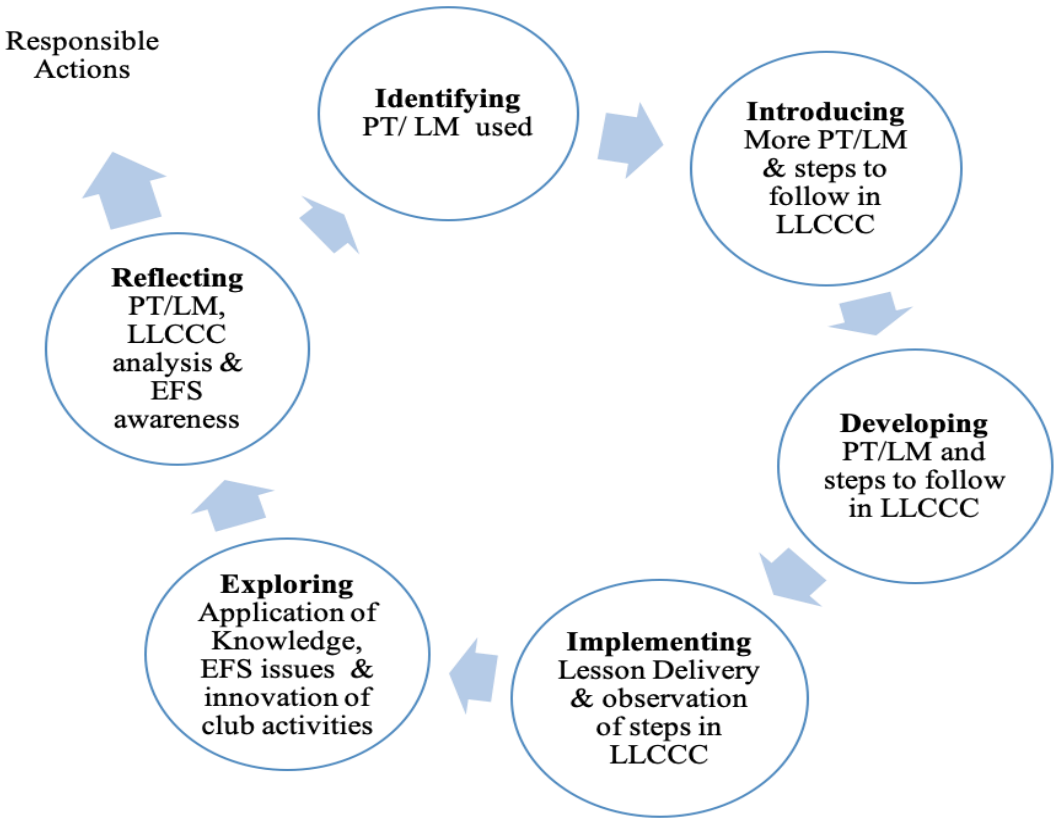
The boxes are showing conceptual areas and the arrows show inter-relationships and causal relations that lead to outcomes. Developed from Corney (1998) and Watkins (2002) Contextual model of school learning. This study was conducted to investigate how PT/LM enable learners to gain knowledge that influences them to take responsible actions on EFS issues of concern and explore how LLCCC can influence learners in clubs to come up with activities that focus on EFS issues of concern at school and in community.

MATERIALS AND METHODS

The research process involved the researcher mentoring teachers through an intervention with the intention of improving classroom practice and observing outcomes through club activities. It was seeking to bring common understanding through a collective rational process among the

researcher as educationist, teachers as educators and learners as sustainability agents. It was therefore epistemologically underpinned by critical theory because with the epistemology of critical theory, reality is collectively apprehendable through a rational social process (Plant 2005: 47).

Intervention cycle



The circles represent stages in the intervention process in relation to research objectives. Information from the previous stage informed the process in the following stage. The arrow shooting outside the cycle shows research findings suggestion for further study. Developed from Watkins (2002) Model of the Learning Process.

Plant (2005:73) states that a case study is an in-depth inquiry into one case with the intention to question, observe and study. The methods used to collect data included scrutiny of T/L records, questionnaires, lesson observation and in-depth interviews with teachers and learners. The researcher gathered views and perceptions from teachers and learners which is an interest of qualitative research. The qualitative feature shaped the research design, because a case study enables the researcher to ascertain the meanings people bring to particular social situations (Plant 2005:57). Plant (2005:73) points out that a case study is 'strong on reality' and therefore the findings could enable people such as teachers and policy makers to increase understanding of a particular case. The intent is responsible actions, which agrees with critical perspective of research implication for action. The choice of Chilanga CDSS was based on convenience because of proximity. It was about 10 Kilometers from where the researcher was based, and transport was easy and not costly, which enabled visiting the school regularly for lesson observation and interviews.

There were two limitations in carrying out research. First was the inspector and teacher relationship. Teachers at the school knew the researcher as inspector, which meant that the relations had power dynamics that influenced how they perceived me (as inspector rather than researcher). It influenced

how free teachers felt to express themselves which presented a challenge to the relational aspects of the research. It may have influenced untruthful responses because of seeking appeasement and therefore affecting data accuracy because it impinged on their interests and privacy, which was an ethical issue of sensitivity. For example, teachers demonstrated commitment during the research process, while in actual sense might not be committed to the cause.

Sampling and methods

The key participants in the research were teachers and learners. Random and purposeful sampling were used to select research participants. Mama ye and Debate clubs associated with Life Skills and English respectively were also selected. The selection of classes for lesson observation was based on the highest number of club members. Information from club patrons showed that Form 3W had the highest number of Mama ye club members and Form 3E had the highest number of Debate club members. The subject teachers to be involved in the research were therefore, those of Life Skills and English in the stated classes. All learners attended lessons but for interviews and responding to questionnaires, the researcher used purposeful sampling because only club members were involved. Club patrons provided names of active members.

The researcher used four methods to generate data namely document analysis which involved scrutiny of Lesson Plans. Questionnaires were administered to 2 teachers and 10 learners: one at the beginning of the research and another at the end. Participant observation was done through lesson observation. Interviews were conducted with the two teachers after every lesson that was observed. The triangulation through multiple methods used in generating data strengthened and ensured trustworthiness of findings. Data coding and analysis was done manually.

RESULTS AND DISCUSSION

The results were presented in three main subtitles according to the anticipated research outcomes which were adoption of PT/LM by teachers, positive attitude change and innovation of club activities by learners.

Adoption of participatory teaching and learning methods

Through analysis of Lesson Plans, questionnaire, interviews and lesson observation, the results established that the teaching and learning methods that were commonly used by teachers before introducing the intervention were lecture, question and answer, and discussion. The PT/LM were question and answer, and discussion as shown in the table.

Use of methods by subject teachers

Subject	Methods	Observations
Life Skills	Lecture	Dominated lesson time
	Question and answer	Only used during introduction and conclusion
	Discussion	Used only during one lesson development stage. Although the teacher referred to it as group discussion, he did not put the learners in groups.
English	Lecture	Dominated lesson time
	Question and answer	Used mainly in the introduction
	Discussion	Used group discussion in one lesson development stage. The smallest group consisted of 15 learners.

The findings revealed that the methods were not effectively used because of teachers' use of didactic teaching, which promoted rote learning and did not encourage individual student participation. The results after introducing the intervention showed that teachers adopted PT/LM that they were not using before for example values clarification, futures wheel and bus stop.

Teachers were conscious about following procedures when using the methods including group discussion. As regards linking lesson content to community contexts (LLCCC), the results showed improvement in teachers' involvement of learners from merely giving them examples or asking them to give examples to giving them opportunity to discuss issues or problems at school and in community and suggest solutions. This demonstrated teachers understanding and appreciation of the PT/LM and LLCCC, willingness and commitment to use them, and most importantly was an indication of improvement in classroom practice and teachers developing positive attitude. One teacher remarked, "This is education for life."

Positive attitude change by learners

The results revealed increase in the number of EFS issues that learners identified and linked to lesson content after the intervention period. One questionnaire was administered before the intervention and another at the end. The table shows learners' responses for Life Skills.

Results of responses to questionnaires by learners on EFS issues

Subject	**EFS issues**	
Life Skills	**Questionnaire 1**	**Questionnaire 2**
	Sanitation	Sanitation
	Waste disposal	Waste disposal
	Family planning	Family planning
		Farming practices
		Deforestation
		Water use

The results demonstrate awareness translating into reflection in learners. It also shows the influence of PT/LM and that LLCCC facilitates application of knowledge. Learners' ability to identify EFS issues is an indication of acquisition of decision-making skills necessary for participation in society, and developing personal and social responsibility; which are the anticipated outcomes for secondary education.

Innovation of club activities by learners

The research outcome was not established because of the change of the research site, which reduced the research period and was also affected by preparation for end of term tests by the school. This led to clubs holding only one meeting instead of the planned five.

CONCLUSION AND RECOMMENDATIONS

The research results showed that PT/LM can be used as a means to implement EFS because teachers adopted PT/LM such as values clarification, futures' wheel and bus stop, and LLCCC, which means that the intervention provided teachers with options to use learner centred pedagogy. It also led to teachers to improve on use of methods. Although innovation of club activities by learners was not established, teachers and learners developed awareness of EFS issues which they linked to lesson content such as poor farming practices, family planning and deforestation. This means that PT/LM and LLCCC helped to increase consciousness in both teachers and learners, hence the empowering effect. In view of the results, the researcher makes the following recommendations:

The Ministry of Education, Science and Technology should enforce regular in-service education and training (INSET) on effective use of PT/LM and LLCCC in order to help teachers effectively use the methods during lesson delivery, which will ensure quality provision of education.

Investigation of forms of support that would encourage teachers to use PT/LM and LLCCC effectively.

Investigation of learners' ability to develop club activities that address EFS issues from their learning experience.

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The Legal Protection of New Plant Varieties in Malawi: Challenges and Solutions For Rural Women Farmers.

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ABSTRACT

The emerging, developing, interesting and academically fertile area in IP and developing countries is the area of New Plant Varieties for its impact on food security and socio-economic developing of the countries. This paper engages into the formal intellectual property law and its impact or lack thereof on Plant breeders and rural women farmers. The focus of the paper is whether the formal law mechanisms could be utilized to emancipate the rural women farmers. This implicates on the rural women farmers in that it lenders them food insecure and with possibility of becoming socially destitute. This is so because a food is a symbolic status with a potential of eradicating the economic challenges faced by rural women farmers. The paper holds that utilising Feminist Marxist legal theory and Ubuntu conceptualisation is the formal law is a good means of protecting new plant varieties in Malawi for the benefit of rural women farmers.

Key words:

INTRODUCTION

Malawi, as of 2015, had an estimated total human population of close to 17,241,754 of which 8,646,249 who are women (live population Malawi report, 2015). The National Statistics Office (2008) found that a total of 88% of Malawians live in rural areas. Most of the people in the rural areas are involved in the agricultural sector as their main source of economic and social livelihood.

As the backbone of Malawi's economy and social aspirations agriculture accounts for one-third of GDP, estimated at 29.4%, and 90% of her export revenues (Malawi Country Report, 2015). The agricultural sector in Malawi offers the greatest number of employment opportunities with about 64.1% of employed persons employed in agriculture, forestry and fishing sectors (Government of Malawi (GoM), 2015). The agricultural sector offers employment to most women, with a total of 92% of those working therein being women (Food Agriculture Organisation (FAO), 2013). The women who are actively involved in the agriculture are not commercial farmers (FAO, 2013). This is more problematic as they are also resident in the rural areas where access to most resources is limited. One of such resource is improved seed varieties especially for the grains for food crops and cash crops (Walter, 2015).

Following the foregoing, access to new plant varieties of quality seeds is a recipe for food security which in the ends brings economic utility and development to a nation (Walter, 2015). This has a direct and indirect implication on the farmers who are smallholders, who stay in the rural areas and

usually they are women. The impact on rural women farmers is obvious due to the fact that most of the said farmers in Malawi most of the times face difficulties to access the new plant varieties of the quality seed for them to plant in their gardens (Muwamba, 2014). Access to improved quality of new plant varieties seeds has been an issue due to the fact that they are expensive and usually sold in faraway places from the rural area (Walter, 2015). Something that does not come out clearly is the role of intellectual property in bring solution to the food security situation in Malawi and the developing nations at large.

In addition to above, Intellectual Property (IP) refers to creations of the mind (World Intellectual Property Organisation (WIPO), 2015). Bently and Sherman (2014:1) defines Intellectual property law, on the other hand, as the protection of the ideas and products thereof which emanate from the mind. This comes with a cost on the part of the holder of the intellectual property right in that he or she has to make the subject matter of protection available and thus potentially accessible to the public in exchange of legal protection for a given period of time (Dutfield, 2003 : 1). The intellectual property regime consist of several aspects of it namely patent, trademarks, Industrial designs, copyright and related rights, geographical indications, trade secrets, plant breeders' rights, and rights to layout designs of integrated circuits (Dutfield, 2003:1) and of these, the most prominent are patents, trademarks, industrial designs and copyright and related rights (WIPO, 2004).

However, due to the growth of intellectual property discourse there has been a new growth of a school of thought on how breeders of new plant varieties could also claim intellectual property right in the said plant varieties in what has been termed as Plant Breeder's Rights (Dutfield, 2003:7-11, Lettington, 2003:69, Niangado and Kebe, 2003:69). The rational is that the improvement of new plant varieties would lead to food security (WIPO, 2004:331).

The legal protection of plant varieties has also been endorsed by the World Trade Organisation Treaty in its Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). Oyewunmi (2015:323) noted that TRIPS Agreement has brought issues of trade and intellectual property under one legal regime through integration of all intellectual property system into international trade structure and the same is enforceable. The TRIPS agreement has also had an impact on agricultural development aspects of new plant variety protection.

Furthermore, The TRIPS agreement does accommodate the legal protection of new plant varieties in *article 27.3 (b).* The provision states that;
(3) Members may also exclude from patentability:

> *(b) plants and animals other than micro-organisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes.* ***However, Members shall provide for the protection of plant varieties either by patents or by an effective sui generis system or by any combination thereof****. The provisions of this subparagraph shall be reviewed four years after the date of entry into force of the WTO Agreement.* ***(Emphasis added)***

Scholars such Erbish and Maredia (2004), Girsberg (2003), Abbort, Cottier and Gurry (2011),Louwaars (2011), De Jonge (2014) have held that the Article 27 (3) (b) of TRIPS agreement is meant to guide the developing countries and least developed countries such as Malawi toward protecting new plant varieties. The Article 27 (3) (b) of TRIPS agreement allows plant varieties to be protected through patents or *sui generis* legal system or indeed through combination of patent law and *sui generis* law (Oyewunmi ,2015:327; Christinck, A and Tvedt, M.W 2015:16; Bently and Sherman, 2014:399). For example, the U.S. Supreme Court decision of *J.E.M AG Supply v Pioneer Hi-Bred,* 534 U.S. 124 (2001) holds that in United States of America plant varieties could be

protected by combination of patent law or sui generis. Malawi is a party to TRIPS agreement thus it has to be obliged to abide by the tenets of Article 27.3 (b) of TRIPS and that is a way of recognizing plant breeders' rights in Malawi.

Furthermore, some have criticised Article 27.3 (b) of TRIPS provisions for being drafted towards the developed countries, where the multinational seed companies are incorporated, hence farmers too must be allowed to exercise intellectual property rights on their farm saved seeds (Bently and Sherman, 2014:400; Abbort, Cottier and Gurry 2011:670-675). The good thing is that the Least Developed Countries (LDCs) such as Malawi enjoy an exemption until at least 2021 when they are to ensure that Article 27 (3) (b) of the TRIPS agreement is implemented (De Jonge, 2014 cited in Christinck, A and Tvedt, M.W 2015:16).

In the international legal regime there has been *sui generis* law on the same which has been provided in The International Convention of Protection of New Varieties of Plants (UPOV) as revised in 1991. The 1991 Act is said to be a stronger regime of intellectual property protection of new plant varieties. The use of UPOV 1991 Act convention is said to be the best for the modelling of the many of the *sui generis* law on legal protection of new plant varieties in the member states of UPOV convention as compared to using patent law system (Dutfield, 2011: 4:5 cited Christinck, A and Tvedt, M.W 2015:66). This is so because UPOV 1991 Act has become the whole mark of the basis of the new plant protection (Kachedwa, M.G 2002:85). However, UPOV 1991 Act is not the only tool for successfully building a private sector plant breeding activities in developing countries as there are example where seed and plant breeding industries have developed without legal protection (Bentley et al., 2011 and Tripp et al., 2007 as cited in Christinck, A and Tvedt, M.W 2015:21).

The formulation of plant breeder's rights through UPOV convention and its revisions thereafter made the need to legally protect the farmers who are the custodians of the materials that the plant breeders depend on in the breeding process in the name of geneplasm. In *Monsanto Canada Inc v Schmeiser* [2001] 12 C.P.R. (4th) 204 (Fed Ct (Can) the facts states that;

> *'In 2001 the Canadian Court of Appeal ruled that a canola farmer, Schmeiser, was liable for substantial damages for patent infringement. It was found that his crop, cross pollinated through natural processes, expressed a gene, the property of Monsanto, conveying resistance to glycophosphate herbicides. Despite a lack of evidence on Monsanto's part, that Schmeiser had exploited the gene by using glycophosphate herbicides on his crop, patent infringement was found by the mere incorporation of the gene into Schmeiser's crop'.*

In the premises of the current discourse the case of *Monsanto Canada Inc v Schmeiser* brings to the arena the impact of uncontrollable and unchecked ulutilisation of Plant Breeder's Rights and how the same could have a direct negative impact on malawian rural women farmers when accessing new plant varities. Thus, this is a call for a formualtion of a legal system that counter-balances interest of plant breeeders without negating the interest of the malawian smallholder rural farmers , especially women.

The International Treaty on Plant Genetic Resources for Food and Agriculture (IT-PGRFA) is also popularly known as the International Seed Treaty However, the paper has noted that countries or contract states enter into the treaty as a matter of choice thus this limited the visibility of this important treaty. Furthermore, the International Seed Treaty in Article 9 does recognize farmers and their communities on their great contributions towards plant genetic resources preservation and improvements on the same through the utilization of their traditional knowledge.

Therefore, the papers notes that this show the weakening of the farmers rights , which is mere a

moral obligation (Blakeney , M 2006:331), compared to plant breeders rights under UPOV convention Act of 1991 whose provision are mandatory in nature.

The Arusha Protocol for the Protection of New Plant Varieties (Arusha Protocol) on the other hand, is the legal basis on protection of new plant varieties in ARIPO member states. Malawi is not yet a party. The paper's discussion on the subject matter is interested in Articles 21 and 22 of the Arusha Protocol. These particular Articles in summary embody breeder's rights and exceptions respectively. The paper notes that the Arusha Protocol is a good basis for formulating a *sui generis* national law on protection of new plant varieties within the ARIPO member states. This being the case it would be appropriate that the regulation falling under Article 22 (3) makes a good clarification to Article 22 (2) with the view of bringing legal protection of farmers saved seed as a basis of food security to the member states.

The authors Christinck, A and Tvedt, M.W (2015:46) points that the greatest challenge for international law is its domestication in the national law and this is through that country's need to incorporate the obligations into the national or domestic laws. For example, Malawi's constitution in Section 211 points out the need for domestication of international law. This situation has left farmers, plant breeders and others in the seed industry at the mercy of domestic legislation. This is also consistent with the basic tenets of intellectual property law which is the 'principle of territoriality'.

This is the main statute that the Malawian legal regime uses to protect new plant varieties is the Seed Act. The key provisions provides as follows:

> *Section 33 Power of Minister to declare seed to be prescribed seed*
> *The Minister may from time to time, by order published in the Gazette, declare any seed to be a prescribed seed, and for each kind specify minimum standards of germination and other characteristics of seed quality*
>
> *Section 44 Variety of certified seed*
> *The Minister may, by order published in the Gazette, specify the variety or varieties of seed which may be cultivated for the purpose of producing seed for certification as Malawi Certified Seed or as Imported Certified Seed.*

The Plant Breeders' Rights Draft Bill was drafted in around May, 2007 and to date it has not been enacted into an Act. However, it is still relevant to the current discussion as it shows the direction which new plant varieties will be legally protected in Malawi when the Plant Breeders' Rights Draft Bill eventually becomes an Act.

The paper has noted that the Plant Breeders' Rights Draft Bill has an embodiment of UPOV Convention of 1991 Act Article 15 and Article 9 of International Seed Treaty. It is the paper's position that this does to a greater extent balances the concerns of many critics of legal protection of new plant varieties and it thus grantees access to seed to the rural women farmers of Malawi.

In Malawi the paper further notes that the jurisprudence or case law concerning plant variety rights has not developed because matters are seldom brought before the courts of law. However, India has been said to be the example of interwoven of the elaborative farmer's rights and plant breeder's rights (Sreenivasulu, 2011:56-70). The paper notes, however, that Malawi cannot just copy and paste this law but rather learn from the successes and failures of the same.
Furthermore, the reason for this new plant variety legal protection is that through upholding of Intellectual property rights by the plant breeders of new plant varieties there will be improved plant varieties which are usually disease resistant and high yielding (WIPO, 2004:331). This has a direct

correlation to increased food security for the farmers, especially the women farmers, and in the ultimate end to the economic development of a country, especially to Malawi whose economy is agrarian in nature.

On the other hand, the breeders of new plant varieties are thus accorded what are termed as Plant Breeders' Right due to the fact the product of the breeding of plant varieties has go through the process of human effort, skill , intellect and more so financial investment (Ngwediagi, 2009:5). Thus, Plant Breeders Rights regime has been justified in the intellectual property discourse as deserving intellectual property protection. The plant breeders are seeking more protection due to the fact that genetically any plant variety is capable of being genetically modified or mutating into a different gene make up (Lesser, 2007, Louwaars, 2011).Therefore this has made the demands of more latitude of legal protection of Plant Breeders' Rights to be more prevailing and significant.

THEORETICAL FRAMEWORK AND CONCEPTUAL FRAMEWORK

Feminist Marxist Legal Theory

Feminist Marxist legal theory is focused on explaining the ways in which women are oppressed through the system of private property ownership as encouraged by capitalism. Ferguson, A. and Hennessy, R. (2010) have summarized Feminist Marxist legal theory in that women's liberation can only be achieved through a radical restructuring of the current capitalist economy, in which much of women's labour is uncompensated. As such, gender oppression is closely related to class oppression and the relationship between men and women in society is similar to the relations between proletariat and bourgeoisie (Ferguson, A. & Hennessy, R., 2010). This is why this paper focuses on whether the intellectual property law protection of new plant varieties could allow, to some extent, selling of farmer saved seeds. The theory has a direct bearing on the paper in that it helps appreciate the need of seed related IP laws to be in tandem with aspirations of women farmers so that access to new plant varieties is safeguarded since it is a critical element for food security.

Ubuntu/umunthu legal concept

In Malawi 'Ubuntu' concept called 'Umunthu'. In the context of this paper, this concept helps to appreciate the ideals of letting the plant breeder allowing his or her Plant Breeder's Rights exercised in unity with farmer's rights since the plant variety is derived from the intellectual property of the plant breeder. A scholar Samkange, S.J.W.T (1980) highlights that 'the *second maxim means that if and when one is faced with a decisive choice between wealth and the preservation of the life of another human being, then one should opt for the preservation of life'.* This is a clear manifestation of the need to conceptualize our laws towards ensuring that there is a balance of capitalism and umunthu so that rural women farmers are capable of being food-secure in short term and economically empowered in the long term due to them accessing improved and high yielding new plant varieties.

MATERIALS AND METHODS

This paper does heavily depended on qualitative approach. This paper had three (3) Focus Group Discussions (FDGs), nine (9) in depth interviews with rural women farmers and five (5) in-depth interviews of key informants, who are actually the Plant Breeders, were conducted from Mid-December 2015 to February, 2016. This field data collection was done in addition to the literature which was used by the study.

The statutes, court cases and some literatures were utilised as secondary data. This is so because that the formal legal system depend on statutes and case authorities. The literatures and interviews are utilized in trying to understand the lived realities of the rural women farmers and the challenges and benefits they face in light of legal protection of new plant varieties.

The study utilised purposive sampling methodology. This is so because the study only involved Plant Breeders in Malawi and women farmers from Malawi's Hunger Project within Mpingo epicentre in Traditional Authority Somba in Blantyre and Jali Epicentre, Traditional Authority Chikowi and Nsondole Epicentre, Traditional Authority Malemia in Zomba District respectively. There were a total of 50 participants. The total sample included five (5) plant breeders and 45 farmers.

DISCUSSION AND ANALYSIS

How does the International Intellectual Property legal regime address protection of new Plant Varieties?

The international Intellectual Property legal regime has provided the need to provided legal protection of new plant varieties whether through patent or *sui generis* law or both as stipulated in Article 27(3) (b) of TRIPS. The UPOV 1991 Act on the other hand, provides a kind of *sui generis law* on the same. International Seed Treaty does to some extent extend the UPOV model to protect farmer's rights.

The paper has noted that the fact that UPOV 1991 Act seems to have more force of law because it is more elaborate and has a concert administrative structure for its implementation and thus it provides a good legal platform for TRIPS as its *sui generis* international law.

It the position of this paper , therefore, that Feminist Marxist legal theory and Ubuntu concept could be used as theoretical basis for supporting UPOV 1991 Act. This would be possible through making smallholder farmers into plant breeders. This is closer to the situation in India. In the long run Malawi will significantly benefit and thus she would not be complaining of the capitalist nature of multinational breeding companies.

Furthermore, The Arusha protocol by ARIPO has spearheaded the protection of new plant varieties in the ARIPO region, of which Malawi is part of. This is a hub of IP law in new plant varieties protection. This paper opines that Malawi would benefit more in having her Plant Breeders Rights law mirrored around this law. The Arusha protocol does provides the basis of good legal basis of which Malawi can depend on.

How does the Malawian legal system (statutory and customary) ensure that smallholder women farmers have access to new plant varieties of seeds?

All the respondents, namely the farmers and the plant breeders, noted that certified maize seed is usually available in most agro-traders and this has been possible because of seed subsidy by government of Malawi. The farm saved seed is just a supplement and it is only replanted for two farming seasons. All the plant breeders interviewed also agreed that certified seed is available and the need to develop new plant varieties is imperative.

Furthermore, all the respondents were aware that intellectual property of certified seeds which they plant resides with those who develop the variety. Furthermore, the plant breeders were aware that the law namely Seed Act does give a legal basis for protection of the new plant varieties they developed. However, most farmers were not sure of any law being available for such purpose except that when a case of counterfeit certified seeds arises it is taken as a police matter.

All the fifty (50) research respondents agreed that Plant Breeders Rights must be protected including exclusive rights as this would ensure that plant breeders provide improved new plant varieties thus there would be increased access to the seeds for the rural farmers including women farmers. The justification is that the plant breeders spend time and money to bring the new plant varieties to the market.

This paper thus argues that Malawi should pass the Plant Breeders Rights Bill into law so that the seed industry can have their seed innovations effectively protected by the law.

The 45 farmers who were interviewed never knew the existence of any law that protect new plant varieties in Malawi. On the other hand, of the 5 plant breeders only 1 was conversant with the Plant Breeder Rights Bill but all of them knew the existence of Seed Act especially the need for approval of new plant varieties from Seed Services Unit at the Ministry of Agriculture. The interviews also revealed that none availability of Plant Breeders Rights law in Malawi has not stopped the plant breeders from introducing new plant varieties of maize. The plant breeders indicated that they do not use Patent law despite having that opportunity to do so because they are not conversant with it. All the breeders ensure that their seed has been certified as provided for in the Seed Act.

The paper's position is that with a *sui generis* law, such as The Plant breeder's Rights Act, in place there will be more players in the seed industry as they would know that their intellectual property in the new plant variety would be protected as Seed Act is not adequate.

Why is the intellectual property theoretical legal framework ambivalent and at odds to practice in accessing new plant varieties of seeds by smallholder women farmers in Malawi?
The new plant varieties are protected using Seed Act which is meant just to certify seed for the Malawi's market. That at it may be, the research done by this paper has shown that plant breeders are still breeding new plant varieties despite having no *sui generis* law on protection of new plant varieties. However due to TRIPS agreement Malawi has to be compliant by providing legal protection of the new plant varieties as per Article 27 (3) (b) of TRIPS Agreement.

The research ably done by this paper has further shown that farmers on a small scale do sell farm saved seeds to each other. The research has further shown that the plant breeders themselves are not worried with this as it is done on the small scale thus it does not impede on their business.

Therefore, this paper holds that the plant breeders themselves know that there is not decisive law on which they can claim their right. This is so because the Seed Act does only certifies and not grant plant breeders rights. Furthermore, despite that the plant breeders are not protected but the very nature of the fact that replanted material does not bring much yield does stop the farmers to use such materials on a large scale.

The position of this paper is that Malawi has to enactment the Plant Breeder's Rights Bill. When this is done Malawi seed industry is likely going to be more innovative and venture into breeding more seed varieties. In the short to long term this will be a secured basis for rural women farmers to be food sufficient and secure propelling them towards increased socio-economic livelihood.

What are possible solutions and opportunities to the challenges so faced by smallholder women farmers in realizing their right to new plant varieties seeds?

Challenges
First challenge is increased cost of new plant varieties. Most farmers, especially rural women farmers, are poor thus it becomes expensive for them to buy the seeds.

The other is limited access to varieties of seeds. The research has revealed that maize is mostly available compared with other crops. This is likely due to the seed subsidy program by Malawi government.

Lastly, the lack of knowledge by the rural women farmers on the existence of laws on new plant varieties has made them not to appreciate the gravity of selling sowing farm saved seeds.

Possible solutions to the challenges

On the other hand, there are several benefits which include use of exemptions to the Plant Breeder's rights by allowing the farmers to replant their own farm saved seeds.

Furthermore, there is also an opportunity for the rural women farmers to be taught and made into groups which are meant to breed new plant varieties which are congruent to local appreciation.

Lastly, there is also an opportunity for government intervention. This can be possible for the government to develop new plant varieties and then they licence seed companies to multiply for supply to the rural farmers. This way it would reduce the cost of the seeds as the government would be the one holding the intellectual property rights. This is in tandem with the inspirations of Feminist Marxist legal theory and Ubuntu concept as a theoretical conceptualisation.

CONCLUSIONS AND RECOMMENDATIONS

The paper has shown that using the legal system for protection of new plant varieties is very important. It is the considered view of this paper that the foregoing will lead to increased food security and a better incentive for the breeders to concentrate on producing more new plant verities. This would have a greater impact on the food security of the rural women farmers.

Feminist Marxist legal theoretical underpinnings

The use of the western Feminist Marxist legal based theoretical underpinnings helps to have a better understanding of women as a class in general and then utilise them to understand Malawian women in particular. The Feminist Marxist legal theory actually helps the reconstruction of the Intellectual Property theories into the Malawian legal pluralism (Manji, A.S 1999: 448)

Gender insensitive customary laws

What most scholars, such as Chanock, M. (1985), Nyamu-Musembi, C (2005:14), have noted is that customary laws are gender insensitive. This argument puts holes in the papers' argument on reliance on Ubuntu/umunthu legal conception for the benefit of the rural women farmers in Malawi.

The paper's position is that while this is the case, but the argument does not take into consideration the use of a legal regime that encompasses Feminist Marxist legal theory with interwoven of Ubuntu/umunthu legal conceptualization. The blending does create an intellectual property regime which does bring to the fore the necessity of allowing rural women farmers to be trained into becoming plant breeding groups so that they can create their own certified seed which they can then sell to fellow rural farmers with a resultant effect of food security and socio-economic development of them.

Implication

It is the view of this paper that as pointed out the law does bring to the frontiers of businesses the recognition of the farmer as a holder of intellectual property in the cultivation of his or her crops in his or her own right. In addition, the paper is basically underscoring the theoretical compatibility. It has been shown that the solutions are compatible with the ideals of the blending of umuthu and Feminist Marxist legal theory. This would help rural women farmers of Malawi to have access to new plant varieties which eventually lead to food security in Malawi.

RECOMMENDATION

Formal seed law reforms

The paper proposes that Malawi needs its own Plant Breeder's Rights Act, which is currently in a Bill format. This would further, in the opinion of the paper, necessitate formulation of new Seed Act in order to be in tandem with the trends in the SADC seed harmonisation policy. The rationale for a formal legal system is that it becomes a basis on one can ascertain rights that have been accrued. The law in the process becomes a source of confidence on the intellectual property rights holder to invest more in new plant varieties. The reciprocal result is that there would be food security and economic development for the rural women farmers specifically and farmers in general.

Turning rural women farmers into plant breeders

The paper holds that there is need to ensure that positive customary seed promulgation aspects are promoted. This can be possible if rural women farmers are trained in plant breeding and making them work in groups as plant breeders. As it has been discussed in the foregoing, Feminist Marxist Legal theory upholds the emancipation of the women from the conferment of poverty.

Empower women rural farmers

Lastly, the paper also recommends that all stakeholders do more in reaching out to the rural women farmers on what the law provides especially on exception to the plant breeder's rights.

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Assessing Secondary Schoolteachers' Knowledge, Attitudes and Practices on Climate Change Education

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ABSTRACT

The concern of the study was to examine secondary school teachers' sources of information, knowledge, attitudes and practices on climate change education, however the study dwelled much on teachers knowledge on climate change impacts to Malawi In relation to climate change instruction as a mitigation strategy. Stratified and simple random sampling techniques were used in selecting the respondents for the study in public government secondary schools in Lilongwe central west division comprising of four schools; mkwichi secondary school and chigoneka community day secondary school in the urban, mitundu secondary school and mitundu community day secondary school in rural. The instruments for data collection were a teacher questionnaire and focus group discussion guide for learners. The study was the descriptive in nature and the population comprised 40 teachers 10 from each public secondary school and 20 learners from each school making a total of 100 participants. Stratified random sampling and simple random sampling were used to draw 40 teachers and 80 learners used for the study. The instrument for data collection had 29 items that were validated and whose reliability co-efficient stood at 0.79. Mean was used to answer the research questions and T-test statistics was used in analyzing the hypotheses at 0.05 level of significance. The questionnaire and the focus group discussion guide was structured by the researcher and validated by experts. The findings revealed that teachers have the knowledge of climate change impacts on man, animals, their environment, as well as the different mitigating strategies but they lack the resource to deliver accurate and updated information on the subject matter. The results also revealed that there's disparity between teachers' knowledge, attitude and practices of climate change in urban and rural secondary schools, between teachers in government secondary schools and those in community day secondary schools. The implication of the findings is that success of climate change education depends on the knowledge of the teacher which influences attitudes and practices. It is recommended that climate change education be introduced into the teacher training institutions and regular training and workshops be organized for teachers.

Key words:

INTRODUCTION

This chapter provides brief detail on background of the study, problem statement, objectives, research questions, and how significant was the study.

Climate change is a long term measurable change in the elements of climate tending towards extreme, which is in addition to rising global temperatures, Climate change constitutes one of the 21st Century key challenges to development, all over the world (UNDP, 2007). As such, climate

change has become an issue of global concern in the recent decades.

The government of Malawi in 2011 developed the National Climate Change Response Strategy (NCCRS) and its implementation plan, the National Climate Change Action Plan (NCCAP) 2013-2017, which outlines actions to be taken to mitigate and build resilience to the impacts of climate change e.g.Malawi national climate change policy section 3, Policy Priority Area 3: Capacity Building, Education and Awareness policy statement number vii, states, "Supporting inclusion of climate change into the educational curriculum at primary school, secondary schools and higher education including technical and vocational training institutions"

In this regard,the Ministry of Education, Science and Technology as part of their effort to integrate climate change education in Malawi's secondary school curricula recently launched a publication called Climate Change Sourcebook for secondary School Teachers Providing tools to support teachers is essential in order to promote climate change education in schools. The book was developed by specialists from the Ministry of Education, Science and Technology, Malawi Institute of Education (MIE), the Environmental Affairs Department, academia, practicing teachers and secondary education advisors. Current climate literacy efforts are situated at the crossroads of significant socio-political, educational, and environmental change. Scientific evidence points to a warming world accompanied by rapid and widespread global change (IPCC, 2007); this imbalance between personal concern and scientific literacy underscores the need for science educators' preparedness to teach about the science of climate change and its impacts. There is increased attention for climate change education because standards have considerable influence on classroom is instruction (Wise, 2010), Science teachers have traditionally view these aspects of socio-scientific issues as problematic to address in the classroom and outside the realm of their roles as science teachers (McGinnis, 2003). All of these challenges raise critical questions about appropriate educational responses to climate change. Teacher's knowledge attitudes and practices on climate change education focuses on the implementation of a comprehensive climate change instruction in secondary schools, which involves collaboration between formal and informal science educators, public mass communication outlets, and science education researchers. Therefore, if teachers have the correct perception on climate change education they may elaborate on ways in which when made clear will address teacher preparation and professional development in the area of climate change education. In preamble, a brief literature review that outlines key insights from past studies of teacher preparation, professional development, attitudes and practices on climate change education. Specifically, the study focused on teachers' climate change pedagogical knowledge, their attitudes on climate change curricular sources and technologies, and the challenges they face in bringing climate change into the classroom. Despite government's effort to promote climate change education, through various sources like teacher training initiatives, radio broadcasts, banners and research projects secondary school learners are not action sensitive to climate change issues why? It is argued that not much is done to strengthen secondary school teachers' capacity to deliver accurate instruction on the subject matter. While there is empirical evidence from diverse countries that teacher understanding of climate change effects is inadequate for teaching it (Papadimitriou *et al* .,2008).Some sociological studies have found that scientific literacy is actually poorly correlated with belief in anthropogenic climate change (e.g. Kahan, 2013).

Climate change specialists have repeatedly pointed out that a solution to climate change problem will require climate change awareness and its proper understanding. The role of teachers will go a long way in achieving this purpose. As succinctly pointed out by Mosothware (1991) teachers can provide a vital link in the delivery of climate change knowledge, its associated problems and solution. How will our teachers deliver accurate information to their students, if they are lack understanding of the subject matter? Litus (2012), said that lack of teacher knowledge of climate change will remain a barrier to effective climate change education. This study was based on the assumption that climate change education is one essential tool that, when implemented well, can

promote both knowledge and action-oriented concerned citizen. The overall objective of the study was to assess secondary school teachers knowledge attitude and practices on climate change education. The literature review focuses on the following factors, climate change information sources, climate change awareness, and ways on improving awareness as these help to make informed decisions to curb climate change.

Teachers knowledge on Climate Change.

Teachers' and prospective teachers' ideas have also been examined (i.e. Boyes, Chambers, &Stanisstreet, 1995; Dimitriou, 2002; 2003; Dove,) the results showing that teachers also hold misconceptions and misunderstandings about climate change (i.e. Dove 1996; Groves & Pugh, 1999). Examples of prevalent misconceptions include the following: that global warming is caused by increased penetration of solar radiation, that it is connected with holes in the ozone layer, that it would result in increased skin cancer, and that use of unleaded petrol would reduce it. Across most groups examined, there appeared to be a general conflation of thinking about global warming and ozone layer depletion.

These misconceptions and misunderstandings were probably due to, among other things, the complexity of the science involved and until recently the controversy and personal attention, by way of mitigating actions, these issues demanded. Given that there is empirical evidence that suggests pro-environmental behavior is predicted by knowledge and education about the issue in debate (Barr, 2007; Weaver, 2002), it is important that prospective teachers, who are in a position to influence their students, begin their teaching careers with a clear understanding of at least the basics of a topic as important as climate change.

With numerous studies conducted since then reveal that the vast majority of people across the world, especially in developing countries, are unaware of climate change despite their high vulnerability to its impacts, (Bostromet al., 1994; Bord Fisher, and O'Conner, 1998; Pew Research Centre, 2006; Pugliese and Ray, 2009; Godfrey et al., 2009). Despite their awareness of changing weather patterns, people in Africa, are particularly misinformed about global climate change (Godfrey et al., 2009; Taderera, 2010).

In this regard, the government has developed the National Climate Change Response Strategy (NCCRS) 2011 and its implementation plan, the National Climate Change Action Plan (NCCAP) 2013-2017, which outlines actions to be taken to mitigate and build resilience to the impacts of climate change e.g.Malawi national climate change policy section 3, Policy Priority Area 3: Capacity Building, Education and Awareness policy statement number vii, states, "Supporting inclusion of climate change into the educational curriculum at primary school, secondary schools and higher education including technical and vocational training institutions"

Teachers Attitude towards Climate Change Education.

Teachers attitude towards climate change as a threat across the world has been increasing over the years thanks to the severity and increased frequency of climate change education (UNDP, 2007), a research done by(Leiserowitz, Kates and Parris, 2005; Leiserowitz, 2006; Pew Research Centre, 2013). Says despite climate change education it is still not considered a priority environmental issue especially in the developed countries various studies show that people in developing countries are more likely to perceive climate change as a threat (GlobeScan, 2006; Pew Research Centre, 2006; Godfrey et al., 2009). Contrary results were, however, reported by Pugliese and Ray (2009) teachers in developing countries are more likely to perceived climate change as a serious problem than teachers in developed world, despite developing countries being the most vulnerable to climate change impacts.

Studies on climate change show that teachers have positive attitude (Lombardi and Sinatra 2012), on the radiation involve in the greenhouse effect (Choi et al. 2010), and on the causes and consequence of climate change (Pruneau et al. 2001). Contrary results were reported by Cordero et al. 2008 who states that negative attitude towards climate change persists even after receiving instruction about climate change and weather these are affected by sources of information like the media and schools (Ho 2009, Kisoglu et al. 2010).

Ways of Improving Awareness

To promote climate change education, it is crucial to strengthen teachers' and educators' capacities to deliver accurate information, integrate local content, promote critical thinking about and take action on climate change mitigation and adaptation (Ochieng and Koske,2013). This includes increasing their understanding of climate and sustainability issues as well as helping them develop necessary skills and providing them with pedagogical support.

Raising awareness and promoting knowledge and skills development, education is an essential component and a catalyst for responding to global climate change (GoM, 2011). Its importance has been increasingly highlighted at the international level. In particular, Article 6 of the UN Framework Convention on Climate Change (UNFCCC) encourages Parties to promote, develop and implement educational, training and public awareness programs on climate change and its effects (IPCC, 2007).

In addition, the United Nations General Assembly proclaimed the UN Decade of Education for Sustainable Development (DESD) 2005-2014, emphasizing that climate change is one of the key action themes of the Decade. Education for Sustainable Development (ESD) aims to promote the knowledge, skills, attitudes and values necessary to shape a sustainable future. It affects all components of the education system which include, among others, legislation, policy, finance, curricula, teacher education, instruction, learning, assessment, school governance and infrastructure and considers learning as a lifelong process taking place in various settings (UNITAR, 2013; UNDP,2007).

More specifically, CCE promotes learning about the causes and effects of climate change as well as possible responses, providing a cross-curricular and multidisciplinary perspective. It develops competences in the field of climate change mitigation and adaptation, with the aim to promote climate resilient development and reduce the vulnerability of communities in the face of an uncertain future (UNITAR, 2013).

Additionally, by preparing learners, communities and education systems to face natural hazards, CCE contributes to disaster risk reduction (DRR) efforts (UNITAR, 2013). Furthermore, teachers and educators need dedicated materials to support their learning activities on climate change. Examples of relevant materials include manuals, teachers' resource guides, lesson models and training modules, but also books, cartoons and videos (to name a few) to guide, inspire and empower students (UNITAR, 2013). Even as resources are put together to mitigate climate change, there is need to educate people on what climate change really is. Increasing people's awareness on climate change through education is an important measure to persuade people at all levels in the community to play an active role in mitigating and adapting to climate change (Ochieng and Koske, 2013).

MATERIAL AND METHODS

This section will describe the course of research focusing on research design, sample and sampling technique, data collection instruments, data analysis.

Study area

This study was conducted in the central region of Malawi (Lilongwe district) particularly central west education division. This division comprises of Lilongwe Rural and Lilongwe urban. Two zones were selected, in rural area and urban area. Lastly, from each zone, two schools were selected for the study making a total of four schools. Mkwichi Secondary School, Mitundu secondary school,Chigoneka community day Secondary School and Mitundu community day secondary school.

Research design

The study used both quantitative and qualitative approach to assess secondary school teachers knowledge attitudes and practices on climate change education the study also Identify teachers' sources of information available to the teachers and how the information they get from these sources affect lesson development and selection of delivery approach. This study was mixed in nature as this enabled the researcher to obtain in-depth, detailed information because participants have more freedom to express themselves. This research design enables more complex aspects of experience to be studied because they are more flexible in nature and impose fewer restrictions on the data (Barker, Pistrang& Elliott, et al.. 1994). Therefore, in order to achieve these objectives, the study benefited from the use of mixed methods of research.

The Target population

In order to achieve the objectives of the study, secondary school teachers were targeted. The group was involved in collecting information that could be triangulated for confirmation, since the major part of the study will involve collection of qualitative data.

Sampling techniques

Purposive sampling technique was used whereby participants were selected according to criteria relevant to this particular research study (in this case participants include; geography, agriculture, biology, social and development studies, and life skills teachers in forms 1,2,3, and 4, In the selected secondary schools). Science teachers were required to answer a questionnaire while learners took part in focus group discussions.

Sample size.

A total sample of 40 teachers was purposively sampled, from the sample 10 questionnaires were administered to 10 teachers at each school, 15 learners from each school took part in the focus group discussion.

Reliability and Validity

In order to ensure the reliability of the techniques of collecting data, the questionnaire was piloted to two members of staff within the education department at LUANAR and three fourth year students of Agriculture Education. The results assured that the questions wording carries a common meaning among the pilot respondents and they shared a common understanding. On the other hand, validity of the data collection techniques was approved as the pilot respondents confirmed the design of the questionnaire and focus group discussion guidelines provided what was assessed or measured. The pilot respondents were credible bearing in mind they have been in teaching professional for quite good time more especially the members of staff.

Data collection techniques

The data was collected through questionnaire and focus group discussions which were utilized to document meaningful experiences within the local contexts regarding the teachers 'readiness to deliver accurate climate change instruction to secondary school students. Published and unpublished literatures on teacher involvement in climate change awareness campaign in Malawi, was also explored to understand the current climate change situation in the country. The questionnaire was

structured in a way that it assessed teachers' knowledge attitudes and practices on climate change education and explored ways of supporting secondary school agriculture teachers so as to improve their awareness to climate change mitigation and adaptation strategies.

Data Analysis and Interpretation

The participants of the study were divided into two groups and two different data collection tools were used. These tools were teacher questionnaire and focus group discussions guide. The qualitative data was summarized and organized into thematic areas using the triangulation approach. This was done in order to synthesize and interpret data from the experiences collected on issue of climate change in order to converge on an accurate representation of reality (Polit&Hungler, 1995). This approach was used in order to minimize biases that could have distorted the results of the study.

Ethical Consideration

A letter from the department of communication and development studies permitted me to go to the chosen areas and meet the participants of the study to answer the questionnaire and take part in focus group discussions where the headmasters and headmistress helped by directing and identifying the targeted group.

RESULTS AND DISCUSSION

Sources of information available to the teachers.

The figure below shows the summary of the main sources of information available to the teachers.

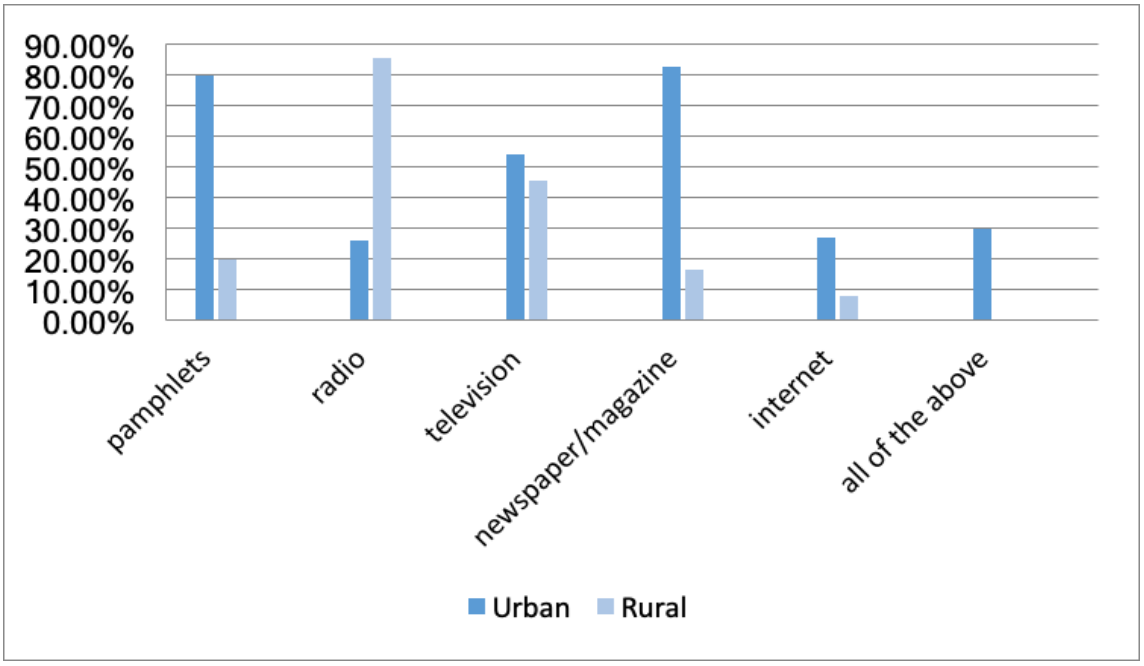

Figure 4.3: Main Sources of Information (%)

Today teachers worldwide are encouraged and expected to use Information and Communication Technology (ICT) in instruction (Gibson & Oberg 2004). Results from both rural and urban show that the information sources the groups cited varied in predictable ways only radio and television appeared as the two main sources of information representing 41% and 23.1% respectively subscribed to by both groups. All participants cited them as an information source for these issues. As might be expected, results suggest that although television and radio still plays an important educating role for teachers, despite the internet which has now gained primacy, replacing books and

magazines as sources of information for them. However teachers said the information they receive from these two media sources is insufficient for teaching as it lack scientific concepts as Such researchers have illustrate the importance of accurate public knowledge of these important issues since as Bronfenbrenner theorized (1979) macrosystem influences have ramifications at the level of the individual.

However only 7.7% of teachers in urban secondary schools use or have access to internet services and do access climate change information from global metrological reports and online websites. Such a percentage is so because there is no internet access in all the selected schools thus teachers have to use their phones and airtime to access the internet which they claim to be expensive and very slow.

"It takes a lot of time to connect to the internet when it finally connects you find that all your airtime is gone". One teacher explained.

Another contributor that has resulted in low use of internet is lack technology skills due to generation gaps that exist between the teachers themselves and also between teachers and students. Young people have been brought up in the digital era, whereas adults have gained their skills in ICT later in life. Consequently, there is generally a 'digital knowledge gap' between a teacher and his/her students. Thus it is mostly a challenge to teachers to select appropriate teaching instruction that will fit student's preconceived knowledge in rural secondary school. Rachel A Karchmer (2001) argues, teachers can learn a great deal from other teachers who regularly use the Internet in instruction.

Not only are such significant differences due to generation gaps and lack of skill. It was also observed that teacher lack of resources and published literature is also a major contributing factor. In all the schools that were involved in the study there's no access to internet, very few computers and all the schools have one radio each and a few books in the library. Thus print media represented 12% and 10% of teachers use pamphlets and newspaper/magazine(s) respectively town criers represented 5.1%,

It is likely that the picture obtained from this study is not an isolated one. Other Researchers have pointed to a lack of curriculum content regarding climate change in schools (Choi, Niyogi, Shepardson, &Charusombat, 2010) leading to teachers receiving more of their information from the media (Robertson & Barbosa, 2015).

Teachers' knowledge on climate change causes in Malawi.

The figure below shows the main causes of climate change as identified by the teachers who took part in the study.

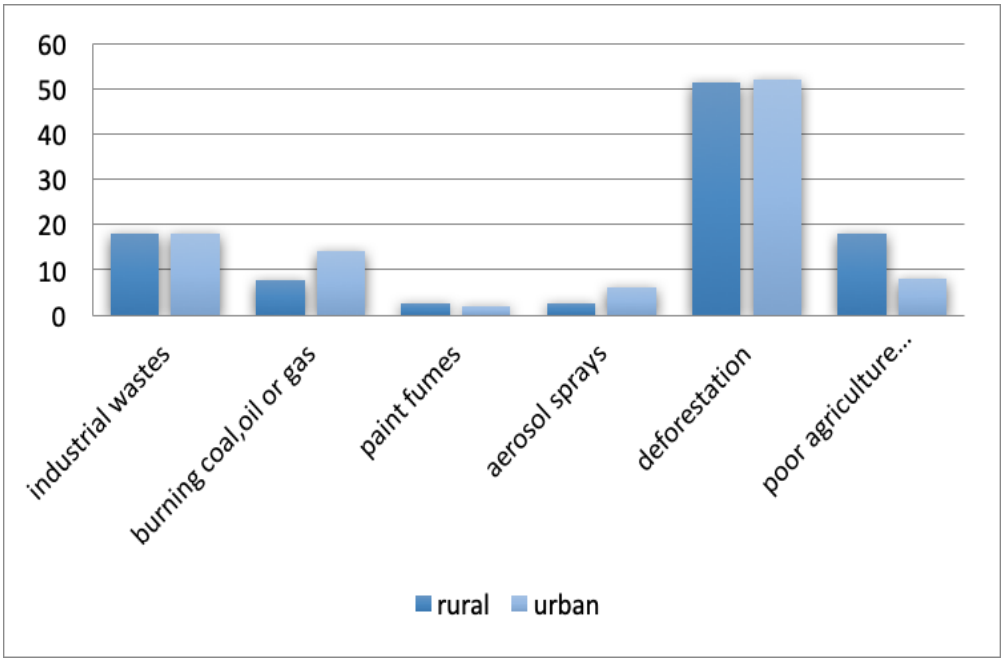

Figure 4. 1: Main causes of climate changes (%) in Malawi

From the above figure it shows 51.3% of the teachers correctly identified that deforestation as the main cause of climate change to Malawi. Seconded by industrial wastes and poor agricultural practices representing 17.9 % despite teachers having the knowledge on the causes of climate change over 50 percent of respondents fail to correlate the science behind causes of climate change and human practices due to lack of training on the topic

Some sociological studies have found that scientific literacy is actually poorly correlated with belief in anthropogenic climate change (e.g. Kahan, 2013).

In rural schools (mitundu secondary an mitundu cdss)It was also observed that there have been a lot of tree planting campaigns around these schools and radio programmes that is why most teachers identified deforestation as the main cause of climate change to Malawi. However, it seems most of respondents are aware of causes of climate change, such as improper management of wastes, burning of fossil fuels e.g. coal, oil and gas, paint fumes, aerosol sprays, and poor agricultural practices despite the poor correlation of the science and the human practices. For example about 30% of the teachers in urban said improper management of wastes pollutes the environment whilst teachers in the rural were able to explain that poor waste management reads to production of methane gas.

It seems teachers mostly in urban secondary schools have a problem to correlate the option of choice and how it causes climate change this was identified to be the biggest problem amongst teachers. A research done by Aladag and Ugurlu (2009) found out that, such poor corrections are probably due to, among other things, the complexity of the science involved, the uncertainties and information sources surrounding them. Riggs, 2009 elaborates that Climate change awareness involves creating knowledge, understanding and values, attitude, skills and abilities among individuals and social groups towards the issues of climate change for attainment of a better quality environment.

The study also found out that both Teachers in rural and urban secondary schools are well informed on adaption measures such as disseminating of information on disaster risk reduction and climate change adaptation, raising awareness about improving health care and sanitation, working in

partnership with NGOs and relevant provincial departments, and forming and improving disaster risk reduction committees at village, commune and district levels.

Teachers Knowledge of Climate Change Effects to Malawi.
The figure below shows climate change effects to Malawi as identified by the teachers who took part in answering the questionnaire.

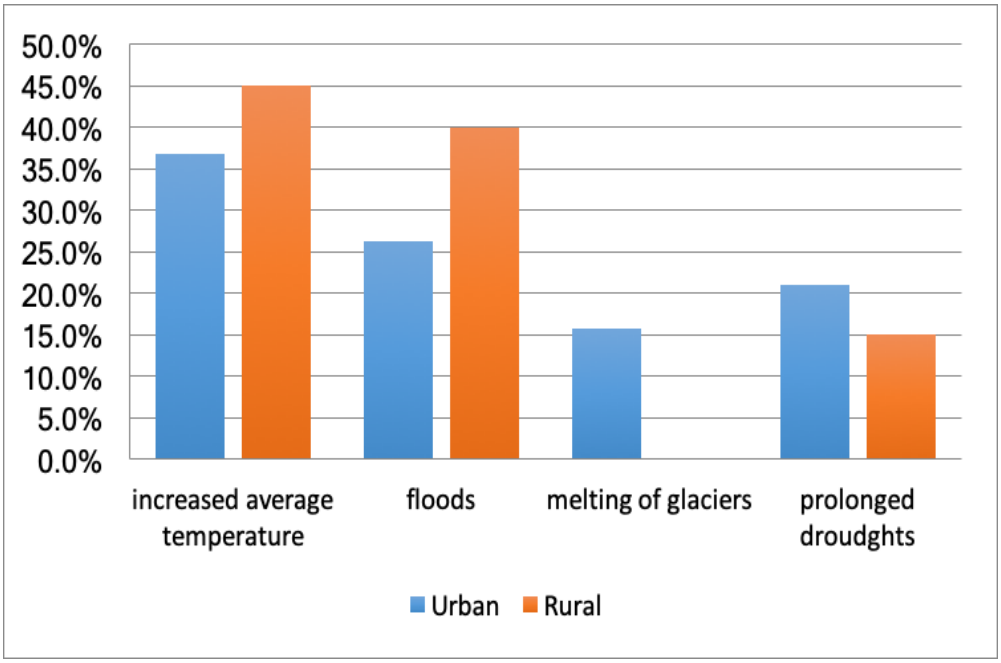

Figure 4.2: Effects of climate change in Malawi

Results show that 41% of the teachers identified increase in average temperature as climate change effect to Malawi while prolonged droughts and floods represented 33% and 18% respectively. However, 8% of the teachers in urban secondary schools did not correctly identify climate change effects to Malawi they identified melting of glaciers of which Malawi doesn't have glaciers. This is so because, teachers in the urban secondary schools have access to various sources of information which includes televisions and the internet as such teachers demonstrate greater levels on the effects of climate change. However such knowledge is useless if teachers fail to apply it and relate it with lesson development and delivery of instruction that will promote learners understanding to climate change such knowledge can be considered as a misconception.

Papadimitriou, 2008 who states that misconceptions about climate change issues are not only held by students but by teachers as well. As such the capacity to deliver accurate information by teachers to student still remains a topic for discussion. Among the many reasons that cause such misconceptions and misunderstanding, lack of training on the topic under discussion was identified as another contributing factor.

"I wish I was much knowledgeable about climate change issues so I could deliver the right instruction to my students". One teacher explained.

According to the national education sector plan (NESP 2008-2017) qualified teachers rarely attend professional development courses (Continuous Professional Development – CPD) once teachers are deployed in various schools in Malawi they part with continuous professional development. Since climate change is treated as a cross-cutting issue, and not a subject teachers are required to make every effort to integrate climate change content into all the subjects in the curriculum teachers both

in the rural and urban have not attended any special training on the subject matter hence they claimed only agriculture teachers attended a training when on how to use climate change sourcebook thus teachers complained it is a challenge to integrate the content into instruction that is outcome based.

Norgaard,2011 points out that understanding the science doesn't necessarily lead a person to feel more concern about climate change; nor does knowledge automatically generate the kind of collective action necessary to adapt to this global problem.
Other researchers have argued that there is empirical evidence that suggests pro-environmental behavior is predicted by knowledge and education about the issue in debate (Barr, 2007). Weaver, 2002 elaborates that it is important that prospective teachers, who are in a position to influence their students, begin their teaching careers with a clear understanding of at least the basics of a topic as important as climate change.
Litus (2012) concludes that lack of teacher knowledge of climate change will remain a barrier to effective climate change education.

Teachers attitude towards climate change education.
The table below shows a summary of teachers attitudes towards climate change education this include both teachers who took part in answering the questionnaire and those who participated in focus group discussions.

Table 4.1: shows teachers attitude towards climate change education

	strongly disagree	**Disagree**	**neutral**	**Agree**	**strongly agree**
Government is doing enough to promote climate change education.	10%	21%	13%	31%	25%
It is already too late to do anything about climate change.	67%	3%		22%	8%
Impacts of climate change on education system.	36.%	31%	5%	10%	18%
I want to teach my students about climate change.	19%	5%	1%	44%	31%
I want to learn more about climate change at school.	20%			26%	54%

The attitude scale was designed toward the measurement of (a) accepting attitudes toward climate change (beliefs) and (b) willingness to take actions (intentions) in line with published theories and research based recommended practice.

From the summary in Table 4.1 above results shows that teachers have a positive attitude towards climate change, a good number of them said they would like to go to school and learn about climate change while others said they want to teach their students about climate change.
To a point that the results validated the national education sector plan (NESP, 2008-2017) which outlined that qualified teachers rarely attend professional development courses (Continuous Professional Development – CPD) once teachers are deployed in various schools.

Fortus, (2014) further contended that very little teaching occurs without a desire to teach (motivation, attitudes, beliefs, self-efficacy, interest, self-concept, etc.). Intentions and beliefs have been recognized as important in science education for decades (Haney, Czeriak, & Lumpe, 1996). Behavioral intentions have been defined by Ajzen, (2002) as indication of an individual's readiness to perform a given behavior, based on attitudinal beliefs and perceived behavioral control, and are assumed to be an immediate predecessor to behavior.

Other researchers have pointed out that, if people evaluate the suggested behavior as positive (attitude) there is a higher intention (motivation) to perform the behavior. Many studies have confirmed a high correlation of attitudes to behavioral intention and subsequently to behavior (Sheppard, Hartwick, &Warshaw, 1988).

The results are in line with a study done by Sinatra, Kardash, Taasoobshirazi, & Lombardi, 2012, who found out that measuring attitude toward human-induced climate change found teachers who have a more accepting attitude toward climate change are more likely to express a willingness to take action. Thus the positive attitude that teachers possess are due their confidence and willingness to take part in climate change education.

Most commonly used Teaching practice.

The figure below shows the most commonly used teaching practices that teachers use to deliver key climate change information to learners.

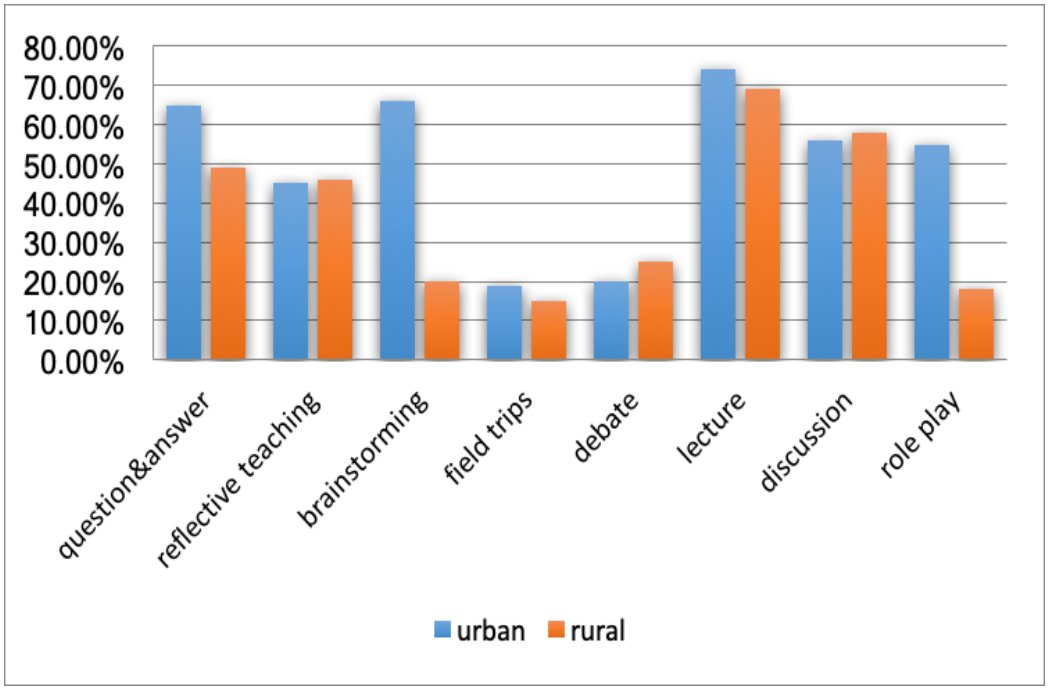

Figure 4: Teaching approaches used by teachers in climate change education.

Results elaborate that teaching method is greatly influenced by the teachers knowledge and competence on the topic thus when teachers were asked how does teaching approach used affect learners understanding and awareness on climate change. Teachers in the rural and urban secondary schools revealed that it is a challenge to use learner centered approach as it is difficult to find opportunities that exist for innovative pedagogical practice. Berger, 2010 said Teachers demonstrate a wide range of knowledge, skill and competence through the use of various teaching strategies.

One teacher at Mitundu secondary school said she uses lecture method explained that she uses the lecture method “Because they're young and wild, a lot of them hold on to the attitude that their parents have. That's why a lot of them say, ‘I don't believe in global warming, I don't believe in evolution, I don’t believe in atomic theory. In any case, will these assert the “correct view?” The teacher continued to say that she encourages her students to consider the evidence on both sides and make up their own minds.

In her case, she explained that: "most of them are teenagers! They haven't had enough exposure to the world to really *make that decision or not. They're repeating the same old process that someone else told them! And you know what? Climate is continuously changing. Thus there's a need to learn how to be able to look at data sets and make up their own mind".*
Her argument was if students can "make up their own minds," their conclusions are going to be more meaningful than those "parroted" back from a teacher, parent, or other third-party source of information. A teacher at Mkwichi secondary school had a different view of the subject matter.

"Does this inquiry-based approach reliably lead students to the "right" answer concerning climate change?" One teacher criticized.

He continued to say Students *don't* always arrive at the "right" answer. Students' doubt and have misconceptions, which arise due many possible reasons. The risk comes in when students didn't receive correct instruction in evidentiary thinking, or didn't receive enough evidence to make a sound conclusion. Or, perhaps the student successfully arrived at a scientifically valid conclusion, but then couldn't reconcile that information with his emotional or religious assumptions he said he prefer reflective teaching other than inquiry based approach. As climate change requires an observation in the weather for the past 30 years, so as to effectively monitor such gradual changes.

It was observed from the study the most frequently used teaching strategies from the multiple response selection list lecture method represented 75% and 70% for rural and urban secondary school respectively, it was noticed that teachers assert that they teach according to the way they were taught, and what they believe is the easiest way to cover the teaching material. Other teachers said the syllabus is shallow it lacks the content to equip teachers with the right knowledge on how to deliver the right instruction to students and t what effect.

"I don't need a syllabus to guide the content of the class the syllabus is too shallow. I depend on my own knowledge…" one teacher explained

The way students learn, or their learning style is the manner through which cognitive, affective, and psychomotor skills process, internalize, and retain any new and difficult information". Over the years, learning style researchers have repeatedly observed that not all students learn in the same way. Students have unique learning styles that articulates the particular conditions and context under which they learn best (Alaka, 2011; Felder and Brent, 2005).

Not surprisingly, studies have found that teaching styles that match students' learning styles, also known as learning preferences, offer a wide number of benefits to students (Domino, 1979; Correspondingly, research has also found that teaching styles that do not match students' learning preferences have detrimental effects on students' learning (Felder, 1996; Hsueh-Yu Cheng &Banya, 1998; Reid, 1987).

"I understand that about half of my students are kinesthetic learners and the rest is a combination visual and auditory learner so I use a combination of lecture method through reflective teaching and debate"… Another teacher explained.
Biggs, 2009, elaborates that students need to be shown how to adapt to problem solving and critical thinking skills that are crucial for an innovative economy and a knowledge society.

This highlights the importance for teachers to consider students learning preferences when making decisions regarding which teaching styles to employ in their classrooms. However, there is wide consensus in the literature stating that traditional education does not address the learning styles of all students (KoIb &sss KoIb, 2005). Teachers' teaching methods regularly put an emphasis on certain learning styles while ignoring others.

Second, even though there is widespread concern regarding what teaching practices teachers are using with students, as Shavelson and Stern (1981) point out, there has been insufficient investigation and information on why teachers choose the methods they do (as cited in Gordinier, 2002). Marshall's, (1991) research, one of the very few studies, revealed that in addition to choosing teaching practices that reflect the way they themselves learn, but once again as the cohort of individuals in the teaching profession is changing, the rationale behind their teaching methods might also differ.

CONCLUSION AND RECOMMENDATIONS

Finally this chapter provides conclusion and recommendations drawn from the findings of the study conducted to assess secondary school teachers' knowledge attitude and practices on climate change education.

CONCLUSION

In summary secondary school teachers' both in rural and urban have general knowledge about climate change and also there exist certain misconceptions and misunderstandings on the topic. Such misconception and misunderstandings are due to lack of Continuous Professional Development – CPD and sources of information available to the teachers; the information they get from the media sources is inadequate for teaching. Therefore, teachers do not use suitable teaching practice because teachers are faced with the challenge to relate the content to teaching method and learner's previous knowledge despite teachers having a positive attitude towards climate change education. The syllabus also is shallow as it lacks the needed content that teachers as implementers should instruct their learners to be action sensitive on issues about climate change.

It is neither the government nor an individual teacher's competence alone that can deal with the challenges faced in lesson delivery. A collaboration of all the stakeholders involved in the implementation of the programme will help in effectively implementing and dealing with the challenges.

Recommendations and areas for further studies

- Provides insightful information that can draw recommendation that can be taken into consideration by the schools, teachers, community and ministry
- Results such as the ones reported here should inform the development of teacher education programs to ensure future teachers are prepared with the best possible skills to engage and empower their students in a changing world.
- The researcher also recommends that the study be done on larger scale for further validation of results.
- Further studies should be done on the extent to which education syllabus is contributing to quality education in relation to climate change literate citizens

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Medical and allied health students' self-regulated learning: the interplay between motivational beliefs and learning strategies

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ABSTRACT

Research on academic self-regulation suggests that students' self-efficacy, intrinsic goal orientation, deep approach to learning and organized studying improve students' academic performance. The primary goal of the study was to investigate the extent to which students perceive their motivational beliefs and their self-regulated learning strategy use, and examine the relationship between the two constructs; motivational beliefs and self-regulated learning strategies. A sample of 205 first year students (121 males and 84 females) from College of Medicine in Malawi responded to a 5-point Likert-type scale questionnaire assessing their self-efficacy, intrinsic goal orientation and learning strategies. Data were analyzed using IBM® SPSS® Statistics, version 20. Compared with learning strategies, students reported higher levels of motivational beliefs; self-efficacy (M = 4.37, SD = 0.64); intrinsic goal orientation (M = 4.09, SD = 0.68). Male students had higher levels of intrinsic goal orientation than their female counterparts ($p < 0.05$), and first-generation students had higher levels of deep strategy than non-first-generation students ($p < 0.05$). Linear regression results indicate that both self-efficacy and intrinsic goal orientation positively predicted deep learning strategies (self-efficacy: $\beta = 0.21$; intrinsic: $\beta = 0.41$), meta-cognitive strategies (self-efficacy: $\beta = 0.30$; intrinsic: $\beta = 0.38$), and resource management (self-efficacy: $\beta = 0.25$; intrinsic: $\beta = 0.26$). The results suggest that first year medical and allied health students possess intrinsically strong motivational beliefs and that these beliefs have an important impact on their deep learning approach and organized studying. Possible implications of the results and recommendations for future research are discussed.

Key words: self-efficacy, intrinsic goal orientation, deep cognitive learning strategies, meta-cognitive learning strategies, resource management

INTRODUCTION

In higher education, especially medical schooling, educating students to become life-long learners who can effectively apply theoretical concepts to their professional contexts is an important aspect of formal education. Due to the nature of their profession, it is understood that students in medical institutions need to be more independent of their teachers in extending and updating their knowledge base. To achieve this educational responsibility, a number of medical institutions have shifted their teaching approach from the traditional teacher-centered to student-centered where the use of interactive and problem-based learning is mostly preferred (Gurpina et al., 2013; Samarakoon et al., 2013; Dolmans et al., 2015). University of Malawi (UNIMA), through College of Medicine (CoM), is also trying to incorporate the Problem-Based Learning (PBL) approach especially in the clinical years (Tembo & Ngwira, 2016). Barrows and Tamblyn (1980) define PBL

as "the learning that results from the process of working towards the understanding of a resolution of a problem" (p. 1). Students in PBL are first presented with a problem by their tutor; then they engage in independent study on their learning issues outside the tutorial, to come back later for discussions on a given problem. According to van den Hurk, (2006), students in PBL need to be encouraged to take responsibility for their own learning process (self-regulated learning) so that they actively contribute to their own learning.

Boekaerts (1996) argues that many researchers support the view that one of the major goals of formal education is to equip students with self-regulatory skills. These skills are viewed as very important to guide one's own learning during formal schooling. Self-regulatory skills also help in up-dating one's knowledge after leaving school. Pintrich (2000) defines self-regulated learning (SRL) as, "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment" (p. 453). Students can be described as self-regulated learners if they effectively use cognitive, meta-cognitive, resource management and motivational skills during their learning process (Zimmerman & Martinez-Pons, 1990). This notion suggests that essential to SRL are the motivational beliefs and the learning strategies or mental processes that learners deliberately employ to help themselves learn and understand something new. From the definition and a brief description of what SRL is, it is clear that in PBL, where SRL is encouraged, students should be motivated enough to take up the responsibility of monitoring their own learning, and it is vital that medical and allied health students become prepared for this new teaching approach as early as first year.

Motivational beliefs

By definition, "motivation is an internal process that activates, guides and maintains behavior overtime" (Slavin, 2006, p. 317). In education, the willingness to put effort into learning is as a result of several factors ranging from student's personality and abilities to characteristics of particular learning tasks, incentives, setting and teacher behavior. Pintrich et al., (1991) summarized all these motivational aspects into three general constructs. The first category is that of expectancy. It refers to students' beliefs that they can accomplish a task, and its components include self-efficacy and control beliefs for learning, which are students' beliefs that outcomes are dependent on one's own effort. The second general category is value, which focuses on the reasons students involve in academic tasks. Its components include value beliefs: intrinsic goal orientation (a focus on learning and mastery); extrinsic goal orientation (a focus on grades and approval from others); and task value beliefs (judgments of how useful, interesting the course material is to the student). The third general motivational construct is affect which focuses on test anxiety. Due to their effect on self-regulated learning strategies, in this study, motivational beliefs of self-efficacy (Khan et al., 2013) and intrinsic goal orientation (McCollum & Kajs, 2007) represented expectancy and value, respectively.

Self-efficacy beliefs

Apart from the mere understanding of factual knowledge, medical and allied health students also need to be self-confident in life-long skills such as problem solving and critical thinking and in applying the theoretical concepts to their professional contexts. This calls for them to be self-efficacious in their learning of medical and allied health courses. Within the self-regulatory learning theory by Pintrich (2000), self-efficacy is one of the motivational constructs. Academic self-efficacy refers to students' personal judgement of their own capabilities to organize and perform study related courses of action to attain designated goals (Bandura, 1997). Self-efficacy is viewed as a significant source of students' inspiration to work, and it is postulated to influence people's choices, level of effort and persistence (Bandura, 1997; Ross et al. 2016). Therefore, students who identify themselves as efficacious apply greater effort on a difficult task and are more likely to persist than those with less certainty of their capabilities. On the contrary, those who perceive

themselves as less efficacious for learning may choose easy tasks, regarding demanding tasks as threats other than challenges. They may also avoid some tasks failing to persist longer on some difficult tasks.

Shih (2002) further links self-efficacy with attribution and control-value theories of learning. On one hand, he argues that students who are less efficacious attribute their successes / failures to such factors as luck or easy task (factors which they have little or no control) hence they feel they cannot succeed on their own. Consequently, they resort into setting themselves easy objectives. On the other hand, efficacious students attribute their successes / failures to factors like ability and effort which are controllable and eventually are motivated to work productively. Due to their attribution and control beliefs, students with high self-efficacy are more likely to continue persisting in their coping efforts when they face obstacles and therefore are more likely to succeed (Bandura, 1997; Ross et al., 2016). Literature also indicates that self-efficacious students aim at mastering the concept especially for future performance (Zimmerman, 2000), as opposed to simply, getting the concept right for the sake of performance. In turn, students who master a challenging task may eventually increase their self-efficacy thereby bringing a reciprocal relationship between the two constructs; mastery and self-efficacy (Jungert & Rosander, 2010). Furthermore, the prior mastery of a concept will likely have a positive influence on the perceived future performance resulting in a higher degree of self-efficacy for the concept.

The mastery of medical and allied health concepts is very significant for students' life-long future practice as compared to simply knowing the ideas for the sake of passing examinations. Since in mastery goal orientation perceptions of efficacy depend on a mastery criterion of performance rather than that of normative (Zimmerman, 2000; Wolters et al., 1996), efficacious students rate their certainty about a certain task's particular difficult level and not in comparison with others in class. This particular educational attribute is highly anticipated in higher education, especially for medical and allied health students since their training aims much at producing health personnel who are independent of their teachers in handling delicate real life cases of health. This profession deals directly with the life of people.

Intrinsic goal orientation

In education, goal orientation is defined as a set of behavioral intentions that determine how students approach and participate in learning activities (McCollum & Kajs, 2007). These behavioral intentions are learners' beliefs regarding their own academic goals that explain why attaining a particular goal is necessary to them. The expectancy-value model of self-regulated learning postulates that the principal goals students possess for participating in an activity are either intrinsically or extrinsically motivated (Pintrich, 2000; Pintrich & Garcia, 1991). According to the model, learners who adopt an intrinsic goal orientation to learning mostly focus on internal factors such as understanding and mastering the materials they study (Pintrich, 1989). Conversely, students who adopt an extrinsic goal orientation approach focus on external factors such as grades, rewards, and approval from others (Pintrich, 2000; 1989). Expressing it differently, students who are intrinsically motivated adopt a mastery goal orientation and those who are extrinsically motivated adopt a performance goal orientation. Mastery goal orientation is when the student is focused on mastery and learning of the material and a performance goal orientation is when the student is focused on demonstrating his/her ability and performance in relation to other students (Wolters et al., 1996).

Compared with extrinsic goal orientation where students' characteristics are not affiliated with academic success (McCollum & Kajs, 2007), a number of studies have confirmed the importance of intrinsic goal orientation on mastery learning approach; it is associated with high-quality learning outcomes. Students who are intrinsically oriented, and who emphasize on the mastery of concepts

tend to place high intrinsic value on learning; are inclined to use deep information processing strategies, are self-efficacious and self-regulated; and attribute their success or failure to effort and strategy use (McCollum & Kajs, 2007; Wolters et al., 1996). McCollum and Kajs (2007) further argue that intrinsically-oriented students tend to pursue challenging tasks, spend a great deal of time on the tasks given, have positive attitude toward class and enjoy lectures. These are the most desirable attributes students need to demonstrate for learning to be meaningful. Consequently, intrinsic goal orientation has extensively been regarded as vital positive predictors of academic performance (Froiland et al., 2012; McCollum & Kajs, 2007). Research on intrinsic motivation has also indicated that intrinsic goal orientation enhances productivity in adults in their working world (Froiland et al., 2012).

Self-regulated learning strategies

From the definition of self-regulated learning (Pintrich, 2000), self-regulated learning strategies can be described as measures that students use to develop study habits, regulate and monitor their learning process, and make adjustments to their own strategies based upon feedback. Students who are self-regulated proactively look for information when needed and take the necessary steps to master it. There are three main approaches to students' learning which can be categorized as surface approach, deep approach, and organized (strategic) studying (Postareff et al., 2016; Entwistle & McCune, 2004). Briggs and Tang (2007) defines surface learning as an approach whereby a student learns only enough to pass assessment and fulfil the minimum requirements of the learning program. Students who adopt surface approach aim at memorizing without understanding the material (Postareff et al., 2016) and use superficial cognitive strategies such as repetition, highlighting, and memorization (Pintrich et al., 1991). The second approach, deep learning, is defined as an approach whereby students meaningfully engage with the course content and treat it as something worthy time spending and understanding (Biggs & Tang 2007). Consequently, students who adopt deep learning approach use appropriate higher cognitive activities needed to learn the material. According to Pintrich et al. (1991), these students use deep and metacognitive learning strategies such as critical thinking, planning, and monitoring to construct meaning in the study material.

The third approach, organized studying (previously referred to as strategic approach; Entwistle & McCune, 2004), refers to the student's ability to seek help from either peers or teachers, and manage study time and effort (Postareff et al., 2016). Pintrich et al. (1991) refer to this approach as resource management, and they argue that besides self-regulation of cognition, students must also be able to control learning resources such as managing and regulating one's study time, environment, and effort; peer learning, and help-seeking (focusing on the use of others in learning). Despite the fact that learners adopting both approaches (surface and deep) can use the organized studying approach, it is more associated with deep learning approach since it is in this approach (deep) where effort to get the concepts learned and mastered is emphasized (Entwistle & McCune, 2004). Considerable research indicates that the use of deep approach and organized studying is highly related to quality of learning, performance, and positive academic outcomes (Ahmed et al., 2012; Pekrun et al., 2002; Young, 2005; Zimmerman & Martinez-Pons, 1990). For the purpose of this study, two approaches were measured: deep approach using 'deep' and 'meta-cognitive' learning strategies, and organized approach using 'resource management'. Surface approach was not included in the study because it reflects shallow information processing which was not the focus of the study.

The interplay between motivational beliefs and learning strategies

Self-efficacy and intrinsic goal orientation are the two motivational beliefs that are closely related to SRL. According to Zimmerman and Cleary (2006) a key determinant of whether learners employ self-regulated learning strategies or not rests on self-efficacy, the beliefs they hold about their capabilities to achieve certain tasks. According to Khan et al. (2013), self-efficacy is postulated to

have a positive relationship with cognitive processes of an individual; the stronger the perceived self-efficacy, the higher the cognitive strategies used. On the contrary, less efficacious students tend to avoid failure and damage their self-esteem by seeking easy tasks, and might even be subjected to employing shallow strategies (Shih, 2002). Just as self-efficacy, research on goal orientation indicates that intrinsic goal orientation is associated with deep information processing strategies while extrinsic goal orientation is associated with shallow information processing strategies (Wolters et al., 1996; McCollum & Kajs, 2007). Students who are intrinsically oriented are self-efficacious and self-regulated; they tend to pursue challenging tasks, spend a great deal of time on the tasks given and attribute their success or failure to effort and strategy use (Wolters et al., 1996; McCollum & Kajs, 2007).

Although a growing body of literature exists on the relationship between motivational beliefs and self-regulated learning strategies, empirical evidence of their relationship in medical education is scanty. As Artino et al. (2010) notes, medical education literature tends to focus mostly on cognitive factors such as prior academic achievement that do not explain much on the variance in academic outcomes. Except for a few, most prior studies on students' motivational beliefs have evaluated medical student self-efficacy and intrinsic motivation in a general context (Woods et al., 2014) and not linking them up with self-regulated learning strategies. Based on the reviewed literature on the possible relationships between motivational beliefs and the learning strategies, and the effects these associations bring in formal education, it was important to study the co-existence of these two constructs in medical education. Research has already ascertained that students' academic performance is, among other factors, much influenced by students' self-efficacy and intrinsic goal orientation (Stegers Jager et al, 2012; Khan et al, 2013; McCollum & Kajs, 2007), and self-regulated learning strategies (Ahmed et al., 2012; Pekrun et al., 2002; Young, 2005).

The major focus of this study, therefore, was two-folds. First, we aimed to investigate the extent to which medical and allied health students perceive their motivational beliefs of self-efficacy and intrinsic goal orientation, and self-regulated learning strategies. Second, we aimed to examine the relationship between the two constructs; the motivational beliefs (self-efficacy and intrinsic goal orientation) and self-regulated learning strategies (deep approach - deep and meta-cognitive strategies, and organized approach - resource management).

MATERIALS AND METHODS

Study design

This was a cross-sectional survey design which used quantitative methods of data collection and analysis. The study's main purpose was to investigate students' motivational beliefs and their self-regulated learning strategies, and establish the role motivational beliefs play on self-regulated learning. Part of a predesigned and pre-tested survey was used to collect the data. No personal information that would identify individual participants was collected. Data were collected from college students during their second semester of their first professional year.

Sample population

A total of 222 undergraduate students from College of Medicine, a constituent college of the UNIMA, were recruited for the study. These were medical and allied health students aged between 18 and 22, who were enrolled in their 2015-2016 first year at the college. Students at this college have diverse economic, cultural, and social backgrounds; the college enrolls students from almost every district of the country, both government and self-sponsored. Each year, the college enrolls students into a one year foundation program (foundation year), as a preparatory training for their medical career. After a year, the students are then enrolled into their first professional year as medical and allied health students (second-year at college), split into four different programs:

Bachelor of Medicine Bachelor of Surgery (MBBS), Bachelor of Pharmacy (PHARM), Bachelor of Physiotherapy (PHYSIO), and Bachelor of Medical Laboratory Sciences (MLS). For the purpose of this study, all enrolled first-year students (second-year at college) were invited to participate in the study; there were no exclusion criteria.

Procedure

Before conducting the survey, the study had to follow some ethical principles to protect the life, privacy and confidentiality of participants. First, an institutional review board, College of Medicine Research Ethics Committee (COMREC), approved the research protocol. Second, the study was made anonymously, meaning that no personal information that would identify individual participants was collected, and finally, informed written consents were obtained from the participants themselves. Surveys assessing students' self-efficacy, intrinsic goal orientation, deep and meta-cognitive strategies, and resource management with respect to their respective major courses were given to the participants in their classrooms. Participants were reminded about the study's anonymity and confidentiality. They responded to the questionnaires at their own free time and completed questionnaires were put in a sealed box, which was put at the dean of students' secretary's office, before the end of business the following day.

Instrumentation

Motivated Strategies for Learning Questionnaire (MSLQ)

The Pintrich et al.'s (1991) Motivated Strategies for Learning Questionnaire (MSLQ) was used to measure student's motivational beliefs and learning strategies in their respective major courses: Introduction to Medical Laboratory Science for MLS, Anatomy for MBBS, Introduction to Physiotherapy for PHYSIO, and Introduction to Pharmacy for PHARM. The MSLQ was chosen because it is designed to measure university students' motivational beliefs and their use of different learning strategies, which were the focal concepts to be addressed in this study. Three separate sub-scales of the MSLQ were used to assess students' motivational beliefs and the learning strategies. Participants responded to eight items assessing their self-efficacy ($\alpha = 0.93$); and four items assessing their intrinsic goal orientation ($\alpha = 0.74$). Deep learning approach was measured by two dimensions of the cognitive and metacognitive sub-scale: deep learning strategies and meta-cognitive learning strategies. Participants responded to a total of 15 items assessing their deep learning strategies: six items for elaboration ($\alpha = 0.76$), four items for organization ($\alpha = 0.64$), and five for critical thinking ($\alpha = 0.80$); and 12 items assessing their meta-cognitive learning strategies ($\alpha = 0.79$). Finally, organized learning approach was measured by 19 items of resource management sub-scale: four items for time and study management ($\alpha = 0.52$), three items for effort regulation ($\alpha = 0.76$), four items for peer learning ($\alpha = 0.69$), and 8 items for help seeking ($\alpha = 0.76$). The questionnaire therefore, consisted of a total of 50 items, scored on a 5-point Likert-type scale, ranging from 1 (not at all true of me) to 5 (very true of me).

Data Analysis

Statistical data analyses were done using IBM® SPSS® statistics version 20. Prior to the data analysis, the collected data were screened for accuracy and missing value. Each item was later checked for normality, and reliability analyses were also done to check for the instrument's consistency. Following the screening and reliability tests, Pearson correlations were calculated to establish the association between variables assessed in the study. Descriptive statistics for all the tested variables were realized and tabulated from raw data. To test if there were disparities in motivational beliefs and learning strategies 1) between male and female participants, and between FGC and NFGC students, independent samples t-test was used ($p < 0.05$); 2) among four study programs of MBBS, PHARM, MLS, and PHYSIO, a one-way analysis of variance (ANOVA) was used ($p < 0.05$). Finally, to find out if students' self-efficacy and intrinsic goal orientation predicted their learning strategies, a simple linear regression ($p < 0.05$) was used.

RESULTS

Of the targeted 222 students, a total number of 205 students (92%) participated in the study and completed the survey. According to their programs of study, 67 students (39 males and 28 females) came from MBBS, 51 students (31 males and 20 females) from PHARM, 47 students (27 males and 20 females) from PHYSIO, and 40 students (24 males and 16 females) from MLS. In total, the male-to-female ratio of the participants was 121 to 84 representing a 59% to 41% ratio in terms of percentages. The reliabilities of the subscales from this survey were also computed; Cronbach alpha for self-efficacy was 0.87; for intrinsic goal orientation, it was 0.59; for deep learning strategies, it was 0.88; for meta-cognitive learning strategies, it was 0.78; and finally for resource management, it was 0.76.

Descriptive and Pearson correlation statistics

Table 1 presents descriptive results and the Pearson correlation analysis, for all the study variables. Correlation results show that there were significant positive relationships among the variables tested. A rather strong correlation can be observed between self-regulated learning variables: deep strategy/meta-cognitive strategies and meta-cognitive/resource management strategies. The strong relationship suggests shared variability between these concepts, and it proves the fact that they are all measuring one construct: learning approaches. However, mild relationships can be observed between learning approaches and motivational beliefs: for instance deep strategy/self-efficacy and resource management/intrinsic goal orientation. This suggests that the constructs are distinct.

Table 1: Descriptive statistics and Pearson correlation analysis (n = 205)

	Variable	Mean	SD	1	2	3	4	5
Motivational beliefs	1. Self-efficacy	4.37	0.64	-				
	2. Intrinsic goal	4.09	0.68	.539**	-			
Deep approach	3. Deep strategy	3.64	0.78	.434**	.528**	-		
	4. Meta-cognitive	3.69	0.74	.507**	.546**	.804**	-	
Org. approach	5. Res. management	3.50	0.61	.393**	.395**	.694**	.706**	-

** = $p < 0.001$

Org. approach = organized approach; Res. Management = resource management

Descriptively, the mean score comparisons among study variables indicate that largely, students reported higher levels of motivational beliefs than the learning strategies. To test if there were significant differences among the variables, one-way repeated measures of analysis of variance (ANOVA) was used, and the results show that the data violated the assumption of Mauchly's test of sphericity. Since the data did not satisfy the assumption of sphericity, Greenhouse-Geisser correction was used to measure the differences and the results show that the mean scores were significantly different $F(3.210, 654.800) = 124.461$, $p < 0.001$). A pair-wise comparison analysis using Bonferroni correction reveals that there were significant differences on almost all paired variables ($p < .05$) except for one pair; deep and meta-cognitive strategies ($p = 1.000$). Figure 1 illustrates the mean differences between the tested variables. From the graph's **mean inspection, t**herefore, we can conclude that students reported higher levels of motivational beliefs of self-efficacy and intrinsic goal orientation than the learning strategies.

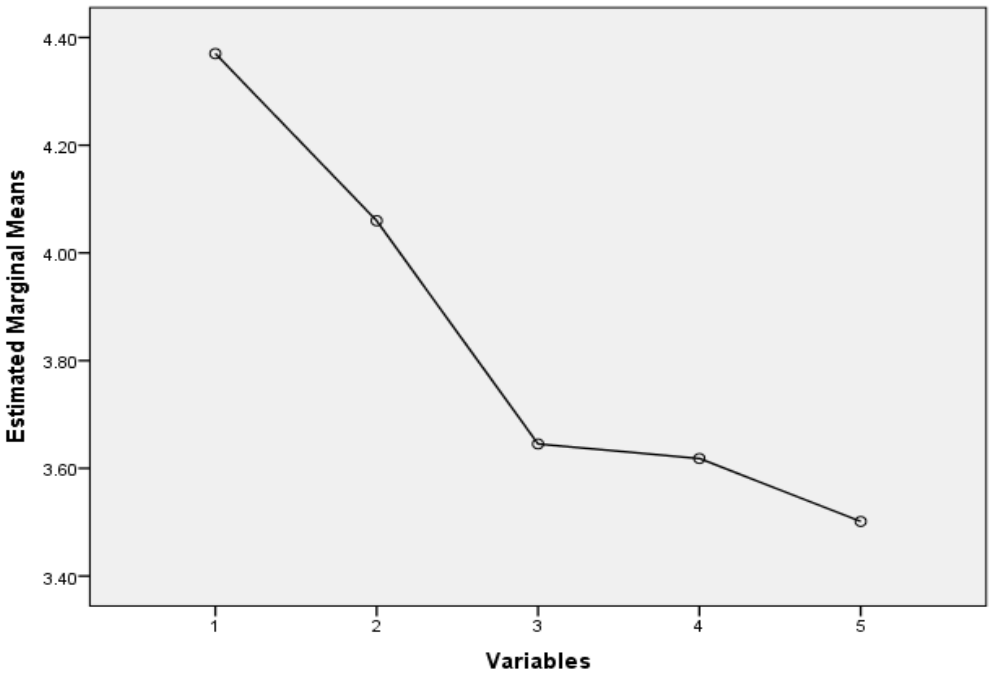

Figure 1: The extent to which students adopted motivational beliefs and learning strategies

1 = self-efficacy, 2 = intrinsic goal orientation, 3 = deep strategy, 4 = meta-cognitive strategy, 5 = resource management

Disparities of intrinsic goal orientation and deep learning approach

Independent samples *t*-tests were used to find out variable differences between male and female students; and first-generation college (FGC) students and non-first-generation college (NFGC) students. Concerning gender differences, the *t*-test results reveal that there was a significant gender difference on intrinsic goal orientation; male students had higher scores than female counterparts; male ($M = 4.14$, $SD = 0.75$); female ($M = 3.92$, $SD = 0.73$); $t(203) = 2.076$, $p < 0.05$. No significant differences were observed on self-efficacy, deep and meta-cognitive learning strategies, and resource management. On family members' education, FGC students reported higher levels of deep cognitive learning strategy use than NFGC students; FGC ($M = 3.75$, $SD = 0.75$); NFGC ($M = 3.52$, $SD = 0.78$); $t(203) = 2.115$, $p < 0.05$. However, on self-efficacy, intrinsic goal orientation, meta-cognitive learning strategies and resource management, no differences were observed between the two generation statuses.

To determine the differences based on students' affiliation to a particular program (MBBS, PHARM, MLS and PHYSIO), a one-way analysis of variance (ANOVA) was conducted. Results reveal that there were no statistically significant differences among the four group means on all the three constructs tested in this study ($p < 0.05$). The main effects of the dimensions were not significant: self-efficacy [$F(3, 201) = 0.18$, $p = 0.910$]; intrinsic goal orientation [$F(3, 201) = 1.58$, $p = 0.196$]; deep strategies [$F(3, 201) = 0.38$, $p = 0.769$]; meta-cognitive strategies [$F(3, 201) = 1.72$, $p = 0.543$]; and resource management [$F(3, 201) = 1.96$, $p = 0.121$].

The influence of motivational beliefs on self-regulated learning strategies

Students' self-efficacy and intrinsic goal orientation were used in a simple linear regression analysis to predict students' deep learning approach through deep learning strategies and meta-cognitive learning strategies, and organized studying approach through resource management. The regression results show that both motivational beliefs of self-efficacy and intrinsic goal orientation positively predicted deep learning strategies (self-efficacy: $\beta = 0.211$; intrinsic: $\beta = 0.414$), meta-cognitive strategies (self-efficacy: $\beta = 0.300$; intrinsic: $\beta = 0.384$), and resource management (self-efficacy: $\beta = 0.254$; intrinsic: $\beta = 0.258$). Table 2 presents results from the simple linear regression analysis.

Table 2: Linear regression results for the study variables (n = 205)

Variable	Predictors	Unstandardized Coefficients		*t*	*p*-value
		B	Std. Error		
Deep strategy	1. Self-efficacy	0.256	0.084	2.411	< 0.001
	2. Intrinsic goal orientation	0.428	0.072	5.964	< 0.001
Meta-cognitive	1. Self-efficacy	0.329	0.073	4.493	< 0.001
	2. Intrinsic goal orientation	0.359	0.062	5.760	< 0.001
Res. management	1. Self-efficacy	0.244	0.071	3.411	0.001
	2. Intrinsic goal orientation	0.211	0.061	3.456	0.001

DISCUSSION

The goal of this study was two-folds. First, it was designed to investigate the extent to which undergraduate medical and allied health students perceive their motivational beliefs of self-efficacy and intrinsic goal orientation, and self-regulated learning strategies. Second, it was aimed to examine the relationship between the two constructs; the motivational beliefs and self-regulated learning strategies. With regard to the first focus, results indicate that students experienced motivational beliefs and learning strategies differently. A pair-wise comparison of variable means reveals that students reported higher levels of motivational beliefs of self-efficacy and intrinsic goal orientation than the learning strategies. One best explanation towards students' higher motivational beliefs is that according to the UNIMA selection system, College of Medicine (as opposed to other constituent colleges of UNIMA) selects students who indicate one of its programs as their first choice. It is therefore expected of learners to demonstrate high levels of motivational beliefs since what they learn is what they wanted as first choice. The current results are also in line with other previous studies conducted during students' initial years of their medical profession (Kusurkar, 2012; Stegers-Jager et al., 2012). These studies found out that students had higher levels of motivational beliefs (value, goal, self-efficacy and control) than cognitive and resource management strategies.

Just as other previous studies (Kusurkar, 2012; Stegers-Jager et al., 2012; Woodhouse, 1997), the current study found relatively low usage of cognitive strategies and resource management among first year college students. This suggests that in relation to their motivational beliefs, students did not effectively use their deep and meta-cognitive learning strategies and did not properly manage their resources in terms of time and study environment, peer learning, help seeking and effort regulation. As suggested by previous studies, this might be due to the lecture-based curriculum (Woodhouse, 1997), which to some extent, is still used at College of Medicine especially in the initial years of medical schooling. An alternative explanation to lack of deep and organized learning approaches by first year students would be that characteristics of the learning environment, such as the examination methods used, influence the degree to which the deep learning approaches are used (Briggs & Tang, 2007; Stegers-Jager et al., 2012). For instance, first year examinations at College of Medicine, which are mostly characterized by recall answers, may reward the use of memorization rather than the use of deep learning. As argued by Woodhouse (1997), it might turn up that as the teaching approaches and examination methods change in upper classes, students change their learning approaches from shallow to deeper processing strategy use.

Taking an advantage of students' high levels of motivational beliefs, which entails high levels of confidence, effort and mastery of new situations in their learning environment, educators need to provide students with conducive environments for their deep information processing strategies. While educators cannot influence the orientation to learning that students initially bring to their studies, they are able to manipulate the learning context, providing an opportunity to influence the approach students would adopt (English et al., 2004). As research indicates, apart from individual factors, there are several factors in the learning environment that affect students' approaches to learning (Gurpina et al., 2013; Briggs & Tang, 2007; Dolmans et al., 2015). Depending on how the teaching and assessment activities award either deep or surface learning approaches, students' orientation to studying may also change. According to Briggs and Tang (2007), teaching factors such as teaching to bring out the underlying structure of the subject matter, teaching to get active rather than passive responses from students, engaging students in the lesson, assessing for understanding of underlying structure rather than facts only, creating a positive working atmosphere, and emphasizing depth rather than breadth of learning, would influence students towards a deep approach to learning. Organized studying and deep learning approaches help the learner to understand new information, relate them with prior knowledge, and apply the knowledge in their professional contexts (English et al., 2004; Briggs & Tang, 2007; Gijbels et al., 2014; Gurpina et al., 2013).

Concerning disparities of motivational beliefs, organized studying and deep learning approach experiences among students, the study revealed that there was gender significant difference on intrinsic goal orientation; male students reported higher levels of intrinsic goal orientation than their female counterparts. This suggests that male students are more likely to be intrinsically motivated than female students. The finding is in line with other research findings in sciences, especially in medical education, which indicate that male students become more motivated to study medical courses (Pintrich, 2000; Khan et al., 2013; Ramos-Sanchez & Nichols, 2007). As Ngwira et al. (2017) argue, this gender difference in intrinsic goal orientation suggests that there are some factors that enhance male students' motivation, or harm female students' motivation when it comes to learning sciences. This could be due to the gender-linked stereotypes and lack of female role models in sciences. In Malawi, this gender gap toward learning science exists as early as primary school (Chamdimba, 2008). Boys' performance outweighs that of girls' in science subjects like Mathematics and consequently, girls believe they are not smart in sciences, even if they are, and this lowers their motivation to learn. Conversely, according to the recent research (Ngwira et al., 2017), compared with girls, boys enjoy learning medical subjects and this enjoyment enhances their intrinsic motivation. Educators in the medical field need to foster and stimulate the development of intrinsic goal orientation in female students, and this enhances deep approach learning which bolsters effective learning.

On family members' education disparities, the study found significant differences on deep cognitive learning strategies; first-generation college (FGC) students perceived using deep cognitive learning strategies more than non-first-generation college (NFGC) students. Research comparing cognitive learning strategies between FGC students and NFGC students are rather limited. However, the current results are in consistent with Naumann, Bandalos and Gutkin (2003) who stated that the FGC students' self-regulated learning strategies were better predictors of their success. This means that their academic success came out of their self-regulation, and cognitive learning strategy is an essential component of self-regulation. In a low-income country with an approximate population of 17 million where over 50% of the population is estimated to live below the international poverty line of 1.25 USD per day (The World Bank, 2017), it is believed that education especially at the tertiary level is essential to eradicate poverty. It is therefore expected of learners, especially FGC students, to work extra hard, trying many ways of dealing with a task thereby employing different cognitive learning strategies such as critical thinking, so that they break through in their studies.

Surprisingly, despite the differences on perceived intrinsic goal orientation between male and female students, and on deep cognitive strategy use between FGC and NFGC students, there were no significant differences on deep cognitive strategy use between the two genders and on goal orientation between the two generation statuses. Furthermore, there were no significant differences on any other measured concepts. The insignificant results, however, are not in line with the study's hypothesis which was based on other research findings in sciences. First, according to literature, male students would have been more self-efficacious than female students (Khan et al., 2013; Ramos-Sanchez & Nichols, 2007) and it was also expected that students who were intrinsically motivated (in this case male students) would have adopted deep learning approach more than their fellow counterparts (Pintrich & Schunk, 1996). Second, FGC students would have been more self-efficacious than NFGC students as previous research on self-efficacy and the college students' generation status indicates that early college success increases the confidence of FGC students, although doubt still exists especially each time they take on new challenges (Orbe, 2008). As Artino et al. (2010) argue, the findings are typical of first year medical and allied health students who are trying many ways of dealing with the perceived difficult and overloaded basic medical courses. Differences might be clear as students reach their upper classes.

Interestingly, despite differences in some of the learning aspects such as intrinsic goal orientation and deep learning strategies among students on gender and generation status, there were no significant differences on all the motivated learning strategies among all the four programs. According to literature (Alam, 2011; Ebomoyi & Agoreyo, 2007), it was expected that due to different learning environments, different subjects would induce different learning experiences among college students. A possible explanation to these results is that maybe it is because in this year of study, subjects do not fully develop into specific courses reflecting their respective programs; all they learn are introductory subjects. It might turn up that as the subjects develop into unique concepts in upper classes, students change the way they approach learning and consequently, differences among them with respect to their program of study might appear. In addition, it can also be noted that before these students start their professional career, they first become enrolled into a one year foundation program as a preparatory training for their medical career. It is during this period that they learn analytical and communication skills for academic purposes which include abilities in studying and resource management which are very important for one's self-regulated learning. Therefore, it implies that skills learnt in their previous year, (foundation year) are immediately and equally applied in this year (first year of their profession) regardless of their different programs of study.

With regard to the second focus of this study, which was to examine the relationship between motivational beliefs and self-regulated learning strategies, findings clearly reveal that motivational beliefs of self-efficacy and intrinsic goal orientation predicted both the deep and organized learning approaches. The results, therefore, suggest that students who were self-efficacious and intrinsically motivated focused their attention on understanding the underlying meanings and the successful applications of the content learnt through an organized study. In other words, students who focused on internal factors such as mastering and understanding the materials were organized and used deep information processing strategies. This means that these students planned, organized, monitored and evaluated their studies. According to previous work on self-efficacy (Usher & Pajares, 2008; Zimmerman & Cleary, 2006; Khan et al., 2013) and goal orientation (Dolmans et al., 2015) students' motivational beliefs have been found to enhance deep learning approach among college students. In higher education, especially in medical schooling, educating students to become life-long learners who can effectively apply the theoretical concepts to their professional contexts is an important aspect of formal education. Therefore it is crucial for students to first become confident and intrinsically motivated in whatever they do for them to effectively use deep learning approach and effectively manage their studies.

Students' motivational beliefs, and deep and organized approaches to learning are important factors to be taken into consideration especially if educators aim at enhancing students' knowledge, attitude and practical abilities. However, despite their higher levels of motivational beliefs, this study has revealed that these medical and allied health students have lower levels of deep and organized studying approaches to learning. As reported by a number of studies conducted in medical field, (Ngwira et al., 2017; Alam, 2011; Gupta et al., 2014; Ebomoyi & Agoreyo, 2007), students already perceive medical subjects especially Anatomy as overloaded and difficult to understand. The perceived overload, coupled with the assessment methods commonly done in medical field, students adopt rote learning as their principal learning strategy to cope with their studies (Varunki et al., 2015). Since research indicate that students' orientation to studying and the context of learning within individual courses may influence students to adopt either deep or surface approaches in different situations (English et al., 2004; Briggs & Tang, 2007), there is a great need for educators, therefore, to foster and stimulate the development of effective approaches to learning in students. As argued by Briggs and Tang (2007) teachers need to refrain from teaching piecemeal content, assessing mainly for memorizing facts, and providing insufficient time by overloading students. These teacher-related factors can influence students towards adopting a surface approach to learning which is not effective for life-long skills during their formal education.

Conclusions, limitations and further research

The present study aimed at investigating the extent to which undergraduate medical and allied health students perceive their motivational beliefs and self-regulated learning strategy, and examining the relationship between the two constructs; the motivational beliefs and self-regulated learning strategies. This is an essential field of research in higher education as previous studies have reported positive effects of these concepts (Wolters et al., 1996; McCollum & Kajs, 2007). Especially in the medical field, knowledge gained at school need to be applied effectively, as these professionals deal directly with the life of people. According to findings from other researches, deep and organized learning approaches help the learner understand new information, relate them with prior knowledge, and apply the knowledge in their professional contexts (English et al., 2004; Briggs & Tang, 2007; Gijbels et al., 2014; Gurpina et al., 2013).

This paper makes three major contributions to the literature. First, from the students' experiences on the learning aspects under investigation in this survey, the study has acknowledged that medical and allied health students have high levels of self-efficacy and intrinsic goal orientation during the initial years of their medical profession. On the contrary, it has been discovered that, like other studies during their initial years (Varunki et al., 2015; Stegers-Jager et al., 2012; Woodhouse, 1997) students possess lower levels of deep information processing strategies. Second, based on the findings, the study has asserted the role motivational beliefs play on deep approach to learning and organized studying. The paper has highlighted the importance of each concept in medical education and the need to foster such orientations in medical and allied health students. Third, based on the different models, findings and recommendations derived from the motivational beliefs and learning approaches' research, the paper has provided possible suggestions on how educators, especially in medical field, can foster and stimulate such approaches to learning. Educators can influence students' goal orientations and learning approaches through manipulation of the learning contexts such as teaching methods, workloads and assessments.

The findings are, however, subject to some limitations. First, this was a cross-sectional study and therefore, it has not given information on changes in self-efficacy and goal orientation, and as well as the learning approaches among students over time. The study's target population was first year students and as they proceed with their studies, their orientation towards motivational beliefs and learning approaches might change. Longitudinal studies, therefore, are needed to investigate changes in both constructs over a period of time, and also whether such changes would affect the relationship among the study variables. Second, due to the large number of potential participants in

the study population, medical education, the study focused on first year students only. Due to its sample uniqueness, results might not simply be generalized beyond this specific target population. This is because students' motivational beliefs and approaches to learning might not be the same at different levels, in different contexts, since these psychological concepts are bound to be affected by the learning environment as well. Consequently, medical researchers need to conduct systematic studies focusing on how students in different medical schools, different programs and different year groups adopt motivational beliefs and learning strategies. Finally, the study did not take into consideration other aspects of motivational beliefs such as task value and control beliefs which are also important in enhancing effective learning among college students. Future research need to consider investigating into these variables as well.

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ENVIRONMENT, CLIMATE CHANGE AND NATURAL RESOURCES

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Characterisation of Solid Waste deposited into the Solid Waste Disposal Site in Lilongwe City, Malawi

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ABSTRACT

Determination of waste generation and composition is crucial for planning and implementation of waste reduction, reuse and recycling programmes and management of waste disposal facilities. A waste characterisation study was conducted in Lilongwe City to determine sources, composition and quantity of solid waste disposed into the city's Solid Waste Disposal Site (SWDS). The Direct Waste Analysis approach was used. A total of 57 samples were collected and weighed as waste delivery vehicles entered the disposal site. Hand-sorting characterisation of waste samples was also employed to estimate the composition of solid wastes corresponding to specific waste sources. The main sources of wastes in the City are households (77.1 percent), commercial entities (20.1 percent) and the remainder are industries, markets, institutions (schools and health facilities) and public places. Organics (food and garden waste) are the major component of wastes generated (67.7 percent), followed by soil, ash, stones and debris (9.2 percent); plastics (8.5 percent) and paper and cardboard (8.1 percent) and 6.4 percent are the other wastes such as textiles, metal and glass,). Waste generation rate for the city was estimated at 0.493 kg/capita/day. The high proportion of organic waste is a typical characteristic of municipal solid waste in low income countries like Malawi. Only 11.69 percent of the waste generated in the city is collected and disposed to the SWDS resulting in large quantities of waste dumped in open spaces and water bodies. Organic waste can be composted; converted to biogas; and used for animal feed amongst others. This study established that waste generated in the City is mainly organics which can be put to good economic use by composting or conversion to biogas - an opportunity for urban agriculture and waste-to-energy sectors; respectively.

Keywords: biogas, characterisation, composting, Lilongwe, solid waste, solid waste disposal site

INTRODUCTION

Limited studies have been carried out in Malawi to assess solid waste generation rates and composition of municipal solid wastes (**NCST, 2015**). Yet, data on waste generation and composition is crucial for the planning and implementation of waste reduction, reuse and recycling programmes. The nature of Municipal solid waste (MSW) varies from place to place, its characteristics and quantity depends on the living standard, lifestyle of the inhabitants and the abundance and type of the natural resources available (**UNEP, 2005)**. MSW includes materials discarded for disposal by households, offices, commercial areas (such as shops, hotels and restaurants), industrial entities, public institutions (such as schools and hospitals) and markets.

Lilongwe City Council has the overall responsibility for the management of all wastes that are generated within its boundaries. The Public Health Act (34:01) of 1969 Article 60 is the main statute which empowers all local authorities in Malawi to keep their administrative area in clean and sanitary conditions. Specific legal provisions are made under Local Government Act 1998 through the General Cleanliness and Solid Waste Management City By-Laws.

Waste characterization comprises a waste stream composition profile by material types (i.e. paper, plastic, metal, organic, etc.) and corresponding solid waste weight estimates that can be used to evaluate the current solid waste management system and assist in determining future programs on waste diversion and conversion process. It is necessary to characterize waste for planning and implementation any waste management programme – waste reduction, reuse and recycling. The main objective of this study was to characterise the wastes that is dumped at Lilongwe City Council's (LCC's) Solid Waste Disposal Site (SWDS).

This study was undertaken as a baseline study on waste characterisation and greenhouse gases (GHGs) emissions of waste disposed to the city's SWDS. Specifically of the study were to characterize various solid waste streams delivered at the city's solid waste disposal site; and quantify various solid waste streams delivered at the solid waste disposal site.

MATERIALS AND METHODS

The study determined the density and characteristics of the waste delivered to the City's solid waste dump site (SWDS). The study employed the Direct Waste Analysis (DWA) approach. One sample was collected from each of the 54 vehicles from a total of 57 vehicles that delivered waste to the SWDS during the period of the study. Each sample, approximately 100kg, was analysed to determine the composition of the waste. The bulk density of each sample from each waste category delivered was determined by filling a container of known volume (the container was initially weighed when empty) with waste from a composite waste sample and then weighed the loaded container. The container was constantly shaken during filling. The bulk density was then calculated by dividing the net weight of the waste by its volume and was expressed in kg/m^3. Each waste sample was weighed and its volume measured in order to determine the density of the waste sample. In addition, a weighbridge was mounted on the entrance to the SWDS. All waste delivery vehicles were weighed before and after delivery of waste to the SWDS. The weight of the waste delivered by each vehicle was determined by subtracting the final weight from the initial weight of the vehicle. The volume of the waste delivered to the SWDS by each vehicle was determined by taking measurements of the waste container. The bulk density of the waste delivered by each vehicle was then determined by dividing the weight of the waste and volume of the waste.

RESULTS AND DISCUSSION

The main sources of solid waste that is delivered to the city's SWDS are households, commercial entities, industries, markets, institutions (health facilities) and public places. The main components of the waste are organic (putrescible and garden), paper and cardboard, plastic, leather, rubber, textiles, glass and e-waste.

Organic materials represented the single largest component of the MSW stream for Lilongwe City accounting for 40.8 percent for food waste and 26.9 percent for garden waste by weight; followed by soil, ash, stones and debris at 9.2 percent; plastics at 8.5 percent; paper and cardboard 8.1 percent; textiles 2.2 percent; metal 1.7 percent; glass 1.4 percent; wood, charcoal, rubber and leather 0.6 percent; E-waste 0.3 percent and diapers 0.2 percent. **Figure 1** shows the overall composition of wastes disposed at the dumpsite.

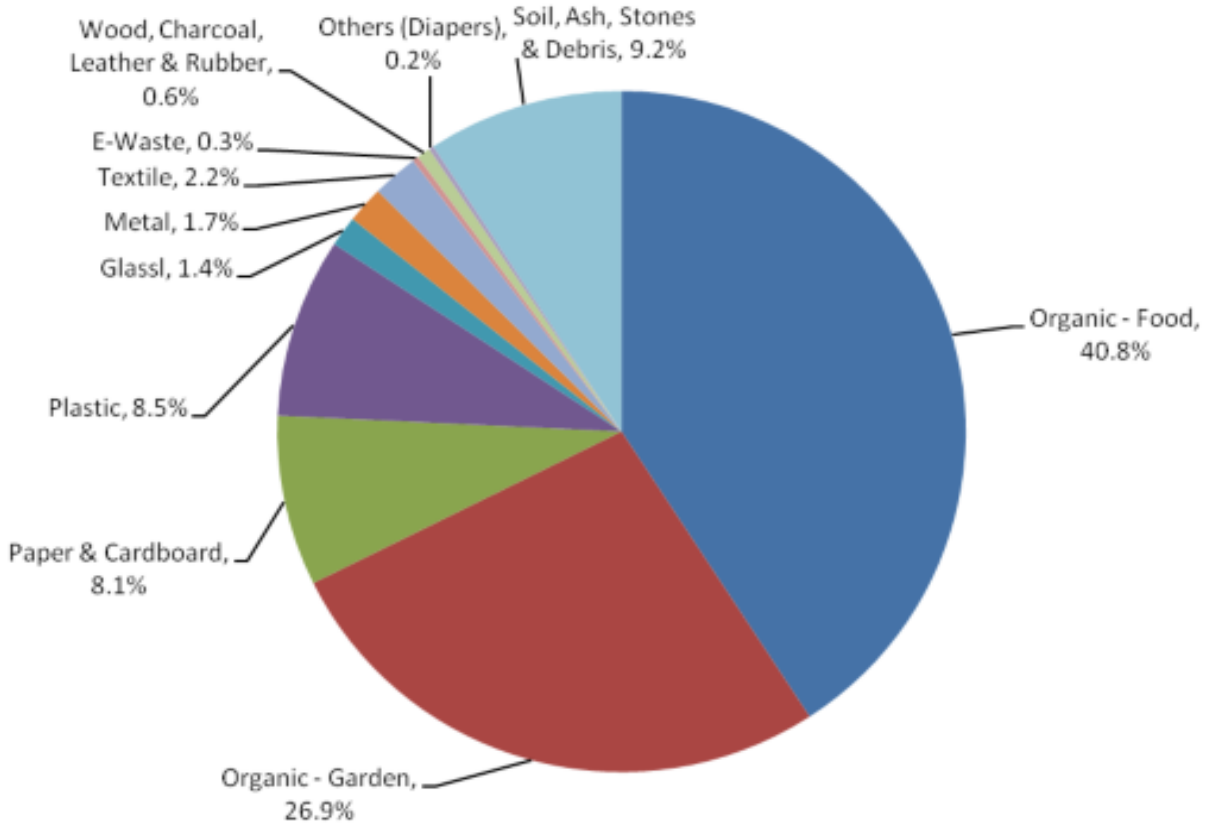

Figure 1: Overall composition of solid waste at Lilongwe City's SWDS

It was also noted that the waste had a high proportion of soil, ash, stones and debris which indicates that waste is stored on bare ground or there is high rate of waste spillage such that the waste is collected together with soil.

The organic content being the largest single component of Lilongwe city's waste, at 67.7 percent is within the UNEP/IETC's range of 35 to 80 percent and also within the generation rate for Lilongwe City range of 53to 97 percent.

The high proportion of organic matter in the waste demonstrates the type of lifestyle for Lilongwe City which is typical characteristic of waste in low income countries. Organic waste can be composted; converted to biogas; and used for animal feed amongst others. Paper and cardboard can be reused, recycled or composted or converted to fuel such as briquettes. Plastic can be reused, recycled or converted to fuel oil. Textile, leather, wood and rubber can be used as solid fuel or recycled. It is therefore apparent that the biggest proportion of the waste generated in the City of Lilongwe can be put to good economic use.

Organic waste, especially putrescible waste can easily decompose quickly and as such if it is not collected on time it will generate leachate, cause bad odour and become a bleeding ground for disease transmitting organisms. It is therefore important that any waste storage and collection system should ensure that organic waste is not left for long period of time before it is collected.

Quantity and bulk density of the waste delivered to the SWDS are shown in Table 2.

Table 9: Quantity of Solid Waste delivered at the SWDS

Waste Category	Quantity (Tons)	Average Quantity (Tons/ Day)	Bulk Density (Kg/ m^3)
Residential Curb-side	43.72	8.74	506.6
Commercial	19.01	3.80	292.6
Hospital	11.48	2.30	1038.1
Mixed (Commercial, HH & Hospital)	33.31	6.66	523.3
Market	58.47	11.69	383.2
Self-haul	1.05	0.21	108.9
Industrial	50.40	10.08	601.0
Sub -Total	**217.44**	**43.49**	**460.6**

The results are presented graphically in Figure 2.

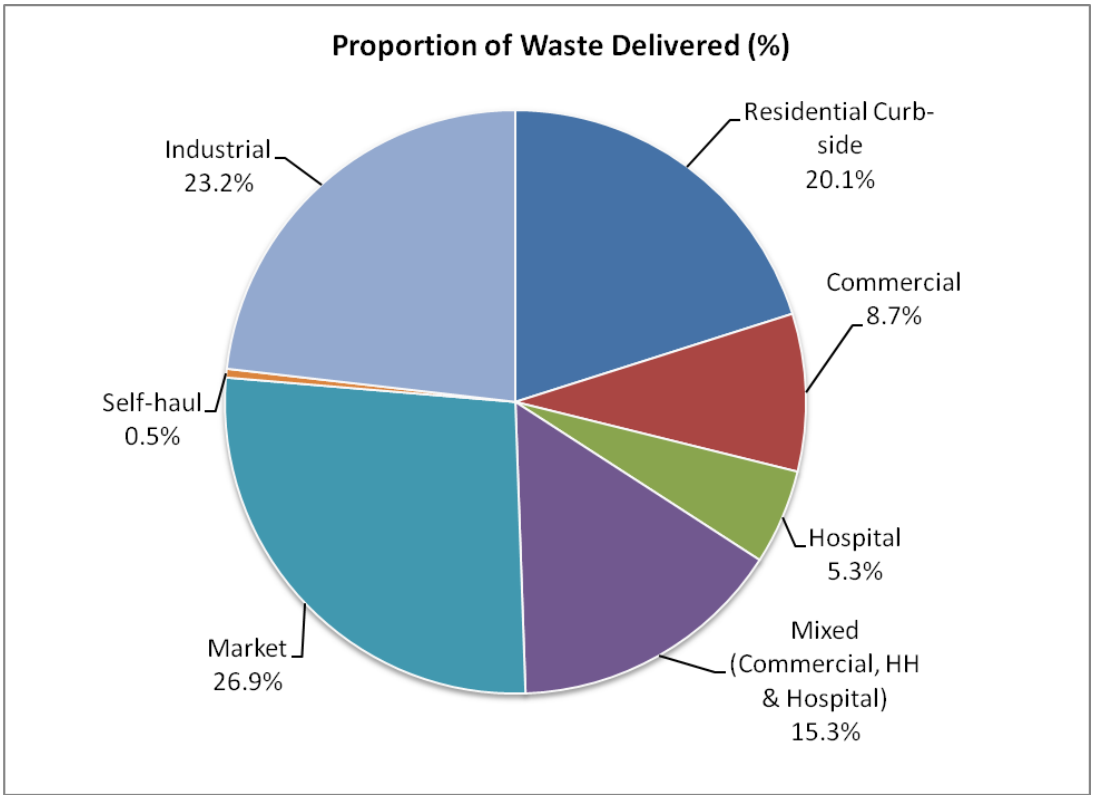

Figure 2: Proportion of Waste delivered to the SWDS (percent)

The average solid waste delivered to the SWDS was 43.49 tons per day with an average density of 460.6kg/m^3. The biggest proportion of the waste was from markets at 26.9 percent followed by industrial at 23.2 percent, household curb-side at 20.1 percent, mixed (commercial, HH and hospital) at 15.3 percent, commercial at 8.3 percent, hospital at 5.3 percent and then self-haul at 0.5 percent. The variation in the bulk densities of the waste demonstrate the different sources and types of the waste that is delivered to the SWDS.

According to **NCST (2015),** waste generation for the city is 0.493 kg/ capita/ day excluding industrial waste. It is estimated that solid waste generated from within the city is 511 tons per day. With an average 43.49 tons of waste disposed into the SWDS, the average waste collection rate for the city is calculated to be 11.69 percent. This is far much lower than previously reported.

In 2009, the average waste collection rate for the city was 30 percent **(JICA, 2010)**. In 2014 the average collection rate was 14 percent **(NCST, 2015)**. In this study the waste collection is determined to be 11.69 percent. The reasons for the reduction can be explained as follows. Firstly, the results in this study are more reliable because they are based on the actual weight of waste collected and delivered to the SWDS. In addition it shows that waste collection has not been improved to meet the increased waste generation. This is evidenced by the fact that currently most of the skip trucks are making 2-4 trips in a day compared to 4 trips in a day in 2014. With the MSW collection efficiency of 11.69 percent, it means that more than 88 percent of the waste is dumped in open spaces where it is burnt uncontrollably, decomposed, swept or blown away. Uncontrolled burning and decomposition of solid waste pollutes water bodies, releases pollutants and greenhouse gases (GHGs) into the atmosphere.

Waste reuse, recycling and resource recovery in the city is very minimal as demonstrated by the large proportions of organic matter, paper and plastic in the waste. Few organizations such as Beautiful Malawi Trust (BEAM), Centre for Community Organization and Development (CCODE) and Our World International (OWI) work with women, unemployed people and school learners to produce mats, necklaces and handbags; and conduct public awareness on solid waste management. At the SWDS metals, food, paper, cardboards, feathers, plastic bottles and plastic paper are sold to intermediate buyers for reuse, recycling and recovery of resources. Overall, there are no deliberate policies in place to promote recycling of general waste.

Key to reuse and recycling is waste segregation or sorting at source of generation. Waste sorting is very low at all levels of the society in Lilongwe City. The main reasons for low levels of sorting are lack of sorting facilities; lack of legal requirement for sorting; lack of awareness among the households on sorting; and lack of adequate demand for sorted material. Waste salvaging at the SWDS for reusable materials is carried out rather than sorting.

CONCLUSION AND RECOMMENDATIONS

Households are the largest source of solid waste generated in the city of Lilongwe (71 percent) followed by commercial entities at 20.1 percent whereas all the other entities account for 2.7 percent. This is critical when planning to effectively implement any waste management programme effectively. It is therefore apparent that city council needs to pay particular attention to household waste if the problems of solid waste management in the city to be reduced. Waste generation rate for the city is determined to be 0.493 kg/ capita/ day (excluding industrial waste). Nearly 70 percent of the waste generated is organics. There thus great opportunities for composting and biogas production. Although, waste segregation/sorting is a prerequisite for reuse and recycling programmes, the level of solid waste sorting is critically low at all levels of the society in the city. There is thus a culture of disposing of unsorted waste (i.e. mixed waste) thereby reducing the life span of the SWDS, and encouraging scavenging.

More than 88 percent of the waste is uncollected resulting in discriminate dumping of the waste in open spaces and water bodies. For an effective and efficient waste collection system there is need for the deployment of suitable waste collection vehicles based on the source and type of waste collected. The city council should develop a solid waste management improvement strategy for the city and promote the collection of solid waste especially from households through the involvement of private operators and Public, Private Partnerships (PPP). The city council should engage

stakeholders such as the communities, private sector, non-governmental organisations and development partners in promoting waste ruse, recycling, resource recovery and waste collection to improve the management of waste in the city.

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Assessment of microbial contamination of groundwater from protected and unprotected shallow wells in Mzuzu City

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ABSTRACT

Many people in most developing countries rely on groundwater as the main source of water supply for drinking and other domestic uses. However, water from fully, partially and unprotected shallow wells may contain pathogenic microbes which can increase the incidence and outbreaks of waterborne diseases. This study was therefore carried out to compare the bacterial contamination of drinking water from fully and partially protected shallow wells in Mzuzu City. Water samples (120) from protected (75) and unprotected (45) shallow wells in Chibavi and Mchengautuwa Townships in Mzuzu City were analyzed for total coliforms (TC), fecal coliforms (FC), Escherichia coli (E. coli) and Salmonella spp. using standard methods. The results showed that 68 % of drinking water samples contained fecal coliforms ranging from geometrical mean of < 1 to 3100 cfu/100 mL and 32 % contained Salmonella spp. However, no significant ($p > 0.05$) differences were observed in levels of fecal coliforms and Salmonella spp. between water samples from fully and partially protected wells. The observed non-significant differences in bacterial levels between fully and partially protected wells could be attributed to groundwater contamination due to other pollution factors such as proximity to pit latrines and septic tanks. The presence of pathogenic bacteria in drinking water sources poses a risk of increasing incidences and outbreaks of waterborne diseases. However, further research is required to investigate the treatment of this water using solar radiation or any appropriate technologies for example, use of plant material. The results from this study showed that drinking water from fully and partial protected shallow wells in the study areas contained pathogenic microbes, implying that water from these sources is not suitable for human consumption, unless it is treated.

Key words: Coliforms, fecal coli form, salmonella spp. waterborne disease, potential pollution source

INTRODUCTION

Many people in less developed countries rely on groundwater as the main source of water supply for drinking and other domestic uses. The major groundwater sources are boreholes that are usually rig-drilled >30-m deep and potentially tap deeper aquifers; and shallow wells (hand-dug wells) that are usually dug <30-m deep and often tap unconfined aquifers (MacDonald and Davies, 2000). Wells are a common ground water source readily explored to meet community water requirement or make up the short fall (Adekunle, 2008; Olukanni and Ugwu, 2013; Ogwueleka, 2014; Olukanni et al., 2014a). However, the majority of people (especially the urban and rural poor) use untreated groundwater for domestic purposes. Egbinola et al. (2014) argued that increased human population

coupled with poor sanitation and infrastructure is undermining the quality of water in shallow wells (Kanyerere, 2012). Because of the fast increase in world's population, Malawi, as the case with other nations, fail to provide safe drinking water to half of their population (Pritchard et al., 2007). Sixty percent (60%) of Malawi's population lacks safe drinking water despite its abundant (Pritchard et al., 2007). Fifty-two percent (52%) of Nigerians do not have access to improved drinking water supply (Orebiyi et al., 2010).

In Malawi, the cities and other urban areas which are growing rapidly face a number of challenges. Key among them is that of urban poverty that is characterized by poor access to water and sanitation as well as unemployment (UN-HABITAT, 2011). The cities also face environmental degradation heightened by poor urban planning (UN-HABITAT, 2011). Water crises are common and women and girls' activities are disrupted as a result of these crises and this does not spare any particular group of people but it is more acute among the poorest urban dwellers (Chipeta, 2009). In urban areas improved water coverage was 95% in 2008, however, the Government of Malawi recent report indicates downward trends in urban piped water supplies and observes that water boards are unable to keep pace with the rapid urbanization in Malawi's growing cities (Malawi Government, 2011 & ISF-UTS, 2011). The high rate of urbanization and rapid population growth in urban settlement and poverty have forced residents to source water from un protected areas (Malawi Government, 2013). These coupled with intermittent water supply or lack of access to piped water in these areas (Haruna et al., 2005 & Msilimba, 2013) and because of inability of poor community to install water board piped water and pay monthly huge water board bills including disconnection bills, lack of steady and continuous flow of tap water provided by the Water Boards during the day results into limited access to potable water in urban areas in Malawi (Chipeta, 2009; Msilimba & Wanda 2013).

When access to safe drinking water is not adequate people resort to collecting water from other alternatives or depend on their own sources (Mukherjee & Chakrarbory, 2012, Tairu et al., 2015) such as stream, river, and own hand dug un protected shallow water. These wells serve as major source of water for household uses (drinking, cooking, washing etc). The microbial quality of groundwater pumped from tube-wells is usually better than in unprotected surface water, but in many cases well discharge may still contain significant levels of fecal indicator bacteria such as fecal coliforms and Escherichia coli (Geen et al., 2011 and Ferguson 2011). In some cases one would find people themselves making initiative in constructing and fitting the wells with improper lid on top. In such cases, the wells may be termed as partially protected. Such wells are commonly located very close to potential sources of well water pollution. Commonest cause of pollution is attributed to close proximity of latrine to wells and unhygienic usage of the wells (Olukanni et al., 2014b & Tairu, 2015). For instance, some wells have no cover/lids, they are dirty and unkempt thus, making the water unfit for use, resulting in water borne diseases. Most hand-dug wells are highly exposed to contamination, making protection of the groundwater source vital (Tairu et al, 2015).

The increasing demand to provide water through such sources has resulted in concerns that some groundwater sources might not be as safe as expected, thereby endangering people's lives (Kanyerere, 2012). One of the major strategies to increase access to water of better quality in Malawi has been to provide piped water, install protected water sources, such as boreholes and protected shallow wells, (Wright et al., 2004). Protection involves the protection from runoff water, and the protection from objects, animals or particles falling inside the well. A shallow well is considered fully protected when fitted with a proper lid on top (Malawi Government, 2005). It has a typical and characteristic feature of the well stein, the inner lining and apron around the well

There are a few potential problems that are typically associated with Protected and unprotected shallow wells in Malawi. For example, their placement in terms of direction and distance to potential contamination sources such as pit latrines, septic tanks and their depths make them vulnerable to microbial contamination. (Wright et al, 2004).Water from Protected and unprotected shallow wells may contain pathogenic microbes which can increase the incidence and outbreaks of waterborne diseases such as diarrheal diseases.

Out of the total population of about 14 million people in Malawi (National Statistical Office, 2009; about 62% (95% urban and 58% rural) have access to safe drinking water and 64% (90% urban and 60% rural) have adequate improved sanitation. Mzuzu City, with an annual population growth rate of about 4.4% is one of the fastest growing urban areas in Malawi that is hit by water and sanitation problems (NSO, 2009). It is estimated that about 81.6% of the population has access to improved water source in Mzuzu City (NSO, 2009; Mzuzu City Assembly, 2008). The remaining 19.4 % draws water from wells, boreholes and streams. In particular, the high-density and lower class community in areas such as Mchengautuwa and Chibavi access water primarily from wells and streams. These areas may be degraded and water sources may equally be affected due to increased anthropogenic activities such as deforestation, poor farming activities, unsound waste management disposal and pit latrine use.

A study conducted by Msilimba and Wanda (2013) in Mzuzu city established that the majority of households (92.6%) were using shallow wells and that 7.4% were using piped tap water provided by Northern Region Water Board. Currently Northern Region Water Board is the most and reliable source of water in Mzuzu city. Msilimba and Wanda (2013) observed that 55.6%, 59.3%, 70.4%, 11.1% and 7.4% of the shallow wells were located at a distance <5 m away from potential well water pollutions sources and these were rubbish pits, stagnant water pool, toilets, animal kraals and refuse dump sites, respectively and rubbish pits, stagnant water pool, toilets, animal kraals and refuse dump sites were observed to be the main ground water contamination sources in Mzuzu city.

So far, in Malawi, studies that have been conducted have been targeting microbial and chemical analyses of borehole and shallow wells intended for drinking purpose both in rural and urban areas. Studies on comparative study on levels of contamination in fully, partially and unprotected shallow wells sources in urban and high-density areas especially in the study area have not been done. The present study was undertaken to investigate indicators of pathogenic bacteria associated with fully and partially protected shallow wells in the urban areas of Mzuzu city, northern Malawi specifically in Chibavi and Mchengautuwa townships. The areas in question have never been previously studied in terms of comparison of levels of pathogenic indicator bacteria in fully, partially and unprotected wells from where urban poor community in densely polluted location draw water for their domestic uses including drinking purposes in May 2017 during the late rainy season of the year. In Mzuzu city, where drinking water was observed to be sourced from fully, partially and un protected shallow wells no evidence based knowledge was available as to whether the fully and partially protected shallow wells equally provided water which is fit for human consumption.

Studies on comparative study of levels of pathogens indicator bacteria in fully, partially and unprotected shallow wells is vital for devising effective strategies to improve the quantity and quality of drinking water for urban poor community especially those who are financially handicapped for them to effectively treat their drinking water at their household level.

Owing to the large number of protected and unprotected wells used as a source of drinking water in rural and urban areas the results of this study will have broad implications for decision making and designing strategies on how to improve the fully and partially and unprotected wells in order to ensure that the social economically handicapped urban community has access to safe and sufficient drinking water and investigations of microbial transport in aquifers in Malawi to establish safe

minimum distance between source of well water pollution and well water. Hence the study was carried out to compare the bacterial contamination of drinking water from fully and partially protected shallow wells in Mzuzu City. Specifically the study aimed at assessing levels of bacterial indicators of pathogens contamination in fully protected, partially protected and unprotected shallow well water and determining the correlation between distance from potential well water pollution sources, well depth and coli form contamination levels in the study area.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Mzuzu city. Mzuzu city is the third largest city situated in Northern region of Malawi (Mzuzu city council, 2013). Malawi is situated in South East Africa and lies within the western branch of the East African Rift Valley System and is located on 11o27´South and 33o55´ East. Mzuzu City is found on the northern end of the Vipya Plateau at altitude between 1300 and 1350 m above sea level in Mzimba District in Northern Malawi. The study area has a subtropical climate with a distinct rainy season during November to May and its average monthly rainfall ranges from 0.3 mm in August to 222 mm in January (Ministry of Water Development (MoWD, 2005). The City is mainly drained by the Lunyangwa River which runs east to west and one of its main tributary is the Ching'ambo stream. The population of Mzuzu was 133,968 as of 2008.About 50.2 percent of the population comprised of males and the remaining 49.8 percent comprised of women. The city has a population density of 2,791 people per km2 and a growth rate of 4.4 percent with a land area of 143.8 km2. (UN-HABITAT, 2011& Mzuzu urban profile, 2010). Specifically the study was conducted in Chibavi and Mchengautuba townships with a populations of 15,805 (Chibavi East: 7729 and Chibbavi west:8076) and 17984 (Chengautuwa east: 10646 and Chengatutuwa west: 7338) respectively (UN-HABITAT, 2011).

S**ampling and water sample analysis**

Preliminary survey of shallow wells was done and their geographical position was determined using Global Positioning System (GPS) prior to data collection. Information about the depth of well, distance to potential well water pollution source and year construction was gathered from the owners of the wells. Other information about site characteristics and nature of the wells were gathered by observation during the Preliminary survey

Thirty seven (37) and 29 shallow wells were found in Chibavi and Mchengautuba respectively, making a total of 66 wells. Multistage probability sampling techniques was employed. Out of the 66 wells, a total of 40 wells, 10(100%) fully protected wells, 15(51.7%) partially protected wells and 15 (55.6%) unprotected wells, were sampled for the study where the shallow wells were grouped into clusters followed by simple random sampling in each cluster. Water samples (120) from protected (75) and unprotected (45) shallow wells in Chibavi and Mchengautuwa were collected for total coliforms (TC), fecal coliforms (FC), *Escherichia coli* (E. coli) and *Salmonella* spp. Analysis.

All aseptic techniques and standard procedures were strictly observed during water sampling and .analysis of the bacteria. Standard methods (membrane filter and pour plate methods) were employed in testing for contamination by total coliforms, fecal coli form a *Escherichia coli* and *Salmonella spp* bacteria. Pour plate method was used with the samples that were suspected to be highly contaminated where 1mℓ of sample water was applied directly to the agar. While a membrane-filtration method was employed mostly when the samples were suspected of low levels of concentration.. When a lower level of contamination was suspected, 100 mℓ of sample water was passed through a 0.47-mm filter paper using a sterile membrane-filtration unit. After filtration, the filter paper was placed on agar within a Petri dish on which 1 mℓ of sterile ringer's solution was spread. Subsequently, the Petri dishes were incubated at 35±2 ^{o}C for 24 hour and the colonies were

immediately identified and counted after the expiry of 24 hour incubation period. Bacterial levels were recorded as colony-forming units per 100 mℓ of water (CFU/100 mℓ). The number of counted colonies for the 1-mℓ samples was multiplied by 100 to maintain consistency of units for concentrations.

Statistical analyses

To compare the bacterial contamination levels in drinking water from fully, partially and un protected shallow wells, Paleontological Statistical Social Package for Education (PAST V-3.16) was used.. Univariate statistics was then used to come up with the range, mean, and standard deviation. Most comparisons were performed, nonparametric statistical analyses. Kruskal-Wallis and Mann-Whitney were used to compare bacterial levels in the fully partially protected and unprotected wells.

An analysis of the correlation between the level of contamination and depths of the wells and distance to potential sources of contamination such as pit latrines and septic tanks was conducted using a linear correlation (r) statistics to determine possible relationships between distance and contamination levels. Such correlation analysis was thought to be potentially useful for identifying whether the placement of wells and depths of the wells could explain some of the bacterial concentration variability. If so, the relationships might help to consider further studies aiming at establishing proper guidelines to reduce a well's vulnerability to contamination basing geographical characteristics of the soils in a given locality. Correlations with $p \leq 0.05$ were considered to be statistically different.

RESULTS AND DISCUSSION

Potential sources well water pollution and bacterial contamination levels

Potential sources of pollution observed during the current study were pit latrine, septic tanks, rubbish pit and animal kraal with pit latrines being the most (83%) occurring potential source of well water pollution source.

It was established that 75% (n= 40) of the total well studied were used for drinking and 67% of these were unprotected shallow wells. The findings support the fact that in Malawi, the majority (60%) of Malawians lack safe drinking water despite its abundant (Pritchard et al., 2007) and is in agreement of the finding by Orebiyi et al. (2010) that majority (52%) of Nigerians do not have access to improved drinking water supply (Orebiyi et al., 2010).

The oldest well was constructed in 1998 and the recent one in 2017. Most (37.5%) of the wells were constructed between 2014 and May, 2017. This indicates a 36.4% increase in the number of shallow well constructed from 2013 to 2017 giving a rate of well construction of 7.3% per year. This shows that use of shallow well water has been increasing in Mzuzu city.

Bacterial contamination levels in well water samples.

The results showed that 30 of 40 (75% of total well studied) of water samples collected from the shallow wells were reported to be used for drinking. Of these 73% were with total and fecal coliforms concentrations ranging from geometric mean of <1 to50245 CFU/100 mℓ and <1 to 5141 CFU/100 mℓ while 70% and 46% registered *E.coli* and *Salmonella spp* ranging from geometric mean of <1 to 896 cfu100 mℓ and <1 to 46 cfu/100 mℓ from respectively .The results as shown in Table 2 indicate that both protected and unprotected wells were vulnerable to bacterial Contamination.

In general 68 % of drinking water samples contained with fecal coliforms ranging from geometrical mean of < 1 to 3100 cfu/100 mL and 32 % contained *Salmonella spp* and failed to meet World health organization , WHO (2011) and Malawi standards, MS(2013 maximum permissible limit of zero coli forms in water intended for drinking purposes(Table3).

Table 1: Percentage wells contaminated with the bacteria studied

Nature	**Total coli form**	**Fecal coli form**	**E.coli**	**Salmonella spp**
Protected (fully and Partially)(n=25)	68	68	60	32
Fully protected(n=10)	50	50	40	30
Partially protected(n=15)	80	80	67	33
Unprotected (n=15	87	87	87	60

The current findings are not far from what (Munyebu,2011) found. Munyebu (2011) found coli form levels in almost 67% of the protected wells and 100% unprotected wells failed to meet the Standard Association of Zimbabwe guidelines of 0 cfu/100 ml (SAZ, 1997). The findings from this study has found that 87% of unprotected wells meet the WHO (2011) and MS 2013 maximum permissible limit of zero cfu/100ml water sample for drinking water. Shallow wells are highly exposed to contamination and unprotected wells particularly those with very large diameters are very likely to get contaminated (Groenwall 2010). The results suggests that water from these sources may pose severe health risks to consumers and is unsuitable for direct human consumption without treatment (Palamuleni & Akoth, 2015)

Comparison of bacterial levels in fully, partially and unprotected shallow wells

Table 3 shows statistically significant analyses results of comparison between concentration levels of the bacteria analyzed.. The results show that there were significant differences ($P \leq 0.05$) in levels of all types of bacteria analyzed between protected (fully and partially protected) and unprotected fully and fully and unprotected except differences in levels of Salmonella. While comparison of bacterial levels in fully and partially protected wells showed no significant differences ($P > 0.05$) in all types of bacteria studied.

Table 2: Comparison of bacterial levels in fully, partially and unprotected shallow wells

Parameter	Total Coliforms	Fecal coliforms	Escherichia coli C	Salmonella
Protected(fully & Partially)	132	43	7	2
Unprotected	1588	421	69	4
P-Value	0.01567	0.01691	0.01058	0.1022
Fully Protected	43	19	4	2
Partially protected	280	74	11	3
P-Value	0.3457	0.2673	0.3048	0.8877
Fully Protected	43	19	4	2
Unprotected	1588	421	69	5
P-Value	0.02845	0.01466	0.01161	0.1139

The observed non-significant differences in bacterial levels between fully and partially protected wells could be attributed to groundwater contamination due to other pollution factors such as proximity to pit latrines and septic tanks and other surface contamination sources. Shallow wells are prone to pollution from seepage of polluted water (Manyebvu, 2011). Shallow wells draw from the ground water nearest the land surface which may be directly affected by surface contamination. Polluted surface water can infiltrate into the soil and quickly affect a shallow well that has not been properly constructed or is located in a coarse-textured soil that easily conducts water. This might explain why there has been no significant differences in contamination levels between fully and partially protected wells.

The presence of pathogenic bacteria in drinking water sources poses a risk of increasing incidences and outbreaks of waterborne diseases.The presence of *E. coli* and *Salmonella spp* shows high risk of consumers suffering from water born diseases such as Typhoid fever, Salmonellosis and Haemolytic uremic syndrome

Potential factors influencing microbial contamination of the shallow well water

Well depth and distance from potential pollution source

Figure 4 and 5 present the measured and reported distance between the well and potential source of well water pollution and the reported depth of well in the study area.

The mean measured distance was 12±6 meter and ranged from 1 to 24 meters. While the reported mean well depth was 7±4 meters and ranged from 1.5 meter to 16 meters.

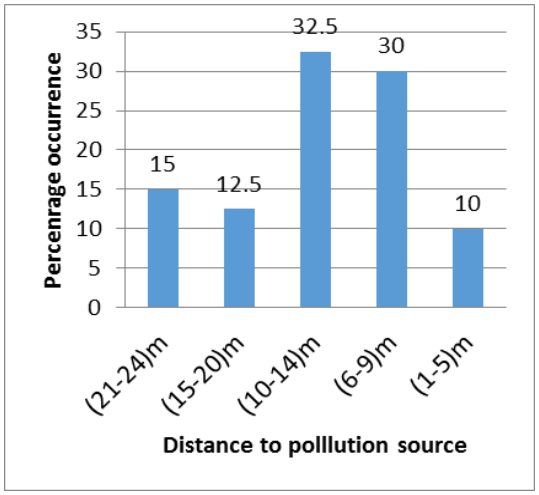

Figure 1: Distance between pollution sources and shallow well

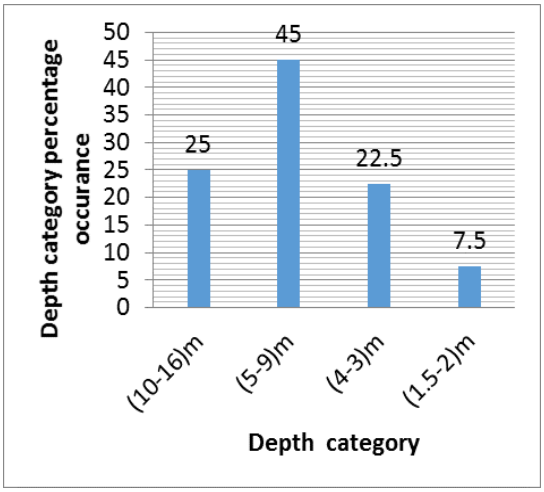

Figure 2: Depth category of well and their percentages

Most (83%) of potential water pollution sources are pit latrines and the majority (72.5%) are within the distance of less than 15 meters with 10% of them being located at a range distance of 1-5 meters from potential pollution sources. This puts the water consumers in the study areas at health risks of suffering from water related diseases such as outbreak of cholera. The observed distance between the wells and potential sources of well water contaminations is much less than Minimum safe distance between pollution source and well water meant for drinking purpose which ranges from 15m to 30 in most geographical settings up to 100m meters depending on the geographical makeup of the soils (WHO 1997, Banks *et al*., 2002; Parker, 2009; Aidoo, 2013)

Malawi has no current official guidelines for the minimum safe distance between pollution sources and water point. (Health and Appropriate Technology Development (WASHTED) as cited in Parker (2009), However, Malawi Bureau of Standards (MS-2013) set a distance of not less than 100 meters between boreholes and sources of pollution such as latrines, septic tanks, refuse dumps, cattle kraals, dip tanks and cemeteries. As to whether this is evidence based or not and also apply to all shallow wells in the whole country is not certain as the Minimum Set Distance (MSD) is dependent on geological makeup of the soils of a particular locality.

Despite Malawi Standards having set MSD, there is no policy that has been put in place to regulate the MSD of 100 meters in Malawi. Hence one finds in high density areas people constructing pit latrine septic tanks and sanitary sewers at a distance of less than 10 meters from bore holes and shallow wells intended for drinking purposes.

The presence of many (30%) very shallow wells of < 5 meters (Figure 5) in the study area is of health concern because shallow wells are prone to pollution from seepage of polluted water (Manyebvu, 2011). Shallow wells draw from the ground water nearest the land surface, which may be directly affected by surface contamination. Polluted surface water can infiltrate into the soil and quickly affect a shallow well that has not been properly constructed or is located in a coarse-textured soil that easily conducts water.

Relationship between distance from potential pollution source, well depth and bacterial contamination levels

Table 4 shows the results of an analysis conducted to assess the relationship between the level of microbial contamination, depths of the wells and distance to potential sources of well water contamination such as pit latrines and septic tanks. The results show weak and non-significant negative relationship (r <-0.3 and P>0.05) between coliforms bacterial contamination levels and distance to potential sources of pollution but a fair and significant relationship (r = -0.3586) and P= 0.0235) between *Salmonella spp* contamination levels and distance to potential sources of pollution. The results have also shown that there was a fair and significant negative relationship (r >-0.3 and P <0.05) between contamination of all the groups of bacterial studied and depth of the well. Hence the results seem to suggest that depth possibly explains the difference in the levels of coliform bacterial contamination

Table 10: Correlation between distance from potential pollution source, well depth and bacterial levels

Site Characteristics	Distance and bacterial levels related	Linear correlation (r)	P(uncorr)
Distance	Total coliforms	-0.115357	0.3441
	Fecal coliforms	-0.0201	0.2136
	Escherichia coli	-0.12374	0.4336
	Salmonella	-0.35865	0.02353
Depth	Total coliforms	-0.34503	0.029226
	Fecal coliforms	-0.41105	0.008
	Escherichia coli	-0.43901	0.0045981
	Salmonella	-0.37511	0.01708

The findings agrees with Manyebvu (2011) who found that well depth was found to be negatively correlated with contamination levels in both protected (p = 0.028, r = -0.552)) and unprotected wells (P = 0.001, r = -0.589). Kanyerere (2012) found there was no significant

general relationship between the distance from latrines and/or animal kraal and the degree of contamination However, Munyebvu (2011) found that distance from pit latrine was negatively correlated with coli form level in unprotected wells, ($r = -0.46$, $p = 0.0352$) The significant correlation between well depths and levels bacterial contamination suggest that depth possibly explains the difference in the levels of coli form contamination.

CONCLUSION AND RECOMMENDATIONS

The results from this study revealed that drinking water from fully and partial protected shallow wells in the study area contained significantly ($P > 0.05$) the same level of pathogenic microbes. In general 68 % of drinking water samples contained fecal coliforms ranging from geometrical mean of < 1 to 3100 cfu/100 ml and 32 % contained *Salmonella spp* and failed to meet World health organization , WHO (2011) and Malawi standards, MS(2013 maximum permissible limit of zero coli forms in water intended for drinking purposes. However, no significant ($P > 0.05$) differences were observed in levels of fecal coliforms and *Salmonella spp*. between water samples from fully and partially protected wells. The presence of coliform bacteria in the studied wells implies that water from these sources is not suitable for human consumption, unless it is treated. The study has also established a fair strong negative and a significant correlation ($r>0.3$, $p<0.05$) between distance of a well from potential contamination source and level of *Salmonella spp* contamination as well as a fair strong negative and significant correlation ($r > 0.3$, $p < 0.05$ between depth of the well and contamination levels of Total coliforms, fecal coliforms, *E. coli* and *Salmonella spp* implying that distance between potential sources of well water contamination and depth of wells are factors influencing microbial contamination of the studied shallow water .

The study suggests that determining and observing a minimum safe distance between wells and potential sources microbial contamination and minimum safe depth of well can be helpful in prevent ground water contamination and that further research is required to investigate the treatment of this water using solar radiation or any appropriate technologies for example, use of plant material.

The study recommends mobilization of onsite treatment interventions to protect the households from further possible consequences of using the water and civic education of the community on best sanitary practices when drawing well water.

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Malawi's GHG emissions inventory for the industrial sector: a gap analysis of the cement industry.

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ABSTRACT

Malawi Government submitted its Intended Nationally Determined Contributions (INDCs) as part of the Paris Agreement in 2015. The Agreement came in force in 2016 and aims at achieving greenhouse gas (GHG) emissions reduction to avoid global warming above 1.5 degrees Celcius. It is, therefore, necessary that countries setup robust systems to record and monitor their emissions in line with the global tracking framework. This paper analysed gaps in GHG reporting in general with a focus on cement industry, a significant GHG emitting sector at global and local scale. The general and industry specific gaps were identified through interviews of key informants and from published literature, and reports. The collected data was analysed and evaluated against a criteria which used 2006 IPCC methodology as a benchmark. Strategies for the identified gaps were developed based on lessons from international best practices but aligned to local circumstances. GHG emission approaches were ranked from Tier 1 to Tier 3. Tier 3 is the most detailed. Malawi reports used Tier 1 approaches. The identified gaps were: there were no data; data source could not be traced; there were no local emission factors; no physical and chemical analysis emitting materials; institutions were unwilling to share data; data confidentiality could not be assured; and there was limited expertise in GHG inventory work. Furthermore, the cement industry has no machine performance and materials analysis data per batch produced. Although the government is trying to improve the status quo, the complexity of tasks is deterring progress. Therefore, the government could concentrate on improving data management system and delegate technical tasks of developing local emission factors to research and academic institutions.

Keywords: Cement industry, emission factors, GHG, Malawi, Paris Agreement, UNFCCC.

INTRODUCTION

There is overwhelming evidence to support the claim that climate change is attributable to the concentration of human induced greenhouse gases (GHG) in the atmosphere. These atmospheric concentrations of GHGs have substantially increased during the recent times. Some studies estimate that concentrations of carbon dioxide (CO_2) would increase from 380ppm in 2009 to 800ppm in 2100 under business as usual scenario (Huntzinger, 2006). This would result in an additional warming of the Earth's surface and atmosphere and may adversely affect natural ecosystems and humankind, thereby undermining the efforts to make earth a liveable place to our current generation and posterity.

The UN has been consistently championing efforts to curb GHG emissions since the UNFCCC 1992-1994. Article 4 section1(a) of the Convention states that all Parties shall " *develop, periodically update, publish and make available to the Conference of Parties (COP), in accordance to Article 12, national inventories of anthropogenic emissions by source and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies agreed upon by the COP."* The UN also spearheaded further cuts in emissions through the Kyoto Protocol and its associated carbon mechanisms (Nations, 1998). The efforts have continued in all the Conference of Parties (CoP) meetings. For instance, during CoP 16 in Cancun, Mexico, countries were urged make "deep cuts" in GHG emissions through nationally appropriate mitigation actions (NAMAs) (UNFCCC, 2011). These efforts climaxed with the submission of Intended National Contributions (INDCs) and signing of the Paris Agreement by 196 countries in 2015. The Agreement came in force in 2016 and aims at achieving greenhouse gas (GHG) emissions reduction to avoid global warming beyond 1.5oC. Countries will be expected to 'assess current progress in reducing GHG emission at national and sectoral level'; 'undertake M&E to assess the impact of mitigation actions' and ' inform future policies'.A good national GHG inventory system would form a critical component of an MRV system that is necessary for country's international reporting requirement. However, previous GHG inventory reports show that many developing countries, like Malawi, face challenges in producing their national GHG emissions inventories(Government of Malawi, 2002, 2011).

The objective of this study is to analysed gaps in GHG reporting for the IPPU in general with a focus on cement industry so that management information systems at industry level could be put in place to feed into the national MRV framework. The study involves review of relevant literature on GHG inventory study in the IPPU locally, regionally and globally; and interview of lead persons in GHG studies in Malawi

GHG Inventories

According to the Intergovernmental Panel on Climate Change (IPCC) revised guidelines of 2016 for the preparation of national GHG inventories, there are four emission source sectors, namely, energy, industrial processes and product use (IPPU), agriculture forestry and other land use (AFOLU) and waste. Malawi has so far undertaken two comprehensive national GHG inventories as part of Malawi's Initial National Communication (INC) and Second National Communication (SNC) to the UNFCCC in 2002 and 2011. The Third National Communication (TNC) is currently being compiled.

Based on the average for the INC and SNC inventories for the period 1994 to 2000, Malawi emits about 2000Gt of CO_2 equivalents per annum. The contribution of GHG emissions by sectors is shown in Figure 1.

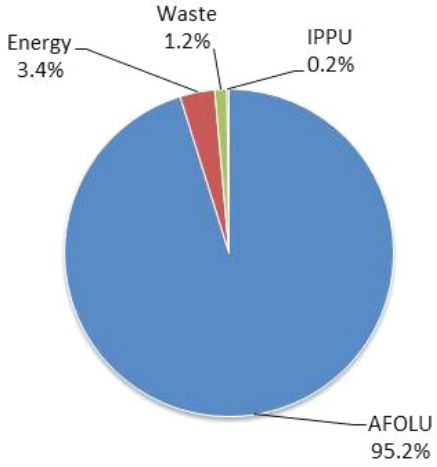
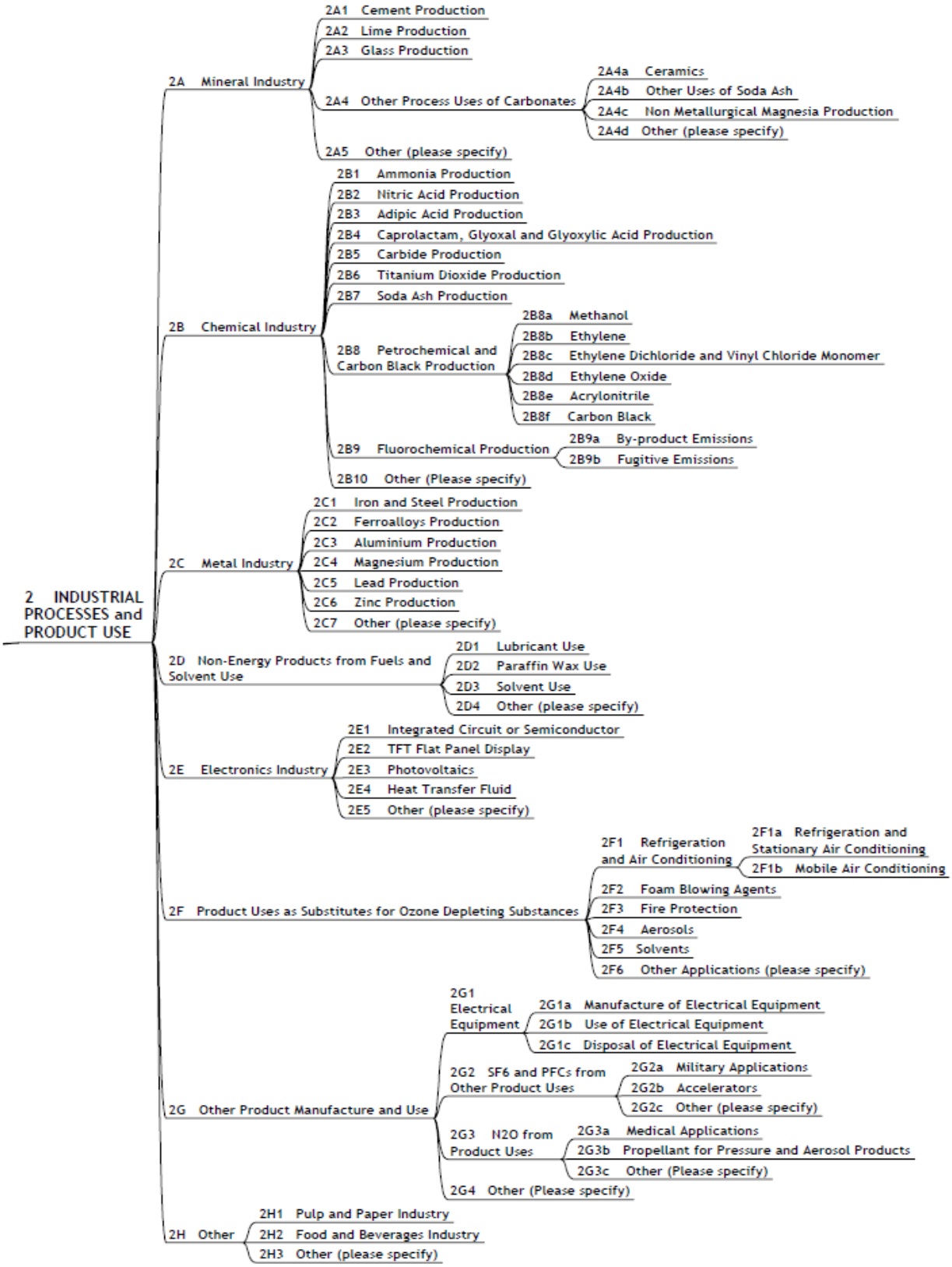


Figure 1: Sectoral contribution of GHG in Malawi Source: Adapted from SNC- GoM (2011).

Although the IPPU sector is the smallest contributor, the growth trends are showing significant growth in the near future. It is worth noting that the scope of the IPPU source category is quite extensive (Figure 1) but only a few are currently relevant to Malawi.



Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3, Chapter1.

Figure 2: Industrial Processes and Product Use categories

As shown in Figure 2, the guidelines provided detailed breakdown to ensure completeness of the source sub-categories. Therefore, each country would expected to update its status in each of the eight categories 2A to 2H.

Emissions Cement Industry

The cement industry is the largest emitter with the IPPU category, accounting for 3 to 4% of the total global GHG emissions. In Malawi, the cement industry emits on average 50.3 Gg of CO_2 per annum which is 98% of emissions in the IPPU.

Figure 2 show the cement manufacturing process, locating where the GHG emission takes place. Cement manufacture consists of four stages: quarrying, material preparation, clinkering and finishing.

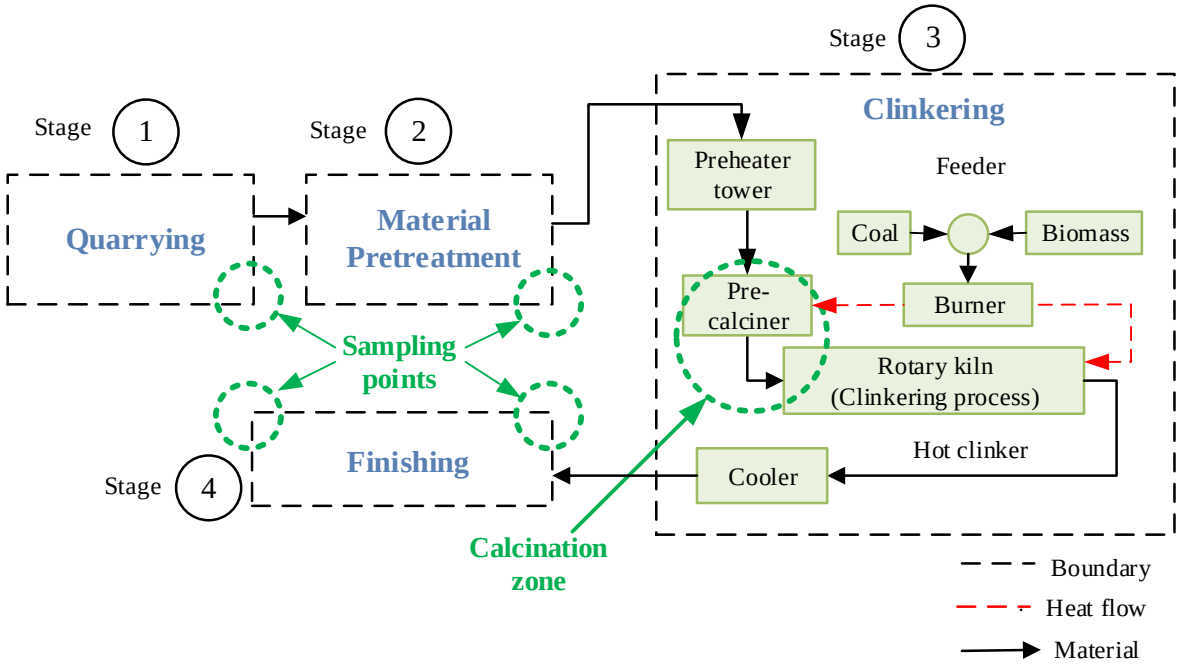


Figure 3: A schematic of cement processing showing sampling points and calcinations zone.

In stage 1, the main raw materials consisting of limestone, clay, bauxite and iron are quarried and ferried to the factory site. The materials are then crushed, weighed, milled and mixed in stage 2. The mixture flows into stage 3 through preheaters, where the mixture is heated by exhaust gases, and then enters the pre-calciner where it is heated further to about 800° Celsius(°C). The limestone ($CaCO_3$) decomposes to calcium oxide (CaO) and carbon dioxide (CO_2), a process known as calcination. This is the source of process-based CO_2 emission and takes place in calcination zone (Figure 3). The mixture of materials flows into the kiln where it is heated further to 1450°C, and reacts to form clinker, new compounds of silicates, ferrites and aluminates of calcium. Clinker is the main constituent of Portland Cement (PC). It is important to note that at various points, material sampling, measurement and analysis takes place. It is important to know the calcium carbonate content of the limestone (stage 1), the quantities of the various components forming the mixture of the raw mill (stage 2), the clinker is weighed together with other components to make the different types of cement[26] and finally weight and chemical analysis of the finished products (stage 4).

[26] For instance Portland cement consists of 95% clinker and 5% gypsum. Other mixtures clinker is partly substituted with lime in the formulation.

There are three cement plants which in Malawi. One plant in Blantyre has only milling operation, using imported clinker. The other two are in Mangochi and Kasungu. Both have recently installed kilns with capacity to produce about 1000 tonnes of clinker per day. Allowing for maintenance, planned shout downs and other losses, Malawi is expected to have capacity to produce more than 600000 t of clinker per year when operating at full capacity once the new plants are commissioned (CemNet.com, 2017; Chinamulungu, 2015; Jimu, 2015).

MATERIALS AND METHODS

Scope

The study involves an assessment of MRV gaps the Industrial Processes and Products Units (IPPU) with the cement industry as a case study. The cement industry is used as a case study. The study is exploratory in the sense that not much has been published in this area here in Malawi.

Data collection

In the data collection, two main approaches were used: review of related literature and interview of key stakeholders.

Desk study

This study involves review of literature on GHG emissions inventories through desk study of National Communications in Malawi and other countries in the SADC region. The gap analysis is based on the IPCC criteria of transparency, consistency, comparability, completeness and accuracy.

Interviews of stakeholders

Experts who are involved in GHG work were asked to rate the adequacy data in specific subsectors in terms of the process of compiling the GHG inventories in their IPPU sector guided by a series of questions benchmarked from the IPCC guidelines.

Table 11: Criteria for Evaluating the Quality of a GHG Inventory

	Factors	**Question**
1	Data Availability	Is the activity taking place? e.g. Is cement produced in Malawi? Who are the manufacturers? What data is required? Is data collected and used in production? costing? planning? monitoring trends?
2	Data Accessibility	Is data made available to a national entity? MRA, Ministry of Trade? NSO? Mining Department? Is a data management information system available? Is there data policy? (for collecting, archiving, sharing, protect from abuse)
3	Data Completeness	Are all manufacturing entities accounted for?
4	Data Traceability/ transparency	Can the data be traced back to the source? Is the method repeatable?
5	Comparability?	Have we used the standard methodology?
6	Consistency?	Has the same approach been used overtime? If not, have the past inventories adjusted in the time series?
7	Accuracy?	Have we been able to estimate margin of error (uncertainty analysis)?

RESULTS AND DISCUSSIONS

The major challenge encountered in the preparation of both the INC and SNC is to do with data. Two sets of data are required, namely, the activity data which shows and the quantity of material that emits the GHGs and emission factors which show the quantity of gas emitted per unit activity data. For instance in the cement industry, it is also important to know the carbonate content of all the raw materials used in the material mixture in stage 2. Although this data is collected, it is not accessible to the inventory compilers. In particular, the following challenges were highlighted by stakeholders:

Lack of harmonised institutionalisation of climate change relevant data/statistics
Malawi has a number of institutions with comprehensive data management systems, some of which could be relevant to climate change reporting such as National Statistical Office, Ministry Trade and Commerce, Malawi Revenue Authority, Reserve Bank of Malawi and others. There has been no deliberate effort to do a detailed analysis of what is available. This has now been covered in this paper (Figure 4). The figure shows that there is already data being collected regularly by various government agencies for their specific uses. The question one needs to raise is whether it is possible that the data could be made available for GHG inventory preparation process.

No formal agreements with institutions generating data;
The assessment further shows that the organisations that generate the data are not obligated by regulations to release the information that the government needs for GHG inventory purpose. For instance, there is need for awareness as to why the data is required at the highest level possible. The manufacturing companies could be worried that their data may fall in the hands of competitors or other unsolicited use. It will be necessary to put measures in place to ensure data security and limit its circulation. Furthermore, the regulations are supposed to ensure safeguards and protection from abuse of such data if it is considered proprietary in nature.

Completeness of data
Since Malawi's economy is agro-based, its industrial sector is still undeveloped. Therefore, there are only a handful of processes that are currently relevant to Malawi GHG inventories. With reference to Figure 2 that was shown earlier, Malawi's manufacturing and service sectors show that the following emissions' sub-categories are relevant: 2A, 2D1, 2D2, 2D3 and 2F. However, during the preparation of the INC and SNC, Malawi reported emissions from cement and lime industries only. For completeness, all the categories need to be addressed whether the data is available or not.

Accuracy of national GHG inventories
In the criteria, countries are required to provide the margin of errors for the inventory figures. The IPCC guidelines provide the method for estimating the errors or uncertainty. Despite that the uncertainty analysis (UA) was not been given the attention it deserves in the compilation of GHG inventories in both the INC and SNC.

Consistency of report compilations
Malawi's national GHG emissions reports have consistently adhered to the 2006 IPCC guidelines. In addition, appropriate corrections and adjustments were made where comparison were made to inventories prior to 2006.

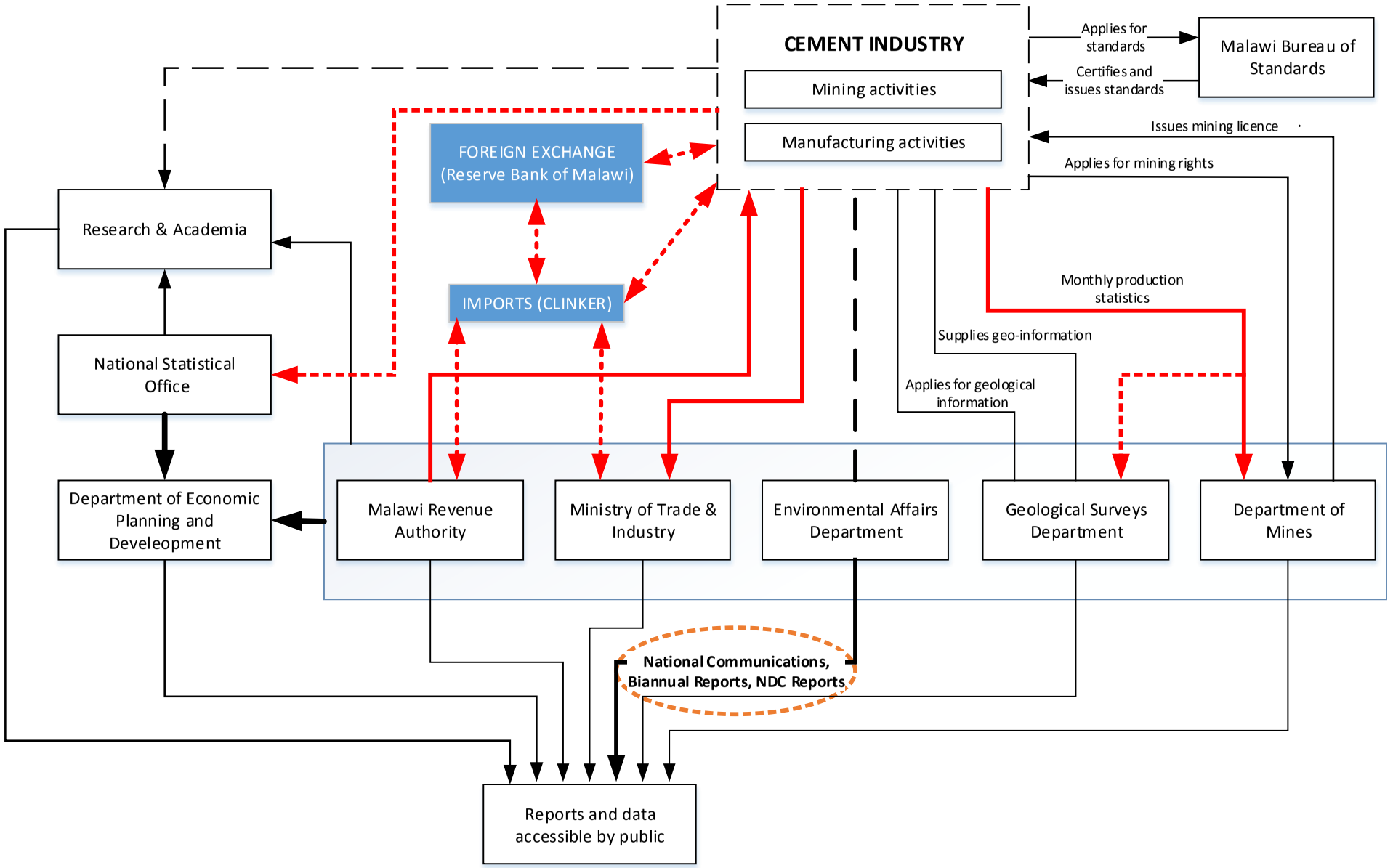


Figure 4: Analysis of GHG data flow in government institutions

CONCLUSIONS

Malawi is obliged through the various multilateral environmental agreements such as the UNFCCC and PA to regularly report its emissions status. The government has been monitoring and evaluating (M&E) its various programmes through the Ministry of Finance, Economic Planning and Development. As such, it could be possible for the country to adapt existing M&E framework or develops and operationalize a specific MRV framework for GHG inventory MRV framework. The framework can be supported by a number of government institutions that already collect a lot of data from industry that could be used to improve the quality of our GHG inventory reports. The reports could not only inform national mitigation efforts but also meet the international reporting requirements such as national communications, biannual reports and NDC.

As it has been illustrated by the cement industry case study, there are some barriers that need to be addressed to facilitate data collection, storage, security and access.

- Firstly, there is need to strengthen the institutions in terms of coordination, collaboration and resources (technical and financial).
- Secondly, a robust and secure management information system should be set up to capture and manage of the data required for inventory preparation.
- Thirdly, the government should quickly look at policy and regulation gaps that could facilitate collection and security of data that may be proprietary in nature.
- Fourthly, there is need to raise awareness at the highest level of all stakeholders on the reporting obligation of the government and the need for cooperation from all organisations that emit GHGs.
- Fifthly, there should be a deliberate action plan to build human capacity in the preparation of GHG emission inventories.
- Finally, the government should support research and academic institutions with research fund to develop local emission and material conversion factors to improve the quality of national GHG inventories.

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The Environmental Management Act, 2017: Opportunities and Limitations to Effective Enforcement

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ABSTRACT

Legislation remains an indispensable tool for effective protection and management of the environment. Availability of laws notwithstanding, desired results do not happen automatically. Effective enforcement is critical to the success of any law. In this regard, the 1994 National Environmental Action Plan highlighted that one big challenge to effective environmental management in Malawi was, among others, the uncoordinated legislative framework which had several gaps, inconsistencies, duplications and conflicts thereby making enforcement difficult. In an attempt to rectify this and other environmental challenges, Parliament recently enacted the Environmental Management Act (EMA), to provide for a coordinated and comprehensive legal framework for environmental protection and management. The president assented to this Bill in February 2017 and it is now recognised as the EMA (2017).This paper intends to critically evaluate this framework environmental law in a bid to highlight the opportunities and limitations which it presents with respect to effective enforcement.

Key words:

INTRODUCTION

Legislation remains an indispensable tool for effective protection and management of the environment. Availability of laws notwithstanding, desired results do not happen automatically. Effective enforcement is critical to the success of any law. In this regard, the 1994 National Environmental Action Plan highlighted that one big challenge to effective environmental management in Malawi was, among others, the uncoordinated legislative framework which had several gaps, inconsistencies, duplications and conflicts thereby making enforcement difficult. This was the main reason for the adoption of the 1996 national environmental policy (revised in 2004) and the subsequent enactment of a framework environmental law, the Environmental Management Act, 1996(EMA). Although this statute provides for an elaborate institutional framework for implementation of environmental management provisions and although it expanded space for stakeholder consultations and gave room for coordination, there is little indication that it improved environmental management in general or sector coordination to any significant degree[27].

In an attempt to address the above concerns, the Environmental Management Act (EMA), 2017 has provided for a coordinated and comprehensive legal framework for environmental protection and management. It was assented to by the president in February 2017 and is now recognised as the EMA 2017[28]. However, the enforcement of environmental laws remains a challenge in many

[27] Gracian Zibelu Banda, Draft report on the revision of the EMA (2004)
[28] What remains for the Act to become operational is the issue of a commencement notice

jurisdictions. What guarantee is there that this Act will achieve the desired objectives? This paper examines this law in a bid to highlight the opportunities and limitations it presents with respect to effective enforcement. In regard to the latter, suggestions will be made accordingly.

BACKGROUND

Malawi is one of the most densely populated countries in continental Africa and this causes a lot of pressure on its limited environmental resources. The 2010 State of Environment and Outlook Report by Ministry of Natural Resources, Energy and Environment outlines the following key environmental problems: soil erosion, deforestation, water resources depletion and degradation, high population growth, depletion of fish stocks, threats to biodiversity, human habitat degradation, and climate change and air pollution. Similar problems were identified in the 2004 National Environmental Policy and the National Environmental Action Plan (NEAP) 1994. Malawi's high population density and its over-dependence on agriculture is the substantial cause of continued environmental degradation. The problems are exacerbated by poverty since a high proportion of the population relies on the exploitation of natural resources like firewood and fish stocks for survival[29].

Over 90% of the value of Malawi's exports is accounted for by natural resource sectors most of which originates from agriculture[30]. Malawi's economy is therefore very much linked to its environment and environmental degradation threatens its social and economic development. The importance of the law in environmental protection and management is therefore critical.

The Environmental Management Act, 2017

As indicated above the Revised Environment Management Act 2017 is the integrated and comprehensive legal framework for environmental protection and management in Malawi. It is the coordinating statute on all environmental matters in Malawi. This Act repeals and replaces the EMA 1996 to provide for a more responsive legal framework for the protection and management of the environment and the conservation and sustainable utilisation of natural resources, in light of new emerging issues in environmental and natural resource management. Its purpose is to make provision for the protection and management of the environment; the conservation and sustainable utilisation of natural resources and for other incidental matters. Section 6 highlights its supreme status by providing that any environment and natural resource law that is inconsistent with the provisions of this Act shall, to the extent of such consistency be invalid-making this law subject only to the constitution. The following are the substantive enforcement mechanisms provided (opportunities for enforcement):

i. The Right to a Clean & Healthy Environment and the Issue of Locus Standi

The Act in section 4(1) provides for the right of every person to a clean and healthy environment and the corresponding duty to safeguard and enhance the environment. The Malawi Constitution does not explicitly provide for an environmental right which undermines its value in environmental protection. In section 13, the constitution merely provides for principles of national policy particularly that, the state shall actively promote the welfare and development of the people of Malawi by progressively adopting and implementing policies and legislation aimed at achieving specified goals which include the environment. In this regard, the goal is to manage the environment responsibly in order to: prevent degradation of the environment; provide a healthy living and working environment for the people of Malawi; accord full recognition to the rights of future generations by means of environmental protection and the sustainable development of natural

[29] State of the environment and outlook report, 2010
[30]Commission of the European Communities, 'Country Environmental Profile for Malawi', 2006

resources and to conserve and enhance the biological diversity of Malawi[31]. However, this provision is merely directory in nature and not justiciable.

While section 4 may not have the same status as a constitutional right, it is nevertheless an essential provision. The EMA, 1996 makes similar provision. However, It has been lamented that one of the difficulties with applications to enforce the environmental rights under the EMA 1996 was to do with restrictive interpretations of the requirement of locus standi[32].The new Act has addressed this problem and expanded the right significantly in two respects:

Firstly, section (4) provides that in furtherance of this right, the Malawi Environmental Protection Authority or any concerned environmental agency or any person shall be entitled to bring an action against any person whose activities or omissions have or are likely to have a significant impact on the environment. Under the EMA 1996; the coordinating agency or other lead environmental agencies have no power to enforce on behalf of the public and rely on the Attorney General's office yet the latter understaffed and has its own priorities. Section 4(4) is therefore a good development for enforcement of environmental law.

Secondly, section 4(5) of this Act is another excellent development for environmental law enforcement in this country. It provides that "*any person proceeding under section 4(4) shall have capacity to bring an action notwithstanding that the person cannot show that the defendant's act or omission has caused or is likely to cause him any personal loss or injury: provided that the legal action*

(a) Is not frivolous or vexatious

(b) Is not an abuse of the court process

Provided further that in every case the determining factor shall be whether such person is acting in the best interest of the environment and in exercise of the duty to safeguard and enhance the environment.

Legal actions are a powerful tool for compelling compliance and imposing sanctions for violation. However, a person wishing to bring an action before court to enforce a right is required to demonstrate that they have locus standi, i.e. sufficient interest in the matter in issue. One of the most commonly lamented barriers to the enforcement of environmental law under the EMA 1996 has been the issue of locus standi. In the consultations prior to the enactment of the EMA 1996 a proposed similar provision was shot down. The interpretation of 'sufficient interest' was in the discretion of the courts and the courts gave varied interpretations. It has been lamented that the Malawi Supreme Court of Appeal has unduly restricted the scope of locus standi as provided for in the constitution which factor has in turn limited the growth of public interest litigation in the country[33]. Public interest litigation is of significant benefit to the bulk of Malawian population who are poor, vulnerable and marginalised and cannot access the courts on their own[34].

The new Act is therefore to be commended for settling this question in clear terms. It has not only granted the right to a clean and healthy environment but has made enforcement of such right possible and easy. In a country where poverty and illiteracy levels are high, and political interference spans many sectors, NGOs and other interested stakeholders are the best positioned to enforce environmental rights. These parties can help in detecting violations and notifying the

[31] Section 13 (d) (i-iv) of the republic of Malawi constitution, 1994

[32] Justin Kalima, 'A critique of the Legal Framework for Wildlife Protection in Malawi', (2009) 3(2) Malawi Law Journal 199, 219.

[33] Mwiza Nkhata, ' Public interest litigation and Locus Standi in Malawian Constitutional Law' (2008) 2(2) Malawi Law Journal, 209. The article compares the treatment of the locus standi requirement in decisions of the high court and the supreme court of appeal. The supreme court required one to establish a personal interest or substantive interest surpassing that of other citizens in order to be held to have sufficient standing to commence an action.

[34] S. Gloppen and F. Kanyongolo, 'Courts and the Poor in Malawi: Economic Marginalisation, Vulnerability and the Law', (2007) 5(2) International Journal of Constitutional Law 258

authorities, applying public pressure, and bringing suits to enforce the law. The recent Salima-Lilongwe water pipeline project case[35] whereby Malawi Law Society commenced an action to secure compliance with Environmental and social impact assessment provisions in the EMA 1996 emphasises the relevance of interested stakeholders in the enforcement of environmental law. Section 4(5) will therefore go a long way in encouraging the much needed public interest litigation and with it effective enforcement of this law/ for the protection of our environment.

ii. The Malawi Environmental Protection Authority

As indicated above, the main motivation for the enactment of the EMA 1996 was that Malawi's environmental legal and institutional framework was too diffuse for effective coordination and enforcement. Nevertheless, though the EMA 1996 attempts to improve stakeholder consultations and give room for sectoral coordination, it has not been successful in this regard[36]. The Act also failed to provide for functions of lead agencies and provided no mechanisms for coordination and elimination of inconsistencies or gaps. Additionally, too many powers were given to the Minster and the fact that the coordinating agency, the Environmental Affairs Department (EAD), is a government department could be seen to compromise its independence and professionalism.

The Act addresses the above concerns. Section 7 establishes an autonomous body, the Malawi Environmental Protection Authority (MEPA) which shall be the principal agency for the protection and management of the environment and sustainable utilisation of natural resources. This authority shall have powers to coordinate, monitor, supervise, and consult with all stakeholders on all activities relating to the utilisation and management of the environment and natural resources. Functions which were given to the Minister for environmental affairs under the EMA 1996 will now be performed by this authority.

Some of its significant functions are covered in section 9: to advise the minister responsible for the environment on formulation and implementation of policies for environmental protection and management; to initiate legislative proposals , standards and guidelines; to enforce the right to a clean and healthy environment; to monitor and enforce compliance with environmental and natural resource related policies and legislation by lead agencies-in this case the authority has been given powers to direct lead agencies to submit regular reports on their activities accordingly; to review and approve environmental and social impact assessments, to receive and investigate complaints, to prepare and publish a national state of the environment report every five years and an annual report on the status of the environment.

This authority shall be a critical enforcement institution for environmental policies and legislation. It has provisions that can enable it to strengthen coordination, implementation and enforcement of environment and natural resources management and being an independent institution means it can work efficiently and professionally without/with minimal political interference in its operations. The only hiccup can be the fact that under section 10 MEPA shall consist of a chairperson, vice chairperson and five other members all of whom shall be appointed by the president. The secretary for the environment and the solicitor general shall be ex-officio members of the authority. Presidential appointments can negatively impact the autonomy and professionalism of the authority and eliminate any hopes of non-political interference in MEPA. Presidential appointees may not inspire confidence as they are perceived to owe allegiance to the appointing authority which might affect their efficiency. However, this remains to be seen.

[35] Discussed below

[36] Gracian Zibelu Banda, Draft report on the revision of the EMA (2004)

iii. The Environmental Affairs Tribunal

Effective Dispute resolution mechanisms greatly impact the enforcement of any law. The EMA 1996 makes provision for the establishment of an environmental tribunal. The tribunal however was granted very limited administrative jurisdiction- mainly considering appeals against decisions and actions of the minister, director or inspectors under the Act. Twenty one years after the enactment of EMA, 1996 this tribunal is yet to be operationalized.

The EMA 2016 Act also makes provision for this tribunal in section 109 but has gone further to considerably expand the jurisdiction and powers of the tribunal. The tribunal shall additionally hear and determine petitions on violations of the right to a clean and healthy environment or any other provision under the Act or any written law relating to environment and natural resource management. Furthermore, the tribunal shall receive complaints from any person, lead agency, private sector and NGOs relating to implementation and enforcement of environment and natural resource management policies and legislation.

Given this wide jurisdiction, this tribunal is essential to the enforcement of environmental law in Malawi. It has potential to quickly and efficiently deal with environmental disputes and enforce the law accordingly. More so considering the cost and delays that come with taking matters to court in Malawi. A further advantage of this tribunal is that it shall be chaired by a legal practitioner who is conversant with environmental law and who shall be appointed by the Malawi Law Society unlike under the EMA 1996 when it was to be chaired by a person appointed by the president. This may address the political interference concerns raised above.

Nevertheless, considering that twenty one years after the enactment of EMA 1996, this tribunal is yet to be operationalized (resource constraints are always the excuse)-there is no guarantee that now government will now operationalize this tribunal with speed. It is perhaps important for our laws to be providing for minimum periods for the establishment of institutional structures.

iv. Environmental and Social Impact Assessments, Monitoring and Auditing

Part VI of the Bill makes extensive provision for environmental and social impact assessments, monitoring and auditing. An Environmental and Social Impact Assessment (ESIA) is a systematic evaluation of a project to determine its impact on the environment and the conservation of natural resources[37]. These are powerful mechanisms for the enforcement of environmental and natural resource policies and legislation as they ensure that developmental projects should not be implemented at the expense of the environment and natural resources. However, although the EMA 1996 makes similar provision, other than the Environmental Impact Assessments (EIA), the other mechanisms are scarcely utilised-the challenge being lack of personnel, technical expertise and funding in the enforcement agency. As long as there is no commitment to address these issues, these mechanisms though good, will not take much effect beyond paper.

The recent case of *The State V Lilongwe Water Board, Minister of Agriculture, Irrigation and Water Development, the Director of Environmental Affairs, the Minister of Natural Resources Energy and Mining Exparte the Malawi Law Society*[38] has a very important bearing in this regard. It involved the need for an EIA in the Salima-Lilogwe/lake Malawi water supply project where Khatho civils limited was contracted by Lilongwe water board and Malawi government to install a water pipeline project pumping water from Salima to Lilongwe. The Malawi Law Society was of the view the contractor, Khatho civils proprietary limited had commenced implementation of the project before an EIA and commenced judicial review proceedings against the mentioned respondents to compel them to do the needful. The matter was heard to determine preliminary

[37] Section 2 of the EMA, 2017
[38] Judicial Review Cause Number 16 of 2017, High Court (Zomba District Registry)(unreported)

issues and both parties agreed that a project of such magnitude could not commence in the absence of an EIA and ESIA. The overarching question was whether project implementation has already started.

This case highlights the fact that there is a potential danger to sacrifice environmental concerns in the implementation of developmental projects perceived as beneficial to the country. It also buttresses the point that interested stakeholders and NGO's are essential in addressing environmental concerns and ensuring accountability of the relevant authorities. It will be interesting to note how the court will determine case at the substantive judicial review hearing.

v. Environmental Protection Orders

Part XI of Act gives MEPA the power to issue environmental protection orders against any person whose acts or omissions have or are likely to have adverse effects on the protection and management of the environment and the conservation and sustainable utilisation of natural resources. This, if efficiently utilised is another powerful enforcement mechanism.

vi. Inspection, Analysis and Records

In section 81, the Act states that MEPA shall establish an inspectorate with the necessary technical staff and facilities to administer monitor and enforce measures for the protection and management of and for the prevention and control of, pollution to the environment. Inspectors play a very important role in the enforcement of environmental standards. Subject to adequate availability of technical staff and facilities (which is not the case now), inspectors are essential to the protection and effective management of the environment as they can prevent the occurrence or aggravation of actual environmental harm.

vii. ***Admininstrative Penalties-old act?***

Section 108 has introduced various administrative penalties. These include written warnings, monetary penalties, directing the wrongdoer to do or refrain from doing an act, directing wrongdoers to remedy the effects of contravention or to compensate victims among others. The monetary penalties indicated are reasonably hefty.

Administrative penalties are a welcome development and are in line with principles of environmental law since they allow preventive action to be taken before environmental damage occurs. With Administrative penalties recourse to legal action shall be the last option and this will reduce the number of matters that go into the court system with its attendant costs and delays. If utilised efficiently, these penalties will properly complement the criminal sanction which has been popular in the enforcement of environmental law in Malawi and help in eliminating the disadvantages that come with criminal enforcement. Other countries like Swaziland are also moving towards decriminalisation and impose administrative fines instead of resorting to criminal law.

viii. Offences Section

Part XV provides for various criminal offences in relation to environmental and natural resource protection and management. Criminal sanctions are commonly used to enforce environmental law. However, it has often been lamented that fines provided under the EMA 1996 are too weak to have any deterrent effect[39]. The Act attempts to address this concern by providing for reasonably hefty fines. Also commendable is the fact that the Act is providing for an additional fine for each day that environmental harm continues after conviction. As this may motivate offenders to expeditiously remedy environmental harm.

[39] R V Maria Akimu Revision case number 9 of 2003

Further to the above, it must be noted that criminal offences are commonly prosecuted by the Malawi Police Service prosecutors and officers from the DPP's chambers yet these officers may not have the requisite expertise in technical environmental matters. Coordination between these departments and MEPA is therefore imperative to the successful prosecution of these offences.

Barriers to Enforcement and Possible Solutions

The above opportunities should be examined side by side with the following corresponding barriers and suggested solutions

Poverty

Poverty remains the primary cause of unsustainable use of the environment and natural resources and an underlying challenge towards effective enforcement. Related to this is the overdependence of our energy economy on biomass fuels like firewood and charcoal, a factor which has significantly contributed to environmental degradation in Malawi. Poverty also reduces motivation among people to care about environmental degradation or pursue environmental justice the primary concern being survival. While there are many poverty alleviation policies and schemes, much of it is in form not substance and until we make serious efforts to actually alleviate poverty and also provide alternatives to biomass fuels, we will keep singing this song.

High Illiteracy Levels and Attitudinal Problems

Another barrier to effective enforcement of environmental law are the high illiteracy levels coupled with casual societal attitudes to environmental wrongs. The extent to which people regard environmental wrongs as being morally wrong will determine their demand for justice, reporting, identification. Unfortunately, most Malawians do not seem to consider environmental wrongs as such as can be evidenced by the brazen littering around. Another example is the case of R V Maria Akimu[40] where officials of the National Parks and Wildlife Department, disguising as would-be purchasers of ivory, working on information, met the defendant at her house. They agreed to buy some pieces of ivory at the defendant's house, at the defendant's father's house and another person's house. They eventually arrested the defendant and recovered the ivory but not without stiff resistance from the defendant's neighbours and relations (who could not understand why an individual should be prosecuted because of animals) when one national parks and wildlife official was badly injured. We have also seen media reports of forestry officials being assaulted for confiscating charcoal from sellers. All this evidences our casual attitude towards, environmental injustices. To this, we can only hope that intensive public awareness and education as well as incentives will motivate the society accordingly.

Resource Constraints

Related to the poverty challenge is the fact that government allocates minimal resources to environmental matters. The Environmental affairs department remains underfunded and understaffed and this negatively impacts their enforcement mandate. For instance, inspectors cannot efficiently enforce environmental standards because they are very few in number, lack technical expertise and other necessary facilities. MEPA will likely face the same challenges unless government allocates sufficient resources to support its mandate.

Delays in Establishing Institutional Mechanisms

Although the new law makes provision for essential enforcement institutions like the MEPA and Environmental Affairs Tribunal, these may not be operationalized with speed. For instance, twenty one years after the enactment of EMA 1996, the Environmental Affairs Tribunal is yet to be operationalized, what guarantee is there that government will now operationalize this tribunal with speed? This is discouraging and a blow to enforcement. Perhaps our laws should be providing for minimum periods for the establishment of institutional structures.

[40] Revision Case Number 9 of 2003

Political Interference

Political interference is a constant challenge to the enforcement of laws in Malawi and one way this happens is through political appointments. Practice has shown that most presidential appointees are prone to political manipulation. Consequently, though MEPA has been given autonomy as an environmental enforcement agency, it is a cause for worry that section 10 states that MEPA shall consist of a chairperson, vice chairperson and five other members all of whom shall be appointed by the president. Presidential appointments have the potential to compromise the autonomy and professionalism of MEPA and with it effective enforcement. We really need to strengthen the effectiveness and independence of enforcement mechanisms. Let's wait and see.

Optimising Criminal Sanctions

Malawian environmental law places more reliance on the criminal sanction than any other sanction for environmental protection and it will remain an important device for securing compliance with the law[41]. They are either applied as a primary sanction or as a supporting sanction where administrative measures fail. However, this is not ideal since the criminal law is reactive not proactive contrary to one of the fundamental principles of environmental law, the preventive principle which requires that, environmental damage should as much as possible be prevented in advance rather than put right or punished after the event[42]. Since most environmental disputes will culminate into criminal cases, we just need to optimise benefits from its use by for instance, depositing fines paid by convicts into the environmental fund to be used in remediation and furthering environmental causes not the consolidated fund (Account1) as is the case. Strengthening the involvement and technical expertise of public prosecutors, investigators and courts in enforcing environmental laws also warrants serious consideration.

Judicial Activism

Over twenty years after enactment, only one case[43] has to my knowledge been brought before the High Court praying for reliefs under EMA 1996 despite the existence of many environmental problems. This is a lost opportunity for the courts to articulate and enforce the right to a clean and safe environment. Given the chance (which might arise with the broad locus standi provisions that we have now), our courts should not be conservative but utilise their role to develop the law in this regard as a mechanism for environmental protection. The high court in Uganda proactively 'delineated' this right in the case of *Uganda Electricity Transmission Company Limited V De Samarine Incorporation LTD*[44].

CONCLUSION

Enforcement remains a major challenge in Environmental and Natural resource Management in Malawi. While the legal framework presents great opportunities, the above limitations must be dealt with to improve enforcement.

[41] Justin Moses Kalima, 'the effectiveness of environmental law in malawi: ana analysis of the principal legal tools for achieving environmental protection with emphasis on the criminal sanction' University of Kwa Zulu Natal (2006)Doctoral Thesis

[42] Gracian Z Banda & Thoko Ngwira, *Introduction To Environmental Law in Malawi* (2007) Environmental Affairs Department, Lilongwe. P 11.

[43] The Salima pipeline project case reffered to above

[44] Misc Cause No 181 of 2004

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Assessment of Heavy Metals in Water, Sediments and Fish from Lake Chilwa, Zomba, Malawi

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ABSTRACT

An assessment of heavy metals in water, sediments and fish was done in Lake Chilwa (2015 to 2016), Zomba, Malawi. Five sampling points namely Bonga, Chaone, Thunde, Mchenga and Kachulu were selected. Samples were analyzed for pH, EC, TDS, temperature, nitrates, phosphates, lead (Pb), cadmium (Cd), manganese (Mn), copper (Cu), zinc (Zn) and iron (Fe) using American Public Health Association (APHA) prescribed standard methods during dry season and rainy season. Generally, physico-chemical parameters were higher in the dry season than the rainy season which was attributed to low water volumes. The results further revealed that Pb was undetectable in water, sediments and fish. However Mn and Cu were detected in fish and sediment samples ($Mn_{sediments}$: 2.25 – 10.66 mg kg^{-1} dry weight (dw); Mn_{fish}: 0.015 – 1.18 mg kg^{-1} dw; $Cu_{sediments}$: n.d – 1.63 mg kg^{-1} dw; Cu_{fish}: 0.41 – 0.92 mg kg^{-1} dw). The concentrations of heavy metals in fish samples were below the maximum limits for edible fish recommended by FAO / WHO: Cd (0.1 mg kg^{-1}), Cu (3 mg kg^{-1}), Fe (43 mg kg^{-1}), Pb (0.2 mg kg^{-1}), Mn (2 – 9 mg kg^{-1}) and Zn (60 mg kg^{-1}). Generally, the levels of heavy metals were ranked in the order sediments > fish > water. The study further revealed significant differences in metal concentration between dry season and rainy season. Mn, Cu and Zn in sediments were significantly higher ($p < 0.05$) in the dry season than rainy season. Conversely Fe in sediments was significantly higher ($p < 0.05$) in the rainy season than the dry season. Results of this study indicate that the main sources of heavy metals in Lake Chilwa are the use of fertilizers, burning of fossil fuels and disposal of metal products. Therefore, there is a need for an integrated approach towards controlling pollution activities in the area.

Key words: Environment, heavy metals, Lake Chilwa, Malawi, pollution,

INTRODUCTION

Globally, freshwater pollution is increasingly becoming an issue of great concern. According to United Nations World Water Assessment Programme (UN WWAP, 2003), the water bodies receive 2 million tons of sewage, industrial and agricultural wastes every day, which is equivalent to the weight of 6.8 billion people. Furthermore, it is estimated that about 1,500 km3 of wastewater is produced every year, which is six times more water than exists in all rivers of the world . The three sources of water pollution namely: industrial, agricultural and sewage wastes are associated with the increased levels of trace elements or heavy metals such as lead (Pb), zinc (Zn), iron (Fe), manganese (Mn), copper (Cu) and cadmium (Cd) in freshwaters (Sajidu, 2008). Similarly, Gupta et al. (2009) noted that industrialization, agriculture, increased population, urbanization and lack of environmental regulations aggravate high levels of heavy metals in surface waters.

In an effort to achieve sustainable economic growth, recently the government of Malawi made a deliberate policy to "transform Malawi from a predominantly importing and consuming to a producing and exporting nation." In this context, the country would seek to increase investments in the productive sectors (Government of Malawi, 2006). Consequently, this would result in increased industrial and agricultural activities that promote pollution of water bodies by heavy metals hence the need for studies of monitoring these toxic elements. This therefore necessitated this study in which an assessment of heavy metals on the Zomba side of Lake Chilwa was conducted.

MATERIALS AND METHODS

Description of the study area

Lake Chilwa is found in the southern districts of Malawi namely: Zomba, Machinga and Phalombe. It also lies on the border with Mozambique (Zegreen & Munyenyembe, 1998). It is the second largest lake in Malawi situated in the center of the low-lying Chilwa-Phalombe plain at 35°45' E and 15°15' S (Ratcliffe, 1971).

The perennial rivers that feed the lake are: Domasi, Likangala, Thondwe, Namadzi and Phalombe (Wetlands International, 2011). The lake has several islands but only two are inhabited i.e. Chisi and Tongwe. Chisi Island is located to the western shore near Kachulu harbor. It is 4 km across and rises to 430 m above the level of the lake (Burgis & Symoens, 1987). Zomba is the nearest city which is approximately 30 km from Kachulu harbor.

Sampling

Figure 1 is a map of Lake Chilwa catchment area showing location of sampling points and other features to the Zomba side. The study had five sampling sites namely: Bonga, Chaone, Thunde, Mchenga and Kachulu. Water sampling for heavy metal analysis was according to APHA (1985). Sediment samples were collected by divers using an Eckman grab as described by Osman & Kloas (2010). Fish samples (*Barbus paludinosus, Clarias gariepinus and Oreochromis shiranus chilwae*) were bought from fishermen in the area.

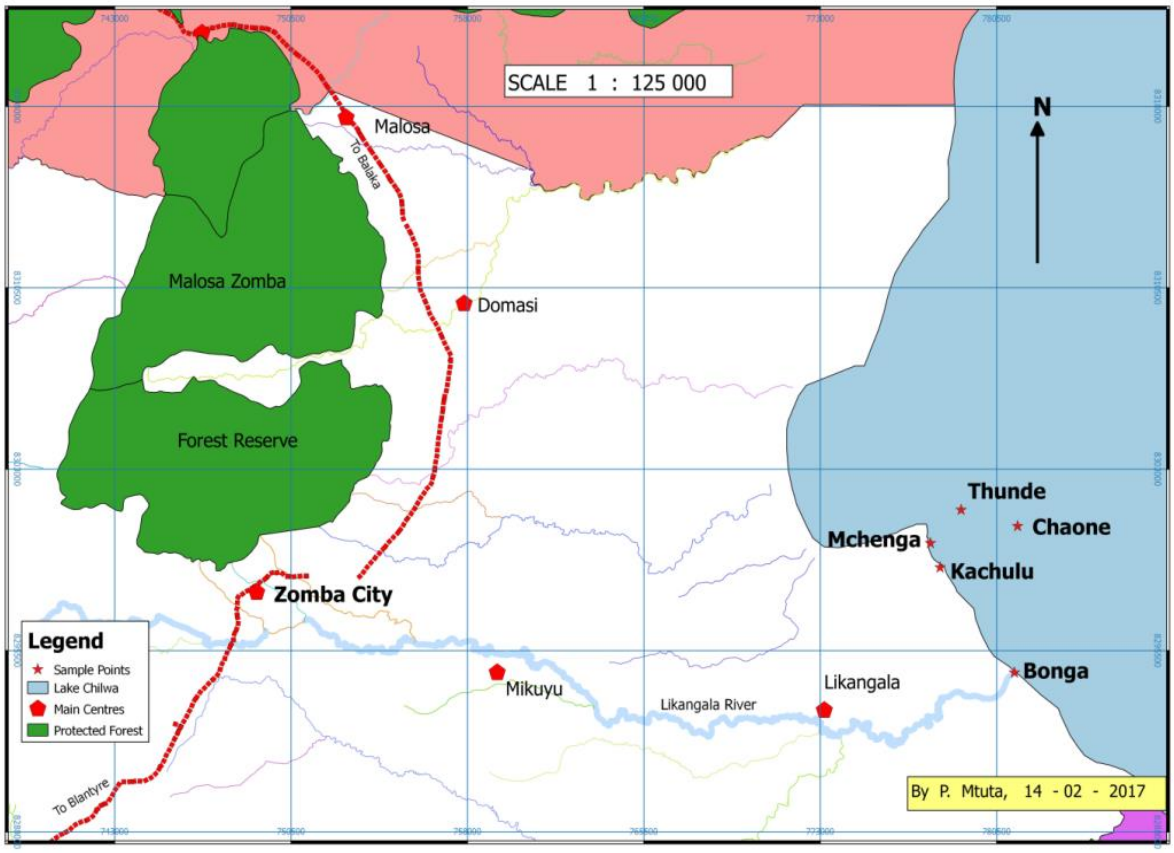

Figure 1: Map of Lake Chilwa to the Zomba side showing sampling points

Analytical methods

Preparation and analysis of samples was according to available standard methods. In summary, water samples were digested using aqua regia. Sediment samples were digested using nitric acid which was also the case with fish samples. pH, EC, TDS and temperature were measured on site using appropriate instruments. A UV/Vis Spectrophotometer (spectronic 20 model) was used for analysis of phosphates and nitrates (APHA, 2005). Heavy metals were analysed by an Atomic Absorption Spectrophotometer (GBC932 model).

RESULTS AND DISCUSSION

Physico-chemical paramaters

Table 1 is a summary of the results for physico-chemical parameters. For pH all the sampling sites but Bonga in rainy season were not within the WHO acceptable pH range for drinking water of 6.5 to– 8.5) (WHO, 2011). On the other hand, all the sampling sites except Thunde (pH = 9.7) in the dry season were within the Malawi Standard drinking water values (pH = 5.0 – 9.5) (MBS, 2005). For water temperature, all the sampling sites recorded higher temperatures in the dry season than in the rainy season which is expected. Also, the mean concentration of total dissolved solids (TDS) for four sampling sites were higher in dry season than in rainy season. This could be attributed to low water levels in dry season that lead to increase in concentration of dissolved solids. Additionally, the mean concentration of electrical conductivity (EC) for the four sampling sites was higher in the dry season than in rainy season. The possible reason could be attributed to low water levels in dry season that lead to increase in concentration of ions.

As for the nutrients, in both seasons all the sampling sites had nitrate levels below WHO drinking water standard (50 mg L^{-1}) (WHO, 2011). On the other hand, Mchenga was the only site that had nitrate levels within Malawi drinking water standards (6.0 – 10 mg L^{-1}) (MBS, 2005). The sources

of nitrates in water samples could be the use of inorganic fertilizers. The highest level of nitrate was observed in the dry season at Mchenga while the lowest was at Kachulu in the same season. This could be attributed to irrigation farming that involves the use of fertilizers in the area around Mchenga as compared to Kachulu where people concentrate on fishing. For the phosphates, the highest level of phosphates were observed in the rainy season at Kachulu sampling site (1.274 mg L^{-1}). The possible reason for higher phosphate levels at Kachulu could be the use of phosphorus detergents for washing clothes and uncontrollable disposal of wastes. It was observed that people used the area near Kachulu harbor for laundry and bathing.

Heavy metals in water and sediments

The study also analysed water and sediment samples for possible presence of selected heavy metals namely: lead (Pb), cadmium (Cd), manganese (Mn), copper (Cu), zinc (Zn) and iron (Fe). The results for sediment samples are presented in Table 2. The study did not detect lead in water and sediments for dry and rainy seasons. Cadmium was only detected in water in the dry season and in sediments in the rainy season at Kachulu sampling site and possible source was inferred to the use of phosphate fertilizers in the area.

Table 1: Seasonal results for physicochemical parameters in water samples with minimum and maximum values compared with WHO and Malawi standards threshold limit values

Parameter	Bonga		Chaone		Thunde		Mchenga		Kachulu		Min	Max	p-value	WHO	MS
	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS					
pH	8.570	6.937	9.360	9.233	9.700	9.437	9.333	8.587	9.433	8.747	6.937	9.70	< 0.001	6.5 – 8.5	5.0 – 9.5
Temp (^oC)	32.53	30.70	33.77	31.70	32.10	31.70	33.23	32.83	33.73	32.60	30.70	33.77	< 0.001		
TDS (mgL^{-1})	2064	77	1948	2047	2045	1818	2158	1272	2119	1657	77	2119	< 0.001		450 – 1000
EC (S/cm)	2808	123	2701	2777	2814	2493	2936	1788	2878	2300	123	2936	< 0.001	700	700 – 1500
NO_3 (mgL^{-1})	0.632	2.033	1.084	2.166	0.865	5.290	0.896	6.565	3.201	0.388	0.388	6.565	0.027	50	6.0 – 10
PO_4 (mgL^{-1})	0.336	0.249	0.288	1.107	0.270	1.209	0.321	0.945	0.233	1.274	0.233	1.274	< 0.001		

DS = dry season, RS = rainy season, p-values for ANOVA test

Table 2: Seasonal results for sediment samples with maximum and minimum values

Parameter ($mg\ kg^{-1}$)	Bonga		Chaone		Thunde		Mchenga		Kachulu		p-value	Min	Max
	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS			
Mn	5.396	3.250	7.746	10.656	9.775	9.785	4.788	2.253	5.509	3.967	0.233	2.253	10.656
Cu	1.273	1.629	0.575	0.000	0.637	0.000	0.249	0.000	0.548	0.405	0.021	0.000	1.629
Zn	1.659	1.527	1.078	0.209	1.825	0.245	0.153	1.086	1.289	0.000	0.029	0.000	1.825
Fe	392.3	445.9	282.8	376.2	357.4	371.6	156.5	232.7	235.3	307.2	< 0.001	156.5	445.9

Manganese and copper were not detected in water samples but in sediments. The study indicated the absence of zinc in water samples for dry season but it was detected in the rainy season. In sediments zinc was detected in both the rainy and dry season. Iron was also detected in both the water samples and the sediments. Generally, in water and sediments samples, highest concentrations of the metals were detected either in harbors or close to river mouths.

Heavy metals in fish

The study also analysed the samples of three different species of fish for possible presence of selected heavy metals namely: lead (Pb), cadmium (Cd), manganese (Mn), copper (Cu), zinc (Zn) and iron (Fe). The results of different fish samples are presented in the Table 3.

Table 3: Seasonal results for fish samples with their minimum and maximum values compared with WHO/ FAO standards threshold limit values

Fish type	Cd (mg kg^{-1})		Mn (mg kg^{-1})		Cu (mg kg^{-1})		Zn (mg kg^{-1})		Fe (mg kg^{-1})	
	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS
O. shiranus chilwae	0.000	0.003	0.246	0.065	0.406	0.544	2.078	4.815	18.637	18.631
C. gariepinus	0.000	0.003	0.467	1.178	0.406	0.917	2.214	1.712	32.314	9.683
B. paludinosus	0.000	0.006	0.015	0.206	0.416	0.683	2.004	2.698	16.342	11.780
Min	0.000	0.003	0.015	0.065	0.406	0.544	2.004	1.712	16.342	9.683
Max	0.000	0.006	0.467	1.178	0.416	0.917	2.214	4.815	32.314	11.780
Overall Mean	0.000	0.004	0.243	0.483	0.409	0.715	2.099	3.075	22.422	13.365
FAO/WHO	0.1		2 - 9		3		60		43	

Lead was not detected in fish. In the dry season cadmium levels were not detected in all fish samples. On the contrary, fish samples for the rainy season showed the presence of cadmium but the levels were below the maximum limit set by FAO / WHO standard for cadmium in fish for consumption (0.1 mg kg^{-1}) (FAO / WHO, 1999). *Barbus paludinosus* recorded high levels of cadmium than the other two species. Manganese was detected in both seasons but also the levels in fish were below the maximum limit set by FAO / WHO (2 – 9 mg kg^{-1}) (FAO/WHO, 1999). Copper was also detected in fish samples for both seasons and the levels were also below the maximum limit set by FAO/WHO. *Clarias gariepinus* recorded higher concentration of copper (0.917 mg kg^{-1}) than *Barbus* and *Oreochromis* species (Table 3). Zinc and Iron were also detected in both seasons but the concentration was also below the maximum limit set by FAO/WHO. *Oriochromis shiranus chilwae* had the highest levels of zinc in the rainy season than the other species. This may also indicate that *Oriochromis* species have high potential for accumulating zinc elements than other two species under study. On the other hand, *Clarias gariepinus* species recorded higher levels of iron than the other two species.

Generally, the study further revealed significant differences in metal concentration between dry season and rainy season. Mn, Cu and Zn in sediments were significantly higher ($p < 0.05$) in the dry season than rainy season. Conversely Fe in sediments was significantly higher ($p < 0.05$) in the rainy season than the dry season.

CONCLUSION AND RECOMMENDATIONS

This study assessed physico-chemical parameters and heavy metals in Lake Chilwa on the Zomba side. The study revealed high pH levels in the dry season than rainy season. All the sampling sites had pH levels above the WHO and MBS limits for drinking water except Bonga in rainy season. Equally, there were higher temperatures in the dry season than the rainy season that were attributed to the weather during sampling. Similarly, there were higher EC in the dry season than rainy season except for Chaone sampling site. The EC of all sampling sites were above the WHO limits for drinking water in the rainy season except for Bonga. Likewise, there were higher levels of total dissolved solids in water in the dry season than rainy season except for Chaone sampling site. The total dissolved solids of all sampling sites but Bonga in the rainy season were above the maximum level for drinking water as suggested by the WHO and Malawi Standards. In both seasons, all the sampling sites had nitrate levels below WHO drinking water standards. Phosphates were observed to be higher in the rainy season than the dry season. This could probably be as a result of fertilizers brought to the Lake by surface runoff.

The study also revealed that the concentration of Pb, Mn and Cu were undetectable in the waters of Lake Chilwa. The possible reason could be that the pH was slightly alkaline which might have an effect on the availability of dissolved metals in water as well as large volume of water. However, Cd and Zn were only detected at Kachulu in the dry and rainy season, respectively. Fe was the only metal that was found in water at all the sampling sites for both seasons. It was observed that Fe and Zn were above WHO drinking water standards but the rest of the metals were below the standards. Further observation showed higher levels of heavy metals in water in the rainy season than dry season. The possible reason could be the churning effect of rain storms that led to the suspension of dissolved solids which constitutes heavy metals. Also during rainy season there was run-off which could potentially transport heavy metals from upland originating from fertilisers, burning fosil fuels and metal products.

Pb was also not detected in sediment samples. Generally, there was higher concentration of other heavy metals such as Mn, Cu, and Zn in the dry than rainy season except for iron which was the opposite. Cd was only detected in sediment samples at Kachulu in the rainy season. This could be an indicator of pollution activities at Kachulu harbour and the nearby settlements.

All heavy metals were detected in fish samples except Pb. Generally, the concentration of metals such as Mn, Cu and Zn were higher in the rainy season than dry season except for iron which was the opposite. Among the fish species that were sampled, *Clarias* species recorded higher levels of all the selected heavy metals except for Cd and Zn. The concentrations of heavy metals in fish were within the FAO/WHO limits of fish suitable for human consumption.

Based on the findings of this study, it is recommended that there is need for the city council to implement proper measures to reduce contamination of the lake by health hazardous chemicals. This may include removal of heavy metals in wastewater effluent which is released into Likangala River which eventually ends up in Lake Chilwa. Also, although the concentration of heavy metals in the fish were within the WHO/FAO limits, however there is a need for further evaluation of these contaminants in several fish species in the area.

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Models for efficient BOD and COD Characterisation of Faecal Sludge from Unplanned Settlements in Cities of Malawi

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ABSTRACT

Research on faecal sludge characterisation has demonstrated higher variability in faecal sludge characteristics when compared to wastewater whose characteristics inform faecal sludge treatment practices in many developing countries. There is a growing emphasis on the need to generate accurate data on faecal sludge characteristics which in turn informs treatment options that match the variability. Lack of such data in developing countries has been attributed to resource constraints. This study explored the applicability of Multiple Linear Regression Predictive Modelling for efficient characterisation of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) of faecal sludge from unplanned settlements in Blantyre, Lilongwe, Zomba and Mzuzu Cities of Malawi. Faecal sludge samples were collected from 20 pit latrines from each of the four cities. In each latrine sampling was done at four depths (0 m, 0.5 m, 1 m and 1.5 m from the sludge surface). Standard methods of laboratory analyses were used to characterise sludge for pH, electrical conductivity (EC), BOD, COD, moisture content (MC), total solids (TS), total volatile solids (TVS) and fixed solids. Models were developed with BOD and COD as dependent variables and pH, EC, TS and TVS as predictor variables. The selected models for BOD and COD prediction had R^2_{pred}-values of 90.9% and 91.6% respectively making the models reliable for prediction at $p < 0.05$.

Keywords: Predictive model, Malawi, faecal sludge characterisation, multiple linear regression, unplanned settlements.

INTRODUCTION

High utilisation of onsite sanitation systems and a shift towards faecal sludge management in developing countries pose a potential risk to the urban environment of many developing countries (Kengne et al., 2009; Magri et al., 2013; Koottatep et al., 2016). The main pathways through which faecal sludge gets into the environment are disposal and/or reuse of the human excreta. Organics in form of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are of environmental concern and need to be monitored since in environment they can lead to reduction or depletion of oxygen content of water bodies with a possible death of aquatic fauna as a consequence (Kanu & Achi, 2011; Lokhande et al., 2011; Strande et al., 2014). Practices such as direct disposal into the environment by pit-emptiers to offset haulage and disposal cost have been reported in many countries. From a technical perspective treatment options such as dewatering on drying beds and alkaline treatment which have been proven workable in developing countries have demonstrated minimal impact on reduction of organics (Strande et al., 2014; Tilley et al., 2014). Thus practitioners need to have a clear picture of the risk from BOD and COD that products from such systems might have on the environment during reuse and/or disposal.

It is also acknowledged that among the options of resource recovery from faecal sludge, energy production is believed to be the most feasible option in terms of cost recovery (Koottatep et al., 2016). Anaerobic digestion is one of the transferred technologies in faecal sludge treatment that is effective in reducing oxygen demand with a possibility of energy recovery through generation of biogas (Strande et al., 2014; Tilley et al., 2014). It is an attractive option to developing countries due to low capital and operating cost, relatively easy to construct and operate as well as moderately good performance (Batstone, 2006). However a limiting factor for most of developing countries in adoption of such technologies, is limited availability of accurate data on faecal sludge characteristics to guide treatment, disposal and/or reuse decision. For example decision on use of the anaerobic digester for energy recovery depends on availability of accurate data on key design and operation parameters such as organic loading rate (expressed in terms of kg COD/m^3.d) (Barber & Stuckey, 1999). One major reason to which lack of such data is attributed to is that sanitation issues are not prioritised in developing countries due to limited resources. This study therefore explored the applicability of multiple linear regression modelling as a less resource intensive method for accurate predictions of BOD and COD in faecal sludge from unplanned settlements of cities of Malawi.

MATERIALS AND METHODS

Sampling

Faecal sludge samples were collected from 80 latrines in informal settlements of Blantyre, Lilongwe, Mzuzu and Zomba Cities. Each of the cities had faecal sludge sampled from 20 latrines. From each latrine sampling was done at 4 depths i.e. the surface (0m), 0.5 m, 1m and 1.5 m from the sludge surface. The latrines were purposefully selected to include only those whose depth was at least 1.5m and had sludge that was not too thick to be pumped by a vacuum tanker. The choice of these sampling depth was informed by theoretical classification of layers occurring in pit latrine as proposed by Bakare et al. (2012) as shown in Figure 1.

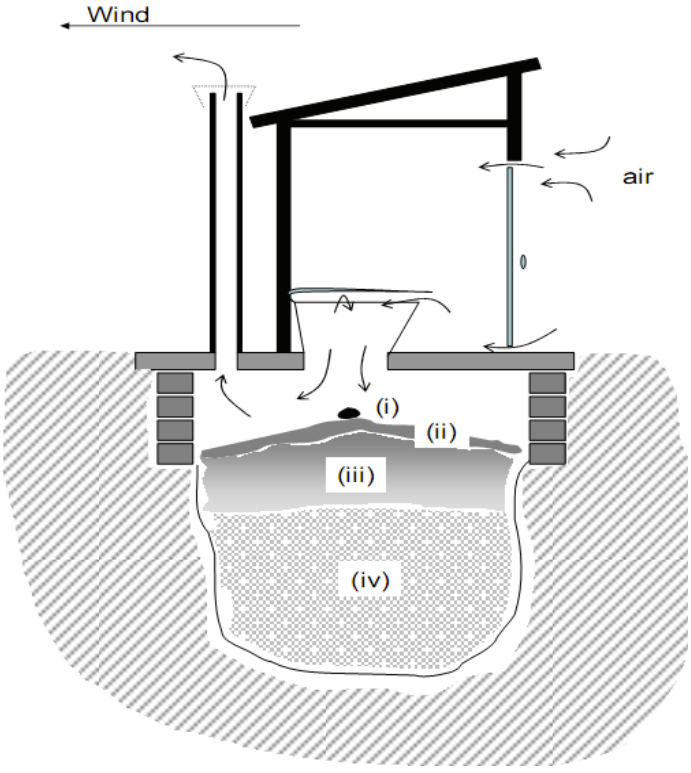

Figure 1: Theoretical categorization in the pit latrine

Based on this classification four distinct layers exist in the pit latrine. The top layer at the surface and just below it contains readily biodegradable material layer at the surface (layer i). Below this layer are partially degraded aerobic surface layer (layer ii), partially degraded anaerobic layer (layer iii) and completely stabilised anaerobic layer at the bottom (layer iv). Sampling was done by driving a reinforced suction hose of vacuum truck to specific depth, sucking sludge into the hose, closing the valve to hold the sludge in the hose then releasing sludge from hose to sampling bottle as shown in Figure 2.

Figure 2: Sludge sampling process

Lab analyses

Laboratory analyses were done at the Malawi Polytechnic. Parameters analysed included pH, electrical conductivity (EC), moisture content (MC), total solids (TS), total volatile solids (TVS), fixed solids (FS), biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Analyses of pH, EC, moisture content and solids (TS, TVS and FS) were done according to Standard Methods for the Examination of Water and Wastewaters (WEF and APHA, 2005). BOD was analysed using the Iodometric Method (Winkler Method) presented in ISO 5813:1983 (International Organisation for Standards, n.d). Analysis of COD was done using the closed reflux, titrimetric method as outlined in BS 6068 - 2.34: 1988 (British Standards Institution, 1988).

Data analysis

GraphPad Prism 6 was used for descriptive statistics analysis to summarise results for latrines from individual cities. Model building/selection was done in Minitab 17 following the steps shown in Figure 3.

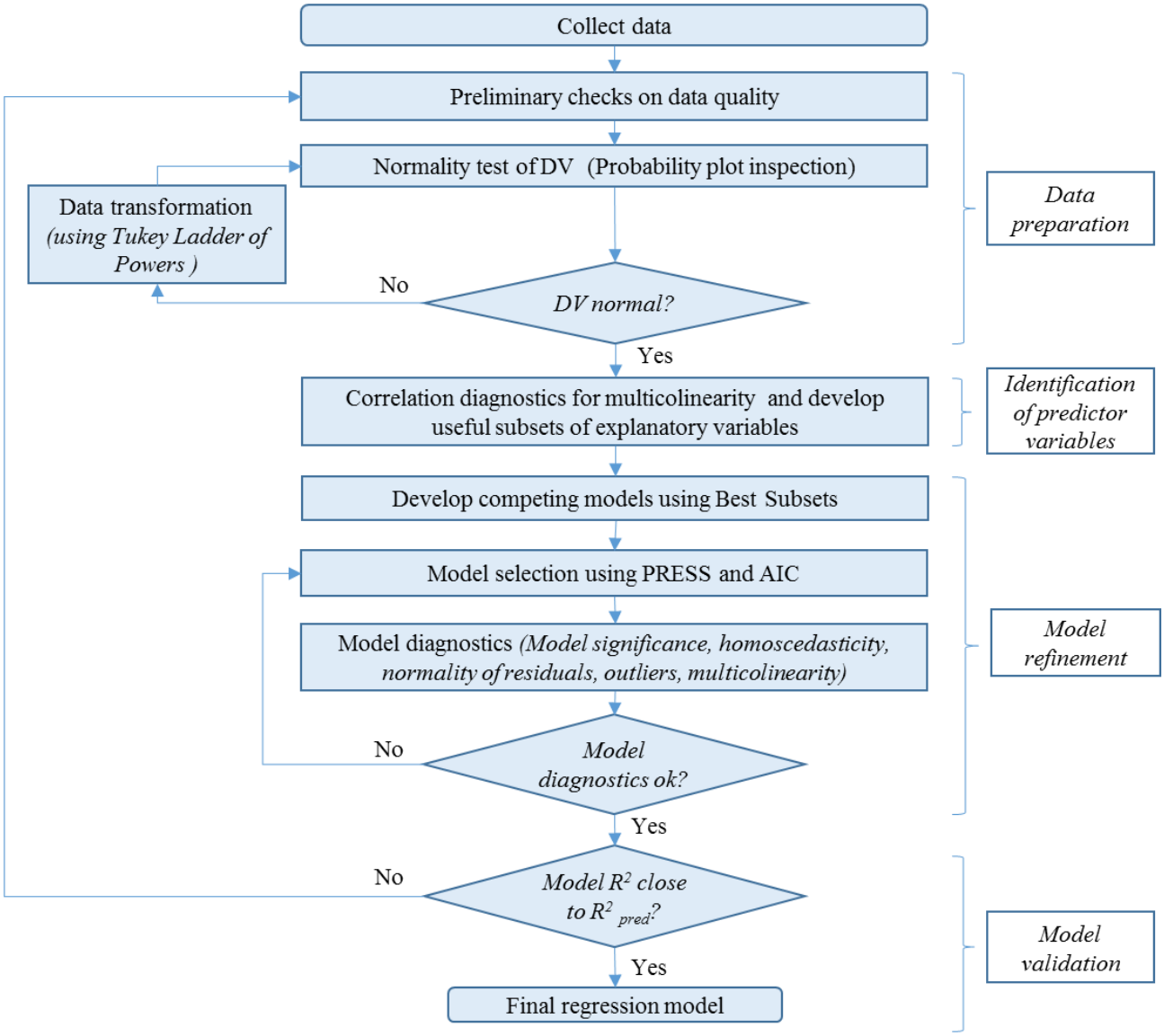

Figure 3: Model building and selection flow chart

Collected data underwent data preparation which involved checking and addressing missing values; and correctness of outliers. Normality test on dependent variables (DV) was done through visual inspection of the probability plot by firstly checking for normality of the untransformed values of the variable. When normality was not satisfied dependent variable transformations were applied according to the Tukey Ladder of Powers until normality was attained (Tukey, 1977).

The second stage involved coming up with combinations of predictor variables to be used to develop competing models. The predictor variables in this study were selected on the basis of their low level of skill and resource requirements. These included pH, electrical conductivity (EC), moisture content MC), total solids (TS), total volatile solids (TVS) and fixed solids (FS). pH and EC were analysed used potentiometric method whose core skill requirement is the ability to calibrate the meter in buffer solution and direct measurement reading from the meter. Moisture content and solids were determined using gravimetric methods whose core skills include weighing, setting the right temperature and direct measurement reading from the weighing scale. Pearson correlation was applied to predictor variables to identify highly correlated predictors that can lead to multicolinearity. Highly correlated predictors were the one whose correlation coefficient fell outside the range of $-0.7 \leq R \leq 0.7$.

Basing on the correlation coefficients of pairs of all predictors, subsets of predictor variables were formulated ensuring that no subset contained highly correlated predictors. The Best Subset function in Minitab 17 was used to generate candidate models from the predictor subsets. From the list of the candidate models the best model was selected using the prediction sum of squares (PRESS) statistic whereby the model with the lowest PRESS was selected. In cases where there were competing models having a same PRESS value, Akaike Information Criterion (AIC) values were calculated and the model with the smallest AIC was selected. AIC was selected because it is based on the principle of parsimony which augers well with efficiency in resource-constrained settings (Bozdogan, 2000). The selected model was then investigated for model significance, homoscedasticity, normality/randomness of residuals, outliers, amount of data for precise estimation of the strength of the regression relationship and multicolinearity of predictors. A model was deemed to be significant when its *p*-value was less than 0.05. Homoscedasticity, normality of residuals and outliers were checked through inspection of the Residuals vs Fitted Values plots. Specifically randomness of points on both sides of zero and large residuals that could have a strong influence on the model were checked. Large residuals and unusual values were identified and investigated back to the untransformed data for their unusual nature. Minitab presents large residuals and unusual values maroon and blue dots respectively in Residuals vs Fitted Values plots. Check for amount of data for precise estimation of the strength of the regression relationship was done using the observation-to-predictor ratio. The minimum observation-to-predictor ratio in literature ranges from 10 to 30 (Schmidt, 1971; Miller & Kunce, 1973; Pedhazur & Schmelkin, 2013). Multicolinearity of the predictor variables fitted in the model was investigated using the variance inflation factor (VIF). VIF values in the range $0 < VIF < 5$ suggest that there is no multicolinearity problem. VIF values of $5 \leq VIF \leq 10$ show moderate multicolinearity while $VIF \geq 10$ is indicative of significant multicolinearity (Moustris et al., 2012).

Model validation was done using the predicted R^2 (R^2_{pred}). R^2_{pred} measures how well a model predicts responses for new observations. Its calculation is based on the leave-out-one cross validation whereby each observation from the data set, a regression model fit and the prediction error calculated for the left out observation. Validation of predictions was done by comparing the R^2 and R^2_{pred} whereby a model was judged to provide valid predictions if R^2_{pred} was close to R^2 (Frost, 2013).

RESULTS AND DISCUSSION

Predictor variables

Figure 4 presents results for characterisation of faecal sludge for the predictors used in the modelling namely pH, electrical conductivity (EC), moisture content (MC), total solids (TS), total volatile solids (TVS) and fixed solids (FS). There was an observable variation of these faecal sludge characteristics at and among the study sites.

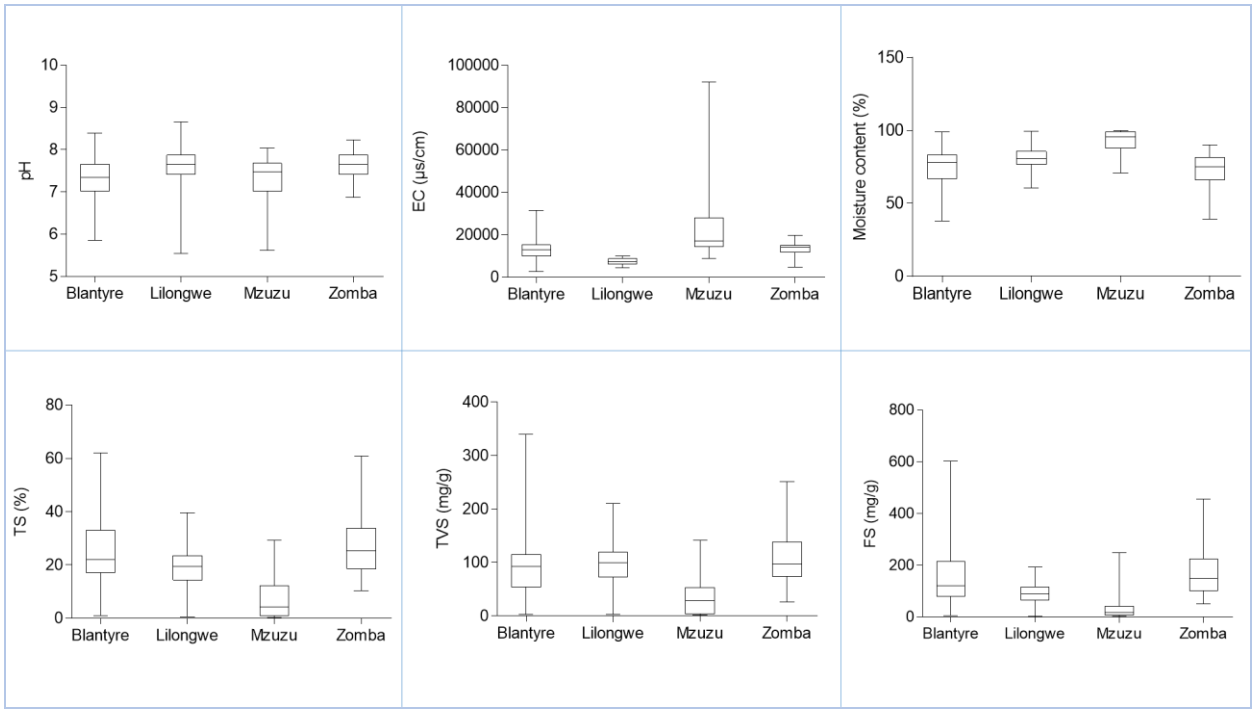

Figure 4: pH, EC, MC, TS, TVS and FS in faecal sludge from the study sites

Biochemical Oxygen Demand

Characterisation results for biochemical oxygen demand on dry weight basis are presented in Figure 5. There are no results for Blantyre because BOD was one of the parameters that were not initially included and faecal sludge characterisation in Blantyre was done before the amendment of parameters to be investigated during which BOD was included.

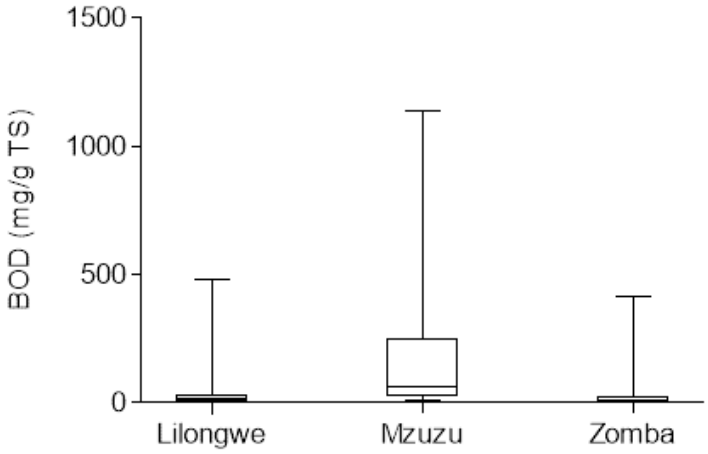

Figure 5: BOD of faecal sludge from the study sites

On wet weight basis the site specific mean BOD values ranged from 9.814 to 16.69 mg/g which is equivalent to 9814 to 16690 mg/l on volumetric basis. The range of BOD values from all the study sites was nearly 20 times higher than the range of 490 to 810.5 mg/l found in wastewater studies in Malawi (Chipofya et al., 2010; Chipofya et al., 2011) and 20mg/l upper limit in the Malawi standard (MS 691: 2005) of effluent discharge in water bodies (Malawi Bureau of Standards, 2005).

The BOD model arrived at in the study was

$$Log_{10}\ BOD = 2.4588\text{-}0.977\ Log_{10}\ TS$$

where BOD is biochemical oxygen demand in in mg/g TS

TS is total solids in percentage units

Table 1 and Figure 6 show model diagnostic outputs and; Residual vs Fitted Values plot receptively.

Table 12: Model diagnostic outputs

Model significance	*<0.0001*
R^2	91.0 %
SSE	6.1717
R^2_{pred}	90.9 %
PRESS	6.3
VIF (Log TS)	1.0
Observation-to-predictor ratio	240

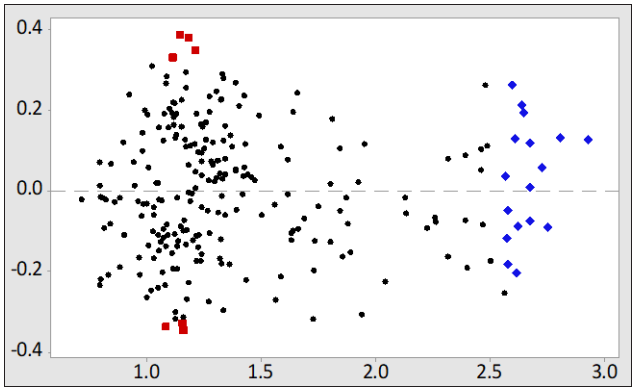

Figure 6: Log BOD Residuals vs Fitted Values

The relationship between variables in the model is significant (*p<0.0001*). The model explains a substantial part of the variability that exists in the data as R^2 is greater than 75% which Hair et al. (2013) define as being substantial. The model does not have any multicolinearity issues as it has one predictor and a VIF value of 1. In addition the model has an observation-to-predictor ratio of 240 which is higher than the minimum of 10 to 30. The model can provide valid predictions as R^2_{pred} (90.9%) is close to R^2 (91.0%). The model also performs well in terms of homoscedasticity and normality/randomness of residuals.

Chemical Oxygen Demand

The results for chemical oxygen demand for the four study sites are presented in Figure 7.

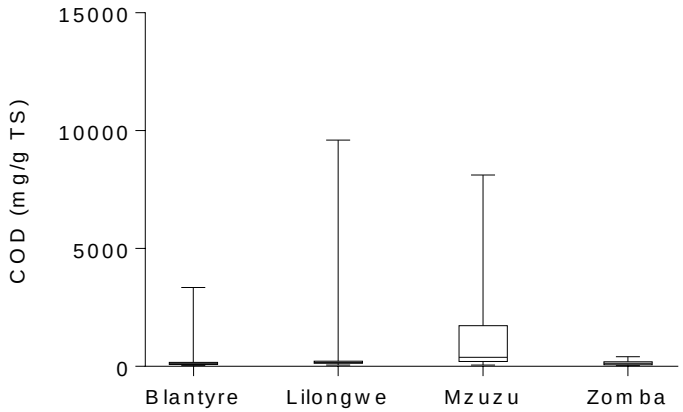

Figure 7: COD of faecal sludge from the study sites

The ranges of COD from the study sites are equivalent to 27250 to 45310 mg/l which is higher by far when compared to levels of 740 to 821.3 mg/l found in wastewater in Malawi (Chipofya et al. (2011). According to the Malawi standard (MS 691: 2005) on effluent discharge in water bodies, COD upper limit is 60mg/l (Malawi Bureau of Standards, 2005).

The model for COD arrived at in this study was:

$$Log_{10}\ COD = 3.668 - 0.8882\ Log_{10}\ TS\text{-}0.0852\ Log_{10}\ EC$$

where COD is chemical oxygen demanding mg/g TS
TS is total solids in percentage units
EC is electrical conductivity in µs/cm

Model diagnostic outputs and; residual vs fitted values plot for the COD model are presented as Table 2 and Figure 8 receptively.

Table 2: Model diagnostic outputs

Model significance	*<0.0001*
R^2	91.8%
SSE	5.3
R^2_{pred}	91.6%
PRESS	5.5
VIF (Log TS)	1.03
VIF (Log EC)	1.03
Observation-to-predictor ratio	160

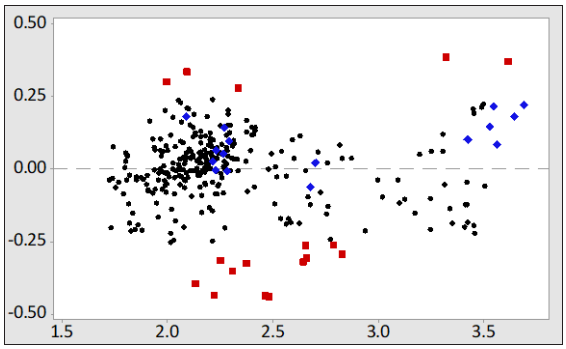

Figure 8: Log COD Residuals vs Fitted Values

The COD model is significant (*p<0.0001*) and explains a substantial part of the variability in the data as R^2 (91.8%) is greater than 75% (Hair et al., 2013). The model does not have multicolinearity in the predictors as both predictors have a VIF of 1.03. The model has an observation-to-predictor ratio of 160 which is greater than the minimum range of 10 to 15. The model can provide valid predictions as R^2_{pred} (91.6%) is close to R^2 (91.8%). From Figure 8 it can be seen that the model performs well in terms of homoscedasticity and normality/randomness of residuals.

CONCLUSION AND RECOMMENDATIONS

The objective of this study was to assess applicability of Multiple Linear Regression modelling for efficient prediction of BOD and COD. The performed analysis has shown that the BOD and COD models are statistically significant (*p < 0.0001*). The models can be used to predict new values of BOD and COD using total solids and electrical conductivity whose determination require low levels of skill and resources. Since the models were developed from latrines from the 4 cities of Malawi, there is need to evaluate the performance of the models developed in this study in predicting BOD and COD for sludge from other urban areas to establish if the models are generalizable to Malawi. More studies need to be done using other modelling techniques for comparison with the models developed in this study.

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Modelling and forecasting of Lake Malawi water level fluctuations using stochastic models

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ABSTRACT

The study considered Seasonal Autoregressive Integrated Moving Average (SARIMA) processes to select an appropriate stochastic model for forecasting the monthly data from the Lake Malawi water levels for the period 1986 through 2015. The appropriate model was chosen based on SARIMA (p, d, q)(P, D, Q)$_S$. The Autocorrelation function (ACF), Partial autocorrelation (PACF), Akaike Information Criteria (AIC), Bayesian Information Criterion (BIC), Box–Ljung statistics, correlogram and distribution of residual errors were estimated. The selected model was SARIMA (1, 1, 0) (2, 1, 1)$_{12}$ for forecasting the monthly data of the Lake Malawi water levels from August, 2015 to December, 2021. The plotted time series showed that the Lake Malawi water levels are decreasing since 2010 to date but not as much as was the case in 1995 through 1997. The future forecast of the Lake Malawi water levels until 2021 showed a mean of 474.45masl ranging from 473.93 to 475.04masl with a confidence interval of 80% and 90% against registered mean of 473.398masl in 1997 and 475.475masl in 1989 which were lowest and highest water levels in the lake respectively since 1986. The forecast for Lake Malawi water levels' mean by the year 2021 is below the actual recorded mean by 0.57masl and 0.69masl from the maximum ever recorded Lake Malawi water level, however, may not likely going to be lower than that recorded in 1997.

Key words: forecasting, SARIMA, Lake Malawi, water level fluctuation, climate change, anthropogenic activities

INTRODUCTION

Malawi has 118,484 km^2 covered by surface water representing 20% of the total surface area (Department of Fisheries, 2012) of which Lake Malawi has a surface area of 29,000 km^2. The lake has a drainage system made up of rivers such as Shire, Lithipe, Bua, Dwangwa, Songwe, North Rukuru and South Rukuru among others. The Lake Malawi is third largest lake in Africa with an average depth of 292 m, bordered by three countries namely Malawi, Mozambique and Tanzania and is situated in the Great African Rift Valley between 9°30'S and 14°30'S (Patterson & Kachinjika, 1995). The most productive areas on the lake are the shallow areas found in in the southeast and southwest arms of the lake (Kanyerere, 2001). The depth of Lake Malawi is influenced by the activities of its basement tectonics and climatic. The climate influence is due to the long dry seasons caused by subtropical climate and the small dimensions of the hydrological

catchment area. The lake dried out almost completely at the beginning of the Pleistocene, due to stable tectonic conditions and dry climate. It is reported that the tectonic lowering of the overflow sill, through subsidence of the rift floor, combined with erosional incision currently being accelerated by anthropogenic activities lowered the water level by 40m since the late Pleistocene. Of late climate change and anthropogenic activities in the catchment areas have resulted into fluctuation of the water levels of Lake Malawi as the case with other water bodies in Africa. However, there is a level at which these two factors can be controlled unlike the stability of the tectonic conditions. This challenge underpins the importance of modelling and forecasting Lake Malawi water levels to appreciate how they will behave in the future using available data. This is very crucial to policy makers responsible of different user-groups of the Lake Malawi whether directly or indirectly to develop strategies that counteract impacts of climate change and anthropogenic activities to Lake Malawi water levels.

Forecasting plays a central role in management as it precedes planning which, in turn, precedes decision making (Makridakis *et al*., 1983). Forecasting is used by policy makers to select an appropriate policy option to meet anticipated goals and objectives (Stergiou and Christou, 1996). Forecasting has been used successfully in metrological services to forecast weather patterns hence advise farmers accordingly, advice on impending natural disasters such as earthquake to save lives.

It is importance that the trend of the Lake Malawi water levels be modelled and forecasted in the face of climate change to provide a possible picture of how water levels will behave in the lake in the years to come. Prediction models are necessary for water resource managers in planning for the future. This is very important to policy makers to device tools to sustainably manage the water resources for the benefit of the nation. The study employed stochastic models to model the Lake Malawi water levels using available times series of the same covering previous days and months from 1986 to 2015. Because the data available is of time series nature, the models which have been used extensively in modelling such data are autoregressive (AR), moving average (MA), autoregressive moving average (ARMA) and autoregressive integrated moving average (ARIMA) models. The models are applicable to stationary data. Differencing among other methods is used to transform the data series that is not stationary. This study has employed SARIMA models to forecast the Lake Malawi water levels as the data was seasonal.

MATERIALS AND METHODS

Description of the time series used analysed

The data that have been used in this study are univariate time series of Lake Malawi water levels from 1986 to 2015 obtained from the Department of Water Resources in Malawi. The unit of measurement used in this study was in meters and refers to the water level at the water level collection point.

The study was aimed at modelling and forecasting patterns of Lake Malawi water levels in Malawi. The time series of Lake Malawi water levels short term forecasts were made by employing SARIMA model as the series showed seasonality and correlation with the water levels from the previous months as proved by the plotted autocorrelogram and/or partial autocorrelogram.

Forecasting using SARIMA model

The SARIMA has been widely applied to forecast time series data with seasonality. The following procedure was used in SARIMA model application in this study;

a. Data was plotted to check if it required differencing. The Dickey-Fuller test was also used to test if the series was stationary or not.
b. Differenced to remove trend, to find *d* and later differenced to remove seasonality, D.
c. Examination of ACF and PACF of differenced series to find P and Q first, by examining just

at lags s, 2s, 3s, etc. and to find p and q by examining between seasonal lags.

d. Fit SARIMA (p, d, q) x $(P, D, Q)_s$ model to original data.
e. Check model diagnostics.
f. Forecast for short term was made.

The SARIMA model works where the data is or made stationary and deseasonalised. Therefore, in this study, Lake Malawi water levels were tested for stationary using two methods namely graphical analysis method and the Dickey – Fuller test. The data was found significant to non – stationarity hence they were differenced to make them stationary. The differencing of the series was achieved by a model:

$$Z_t = Y_t - Y_{t-1} \quad (1)$$

Where:

Z_t is differenced value of the new differenced series at time *t*
Y_t is the value of the original series at time *t*
Y_{t-1} is the value of the original series at time t-1

The differenced data was later plotted and subjected to stationarity test using the same graphical analysis method and the Dickey–Fuller test and this time they were found stationary meaning the data was ready for modelling.

Selecting a candidate SARIMA model

The stationary differenced data for the Lake Malawi water levels four species was used to come up with correlogram and partial correlogram in order to identify an appropriate model for the lake water levels. This process is called model identification. It simply involved finding the most appropriate values of p and q for an ARIMA (p, d, q) model by examining the correlogram and partial correlogram of the stationary time series.

The autocorrelation function $\rho(k)$ at lag *k* was denoted by:

$$\rho(k) = \frac{\gamma(k)}{\gamma(0)} \quad (2)$$

Where $\gamma(k)$ is the autocovariance function at lag *k* of a stationary random function {Y (t)} given by:

$$\gamma(k) = cov\{Y(t), Y(t\text{-}k)\} \quad (3)$$

When the PACF had a cut-off at p while the ACF tails off, it gave an autoregressive (AR) of order p. When also the ACF had a non-zero lag at q it gives a moving-average (MA) of order q. However, when there was non-zero lag(s) on both ACF and PACF, it implied that the application of the autoregressive moving-average of order p and q was possible. It also meant that because the data was differenced once, then even the autoregressive integrated moving-average (ARIMA) p, d, q was possible. Where *d* is number of times the data has been differenced to remove the noise within it.

An autoregressive model (AR) of a time series $\{X_t\}$ is a regression model of that time series on its previous history (Craine, 2005). Autoregressive process of order (p) was found by using the following model;

$$X_t = \sum_{j=1}^{p} \emptyset_{t\text{-}j} + \varepsilon_t \quad (4)$$

A moving average (MA) model of a time series was aimed at averaging out previous error steps of a time series $\{X_t\}$ to attempt to smooth the process or make the time series stationary. Moving Average process of order (q) was found by using the following model;

$$X_t = \sum_{j=1}^{q} \theta_j \, \varepsilon_{t-j} + \varepsilon_t \quad (5)$$

The combination of linear autoregressive and moving average properties results into the autoregressive moving average (ARMA): ARMA of order (*p*, *q*) is,

$$X_t = \sum_{i=1}^{p} \emptyset_i \, X_{t-i} + \sum_{j=1}^{q} \theta_j \, \varepsilon_{t-j} + \varepsilon_t \quad (6)$$

The general form of ARIMA model of order (p, d, q) is

$$x_t = \phi_1 x_{t-1} + \phi_2 x_{t-2} + \cdots\cdots\cdots + \phi_p x_{t-p} + w_t + \theta_1 w_{t-1} + \theta_2 w_{t-2} + \cdots\cdots\cdots + \theta_q w_{t-q} \quad (7)$$

Where:

$\boldsymbol{x_t}$ is the original data series or differenced of degree *d* of the original data at time *t*;
$\boldsymbol{w_t}$ is the white noise at time *t*.
$\boldsymbol{\phi_1, \phi_2, \ldots, \phi_p}$ are the autoregressive variables.
$\boldsymbol{p}$ is the autoregressive order.
$\boldsymbol{\theta_1, \theta_2, \ldots, \theta_q}$ are the moving average variables.
$\boldsymbol{q}$ is the moving average order.

Then, the general form of SARIMA model (p, d, q)$(P,D,Q)_s$ is donated as:

$$\Phi (B^S)\omega(B)\nabla^D{}_S \nabla^d X_t = \theta (B^S)\theta (B)\varepsilon_t$$

Where:

X_t = value of variable at time t
$\Phi (B^S)$ = seasonal autoregressive coefficients
$\theta (B^S)$ = seasonal moving average
$\nabla^D{}_S$ = seasonal d-fold difference operator
$\omega(B)$ = Nonseasonal component
$\theta (B)$ = Nonseasonal moving average

Model variable estimation

When the models had been identified to be AR, MA, ARMA, ARIMA or SARIMA the next step was to estimate the best possible variables of the identified models. This is called model fitting. These best possible variables were found using Akaike Information Criteria (Akaike 1973). The best model is obtained on the basis of minimum value of Akaike Information Criteria (AIC) (Satya *et al*. 2007). The AIC was found by

$$AIC = -2 \log L + 2m \quad (9)$$

Where:

m is $p + q$
L is the likelihood function

The AIC was used to obtain a model that well represent the data on the basis of minimum value of AIC.

Forecasting

Once the appropriate best candidate SARIMA (p, d, q)(P, D, Q)$_s$ model was selected for Lake Malawi water levels time series data for the species then the variables of the selected SARIMA model was estimated. The fitted SARIMA model was then used as a predictive model for making forecasts for the future (next seven (7) years) of Lake Malawi water levels fluctuations.

Diagnostic checks

After the forecast were made, diagnostic tests were carried out to check to what extent the forecast could be trusted. The diagnostic tests were performed by using method of autocorrelation of the residuals and the Ljung-Box test. A good forecast should come from an SARIMA model with forecast errors that have a mean of zero, with no significant correlations between successive forecast errors and have constant variance. Once the model was found to be inappropriate, the process was restarted through the four steps in the SARIMA modelling until the diagnostic checks validates the model as fitting.

RESULTS AND DISCUSSION

Identifications of models

The plotted original series was visibly not stationary as shown in Figure 1. The original series was fluctuating so much over the years hence did not have a constant variance.

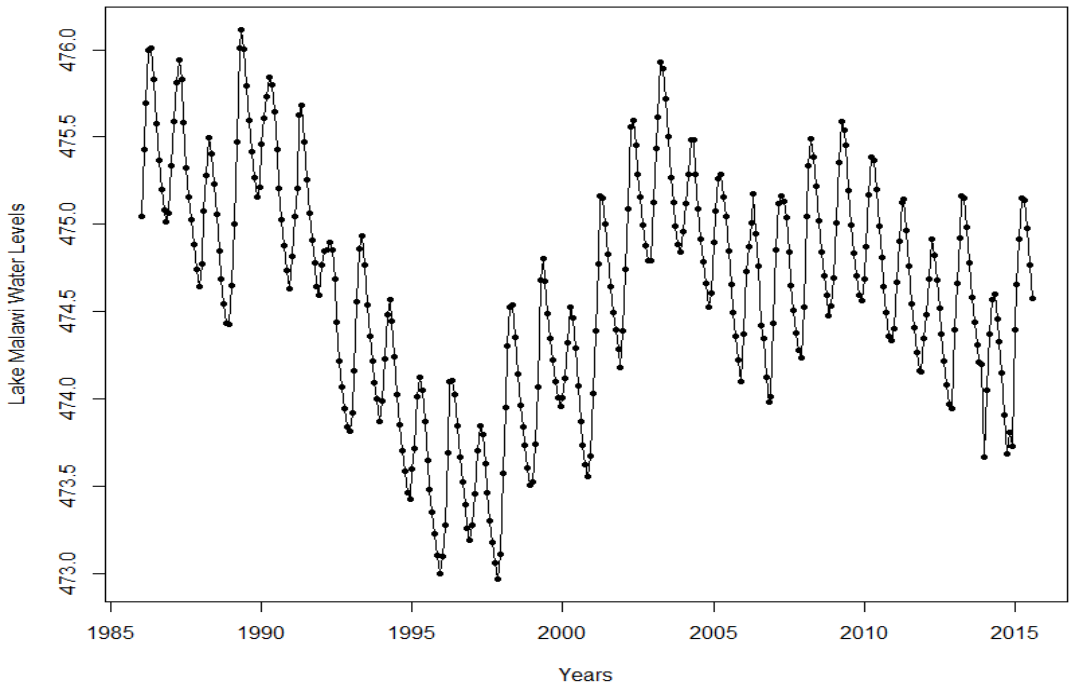

Figure 1: Lake Malawi water level fluctuation from 1985 to 2015.

Autocorrelation function (ACF) plot in Figure 2 showed several non-zero lags that tailed off at lag 4 hence proving that the original series was indeed not stationary.

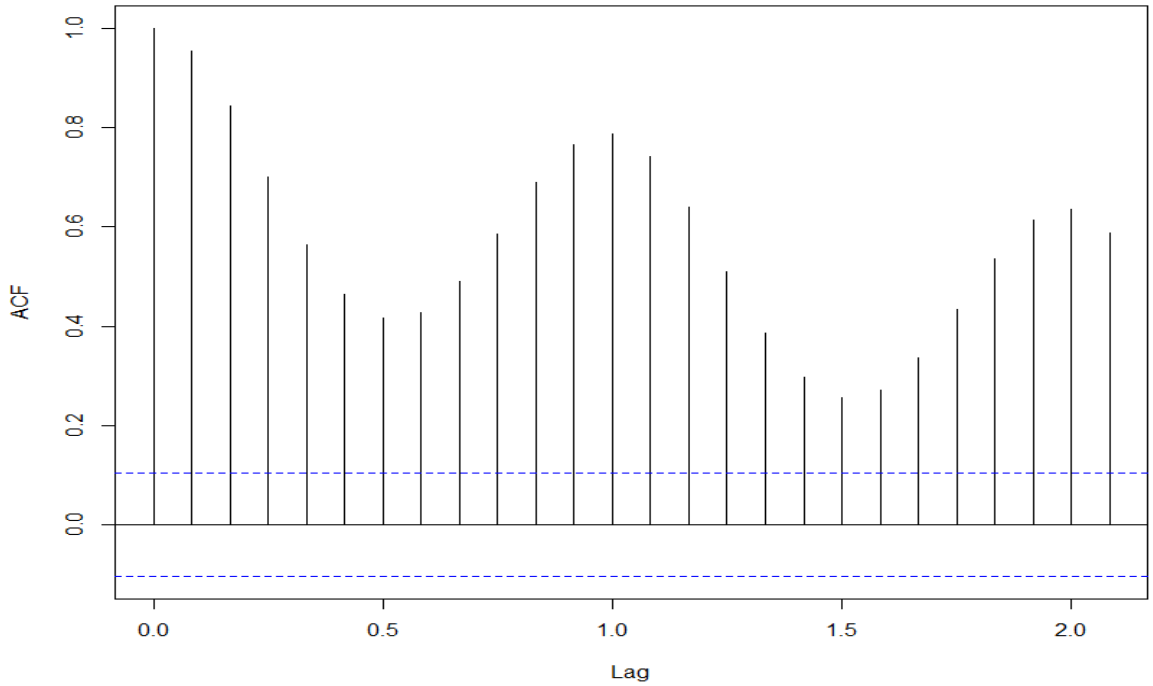

Figure 2: Autocorrelation function generated from Lake Malawi Water Levels from 1986 to 2015.

Dickey-Fuller test on the original series of the Lake Malawi water levels in Table 1 showed that the original data was not stationary and required some form of transformation. The Dickey-Fuller test proved this by giving a *p-value* of 0.1937 which demanded the rejection of the stationarity as an alternative hypothesis. The data had also seasonality trend as shown by the decomposing analysis in Figure 3.

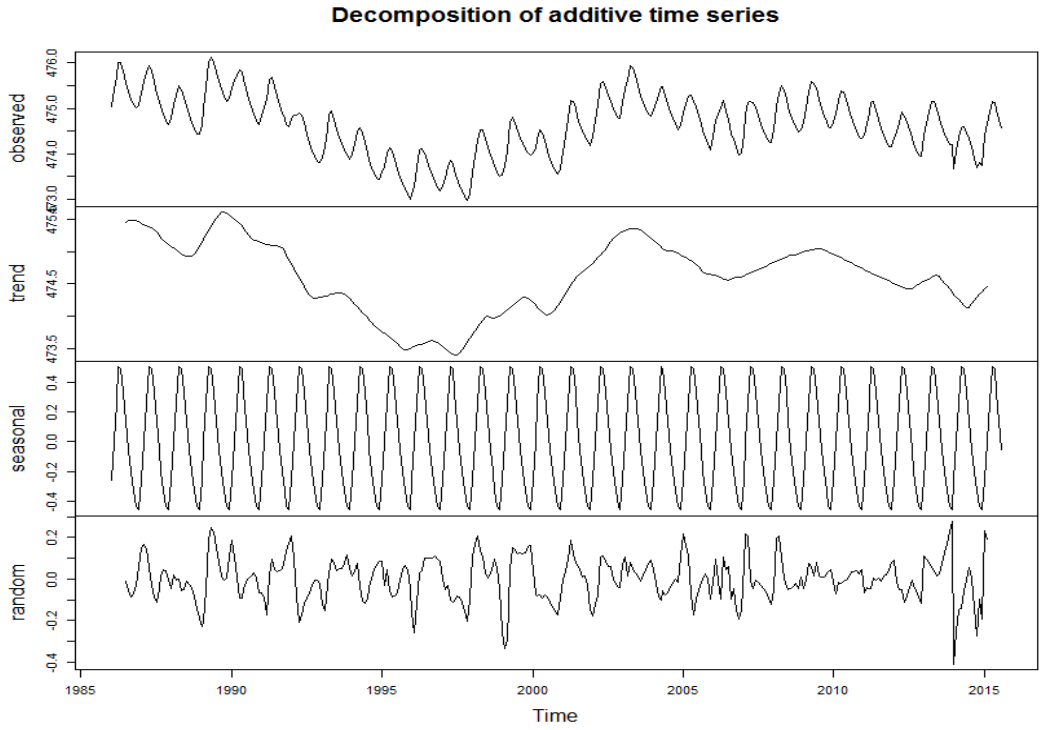

Figure 3: Decomposed Lake Malawi water levels time series from 1985 to 2015.

The removal of the non-stationarity and seasonality was carried out through differencing. The data was differenced once for trend and resultant time series proved to be stationary and ready for SARIMA modelling. The seasonality shown in Figure 3 was removed by employing a seasonal differencing at every 12 months. The graphical analysis method on the plotted differenced time series data showed stationarity as shown in Figure 3, as it showed that it had a constant variance and a mean of zero.

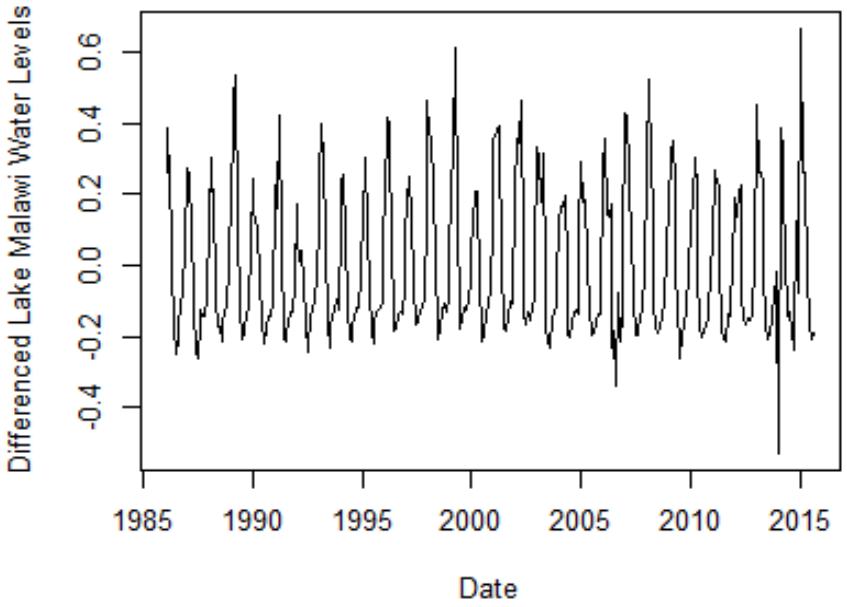

Figure 4: Stationary differenced Lake Malawi water levels from 1985 to 2015.

The Dickey-Fuller test proved the stationarity in the differenced time series data by the smaller *p-value* of 0.00 in Table 1. The Dickey-Fuller test results in Table 1 also showed that the difference time series data was no longer explosive as indicated by the higher *p-value* of 0.99 hence the differenced time series was indeed stationary. The differencing made the new time series values to vary over time with a constant mean and constant variance hence stationary as shown in Figure 4. This implied that the differenced data was ready for modelling and forecasting.

Table 1: Dickey-Fuller and Augmented Dickey-Fuller Test results on Lake Malawi water levels

Type of data	Alternative Hypothesis	Dickey-Fuller statistic	Lag order	p-value
Non-differenced data	Stationarity	-2.908	0	0.1937
Difference data	Stationarity	-8.0098	0	0.01
Difference data	Explosiveness	-8.0098	0	0.99

p≥0.05 data is not stationary
p≥0.05 data is not explosive hence stationary

As the new series was successfully proved to be stationary by the Dickey-Fuller test and the graphical analysis method, then autocorrelogram and partial autocorrelogram were plotted to determine the values of p and q in the ARIMA models. The plotted partial autocorrelation function showed second-order autoregressive (AR) model as shown in Figure 6 while the plotted autocorrelation function showed second-order moving average (MA) model as shown in Figure 5. The autocorrelogram and partial autocorrelogram, in Figures 5 and 6 were used to identify various competing model.

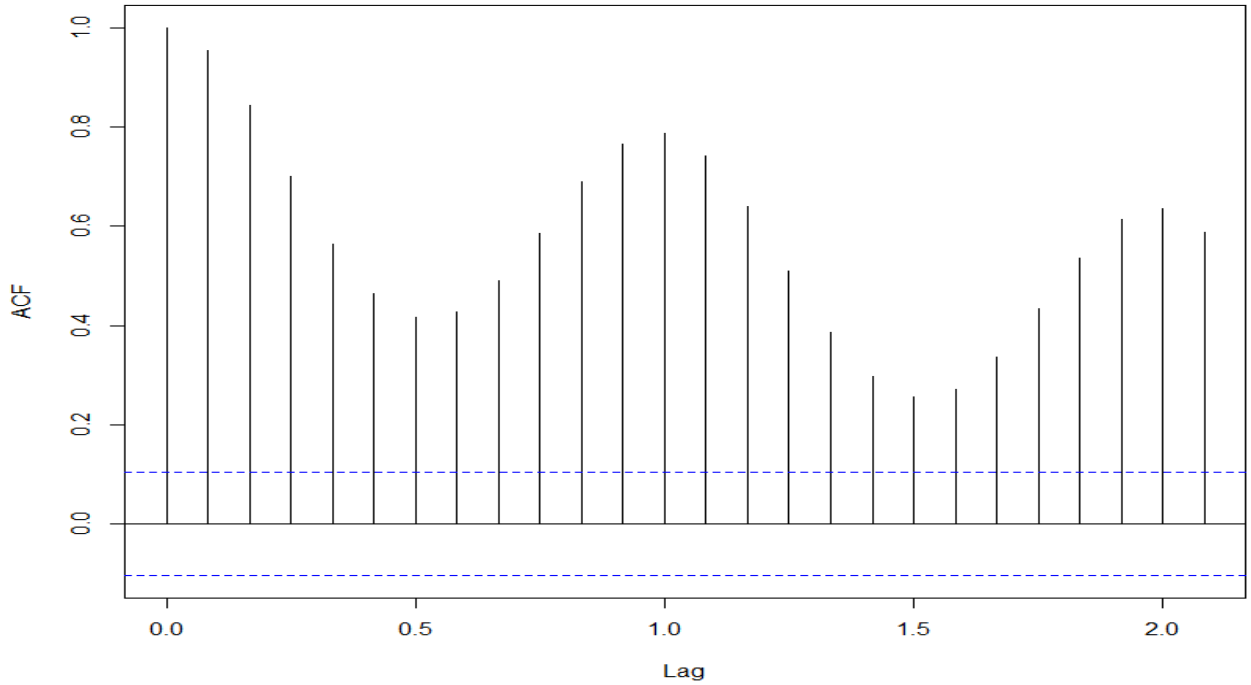

Figure 5: Autocorrelation function of differenced Lake Malawi water levels

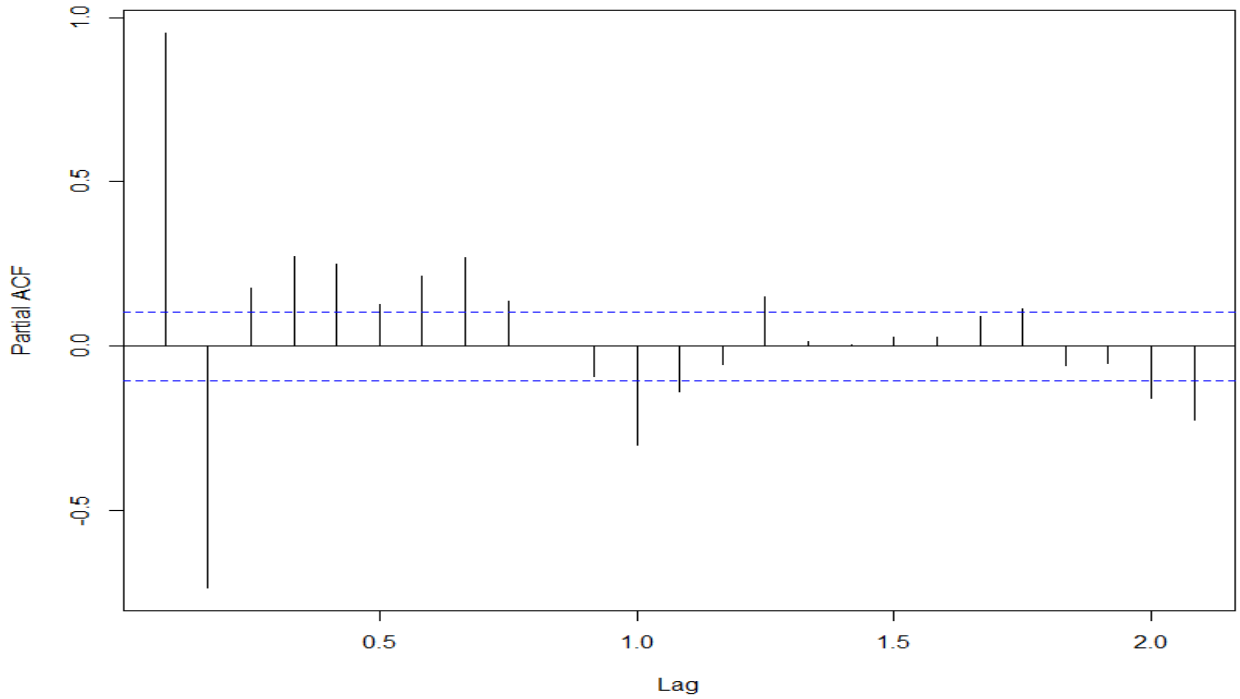

Figure 6: Partial autocorrelation function of differenced Lake Malawi water levels showing second-order autoregressive (AR) model

The most competing models identified together with their corresponding fit statistics are shown in Table 2. The model in the SARIMA family with the lowest AIC values was selected. The value of the AIC of the selected SARIMA model was -661.93 as also shown in the Table 2. Owing to that, the most suitable model for forecasting Lake Malawi water levels is SARIMA (1, 1, 0) $(2, 1, 1)_{12}$, as this model had the lowest AIC values.

Table 2: Fit statistics for various competing SARIMA models

SARIMA (p, d, q) (P, D, Q)$_{12}$	**AIC**
SARIMA (0, 1, 1)(1, 1, 1)$_{12}$	-659.44
SARIMA (0, 1, 2)(1, 1, 1)$_{12}$	-659.46
SARIMA (1, 1, 0)(1, 1, 1)$_{12}$	-661.31
SARIMA (1, 1, 1)(1, 1, 1)$_{12}$	-659.31
SARIMA (1, 1, 0)(2, 1, 1)$_{12}$	-661.93

Model with the lowest AIC and BIC is the best fit

The Box–Pierce (and Ljung–Box) test also proved that model (1, 1, 0) (2, 1, 1)$_{12}$ was found to be among the best fitting models as shown in Figures 7, 8, 9, 10 and 11.

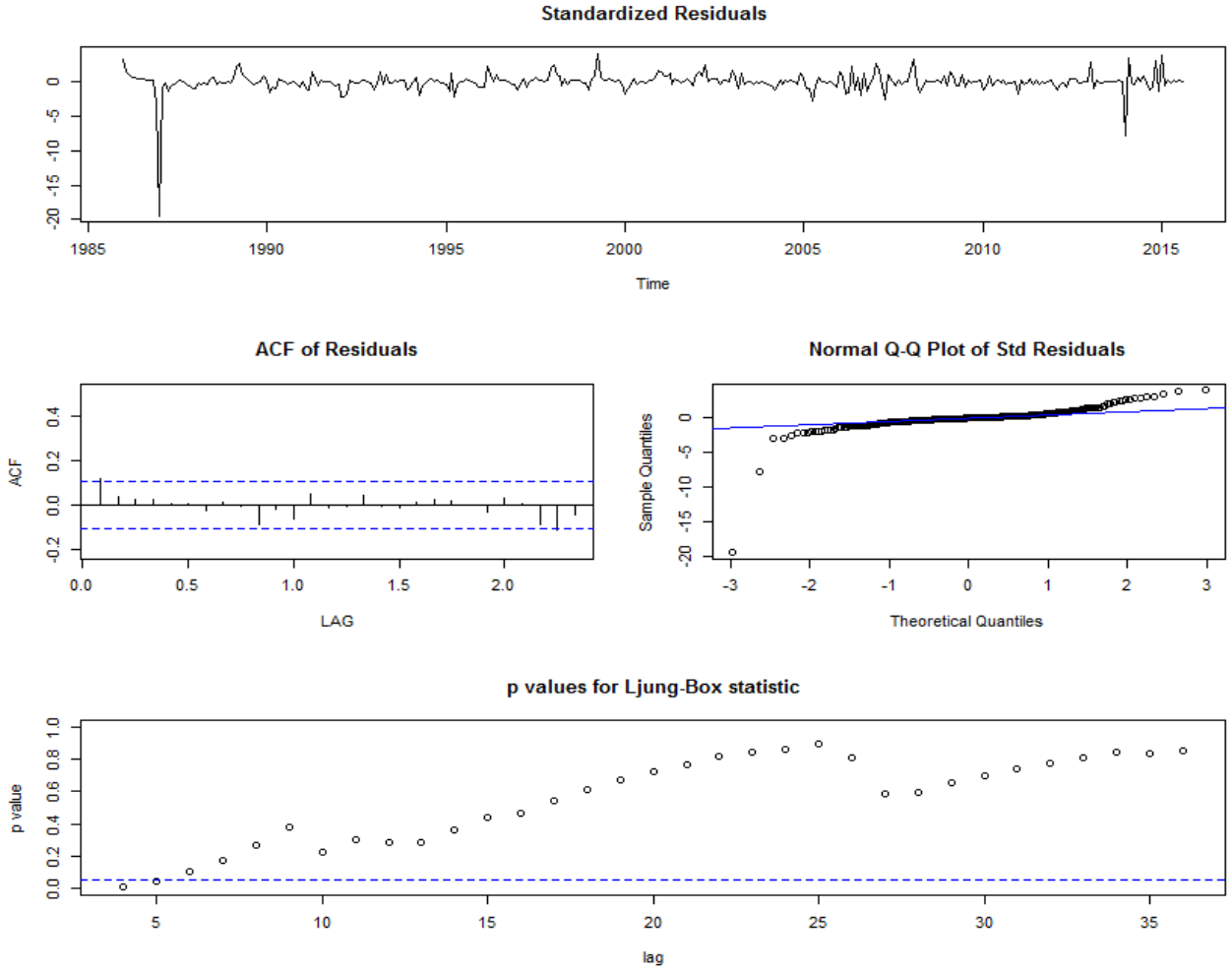

Figure 7: The Box–Pierce (and Ljung–Box) test out-put for SARIMA (0, 1, 1)(1, 1, 1)$_{12}$

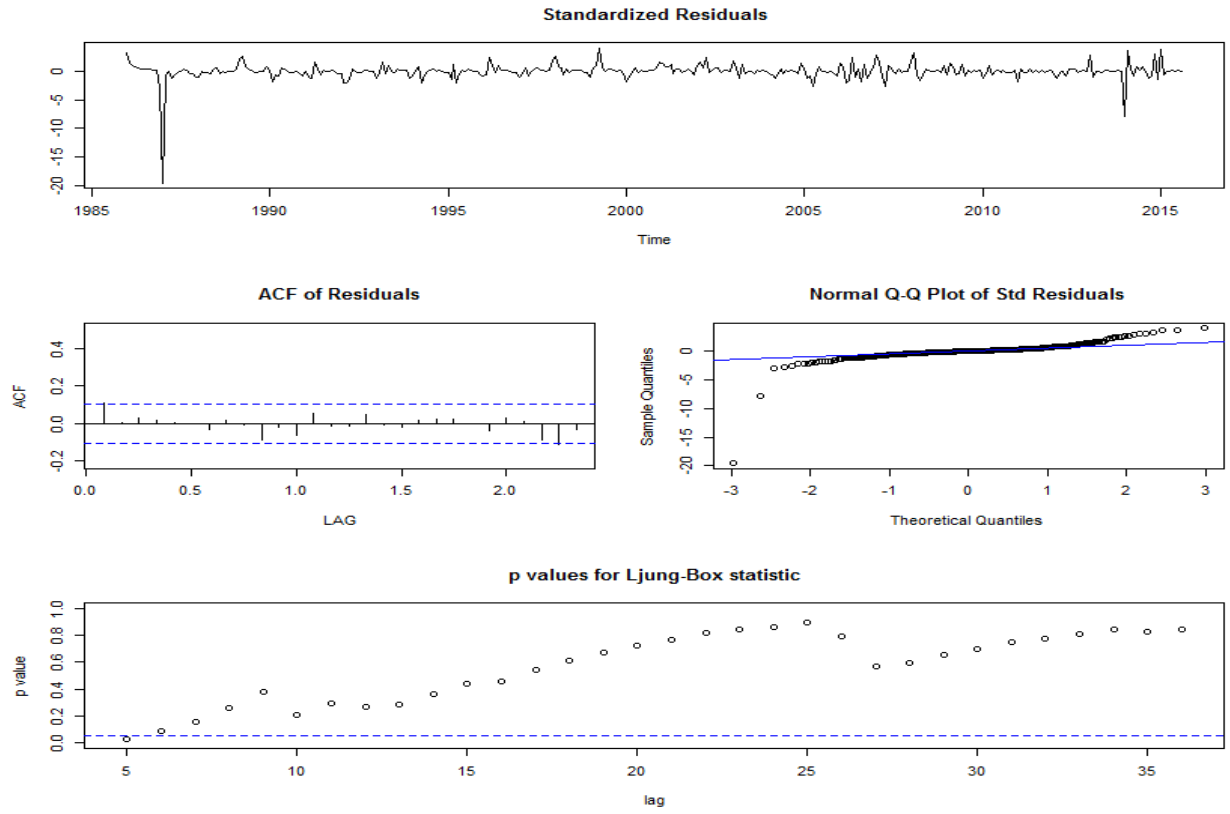

Figure 8: The Box–Pierce (and Ljung–Box) test out-put for SARIMA (0, 1, 2)(1, 1, 1)12 generated

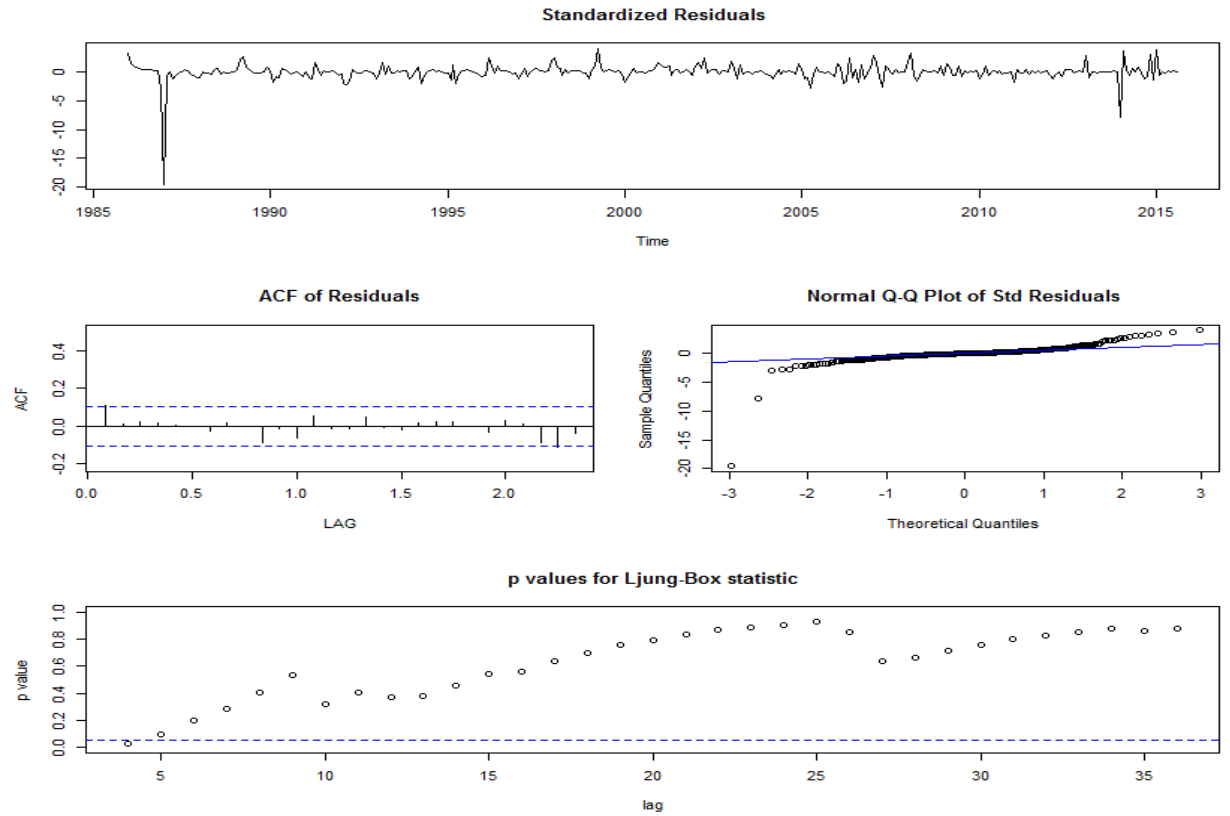

Figure 9: The Box–Pierce (and Ljung–Box) test out-put for SARIMA (1, 1, 0)(1, 1, 1)$_{12}$

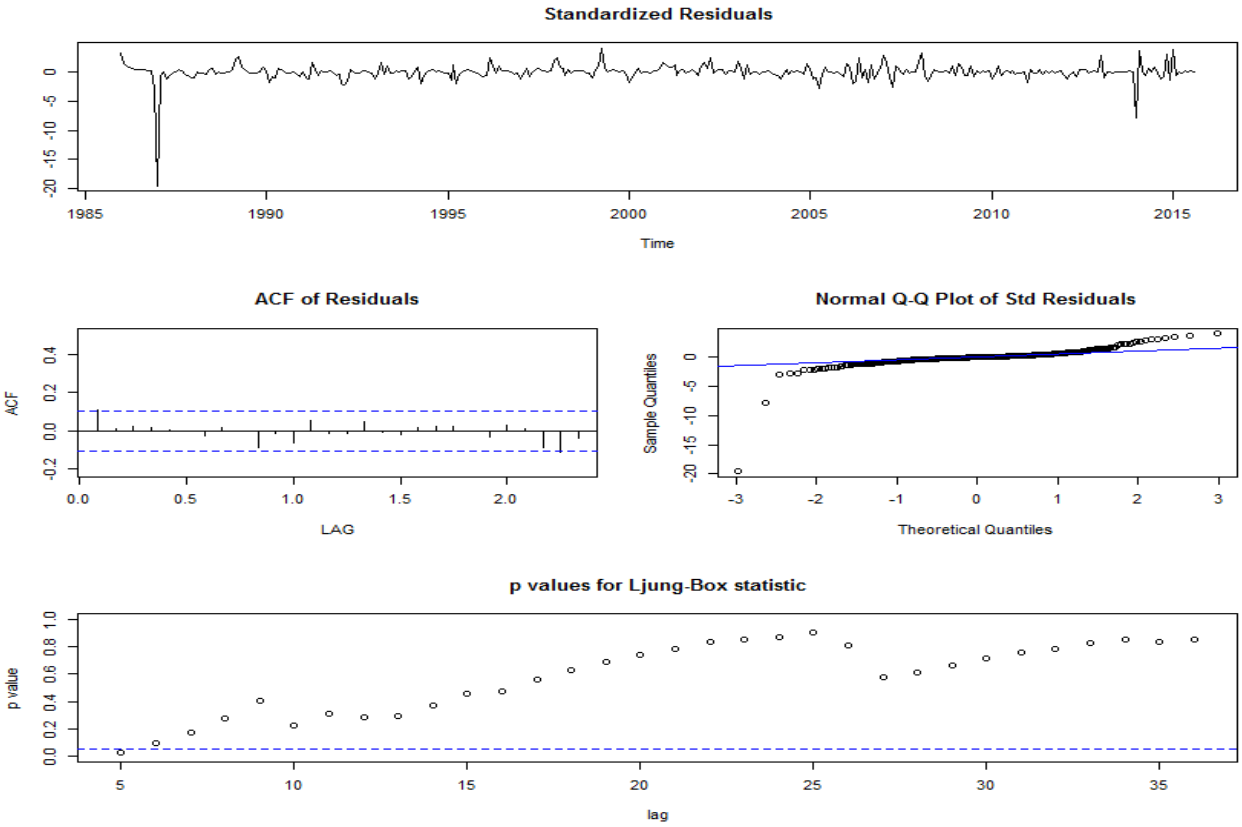

Figure 10: The Box–Pierce (and Ljung–Box) test out-put for SARIMA (1, 1, 1)(1, 1, 1)12

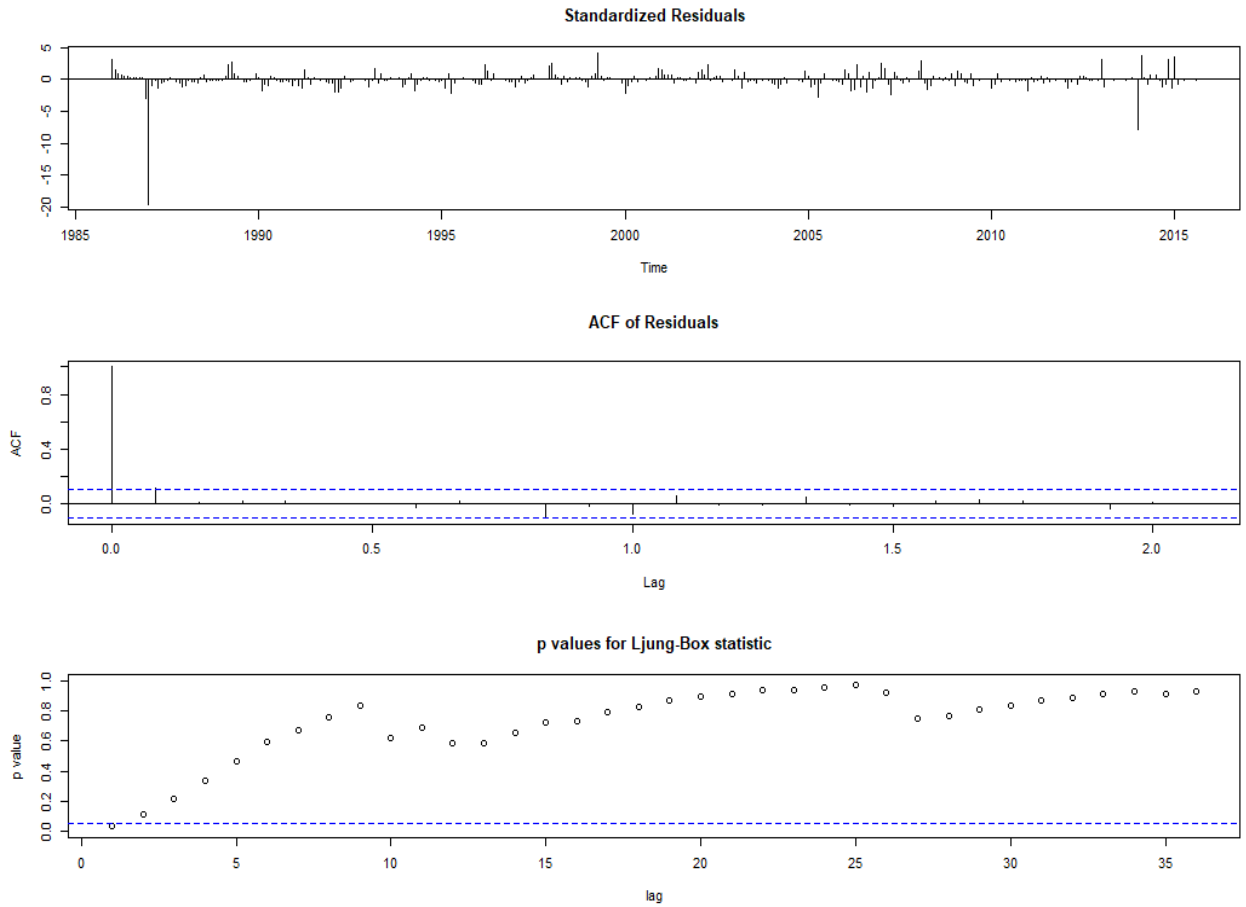

Figure 11: The Box–Pierce (and Ljung–Box) test out-put for SARIMA (1, 1, 0)(2, 1, 1)$_{12}$

This implied SARIMA (1, 1, 0)(2, 1, 1)$_{12}$ model was still outstanding among the five (5). The Box–Pierce test basically examines the Null of independently distributed residual errors, derived from the idea that the residual errors of a "correctly specified" model are independently distributed. In a case where the residual errors are not independently distributed, then it indicates that they come from a miss-specified model.

Model Estimation

All the analyses of the time series in this study were performed by R software version 3.3.1 (2016-06-21). The software was used to estimate the variables of the selected models as shown in Table 3.

Table 3: Selected competing models' variables with their AIC

	SARIMA (0, 1, 1) (1, 1, 1)$_{12}$	**Se**	**SARIMA (0, 1, 2) (1, 1, 1)$_{12}$**	**se**	**SARIMA (1, 1, 0) (1, 1, 1)$_{12}$**	**Se**	**SARIMA (1, 1, 1) (1, 1, 1)$_{12}$**	**se**	**SARIMA (1, 1, 0) (2, 1, 1)$_{12}$**	**se**
Constant										
L1. AR					0.2720	0.0522	0.2661	0.1834	0.2752	0.0522
L1. MA	0.2544	0.0493	0.2727	0.0544			0.0063	0.1905		
L2. MA			0.0776	0.0545						
L1. SAR	-0.2438	0.0567	-0.2317	0.0577	-0.2324	0.0562	-0.2327	0.0574	-0.2180	0.0568
L2. SAR									0.1061	0.0657
L1. SMA	-0.9991	0.0625	-0.9990	0.0665	-0.9990	0.0662	-0.9990	0.0661	-0.9994	0.0480
ME	-0.5549746		-0.5179501		-0.3476219		-0.5113396		-0.3457697	
MAE	0.6126432		0.580155		0.4196812		0.5737838		0.4139066	
MAPE	423.8729		395.0768		282.5719		389.518		279.1434	
RMSE	0.800835		0.7553016		0.5309216		0.7471556		0.524839	
AIC	**-659.44**		**-659.46**		**-661.31**		**-659.31**		**-661.93**	

Model with the lowest AIC is the best fit

The model with significant coefficients variables with least AIC is better in terms of forecasting performance than the one with insignificant coefficients variables with large AIC (Guti´errez-Estrada *et al*. 2004, Czerwinski *et al*. 2007). All these tests and examinations proved that the SARIMA (1, 1, 0)(2, 1, 1)$_{12}$ model is the best model to forecasting of the future of Lake Malawi water levels.

Diagnostic Checks

After identifying SARIMA (1, 1, 0)(2, 1, 1)$_{12}$ as the best fitting model, the next step was to forecast the future Lake Malawi water levels. However, several diagnostic checks were made on the identified model before the actual forecasting such as examination of the residuals of the model to identify any systematic structure still in it requiring improvement of the selected SARIMA (1, 1, 0)(2, 1, 1)$_{12}$ model (Singini *et al*. 2012, Lazaro and Jere, 2013). The diagnostic checks were made by examining the autocorrelations of the residual errors of various orders. In this regard, the Box–Pierce (and Ljung–Box) test and residual errors plots were made to see if the residual errors had a mean of zero. ACF for residual errors was plotted as shown in Figures 9, and showed that there was no non-zero lags. This indicated that there were no significant autocorrelations among the residual errors to exceed the 95% significance bounds. The Box–Pierce (and Ljung–Box) test also showed that the model fitted the series very well as the *p-value* was close to one (1) as shown in the Ljung–Box statistic in Figure 9. The time plot of the forecast errors shown in Figures 9 proves that the forecast errors has a constant variance. These diagnostic tests proved that the selected SARIMA (1, 1, 0)(2, 1, 1)$_{12}$ model was indeed an appropriate model for forecasting Lake Malawi water levels.

Forecasting

The fitted model was used to forecasts for Lake Malawi water levels from September, 2016 to 2022 at a confidence interval of 80% and 95% and they included a zero (0) as shown in Table 4. The ability of the model to forecast was tested to check the level of accuracy on the post sample forecasting. The graph in Figure 14 shows actual catches and the forecasted trend with their confidence interval of 80% and 95%. A good model should have a low forecasting error as the case with SARIMA (1, 1, 0)(2, 1, 1)$_{12}$, therefore when the distance between the forecasted and actual values are low then the model has a good forecasting power (Czerwinski *et al*. 2007, Singini 2012, Lazaro and Jere, 2013).

Table 4: Forecast catches of Lake Malawi water levels with 80% and 95% confidence intervals.

Year	*Forecasted Lake Malawi water level*											
	January	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*November*	*December*
2015									474.4503	474.3365	474.1817	474.1700
2016	474.1859	474.4622	474.7305	474.9640	474.9542	474.7948	474.6001	474.4097	474.2483	474.1009	474.0302	473.9972
2017	474.2814	474.5404	474.8002	475.0395	475.0234	474.8609	474.6557	474.4639	474.3224	474.1938	474.0753	474.0540
2018	474.2108	474.4755	474.7382	474.9755	474.9615	474.8000	474.5983	474.4069	474.2573	474.1211	474.0219	473.9958
2019	474.2088	474.4705	474.7316	474.9699	474.9548	474.7927	474.5892	474.3976	474.2518	474.1193	474.0108	473.9870
2020	474.1742	474.4372	474.6989	474.9368	474.9222	474.7603	474.5576	474.3661	474.2186	474.0844	473.9800	473.9552
2021	474.1540	474.4164	474.6778	474.9160	474.9010	474.7391	474.5360	474.3444	474.1977	474.0643	473.9580	473.9337

Where the confidence interval includes a zero (0); extinction of the species cannot be ruled out

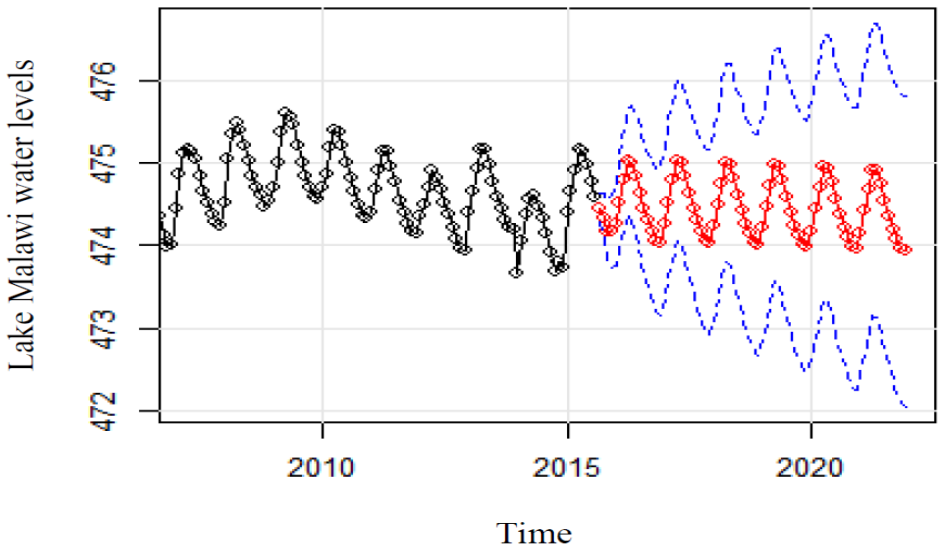

Figure 12: Forecasted Lake Malawi Water levels using SARIMA (1, 1, 0)(2, 1, 1)$_{12}$

The forecast for Lake Malawi water levels have a mean of 474.45 meters by the year 2021 and the mean of the actual recorded was 474.76 meters which is below the actual recorded mean by 0.31 meter and 0.69 meter from the maximum (475.14 meters) ever recorded Lake Malawi water level. The selected SARIMA (1, 1, 0)(2, 1, 1)$_{12}$, has also a very good forecast precision as proven by the lower values of ME, RMSE, MAPE and MAE in Table 3 hence the forecast from this model can be

trusted. These results are a clear demonstration that the Lake Malawi water levels will drop as compared to the mean of recorded water levels of the lake. This has not come as a surprise as Lake Malawi water mark on the shore has dropped with 35 meters into the lake since 2010 at Senga Bay Fisheries Research Centre in Salima District (Personal observation). Other lakes in the tropical region are reportedly experiencing water level fluctuation due to climate change. The fluctuation and drop of water level of Lake Malawi in the time series and the forecast could be due to the climate change and tectonics of the lake bed. It is therefore crucial that all direct or indirect water users should take into consideration the result of this study for continued and sustainable use of the water resource.

CONCLUSION

The SARIMA $(1, 1, 0)(2, 1, 1)_{12}$ was generated successfully to forecast the Lake Malawi water levels from the September, 2015 to December, 2021. The forecast for Lake Malawi water levels showed that the water levels will relatively drop by 0.57 meters as compared to the mean water levels of the record in the previous years. This will have negative implications over use of Lake Malawi and rivers that flow out of it for irrigation, pumping of water for domestic use and hydroelectric power generation among others.

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Mineral and Phytochemical Composition of *Adansonia Digitata* L. Root Tubers in Selected Natural Populations of Malawi

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ABSTRACT

Adansonia digitata L. *(Baobab) is an indigenous fruit tree that belongs to the family Bombacacea. In Malawi it naturally occurs in different silvicultural zones. Among its several uses, the root tubers are valued for food and medicinal purposes. A study was therefore conducted to assess the mineral and phytochemical composition of Adansonia digitata root tuber in selected natural populations of Malawi. Seeds from Karonga, Salima, Mwanza, Chikwawa and Likoma were sown at Mzuzu University Forestry department nursery. At the age of 4 months, mineral content of the root tubers was determined using Atomic absorption spectrophotometer at Agricultural Research and Extension Trust whereas phytochemical screening of the root tuber was carried out at Mzuzu University Chemistry Laboratory. Variation in mineral composition of the root tubers was assessed using one way ANOVA (Minitab 16) while the concentration of phytochemicals was assessed using qualitative scores (+++, ++, +, -). Highest amount of Mg (44.16mg/100g) was recorded in Chikhwawa. Ca levels were highest (69.39mg/100g) in Karonga. Fe content was greater (8.89mg/100g) in Karonga. The highest amount of Cu (0.155mg/100g) was detected in Salima. The amount of Mn was highest (0.815mg/100g) in Karonga. Levels of Cd were highest (0.0343mg/100g) in Likoma. Amount of Pb was greater (0.2100mg/100g) in Mwanza and Karonga. No significant differences (P>0.05) were observed in the amount of K and Zn among the study populations. Salima and Mwanza populations showed strong concentration of terpenoids. Moderate concentrations of saponins were detected in root tubers from Mwanza, Salima, Karonga and Chikhwawa. Alkaloids and Flavonoids were absent in root tubers from all the study populations. Differences in the mineral content and phytochemicals in A. digitata root tuber could be due to genetic variations as all the tubers from all provenances were raised in the same environment. The study has shown that A. digitata root tubers contain minerals and phytochemicals which suggest their nutritional and medicinal potential. However more research is required to establish the causes of high levels of lead in baobab root tubers.*

Key words: *Adansonia digitata*, mineral, phytochemical, root tuber

INTRODUCTION

Adansonia digitata L. (Baobab) is a deciduous indigenous fruit tree that belongs to the family Bombacaceae (Wickens and Lowe, 2008) and is native to Africa (Namratha and Sahithi, 2015). The tree is found in most of Sub-sahara Africa's semi-arid and sub-humid regions as well as in western Madagascar (Diop *et al.*, 2005). In Southern Africa, *Adansonia digitata* is commonly found in Malawi, Zimbabwe, Mozambique and South Africa (Kamatou *et al*, 2011). In Malawi, *Adansonia digitata* is mostly found in dry woodlands (Munyebvu, 2015). It usually grows as a solitary

individual though sometimes it can be found in small groups depending on soil type (Sharma *et al.*, 2015). Baobab tree can grow up to 25 meters in height, 28 meters in girth and can live for several hundred years (Sugandha *et al.*, 2013). It has a shallow root system that rarely extends beyond 2 meters in depth for mature trees (Munyebvu, 2015). The tree excels in a wide range of well drained soils but not in deep unconsolidated sands (Kamatou *et al.*, 2011). Fluvisols which are not subjected to flooding have been reported to favor the growth of baobab (Sanchez, 2011). The species does not occur in water logged and frost areas (Sharma et al, 2015). It requires annual temperature range of 20-30°C but can also tolerate high temperatures of 40-42°C (Bamalli *et al.*, 2016). Lower altitudes with annual rainfall in the range 100-1000ml have been reported to be ideal for the growth of Baobab tree (Gebauer *et al*., 2002; Rahul *et al*., 2015).

Adansonia digitata is a multipurpose tree that is mostly valued for food and traditional medicine (Rahul *et al.*, 2015). The root tubers, twigs, fruits, seeds, leaves and flowers are all edible and have been found to possess various minerals (Ca, Fe, Cu, Mn, Zn, K, Mg) and phytochemicals (Bamalli *et al*., 2016). In addition, a variety of phytochemicals (terpenoids, flavonoids and steroids) which are responsible for medicinal purposes have been chemically isolated from various parts of the baobab tree (De Caluwe *et al*., 2010). Even without such knowledge, rural people have developed unique indigenous knowledge related to use of traditional medicine (Emmanuel and Didier, 2012). However the use of baobab tree parts has been reported to vary considerably from place to place (Kamatou *et al*, 2011). In Malawi, a study by Munthali (2011) found that many people in Chikhwawa (56.3%) and Karonga (46.4%) utilize baobab root for medicinal purposes. In southern Malawi, an infusion of baobab root has for a long time been used to treat sore throats (Morris, 1996). The wide ecological adaption of *Adansonia digitata* suggests the species has evolved a wide genetic diversity across its geographical range (Munthali, 2011). In this regard, it is possible that variations in mineral and phytochemical composition of baobab root tubers are influenced by geographical or genetic differences and hence their use can not be generalized. Therefore this study was carried out to determine the variation in mineral and phytochemical composition of baobab root tubers in selected natural populations of Malawi. Knowledge of this variation would be useful in characterizing baobab populations whose root tubers are exploited for food and medicinal purposes. In addition, findings of this study will be essential for future selection programs aimed at producing Baobab populations of specific mineral and phytochemical content.

MATERIALS AND METHODS

Study area and experimental material

Adansonia digitata seeds representing a total of 59 half-sib families were collected in Malawi from five provenances (Karonga, Salima, Mwanza, Chikhwawa and Likoma). The seeds were collected from randomly selected parents at a distance of about 100m apart and were sown at Mzuzu University Forestry department nursery in October, 2015. The seeds were pretreated through nicking to allow water penetration. Mzuzu University lies in silvicultural zone M and falls at an altitude of 1270m above sea level with mean annual temperature ranges of 13.5°C to 24°C and mean annual rainfall of 1150mm (Hardcastle, 1978).

Table 1: Site characteristics for five sampled Baobab provenances

Provence	Silvicultural zone	Altitude (m)	MAR (mm)	T (°C)	Soil type
Karonga	L	750-1000	>1600	23-25	Ferrisols, domant regosols
Salima	Ba	200-1000	710-850	20-25	Alluvial calcimorphic soils
Mwanza	J	900-1500	>1200	19-21	Sandy ferrallitic
Chikhwawa	A	<200	710-840	<25	Vertisols
Likoma	L	475-1000	>1600	23-25	Ferrisols, regosols, lithosols

Source: (Hardcastle, 1978)

Experimental design

The trial was laid out as a complete randomized design with four replicates. For each treatment, two seeds were sown in ten black polythene tubes at 4cm depth. Sand and dark-grey miombo soils mixed in the ratio 1:2 respectively were used as rooting medium. Watering was carried out twice a day to keep the rooting medium moist. After germination, the seedlings were thinned to remain with one seedling per tube.

Collection and processing of *Adansonia digitata* root tubers

At the age of five months, Baobab root tubers (Figure 1) were collected from the nursery by uprooting the entire plant.

Figure 1: Baobab root tubers

The root tubers were then cleaned to remove mud. Thereafter the root tubers were sliced into small pieces by sterilized blades. The samples were then pounded using a mortar and pestle. The wet samples was then transferred into dry beakers and then dried in an electric oven (Series 9000) at 105°C overnight.

Determination of minerals

For each treatment, the dried sample (5g) of baobab root tuber was ashed by heating the sample at 650°C for 6hrs in a furnace (CWF 1200). 7ml of 6M Hydrochloric acid solution was then added to the ash. The mixture was heated on a hot plate with the aid of four anti-bumping granules and was left to boil up to the point it was completely dry. 10ml of 3M Hydrochloric acid was then added to the dried samples and then heated. The heated samples were filtered into 100ml volumetric flasks. The filtered samples were finally diluted with distilled water up to the 100ml mark. The solutions were then transferred to Agricultural Research and Extension Trust for determination of minerals using Atomic Absorption Spectrophotometer (AAS). The metal content was calculated using the

equation described by Osborne and Voogt (1978) as follows
Metal content (mg/100g) = [(a-b) x V] / 10W
Where W is the weight (g) of the sample, V is the volume (ml) of extract, a is the concentration (m/100g) of sample solution and b is the concentration of blank solution

Phytochemical screening of *Adansonia digitata* root tuber
Phytochemical screening of *Adansonia digitata* root tubers was carried out using qualitative methods described by Harbone (1973), Sofowora (1993), Trease and Evans (1989). The analyses were carried out on dry and pounded samples. All the analyses were carried out at Mzuzu University Chemistry laboratory.

Test for alkaloids
A test for the presence of alkaloids was done using Dragendorff and Mayer's reagents. 5g of dried powdered sample was macerated in 5% (v/v) hydrochloric acid solution for 24 hours. Two portions of the filtrate (1 ml each) were treated with 10 drops of Dragendorff and Mayer's reagent separately. Absence of the red and cream white color was taken as an indication for the absence of alkaloids, (Harbone, 1973).

Test for terpenoids
1g of dried powdered sample was macerated in 20ml of diethyl ether in a stoppered conical flask for 48hrs. A portion of the filtrate (10 drops) in porcelain crucible was dried in a water bath followed by the addition of 10 drops of concentrated sulphuric acid. The colour produced was recorded. Another portion was treated the same but starting with the addition of acetic anhydride followed by 10 drops of concentrated sulphuric acid. The appearance of green, blue and pink to purple colors indicate the presence of terpenoids (Harbone, 1973).

Test for saponins
An infusion of (5%w/v) was prepared by macerating 1g of dried powdered sample in 20ml of distilled water. This was left to stand for 24hrs and the extract was filtered using Whatman filter paper No.1. 10ml of the filtrate was transferred into a test tube and was shaken vigorously for 10 seconds. The foam that persisted for 20 minutes was measured using a ruler and used as an indication for the presence of saponins (Sofowora, 1993).

Test for flavonoids
5g of dry powdered sample was macerated in 50ml of distilled water and the mixture was left to stand for 24hrs. 0.5ml solution containing hydrochloric acid, methanol and water (1:1:1) was added to the filtrate followed by some few magnesium turnings. Absence of the pink or red color was used to indicate absence of flavonoids (Trease and Evans, 1989).

Data analysis
One way ANOVA in MINITAB 16 was used to assess the variation in mineral content of *Adansonia digitata* root tubers among the study populations. The concentration of phytochemicals was assessed using qualitative scores (+++, ++, +, -). +++ denote strong concentration, ++ representing moderate concentration, + indicating weak concentration and – indicating absence of phytochemical.

RESULTS

Mineral composition of Baobab root tubers
Table 2 shows the variation of mineral elements in all the treatments. There were great variations in the mineral content of baobab root tubers among the study populations. The highest mineral was Ca (42.91±2.60mg/100g) whilst the least was Cd (0.01475±0.0015mg/100g). The variance percentage

ranged from 223.89% for K to 2500% for Pb and Cd.

Table 2: Variation in mineral content of Baobab root tubers

Element	Mean(mg/100g)	S.E Mean	Interval	Variance	Variance%
Mg	22.72	1.89	8.41-56.01	47.60	565.99
Ca	42.91	2.60	15.89-123.39	107.50	676.53
K	6.608	0.267	3.180-10.300	7.12	223.89
Fe	5.141	0.22	2.10-10.59	8.49	404.29
Cu	0.0694	0.0052	0.0200-0.1900	0.17	850
Zn	0.2212	0.0131	0.1100-0.6400	0.53	481.81
Mn	0.491	0.0181	0.2600-1.0400	0.93	357.69
Cd	0.01475	0.0015	0.0014-0.0364	0.035	2500
Pb	0.1212	0.0104	0.0100-0.2600	0.25	2500

Table 3 shows the mineral composition of baobab root tubers among the study populations. There were significant differences ($P<0.05$) in the amount of Mg, Ca, Fe, Cu, Mn, Cd and Pb. No significant differences were observed in the levels of K and Zn. Highest amount of Mg (44.160mg/100g) was recorded in a family from Chikhwawa (C2) and lowest amount of Mg (9.84mg/100g) was also found in a family from Chikhwawa (C5). Ca levels were higher (69.39mg/100g) in Karonga (K12) and lowest (25.02mg/100g) in Likoma (L7). Fe content was highest (8.89mg/100g) in Karonga (K8) and lowest (3.13mg/100g) in Chikhwawa (C6). Levels of Cu were highest (0.155mg/100g) in Salima (S15) and lowest (0.0250mg/100g) in Karonga (K11, K5 and K8). The highest amount of Mn (0.815mg/100g) was found in a family from Karonga (K8) while the lowest amount (0.335mg/100g) was detected in families from Chikhwawa (C2 and C5). Cd levels were highest (0.0343mg/100g) in family from Likoma (L7) and lowest (0.0024mg/100g) in population from Mwanza (M7). The highest amount of Pb (0.2100mg/100g) was recorded in families from Mwanza (M15) and Karonga (K8) while lowest levels (0.025mg/100g) were found in families from Chikhwawa (C2), Salima (S13) and Mwanza (M9).

Table 3: Mineral content of Baobab root tubers for 25 families in five provenances

	Mineral element (mg/100g)								
Code	**Mg**	**Ca**	**K**	**Fe**	**Cu**	**Zn**	**Mn**	**Cd**	**Pb**
C10	11.11	28.54	8.59	6.13	0.035	0.170	0.470	0.014	0.185
C2	44.16	33.44	6.94	5.30	0.090	0.170	0.355	0.029	0.025
C3	34.79	26.45	7.51	3.15	0.060	0.165	0.460	0.023	0.030
C5	9.840	43.26	4.35	4.69	0.030	0.170	0.355	0.009	0.195
C6	39.29	38.42	7.81	3.13	0.085	0.170	0.450	0.030	0.045
K11	13.91	35.14	5.30	4.86	0.025	0.155	0.420	0.007	0.190
K12	15.28	69.39	8.96	5.57	0.045	0.255	0.665	0.008	0.155
K3	13.17	47.93	5.34	7.25	0.035	0.415	0.465	0.003	0.070
K5	9.960	62.65	7.59	5.98	0.025	0.210	0.545	0.005	0.120
K8	19.32	87.37	5.65	8.89	0.025	0.320	0.815	0.007	0.210
L2	32.99	25.72	7.30	4.04	0.070	0.155	0.465	0.026	0.065
L3	14.24	54.19	5.15	3.84	0.085	0.185	0.630	0.007	0.175
L4	12.39	32.85	6.07	3.46	0.045	0.160	0.340	0.009	0.190
L7	41.05	25.02	9.78	6.87	0.110	0.145	0.495	0.034	0.040
L9	38.84	42.65	4.88	3.41	0.110	0.155	0.470	0.027	0.075
M13	14.81	49.85	5.01	3.81	0.080	0.230	0.495	0.005	0.130
M15	10.30	44.26	7.84	4.23	0.045	0.235	0.350	0.007	0.210
M3	27.52	33.50	7.92	7.07	0.105	0.345	0.490	0.003	0.145
M7	12.37	43.14	4.67	5.61	0.080	0.210	0.610	0.002	0.130
M9	43.48	27.72	6.09	5.30	0.125	0.180	0.385	0.028	0.025
S11	11.77	51.18	5.99	5.63	0.055	0.275	0.470	0.005	0.185
S13	32.10	28.78	5.84	4.97	0.090	0.18	0.405	0.029	0.025
S15	40.16	39.91	6.49	5.66	0.155	0.275	0.550	0.025	0.040
S2	12.93	58.45	7.66	4.12	0.050	0.36	0.515	0.007	0.190
S6	12.10	43.01	6.42	5.15	0.075	0.265	0.625	0.007	0.180
Pooled StDv	**5.64**	**14.91**	**1.735**	**0.91**	**0.019**	**0.08**	**0.086**	**0.003**	**0.038**

C = Chikhwawa, K = Karonga, L = Likoma, S = Salima, M = Mwanza

Phytochemical variation in Baobab root tubers

Table 4 shows phytochemical composition of *A. digitata* root tubers from the five study areas. Root tubers from Salima and Mwanza showed strong concentration of terpenoids. Moderate concentrations of terpenoids were observed in root tubers from Karonga and Chikhwawa while weak concentrations were recorded in root tubers from Likoma. Moderate concentrations of saponins were detected in root tubers from Mwanza, Salima, Karonga and Chikhwawa while weak concentrations were recorded in root tubers from Likoma. Alkaloids and Flavonoids were absent in root tubers from all the five provenances.

Table 4: Phytochemical variation in baobab root tubers from five provenances

	Phytochemical			
Provenance	Terpenoids	Saponins	Alkaloids	Flavonoids
Mwanza	+++	++	-	-
Salima	+++	++	-	-
Karonga	++	++	-	-
Chikhwawa	++	++	-	-
Likoma	+	+	-	-

+++=Strong concentration, ++=Moderate concentration, +=Weak concentration, =Absent

DISCUSSION

This study has shown that the mineral content and phytochemical composition of *A. digitata* root tuber differ significantly across geographical localities of Malawi. Zobel and Talbert (1984) and Cyhan *et al.* (2011) suggested that variations arise from genetic and environmental differences. The differences in the mineral content and phytochemical composition of *A. digitata* root tubers in this study could therefore be attributed to genetics as all the provenances were raised in the same environment. This conclusion supports the earlier hypothesis by Munthali (2011) who stated that baobab has evolved a wide genetic diversity across its geographical range. The high variance percentages (Table2) in the important minerals (Mg, Ca, K, Fe, Cu, Zn) present in Baobab root tubers clearly show the importance of selection at provenance and family levels. Tizioto *et al*. (2015) noted that the effect of various quantitative trait loci generally explains the genetic variance in the mineral content of specific organisms. Such variations may even provide room for selecting individuals within a family.

Magnesium is important in protein synthesis, release of energy from muscle storage and is essential in regulating body temperature (Flowkoski et al., 2009). High levels of magnesium (44.16mg/100g) in Chikhwawa family (C2) suggest baobab root tubers are an important source of magnesium for nutritional purposes. Moreover Mg levels (44.160mg/100g) in this study are higher than in raw sweet potatoes (30mg/100g), cassava (16mg/100g) and yams (17mg/100g) as reported by Chandrasekara and Kumar (2016). Calcium is very important in tooth formation and reduces the risk of osteoporosis, a condition in which decreased bone mass weakens the bone (Cohen and Roe, 2000). In all the families, calcium levels (25.02mg/100g-60.39mg/100g) were much higher compared to lower levels (18.20mg/100g) recorded in *A. digitata* leaves by (Ijeomah *et al.*, 2012). The high content of calcium (69.39mg/100g) in Baobab root tubers indicates that they may be used to improve tooth and bone strength. Potassium plays an important role in lowering blood pressure

and release of energy from fats, proteins and carbohydrates (Salunkhe *et al*., 1991). No significant differences (P>0.05) were observed in potassium levels (6.608mg/100g) among the study populations indicating that its content is the same in different geographical localities of Malawi. Iron is a major component of hemoglobin and has been reported to be very important in the oxidation of carbohydrate, protein and fats (Ijeomah *et a*l., 2012). High Iron levels found in this study (8.89mg/100g) in Karonga (K8) are greater than the value (3.95mg/100g) recorded in dry baobab fruit pulp by Phytotrade Africa (2009). Iron content could therefore support use of Baobab roots in improving levels of hemoglobin as well as the general human nutrition. Manganese supports brain functioning and is required for blood sugar regulation (Flowkoski *et al.,* 2009). High levels (Table 3) of manganese (0.185mg/100g) in Karonga (K8) indicate potential use in treating diabetes. Furthermore, Mn levels recorded in this study (0.185mg/100g) are higher compared to Mn content in raw apple (0.035mg/100g) and avocado (0.095mg/100g) as presented by Flowkoski *et al*. (2012). Zinc is involved in digestion, metabolism and is an important antioxidant (Flowkoski *et al*., 2009). Zinc levels (0.2212mg/100g) among the study populations indicate that its content in baobab root tuber is the same across populations. However Zn levels (0.221mg/100g) recorded in this study are lower compared to levels (0.680mg/100g) found in avocado (Flowkoski et *al.,* 2012). Copper is a redox active metal necessary for the formation of hemoglobin and is required for the function of over 30 proteins (Arredondo and Nunez, 2005). Presence of copper (0.155mg/100g) in baobab root tubers indicates potential use in prevention of anemia and malnutrition deficiencies common in Malawi. However the higher levels of Cu (0.155mg/100g) found in this study are very lower compared to Cu levels (13.00mg/100g) detected in Boabab leaves (Ijeoma *et al.,* 2012). Ijeomah *et al.* (2012) reported that Lead (Pb) is an element that is not needed in the body. Hutton (1987) noted that levels of lead (>0.03mg/100g) may cause impairment of the central nervous system in children. The highest concentration of lead (0.2100mg/100g) in this study exceeds FAO/WHO standard of 0.03mg/100g. Presence of lead in higher levels than the standard value allowed for food substances constitutes a serious health problem. Cadmium is an inorganic metal that causes anemia and heart diseases (Ijeomah *et al.,* 2012). High levels of Cadmium (0.0343mg/100g) in population from Likoma (L7) indicate a health concern in the utilization of baobab root tuber either for food or medicinal purposes. A study by Ijeomah *et al*. (2012) failed to detect lead but found cadmium (0.85mg/100g) in baobab leaves and reported that lead and cadmium are naturally present in the environment. In the current study, soil samples and water used in the experiment were not tested for lead and cadmium. It could be possible that high levels of lead and cadmium were attributed to the soil and water used in the experiment. Still more, presence of lead and cadmium in baobab root tubers could be genetically influenced. Further research is required to establish the sources of high levels of lead and cadmium in Baobab roots. Morris (1996) cited in Bamalli *et al*. (2016) has reported that in southern Malawi children consume baobab root tuber to treat sore throat. However no oral knowledge has so far been reported on the harmful side effects relating to the use of baobab root tubers.

The presence of terpenoids and saponins in baobab root tuber agrees with the previous findings by Fasola and Iyamah (2014) who also reported the occurrence of saponins and terpenoids in baobab root tubers. The antimicrobial activity of baobab root has been reported to be influenced by the presence of saponins and terpenoids (Masola *et al*, 2009). The availability of terpenoids and saponins in baobab root tubers therefore justifies their traditional application in the treatment of microbial infections. From the results of this study, baobab root tubers from all the provenances could hence be utilized to treat microbial infections. However the varying concentration of terpenoids and saponins in baobab root tubers still need to be considered inorder to optimize their efficacy in the treatment of microbial infections. Terpenoids are precursors in the human body which help to produce steroids like sex hormones such as testosterone (Prior and Cao, 2000). The traditional use of *A. digitata* root tubers either for food or medicinal purposes could hence be helpful in increasing testosterone levels in males with fertility problems. Because of strong concentrations of terpenoids, baobab root tubers could be utilized to optimize male testosterone levels. Chandrasekara and Kumar

(2016) reported that saponins regulate blood sugars levels in the human body. Presence of saponins in baobab root tubers from all the provenances could therefore defend their traditional use in treating diabetes. Flavonoids are chemical compounds with antidiarrheal activity (Ivanova *et al*., 2011). Absence of flavonoids points out that baobab root tubers from all the five provenances may not be a practical remedy for treating diarrhea. Alkaloids are chemical compounds mostly containing basic nitrogen atoms and are used as a remedy for gout with analgesic and anti-malarial activity (Woolley, 2001; Kakhia, 2012). The absence of alkaloids in baobab root tubers from all the provenances therefore shows that they are not an ideal remedy for treating gout, malaria and for eliminating body pain. Absence of alkaloids and flavonoids is in contrast to the findings of Fasola and Iyamah (2014) who recorded the availability of alkaloids and flavonoids in baobab root tubers and attributed their variations to environmental differences and maturity of the plant part used. In the current study, seedlings were used perhaps before the plants started reserving or storing alkaloids and flavonoids in the roots.

CONCLUSION AND RECOMMENDATIONS

This study has revealed that *A. digitata* root tubers are an important source of magnesium, calcium, potassium, iron, copper, zinc and manganese which are required for the proper functioning of the human body. However baobab root tubers have also shown to contain heavy metals (Pb and Cd) which are not required in heavy doses by the human body. Root tubers of *A. digitata* have demostrated to possess important phytochemicals such as terpenoids and saponins crucial in treatment of ailments while absent in alkaloids and flavonoids. The mineral and phytochemical composition of *A. digitata* root tuber has proved to be genetically distinct across geographical localities of Malawi. Therefore because of these differences, the use of *A. digitata* root tubers for food and medicinal purposes should not be generalized. Further studies are required to establish the causes of high lead and cadmium levels in baobab root tubers. In addition, domestication efforts must consider variation in mineral and phytochemical composition of baobab root tubers if target ideotypes of baobab are to be produced.

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Above- And Belowground Biomass Models for Trees in Miombo Woodlands of Malawi

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ABSTRACT

Availability of biomass models is important for reliable estimation of forest biomass and carbon stocks. This study aimed at developing general (covering multiple tree species over a wide range of sites) above- and belowground, stems, branches and twigs biomass models for trees in miombo woodlands of Malawi. The dataset was based on 74 destructively sampled trees from 33 different tree species with diameter at breast height (dbh) and total tree height (ht) ranges of 5.3 - 111.2 cm and 3.0 - 25.0 m, respectively. The data were collected from four forest reserves located in different ecological zones. We tested different model forms utilizing dbh, ht and wood specific gravity as independent variables. Model comparison was based on Akaike Information Criteria (AIC). For all the models we presented pseudoR^2, Root mean Square Error (RMSE), a covariance matrix for the parameter estimates, Mean Prediction Error (MPE) and relative Mean Prediction Error (MPE%). The models had pseudoR^2 and MPE% values ranging from 0.82 - 0.97 and 0.9% - 2.8%, respectively. Computation of MPE% were based on leave-one-out-cross validation. Model performances and evaluations indicated that the models can be used over a wide range of geographical and ecological conditions in Malawi. The generally large MPE% values seen when applying previously developed models from neighbouring countries on our data demonstrated the importance of developing local models for Malawi

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Keywords: destructive sampling; root to shoot ratio; root excavation; dry tropical forest; multiple sites; multiple species; leave-one-out-cross validation; covariance matrix.

INTRODUCTION

Miombo woodlands, classified as dry forests, are dominated by woody plants, primarily trees, whose canopy cover more than 10% of the ground surface, occurring in a climate with a dry season of three months or more [1]. The woodlands are dominated by deciduous trees mainly belonging to *Brachystegia*, *Julbernadia* and *Isoberlinia* genera covering an area of approximately 2.7 million km^2 spanning ten countries in eastern and central Africa including Malawi [1-5]. Miombo woodlands may be divided into dry and wet miombo. Dry miombo occurs in areas receiving less than 1000 mm rainfall annually in Zimbabwe, central Tanzania, and in the southern areas of Mozambique, Malawi and Zambia. Wet miombo occur in areas receiving more than 1000 mm rainfall annually in eastern Angola, northern Zambia, south western Tanzania and central Malawi [1,6]. In Malawi, miombo woodlands, which constitute 92.4% of the country's total forested area, are mainly located in forest and game reserves that were established for water catchment, soil and biodiversity conservation [2,7].

Miombo woodlands play a critical role in the livelihoods of Malawian communities because they provide social, economic and environmental benefits such as firewood, poles, timber, medicinal plants, food and catchment protection, among others [8]. However, increase in population growth, currently estimated at an annual growth rate of 2.8% [9], has led to high demand for firewood, charcoal and timber production. As a result, the woodlands are being deforested at an increasing rate of approximately 1% per year [8].

To sustain the provision of the mentioned services, there is an urgent need for instituting sustainable forest management measures including estimation of growing stock, productivity, biomass and yields [10,11]. Assessment of forest biomass is of particular interest to most countries, including Malawi, because it enables estimation of forest carbon stocks. Due to the natural capacity of trees to sequester carbon dioxide, miombo woodlands are considered as an important element in global climate change mitigation programs such as the Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanism. This mechanism provides a framework through which developing countries may be rewarded financially for reductions in carbon emissions.

The Malawi government recently conducted a study aiming at developing its monitoring, reporting and verification (MRV) system for quantifying carbon emissions from different land use changes including forests in the country [7]. The study, among others, established baseline forest biomass and carbon stock estimates for targeted forest reserves in miombo woodlands of Malawi. However, the forest biomass and carbon estimates are probably unreliable because of the nature of allometric models that were used. For example, the aboveground forest biomass estimates were based on a pan-tropical biomass model developed by Chave et al. [12]. This model was developed using data from trees in tropical America and Asia but no data were from Africa and from miombo woodlands. In addition, the belowground forest biomass estimates were based on an allometric model developed by Cairns et al. [13]. Unlike Chave et al. [12], this dataset included some trees from Africa, i.e. Democratic Republic of the Congo, Ghana and Ivory Coast. However, the trees were from moist evergreen equatorial tropical forests, whose structure is different from miombo woodlands.

As of 2011, there were approximately 370 allometric models for predicting tree biomass in sub-Saharan Africa [14]. The majority of these models were developed for tropical rainforests in western Africa. Among the models developed in south-eastern Africa, only a few were developed for miombo woodlands. These models comprise of : a) species-specific-single-site models developed for specific tree species based a dataset from one site (Mwakalukwa et al. [15]); b) species-specific-multi-site models developed for specific tree species based a dataset from several sites (Mate et al. [16]); multi-species-single-site models developed for multiple tree species based on a dataset from one site (Chidumayo [17], Chamshama et al. [18], Malimbwi et al. [19], Ryan et al. [4], Mwakalukwa et al. [15]) and d) multi-species-multi-site models developed for multiple tree species based on a dataset from several sites (Mugasha et al. [20]).

Miombo woodlands are characterized by high tree species diversity where the number of species are ranging from 80 to 300 [21-26]. Due to such large number of tree species, the applicability of species-specific models is limited. Furthermore, applicability of single-site models over different ecological zones is also limited due to their narrow geographical range. A scenario with general models, combining multiple species collected over several sites, would therefore be the best alternative, for example in cases where national forest inventories are to be carried out. No such models exist for miombo woodlands in Malawi.

Most of the previously mentioned studies focused on aboveground biomass. However, estimation of belowground biomass in miombo woodlands is also vital. Belowground tree biomass, as basis for model development, can be determined using a variety of ways including: complete excavation of

roots, soil core sampling for fine and medium roots and root sampling. Estimation of belowground tree biomass can then be done by using the root to shoot ratio (RS-ratio), i.e. the ratio between belowground and aboveground dry weights (see e.g. [27,28]), or by means of models. The availability of belowground biomass models for miombo woodlands is scanty except for a few developed by Mugasha et al. [20], Chidumayo [17] and Ryan et al. [4]. No such models have been developed for Malawi.

Since estimates of forest biomass and carbon stocks are based on measurements of a sample of the population, sampling related uncertainties are inevitable [29]. Furthermore, since forest biomass and carbon cannot be measured directly, models are used to estimate these variables. However, use of models also brings model-related uncertainties stemming from sources such as: a) model misspecifications, b) uncertainties in values of independent variables, c) residual variability, i.e. differences between observations and predictions obtained from correctly specified models, and d) uncertainty in the model parameter estimates (see e.g. [30,31]). Among these, uncertainty in parameter estimates has great influence on model-related uncertainties in biomass estimations [29]. However, very few studies report the covariance structure of parameter estimates of developed models, and this makes it impossible to analyse the uncertainty of estimated forest biomass and carbon stocks (see [29]). Such information is critical especially for models utilized in MRV systems for the REDD+ mechanism under the Inter-governmental Panel on Climate Change (IPCC) (see [32]) because the reporting of carbon should be accompanied by appropriate measures of the uncertainty.

This study seeks to develop general (multi-species-multi-site) above- and belowground biomass models that could be applicable across the entire distribution of miombo woodlands in Malawi. The models are also accompanied with information on covariance structures to enable quantification of model-related uncertainties. We will furthermore provide basic statistics on RS-ratios and compare the performance of our models with existing models from neighbouring countries.Materials and methods.

Sites description

The sample trees for model development were selected from four forest reserves, namely; Mtangatanga, Kongwe, Mua-livulezi, and Tsamba (see Figure 1, Table 1). The selection of study sites was based on geographical location, management regime and ecological conditions so as to capture a wide range of factors that may influence tree growth [1].

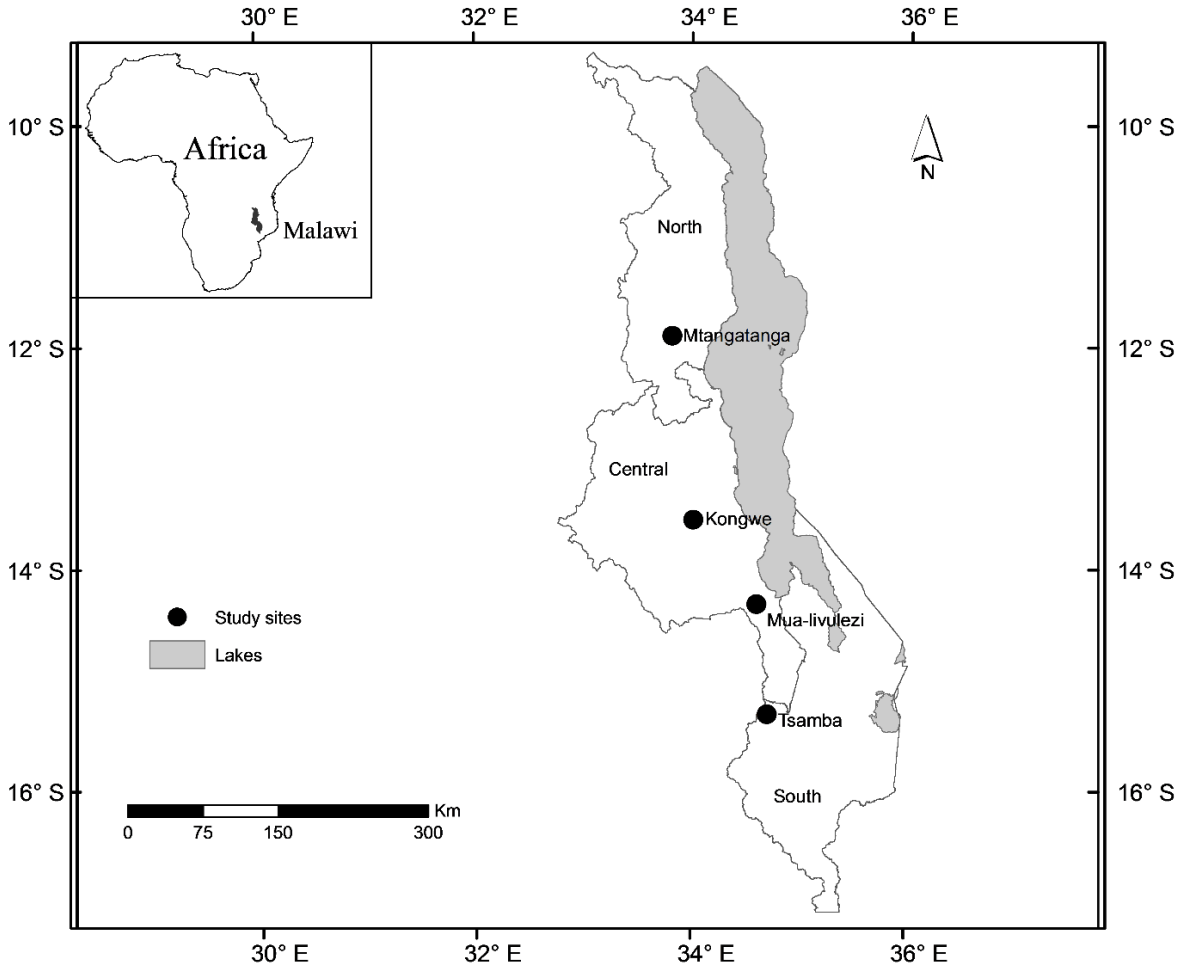


Figure 1: Map of Malawi showing the location of the study sites. The coordinate system was based on Geographic Coordinate System (GCS).

Table 1: Description of study sites

	Mtangatanga	Kongwe	Mua-livulezi	Tsamba
Region	Northern	Central	Central	Southern
District	Mzimba	Dowa	Dedza	Neno
Location	$11^0$56' S $33^0$42'E	$13^0$35'S $33^0$55'E	$14^0$21'S $34^0$37'E	$15^0$21'S $34^0$36'E
Area (ha)	8443	1813	12147	3240
Altitude (m)	1500 - 1700	1000 - 1500	400 - 900	700 - 1500
Dominant soil type	Humic ferrallitic	Ferruginous	Lithosols	Ferrallitic
Management regime	Co-management	Government	Co-management	Government
Silvicultural classification	Moist *Brachystegia*	Moist *Brachystegia*	Dry *Brachystegia*	Moist *Brachystegia*
Mean minimum annual temp (^{0}C)	6	6	13	8
Mean maximum annual temp (^{0}C)	29	29	32	28
Total annual rainfall range (mm)	960 - 1050	960 - 1050	840 - 960	1200 - 1600
Rain period	Dec - April	Nov - April	Nov - April	Nov - April
Dry months	May - Nov	May - Oct	May - Oct	May - Oct

Data sources: Rainfall and temperature data (1975 - 2005) from Ministry of Natural Resources, Energy and Mining, Department of Climate Change and Meteorological Services in Malawi. Soil and silvicultural classification according to Hardcastle [33].

Selection of sample trees.
We conducted systematic sample plot inventories covering each site to collect information on ranges in tree size and species distribution to guide the selection of sample trees (see e.g. [20]). We used circular plots with a radius of 11.28 m (400 m^2). On each plot, we measured diameter at breast height (dbh) of all trees with dbh > 4 cm and determined their scientific names. In addition, we sampled three trees within each plot, i.e. one with small, one with medium and one with large dbh, and measured their total heights (ht). The inventories covered a total of 221 sample plots with 70, 30, 71 and 50 plots for Mtangatanga, Kongwe, Mua-livulezi and Tsamba, respectively. The maximum recorded dbh values based on all sample plots in Mtangatanga, Kongwe, Mua-livulezi and Tsamba were 61 cm, 73 cm, 70 cm and 56 cm, respectively, while the number of species identified for the respective sites were 66, 45, 77 and 65. In total, for all the study sites, we identified 139 species during the inventory. The most frequent species for Mtangatanga, Kongwe, Mua-livulezi and Tsamba were *Uapaca kirkiana, Brachystegia spiciformis, Diplorhynchus condylocarpon* and *Uapaca kirkiana*, respectively.

A total of 74 trees were sampled based on the observed dbh and tree species frequency for the sites. We ensured that the trees were selected from all the observed dbh classes observed in the sample plot inventories. In addition, we selected a total of eight trees with larger dbh than those observed in the sample plot inventories to reduce uncertainty when predicting biomass of very large trees. We also selected at least one tree among the eight most frequent species observed in each site. The remaining sample trees were selected randomly among all species. In total, 33 tree species were selected, comprising 10, 10, 12 and 10 different tree species in Mtangatanga, Kongwe, Mua-livulezi and Tsamba, respectively.

Before felling (at a stump height of 30 cm), we recorded scientific and local names, and measured dbh, stump diameter (at 30 cm above ground) and ht. We used a calliper or a diameter tape, depending on tree sizes, to measure dbh and stump diameter, while a Suunto hypsometer was used for all ht measurements. Table 2 and Appendix 1 presents a statistical summary of the sampled trees and information on individual trees, respectively. These trees have previously been used to develop general volume models for miombo woodlands in Malawi [34].

Table 2: Statistical summary of diameter at breast height (dbh) and total tree height (ht) for sample trees

Site	**dbh (cm)**					**ht (m)**			
	N	Mean	Min.	Max.	STD	Mean	Min.	Max.	STD
Mtangatanga	20	35.5	6.0	111.2	26.7	10.7	4.0	18.0	4.3
Kongwe	18	34.9	9.0	75.7	19.6	11.7	5.0	22.0	4.7
Tsamba	18	30.2	8.4	75.0	17.5	12.6	6.5	25.0	5.1
Mua-livulezi	18	32.8	5.3	81.7	23.0	11.6	3.0	22.0	5.8
All	74	33.4	5.3	111.2	21.8	11.6	3.0	25.0	4.9

Note: n is the number of trees, STD = standard deviation

Destructive sampling
After felling, we separated each sample tree into the following aboveground components: stem (from the stump at 30 cm above ground to the point where first branches start), branches (all parts of the tree above the defined stem and up to a minimum diameter of 2.5 cm) and twigs (all branches with a diameter less than 2.5 cm). Two trees, Cussonia arborea and Erythrina abyssinica for Kongwe did not have branches that qualified as twigs, i.e. all branches were greater than 2.5 cm. For small trees not considered as suitable for timber production (dbh < 15 cm, in total 14 trees), stem biomass were allocated to branches (e.g. [34,35]). We excluded leaves from twigs, leaves are thus not included in the modelling.

To facilitate measurements and weighing, stems and branches were crosscut into manageable pieces of approximately 1-2 m in length and then weighed for fresh weight using a mechanical hanging spring balance (0 – 200 kg). Twigs from each tree were separately bundled and weighed for fresh weight. Three small sub-samples from each of the components (stem, branches and twigs) were taken from each sample tree and weighed with an electronic balance for fresh weight and finally brought to laboratory for further analyses. The sub-samples were taken from the biggest, medium and smallest diameter parts of each tree components.

Our sampling strategy involved sampling the roots of a tree at two levels, namely main roots (roots emanating directly from the root crown) and side roots (roots emanating from the main roots). For each level, we selected three roots based on their sizes i.e. small, medium and large. The first step for belowground excavation involved clearing the top soil around the base of a tree to expose the points at which the roots were emanating from the tree. We then selected three main roots, i.e. the roots with the biggest, medium and smallest diameters, for total excavation and recorded their diameters at the point where they joined the root crown. The diameters of all main roots not excavated were recorded at the point they were joining the root crown. From each of the selected main roots, we selected up to three side roots, i.e. the roots with the biggest, medium and smallest diameters. For each of the selected side roots, we recorded the diameter where they joined the main root. For the remaining side roots, we also recorded the diameters at the branching point of the main root. The selected side and main roots were then fully excavated up to the minimum diameter of 1 cm and weighed. In cases where the full roots could not be excavated due to obstacles such as rocks, the diameter of the last bit of the root was recorded and we treated the remaining unexcavated part as a side root. An effort was made to ensure that all the trees were fully excavated up to the last 1 cm also for the tap roots. In total, 38 out of the 41 trees, had tap roots. Out of these 38 trees, we were not able to fully excavate 16. In such cases the diameter at the breaking point of the unexcavated tap root was recorded and further treated as a side root. On average, the trees were dug down to 2.5 m depth. Lastly, we recorded the fresh weight of the root crown for each tree.

Three small sub-samples were taken from each main and side root, and one was taken from the root crown for each of the sample trees. The sub-samples were weighed for fresh weight using an electronic balance and finally brought to laboratory for further analyses.

Laboratory analyses and determination of biomass dry weight

All sub-samples, from both above- and belowground, for each tree were dried in an oven in a laboratory at a temperature of 80 0C until a constant weight was achieved (constant weight observed over 2-3 days). We then recorded dry weights of the individual sub-samples. Subsequently, we used the sub-sample dry and fresh weights to determine the tree- and section specific dry to fresh weight ratios (DFratios) (see Appendix 2).

We then calculated the dry weight of each section as a product of tree- and section specific DF-ratios and the fresh weights of the respective trees and tree sections. Subsequently, we computed the total aboveground dry weight by summing the dry weights of the stem, branches and twigs of each tree. Aboveground total tree biomass (dry weight) plotted over dbh and ht for each site are displayed in Figure 2.

To determine the total belowground dry weights of the excavated parts of the trees we first converted all the fresh weights from the different sections to dry weight biomass by multiplying the tree- and section specific DFratios and their respective fresh weights. We then developed a general (combined data from all sites) side root model by regressing the dry weight biomass of the fully excavated side roots and their diameters (cm). We assumed the relationship between side root biomass and root diameter (similarly for main roots, see below) to exhibit a power-law relationship described as:

$$B = a \times \mathrm{d}^{\mathrm{b}} \qquad (1)$$

where B = dry weight biomass of a side root or main root (kg); d = diameter (cm) of a side or main root at the point it is joining the main root or the root crown, respectively; a and b are parameter estimates. The following side root model was developed:

$$B = 0.198102 \times d^{1.656968} \quad PseudoR^2 = 0.67 \; MPE\% = -2.0 \tag{2}$$

where

$$\text{PseudoR}^2 = 1 - \left(\frac{SSR}{CSST}\right) \tag{3}$$

SSR is the sum of squared residuals (SSR) and CSST is the corrected total sum of squares (CSST). The mean prediction error (MPE), and the relative mean prediction error (MPE%) is defined as

$$MPE = \sum_{i=1}^{n} \frac{(y_i - \hat{y}_i)}{n}, \; MPE\% = \frac{MPE}{\bar{y}} \times 100 \tag{4}$$

y_i is the observed biomass of tree i, is the predicted biomass of tree i and is the mean observed biomass. Both MPE and MPE% are based on leave-one-out-cross validation.
The MPE% value for the side root model was not significantly different from zero indicating appropriate model performance.

The side root model was used to predict the dry weight biomass of all the side roots that were not excavated for the main sample root. The total dry weight of all side roots for each main sample root was then determined by summing dry weights of the excavated side roots and predicted dry weights of unexcavated side roots. Finally the complete dry weight of the sample main root was determined by summing the total dry weights of all side roots and the excavated parts of the main root. The following main root model was then developed and applied to predict the dry weights of main roots not excavated;

$$B = 0.063132 \times d^{2.174388}, \; PseudoR^2 = 0.79, \; MPE\% = -0.4 \tag{5}$$

The MPE% value for the main root model was not significantly different from zero indicating appropriate model performance.
To determine the dry weight of unexcavated parts of the tap roots (16 trees), we applied the general side root model.
Total belowground dry weight biomass for each tree was finally determined by summarizing dry weights of all excavated and unexcavated main roots, dry weight of the tap root and the dry weight of the root crown. Total belowground biomass (dry weight) plotted over dbh and ht for each site are displayed in Figure 3.
The RS-ratio for each excavated tree was computed as the ratio between belowground and aboveground dry weights.

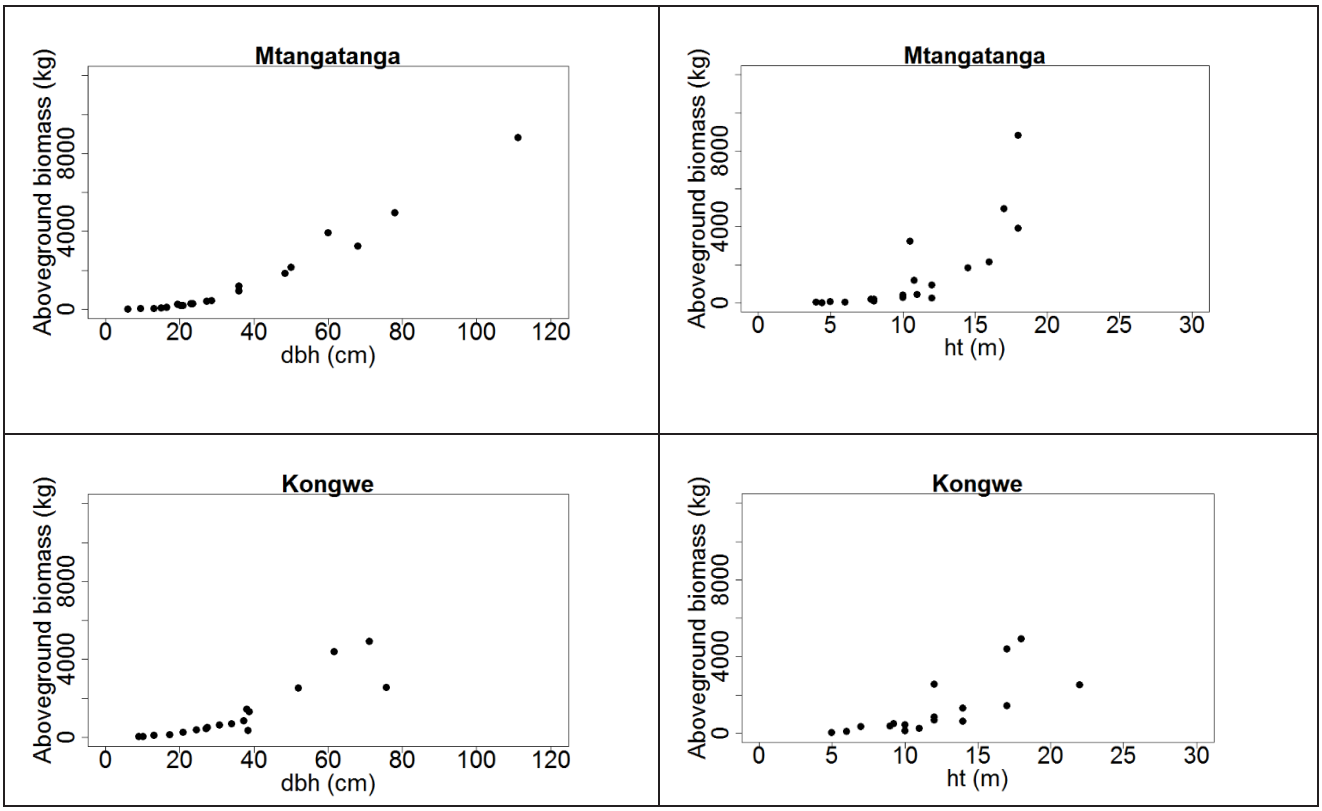
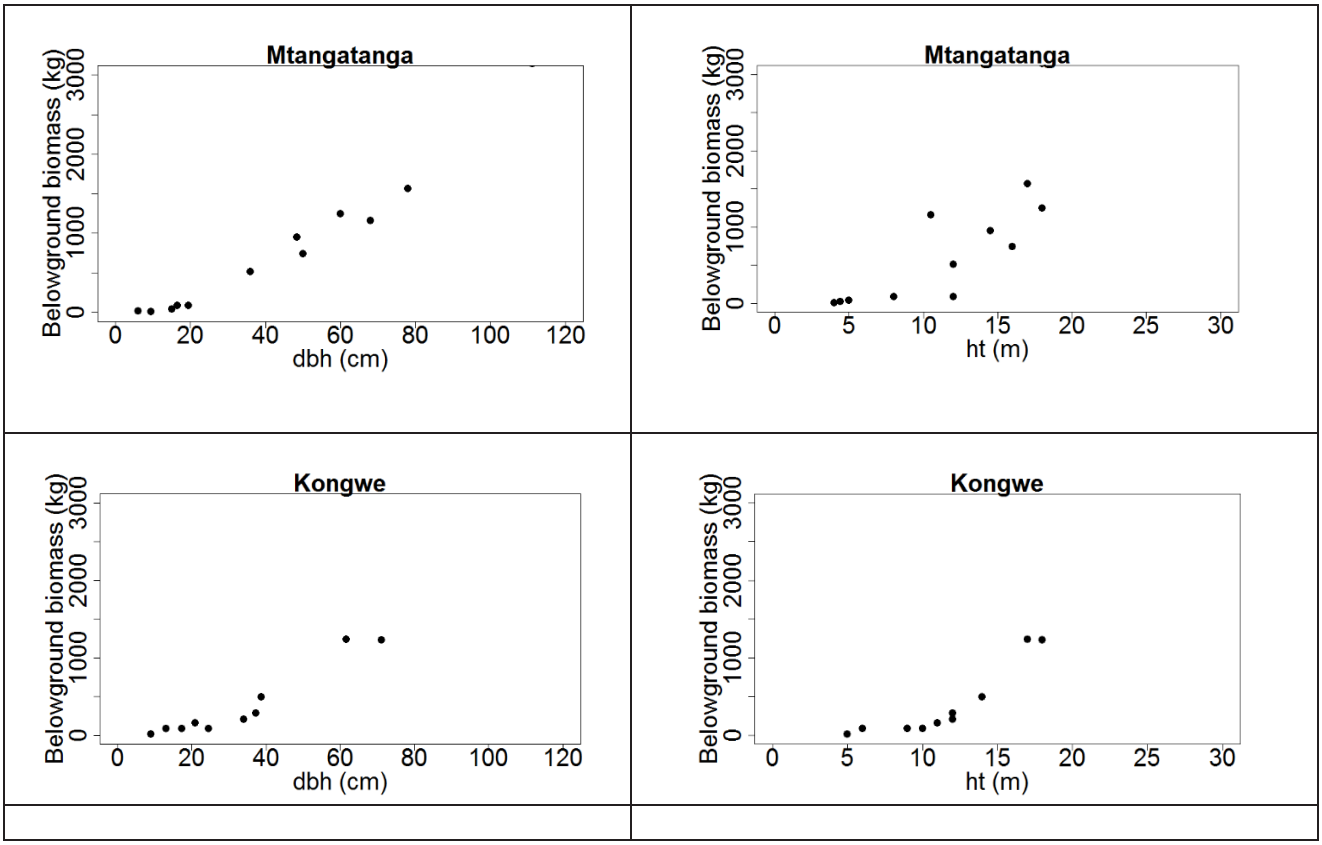


Figure 2: Total aboveground tree biomass (kg dry weight) distribution over dbh (cm) and ht (m) for Mtangatanga, Kongwe, Mua-livulezi and Tsamba and forest reserves.



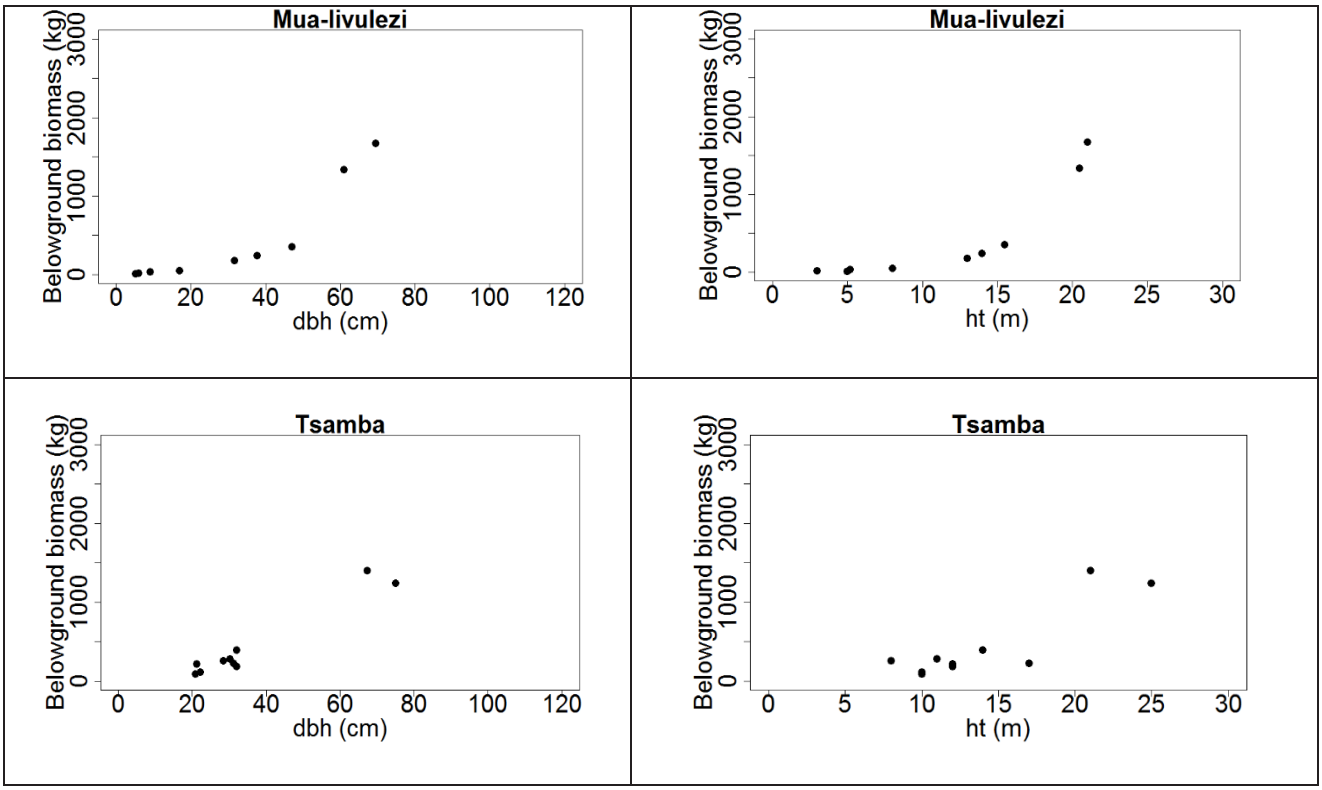


Figure 3: Total belowground tree biomass (kg dry weight) distribution over dbh (cm) and ht (m) for Mtangatanga, Kongwe, Mua-livulezi and Tsamba and forest reserves.

Model development and evaluation

Before fitting the models, we assessed the basic diagnostic plots of biomass over dbh and ht. As expected, the plots indicated non-linear patterns in the relationships between biomass and dbh and ht (Figures 2 and 3). Since wood specific gravity (ρ) is considered as important for explaining variation in biomass of trees (e.g. [36]), we also included this variable in the modelling. We therefore tested the following models:

Model 1: $$B = a \times \mathrm{dbh}^{b} \quad (6)$$

Model 2 : $$B = a \times \mathrm{dbh}^{b} \times ht^{c} \quad (7)$$

Model 3: $$B = a \times \mathrm{dbh}^{b} \times \rho^{c} \quad (8)$$

Model 4: $$B = a \times \mathrm{dbh}^{b} \times ht^{c} \times \rho^{d} \quad (9)$$

where B is biomass (kg), dbh is diameter at breast height (cm), ht is total tree height (m) and ρ is the species-specific mean wood specific gravity (g/cm3) extracted from the global wood density database [37,38] and a, b, c and d are parameter estimates.

Since the data was collected from different study sites located in different geographical regions and ecological zones across Malawi, we anticipated that individual tree attributes would be different depending on site. We therefore initially fitted mixed effects models, with site as a random effect, to the side root, main root and total belowground and aboveground biomass datasets using PROC NLMIXED of SAS 9.4 [39]. This procedure fits nonlinear mixed models, that is, models in which both fixed and random effects enter nonlinearly. PROC NLMIXED fits nonlinear mixed models by maximizing an approximation to the likelihood integrated over the random effects using the

maximum likelihood estimation method.
The developed mixed effects models were compared with weighted nonlinear regression models developed using PROC MODEL procedure of SAS 9.4 [39]. This procedure analyses models in which the relationships among the variables comprise a system of one or more nonlinear equations using the full information maximum likelihood (FIML) estimation method.

For each model derived from the two procedures, i.e. mixed effects and weighted regression, we computed Akaike Information Criteria (AIC) values [40]. AIC is a measure for testing the goodness-of-fit of models whilst correcting for model complexity. We used the AIC values to compare the mixed effects models with the weighted regression nonlinear models. The results showed that, in all cases, weighted regression models produced lower AIC values than the mixed effects models. We thus decided to develop our final models based on weighted regression.

Model efficiency and performance of the developed models were assessed based on results from a leave-one-out cross validation procedure [41]. This procedure involves splitting the dataset of n observations into two parts, namely, a training dataset and validation dataset. The validation dataset comprises a single observation (x1, y1) and the training dataset comprises the remaining {(x2, y2),….., (xn, yn)} observations. The model is fitted on the n-1 observations in the training dataset and a prediction is made for the single observation in the validation dataset, using its value x1. Since (x1, y1) was not used in the fitting process, Square Error (SE) = (y1 -)2 provides an estimate for the test error. This procedure is repeated n times and thus producing n test errors, SE1…….SEn. The leave-one-out-cross validation estimate for the test error is the mean of these n test error estimates (MSE).

The cross validation results were then used to calculate Root Mean Square Error (RMSE). RMSE was calculated as follows;

$$RMSE = \sqrt{MSE} \tag{10}$$

$$RMSE\% = \frac{RMSE}{\bar{y}} \times 100 \tag{11}$$

where is the mean observed biomass and RMSE% is the relative Root Mean Square Error.
Model comparison was based on AIC values. Models with insignificant parameter estimates were not considered irrespective of AIC values. For all the models, we presented pseudo-R2, RMSE, RMSE%, covariance matrix for the parameter estimates, MPE and MPE% values. Student t-tests were done to determine whether the MPE values were significantly different from zero.

We also tested a number of previously developed biomass models (Table 3) on our data. This included models developed for miombo woodlands in neighbouring countries, i.e. Ryan et al. [4] in Mozambique, Mugasha et al. [20] in Tanzania and Chidumayo [17] in Zambia, and the pan-tropical model developed by Chave et al. [36] MPE values were computed, and then student t-tests applied to determine whether the MPE values were significantly different from zero.

For a graphical display of the behaviour of models with ht as independent variable, i.e. Mugasha et al. [20] and Chave et al. [36] (see Table 3), we applied a height-diameter model developed from our sample trees:

$$ht = 1.3 + \exp 3.787685 - 6.62809 \times \ \mathrm{dbh}^{-0.45222}. \tag{12}$$

Furthermore, for Chave et al. [36], we extracted ρ values for the trees that were used in model development from the global wood density database [37,38] and subsequently calculated a mean ρ value, which was then used for the graphical display of this model.

Table 3: Statistics of previously developed models tested on modeling data.

Tree section	Author	Model	Sites	Sample trees	dbh range (cm)	Species
Above-ground	Mugasha et al. [20]	$B = 0.1027 \times \mathrm{dbh}^{2.4798}$	4	167	1.1 - 110	60
	Mugasha et al. [20]	$B = 0.0763 \times dbh^{2.2046} \times ht^{0.4918}$	4	167	1.1 - 110	60
	Ryan et al. [4][a]	$C = -3.629 + 2.601 \times \log(dbh)$	1	29	5 - 73	6
	Chidumayo [17]	$B = -2.5265 + 2.5553 \times \log(dbh)$	1	113	2 - 39	19
	Chave et al. [36][b]	$B = 0.0673 \times (\rho \times dbh^2 \times ht)^{0.976}$	58	4004	5 - 180	Unclear
Below-ground	Mugasha et al. [20]	$B = 0.2113 \times \mathrm{dbh}^{1.9838}$	4	80	3.3 - 95	60
	Mugasha et al. [20]	$B = 0.1766 \times dbh^{1.7844} \times ht^{0.3434}$	4	80	3.3 - 95	60
	Ryan et al. [4][a]	$C = -3.370 + 2.262 \times \log(dbh)$	1	23	5 - 72	6
	Chidumayo [17]	$B = -1.9439 + 2.1712 \times \log(dbh)$	1	12	4 - 35	19

aCarbon converted to biomass as , b ρ (g/cm3) derived from global wood density database [37,38].

RESULTS

The mean RS-ratio of the 41 trees sampled both above- and belowground was 0.47 (Table 4). No significant differences in RS-ratios were found between sites (p = 0.8684). The RS-ratio decreased nonlinearly with increase with dbh (see Figure 4).

Table 4. Root to shoot ratio (RS-ratio) over sites.

Site	n	Mean	Min	Max	STD
Mtangatanga	12	0.49	0.32	1.15	0.25
Kongwe	10	0.44	0.22	0.91	0.22
Mua-livulezi	9	0.51	0.27	0.92	0.27
Tsamba	10	0.44	0.21	0.78	0.16
All	41	0.47	0.18	1.15	0.22

Note: n is the number of trees, STD = standard deviation

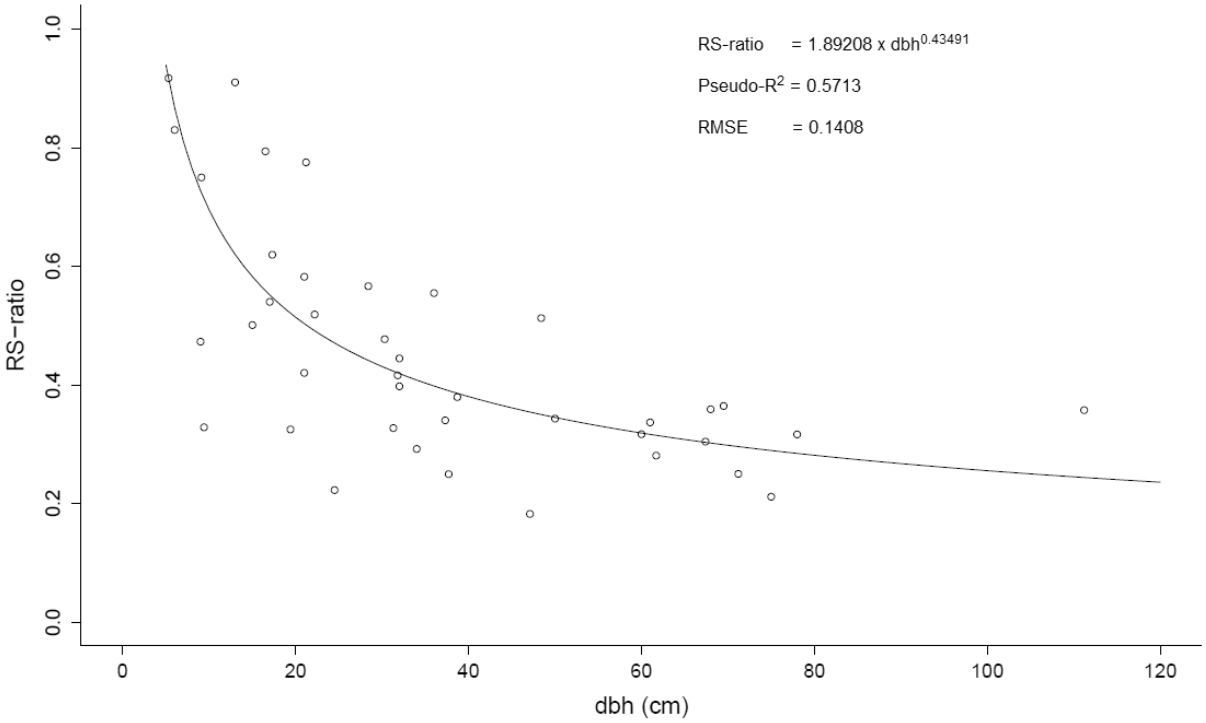


Figure 4: Display of root to shoot ratio (RS-ratio) over diameter at breast height (dbh). The dots represent observations for individual trees and the line represents the fitted nonlinear model.

Parameter estimates and performance criteria for the above- and belowground models are shown in Table 5. For aboveground biomass, all models, except Model 4, had significant parameter estimates and appropriate performance criteria. None of the models had MPE% values significantly different from zero ($p > 0.05$). Among these models, Model 2 with dbh and ht as independent variables provided the smallest AIC value. The pseudoR^2 values for the models were ranging from 0.93 to 0.97. For belowground biomass, Model 1 was the only one where all parameter estimates were significant. Covariance matrices for all models with significant parameter estimates in Table 5 are shown in Appendix 3.

Among the models with significant parameter estimates for twigs, branches and stems biomass (see Table 6), Models 1, 2 and 2, respectively, provided the smallest AIC values. The pseudoR^2 values for the twigs, branches and stem models with significant parameter estimates were 0.82, 0.91-0.92 and 0.77-0.88, respectively.

Table 5. Model parameters and performance criteria of above- and belowground biomass models.

Component	Model	n	Model	Pseudo-R^2	RMSE (kg)	RMSE (%)	MPE (kg)	MPE (%)	AIC
Above ground	1	74	$0.21691 \times dbh^{2.318391}$	0.93	751.18	60.6	-22.21	-1.8	981.89
	2	74	$\mathbf{0.103685 \times dbh^{1.921719} \times ht^{0.844561}}$	**0.97**	**426.59**	**34.4**	**-19.75**	**-1.6**	**954.27**
	3	74	$0.290457 \times dbh^{2.283998} \times \rho^{0.443619}$	0.94	923.06	74.5	-53.18	-4.3	977.05
	4	74	$0.129899 \times dbh^{1.90203} \times ht^{0.828647} \times \rho^{0.296271NS}$	0.97	542.05	43.7	-37.11	-3.0	952.35
Below ground	1	41	$\mathbf{0.284615 \times dbh^{1.992658}}$	**0.94**	**161.68**	**30.7**	**-4.81**	**-0.9**	**481.23**
	2	41	$0.224132 \times dbh^{1.899061} \times ht^{0.222554NS}$	0.94	169.73	32.2	-7.43	-1.4	481.73
	3	41	$0.415451 \times dbh^{1.933905} \times \rho^{0.465663NS}$	0.94	175.37	33.3	-5.04	-1.0	481.74
	4	41	$0.350488 \times dbh^{1.732452} \times ht^{0.395127NS} \times \rho^{0.836154NS}$	0.94	170.16	32.3	-6.52	-1.2	479.66

^{NS} Parameter estimate not significant ($p > 0.05$). Note: biomass in kg, dbh in cm, ht in m, and ρ in g/cm^3, Bold: best model according to AIC

Table 6. Model and performance criteria for twigs, branches and merchantable stem biomass models.

Component	Model	n	Model	Pseudo-R^2	RMSE		MPE		AIC
					(kg)	(%)	(kg)	(%)	
Twigs	**1**	**72**	$\mathbf{0.07239 \times dbh^{1.858897}}$	**0.82**	**39.32**	**62.5**	**-0.75**	**-1.2**	**602.84**
	2	72	$0.070224 \times dbh^{1.598204} \times ht^{0.384139NS}$	0.84	37.82	60.1	-1.09	-1.7	634.09
	3	72	$0.130116 \times dbh^{1.764995} \times \rho^{0.687581NS}$	0.83	44.29	70.4	-1.36	-2.2	616.35
	4	72	$0.109969^{NS} \times dbh^{1.446488} \times ht^{0.549901} \times \rho^{0.951968}$	0.83	40.18	63.9	-1.54	-2.4	631.63
Branches	1	74	$0.137316 \times dbh^{2.328104}$	0.91	659.80	80.9	-25.44	-3.1	973.58
	2	**74**	$\mathbf{0.051157 \times dbh^{2.161115} \times ht^{0.598879}}$	**0.92**	**565.21**	**69.3**	**-22.62**	**-2.8**	**933.50**
	3	74	$0.123375 \times dbh^{2.379626} \times \rho^{0.30643NS}$	0.91	788.99	96.8	-47.53	-5.8	946.79
	4	74	$0.059792 \times dbh^{2.150762} \times ht^{0.582627} \times \rho^{0.20053NS}$	0.92	692.17	84.9	-39.25	-4.8	934.74
Stems	1	60	$0.145576 \times dbh^{2.116265}$	0.77	299.91	66.9	-1.18	-0.3	773.89
	2	**60**	$\mathbf{0.030811 \times dbh^{1.572422} \times ht^{1.345696}}$	**0.88**	**249.88**	**55.8**	**5.29**	**1.2**	**737.16**
	3	60	$0.221213 \times dbh^{2.059249} \times \rho^{0.544483}$	0.79	330.15	73.7	-13.91	-3.1	772.48
	4	60	$0.039194 \times dbh^{1.554911} \times ht^{1.329832} \times \rho^{0.36722NS}$	0.88	256.20	57.2	2.55	0.6	737.75

[NS] Parameter estimate not significant ($p > 0.05$). Note: biomass in kg, dbh in cm, ht in m, and ρ in g/cm3 Bold: best model according to AIC

We further evaluated the above- and belowground biomass models over sites and dbh classes (Table 7). None of the tested models produced MPE values significantly different from zero ($p > 0.05$) overall or for any site. However, a significant MPE was observed for dbh class 0-20 cm for Model 3. For the aboveground biomass models, MPE% values ranged from 0.4% to 15.1% while for the belowground biomass model, the MPE% values ranged from 2.1% to 3.9%.

Finally we tested the previously developed models (see Table 3) on our dataset (Table 8). The MPE% when applying the aboveground biomass models developed by Mugasha et al. [20], Ryan et al. [4], Chidumayo [17] and Chave et al. [36] ranged from 2.8 to 30.8 (under prediction). The above- and belowground biomass models developed by Chidumayo [17] generally produced the lowest MPE% values, i.e. 2.8% and -4.7%, respectively. Figures 5 and 6 display above- and belowground biomass over dbh for some of the models develop in the current study and some from the previous studies.

Table 7: Evaluation of the models over study sites and dbh classes.

Component	Model	Variable		n	Observed	Predicted	MPE	
					(kg)	(kg)	(kg)	(%)
Aboveground	1	Site	Mtangatanga	20	1465.46	1606.23	-140.78	-9.6
			Kongwe	18	1195.37	1200.61	-5.24	-0.4
			Mua-livulezi	18	1316.71	1231.45	85.26	6.5
			Tsamba	18	956.25	882.41	73.84	7.7
		dbh class	0-20	21	79.72	93.36	-13.64	-17.1
		(cm)	21-40	35	545.55	584.08	-38.53	-7.1
			41-60	6	2225.43	1911.58	313.85	14.1
			>60	12	4801.51	4826.03	-24.52	-0.5
		All		74	1239.72	1240.34	-0.62	-0.1
	2	Site	Mtangatanga	20	1465.46	1424.10	41.36	2.8
			Kongwe	18	1195.37	1146.81	48.56	4.1
			Mua-livulezi	18	1316.71	1337.79	-21.09	-1.6
			Tsamba	18	956.25	1032.17	-75.92	-7.9
		dbh class	0-20	21	79.72	86.26	-6.54	-8.2
		(cm)	21-40	35	545.55	578.46	-32.91	-6.0
			41-60	6	2225.43	2111.90	112.51	5.1
			>60	12	4801.51	4754.08	47.43	1.0
		All		74	1239.72	1240.32	-0.61	-0.1
	3	Site	Mtangatanga	20	1465.46	1686.27	-220.82	-15.1
			Kongwe	18	1195.37	1133.28	62.09	5.2
			Mua-livulezi	18	1316.71	1205.35	111.36	8.5
			Tsamba	18	956.25	889.28	66.97	7.0
		dbh class	0-20	21	79.72	96.25	-16.53	-20.7*
		(cm)	21-40	35	545.55	585.55	-40.00	-7.3
			41-60	6	2225.43	1936.38	289.05	13.0
			>60	12	4801.51	4807.83	-6.33	-0.1
		All		74	1239.72	1240.92	-1.20	-0.1
Belowground	1	Site	Mtangatanga	12	795.91	777.003	18.91	2.4
			Kongwe	10	386.30	401.365	-15.07	-3.9
			Mua-livulezi	9	427.68	418.911	8.77	2.1
			Tsamba	10	435.33	450.847	-15.52	-3.6
		dbh class	0-20	12	42.13	46.12	-3.99	-9.5
		(cm)	21-40	16	240.31	259.28	-18.96	-7.9
			41-60	4	821.28	736.86	84.41	10.3
			>60	9	1553.41	1551.89	1.51	0.1
		All		41	527.23	527.228	-0.00	-0.0

*MPE is significantly different from zero ($p < 0.05$)

Table 8: Evaluation of previously developed models.

Tree component	Model	Independent variable(s)	n	Observed (kg)	Predicted (kg)	MPE (kg)	(%)
Aboveground	Mugasha et al. [20]	dbh	74	1239.72	1135.70	104.02	8.4
	Mugasha et al. [20]	dbh, ht	74	1239.72	1076.68	163.04	13.2**
	Ryan et al. [4]	dbh	74	1239.72	1068.84	170.88	13.8*
	Chidumayo [17]	dbh	74	1239.72	1205.63	34.09	2.8
	Chave et al. [36]	dbh, ρ, ht	74	1239.72	953.66	286.06	23.1***
Belowground	Mugasha et al. [20]	dbh	41	527.23	377.51	149.72	28.4***
	Mugasha et al. [20]	dbh, ht	41	527.23	364.83	162.40	30.8***
	Ryan et al. [4]	dbh	41	527.23	426.92	100.31	19.0***
	Chidumayo [17]	dbh	41	527.23	551.89	-24.66	-4.7

*MPE is significantly different from zero at ($p < 0.05$), ** MPE is significantly different from zero at ($p < 0.01$) and ***MPE is significantly different from zero at ($p < 0.001$)

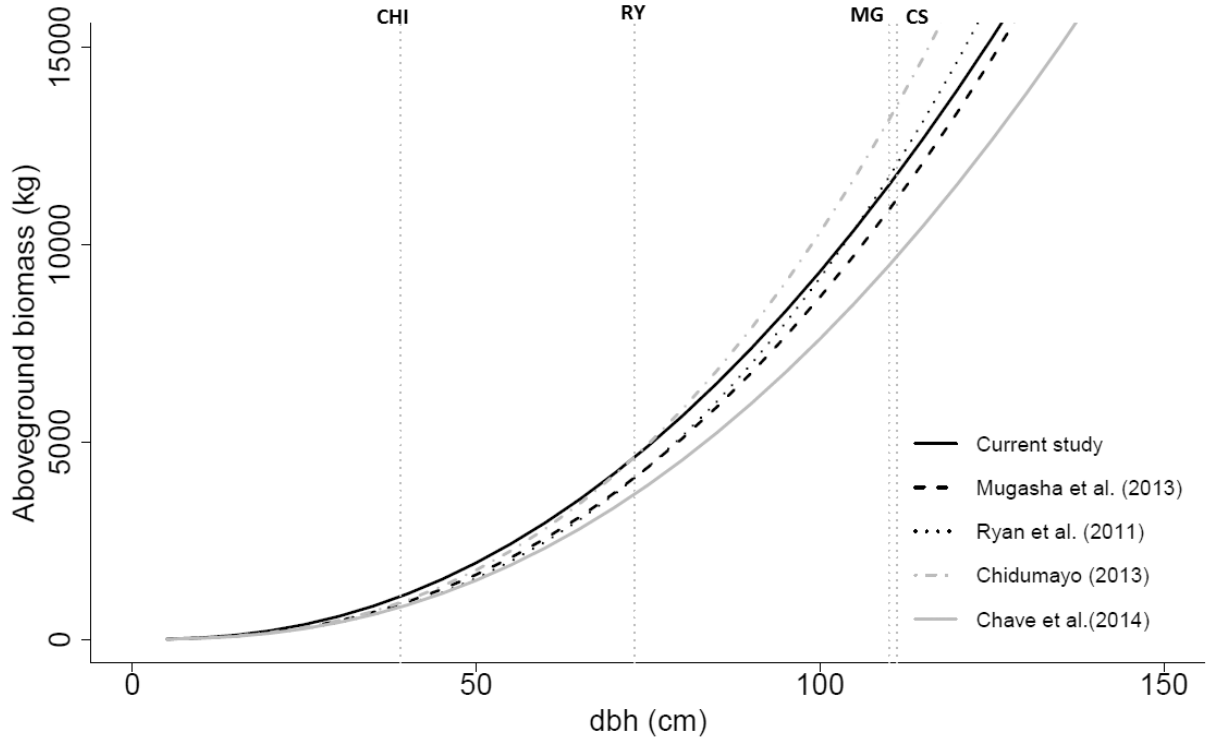


Figure 5: Display of aboveground biomass (dry weight) over dbh based on the general models developed in this study (with dbh and ht as independent variables), by Mugasha et al. [20] (with dbh and ht as independent variables), by Ryan et al. [4] (with dbh as only independent variable), by Chidumayo [17] (with dbh only as independent variable) and by Chave et al. [36] (with dbh, ρ, and ht as independent variables). CHI, RY, MG and CS are the maximum dbh values for the data used in the models developed by Chidumayo [17], Ryan et al. [4], Mugasha et al. [20] and current study, respectively.

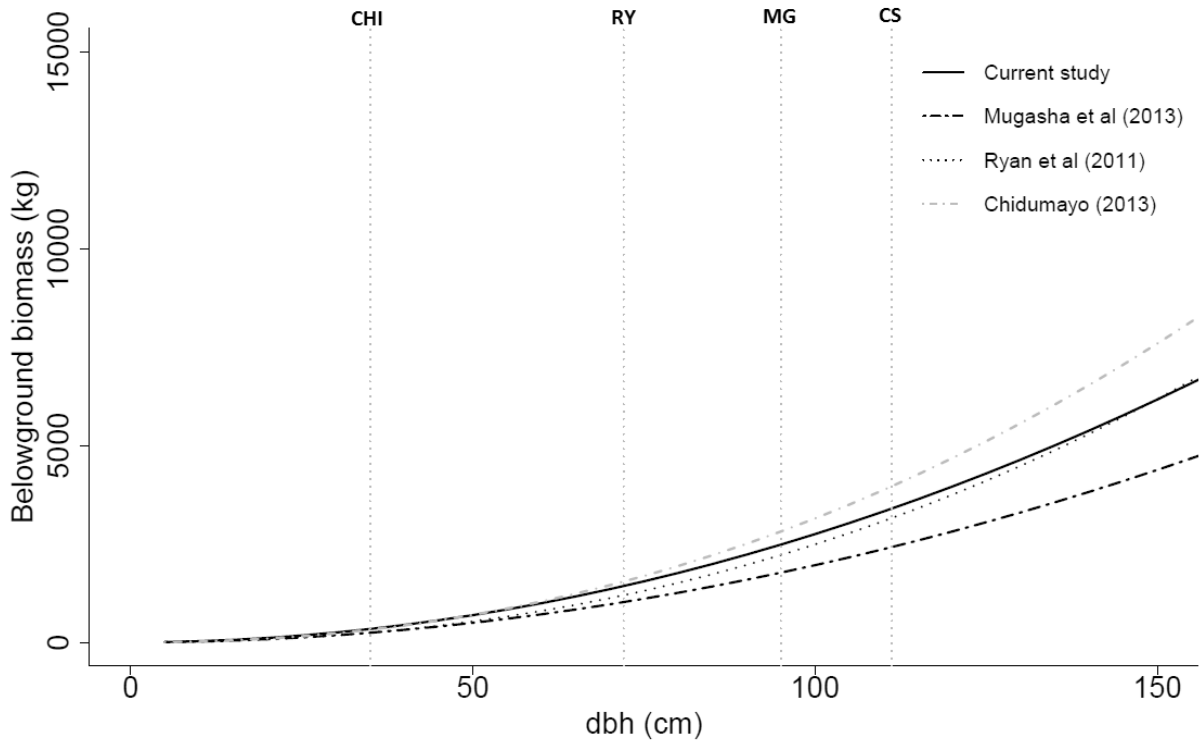


Figure 6: Display of belowground biomass (dry weight) over dbh based on the general models developed in this study, by Mugasha et al. [20], by Ryan et al. [4] and by Chidumayo [17]. All models had dbh as the only independent variable. CHI, RY, MG and CS are the maximum dbh values for the data used in the models developed by Chidumayo [17], Ryan et al. [4], Mugasha et al. [20] and current study, respectively.

DISCUSSION

Capturing of a wide range of natural variability in factors that affect tree growth such as soil types, temperature and rainfall is important for developing robust biomass models [20,36]. The modelling dataset for this study was collected from sites located in all the three regions of Malawi, i.e. north, central and south (see Figure 1). Application of sound sampling procedures when selecting sample trees is also critical in development of models as it may help in reducing the probability of biases. In this study, we selected trees based on information from independent prior systematic sample plot inventories for each site. We also included a number of very large trees to avoid extrapolation beyond the data ranges as much as possible. Our sample trees comprised of 33 out of the 139 different tree species identified during the forest inventories for the four study sites. Compared to most previous studies our dataset included a relatively large number of tree species. The modelling dataset of Mugasha et al.[20] comprised 60 tree species, while those of Chidumayo [17] and Ryan et al. [4], had 19 and 6 species, respectively. It is also worth mentioning that although the proportion of the number of tree species in our dataset is relatively low compared to total number of tree species reported in miombo woodlands [21-26], the information from the prior forest inventories ensured that the most frequent species were always represented, in addition to species selected randomly among the remaining less frequent species.

RS-ratio may be an important alternative for estimating belowground tree biomass in cases where allometric models are not available (see [13,42]). The mean RS-ratio from the present study (0.41, see Table 4) is higher than those reported by Mugasha et al. [20] and Ryan et al. [4] for miombo woodlands (0.40 and 0.42 respectively). However, Chidumayo [17] reported a mean value of 0.54

which is comparatively larger. Since the RS-ratio is decreasing with increasing dbh (Figure 4), the mean value depends heavily on the size distribution of the trees in the sample. The high mean RS-ratio found by Chidumayo [17] is therefore likely to be a result of the relatively small range of trees sizes in his dataset (see Table 3) rather than a higher proportion of root biomass in trees from mombo woodlands in Zambia. It is also worth mentioning that mean RS-ratios frequently are used to estimate belowground biomass (e.g. [43]). However, by using a fixed mean RS-ratio for a relationship that most probably is non-linear (Figure 4), a bias will be introduced (see e.g. [44]). Therefore, application of mean RS-ratios to estimate belowground should be done with care. In the lack of belowground models, however, RS-ratios depending on dbh could be an adequate alternative.

Among the aboveground biomass models with significant parameter estimates, Model 2 (with dbh and ht as independent variables) had the smallest AIC value (Table 5). Models with both dbh and ht as independent variables tend to be better than those with dbh only (see e.g. [20,36]). Inclusion of ρ as independent variable (Model 3), in place of ht (Model 2), did not improve aboveground biomass prediction. This could be attributed to the fact that the ρ values were not obtained directly from the sample trees, but from the global wood density database [37,38]. The fact that we failed, contrary to expectations (see e.g. [36]), when including both ht and ρ as independent variables in addition to dbh (Model 4, Table 5), could also be related to the use of ρ from the global wood density database. The fit statistics of the best aboveground model, i.e. the model with the smallest AIC value (Model 2), is similar (pseudo-R2 = 0.97) to that of the models developed by Mugasha et al. [20] (pseudo-R2 = 0.95), Chidumayo [17] (R2 = 0.98) and Ryan et al. [4] (adjusted-R2 = 0.93).

Although Model 2 is generally considered the best aboveground biomass model, it should be noted that Models 1 and 3 can still be applied during forest inventories in cases where ht is lacking or considered as inaccurate. Application of Model 2 require measuring both dbh and ht during a forest inventory. In such cases, ht for individual trees are usually predicted based on dbh-ht models developed from sample trees collected from the study site because ht measurements on all trees is too time consuming. However, tree height measurements are also prone to errors, especially in closed-canopy forests, due to differences in crown shapes and inaccurate sights of tree tops and due to challenges in steep terrain [45,46].

Among the belowground biomass models, the only viable model, i.e. with significant parameter estimates, was the one with dbh as the only independent variable (Model 1). The fit statistics of this model is similar (pseudo-R2 = 0.94) to that of the models developed by Mugasha et al. [20] (pseudo-R2 = 0.92), Chidumayo [17] (R2 = 0.95) and Ryan et al. [4] (adjusted-R2 = 0.94).

Proper implementation of the REDD+ mechanism in participating countries, including Malawi, requires biomass estimates to be accompanied with an estimate of uncertainty (see [32]). Uncertainty of biomass estimates is usually computed from estimates of errors in the parameters of employed biomass models [31]. We have therefore, in Appendix 3, displayed the covariance matrices of model parameters for all the valid models in Table 5 to enable potential users in estimating the uncertainty in biomass estimates during national forest inventories and monitoring, reporting and verification systems under the REDD+ mechanism (see [31,32]).

Tree component biomass models, i.e. models for twigs, branches and stems, may be useful when planning commercial extraction of timber or quantification of biomass for domestic fuelwood or charcoal production (see [34]). All tree component models with significant parameter estimates produced MPE% values not significantly different from zero (see Table 6). This is an indication of an appropriate performance.

The evaluation of the developed above- and belowground models on our own data showed that no models produced MPE% significantly different from zero for any site (Table 7), thus indicating appropriate performance. The trend was the same over dbh classes except for the smallest dbh class under Model 3. It should be noted that the magnitude of MPE% seen over sites in Table 7 are the kind of errors that should be expected over sites if we were to apply our models across Malawi, e.g. in a national forest inventory.

Generally, the previously developed models from neighbouring countries resulted into large prediction errors significantly different from zero when they were applied on our data (Table 8). Exceptions from this were seen for one of the aboveground biomass models developed by Mugasha et al. [20] and for the above- and belowground models developed by Chidumayo [17]. For the recently developed pan tropical aboveground biomass model developed by Chave et al. [36] the prediction error was also large and significantly different zero. The generally large prediction errors when appliying the previously developed models is of course not surprising since they are applied outside their respective data ranges. These results, however, also demonstrate the importance of developing local models for Malawi.

CONCLUSIONS

We have developed general above- and belowground, stem, branches and twigs biomass models for miombo woodlands of Malawi. The performance criteria derived from the models and the results of the evaluations suggest that the models can be used over a wide range of geographical and ecological conditions in Malawi. The generally large prediction errors seen when applying the previously developed models from neighbouring countries on our data demonstrated the importance of developing local models for Malawi.

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Appendix 1: Dataset used for model development

Site	Scientific name	Local name	dbh (cm)	ht (m)	Twig biomass	Branch biomass	Stem biomass	Total below ground biomass	Use
Mtangatanga	*Brachystegia glaucescens*	Musani	6.0	4.4	2.69	2.25	10.55	17.83	a,b
	Erica banguelensis	Msankhanya	9.4	4.0	4.79	8.30	5.62	6.15	a,b
	Erica banguelensis	Msankhanya	13.0	6.0	1.65	13.38	16.60	N/A	a
	Uapaca kirkiana	Msuku	15.0	5.0	16.00	20.26	37.18	36.79	a,b
	Julbernadia paniculata	Mtondo	16.5	8.0	9.49	37.45	59.10	84.21	a,b
	Isoberlinia angolensis	Kabale	19.4	12.0	24.36	122.09	119.83	86.52	a,b
	Brachystegia boehmii	Mombo	20.2	8.0	13.33	119.37	61.28	N/A	a
	Uapaca kirkiana	Msuku	21.0	7.8	19.42	93.32	62.41	N/A	a
	Brachystegia utilis	Nzale	23.0	10.0	30.68	150.68	97.42	N/A	a
	Brachystegia taxifolia	Mchinji	23.6	10.0	34.50	135.62	101.65	N/A	a
	Julbernadia paniculata	Mtondo	27.3	10.0	29.16	238.00	145.08	N/A	a
	Isoberlinia angolensis	Kabale	28.6	11.0	29.72	363.65	51.60	N/A	a
	Brachystegia spiciformis	Chumbe	36.0	12.0	52.65	512.81	355.59	N/A	a
	Brachystegia longifolia	Sanga	36.0	10.8	88.75	722.68	361.59	511.14	a,b
	Brachystegia glaucescens	Musani	48.4	14.5	189.28	1106.47	551.38	947.07	a,b
	Brachystegia glaucescens	Musani	50.0	16.0	163.97	1512.85	483.90	741.53	a,b
	Brachystegia spiciformis	Chumbe	60.0	18.0	218.80	2725.55	990.68	1247.00	a,b
	Brachystegia glaucescens	Musani	68.0	10.5	162.44	2637.49	433.22	1160.66	a,b
	Brachystegia glaucescens	Musani	78.0	17.0	230.86	3887.22	834.01	1567.18	a,b
	Brachystegia glaucescens	Musani	111.2	18.0	284.98	5425.11	3088.39	3144.87	a,b
Kongwe	*Julbernadia paniculata*	Mtondo	9.0	5.0	3.97	6.55	12.87	11.06	a,b
	Uapaca kirkiana	Msuku	10.2	5.0	7.30	9.41	9.47	N/A	a
	Brachystegia spiciformis	Chumbe	13.0	6.0	9.21	43.34	42.34	86.39	a,b
	Brachystegia manga	Mpapa/Bovo	17.3	10.0	12.30	72.42	53.67	85.74	a,b
	Julbernadia paniculata	Mtondo	21.0	11.0	17.22	138.18	109.47	154.26	a,b
	Brachystegia utilis	Nzale	24.5	9.0	29.54	228.64	110.37	82.05	a,b
	Monotes africanus	Mkalakate	27.2	10.0	35.01	284.26	117.93	N/A	a
	Brachystegia spiciformis	Chumbe	27.5	9.3	61.63	352.88	85.43	N/A	a
	Brachystegia boehmii	Mombo	30.8	14.0	84.86	316.54	235.11	N/A	a
	Uapaca kirkiana	Msuku	34.0	12.0	64.18	492.47	132.92	201.39	a,b
	Parinari curatellifolia	Muula	37.3	12.0	78.86	534.28	226.55	285.68	a,b
	Brachystegia manga	Mpapa/Bovo	38.1	17.0	55.18	961.04	428.88	N/A	a
	Cussonia arborea	Mbwabwa	38.4	7.0	N/A	286.02	60.55	N/A	a
	Brachystegia spiciformis	Chumbe	38.7	14.0	81.81	927.90	288.68	492.70	a,b
	Brachystegia manga	Mpapa/Bovo	52.0	22.0	161.37	1655.77	716.85	N/A	a
	Brachystegia manga	Mpapa/Bovo	61.7	17.0	238.23	3176.82	985.23	1235.32	a,b
	Brachystegia spiciformis	Chumbe	71.2	18.0	252.66	3136.09	1525.32	1228.41	a,b
	Erythrina abyssinica	Muwale	75.7	12.0	N/A	2282.05	277.06	N/A	a
Mua-livulezi	*Markhamia obtusifolia*	Msewa	5.3	5.0	1.18	1.86	3.24	5.76	a,b
	Combretum apiculatum	Kakunguni	6.0	3.0	2.40	5.04	7.54	12.44	a,b
	Bauhinia petersiana	Mphandula	9.1	5.2	7.35	7.70	21.41	27.35	a,b
	Bauhinia thoningii	Msekese	13.0	5.0	5.23	24.82	31.50	N/A	a
	Diplorhynchus condylocarpon	Thombozi	16.2	10.4	6.12	34.85	43.70	N/A	a
	Anonna senegalensis	Mpoza	17.0	8.0	9.68	38.84	35.39	45.32	a,b
	Markhamia obtusifolia	Msewa	20.0	9.3	8.74	72.34	61.76	N/A	a
	Pterocarpus rotundifolius	M'balitsa	22.0	8.5	15.57	109.46	45.10	N/A	a
	Albizzia versicolor	Mtangatanga	23.2	10.4	9.47	119.91	85.21	N/A	a
	Bauhinia petersiana	Mphandula	27.4	7.9	54.06	228.20	84.36	N/A	a
	Diplorhynchus condylocarpon	Thombozi	31.8	13.0	16.73	243.98	146.54	169.49	a,b
	Vachellia galpinni	Mgundanjira	37.7	14.0	21.36	406.84	504.09	232.60	a,b
	Pterocarpus rotundifolius	M'balitsa	42.0	15.0	47.76	559.66	352.17	N/A	a
	Brachystegia spiciformis	Chumbe	47.1	15.5	94.37	1274.86	546.90	349.50	a,b
	Brachystegia bussei	Mtwana	61.0	20.5	141.81	2913.06	915.62	1337.13	a,b

	Pseudolachnostaylis maprouneifolia	Msolo	61.0	15.6	60.39	2092.83	840.73	N/A	a
	Brachystegia spiciformis	Chumbe	69.5	21.0	189.17	2606.48	1784.99	1669.53	a,b
	Brachystegia bussei	Mtwana	81.7	22.0	228.04	5136.15	1394.20	N/A	a
Tsamba	*Uapaca kirkiana*	Msuku	8.4	6.5	2.67	4.52	10.83	N/A	a
	Brachystegia floribunda	Tsamba	9.5	9.0	5.22	8.41	23.83	N/A	a
	Pseudolachnostaylis maprouneifolia	Msolo	12.4	7.0	18.28	42.16	45.47	N/A	a
	Brachystegia floribunda	Tsamba	19.9	8.0	19.30	160.96	107.38	N/A	a
	Parinari excelsa	Mpembu	21.0	10.0	15.17	77.09	112.80	86.19	a,b
	Julbernadia globiflora	Kachumbe	21.0	10.0	19.49	48.01	155.53	N/A	a
	Brachystegia spiciformis	Chumbe	21.2	12.0	28.07	112.12	131.52	210.71	a,b
	Uapaca sansibarica	Msokolowe	22.2	10.0	15.39	109.87	87.04	110.15	a,b
	Pericorpsis angolensis	Muwanga	28.4	8.0	17.72	144.37	278.13	249.44	a,b
	Uapaca kirkiana	Msuku	30.3	11.0	22.90	377.42	181.62	277.68	a,b
	Pterocarpus angolensis	Mlombwa	31.3	17.0	15.63	426.49	225.54	218.46	a,b
	Brachystegia utilis	Nzale	32.0	14.0	64.15	554.46	248.95	385.79	a,b
	Uapaca sansibarica	Msokolowe	32.0	12.0	11.94	264.23	169.71	177.29	a,b
	Brachystegia floribunda	Tsamba	34.5	12.0	31.52	143.19	508.27	N/A	a
	Julbernadia globiflora	Kachumbe	37.5	18.0	44.30	520.50	449.21	N/A	a
	Faurea speciosa	Chisese	38.7	16.0	27.74	248.80	417.18	N/A	a
	Julbernadia globiflora	Mchenga	67.4	21.0	189.86	3282.79	1118.56	1397.53	a,b
	Brachystegia spiciformis	Chumbe	75.0	25.0	258.27	2899.10	2708.86	1240.02	a,b

Note: a = aboveground only; a, b = both above-and belowground; N/A = not applicable.

Appendix 2: DF-ratio for stem, branches, twigs, roots, and root crown in the four study sites

Site	**Aboveground**									**Belowground**						
	n	Stem			Branches			Twigs			n	Roots			Root crown		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max		Mean	Min	Max	Mean	Min	Max
Mtangatanga	20	0.61	0.48	0.77	0.57	0.44	0.73	0.51	0.30	0.66	12	0.58	0.46	0.69	0.59	0.53	0.67
Kongwe	18	0.56	0.36	0.71	0.54	0.35	0.65	0.52	0.37	0.65	10	0.58	0.48	0.72	0.57	0.39	0.67
Mua-livulezi	18	0.60	0.54	0.69	0.61	0.54	0.67	0.56	0.44	0.66	9	0.60	0.49	0.70	0.59	0.46	0.68
Tsamba	18	0.59	0.45	0.70	0.58	0.45	0.67	0.53	0.38	0.65	10	0.52	0.45	0.63	0.57	0.51	0.61
All	74	0.59	0.36	0.77	0.58	0.35	0.73	0.53	0.30	0.66	41	0.57	0.45	0.73	0.58	0.39	0.68

Note: The number of sample trees for Kongwe for the twigs section is 16 instead of 18 because two trees did not have twigs.

Appendix 3: Covariance matrices of all valid above- and belowground models

Component	Model	Model	Variable	Covariance matrix		
Side root		$0.198102 \times dbh^{1.656968}$		intercept	dbh	
			intercept	0.00067		
			dbh	-0.00106	0.00176	
Main root		$0.063132 \times dbh^{2.174388}$		intercept	dbh	
			intercept	0.000224		
			dbh	-0.000981	0.00434	
Belowground	1	$0.284615 \times dbh^{1.992658}$		intercept	dbh	
			intercept	0.01184		
			dbh	-0.01018	0.00882	
Aboveground	1	$0.21691 \times dbh^{2.318391}$		intercept	dbh	
			intercept	0.00251		
			dbh	-0.00263	0.00278	
	2	$0.103685 \times dbh^{1.921719} \times ht^{0.844561}$		intercept	dbh	ht
			intercept	0.00058		
			dbh	-0.00045	0.00166	
			ht	-0.00129	-0.00094	0.00580
	3	$0.290457 \times dbh^{2.283998} \times \rho^{0.443619}$		intercept	dbh	ρ
			intercept	0.00592		
			dbh	-0.00422	0.00305	
			ρ	0.00557	-0.00346	0.01364

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Municipal solid waste management, pollution, human health and climate change: A critical review of the City of Blantyre.

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ABSTRACT

Malawi signed the Paris Agreement is September 2015 in solidarity with other nations to reduce greenhouse gas (GHG) emissions and contribute towards the prevention of rise in global temperature above 1.5 degrees Celsius. Malawi's efforts are guided by the Intended Nationally Determined Contributions (INDCs) that was submitted. One of the GHG emitting sectors is waste. This research reviewed solid waste management practices in the city of Blantyre, assessed the impacts and proposed paradigm shift towards sustainable waste management. The study used critical review of literature, analysis of secondary data and interviewed key informants. The results showed the following challenges: indiscriminate dumping of waste, under collection of wastes, mixed waste streams including toxic wastes, open burning of wastes, under maintained waste trucks, lack of purpose built landfills, undervaluation of wastes, lack of political will, limited institutional capacities, outdated curricular as well as unclear institutional and regulatory mandates. The city population, especially in the traditional and low income housing areas, is perpetually exposed to waterborne diseases and stench especially during the wet season. Leachates from dumpsites containing heavy metals and other toxic chemicals contaminate ground water systems and shallow wells. Furthermore, open burning of wastes emits greenhouse and particulate and gaseous toxins (e.g. furans and dioxins). In conclusion, the delegated responsibilities to local government must be accompanied with financial, human and infrastructural resources to facilitate the implementation and enforcement of the Regulations. Therefore, there is need for raising awareness, training and community support, careful location and zoning of dump sites, improvement in the waste management practices at all levels, action plans and by-laws that are in harmony with national standards, policies and regulations. This approach would result in reduced air, water and soil pollution; improved health of communities; reduced GHG emissions and resource (energy and raw materials) recovery.

Key words: Blantyre, solid waste management, climate change, GHG, pollution, human health.

INTRODUCTION

Background

Management of municipal solid waste (MSW) is one of the biggest challenges faced by cities in low and middle income countries (Hoornweg and Bhada-Tata, 2012; UNEP, 2015; Wilson and Velis, 2015). According to World Bank report of 2012, about 1.3 billion tonnes of municipal solid waste (MSW) were generated globally and projected to reach 2.2 billion tonnes by 2025; sub-Saharan Africa's contribution in 2012 was estimated at 62 million tonnes. (Hoornweg and Bhada-Tata, 2012).

Quantity and composition of waste generated depends on the economic activities of the countries and the socio-economic status of the population. For instance, agro-based economics, covering most of the low income countries, tend to have large quantities of bio-degradable organic matter in their composition while countries which rely on tourism, such as island states, tend to have high percentage of packaging materials (plastics and glass) in their waste composition. In terms of human population, the United Nations estimated that about 54% of the world population was living in urban areas in 2014; the figure is expected to reach 66% by 2050 (UNDESA, 2014). The rate of urbanisation is higher in the low income countries than in high income countries. Thus as low income countries develop and industrialise, waste generation per capita rates are also expected to rise since people's living standards and spending power are also expected to improve (Kathiravale, Yunus and Abu, 2007; Hoornweg and Bhada-Tata, 2012). Higher levels of urbanization also mean more wastes to worry about as a result of both higher per capita rates and the actual population increases. Furthermore, although urban areas and cities are seen as a symbol of prosperity where people can fulfil their dreams, poor planning for urbanisation results in a number of social, economic and environmental challenges (UN-HABITAT, 2010). One of the environmental challenges associated with urbanisation is waste and its management.

Despite the fact that MSW is cited as a problem and the authorities know about sustainable waste management, waste management does not seem to get the attention and support it deserves (UNEP, 2015). (Hoornweg and Bhada-Tata, 2012; Wilson and Velis, 2015; Prüss-Ustün *et al.*, 2016). Most of the generated waste is not collected. Uncollected and poorly managed MSW may cause pollution, increase the risk of environmental diseases and emit greenhouse gases.

This study reviews solid waste management practices in the city of Blantyre, assesses the impacts and proposes paradigm shift towards sustainable waste management. Specifically, the study undertakes a critical analysis of the link between waste management practices on one hand and pollution, human health and climate change on the other using DPSIR[45] framework. The overall aim of this paper is to catalyse constructive debate towards sustainable waste management in the city of Blantyre.

Case study site: Blantyre, Malawi

Blantyre, the commercial hub of Malawi, is one of the oldest urban settlements in the region. It was established by Scottish Missionaries in the 1870s and was named after Blantyre of Scotland, a birth place of the famous missionary and explorer, Dr. David Livingstone. Blantyre is a city with many hills and valleys, as well as rugged terrain. Blantyre city is the urban component of Blantyre District. Blantyre district is surrounded by six districts, namely, Zomba, Chiradzuku, Thyolo, Chikhwawa, Mwanza and Neno which affect day population as well as wastes in the market place - produce brought from the adjacent districts. The city covers an area of over 220 square kilometres (sq. km). According to NSO (2008), the population of Blantyre is estimated to be 0.96 million in 2017 and will grow to 1.53 million in 2030. Malawi is one of the most densely populated countries in the Southern Africa Development Community (SADC) region and has a high rate of urbanization (UN-HABITAT, 2012; UNDESA, 2014). It has a very high population density, with 3,269 people per sq. km against the national average of 158 people per sq km. The city of Blantyre is the industrial and commercial hub of Malawi.

[45] DPSIR is an analytical framework which is based on causal links between Drivers, Pressures, State, Impacts and Responses (DPSIR). It is a tool usually used in the assessment of the state of environment.

Table 13: Population projection for cities to year 2030 (millions)

Cities	2017	2020	2025	2030
Blantyre	0.96	1.07	1.29	1.53
National Total	17.37	19.10	22.40	26.10

Adapted from population projections of 2008 (NSO, 2008)

Although the city area has not grown in the recent past, the population of Blantyre is growing at 3.91% per annum. There are three types of settlements in Blantyre: high and middle income housing areas in the planned settlements and low income housing areas in the traditional and unplanned part of the city. The population in low income settlements varies from 60% to 70% (Manda, 2009; UN-HABITAT, 2011; CCODE and Malawi Homeless People's Foundation, 2014). The city councils are responsible for waste management in the area of its jurisdiction (Government of Malawi, 1998). Currently, waste collection is done in planned settlements, markets, commercial sites and institutions within the city boundaries. Therefore, majority of the citizens who live in the unplanned settlements have no access to waste collection services (Government of Malawi, 2011; Maoulid, 2012; CCODE and Malawi Homeless People's Foundation, 2014). It is estimated that only 30% of the generated wastes are actually collected (UN-HABITAT, 2012). As a result, most of the waste is carelessly disposed of in drains, river banks, road sides and street corners (Government of Malawi, 2010; Maoulid, 2012). Health facilities have small incinerators to burn hospital wastes but their general wastes are also collected by the city councils. The waste collected are disposed of in designated sites where the wastes are dumped and occasionally covered with a layer of soil since there are no purposely-constructed landfills (Government of Malawi, 2011; Maoulid, 2012; NCST, 2014).

MATERIALS AND METHODS

Scope

The study covers the city of Blantyre. It investigates MSW and MSW management, and their impact on environmental pollution (land, water and air), human health and climate change.

Data collection

Desk study

The study reviewed literature related to waste, waste generation, waste management, waste and environmental pollution, waste and human health and waste and climate change. Secondary data from local studies and published data by NSO, NSCT, UNHABITAT and other published reports have been used in the estimation of MSW generation and projections (NSO, 2008; UN-HABITAT, 2010, 2011; NCST, 2014).

Analysis

GHG emission estimations used IPCC 2006 guidelines for the preparation of national GHG inventories(Government of Malawi, 2002, 2011; IPCC, 2006).

DPSIR framework was used to analyse the causal relationships between waste generation drivers and the associated pressures, states and impacts as well as assess how various responses could be directed to the various stages of the framework. Although the framework is the preferred tool for preparation of state of environment reports, DPSIR is gaining application in other areas as well. The authors have not identified any records to show the use of the tool in waste sector under Malawi scenario. Thus its application in this study could contribute towards holistic approach to waste management practices in Malawi.

RESULTS AND DISCUSSION

Waste generation in the city of Blantyre

The figure below shows an analysis that was undertaken to assess the contribution of wastes in Malawi's four cities using the data collected in the NCST waste management study of 2014.

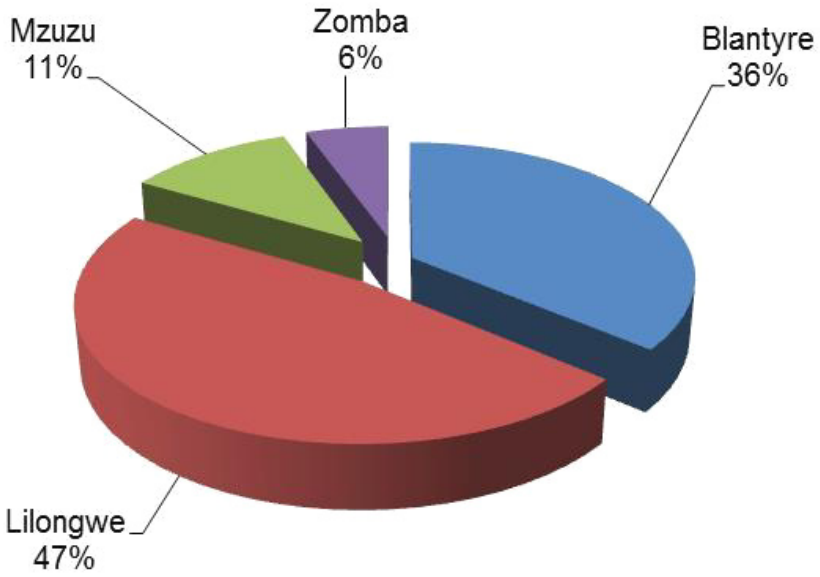

Figure 1: Waste contributions in the Malawi's cities

The assessment showed that Blantyre contributed about 36% of the total wastes generated in 2014.

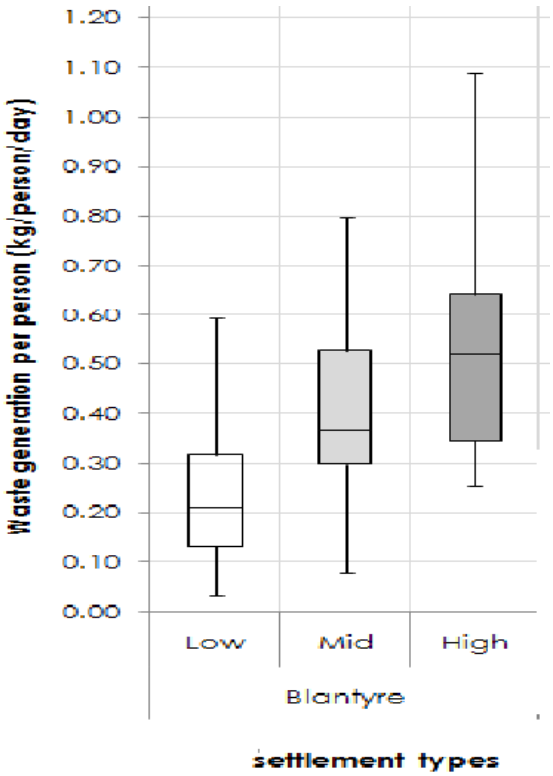

Figure 2: Waste generation rates in settlements within city of Blantyte

Computed mean waste generation rates in Blantyre are 0.22, 0.37 and 0.53 in low, middle and high income settlements respectively. Therefore, when undertaking a study, there is need to associate waste with the settlement types.

Situation analysis of waste management in Blantyre

Literature has revealed serious lapses in the way the waste management is treated in Malawi. It is one of the services that seem to receive minimal support despite its importance to the well-being of the citizens. Various studies show widespread and entrenched challenges related to waste management in Blantyre and other cities of Malawi (Manda, 2009; UN-HABITAT, 2011; NCST, 2014). The findings are summarised below:

- Firstly, waste is poorly managed at source. Wastes of all types and states are dumped in the same container for disposal. The culture of waste separation does not exist or not promoted through provision of appropriate containers for different waste streams. Mixed wastes are more difficult to handle and would require sorting to recover materials for recycling or reusing.
- Secondly, the waste collection services target middle and high income settlements where roads are accessible; the majority of the citizens living in unplanned settlements or traditional housing areas are not able to access waste collection services. Estimates show that between 60% and 70% of the people live in unplanned settlements. Thus, residents either use rubbish pits or dispose the wastes in gullies and roadsides indiscriminately.
- Thirdly, the city seems to luck appropriate equipment and infrastructure to manage wastes efficiently. Since most of the wastes are organic matter with low densities, the dump trucks collection efficiency is very poor considering the dead weight of the trucks (for instance a 10 tonne truck carrying 3 tonnes of waste per trip).
- Fourthly, it was observed that the city does not have purpose-built or engineered waste disposal facility or landfill. Wastes are instead disposed of at a waste dumpsite, usually an old quarry site rather a site properly selected following an appropriate criteria or as designated in the city's master plan. In addition, the sites are not secured and, therefore, prone to access by waste pickers thereby exposing them to health risks. Although waste heaps are flattened and covered with a layer of soil, the practice does not prevent toxic wastes and leachates to contaminate soils and ground water. Furthermore, the wastes are openly burnt resulting in the release of toxic particulate and gaseous emissions and GHGs.
- Fifthly, there are many institutions that play a part in sustainable management of the wastes. The custodian of the policy and regulations is the Department of Environmental Affairs (EAD). But waste is managed by Local Government/ city councils within the area of their jurisdiction. Unlike in other countries, there is no institution in Malawi that specifically focuses on waste and its sustainable management. As such, there are little or no investments in the improvement of status quo. Although cities are disposing wastes at dumpsites instead of engineered landfill, there are no institutions that enforce regulations that would effectively force the cities and government to urgently do something about it. For now, air, water and land continue to be polluted.

Towards development of an approach to address waste management challenges

In order to improve the waste management situation in the city of Blantyre, there is need to assess holistically the interaction between the various elements of the DPSIR framework as shown in Figure 3.

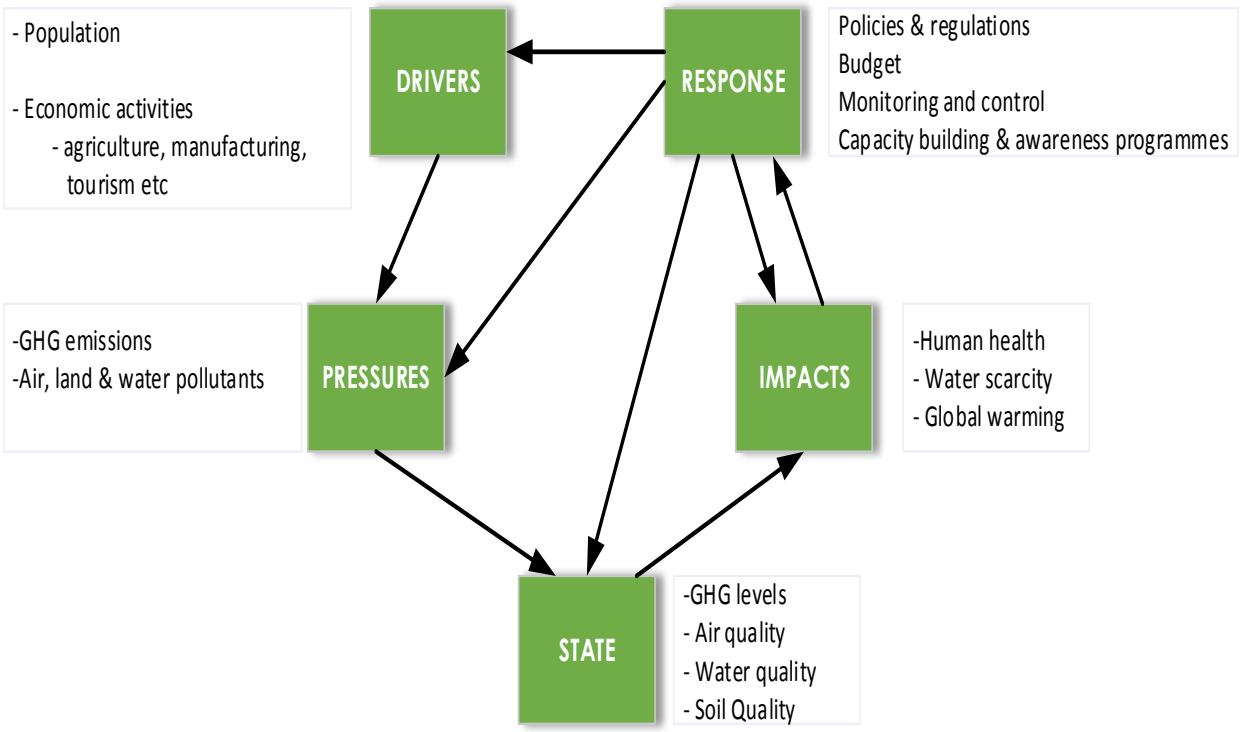

Figure 3: Interaction between elements of DPSIR framework

Drivers

As it was highlighted, the main drivers of waste generation are populations and economic activities. The population affects the basic numbers, rate of urbanisation and its socio-economic characteristics of settlements. On the other hand, the economic activities refer to the activities that the country's economy depends on such as manufacturing, tourism, other service industries and agriculture production. In the city of Blantyre, the population growth is expected to decline slightly from 3.91 in 2017 to 3.41 per year by 2030. Another aspect of population that is of interest is the migration of population from rural to urban in search of work and other opportunities of better life in the cities. Although higher population density may result in more efficiency in waste collection, there is danger with respect to strain on the service resources and control of diseases in case of an outbreak. In addition, as the population earns more, they can afford more and different kinds of goods and services. Waste generation may also be affected by what they, keep, recycle, re-use or throwaway based on social-cultural norms and beliefs. Since most people would buy and unprocessed foods, accounts for the high content of organic matter in the MSW. Manufacturing and service companies strive to meet the ever demanding and diverse needs of goods and services of their consumers. The production and consumption of some these goods and services often produced waste materials. Waste materials are defined as (EU). Therefore, population and economic activities are the principal drivers of diverse range of solid waste generation which is increasingly becoming a big concern at global level. In fact, many city authorities are struggling to manage municipal and industrial wastes

Pressures

Quantity, composition and waste disposal methods affect the type and level of pollution. For instance, low income countries like Malawi have waste that contain high level (more than 60%) of biodegradable organic matter. If this waste is buried, anaerobic digestion could take place resulting in the release methane gas, a potent GHG, into the atmosphere. .Other pollutants come from open burning. Open burning of waste not only release of carbon dioxide from the combustion process, but also other toxic pollutants such as dioxins and furans which are extremely hazardous to human health.

States

Since Malawi does not systematically monitor air quality levels. Various qualitative studies show that the state of air quality is declining. In terms of contamination of soils at dumpsite, studies conducted in Zomba dumpsite showed that soils from site contain levels of heavy metals well above those recommended by World Health Organisation (WHO). Since Blantyre dumpsites are bigger and receive more loads, it is expected that the soils at dumpsite in Blantyre are equally or more polluted. In addition, mixed wastes contain other pollutants such as heavy metals which would after water quality.

Impacts

Although studies fail to directly attribute diseases to environmental pollution, there is strong agreement to the fact that associated risk factors are higher to those exposed to the hazards. Some of diseases or conditions associated to high exposure levels include cancers, low birth weights and birth defects. In addition, mixed wastes containing toxic materials exposes workers to occupational diseases. Leachates from dumpsites affect the quality of surface and underground water sources. This reduces the availability of portable water for humans and livestock. Finally, methane which is uncontrollably released into the atmosphere adds to the problem of global warming especially due to the fact that methane has a much higher global warming potential compared to carbon dioxide.

Responses

Table 2: shows suggested response measures targeted at the various elements of the DPSIR framework.

DPSIR Element	Specific issue	Proposed response measure
Drivers	Population	Promote population control
		Promote planned urban settlements
	Economic	Promote green manufacturing and eco-tourism
		Promote recyclable or reusable packaging materials
		Establish and support recycling enterprises
Pressure	GHG emissions	Harvest biogas from landfill to use as fuel
		Produce refuse derived fuels from wastes
	Air pollution	Ban open burning of wastes
	Land pollution	Toxic wastes should not be mixed with other domestic waste materials- provide alternative dumping sites.
	Water pollution	City authorities should use engineered landfills for waste disposal at all times- they must lead by examples.
State	Air quality	Enforce air quality standards
	Water quality	Enforce use of engineered landfill to prevent leachates polluting water
	Soil quality	Enforce use of engineered landfill to prevent leachates polluting soil
Impact	Human health	Enforce implementation of sustainable waste management by city authorities and other stakeholders
	Water scarcity	Enforce use of engineered landfill to prevent leachates polluting soil and water
	Global warming	Capture methane from dumpsite/landfill for use as fuel
Response	Response regulations	Develop and enforce appropriate regualtions

In order to develop appropriate and detailed response measures, it will be necessary to undertake review of relevant policies and regulations

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Sustainable management of MSW is a task that requires efforts not only from the city authorities, but also all the waste generators, general public and the central government. The government need to provide budgetary support on waste management infrastructure and facilities.

The air, water and land pollution levels and GHG emissions are likely to get worse if no interventions are urgently put in place to address the challenges shared in this paper. Although studies are cautious to directly link diseases to pollution exposures, Malawi needs to proactively adopt precautionary principles. This would avoid cost remedial actions in future.

The DPSIR analysis indicates that comprehensive corrective measures should be targeted across all the elements of the DPSIR framework. Although majority of the interventions relate to development of appropriate regulations and enforcements, Malawi urgently requires engineered landfill facilities in Blantyre and other cities.

Recommendations

In order to initiate change from status quo, the following actions are recommended:

- Blantyre City Council (BCC) in collaboration with other relevant partners should organise a stakeholders conference on the issue of waste Management in the city of Blantyre;
- BCC should promote and support research in waste characterisation, waste management and associated studies;
- BCC should work closely with tertiary institutions to develop training programmes at degree, technician and artisanal level in various aspects of waste and waste management;
- BCC should work closely with various stakeholders to develop ways of sustainably funding waste management activities in the city;
- BCC should lead by example in adhering and enforcing regulations on waste management.

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Urban governance in Malawi: How does it fair in the social justice and environmental litmus test?

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ABSTRACT

Urban governance has an impact on the life of the urban residents and other people therein. This impact goes even beyond to determine the urban environment in which people live, travel and work. This research study was mainly primary, and it aimed at investigating how urban governance in Malawi is performing in the context of social justice and the environment. Primary data was randomly collected in the four cities of Blantyre, Zomba, Lilongwe and Mzuzu using interview questionnaires and FGDs. Observation also formed part of data collection. Respondents were city residents and those who work, travel through, and visit these cities. Both qualitative and quantitative data was collected and analysed. Qualitative data from the survey was analysed by establishing patterns and themes from responses, while quantitative data was analysed using Excel and SPSS to generate frequencies, tables and charts that visualize the study results. Generally, using social justice lens and environmental perspective, the study found out that urban areas in Malawi are characterized by problems that range from subserviced and unserviced settlements, poverty, unrepaired facilities, lack of citizen participation and consultation in decision making, and so forth. Practically, the Malawian urban management scenario accommodates the exposition and perpetuation of some social injustices on some urbanites. Urban areas in Malawi are characterised in one way or the other, by some elements of deprivation, and the urban environment lacks standard aesthetic outlook. In response to the problems identified, the study suggested solutions like enhancement of urban community engagement in needs identification and decision making; ensuring that all levels of the government system understand their roles and responsibilities; fostering effective intergovernmental relationships and sound public - private partnership; encouraging innovative urban management that contributes to successful outcomes for the community; public awareness campaigns on citizenship roles in cities; and enforcement of quality assurance.

Key words: Urban governance, social justice, environment, deprivation, participation

INTRODUCTION

Urban governance, a term most commonly synonymously used with *urban management*, is one of the areas of profound interest to physical (town and country) planning – a discipline that involves the active process of organizing structures and functions in a bid to realize effective land use. The introduction of planning in Malawi during the political hegemony marked the birth of urban governance in the country, though it gradually had to take shape over the years.

Globally, urban governance is referred to as the software that enables the urban software to function. It is an enabling environment that requires adequate legal frameworks, efficient political, managerial and administrative processes, as well as strong and capable local institutions that are

able to respond to the urban citizenry needs (UN-Habitat, 2015). Avis (2016) defines urban governance as how government (local, regional, national) and stakeholders decide how to plan, finance and manage urban areas, involving a continuous process of negotiation and contestation over the allocation of social and material resources and political power. Urban governance encompasses a host of economic and social forces, institutions and relationships, which include labour markets, goods and services; household, kin and social relationships; and basic infrastructure, land, services and public safety (Devas et al., 2004). Tenets of effective urban governance include strong and capable leadership that ensures access of all to better living conditions; inclusion of more and more voices (participation) to respond to the challenges of urban governance; capacity building programmes; enhanced accountability; empowerment of citizen engagement; and ensuring of environmental sustainability and resilience, combating of climate change, preservation of ecosystems and biodiversity, and building of communities that are more resilient to natural and human threats (UN-Habitat, 2015). Urban governance involves a range of actors whose relationships determine what happens in the city, and in managing urban transformations, government (at all levels) need to play a strategic role in forging partnerships with and among key stakeholders (UNESCAP & UN-Habitat (2010;2015).

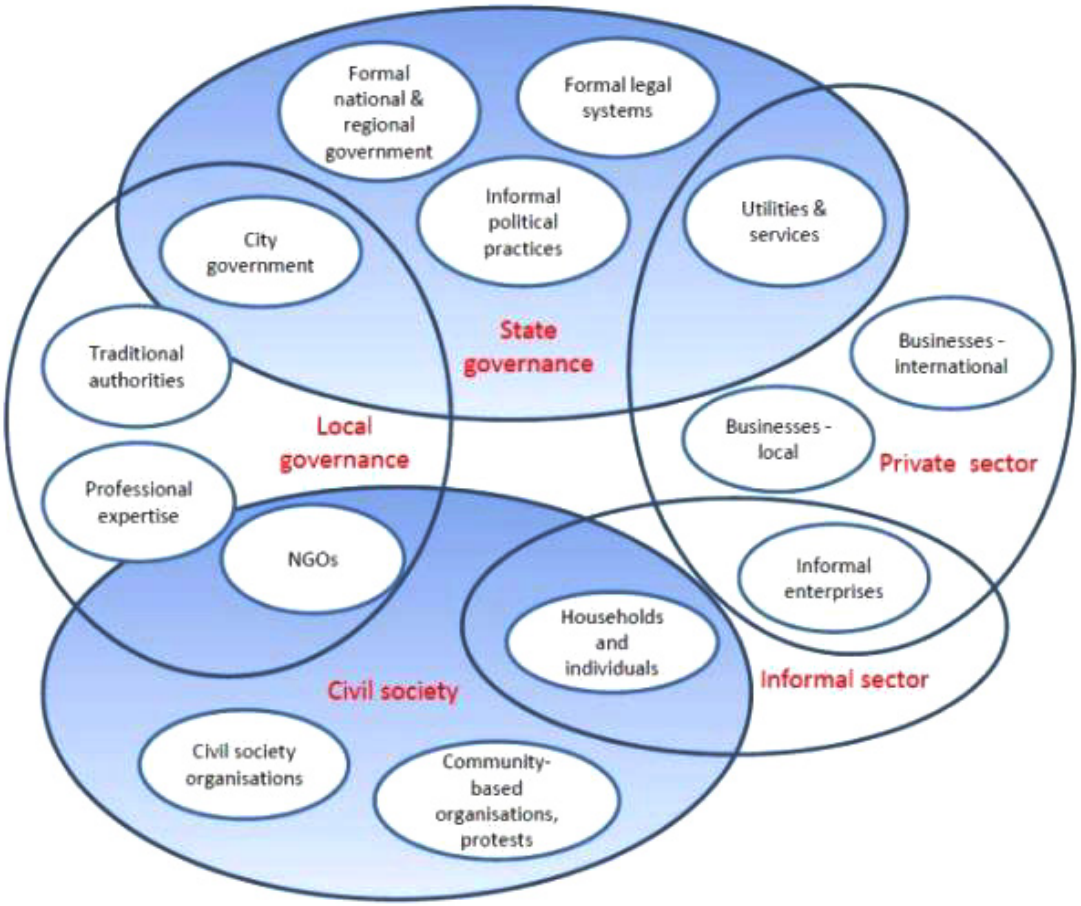

Figure 1: Actors & institutions of urban governance **(***Source*: Brown (2015))

Urban governance is important in ways that it plays a critical role in shaping the physical and social character of urban regions; influences the quantity and quality of local services and efficiency of delivery; determines the sharing of costs and distribution of resources among different groups; and affects residents' ability to access local government and engage in decision-making, influencing local government accountability and responsiveness to citizen demands (Slack & Cote, 2014).

Large gaps often exist between poor and better-off urban residents in terms of access to social, economic and political opportunities (particularly decision-making) and the ability to participate in, and leverage, the benefits associated with urban living (Avis, 2016).

Urban governance in the developing world

The burgeoning urban population in the Third World means that there is need for efficient and sustainable systems of urban governance. Sheuya and others (2007) state that rapid urbanization in developing countries started much later and followed a pattern that is quite different from that of the developed world. These authors further indicate that despite the fact that the emerging urban settings of the Third World followed the same sequence of rapid population increases, dramatic rural–urban migration rates and major environmental impacts, this has often been characterised by low or medium economic growth rates, as the authorities responsible for managing the urban areas are often ill-equipped to meet the demands of the population influx. Estimates indicate that by 2015, more than half of the world‘s population, the majority in developing countries, would live in urban areas, and that by 2030, two-thirds of people will be living in cities (UN-Habitat, 2011). With most of the world‘s population living in cities and major urban areas, urban development is giving rise to the proliferation of informal settlements, trade, declining ecosystems and failing infrastructure, all of which expose world urban residents, more especially in the developing world, to undesirable urban environments (Kadaluka, 2009). Satterthwaite (2005) indicates that urbanisation being one of the issues of major concern in developing countries, some of the related issues include escalating poverty, slums and squatter development, failure to deliver infrastructure needed in the urban areas, inadequate proper housing and lack of employment opportunities. This is not the end of it all as most urban areas in the Third World are faced with an array of waste management problems ranging from collection to disposal. This is despite some research projections that all developing regions will have more people living in urban than rural areas by the year 2030 (UN-Habitat, 2011). In a world of unprecedented increase in overall opulence, millions of people living in the Third World are still unfree by remaining imprisoned in one way or another by economic poverty, social deprivation, political tyranny or cultural authoritarianism (Sen, 2004) One other special cause for concern is that overall, a billion people, a third of people living in urban areas, live in informal settlements (Sheuya et al, 2007). As this mainly happens in the developing world, it is not usually by choice, but circumstances that are a product of decisions made by respective urban authorities. Inadequate and deteriorating infrastructure is among the most pressing and difficult issues facing the cities and towns of the developing world, and in Sub-Saharan Africa, rapid urbanization has outstripped governments‘ capacities to, among other things, provide basic services and guide urban growth (Kachenje et.al, 2010, in Kadaluka, 2014). In view of the foregoing, and more particularly due to the rights that these residents are supposed to enjoy while living in the cities, these circumstances then bring in the issue of social justice.

A glimpse of urban governance in Malawi

Historically, urban governance in Malawi has been shaped and re-shaped by the country‘s development policy and interaction with key international urban players over the country‘s three periods of political development namely: 1) colonial era (1948-1964); 2) post-colonial era (1964-1993), and 3) post one party era (1993 to present) (Chinsinga, 2015).

The legislative framework exists and is reasonably tuned, though cities in Malawi find it extremely difficult to exercise development control, planning and infrastructure development function as stipulated in the statutes. The Town and Country Planning Act, 1988, and the Local Government Act, 1998, which are the legal instruments for urban governance in Malawi, are not harmonized, and the Local Government Act does not provide for an elaborate institutional framework for the development activities in urban areas (Chinsinga, 2015). The apparent neglect of urban governance in Malawi has led to a situation whereby urbanization, estimated at 6.3% per annum, has outstripped the government‘s capacity to provide services and strategically guide urban growth

(Mkula, 2014a; Nkhoma & Jameson, 2014). Malawian cities are grappling with an explosion of unplanned development and settlements which are making it difficult for the cities to realize their full potential for socio-economic prosperity, and consequently, the cities are predominantly characterized by structures that are only accessible by footpaths; structures without viable drainage systems; widespread use of pit latrines; water access through communal standpipes or even boreholes which is contrary to the statutory stipulations; most of the open spaces and road reserves are encroached for low income housing and small-scale industries; vendors encroaching road reserves, open spaces, shop fronts and parking spaces; and alternation of buildings without planning permission. This leads to Malawian cities generally being characterized by inadequate and deteriorating infrastructure which is exposing urban residents to myriad types of disasters (Chinsinga, 2015). The percentages of urban population that lives in informal (unplanned) settlements in Malawi are 60, 76, 65, and 60 for Zomba, Lilongwe, Blantyre and Mzuzu cities, respectively (UN-Habitat, 2011). Nkhoma and Jameson (2014:56) state that the city councils have no plans for these unrecognised settlements, because to them, slums or informal settlements are non-existent; poor people live in villages‖ . This kind of attitude by Malawian urban governance towards informal settlements leaves these areas unattended to, or just given little attention, and this is even manifested by the absence of informal settlement units of city councils through which these communities can channel their grievances (Mamiwa, 2015). Social justice Fabre (2003) indicates that individuals have social rights to adequate minimum income, housing, education, and health care, and resources that will enable them to enjoy a decent living. Urban governance is supposed to ensure that every individual in a particular urban jurisdiction has access to all the basic necessities for a descent living such as food, cloth, shelter and health care, through creation of environments that necessitate that access. Urban governance in the context of low-income countries should improve universal access to basic services and reduce poverty, because marginalization and injustices (exclusion from public service delivery, formal labour markets and protection of state security) erode the public legitimacy to provide for equal access to services for all the urban residents (UN-Habitat, 2015). Social justice arguments stress that all humans are equal and deserve equal access to all basic necessities to a descent life in society (Mamiwa, 2015). Higher income inequality in urban areas and a number of local and socioeconomic factors spell considerable misery for specific groups in urban settings, which is mostly the case in the developing world (Asian Development Bank, n.d). Asian Development Bank (n.d) further emphasises that the key to good performance is the community and its citizens' active participation in the development of their own towns and cities.

In its early days, the term social justice specifically targeted poverty and the need for an equal distribution of resources, whereas today, the term has acquired a broader and more detailed definition (including issues of segregation) that accounts for specific modes of moral treatment, and the blueprint for achieving social justice is often structured by governmental implementation of laws/rights that provide equal distribution of resources and opportunities, which in effect protects human dignity (https://www.pachamama.org/social-justice/what-is-social-justice). Social justice institutions work to provide and expand education, healthcare, public services, and labor rights, and strive to ensure equitable distribution of wealth and opportunity (http://www.investopedia.com/terms/s/social-justice.asp)

Urban environmental performance

While cities are engines of economic prosperity and social development, urban environmental challenges have become a pressing global issue due to undesirable impacts on the environment caused by rapid urbanization (Komeily & Srinivasan, 2015). Cities are growing in terms of both population and geographical spread, and have become the key determinant of environmental quality at local, regional and global scales (Ameen & Mourshed, 2017). Global urban population reached 3.5 billion in 2010, and it is predicted to double by 2050 (UNDESA, 2010). Urban development

factors such as land use changes, energy consumption and associated greenhouse gas emissions, water consumption and availability, waste generation and recycling, pollution, sanitation, and infrastructure are likely to become more challenging (Clarke & Ramalingam, 2012). Further to this, local and global factors such as natural disasters, wars, corruption, and economic downturn can exacerbate the situation (Smith, 2013). Urban environmental performance is a multidimensional construct and is determined by the relative ecological compatibility of city functioning within the sustainability of city environment and the scope of environmental management activities in the sphere of environmental management (Bakumenko, et al, 2015). Urban environmental performance is influenced by the degree of efficiency and effectiveness of an urban governance system in place and practice. Waste management in urban areas, is a good example of urban planning and governance issue, which has subsequent environmental repercussions (Mamiwa, 2015). Urban planning perspective is an important component in the design of solid waste disposal policies, and its central concern with the management of land resources and the regulation of land uses makes it involved in aspects of waste production as well as the formulation and implementation of specific waste disposal options which are environmentally feasible (Hills, 2013). It therefore influences environmental management and health, as well.

This study was conducted to assess the performance of urban governance in Malawi from the perspectives of social justice and environmental management.

MATERIALS AND METHODS

The study was conducted in the four cities of Malawi viz, Blantyre, Zomba, Lilongwe and Mzuzu.

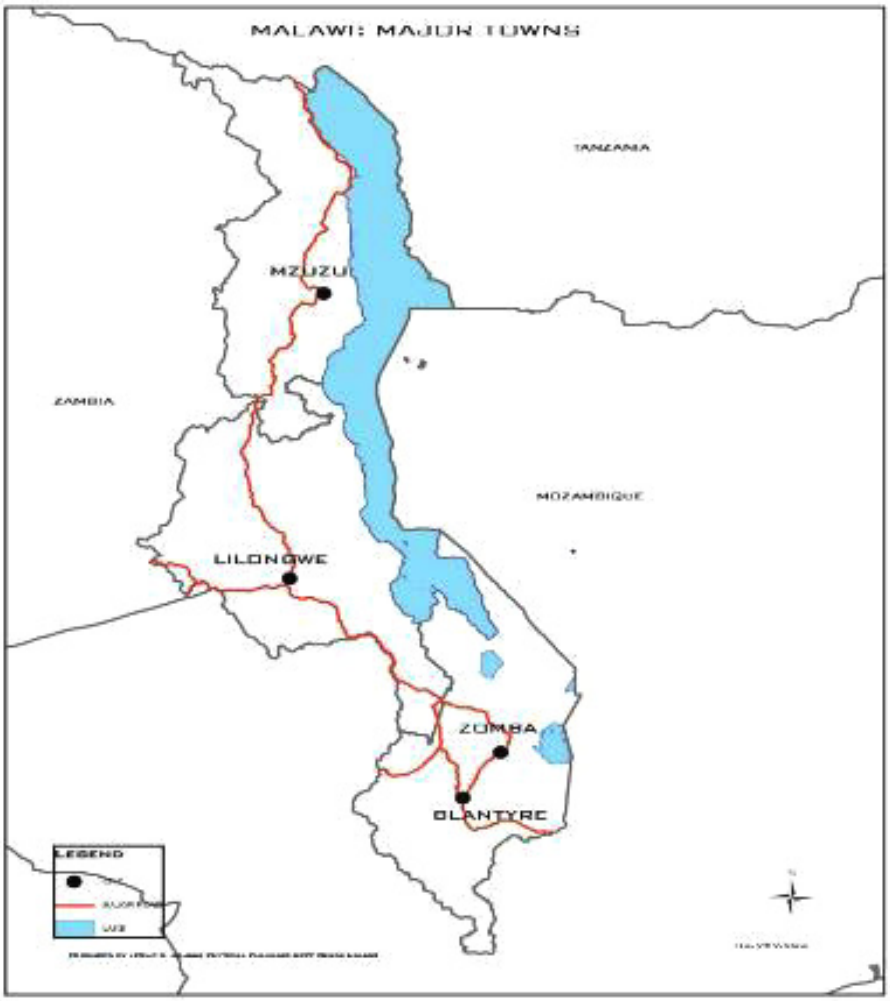

Figure 1: Map of Malawi showing location of cities (Source: Majawa, L. (2009)

This research was mainly primary, though secondary data was substantially used to complement primary data. Primary data was randomly collected in the four cities using interview questionnaires and Focus Group Discussions (FDGs). Observation also formed part of data collection. Respondents and participants were city residents in various locations and those who work, travel through, and visit these cities. Some officials from city assemblies (councils) were also interviewed.

Data analysis

Both qualitative and quantitative techniques were used to analyse data that was collected. Qualitative data from the survey was analysed by establishing patterns and recurrent themes from responses, while quantitative data was analysed using Excel and SPSS to generate frequencies, tables and charts that visualize the study results.

RESULTS AND DISCUSSION

Most city residents in Malawi are not aware that social justice and environmental performance are products of urban governance. The percentage rates of awareness were as indicated below.

Table 1: Percentage rates of awareness

City	No. of respondents	No. aware	No. not aware	% aware	% not aware
Blantyre	200	78	122	39	61
Zomba	100	32	68	32	68
Lilongwe	200	71	129	35.5	64.5
Mzuzu	100	36	64	36	64

Most city residents and other stakeholders in the four cities know that they have rights to education, life, freedom of expression, engage in economic activities (like jobs, businesses, etc). However, few city residents know of other social rights, like right to sustainable social infrastructure, descent and affordable housing, and so forth.

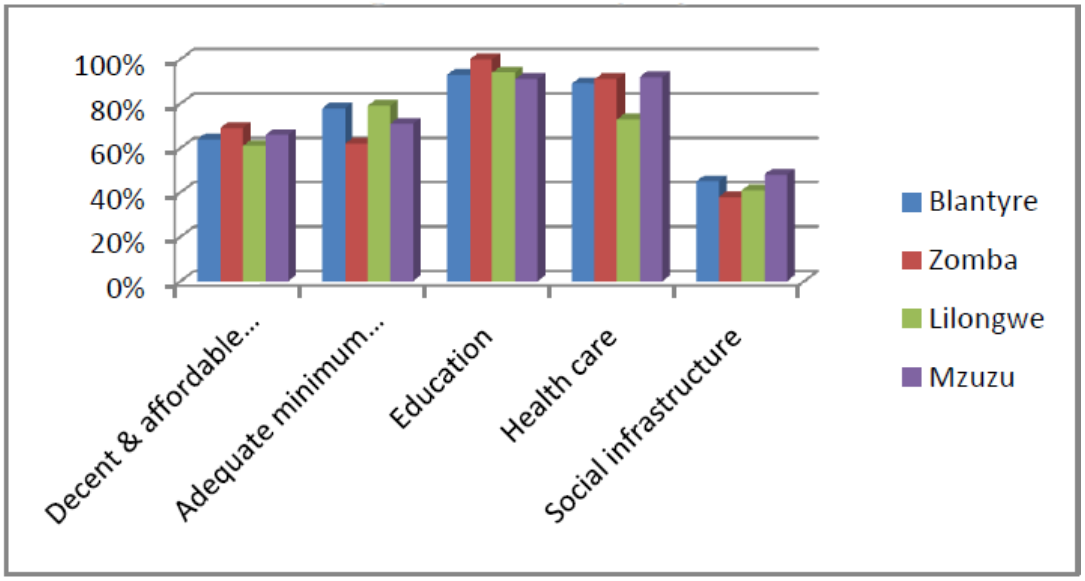

Figure 3: Social rights awareness by city residents

Despite some recognizable effort made by city authorities in Malawi to provide municipal services, there are gaps in urban governance in providing for social justice and sound environmental performance. These concerns include inadequate provision of cycle and pedestrian paths along and

within the cities, lack of secure parking for bicycles, lack of free and decent public toilets, high unemployment, unaffordable land for housing for the city poor, unaffordable and unreasonably located housing for the poor, poor (and lack of) municipal service delivery, poorly and inconveniently located recreation facilities, and unfavourable business environment and facilities for small-scale businesses.

Impact of the gaps

The highlighted gaps have created situations where some city residents resort to develop housing informally and in environmentally sensitive areas that could endanger their lives and property (like flood and landslide prone areas); some cycle in dangerous roads where motorists do not care about them; walking in streets, most of which have no lights, which perpetuate crime (they are attacked at night); some streets have no pedestrian paths, while others have eroded shoulders and this makes walking along such streets very dangerous; inconveniences caused by lack of free public toilets; poverty due to high unemployment; high transportation costs to long distances where job opportunities are available; gentrification of the city centers, poorly serviced locations in terms of waste collection; and inconveniences and moral decay orchestrated by some recreation facilities like bars.

CONCLUSION AND RECOMMENDATIONS

Urban governance in Malawi is violating social justice and orchestrating poor environmental performance by neglecting and depriving city residents in the informal settlements of their rights to decent, affordable housing, as well as their access and opportunities to, and full enjoyment of services like safe water, electricity, sewerage, waste collection, security, and transport infrastructure, as well as contributing to environmental pollution. This extends to decision-making, where city residents are not given a platform by local authorities for expressing their views on how development should be done in their areas. Nonetheless, what is important to bear in mind is that these informal settlement areas are part of the cities, and their development has been the outcome of urban governance failure to have right policies and programmes in place to deal with planning, urbanisation, and environmental monitoring and protection. Generally, city residents have a right to demand for an improvement, and action is all that is required of the responsible city authorities, as well as government at large, so that the status quo is improved. The population of informal housing dwellers was at 2.6 million in 2009, and it must be far much more by now, which is a huge population that urban governance may not afford to neglect. The study recommends for the provision of enabling environment (in terms of regulation and subsidies programmes) for the poor to afford proper land and formal decent housing in the cities; sustainable designs and regular maintenance of infrastructure like roads that promote walking and cycling; city streets and roads that have lights which are regularly maintained to ensure functionality; provision and regular maintenance of public toilets; urban governance policies that stimulate economic activities and growth (multiplier effect) so that more jobs are created for the city residents; pro-poor housing projects in strategic locations to enable people to travel to work places with ease and at reasonable distance – walking and cycling to be taken into consideration; civil society to take its role in civic awareness of and demanding for social justice and environmental performance; adequate financing for service delivery like vehicles for waste collection; identification of new sites for city landfills; proper transportation of city solid waste to avoid spreading of bad odour and spilling of waste on the roads; strictly adhered to scheduled municipal service delivery; strict adherence to regulating the establishment of some businesses like bars in the settlements to avoid nuisance and moral decay; strict adherence to city environmental monitoring to ensure sound environmental performance; adequate, appropriate and timely response to emergencies like city fires and floods; engagement of citizens (public consultation and participation) in decisions that affect city development and development control; monitoring of quality assurance by government using established Key Performance Indicators (KPIs) for local governments; fostering of public-private partnerships;

innovative urban management that contributes to successful outcomes for the city communities; and encouraging more research in urban governance.

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Estimating risk factors for severity of motor vehicle accident in Malawi with Gologit, ordered multinomial logit and Bayesian ordered multinomial logit models

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ABSTRACT

Malawi is among the low- income countries in which citizens are dying from preventable and treatable causes such as road traffic accidents. Efforts to reduce severe road accidents have been done. However, more safety studies that use sophisticated statistical data analysis techniques and whose aim is to identify risk factors associated with severity of road accidents are recommended. We used the 1995 to 2007 motor vehicle accident secondary data from the National Road Safety Council of Malawi to demonstrate analysis of accidents data using generalised ordered, multinomial logit and Bayesian multinomial logit models. A better model was achieved through assessment of R^2, through test of significance and through comparison of variable estimates. Risk factors were drawn from significant variables. Surroundings and accident type were the only variables which were significant in OMNL ($P < 0.05$, CI that exclude a 1; (-1.2212, -0.8779), (-0.5263, -0.2066)) and in BOMNL ($P < 0.05$, and 2.5% quartiles that exclude a 1 (-1.2370, -0.8791) and (-0.5399, -0.2002)). The greatest effect of the two variables was to decrease the likelihood that the accident will be severe. BOMNL produced improved estimates. Drunk driving and risk taking behaviours are the risk factors suspected to increase severity.

Key words: Motor vehicles; Accident risk factors; Severity; Bayesian; Ordered Multinomial logit model.

INTRODUCTION

Malawi is among the low - and middle income countries in which citizens are dying mostly from causes that are preventable and treatable. Factors such as road traffic accidents, complications during pregnancy and child birth, suicide, violence, HIV/AIDS and tuberculosis (TB) are preventable and have been reported as major causes of mortality to citizens of low - and middle income countries (WHO, 2009).

Rampant increase of road traffic accidents annually are particularly a major worry to low - and middle income countries. According to Ghee, Silcock, Astrop and Jacobs (1997) half a million of road accident fatalities are estimated each year worldwide and about 70% of these occur in the developing world. Ghee *et al* (1997) stated that while a general decline in the numbers of fatalities in industrialised countries was observed over the years but an increase was observed in developing countries. Further to that, developing countries such as Malawi registered fatality rates of 10 to 20 times higher than the rest, thus, taking into account the levels of motorisation found by expressing accident statistics as rate per registered vehicle.

Malawi is also among the Southern African developing countries with rampant road traffic accidents in the recent years. This is partly due to the fact that roads are major form of transportation system in Malawi. Severity of road traffic accidents in Malawi range from those that are considered minor to those that are considered fatal. Data collected in Malawian roads show higher percentages of occurrence of minor accidents followed by serious severity accidents and fatal accidents are the least reported.

Although the National Roads Safety Council of Malawi (NRSCM, 2006) documented a decreased occurrence of road accidents during the years 1995 to 2005, rates of occurrence of road traffic accidents are high and remain as one leading cause of death in Malawi. The NRSCM document indicated that 5,195 road accidents were reported to the Malawi Police in 2006 as compared to 7,191 road accidents reported in 2005, representing a 28% decrease. A corresponding decrease of 23% and 11% of road accidents as well as fatalities due to accidents respectively, were also reported in the year 2005 and 2006. The report pointed out the following as major reasons for the decrease of road accidents; the proactive approach in effective enforcement and civic education by Malawi Police Service (MPS), NRSCM and Road Traffic Directorate (RTD); the role played by NRA in road maintenance and rehabilitation; Government support and commitment to the promotion of road safety through increased funding to its institutions dealing in traffic management as well as community participation in road safety. In addition, many people who survived road accidents sustained serious body deformations or huge scars from serious and minor injuries respectively (NRSCM, 2006).

Recently, road traffic accidents are on the rise despite putting measures in place to minimise occurrence of road traffic accidents in Malawi. Either the measures that are in place to check on risk factors and associated severity of the causes of road traffic accidents are inadequate or ineffective. Perhaps there is laxity of the people in the ministries responsible for providing safety to citizens. For instance, lack of implementation of timely and proper measures to rescue and treat road traffic accident victims has resulted in loss of life for survivors of road traffic accidents due to minor or serious injuries. Lack of ambulances, inadequate medical facilities, lack of proper medical care, inadequacy of medical personnel such as nurses and negligence could be challenges facing Malawi and many such low - and middle income countries for this campaign (Ghee C. *et al*, 1997). With a total population of more than 15 million (2010 estimate), only 19.8 percent of which is urban, Malawi is one of the least urbanised countries in Africa. Its urban growth rate, however, is one of the highest on the continent (5.19 percent between 2005-2010). The high fertility rate and rural-urban migration, which occurs as a result of droughts, decreasing rural land-holdings, limited off-farm economic activities, and rural environmental degradation, are the main reasons behind the high urbanisation rates (UN-HABITAT, 2009). Urban centres such as cities and towns have large volumes of motor vehicles which citizens use for different reasons including commuting to work, for business or for pleasure. The high volumes of motor vehicles in urban centres pose a great risk of road traffic accidents to the urban population. In some cases, regular commuting through motor vehicles from rural areas to nearby towns for various reasons exposes the majority of citizens to road traffic accidents (Dobson, 1999).

High incident rates of road traffic accidents in Malawi have also been attributed to poor standards of the road transportation system. The condition of all road types, especially the tarmac roads are not good. Some of the tarmac roads are characterised with potholes whilst other road types, for instance those made of gravel and earth are in need of constant maintenance as their condition is constantly compromised by adverse weather conditions such as strong winds and heavy rains. Further, human factors have also been attributed to severe road accidents in the country (NRSCM, 2006). These factors constitute variables of driver's characteristics, including under qualified drivers who use fake driving licences, careless driving, driving under the influence of alcohol, no use of sit belt, and overloading or use of motor vehicles that are not roadworthy. With such factors holding true,

probability of severe road accidents shall always be high (Aljanahi, 2009 and Assum, 1998).

According to (Assum, 1998), there is a chain of causes ranging from the inadequately controlled forces bringing about each accident, to the institutional, political, economic, and social reasons behind this inadequacy. Assum further reported that accident level and the societal level are the two important levels of causation of road accidents such that for every single accident, one factor or a combination of factors may be established as a cause. The causes or factors usually pertain to the road, the vehicle, or the road user. Much as road accidents are difficult to do away with, but their occurrence and severity can be reduced. Such efforts have been undertaken and significant results have been realised. Some important evidence of efforts to reduce road accidents is obtained from activities of Malawi Traffic Police Service (MTPS) and NRSCM. These institutions manage to collaborate in collection of road accident data. The NRSCM analyses the collected data and produce reports of risk factors associated with the occurrence of road accidents as well as its severity. Based on the findings of data analysis by NRSCM, sensitisation campaigns to urban and rural masses on road safety are organised and conducted. While Governments and other stake holders are doing 4 their best to reduce general loss of life, there is more that needs to be done to rescue productive citizens of Malawi from deaths that can be prevented or treated.

Huge amount of data on fatalities and injuries from car crash is collected from Malawian roads every year as case reports. However, the data appears it is captured without a proper recording and notification system. This is a common problem to many countries and it leads to under-reporting and loss of crucial variables. This creates a problem related to identification and estimation of risk factors from such datasets (Takala, 2005). Inference from analysis of such inconsistence datasets can be faulty. However, inference from such datasets can be improved not only by systematically recording it but also by subjecting data to proper and more robust statistical analysis such as modelling techniques (Tarko, 2009). Modelling techniques provide for a deeper statistical analysis that may yield robust estimates and statistics. However, no literature is available about the use of such techniques on Malawian road traffic accident datasets. Hence, reasonable risk factors contributing to occurrence and severity of road traffic accidents to recommend for better safety measures are always difficult to come by. With modelling, assumptions cannot be ignored. Data is thoroughly cleaned and augmented to yield parameter estimates that are reliable and which can inform better decision making. Hence there is need to step up efforts to use better tools such as more statistical modelling techniques on analysis of monthly or annual road accidents data from the country's roads.

MATERIALS AND METHODS

Data source and description

To investigate severity of motor vehicle accidents based particularly on levels of motor vehicle damages and/ or whether an accident was fatal as well as on severity of occupants' injury, road accident data from Malawi collected from 1995 to 2007 by NRSC was used. Crash records related to all types of vehicles were considered and comprised a total of 16, 474 out of 28, 127 total records of all types of accidents available in the dataset, representing 58.6%. The dependent variable, accident severity, had five categories based on the recorded degree of injury involved and damages incurred. These include: fatal, serious injury, minor injury, damages only or animals only. However, the study only considered categories of; fatal, serious injury and minor injury, in that order. From the 11 years of data, 4.1% accidents were classified as fatal, 5.0% as serious severe, 19.6% as minor and 71.4% as no injury accidents.

Classification of an accident to a particular level of severity was based on the worst condition sustained among the casualties (Rifaat and Chin, 2005). In this case, an accident was considered as fatal or of serious severity if it resulted to death or serious injuries to a driver and/ or occupant of the motor vehicle involved in an accident. Information on the actual criteria used to classify an injury, and the body that decides on category of the injuries in the dataset were not available. However the study used one injury classification criterion which stipulates that a casualty is considered fatal if the person was killed within 30 days of the accident. In addition, a severely-injured casualty is the one who had suffered some kind of fracture, concussion, internal lesions, crushing, severe cuts and laceration or severe general shock requiring hospitalization or other forms of bodily pain requiring at least 7 days of medical leave. On the other hand, a person is considered to have a minor injury if the victim had suffered from other forms of injury requiring conveyance from the accident scene to hospital by an ambulance or otherwise, the medical treatment requiring medical leave of at least 3 days (Rifaat and Chin, 2005).

The dataset contained more than 30 independent variables which were available for use to explain the injury severity of drivers and passengers (occupants). The variables appear in nine factors, and are observed to fall under the major physical factor categories of crash characteristics, road characteristics, environmental characteristics and surroundings. It was noticed that the dataset contained no variables related to the human factors, which captures such records as variables of driver or occupants characteristics including alcohol or drug usage. With such important variables missing, risk factors sometimes become very difficult to come by.

Statistical Analysis

The analysis considered eight variables from the dataset to fit Ordered Logit, Generalised Ordered Logit and Multinomial Logit Models to identify risk factors associated with severity of accidents during the study period. The variables considered are given in table 2.The first to be fitted was the Ordered Logit model. The model assumes the variables meet the *parallel lines* or *proportional odds* assumption. The *parallel lines* assumption was examined for all the variables used in the study. Otherwise, failure to achieve the assumption would lead to fitting a generalised ordered logit model that introduces constraints on the variables that fail to meet the parallel lines assumption. The parallel lines model used in the study is given as:

$$P(Y_i > j) = g(X\beta) = \frac{\exp(\alpha_j + X_i\beta)}{1+[\exp(\alpha_j + X_i\beta)]}, j = 2,3 \quad (1)$$

Fitting of the Partial Proportional Odds Logit Model was the first alternative to a Parallel Lines Model. The model was considered advantageous as compared to the fitted Ordered Logit since it provided additional information on deviations of the variables from the Parallel Lines assumption which were given as gammas. The partial proportional odds model considered in the study was specified as:

$$P(Y_i > j) = \frac{\exp(\alpha_j + X1_i\beta1 + X2_i\beta2+,...,+X8_i\beta8)}{1+[\exp(\alpha_j + X1_i\beta2 + X2_i\beta2+,...,+X8_i\beta8)]}, j = 2,3 \quad (2)$$

A Multinomial Logit or a Generalised Ordered Logit model analysis might lead to similar conclusions as Partial Proportional Odds Model but there would be many more parameters to look at. The increased number of parameters could cause some effects to become statistically insignificant. The Generalised Ordered Logit Model considered in the study was specified as follows:

$$P(Y_i > j) = g(X\beta_j) = \frac{\exp(\alpha_j + X_i\beta_j)}{1+[\exp(\alpha_j + X_i\beta_j)]}, j = 2,3 \quad (3)$$

When performing the Partial Proportional Odds Model or a Generalised Ordered Logit Model on this study, a backwards stepwise selection procedure was employed, starting with the least parsimonious model and gradually imposing constraints. The backwards stepwise selection procedure provides an empirical means of identifying areas where assumptions are violated, although the procedure can also capitalise on chance just like other stepwise procedures (Williams, 2006). The backwards stepwise selection procedure was done using a *0.5* level of significance to have confidence in the final model.

The Multinomial Logit Model, though considered complicated in interpretation of the coefficient estimates of the variables, was then implemented. Just like the generalised ordered logit model, it relaxed the Parallel Lines assumption and does not impose any constraints to the variables. When fitting the Multinomial Logit Model on the accident dataset, one of the response categories was nominated as a baseline or reference cell, calculated log-odds for all other categories relative to the baseline, and then let the log-odds be a linear function of the predictors. The highest category (category 3, fatal accident) was picked from which odds that i^{th} accident falls in category j as opposed to the baseline as p_{i1}/p_{iJ} were calculated.

The coefficient estimates from the OMNL and BOMNL models were compared. However, comparison of the two models in terms of goodness of fit was not performed due to limitations brought about by the statistical software used to fit the two models. That is, the limitation resulted into the two Ordered Multinomial Logit Models reporting different fitting information criterion. Bayesian platform reported Bayesian Information Criterion (BIC) while the maximum likelihood platform reported residual.

Statistical Modelling

The variables were recoded and dummy variables computed for meaningful interpretation of coefficient estimates of the factors used in fitting the models Table 1. The dummies were then set to their most default forms (zero) and one variable (variable set to one) was used as a benchmark for comparison with other variables in the factor within which it was extracted. The underlining hypothesis on which the models were fitted and interpreted was that all coefficient estimates of independent variables (dummy variables) are zeros.

Table 1. Dummy variables created from variables in the dataset

Variable type	Variable name	Variable Label	Description
Dependent	Severity	Accident Severity	1 = Minor, 2 = Serious, 3 = Fatal
Independent	Weather cond	Weather condition	0 = Adverse conditions, 1 = Dry
	roadsurface	Road surface	0 = Gravel_earth, 1 = Bitumen
	roadgeom	Road geometry	0 = Elsewhere, 1 = Straight road
	surroundings	Road surroundings	0 = Rural, 1 = Urban
	lightcond	Light condition	0 = Night, 1 = daylight
	roadcond	Road condition	0 = Poor, 1 = better
	acc_type	Accident type	0 = Rollover, 1 = Collision
	obstruction	Obstruction	0 = Other object, 1 = Stationary vehicle

The estimated coefficients (β) of dummies in both the Bayesian and Maximum Likelihood Multinomial Logit Models were expected to differ in their signs. The positive value of the estimated coefficient (β) indicated an increase in motor vehicle accident severity whereas the negative values signified a decrease in motor vehicle accident severity. As the value of the independent variables increases, the effect of the identified factors on accident severity in the fitted models was studied by

examining the injury odds ratios against the reference case. The significant variables within the factors were mainly identified using *p*-values and confidence intervals of test statistics as well as its importance to assist explaining severity of motor vehicle accidents. The interpretation of the effect of independent variables on the levels of accident severity was followed by suggestions for precautionary measures to be taken to enhance safety as well as suggestions for future research. The response variable (Y_i) considered was severity of a particular accident with $J = 3$ as the number of categories of Y_i, namely: "1" = fatal, "2" = serious and "3" = minor. β_0 represented the intercept while $\beta_p X_p$ described a set of independent variables and its corresponding coefficient estimate extracted from factors of road geometry, road surface, surroundings, road conditions, weather, time period of the day, accident type and obstruction. That is, X_p represented a particular predictor variable of accident severity, and β_p was the coefficient of a particular predictor. Stata (version 10), *R*-project (version 2.13.0) and SPSS (version 16) were also employed in modelling and data transformation.

Model Evaluation

Evaluation of goodness-of-fit of the Ordered Multinomial Logit Models was achieved through considering the likelihood ratio index (LRI) or the McFadden's pseudo R^2. These ratios have been useful in most studies of this nature. For instance, they have been useful in evaluating discrete choice or classification models. However, goodness-of-fit for Bayesian models was achieved through considering deviance information criterion (DIC).

RESULTS AND DISCUSSION

Data Descriptive

Table 2. Measure of association of accident severity with different input variables in the study

Input Variable		Categories of dependent variable (accident severity)			P-Value
		Fatal	Serious	Minor	
Road geometry	Straight road	750	750	2, 635	
	Otherwise	106	160	627	<0.001**
Road condition	Good/Fair	3,363	2,793	9,216	
	Potholes	111	72	270	
	Corrugated	77	71	226	0.156
	Slippery	20	32	70	
Road surface	Bitumen	3,192	2,626	8,883	
	Gravel	51	48	154	0.005*
	Earth	353	300	810	
Surroundings	Rural	631	552	1,544	
	Urban	139	286	1,463	
	Peri-urban	102	93	346	<0.001**
	Farm, Compound	23	15	55	
District	Cities	2,475	1,540	3,826	
	Others	1,130	1,446	6,057	<0.001**
Weather	Dry	853	906	3,245	
	Rainy	0	2	3	0.551
	Others	3	2	14	
Accident type	Head on car crash	243	351	1,567	
	Rollover	423	393	1,100	<0.001**
	Collision	231	205	747	
Lighting condition	Daylight	3,465	68.91	68.91	
	Night	1,448	28.80	97.71	0.108
	Dawn/Dusk	115	2.29	100.0	
Time of the day	Day time	1,216	1,182	4,064	
	Night hours	2,389	1,804	5,819	<0.001**

It is observed from table 2 that six out of nine variables that were available for use to explain accident severity in the study period passed a chi-square test of significance at set alpha level of *0.05* (*P < 0.05*). The variables of road geometry, place of residence (surroundings), district, accident type and time period of day of accident were highly significant (*P < 0.001*), and only variable of road surface being marginally significant (*P = 0.005*). However, the variables of road condition, weather condition and lighting condition of the accident time failed the chi-square test of significance by having their probability values greater than the set critical alpha value (*P > 0.05*).

Despite some variables failing the chi-square test of significance, the study utilised all the variables available. This was justified on the basis that all the covariates would still assist to explain severity of accidents on the roads of Malawi and lead to identification of risk factors. The result of the test was however useful to explain the behavioural changes of variables when fitted in the models.

Results from the Parallel Lines and Partial Proportional Odds Models

The Ordered Logit Model performed three iterations using *5140* observations. The third iteration produced a *-4448.31* log likelihood and a Pseudo R^2 of *0.027* on a likelihood ratio chi-square of *248.45*. The Pseudo R^2 implies that the model covariates were only able to explain about 2.7% of the total variation in the model. However, the model was significant (*Prob > chi^2 = 0.001*). This means that the final model fitted the data well as compared to the null model. Nevertheless, analysis of the final model shows that only three variables were significantly associated with accident severity during the study period (table 3). The variables were *surroundings*, *lighting condition* and *accident type.*

Table 3. Adjusted odds ratios across accident severity panels through O*logit*

Variable	AOR (95% CI)	p-value
Weather condition		
Adverse	1.00 (ref)	
Dry	0.93 (0.80, 1.08)	0.346
Road surface		
Gravel	1.00 (ref)	
Bitumen	0.93 (0.78, 1.11)	0.422
Road geometry		
Straight	1.00 (ref)	
Elsewhere	0.97 (0.86 1.09)	0.610
Surroundings		
Urban	1.00 (ref)	
Rural	2.18 (1.93, 2.47)	<0.001
Light condition		
Daylight	1.00 (ref)	
Night	1.28 (1.13, 1.44)	<0.001
Road condition		
Poor	1.00 (ref)	
Better	1.02 (0.77, 1.36)	0.885
Accident type		
Collision	1.00 (ref)	
Roll over	1.37 (1.21, 1.54)	<0.001
Presence of obstruction		
Stationery vehicle	1.00 (ref)	
Other	0.89 (0.63, 1.27)	0.529
/cut1	-1.15 (-1.61, -0.69)	

/cut2	-0.14 (-0.60, 0.32)

Checking with the odds ratio of the significant variables, it is clear that the odds of severe accidents were *2.18* higher in rural settings compared to urban settings (*AOR = 2.18, 95% CI = (1.93, 2.47)*). Also, the odds of severe accidents were higher during night hours compared to day time (*AOR = 1.28, 95% CI (1.13, 1.44)*). However, this model could not be used for interpretation of results. This was so because of a significant test statistic ($P > chi^2 = 0.026$) of *brant* test which provided evidence that the parallel regression assumption was violated, but the main problem seems to be with the variable surroundings ($P > chi^2 = 0.05$). Since the assumptions of the parallel lines model are violated, using the model can lead to incorrect, incomplete, or misleading results (Williams, 2007). Alternative models were fitted and their goodness of fit was assessed. Generalised Ordered Logit was first option. It relaxed the variables from restrictive parallel lines assumption but had variable coefficients difficult to interpret. A better alternative was the Partial Proportional Odds Model, which constrained only some variables to meet parallel regression assumption.

The restricted Generalised Ordered Logistic Model (table 4) imposed constraints on variables that did not meet the Parallel Lines assumption thereby making the results more easily interpretable. The model imposed constraints on majority (seven out of eight) of the variables in the study except on the variable of *surroundings*. This had an effect especially on changing the interpretation of the meaning attached to the coefficients of the variables which had constraints imposed on them. This also could compromise validity of the results.

Table 4. Adjusted odds ratios across accident severity through a restricted *Gologit*

Variable	Serious severity AOR (95% CI)	p-value	Serious+Fatal severity AOR (95% CI)	p-value
Weather condition				
Adverse	1.00 (ref)		1.00 (ref)	
Dry	0.93 (0.80 1.08)	0.346	0.93 (0.80 1.08)	0.352
Road surface				
Gravel	1.00 (ref)		1.00 (ref)	
Bitumen	0.93 (0.78, 1.11)	0.422	0.93 (0.78 1.11)	0.435
Road geometry				
Straight	1.00 (ref)		1.00 (ref)	
Elsewhere	0.97 (0.86, 1.09)	0.610	0.97 (0.86 1.09)	0.597
Surroundings				
Urban	1.00 (ref)		1.00 (ref)	
Rural	2.56 (2.17, 3.03)	<0.001	2.10 (1.85 2.38)	<0.001
Light condition				
Daylight	1.00 (ref)		1.00 (ref)	
Night	1.28 (1.13, 1.45)	<0.001	1.28 (1.13 1.45)	<0.001
Road condition				
Poor	1.00 (ref)		1.00 (ref)	
Better	1.02 (0.77 1.36)	0.885	1.02 (0.77 1.36)	0.897
Accident type				
Collision	1.00 (ref)		1.00 (ref)	
Roll over	1.37 (1.21 1.54)	<0.001	1.37 (1.21 1.54)	<0.001
Presence of obstruction				
Stationery vehicle	1.00 (ref)		1.00 (ref)	
Other	0.89 (0.63 1.27)	0.529	0.89 (0.63 1.27)	0.540
Minor = base outcome				

The Wald test of Parallel Lines assumption for the final model shows an insignificant test statistic ($Prob > chi^2 = 0.1665$). This indicates that the final model (table 4) did not violate the Parallel Lines assumption. The restricted *Gologit* model is significant ($Prob > chi^2 = 0.0001$) with a log likelihood of *-4443.79* and a pseudo R^2 of *0.0282*. The R^2 shows that only about *2.8%* of the variation in the model is explained by the variables used to fit the model. Therefore, there is little evidence suggesting a better model fit. However, this model only slightly improved fitting as compared to the Parallel Lines Model with a pseudo R^2 of *2.8%*.

Taking lighting condition of accident place on the minor severity panel for example, the odds of severe accidents are *1.28* higher during night hours as compared to accidents occurring during daytime, and the association is significant *(p < 0.001, 95% CI (1.13, 1.45)*. A similar interpretation of the input variable lighting condition applies on the serious severity panel. This is because both panels have *1.28* as odds ratio to be contrasted with the base outcome (fatal accidents). However, since variable of *surroundings* has different odds ratios on the panels of minor and serious severity, a one unit increase in the severity panel is observed to decrease odds of severe accidents with respect to fatal accident as a base outcome. That is, the odds of severe accidents were *2.56* higher in rural settings as compared to urban settings with respect minor severity category. However, taking consideration of the serious severity category, the odds of severe accidents were *2.10* higher in rural settings as compared to urban settings. Generally, accidents that occurred in *urban surroundings* tended to become less severe than those that occurred in *rural surroundings* during the study period. Therefore, the strongest effect of *surrounding* variable was associated with less severe accidents in the study period.

Results from the Ordered Multinomial Logit Model

Similar to the Parallel Lines Model, *Mlogit* performed three iterations and resulted in the log likelihood estimate of *-4439.63*. The results show that the model has likelihood ratio chi-square (16) of *265.80* and the model is significant (*Prob > chi^2 = 0.0001*). The goodness-of-fit of *Mlogit* assessment is given by pseudo R^2 of *0.0291*. Therefore the variables help to explain about *2.9%* of the variations in the model. There is a slight improvement in model fitting with the Multinomial Logit Model as compared to *Ologit* and *Gologit* models estimated in this study. The Ordered Multinomial Logit Model shows that three covariates were significantly associated with more severe (fatal) road accidents during the study period. The covariates include location of accident (*surroundings*), *lighting condition* of the time of accident and *accident type*.

Considering *surrounding* variable, the risk of fatal accidents was significantly higher than that of serious and minor severe accidents in rural settings compared to urban settings. The odds of severe accidents were *0.35* higher in rural settings as compared to urban settings with respect to minor severity category (*P < 0.001, 95% CI (0.29, 0 .42)*). However, considering serious severity category, the odds of severe accidents were *0.62* higher in rural settings as compared to urban settings (*P < 0.001, 95% CI (0.53, 0.72))*. With respect to *lighting condition*, accident severity risk was higher with accident occurring at night than those occurring during daytime. Comparing fatal and minor severity accidents, the odds of fatal accidents were *0.71* higher during night hours compared to daytime (*P < 0.001, 95% CI (0 .60, 0.83)*). Considering a contrast of fatal and serious severity accidents, the odds of fatal accidents were *0.90* higher than that of serious accidents particularly during night hours compared to daytime

Considering the significant variable of *accident type*, relative risk ratio was also increasing with increase in severity of accidents. The relative risk ratio of fatal accidents was significantly higher than that of serious and minor severe accidents. However, the accident severity risk was higher with rollover accidents compared to collision accidents. The odds of more severe (fatal) accidents were *0.69* higher than that of minor accidents particularly with rollover accidents compared to collision accidents (*P < 0.001, 95% CI (0 .59, 0 .81)*). However, the odds of fatal accidents were *1.37* higher than that of minor accidents with rollover accidents compared to collision accidents (*P < 0.001, 95% CI (*0.65, 0.89*)*).

Results from the Bayesian Ordered Multinomial Logit Model

Similar to an OMNL regression model (table 9), the Bayesian Multinomial Logit (BOMNL) regression model in table 10 was fitted with consideration of category 3 (fatal accidents) as the base outcome. However, through MCMC estimation techniques, using 12,000 iterations, BOMNL model

produced posterior mean estimates of each variable unlike the *Gologit* and the *Mlogit* models which reported odds ratio estimates and the model was significant. However, examination of the estimates from BOMNL reveal similar story to that of *Gologit* and *Mlogit*.

The BOMNL model slightly improved the parameter estimates as compared to results provided by the maximum likelihood Multinomial Logit Model, OMNL. This is particularly suggested by comparing the coefficient estimates of the intercepts of the two models. Analysis of the parameter estimates and intercepts in BOMNL shows that they tended to be more positive than those of the OMNL.

Table 5. Severity posterior means through a Bayesian Ordered Multinomial Logit

Variable	Minor severity Mean (2.5%, 97.5% Quant)	Median	Serious severity Mean (2.5%, 97.5% Quant)	Median
Weather condition				
Adverse	1.00 (ref)		1.00 (ref)	
Dry	-0.10 (-0.31, -0.10)	-011	-0.09 (-0.32, 0.16)	-0.09
Road surface				
Gravel	1.00 (ref)		1.00 (ref)	
Bitumen-	-0.11 (-0.32, 0.11)	-0.11	-0.07 (-0.35, 0.20)	-0.07
Road geometry				
Straight	1.00 (ref)		1.00 (ref)	
Elsewhere	-0.11 (-0.27, 0.06)	-0.11	-0.18 (-0.39, 0.02)	-0.18
Surroundings				
Urban	1.00 (ref)		1.00 (ref)	
Rural	1.05 (0.88, 1.22)	1.05	0.56 (0.36, 0.76)	0.56
Light condition				
Daylight	1.00 (ref)		1.00 (ref)	
Night	0.34 (0.17, 0.50)	0.35	0.24 (0.05, 0.43)	0.24
Road condition				
Poor	1.00 (ref)		1.00 (ref)	
Better	0.15 (-0.19, 0.46)	0.14	0.40 (-0.07, 0.88)	0.40
Accident type				
Collision	1.00 (ref)		1.00 (ref)	
Roll over	0.37 (0.22, 0.53)	0.37	0.10 (-0.11, 0.29)	0.10
Presence of obstruction				
Stationery vehicle	1.00 (ref)		1.00 (ref)	
Other	-0.11 (-0.55, 0.34)	-0.10	0.06 (0.48, 0.60)	0.06
Fatal = base outcome				

Despite the improvements on parameter estimates, the BOMNL however did not adjust the variables that were insignificant in the OMNL and *Gologit* models to be significant. Just like in Parallel Lines, Partial Proportional Odds and in OMNL models, *Surroundings*, *lighting condition* and *accident type* were the only variables which are significant in BOMNL model. The significance is shown by their credible intervals given by 2.5% and 97.5% in the model. The implication was that, driving in *urban surroundings*, during *daytime* and occurrence of accidents of *collision type* was more risky since severity of accidents was significantly associated with such conditions. Since coefficient estimates of the intercepts are bearing negative signs, generally, the greatest effect of the significant covariates were to decrease the likelihood that the accident will belong to higher severity categories.

Results from OMNL and BOMNL suggest that cautious driving and fewer incidents of risky behaviours such as careless overtaking of vehicles on the road might have led to less number of severe road accidents during *day time* especially with *collision* accident type and driving in urban *surroundings*. This is suspected from examination of odds ratio and coefficient estimates of the covariates of *surroundings* of accident spot, *lighting condition* of time of day of accident and *accident type* which are significant and generally seem to decrease with increase in accident severity. That is, they are more associated with less severe accidents.

Urban surroundings are generally densely populated with increased motor vehicle volumes and road activities. These include more traffic on the road, more pedestrian movements and vending along the roads. Also, urban roads are usually highly and constantly patrolled by traffic police. As a result, drivers of motor vehicles are usually alert and drive carefully on urban roads. Such caution driving behaviours might have assisted to prevent collision accident as most of such accidents are bound to occur in instances of over-taking which is unlikely in urban surroundings due to busy roads. Nevertheless, urban surroundings in Malawi are still severe accident prone areas. Most roads in urban surroundings are covered in tarmac and majority of them have lived past their life span. Most of these roads are not in good condition as evidenced by potholes. Hence careless driving in surroundings consisting of high motor vehicle volume with bad road conditions can result in more severe accidents. The residual deviances reported by models listed in table 12 are huge, implying the Bayesian models fit the data well. This is additional evidence that BOMNL has better parameter estimates than the OMNL model.

The models considered in the study were observed to have picked similar variables which are significant. These are variables of *surroundings, lighting condition* and *accident type* (table 11). The selected variables also had similar impact in decreasing severity of accidents in the study period. This was indicated by analysing the positive and negative signs of the coefficient of the variables. This is despite the fact that some models improved the estimates to more positive.

Table 6. Model fitting criterion information

Maximum Likelihood Estimation Models	**Pseudo R^2**	
Ordered logit Model	0.0272	
Generalised Ordered Logit	0.0292	
Generalised Ordered Logit (with constraints)	0.0282	
Ordered Multinomial Logit	0.0291	
Bayesian Models	**DIC based on Saturated Deviance**	
Bayesian Ordered Multinomial Logit	Deviance (bar_mu):	8879.32
	pD:	17.91
	DIC:	8915.14

CONCLUSION AND RECOMMENDATIONS

Modelling accident data can be more advantages over other data analysis techniques like chi-square and frequencies. Although modelling is rigorous and tedious since it involves paying attention to model assumptions which might be violated and lead to models that do not fit the data well, however it has capacity and can be trusted to inform better decisions on road safety.
Chi-square and frequency tables correlate only a few variables at a time, they report association of

individual factors with the response variables and only assist in revealing trend or distribution of a response variable. On the contrary, modelling has capacity to establish association of various factors with the response variable at once. For instance, a Pearson chi-square test of association employed in this study only assisted to establish association of accident severity with each of the eight independent variables. However, when data was modelled, the association was given at an individual input variable level as well as at a level of collective impact of the eight variables on frequencies and severity of accidents on the roads of Malawi.

For an instant look at distribution but also in order to account for descriptive analysis, frequencies and chi-square techniques can be very useful tools. For instance, the two techniques were useful during data exploration before implementation of modelling in this study. That is, modelling itself does not exist and operate alone but in collaboration with other techniques in order to achieve its objective. Chi-square has capacity to inform models on which factors to consider taking on board based on their individual significant association with the response variable. On the other hand, frequency can give clues of most likely distribution of the response variable. This can assist with choice of a type of model to implement, or assist with the measures to be taken to manipulate the response variable so that a choice model can still be implemented.

Simple statistical analysis techniques normally produce simple estimates of statistics that are often easy and straight forward to interpret. Such estimates usually do not inform much on their impact to the response variable since they often lack a reliable measure of significance, as is the case of frequencies, or may rely only on a single measure of significance such as a probability value as is the case with chi-square tests. With modelling, significant variables may be required from a test of association. Then models are run in search of a better model explaining the data from which the magnitude of association of input and response variables is determined by the significant estimates. During modelling, significance is normally decided based on two techniques including the probability value as well as through the reported credible intervals.

Use of modelling techniques in data analysis not only can provide for a solution to unreliable estimates but also bring in more accurate statistical tools for testing data. This is due to the fact that modelling takes data through a deliberate and useful process of cleansing, augmentation and assumption checking. As a result, parameter estimates that are reliable and which can inform better decision making are always likely to come by. The risk factors obtained by analysing significant estimates from modelling can have a better story to tell on how Malawians should interact with motor vehicles and the road network as was observed in this study as follows. .

Generally, there was estimation improvement of intercept and variable coefficients to more positive with fitting of BOMNL model. The model however picked similar variables to those picked by Parallel Lines, Partial Proportional Odds and Multinomial Logit Models as significantly associated with severity of accidents. These included accident location (*surroundings*), *lighting condition* of time of accident and *accident type*. Examination of the model fitting information, *Pseudo* R^2 of the *Ologit*, *Partial Proportional Odds* and *Mlogit* Models suggested that *Mlogit* reported a bigger *Pseudo* R^2. However the difference in the magnitude of the *Pseudo* R^2 among the models was just very tiny to endorse the *Mlogit* as a better model as compared to its counterparts.

Overall, it could be stated confidently that due to incorporation of normal (informative) priors when fitting Bayesian models, the parameter estimates realised in BOMNL model were more reasonable than those in OMNL. However, it is clear from the model that driving in dry weather conditions, in better road conditions especially of bitumen surfaces and straight road geometries had resulted to severe accidents in the study period.

On the contrary, driving in urban surroundings, occurrence of accidents of collision type and driving during daytime significantly impacted “less severe accidents” since they contributed to less

number of fatal accidents during the study period.

The risk factors associated with variables that had a positive impact in causing more severe accidents include careless driving in straight roads with bitumen surfaces as well as in good weather and better road conditions. Therefore, road improvements are required to cover for the potholed conditions.

In addition, it is suggested that substance abuse by drivers, cell phone use during driving may result to carelessness and risk taking behaviours when driving. Substances like alcohol when taken in excess amounts reduce the control and driving capabilities of the driver hence more prone to severe accidents (Beckett, 1998). Cell phone use can disturb driver attention and concentration when driving even in better roads or in good weather conditions. However, caution driving tendencies in urban surroundings, in which car volumes are greater and with increased road use activities than other surroundings may have resulted in less severe accidents in the study period.

According to Xie *et al* (2009), drunken driving, carelessness or risk taking behaviours on the roads are highly associated with the youth than any age group. Hence there is a need to step up the efforts of discouraging drunken driving, carelessness or risk taking behaviours particularly amongst the youth through information dissemination of their dangers.

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ADDENDUM

Conference Organising Process

(a) Call for Abstracts

A call for abstracts was placed in the print media, email circulation list and the NCST website. The call lasted for 30 days. A total of 263 abstracts were received.

(b) **Assessing Abstracts**

(i) Initial screening

The abstracts were screened to ascertain compliance to the submission requirements as outlined in the call for abstracts, as detailed below:

- Title of Research/Study
- Authors first name followed by last name, institutional affiliation, email address and phone number.
- Objective(s) of the study-does the study have concise objectives?
- Method(s) used to achieve the objectives
- Results – a clear summary of the results.
- Conclusions/recommendations
- Format for the abstracts
    - ✓ Times New Roman Font 12
    - ✓ Single spacing
    - ✓ Maximum 300 words in MS word
    - ✓ Statement indicating the year the research/study was conducted.

(ii) Expert / Peer Review

This stage involved expert review by independent reviewers which concentrated on technical aspects of the abstracts. The focus was mainly on the:

- Introduction;
- Methodology;
- Results;
- Discussion;
- Conclusion;
- Relevance of the study (Thematic area, body of knowledge);
- Quality of Science (Principles, theories);
- Logical Flow; and
- Significance of the study (applicability).

(c) Expected outputs and outcomes

(i) Expected outputs

The following were the expected outputs:

- Proceedings of the 2017 Annual Research Dissemination Conference on "Research and Innovation: a catalyst for sustainable development"
- Published Papers in Peer Reviewed Journals

(ii) Expected outcomes

- Improved uptake of research results.
- Improved linkages, collaboration, networking and partnerships among researchers and research and development institutions.
- Improvement of evidence based policy decision making process.

(d) Conference Methodology

The Conference lasted for two days primarily implemented a vibrant participatory system to encourage networking and exchange of ideas. It basically took three approaches;

(i) Keynote Lectures

Selected topics were presented by specialists in their particular fields. The presentations were followed by brainstorming sessions where questions that have arisen in the course of presentation were responded to.

(ii) Facilitated Sessions

These presentations were made by Presenters who submitted abstracts according to the conference subthemes. Due to the large number of presentations in these two days, the presentations run in parallel sessions.

MPPRAP IN BRIEF

The Malawi Public Policy Research and Analysis Project (MPPRAP) is being coordinated by the Department of Economic Planning and Development in the Ministry of Finance, Economic Planning and Development with financial support from the African Capacity Building Foundation (ACBF).

The Government of Malawi is committed to implementing sound macroeconomic policies as a way of creating a conducive environment for all-round development in the country. However, the current indicators show a slow economic growth. This has been attributed to challenges including dependence on limited agricultural products, high population density, inefficient public spending and unsustainable policy directions.

On the policy front, there is a disengagement between the policies developed and the implementation. This is considered an impediment in the overall development process. The second Malawi Government Development Strategy, which is an overarching policy for development in the country, recognizes evidence-based policy research and formulation as one way of addressing the challenges affecting policy management. This necessitated the need to establish the Malawi Public Policy Research and Analysis Project (MPPRAP) with an aim of improving policy research, formulation analysis and review.

Overall goal

Enhance effectiveness and relevance of public policies in Malawi

Specific Objectives

- To promote evidence based policy formulation and review through policy research.
- To strengthen capacity of public officials and non-state actors in policy formulation and analysis.
- To improve capacity for policy implementation and management through the establishment of semi-autonomous policy research institute

PROJECT COMPONENTS AND ACTIVITIES

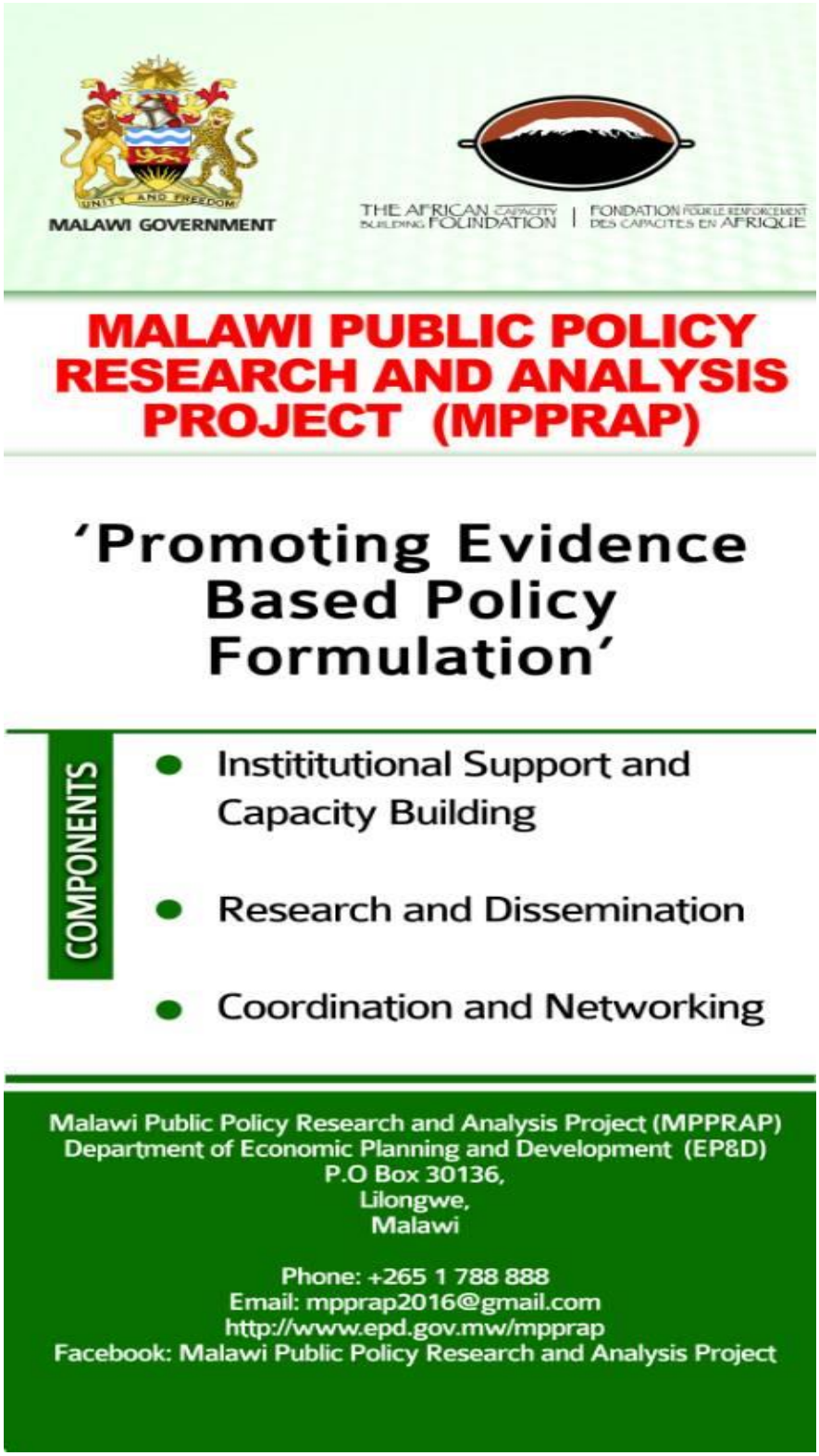
- Institutional support and capacity building
- Research and dissemination
- Coordination and networking

Key project activities

- Conducting Research Studies and Assessments
- Publication and Dissemination of Research Findings, Policy Briefs and Position Papers
- Establishing and Operationalizing the Malawi Policy Research Network (MPRN)
- Producing the MPPRAP Quarterly Bulletin
- Organizing Annual Conferences, Round-Table, Panel Discussions and Coordination Forums.
- Establishment of a Resource Centre for all Policy and Research Documents

CO-SPONSOR OF THE 2018 NCST RESEARCH DISSEMINATION CONFERENCE

MINISTRY OF FINANCE, ECONOMIC PLANNING AND DEVELOPMENT THROUGH MALAWI PUBLIC POLICY RESEARCH AND ANALYSIS PROJECT (MPPRAP)



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