IMPLICATIONS OF INSTITUTIONAL CLIENT-SERVER GEOGRAPHIC INFORMATION SYSTEMS ON AGRICULTURAL SERVICE DELIVERY: CASE OF MZUZU AGRICULTURAL DEVELOPMENT DIVISION

MASTER OF SCIENCES IN INFORMATICS

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DECLARATION

I, **Daniel Nkosi**, declare that this dissertation is my original work which has not been submitted to any other institution for similar purposes. Where other people's work has been used acknowledgements have been made.

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CERTIFICATE OF APPROVAL

The undersigned certify that this thesis represents the student's own work and effort and has been submitted with our approval.

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DEDICATION

This is dedicated to Waliko Nkosi and Chanju Mphande. I am deeply indebted for the encouragement you gave that infused in me the energy to carry on and further made me to see that it’s all about God. This is surely yours.

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I am so thankful for the Lord in causing me to meet the right people to see me through this work.

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ABSTRACT

Geographical Information System is widely used in agriculture production and service delivery in developed countries but in Malawi, like most developing countries, its application in agricultural service delivery and farm production is limited. Using the case of MZADD, this study assesses the adoption of a client-server GIS application as an innovation of reducing institutional challenge and facilitating spatial data sharing among subject matter specialists. Using mixed method research approach and an explanatory research design the study collected data using a framed field experimental approach. In the study spatial data of MZADD from the Department of Land Resources Conservation and non-spatial data of hybrid maize from Department of Crops with conditions for producing optimum hybrid maize yield were used to produce a map showing areas most likely to produce optimum yield for hybrid maize to assist subject matter specialist to know which areas are in need of their agricultural advice. The study found that in MZADD areas that are less likely to have optimum hybrid maize yield are parts of Mzenga, Emsizini, Bolero and Malidade. This information would help subject matter specialists introduce necessary interventions in these areas to stimulate production of the optimum yield to ensure food security. If MZADD is to adopt a GIS client-server application it would mean training members of staff in basic GIS and that it should have reliable connection between personal computers and the central repository housing the application.

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LIST OF ABBREVIATIONS

ADSL	Asymmetric Digital Subscriber Line
AEDC	Agriculture Extension Development Controllers
AEDOs	Agriculture Extension Development Officers
AHP	Analytic Hierarchy Process
AGRESS	Agricultural Gender Roles Extension Support Services
APE	Agriculture Production Estimates
CGIS	Canadian Geographic Information System
CALHDO	Chief Agriculture Livestock Health Development Officer
CLRCO	Chief Land Resources Conservation Officer
COTS	Commercial-Off-The-Shelf
CAD	Computer Aided Design
DBMS	Database Management System
DIME	Dual Independent Map Encoding
ECU	Experimental Cartography Unit
EPAs	Extension Planning Areas

FC	Financial Controller
FNO	Food Nutrition Officer
FOSS	Free Open Source Software
GIS	Geographic Information System
IT	Information Technology
IFMIS	Integrated Financial Management Information System
LAN	Local Area Network
MTL	Malawi Telecommunications Limited
MoAFS	Ministry of Agriculture and Food Security
MZADD	Mzuzu Agriculture Development Division
MZADD MU	Mzuzu Agriculture Development Division Management Unit
ORDBMS	Object Relational Database Management Systems
PRA	Participatory Research Approach
PDF	Portable Document Files
PEMO	Principal Extension Management Officer
PM	Program Manager
QGIS	Quantum Geographic Information Systems

RPC	Remote Procedure Calling
RTC	Resource Training Centres
SDI	Spatial Data Infrastructure
TOE	Technology Organization Environment
US	United States
UI	User Interface

1.0 CHAPTER 1- INTRODUCTION

1.1 Background

Access to social, economic and environmental information is critical at both service provision level and at farmer level to support decision making in farming. According to International Institute of Rural Reconstruction & African Conservation Tillage Network (2005), farming attributes to 60% of Africans sustenance and livelihood. The application of Information Technology (IT) plays a central role in agriculture sector as a means of providing reliable and timely information to farming communities in sub-Saharan Africa.

Agricultural extension workers need a wide range of information in order to adequately support smallholder farmers' livelihood. Much of this information can be generated and adequately managed through GIS technology (Esri, 2013). When used by agricultural experts, to provide services to a farmer GIS can be used for; data management, analysing data of harvested produce, selection of prospective planting sites, in-field data collection and also determining irrigation requirements. A world class vine yard, Scheid Vineyard, in Monterey county California, records sites with pest and diseases and load the data into GIS, when the data is analysed the invasion and spreading of crop pests and diseases is combated and minimised in the Vineyard (Esri, 2013).

Economists, agronomist, community planners and farmers use GIS to research and device practices that will enable sustainability of food production and ensure the survival of human race (Braun & Pantel, 2008). The use of remote sensing for crop acreage and crop yield estimation has gained importance in recent years as a means of obtaining these estimates in a faster way and at a cheap cost (Murthy et al., 1996 cited by Sahoo et al., 2005; Sawasawa, 2003). Nelson et al. (1999) has used GIS to identify recurring patterns in plant disease as well as other problems like insect and weed infestations. When farmers include this information in the production of crops it helps in precision farming, according to Esri (2013), GIS is the backbone for precision farming at Scheid Vineyard. Precision farming is a term that is used when farmers reduce run offs of fertilizers and reduce total expenditures of production that would have been incurred otherwise (International Institute of Rural Reconstruction & African Conservation Tillage Network, 2005).

Despite the perceived usefulness of the GIS technology in agriculture, it is yet to be fully adopted in many developing countries (Jha & Chowdary, 2006). Literature shows that a new technology can be intimidating so much so that an organization becomes inefficient following the inception of the technology. This is because members of staff have to get to know it and then accept it (Fine, 2003; Laudon, 2012). According to Technology Acceptance Model (TAM) motivation of a user to use a new technology is based on three factors; perceived ease of use, perceived usefulness and attitude toward using the new system (Chuttur, 2009). GIS is a new technology in most developing countries. Like any other new technology for it to be accepted, the intended users must be motivated to use it. Furthermore, developing countries are facing a lot of challenges to adopt GIS technology due to institutional challenges such as lack of linkage between the decision makers, planners and/or the end users due to inadequate dissemination structures or restricted accessibility (Tanser & le Sueur, 2002; Jha & Chowdary, 2006).

Geographic Information System (GIS) is one of the major medium of managing and sharing information that has been widely promoted (Johnson & Johnson, 2001; Braun & Pantel, 2008). However, GIS technology has not been successful as a tool in sharing information because of many reasons such as; cost implications and limited capacities of GIS expertise in developing countries (Dunn et al., 1997). Furthermore late adoption of GIS technology in developing countries has been attributed to institutional challenges and in-availability of spatial data (Jha & Chowdary, 2006). Spatial means space and spatial data is data about location. Spatial data is categorised into raster data, top-down photography of earth, and vector data, non-photographic data based on lines, points and polygon (Davis, 2007). Recently spatial data has been democratized through open source community that supports sharing of spatial data and one common application that is used is that of Geonetwork (Davis, 2007; OSGeo, 2009).

Even though literature shows that adoption of GIS is hindered by high cost of buying hardware, software and training of staff (Dunn et al., 1997; Jha & Chowdary, 2006) presently the availability of Free Open Source Software (FOSS) to some extent has removed the notion that GIS applications are expensive. Nowadays markets have FOSS applications that work as good as proprietary commercial software (Davis, 2007). FOSS is defined as software with four freedoms attached;(1) the freedom to run the program for any purpose, (2) the freedom to study how the program works and adapt it to your needs, (3) the freedom to redistribute copies and (4) the freedom to improve the program and release the improvements to the public, so that the whole community benefit (Vanmeulebrouk et al., 2008, p.2).

There is growing belief that use of FOSS, like client-server models, can off-set challenges associated with traditional desktop GIS such as cost and access. Geonetwork is one of FOSS client-server application used in manipulation and sharing of spatial data. The emerging way of information exchange nowadays via network is powered by web technology on the Internet/Intranet. The web-oriented user interface can contribute to the remote operation of GIS applications, with which users can communicate interactively using Graphical User Interface (GUI) through distributed computing systems (Lee et al., 1998).

1.2 Problem Statement

The line departments at Mzuzu Agriculture Development Division (MZADD), Extension, Land Resources and Conservation, Livestock, and Crops have GIS desktop software installed on their laptops and desktop computers. The GIS software in use includes, Quantum GIS and ArcGIS Desktop. However, the department of Land Resources Conservation is the only department that predominantly uses GIS technology in its activities. Presently MZADD does not have a centralized repository and therefore information reside on individual computers and laptops.

Standalone GIS applications at MZADD make it difficult if not impossible for the technical personnel to share stored data to support where it is needed. Furthermore there is duplication of work and inconsistency in the data collected by the division. Standalone GIS application influences the institutional challenge (Jha & Chowdary, 2006). This situation arises due to GIS experts not being able to share spatial data with other users who do not have access to GIS desktop and knowledge of GIS. As a result non-GIS experts are excluded; these might include decision makers at MZADD. Currently it is not known if subject matter specialists at MZADD utilise GIS in their service delivery to farmers and decision-making in process of their work.

Using the case of MZADD, this study proposes a client-server GIS application as an innovation of reducing institutional challenge and facilitating spatial data sharing. When a client-server GIS application is viewed as a community-oriented GIS application, it can reduce some problems that are associated with data, technology and institution that are attributed to by desktop GIS (Rybaczuk, 2001). In essence a community-oriented GIS application improves communication between departments and within them by facilitating information flows when they are online.

Wisse (2006) observes that currently there are many developments of geospatial data infrastructure but not many studies have been conducted on the performance of client-server GIS in an institution within developing country context. With this in mind studying implications of client-server GIS application will add to the literature of geospatial data infrastructure.

1.3 Objectives of the Research

The aim of this research is to identify implications of adopting a client-server GIS application as innovation of reducing institutional challenge and facilitating spatial data sharing among subject matter specialists.

The specific objectives of this research have been identified as:

1. To analyse current information sharing practices at MZADD.
2. To determine whether an institutional client-server GIS application can be an alternative way of sharing spatial data in an institution.
3. To identify challenges of introducing institutional client-server GIS application.

The research specifically seeks to answer the following questions;

a) Can a client-server GIS application be an abler of spatial data sharing within an institution?
b) How can a client-server GIS application be used by subject matter specialists within an institution to assist in agricultural service delivery?
c) What are key implications of introducing institutional client-server GIS application?

1.4 Justification

Internally improved Information Technology (IT) systems can potentially enhance and strengthen an organizational infrastructure by increasing the efficiency of information sharing between departments, staff, board, and volunteers (Fine, 2003). For MZADD implementing a client-server GIS application can be considered as implementing an improved IT system over the current standalone GIS application. Setting up an institutional client-server GIS application is a step towards setting up a national spatial data infrastructure. A national spatial data infrastructure is composed of networked spatial data infrastructures which have been designed to serve specific purposes at institutional, regional or national level it provides a basis for spatial data discovery, evaluation and download for users and providers (Groot, 1997; Ajmar et al., 2008).

1.5 Organization of the Research

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This dissertation has been organized into 5 chapters. Chapter 1 is Introduction followed by Chapter 2 which covers theoretical discussions by focussing on GIS, client-server GIS and Prototype. Chapter 3 gives the methodology which is guided by the theories discussed in Chapter 2. Chapter 4 presents results and discussion on the data that was obtained. The dissertation is then summarised in chapter 5 with the overall thesis summary and recommendations for future studies.

2.0 CHAPTER 2- LITERATURE REVIEW

2.1 Evolution of GIS: Data Sharing and Data Storage

Geographic Information System (GIS) is a computer system that has the capability of assembling, storing, manipulating, and displaying data referenced by geographic coordinates (Nelson et al., 1999; Longley et al., 2005; Taylor & Blewitt, 2006; Jones, 2007). The technology is generally used to present a model of the world (Hall et al., 2011).

As illustrated in **Error! Reference source not found.**, innovations of having the model of the world presented electronically date back to 1960s (Longley et al., 2005): (a) Mid 1960s Canadian GIS (CGIS) was developed in Canada for land inventory (b) Late 1960 United States (US) bureau of census produced the Dual Independent Map Encoding (DIME) program, for referencing and aggregating census records (c) Harvard University of Computer graphics and Spatial Analysis developed ODYSSEY GIS in late 1970s after the University studied and noted the similarity in CGIS and DIME (d) In 1968 Experimental Cartography Unit (ECU) with British Geological Computer in United Kingdom came up with Computer Mapping. According to Longley et al. (2005), this innovation led to most Cartographic agencies in UK to computerise their tasks.

Table 1: Dates of Technology Innovations (source: Longley et al., 2005)

Year	**Contribution**	**Institution/Person**
Mid 1960s	Canadian GIS	Government of Canada
Late 1960	Dual Independent Map Encoding (DIME)	United States Bureau of Census
1968	Computer Mapping	Experimental Cartography Unit with British Geological Computer
1970	ODYSSEY GIS	Harvard University of Computer graphics
1980	GIS in Forestry and Natural Resources	Forestry Companies and Natural Resources Agencies in Europe
Mid 1990	Public Participation GIS	Harlan Onsrud, Paul Schroeder and Xavier Lopez

In 1980s with price decrease in computer hardware, Forestry companies and Natural resources agencies started using GIS in Europe (Longley et al., 2005). GIS in Forestry and Natural resource was mainly used to keep track of timber resources and regulate their use. The continuing in falling prices of computers has seen the growth in the GIS software industry.

From this history, it is apparent that spatial data sharing was a challenge among the early GIS innovations because the technology was under development. For example, the development of ODYSSEY GIS to generalize functionality of DIME and CGIS meant that the two applications were not compatible with each other in the sharing of data. There were innovations in the US and UK occurring at almost the same time that focused on totally different areas. The US was looking at Land inventory and Census, whereas UK was looking at Cartography and Timber inventory. There is no mention whether the system were complementing each other or not. This simply means that data from Census and Land inventory GIS could not be exchanged with that of Cartography and Timber inventory GIS. If at all there was electronic information exchange between UK and US, it must have been done on disk or other means other than the Internet. At the time World Wide Web (www) had not started because literature shows that www started in 1993 (Longley et al., 2005).

In mid 1990s Harlan Onsrud, Paul Schroeder and Xavier Lopez met to come up with a convenient way of making GIS accessible in an institutional as well as the society, hence making network as one of the technical fundamental components of GIS (Obermeyer, 1998). The coming of the Internet has rapidly helped to improve upon communication and digital sharing of information. The Internet web browsers were utilized and were seen as a cheap way to interact with maps (Taylor & Blewitt 2006). The reason for this was that specialized software was not downloaded and installed for people to start using GIS (Longley et al., 2005). Examples of GIS applications on the Internet are; disseminating information selling of goods (e.g. on www.yellow.com) and services (e.g. on www.landseer.com.sg). The Internet has influenced the growth in the GIS industry.

Due to the portability of the Internet, GIS enabled portable devices have utilized this capability to deliver GIS-based representation on the move through broadband connection and has also given rise to GIS services which offer users in desperate location access to a centralized GIS application (Longley et al., 2005). GIServices are used in mobile and handheld applications and location based services.

GIS software has three-tier architecture namely user interface, functions or tools and data management (see Figure 1). Longley et al. (2005) have dubbed these components as Presentation, Business logic and Data server respectively. The user interface is a point where users interact with the GIS software. Functions are the various capabilities the GIS software is able to perform. These capabilities include overlaying of maps, data modelling, data analysis, data editing and data capturing. Data management helps in efficiently and effectively storing of data in and access of data from database. This is usually done by Object Relational Database Management Systems (ORDBMS) (Longley et al., 2005). Examples of ORDBMS are Oracle, PostgreSQL and Informix Dynamic server.

ORDBMS do not manage spatial data by default. For any ORDBMS to manage spatial data a specific spatial extension has to be configured in it (Longley et al., 2005). PostgreSQL requires PostGIS, Oracle requires Oracle Spatial and Informix Dynamic server uses Informix Spatial Datablade.

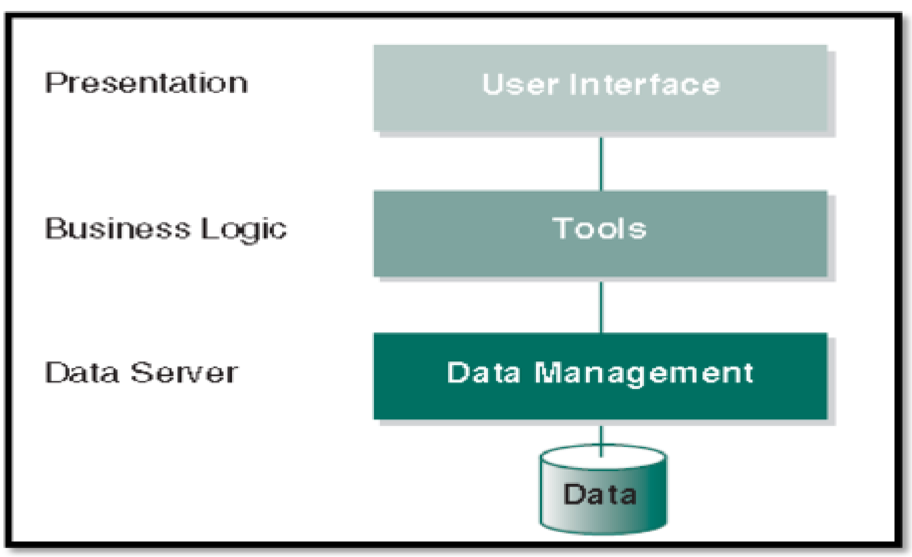

Figure 1 Components of GIS software (**source:** Longley et al., 2005, p. 160)

There are four computer system architectural configurations that can be used to build the three-tier GIS architecture (Longley et al., 2005). These configurations are (1) Desktop (2) Centralized desktop (3) Centralized Server and (4) Client-server. In mid-1990 desktop GIS was the main implementation of most GIS. The desktop GIS configuration is where all the components (user interface, functions and data management), and the data that is managed, reside on one computer which disadvantages data sharing and furthermore, data will just be idle whilst other quarters are in need of it. Table 2 shows examples of desktop GIS software on the market. GIS viewers are considered as thin clients which are built for viewing, querying and simple mapping of spatial data and no analysis is performed on the data viewed (Steiniger & Bocher, 2009). Desktop mapping software has tools for making maps, reports and charts. Full featured GIS application add to desktop mapping software data collection and editing, database administration and advanced geo-processing and analysis tools. Recent implementation of viewers, desktop mapping and full featured GIS provide additional functionality of accessing data from remote computers (Steiniger & Bocher, 2009).

Table 2: Examples of Desktop GIS software

Functions	**Examples of GIS sotware**
Viewers	ArcReader, GeoMedia Viewer, Proviewer
Desktop Mapping & GIS Software System	Map 3D, ArcView, Spatial Intelligence, GeoMedia, MapInfo Professional
Full featured (Editor/Analysis systems)	ArcInfo, GeoMedia Professional, SmallWorld GIS

Contrary to the desktop setup is the centralized desktop setup that has all the components of the GIS software installed on a central server. Here additional software like windows terminal server is installed on the server. The additional software allows other computers connected to the server to access the centralized GIS software remotely, as if it were installed on their desktop.

In the configuration of a centralized server a number of computers are connected to a central computer which stores data files. Each computer downloads a file from the server using the data server. Literature shows that centralized server set up is not efficient in the sense that the whole data file is downloaded to a computer when at times it is just part of the file that is needed (Longley et al., 2005).

In a client-server setup, the client computer houses user interface and functions while the database server and data reside on the server computer. In this setup, a number of computers can be configured as server computers each having its database server and data. This type of configuration is ideal in a local area network.

The foregoing discussion indicates that GIS software is looked at as an infrastructure for storing, accessing and manipulating data stored in the database on standalone computers until recently when sharing of stored data on a centralized server has become important. Computers in a networked environment connected to the server make use of the data on it. A client-server setup provides an ideal means of sharing data in a networked environment (Longley et al., 2005).

2.2 Application Areas of GIS

Knowledge of where something happen matters in people and in organizations (Roy et al., 2007; Jankowski & Nyerges, 2001). Decision systems, expert systems and intelligent systems when integrated with domain specific knowledge help in making informed decisions and representing a model of the world which we live in (Eldrandaly, 2007). An information system that can ably present places on earth and give information about them is Geographic Information System (GIS) (Eldrandaly, 2007). GIS applications are a series of loosely coupled and highly cohesive map layers, which are either raster data or vector data (Davis, 2007).

Application of GIS by people and organizations can either be on a day-to-day basis (monitoring resources, gain competitive advantage, database usage) or for strategic purposes (creating and evaluating scenarios) (Longley et al., 2005). Examples of application area of GIS are landfill management (Gbanie et al., 2013), land-use suitability modelling (Malczewski, 2004; Hossain & Das, 2010), public participation in planning (Appleton & Lovett, 2005; Hanzl, 2007; Higgs et al., 2008), crop yield estimation (Sawasawa, 2003).

Application of GIS in some areas requires only GIS specific software but in other cases GIS specific software is aided by other software. In land-use suitability modelling GIS specific software like ArcView/Spatial analyst and Indris macro modeller do suffice (Malczewski, 2004). For public participation in urban planning ArcView GIS specific application is aided by Nature Visual Studio and 3D Computer Aided Design (CAD) packages (Appleton & Lovett, 2005). In managing disposal of waste in Sierra Leone, Landfill management was done using ArcGIS Desktop 10 (Gbanie et al., 2013). Using GIS in corroboration with other packages enhances its capabilities. However, this only puts off non GIS expert users from using the technology because adding another software entails that a user has two software to learn (Deng & Di, 2009).

Scheid Vineyard in USA, uses GIS as the backbone of its precision farming (Esri 2013). The vineyard uses GIS to store various data which is queried for decision making, this helps to determine prospective planting sites and determine irrigation requirements. The web soil survey data that is integrated in the GIS application helps the vineyard to determine suitability of crops in the area.

Malawi like most developing countries has not yet fully adopted GIS technology (Jha & Chowdary, 2006). In 1989 Ministry of Agriculture and Food Security (MoAFS) produced a comprehensive land resources appraisal spatial data for Malawi. This information is widely used to support crop and livestock production as well as sustainable land management. Recently, the "Atlas of Malawi Land Cover and Land Cover Change" has been produced by the FAO in collaboration with the Department of Land Resources and Conservation in MoAFS which enriches Malawi with spatial information (FAO, 2012).

When compared to other business sectors worldwide GIS user community in production agriculture is rather small (Pierce & Clay, 2007). There is a lack of formal opportunities to share applications and innovations of GIS specifically focused on agriculture (Pierce &

Clay, 2007). According to Jha & Chowdary (2006) the following are some of the reasons why GIS technology has not been fully adopted; (1) inadequacy of digital data (2) contrasting file formats (3) expensive GIS hardware and software (4) institutional impediments and (5) GIS experts do not effectively communicate to top management about GIS.

2.3 Client-Server Application

Client-server application is a piece of software that runs on a client computer and makes requests to the service provider or the server (Orfali et al., 1994; Shi, 2004). A client-server model is an extension of the object-based programming model, in object-based model large pieces of software are structured into smaller components that have well defined interfaces (Rao & Vinay, 2009). The components interact by exchanging messages, what is known as Remote Procedure Calling (RPC). The calling component is the client and the called upon component is the server (Longley et al., 2005).

The client-server can be designed into either two-tier architecture or three-tier architecture (Rao & Vinay, 2009). In two-tier architecture client talk directly to the server and this is suitable for small environment (Orfali et al., 1994). Here small environment is considered as an environment where there is one or two servers with one or two dozens of clients. However according to Shi (2004) this approach is less scalable. In three-tier architecture scalability is not an issue due to the presence of the intermediary process that caches frequently accessed data; it distributes clients' requests to several servers. At times this process acts as a translation service. It can also act as a security service to grant access only to trusted clients.

In GIS applications, a client-server model is achieved through the use of Web Services which is a developer oriented software component. It is also known as web GIS. Web GIS can be accessed and integrated through application programming interfaces (APIs) to provide a basis for componentizing distributed GIS data and functional modules (Shi, 2004). Web GIS provides an open and distributed architecture for disseminating geospatial data and web processing tools on the Internet (Longley et al., 2005). This enables organizations to distribute maps and tools without time and cost restrictions. According to Longley et al. (2005), web GIS architecture has two components; client and server. The client is a point or terminal where users interact with spatial data using the available GIS functions. GIS programs displays different forms of outputs based on user commands, tools and tasks that have been triggered by the client-side and the server's reaction to them (Shi, 2004).

A web GIS server is further categorized into four components; Web Server, Application Server, Map Server and Data Server (Orfali et al., 1994). Web servers, such as Apache and Jetty, respond to HTTP requests that are made by the browser on the terminal of a user from the client-side. Examples of web GIS include; ESRI ArcGIS Server Architecture, Geoserver Architecture, IONIC RedSpider Web Architecture and ERDAS Apollo Products (Orfali et al., 1994). ESRI ArcGIS Server, IONIC RedSpider and ERDAS Apollo are Commercial-Off-The-Shelf (COTS) products. Geoserver Architecture is from the family of free open source software.

Application server is the software that helps in developing and managing large number of applications in a distributed environment. The application server, such as windows terminal server, acts as a middleware that establishes, maintains and terminates connection between the web server and the map server (Orfali et al., 1994). When a user connect through windows terminal server to a remote computer they interact with applications on the remote computer as if they are installed on their computer (Longley et al., 2005).

Map server provides specific functions such as; spatial analysis, spatial and attribute queries, geo-coding, geo-processing and generates and delivers dynamic maps to clients based on user requests. Map servers generate output in two forms, first one being that of sending feature information to client for further manipulation and secondly, graphical images (Orfali et al., 1994). Map servers allow users to interact and perform available GIS functions through a web browser, the client in this case is called a thin client (Shi, 2004).

Data server manages data, both spatial and non-spatial, in a relational or non-relational database management system (DBMS). The DBMS is a source to web map services (Ajmar et al., 2008). The data in the databases is made available to a client through SQL statement requests. With this configuration, the server machine houses a DBMS and the data contained therein. The presentation and business logic reside on client machine (Longley et al., 2005).

2.4 Web GIS: Geonetwork

There is a lot of literature on web GIS (Agosto et al., 2011; Díaz et al., 2011; EnviroInfo ISPRA 2011 et al., 2011; Careem & Karunarathne, 2012; Ko, 2013;). For instance:

- In their study, Díaz et al. (2011) look at users contribution of information or data to the Geospatial Cyber Infrastructure (GCI) through the use of service framework connection. Users make contribution to the GCI using desktop GIS. GCI is well advanced compared to other web GIS in that apart from data viewing it allows spatial data analysis and downloads.
- EnviroInfo ISPRA 2011 et al. (2011) use Geonetwork in Virtual Research Environment (VRE) for long term monitoring of a waste deposit. The Geonetwork combines information from desperate resources on individuals, chemical substances, biotic and a-biotic materials as well as socio-economic data.
- Agosto et al. (2011) look at building web GIS specifically for emergency response and management using FOSS tools. In his study the author recommends the use of model controller view (MCV) as a quick way to build web GIS.
- Careem & Karunarathne (2012) studies Open Web Service to Catalogue Service for Web (OWS2CSW) which is a process used in Extract Transform Load (ETL). Using this process the authors were looking at an efficient way of retrieving spatial data.
- Ko (2013) studies a 3D web-GIS for RFID to aid in construction works. The system communicates to officers out of the construction site of objects found that might require decisions from them.

All these studies concentrate on the technology development and less on how the technology can be accepted by a community for which it is intended for. This study looks at the implications of introducing a client-server GIS application, which is also a web GIS, at MZADD. In this study, Geonetwork has been chosen as the platform for the client-server GIS application. The application is targeted to agricultural extension staff whose main job is to advice farmers on best farming practices.

Geonetwork is a geospatial catalogue application that is used for sharing data (OSGeo, 2009; Careem & Karunarathne, 2012). Development of Geonetwork was initiated by United Nations in 2001 and other partners have continued with the development (OSGeo, 2009; Grill & Schneider, 2009; Careem & Karunarathne, 2012) including Food Agriculture Organization (FAO), UN Office for the Coordination of Humanitarian Affairs (UNOCHA), Consultative Group on International Agricultural Research (CSICGIAR), The UN Environmental Program (UNEP) and the European Space Agency (ESA).

The main aim of Geonetwork application is to provide a platform for sharing spatial data, but the application can as well be used for sharing word documents, excel documents and portable document files (PDF). Geonetwork open source solution can be implemented as a standalone or a client-server solution (OSGeo, 2009). Geonetwork comes embedded with Geoserver, jetty web server, and a database called Hb (OSGeo, 2009). As open source software, it implies that the software is readily available and there is no cost implications associated with it. It is distributed with its source code and is readily available for download on the Internet. Open source GIS software has the capability similar to those of COTS GIS products and in future it is believed that open source GIS may substitute COTS GIS once it is considered as mature and has a lot of community members for support services (Ajmar et al., 2008; Steiniger & Bocher, 2009). The availability of open source GIS software removes cost as one of the limiting factors which developing countries face to use GIS applications (Jha & Chowdary, 2006). Alternative to embedded database, Geonetwork can be configured with an external database on the condition that the database is able to handle spatial data. Database which can be configured with Geonetwork include PostgreSQL, MySQL and Oracle database.

According to the developers of Geonetwork, the application (1) offers improved access to and integrated use of spatial data and information, (2) supports decision making, (3) promotes multidisciplinary approach to sustainable development and (4) enhances understanding of the benefits of geographic information (OSGeo, 2009). Benefits (1) and (4) are in line with this study, as this study intends to promote data sharing and motivate non GIS users to utilise GIS. These can be achieved through the capability of improved access to integrated use of spatial data and also through the capability of enhancing understanding of the benefits of geographic information. One way of appreciating the benefits of geographic information is by looking at application areas which GIS can be applied to.

2.5 Prototype

Prototype is a model of a real thing (Carr & Verner, 1997; Houde & Hill, 1997) and mainly used to act as communication media between the developers and the intended users of the system (Houde & Hill, 1997). Through prototype developers are able to obtain non-declarative knowledge from users. Developers obtain this information whilst observing the users interact with the prototype (Carr & Verner, 1997). Prototyping fits well in the technology organization environment theory as it is concerned with the interaction of users with the system in the organization or the environment where the two components are based. Prototype can be paper based or computer based whilst modelling the entire system with real data or just few screens with sample data. Houde & Hill (1997) define four methods of prototyping, these include; illustrative, simulated, functional and evolutionary. An illustrative method just produces mock ups of reports and screens. Simulated imitates some functions of the final product but does not use real data or database and no model is implemented. A functional method has actual functions of the final product, it uses real data and/or database, a model is not implemented as well in this method. Whilst Evolutionary produces models that becomes part of the final operational system.

The prototyping methods can be categorized as throw-away and evolutionary (Houde & Hill, 1997). Throw-away method is disposed away when its intended use is achieved. Illustrative, simulated and functional methods of prototype fall under the category of throw-away prototype. An Evolutionary prototype progressively develops into the final product. The methods can be classified as low fidelity, medium fidelity and high fidelity prototypes (Carr & Verner, 1997). Low fidelity prototypes are quickly constructed to depict concepts, design alternatives and screen lay outs. Medium fidelity prototype partially simulates the system interaction and functionality. And high fidelity prototype is fully interactive and simulates much of the functionality of the final product.

Lastly, process of prototyping can be classified into explorative and experimental. Acting as a communication medium and facilitator between users and developers an explorative prototype is mainly used to gather system requirements (Carr & Verner, 1997). Whereas an experimental system is built to determine whether the planned system will be adequate and acceptable when finished (Carr & Verner, 1997). Prototyping is used in Software Development Life Cycle (SDLC), Rapid Application Development (RAD) and Object-Oriented methodologies among others. In Rapid Application Development prototyping is considered as being cheaper, faster and a better method. This is because it helps in; gathering requirements using workshops or focus groups, provides an early user interaction with the intended system, there is reuse of software components and there is less formality in review and other team communication.

In this study prototyping was experimental with medium fidelity and functional based. The aim of building the client-server GIS is to determine its suitability at Mzuzu ADD. For ease of observing users interact with the system and obtain better feedback the developed prototype was intended to be iterative and functional.

2.6 Conception Framework

A lot of studies of IT adoption have been done at individual level and less at organizational level (Arpaci et al. 2012). This study is based on Technology Organization Environment (TOE) framework to study technology adoption at an organizational level.

This framework looks at three contexts as key for a technology to be adopted at an organizational level (Lippert & Govindarajulu 2006; Scott 2007; Oliveira & Martins 2011; Shemi & Proctor 2013). These contexts are technology, organization and environment. Technology context considers the importance of the technology internally and externally in improving productivity of an organization. Organization context looks at the organization's resources in accepting an innovation whereas environment context is a setting in which an organization conducts its business and is influenced by its competitors and suppliers of the organization's resources (Lippert & Govindarajulu, 2006).

As shown in table 3, under the three context different authors attach different number of factors as being influential in the technology adoption (Lippert & Govindarajulu, 2006; Scott, 2007; Oliveira & Martins, 2011). Lippert & Govindarajulu (2006) in their study of web technology adoption identified a total of 11 factors in the three contexts as being crucial for an organization to adopt a technology. Oliveira & Martins (2011) whilst doing a literature review on TOE, used 9 factors. Scott (2007) used 6 factors to explain that the three contexts are inter-related. Scott (2007) argued that the contexts are related in that the goal of each context lead to a technology being adopted or rejected by an organization. In their qualitative study of e-commerce adoption Shemi & Proctor (2013) used 14 factors under the three context of TOE, and concluded that some of the reasons e-commerce is yet to be adopted in developing countries are due to lack of perceived benefits of ICT by top management and that suppliers and customers prefer tradition methods of doing business.

Through a questionnaire survey, to explore determinants of technology adoption in China's logistic industry Lin & Ho (2008) used 6 factors under the contexts of technology, organization and environment. Like the other mentioned authors, they found that the three context are associated positively if an organization is to adopt or reject a technology. They further found that the factors under the contexts of TOE framework are not correlated.

Table 3: Factors under contexts of TOE

Authors	**Technology**	**Organization**	**Environment**
Lippert & Govindarajulu (2006)	• Availability of technology	• Size • Scope • Centralization • Formalization • Interconnectedness • Complexity of Managers • Quality and Availability of human resource	• Competitors • Suppliers of resources to the firm • Interactions with the government
Scott (2007)	• Technology know how	• Organization culture • Organization process to take up a new innovation	• Customer base • Regulatory • Government
Lin & Ho (2008)	• Explicitness of technology • Accumulation of technology	• Organizational encouragements • High quality human resource	• Environmental uncertainty • Government support
Oliveira & Martins (2011)	• Availability • Characteristics	• Formal and Informal linking structures • Communication process • Size • Slack	• Industry characteristics and market structure • Technology support infrastructure • Government regulations
Shemi & Proctor (2013)	• Nature of technology • Characteristics of the technology to be adopted	• Skilled of ICT personnel • Finance • Security concerns • Organizational culture	• Business environment • Credit cards and payment system • Macro-economic and regulatory policies • Business partner preference • Peculiar nature of certain industries • Economic and political stability • Occurrence of natural disasters • Local business culture

From these studies one can conclude that factors under the contexts of TOE framework are used in accordance with the suitability of the study being conducted. Oliveira & Martins (2011) attest that factors used under the three contexts of TOE may vary in different studies. In this qualitative study with reference to the previous studies, a total of six factors in the contexts of technology, organization and environment were used to study the adoption of prototype of a client-server GIS application. These factors had been chosen with relevance to the case under study, MZADD. Under technology the study tried to address accumulation of technology and availability. In the context of organization, the study used communication process and quality and availability of human resource. Under the context of environment the study tried to address the technology support infrastructure and suppliers (Table 4). This research looked at the presence or absence of these six proven factors which are essential in the intentions to adopt and in the actual adoption of a technology in an organization (Lippert & Govindarajulu, 2006).

Table 4: Conceptual framework

Context	**Factors**	**Description**
Technology	Accumulation of technology	Looks at how the new technology fits with the already existing technology within the firm
	Availability	This is the reliability of technology.
Organization	Communication process	This is associated with the primary ways of how business is conducted within an organization
	Quality and availability of human resource	This is the technological knowledge of an organization and perceived benefits from an innovation by the firm. This can also be looked at as the technological sophistication in carrying out various operations by employees.
Environment	Competitive pressure	These are two or more organization with interest in the same customers
	Supplier	This is concerned with dependent partner's readiness to take up an innovation

The basis of each of these contexts is grounded on the existing research. Under technology context an innovation is likely to be adopted if it is available whenever it is needed and if can be implemented without much changes to the existing technology (Lippert & Govindarajulu, 2006; Scott, 2007). In organizational context when it comes to communication process, leadership influences change in an organization by changing the mind-set of the workforce, perceived benefits encourages adoption of an innovation (Scott, 2007). Under environmental context an organization is more like to adopt a technology if its resource suppliers or institutions that directly depend on it are ready to take up a technology and an organization will be pressured to adopt a technology to gain a competitive advantage (Lippert & Govindarajulu, 2006; Scott, 2007; Shemi & Proctor, 2013).

Despite Arpaci et al. (2012) saying that there are many studies on technology adoption at an institutional level, other technology adoption theories like Diffusion of Innovation (DOI), Institutional, Lecovou Theories cannot compare to TOE because of its theoretical basis and the number of empirical studies that have been conducted to support the theory (Oliveira & Martins, 2011). Arpaci et al. (2012) attests that TOE has been used with success to study adoption of a technology within an organization.

3.0 CHAPTER 3 – METHODOLOGY

3.1 Approach

The research method used in this study is mixed method and it takes up an explanatory research design. The study used a framed field experimental approach. According to Janssens & Kramer (2012) an experimental approach is advantageous compared to other empirical approaches in that: (1) laboratory environment offers control to factors like social networks (non-business related interactions), beliefs and health which might otherwise have bias to the results of the study; (2) experiment offers insights into decisions that can be made within a short time span; and (3) participants interact with a prototype application directly, which elicits behaviour that differs from hypothetical survey questions.

The framed field experiment studies the subjects in their natural settings except that subjects are notified that they are part of an experiment. This type of experiment exhibits external validity to the experiment (Lusk et al., 2006). This study qualifies to be a framed field experiment because it was conducted at an actual working place of the respondents (Harrison & List, 2004). Onsrud (2007) insists that data sharing models can be studied in their natural settings.

3.2 Sample Design

Convenient sampling method (Marshall 1996) was used to select respondents for the study. The respondents were all members of staff of MZADD who have computers in their offices and are connected to MZADD local area network these were 25 employees out of 91 employees representing 27.17% of employees qualifying for the study. Informed consents were distributed to all qualifying employees and 15 out of 25 were returned representing a return rate of 60%. The respondents were categorized in accordance to the departments which they belong (Table 5**Error! Reference source not found.**). All 15 respondents were interviewed, trained in the usage of the prototype and observed. There is no rule of thumb for sample size of a qualitative study, the sample size tend to be small and it can vary from 1 to 100 (Marshall 1996; Baker 2012).

Table 5: Study Respondents

Department	**Male**	**Female**
Crops	2	1
Land Resources	1	1
Livestock	4	0
Extension	1	1
Planning	1	0
Finance	1	0
Human Resource	2	0

3.3 Data Collection

The primary data is collected through semi-structured interviews and direct observation. Secondary data was collected through document analysis, data collected from Agriculture production estimates survey and spatial data produced by the department of land resources.

3.3.1 Semi-Structured Interviews

A lot of information can be gathered by directly questioning or talking to people especially where the sample size is small (Creswell 2002; Adams, 2007). The semi-structured interview proceedings were recorded by taking of notes and voice recordings through a smart phone, iphone 3G. The aim of the interviews was to solicit current data/information and GIS practices. The interview questions were categorized into two sections; (1) departmental checklist questions and (2) individual checklist questions (see APPENDIX 1).

3.3.2 Secondary data

Some data was gathered through document review. Onsrud (2007) argues that document review helps in adding evidence from other sources which improve the rigor of the findings. This study used document review to study functions of various departments at MZADD which substantiated primary data gathered through interviews and observations.

In this study the Guide to Agricultural Production and Natural Resources Management in Malawi was reviewed to study the roles and functions of various departments at MZADD (MoAFS, 2012). Data for Agriculture production estimates survey for 2010-11 growing season was used to obtain yield for hybrid maize and area which was used, Maize is the main staple food for Malawi and one way of improving its yield per unit area is through the use of Hybrid maize (MoAFS, 2012). The following spatial data were obtained from the department of land resources and conservation Mzuzu_bnd, mw_epas, mw_lakes and mw_landuse (Table 6).

Table 6: Spatial data used in the study

Name of shape file	**Description**
Mzuzu_bnd	Vector map showing boundary for Mzuzu ADD
Mw_epas	Vector map showing all the Extension Planning Areas of Malawi
Mw_lakes	Vector map showing all lakes of Malawi
Mw_landuse	Vector map showing the land usage in Malawi
Mzuzu_soils	Vector map showing soils in Mzuzu ADD

3.3.3 Observations

Important findings in research have been accidental and captured through observation (Adams, 2007). As an employee working with the organization, in order to conduct the observation, no prior permission was sort from the participants (Adams, 2007). Observations in this study were conducted on daily basis, during trainings and after the interviews. Research participants were observed on how they carry out their duties. Special attention was on how they share information and general computer interactions.

3.3.4 Evaluation of the Prototype

Data collection was also done through prototype evaluation. The prototype helped in getting respondents feedback on the suitability of a client-server GIS application. Respondents were trained on the use of the prototype. The training session also helped in analysing participants' computer competency.

The prototype was evaluated using the DECIDE framework. DECIDE framework as suggested by Sharp et al. (2007) has 6 guidelines for prototype evaluation; (1) determine the goals: (2) explore the questions: (3) choose the evaluation approach and methods: (4) Identify the practical issues: (5) decide how to deal with the ethical issues: (6) evaluate, analyse, interpret and present the data

The goals of evaluating the prototype were; (1) to find if a client-server application can be an abler in spatial data sharing and (2) to assess if the client-server application can be a motivator in spatial data usage. The prototype addressed questions on perceived ease of use at first glance, challenges of using the prototype and soliciting ideas for a better application suitable for the respondents. The main evaluation approach that was employed was training. During the study two types of trainings were conducted, group and individual training. Figure 2 shows participants of the initial training that was conducted at management level. The purpose of the training was to introduce participants to the client-server GIS application's functionality and operation. The 11 individual trainings were done in the respective offices of participants. Participants from the department of Livestock opted that they should be trained as a department. On average the trainings lasted 50 minutes. The trainings were done from 1st to 5th July 2013. Observations during practical sessions, where users interacted with Geonetwork, helped to obtain data on general computer usage and general understanding of the prototype from these sessions. After the trainings, all participants were emailed a copy of the manual on how to use the client-server GIS application that was implemented at MZADD. The manual is a modification of the Geonetwork manual that comes with the software.

Figure 2 Introducing Geonetwork during management meeting

Through systematic random sampling, five participants were chosen and interviewed to obtain feedback, limitation and challenges of user interaction with the client-server application. The interview questions revolved around questions of prototype interaction (see APPENDIX 2). This study targeted all members of staff at MZADD whose offices had computers and were connected to the MZADD local area network. By default all heads of sections are in this category. It was not possible to have a fixed 3 days training schedule as planned as officers were not available at the same times. Each officer formulates their own program for the times they are to work away from the office. Most of the times the programs are different and they are carried upon availability of resources. As a result the researcher resulted to have the training conducted mostly on individual basis. Computers in the respondents offices were used to access the client-server GIS application installed on the server, no configuration was required. The application was accessed from the web browser.

3.4 Data Validity

To validate the data collected in this study, triangulation was used. Triangulation is important in that it helps in viewing the accuracy of the data collected but also helps in giving alternative explanation of a phenomena (Adams, 2007). This study used theory, methodological and member triangulation. Each of the three methods of data collection employed in this study augmented information gathered from the other methods. For member triangulation interview recordings were replayed to the interviewees and the data collected through note taking was reread to them. The interviewee confirmed the interview and where there was need for additions they were adding. As another way to validate data gathered, similar departmental questions were asked to more than one member of the department separately.

3.5 Data Analysis

The qualitative data gathered in this study was analysed using Constant Comparative Analysis, and Content and Thematic analysis. Constant Comparative Analysis is an approach that compares qualitative data obtained through different methods to conceptualize relationships among the pieces of data (Thorne, 2000). Content and thematic analysis are used as descriptive approaches in qualitative data analysis (Vaismoradi et al., 2013). Data noted down and recorded for each interview and notes obtained in observation were transcribed in Microsoft Excel. The contents of similar concepts were categorised into one. From these categories themes were deduced.

The study also uses spatial analysis to analyse spatial data. In conducting spatial analysis in this study the data was clipped, overlaid and interpolation of yield and rainfall data were produced. Analytic Hierarchy Process (AHP) was used to weigh factors on their level of influence to yields for hybrid maize.

3.6 Ethical Consideration

Before conducting the study permission was obtained from the Program Manager to use MZADD information technology infrastructure and employee's time (see Appendix 3). Prior to carrying out the study 25 informed consent forms were distributed to employees with computers in their offices (see Appendix 4). Eighteen members of staff consented to be part of the study.

When conducting interviews with the 18 members of staff the questionnaires were distributed prior to the interviews. This was done so as not catch them off guard during the interview and also to make necessary preparations. Before conducting the interviews, interviewees were communicated that the interview would be recorded and notes would be taken whilst the interview was taking, the information gathered was meant just for the study and that no names would be used in the write up. It was at the discretion of the interviewee consent to or not to participate.

4.0 CHAPTER 4 - RESULTS AND DISCUSSIONS

4.1 Current Information Sharing Practices at MZADD

4.1.1 MZADD and Its Environment

In this study environment includes all external entities which influence business to an organization in one way or the other (Lippert & Govindarajulu, 2006). External entities that directly interact with MZADD Management Unit are the Headquarters in Lilongwe and district agricultural offices (Mzimba, Rumphi, Nkhata-bay and Likoma) (Figure 3**Error! Reference source not found.**). MZADD has long tradition of data collection and sharing in place. According to respondents, since 1970s the major data collection and sharing was manual and hardcopy. Communication among districts, Management Unit in Mzuzu and Headquarters in Lilongwe has been through posts, hand delivery and facsimiles. However, there has been revolution regarding data sharing since the year 2000. Presently, communication is through electronic mails (emails) and phones. Communication with phones is either through voice or short message sending. As of this study, MZADD has no teller made system for information interchange with its immediate environment. Systems for information interchange create a smoother interface to the environment rather than just satisfying the internal needs of the firm (Barrett & Konsynski, 1982).

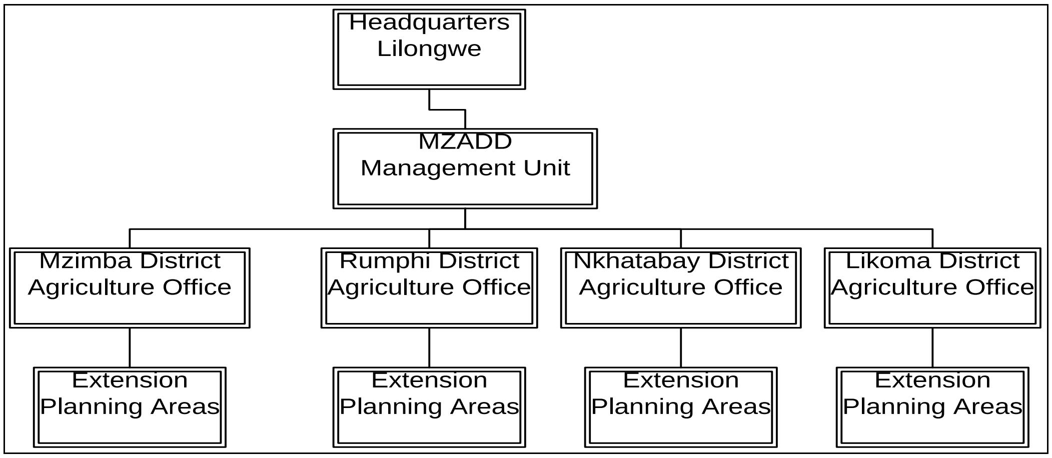

Figure 3 MZADD Management Unit and its environment

Internally, there are four line departments namely Crops, Extension, Land Resources & Conservation and Livestock which are responsible for collecting information related to Agriculture. According to respondents, the type of data collected by the line departments can be summarised as in Table 7, which has further been categorised into spatial and non-spatial. The common spatial data collected by all departments is mainly that of a particular position or a place prevalent to the detailed information or non-spatial data of their interest whereas for the department of Land Resources and conservation the collected spatial data can be a map that represents the whole ADD, with a particular theme, for example a network of roads giving information on how to reach a specific points. The personnel responsible for data collection are mainly Agriculture Extension Development Officers (AEDOs) who are located in various sections in an Extension Planning Area (EPA), they collect data for all departments. The collected data is sent to the Agriculture Extension Development Coordinators (AEDCs) who are the responsible officers of EPAs in districts, they consolidate and categorise the collected data according to the line departments. The AEDCs then send the departmental data to respective departments at district level (Figure 4).

Table 7: Data collected from the field

Type of data	**Crops**	**Extension**	**Land Resources**	**Livestock**
Spatial	Location, crop production (hectares and production)	Location	Hectare of an Extension planning Area, Conservation Agriculture sites, Land degradation sites, soil erosion sites, rain water harvesting sites, Land usage, soils	Location
Non Spatial	Crops storage techniques, crops pests and diseases, labor saving technologies, seed multiplication programs, rainfall figures, food situation, disasters,	Number of farmers adopting a technology, number of groups in cooperatives, success stories of a technology, challenges, Agriculture demonstrations, types of farmer group mobilized, type of staff & farmer trainings conducted, Village profiles, Farmer business Organization	soil fertility improvements	Livestock specimen, Condition of slaughter houses, butcheries, Livestock census, Livestock Births/deaths and losses, animal disease outbreaks, meet inspections

The departments at district level produce work plans which are printed out and sent to the Agriculture Extension Development Controllers (AEDC) at the Extension Planning Area (EPA). Table 8 displays how technologically aware are the environments of MZADD management unit. As shown in Table 8 most offices at EPAs do not have electricity, access to internet nor computers thus work plans are sent through officers who might be going in that direction or the AEDCs are notified by phone to collect the work plans if they happen to be in town. The work plans are from all the departments. From these work plans the AEDC produces an Extension Planning Area (EPA) work plan which is distributed to all Agriculture Extension Development Officers (AEDOs) to guide in data collection, irrespective of department.

Table 8: Use and Availability of technology

Station	**Availability of Electricity**	**Use of Computer in data Compilation**	**Use of internet to share information**
Head Quarters	High	High	High
Management Unit	High	High	High
District	High	Moderate	Low
EPA	Low	Low	Low
DEFINITIONS	**High**= electricity in more than 10 rooms/buildings **Moderate**= electricity in less than or equal to 10 but not less than 5 rooms/buildings **Low=** less than or equal to 5 rooms/buildings	**High**= availability of more than 10 Computers **Moderate**= Availability of less than or equal to 10 but not less than 5 Computers **Low=** less than or equal to 5 computers	**High**= more than 10 connected computers **Moderate**= less than or equal to 10 but not less than 5 connected computers **Low=** less than or equal to 5 connected computers

Figure 4 illustrates data flow from section up to the Headquarters where the data is turned into information in form of reports. Data from various sections is sent to the EPA to be consolidated as EPA data and processed to come up with the EPA information. The EPA data and information is archived as well as forwarded to the District Agriculture Office in hard copies. At times representatives from all EPAs go to the district to capture that data into the computer.

The District Agriculture Office collects data from various EPAs and consolidates it to produce district data. Where necessary, the district performs call back to the EPAs to seek clarity of the data they received or just to acknowledge receipt, but this is not done very often. The district then archives the data but also upon the approval of the District Agriculture Development Officer (DADO) the district forwards the same to MZADD Management Unit. Here often a softcopy accompanies a hardcopy. At Management Unit, each department receives data from their respective departments at district level and consolidates it. The consolidated data from all departments is then forwarded to the department of planning to produce data for Mzuzu Agricultural Development Division.

The circulation of data at management unit level is through personal email accounts, flash drives, compact-discs, and also through hard copies. The department of Planning along with subject matter specialist analyse and categorise the data to produce information for the ADD. Upon request heads of department at management unit forward departmental data to their respective directors at headquarters in softcopies through emails or hand delivered softcopies through flash drives together with hard copies. Like at district level, data at MZADD is archived and forwarded to the Ministry's Headquarters up on the approval of the Programme Manager. At this point, with data from all ADDs in Malawi, the ministry has national data on Agriculture to help in coming up with appropriate measures in huger mitigation and to achieve a food secure Malawi.

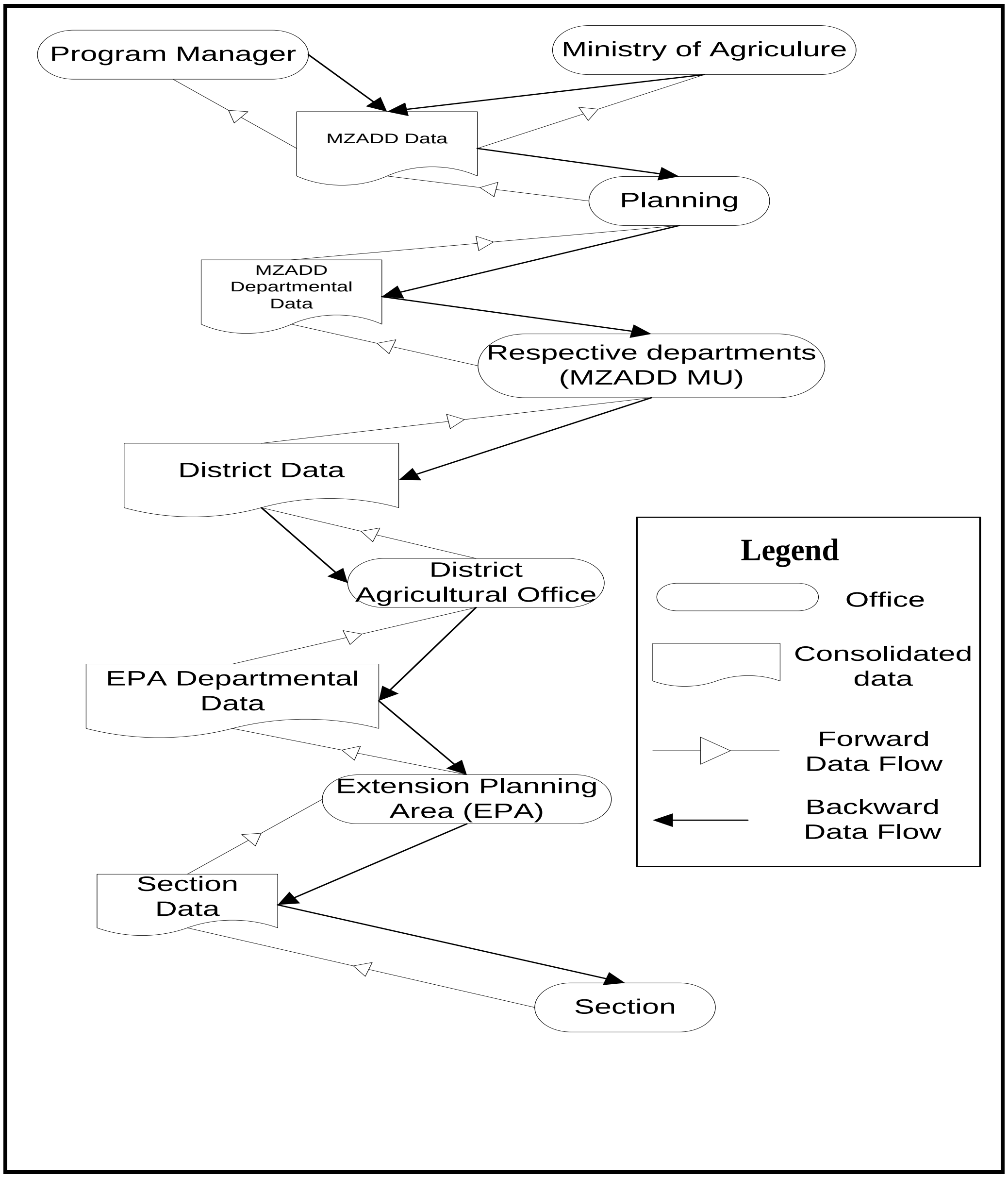

Figure 4 MZADD Data flow

In summary the main methods of data sharing are personal email accounts, hardcopies, flash drives and compact disks. Further to these the department of Crops has a yahoo departmental email account which is accessible by all members of the department. Information gathered in the field is usually uploaded to this account for all members of the department to access and forwarded to planning department up on request. MZADD management unit has no Information System for sharing data and information. Information system for sharing information helps in streamlining an organization's work processes and reduces paper work and also electronic information sharing makes it easy to duplicate and manipulate information. Networking plays a major role in enabling such information sharing by providing means of accessing data remotely (Landsbergen & Wolken, 2001)

4.1.2 Network and/Internet Connectivity at MZADD

The Internet is sourced from the server building block then distributed to veterinary and administration blocks (Figure 5). The distribution is through radio links which are located on top of building blocks. The connection between the radio links is wireless. This connection enables the computers to exist in one domain and access the Internet from one source. Radio links serve two purposes connecting building blocks but also acting as wireless access points. In this way the Internet connectivity is via wireless for wireless enabled devices and network cables for most computers.

When the internet from the local wireless and network cable connection is down, the officers often use the Internet doggles. It was further revealed that doggles and laptops are often used away from office. Respondents indicated that with good network coverage of mobile service providers, mobile internet seems to be an alternative to fixed cable connectivity. Officers using doggles are in their own network domain and not that of MZADD management unit.

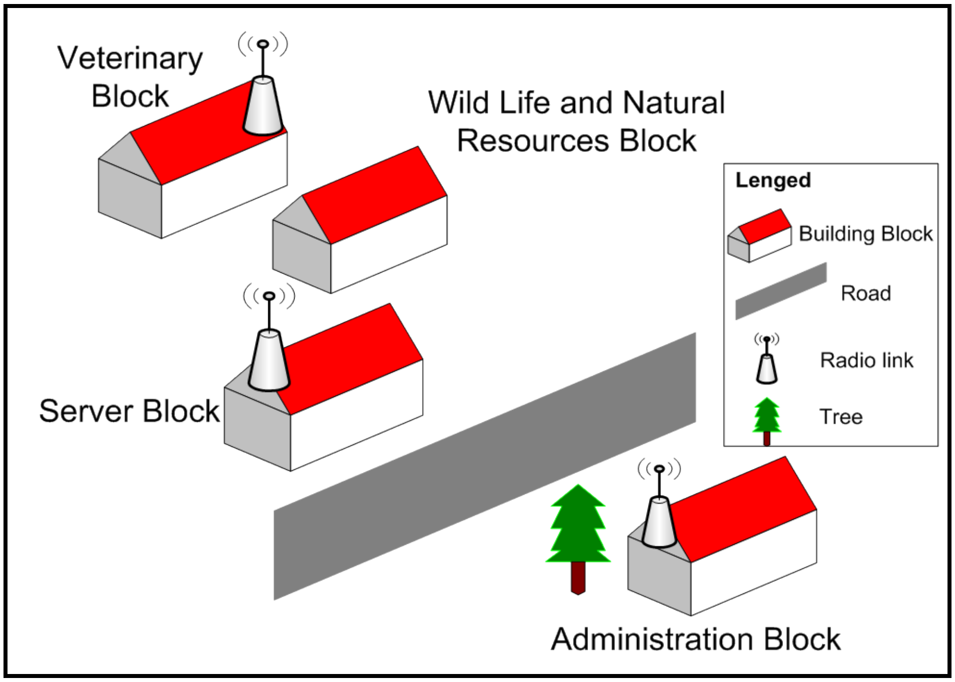

Figure 5 MZADD Building blocks

The department of Planning through the Information Technology (IT) section has sourced internet services from the Malawi Telecommunications Limited (MTL), which provides Asymmetric Digital Subscriber Line (ADSL) internet connectivity through an ADSL wireless router. In the office where the ADSL wireless router is housed, server block (Figure 5), other hardware that helps in connectivity include; Dell Edge server and a 24-port D-Link switch. The switch enables 21 computers in the Server block to connect to Internet. The Dell Edge server provides connectivity to 6 more computers (Figure 6).

Each office has one Ethernet cable except for the computer room and the Registry office which have 5 cables each. In offices where there are two desktop computers, when one is connected to the internet using the Ethernet cable, the other one uses a doggle if there is need. Otherwise, the other computer is not connected neither to the internet nor the LAN.

In some offices with a desktop computer and a laptop, the desktop is connected to internet using the available Ethernet cable. Mostly the laptop connects wirelessly both to the internet and LAN. The available access points for wireless connectivity include; the wireless router from the IT office and the radio links on the roof of the server, administration and the veterinary blocks.

Table 9: Number of computers

Name of Block	**Number of computer**
Server	32
Administration	19
Livestock	8
Total	**59**

As shown in Table 9 the ADD has a total of 59 computers, Figure 6 through Figure 8 depicts the interconnectivity of computers. The 32 computers in the server building block have no intermittent supply of internet unless there's a problem from the service provider. The 19 Computers in the Administration block are connected by 48 port CISCO switch (Figure 7). Through the radio link, computers from the Administration block access the internet from the IT office in the server block. The radio link further acts as a wireless access point. Thus enabling wireless enabled devices connect to the internet through it within the Administration block. However 4 offices within the block have access to internet through the JICA office which is outside the MZADD local network with two offices sorely depending on it and two with an option of switching between JICA and MZADD network.

In the department of Livestock the 8 computers are connected by a 16 port switch (Figure 8). Through its connection to the radio link the switch connects the 8 computers to the internet sourced from the IT office. This also makes the 8 computers to exist on the MZADD local network domain.

Connection to Administration and Veterinary blocks to the Server blocks is usually problematic. One reason is that the radio links at times are down when they have been on for several days. They go off without being noticed. The other reason is that, the radio links lose configuration settings. The problematic connection makes 27 (46%) computers to be in a separate network domain from that of the server building block and unless JICA internet or doggles are used, they do not have access to the internet.

The existence of Internet and computers has facilitated information to be shared electronically through emails and flash drives however the two methods are somehow restrictive in nature. Any information whether in word, excel, pdf, or zipped spatial data can be shared through email as long as it does not exceed 25 megabytes, yet most of the times spatial data tend to be more than 25 megabytes. Sharing electronic information among work colleagues through flash drives can be considered as productive and readily accessible but has psychological costs. The information seeker may be reluctant in asking information as they may have some inferiority complex and if the provider of the information portrays some impatience or reluctance in providing the information, the information seeker may become prohibited (Dewhirst, 1971). This study suggests information sharing through a centralised repository that is in form of a client-server Geographic Information System.

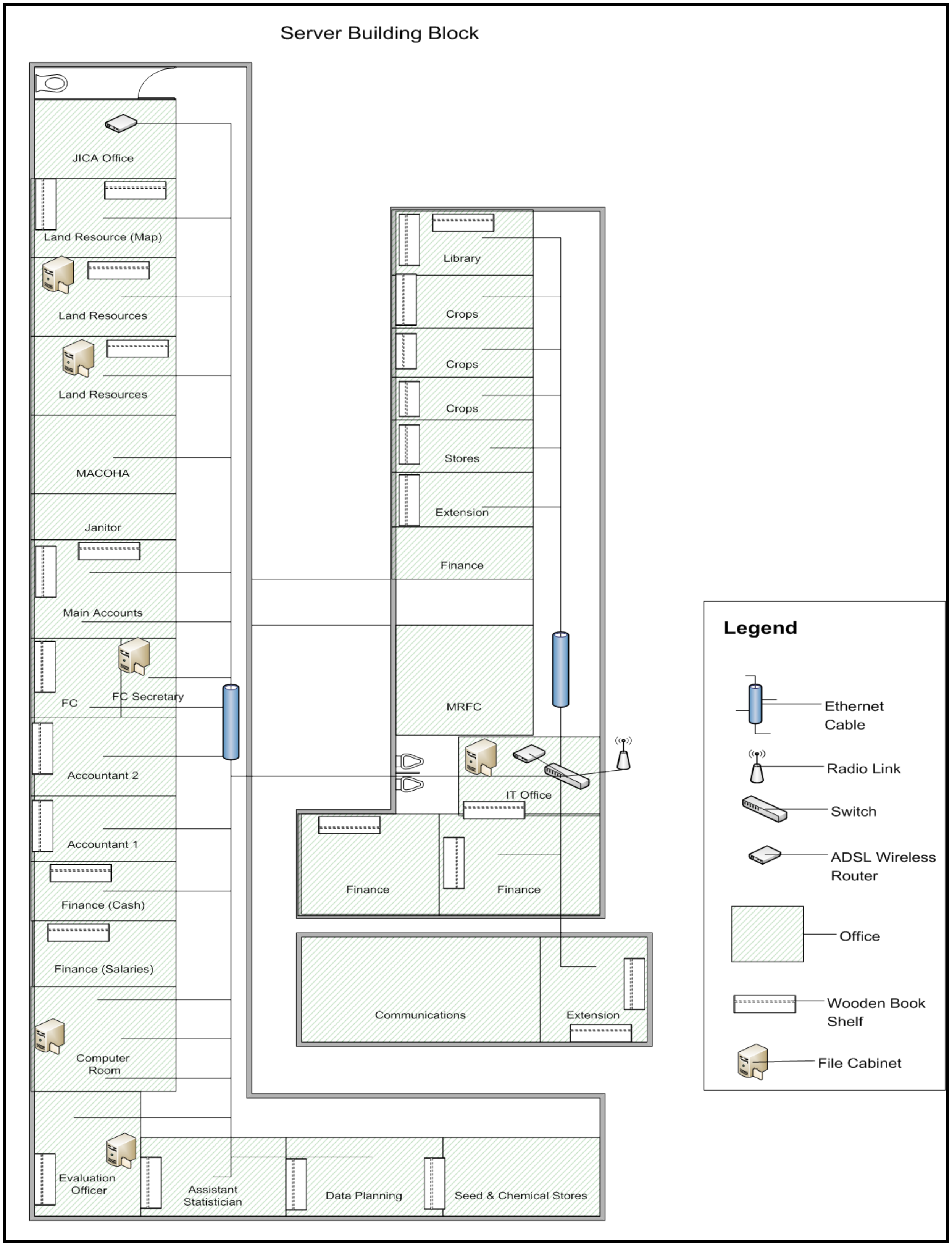

Figure 6 Network connectivity in Server block

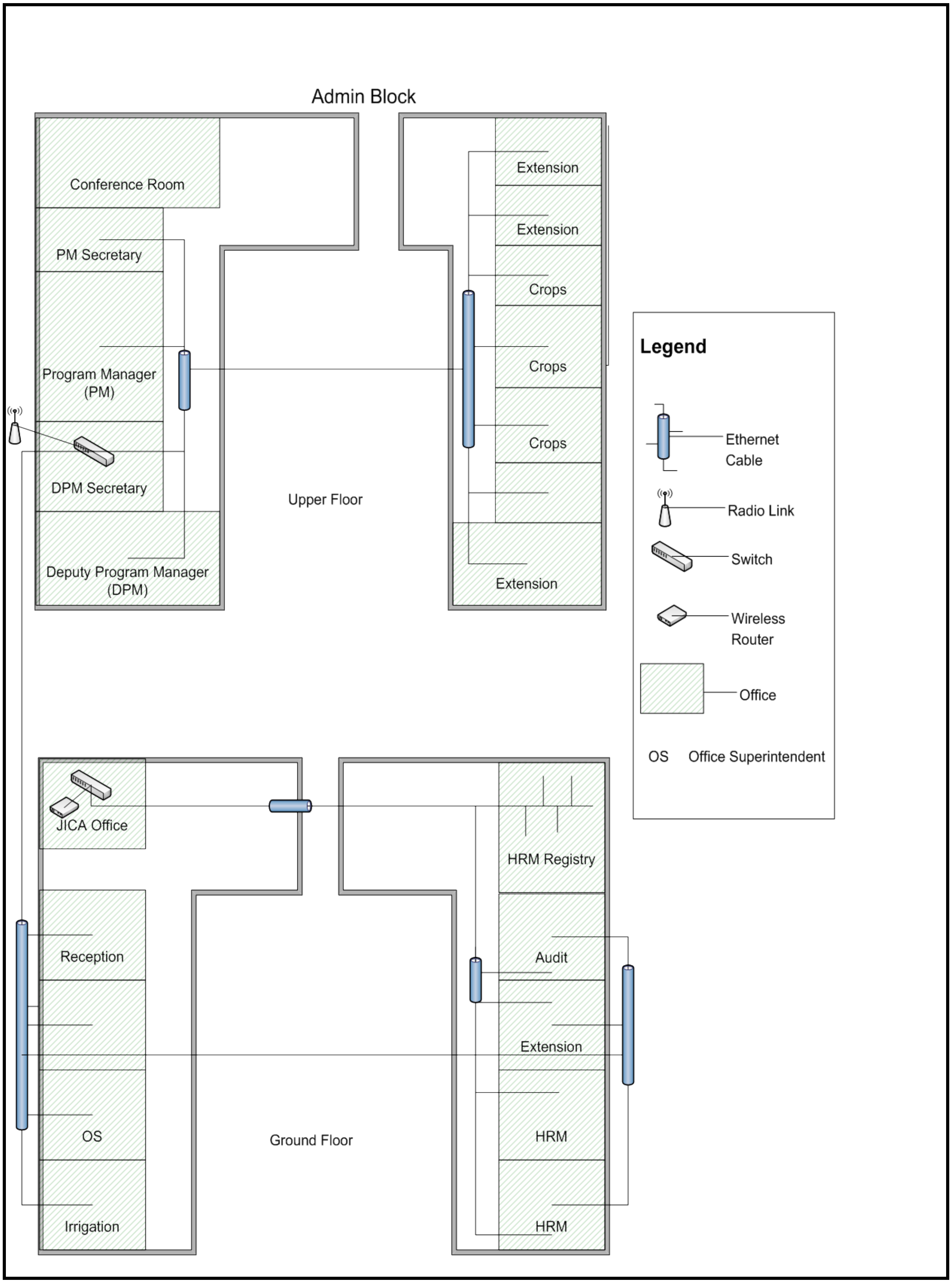

Figure 7 Network connectivity in Administration block

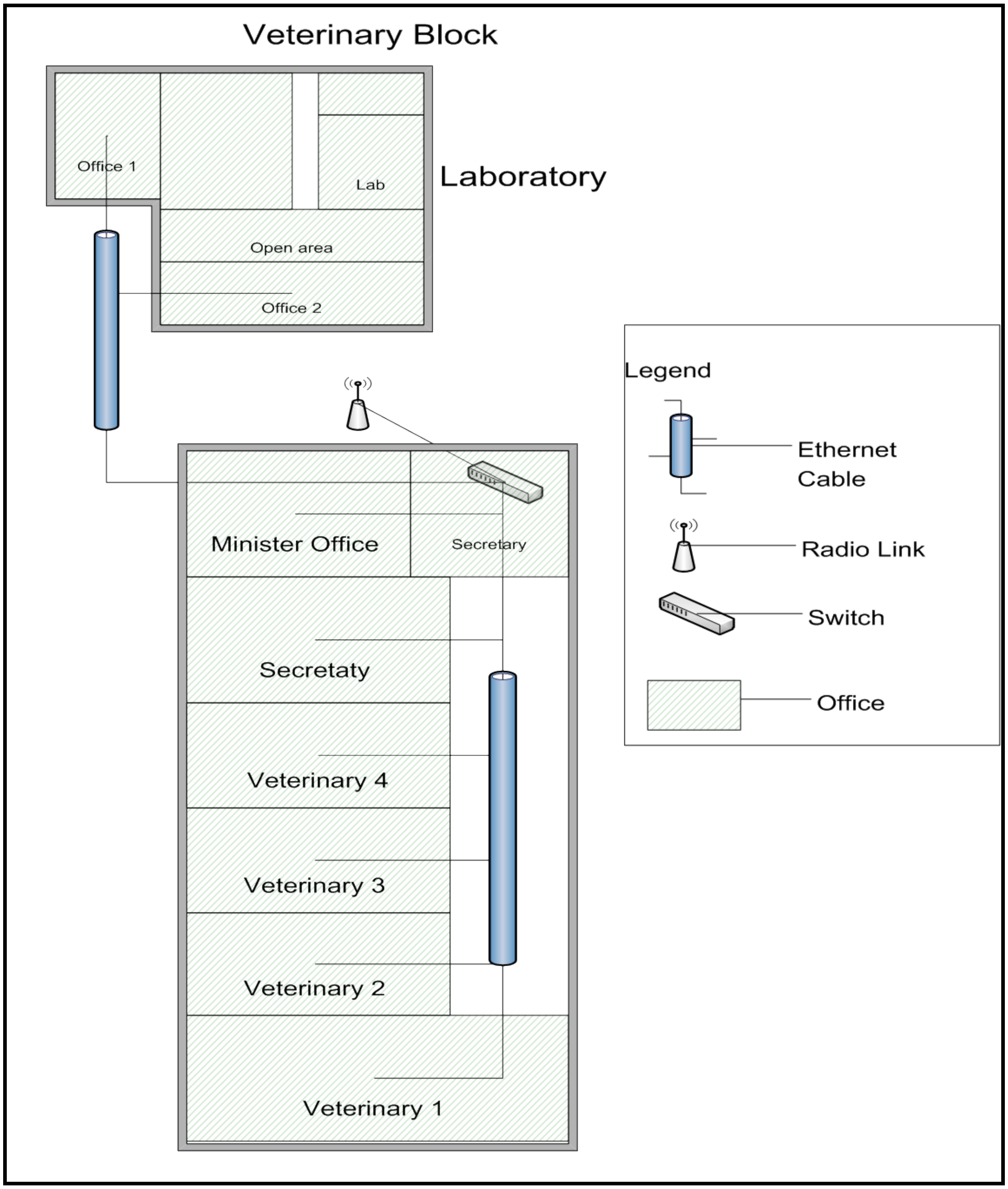

Figure 8 Network connectivity in Veterinary block

4.2 Prototype of an Institutional Client-Server GIS

4.2.1 Geonetwork Setup

From the preceding section, MZADD does not have a centralized repository and this has resulted into other means of sharing information, like personal emails, flash drives, compact disks and hard copies other than storing and obtaining information from a central localized point. Furthermore, the department of Land Resources and Conservation is the only department that collects spatial and produce thematic maps which can be used by all departments, the current information sharing practices has information shared upon request. This, in a way, hinders one to explore the available information freely and use it accordingly. From the previous section, production data of crops is underutilized in the sense that the produced data from Agriculture Production Estimate Survey (APES) is not used in assisting farmers in area that have low yields, the data once consolidated it is sent to Headquarters for mitigation measures in case of calamities.

In order to have information centralized and encourage the use of spatial data and ease the sharing of information this study proposes Geonetwork. Geonetwork is purposively selected and implemented as client-server GIS solution for three reasons (1) to facilitate local data sharing in form of word documents, Excel documents and portable documents files (2) to facilitate sharing of spatial data locally as one way to motivate respondents to use GIS applications and (3) it has no costs attached to it. The Geonetwork server has been centrally installed so much so that every computer at the ADD can access the application.

Figure 9 is an illustration of a schematic setup of Geonetwork. In this study Geonetwork is configured with PostgreSQL and the embedded jetty web server enables locally connected users to access the Geonetwork on http://server01:8080/geonetwork and the embedded Geoserver on http://server01:8080/geoserver. Server01 is the computer name of the Dell Edge server computer and 8080 is the port number on which Geonetwork and Geoserver are listening to on the server. Internet Explorer 8 and 9 browser, Google Chrome browser and Mozilla fire fox 4.5 browser are available and able to access both Geoserver and Geonetwork from client machines. A total of 20 users have been configured to login and use the application accordingly.

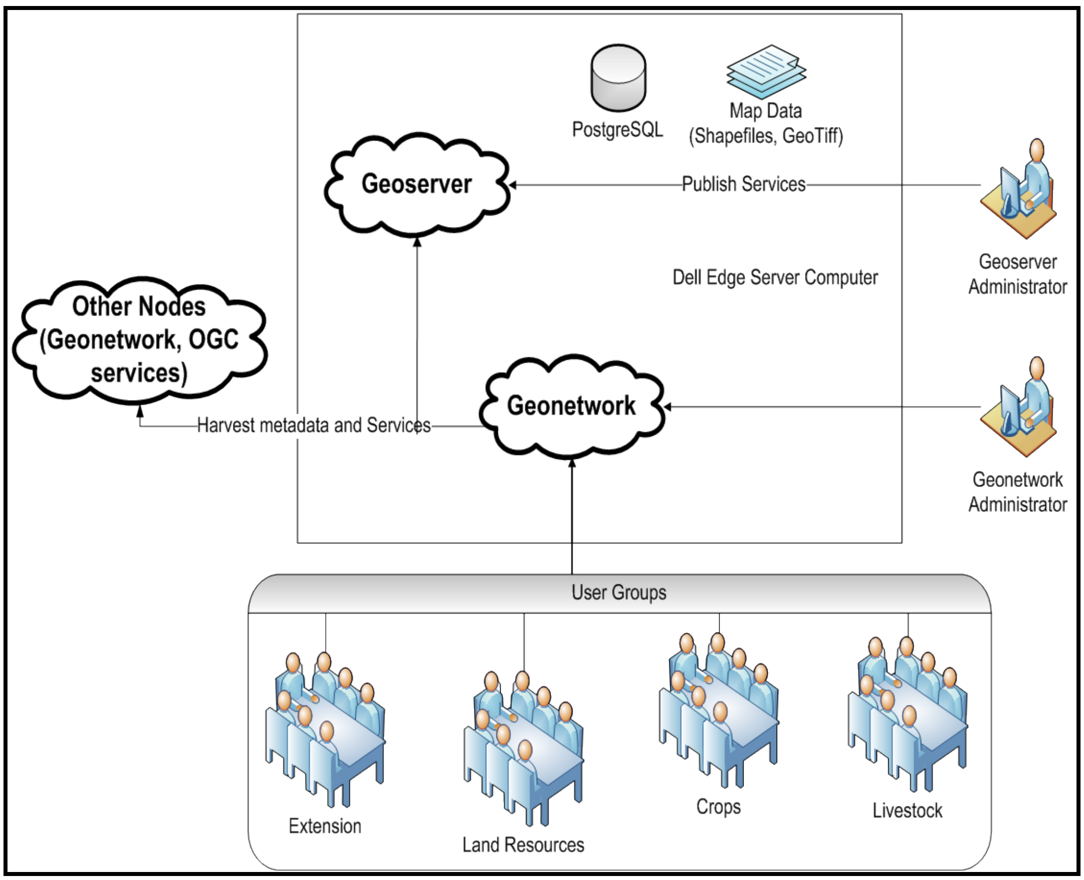

Figure 9 Schematic Setup of Geonetwork

When creating a user, a role must be specified for the user and a group to which the user belongs. Roles of the user are (1) Editor (2) Registered User (3) Content Reviewer (4) User Administrator (5) Geonetwork Administrator. Geonetwork Administrator is the super user. It has unlimited access to the application. User Administrator has the access right to create, import, and edit metadata records, transfer ownership, and user management for its own group. Content Reviewer has the access right to create, import, and edit metadata records within its own group. Editor has the access right to create, import, and edit metadata records within its own group. Registered User can only view metadata records that they have access right to.

In this study all department names of MZADD are created as groups. Thus the 10 groups are (1) Crops (2) Extension (3) Land Resources (4) Veterinary (5) Finance (6) Planning (7) Human Resources (8) Office of Superintendent (9) Workshop (10) Building. Even though Geonetwork in this study is configured to be accessed on a Local Area Network, it can still be used to harvest data from the Internet. All that is needed to harvest data from the Internet is the URL of the web from which one wants to harvest data from and the login credentials.

4.2.2 Client-Server GIS as an abler for Data Sharing

The department of Land Resources is the only department that is well conversant with GIS through production of thematic maps. As of this study the department had produced road network maps, showing how to get to various extension planning areas the ADD is responsible for and these maps are available in soft and printed copies. The printed maps have been hanged in various offices for use. Through this department, Geonetwork was uploaded with polygons, points and lines spatial data of Mzuzu ADD. The Polygons were Mzuzu ADD and Extension Planning area boundary, types of soils in Mzuzu ADD, how land is put to use and details of climatic conditions of various areas in Mzuzu ADD. Point data was a shape file showing location of centres for various districts and line data was a shape file showing a network of roads in Mzuzu ADD (Table 10).

Table 10: Spatial data on Geonetwork

Type of Spatial data	**Details**
Polygon	Mzuzu ADD boundary
	Mzuzu ADD soils
	Mzuzu ADD land use
	Agriculture climatic zone
	Extension Planning Area boundary
Point	District centers
Line	Roads

The non-spatial data, including crop yield figures and livestock census, were obtained from the departments of Crops and Livestock, respectively. These were uploaded on the Geonetwork as excel book and also entered in the postgreSQL database. The available data, both spatial and non-spatial has enabled respondents to produce maps with crop yield figures which were included in reports presented at the headquarters. Respondents appreciated interacting with livestock census data that was entered in a point shape file of district and thus producing a density map of livestock census that was uploaded in Geonetwork. In his own word one respondent said

> "This application presents data in an easy to read and interpret manner. The application is more informative than tabular data."

It was also observed that 3 respondents downloaded data from Geonetwork to their computers for further manipulation using Quantum GIS. Through Geonetwork respondents were able to share excel documents and reports that were in word documents. As far as spatial data sharing is concerned from this study the setup of spatial data sharing is in such that department of Land Resources and Conservation is the provider of spatial data and all department can use the spatial data to produce various thematic maps by providing data their collect as attribute data to various features to the spatial data.

4.2.3 Using Client-Server GIS Spatial Data and ArcGIS in Yield Production Analysis

When spatial data is uploaded on Geonetwork, the application allows users to interactively interact with it. The uploaded data is overlaid over a global map. Users can zoom in/out, pan, adjust opacity and print the map by selecting the desired areas of interest. Users have also the provision of downloading shape files for use on installed standalone GIS applications like Quantum GIS and ArcGIS. In this study, MZADD crop yield data once compiled as ADD data it is not further used at ADD level to assist farmers but rather sent to Headquarters for mitigation measures in case of calamities. Client-server GIS can avail spatial data that is uploaded by the department of Land Resources for use by other departments. Through the use of spatial data obtained from the department of Land Resources and data for hybrid maize, its production and area under it, obtained from the department of Crops and through spatial analyst tools this study produces a map that displays areas which are likely to produce the potential yield for hybrid maize given some of the factors that influence maize production like land use and type of soils whilst other factors are held constant. The analysis is further controlled by yield figures and the annual rainfall of 2010-11 growing season. This is done to demonstrate how the department of Crops can use data uploaded by the department of Land Resources and Conservation.

In order to produce a map showing likely areas to produce potential yield for hybrid maize, the following shape files were used Mzuzu_bnd.shp (Mzuzu ADD boundary), mw_epas.shp (Malawi EPA), mw_lakes.shp (Malawi Lakes), mw_landuse.shp (Malawi Land Use) and mzuzu_soils (Figure 10) and also a tabulation excel document with figures for various crops including production, rainfall and area for hybrid maize in the 2010-11 growing season, Table 11.

Table 11: files used for analysis

Name of file	**Description**
Mzuzu_bnd	Vector map showing boundary for Mzuzu ADD
Mw_epas	Vector map showing all the Extension Planning Areas of Malawi
Mw_lakes	Vector map showing all lakes of Malawi
Mw_landuse	Vector map showing the land usage in Mzuzu ADD
Mzuzu_soils	Vector map showing soils in Mzuzu
MZADD TABULATION SHEET THIRD ROUND FINAL 2010.xls	Excel document showing yield data of various crops grown in Mzuzu ADD

In order to conduct the spatial analysis in ArcGIS 10.0 the initial spatial data MZADD boundary was clipped on Malawi EPA map (mw_epas.shp), Malawi Land Use map (mw_landuse.shp) to produce maps of MZADD EPAs and MZADD Land Use respectively. Through data management tools MZADD EPAs map was then converted to a point shape file and to this point shape file, columns for production and that of area

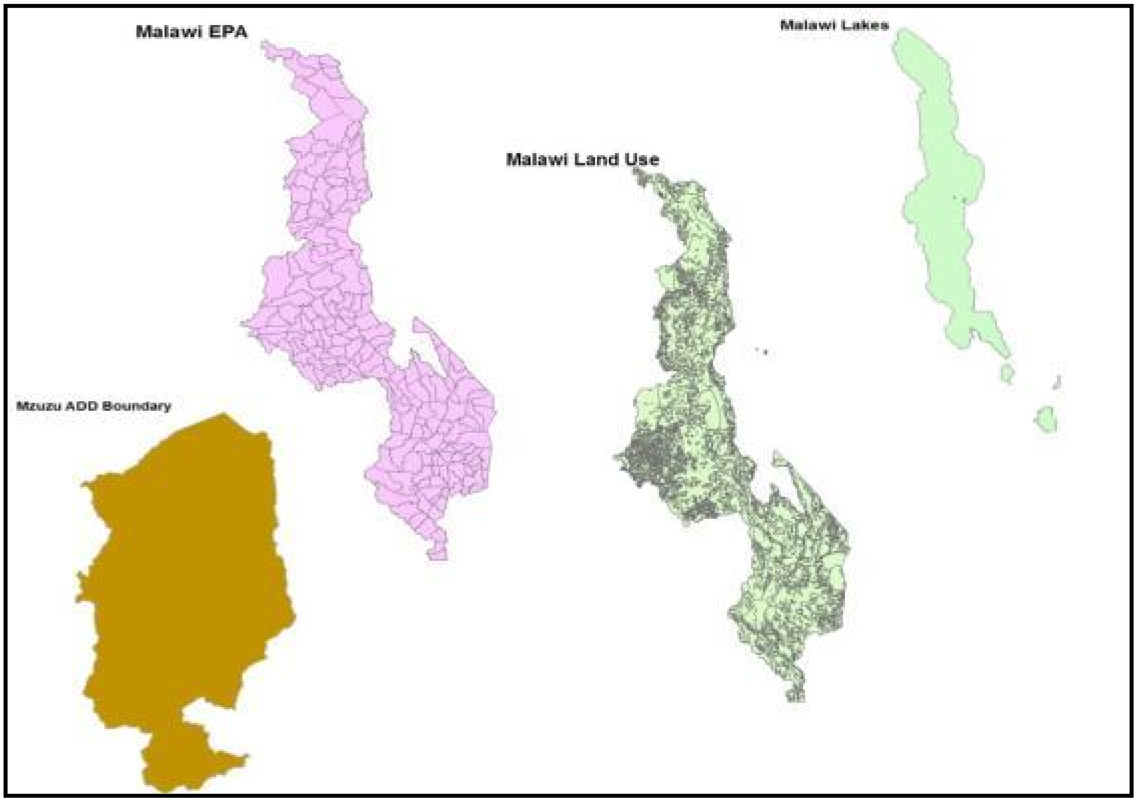

Figure 10 Initial Maps obtained from the Department of Land Resources

were added to the attribute table and filled with figures from Agricultural Production Estimates Survey data of 2010-11 growing season. Maize production data is obtained by the physical weighing of the crop produce, when they are dry and with less moisture content, after harvesting. Then a column for yield was added and the values for this column were filled using field calculator according to Equation 1.

$$Yield = \left(\frac{Production\ (Kg)}{Area\ (ha)}\right) * 1000$$

Equation 1

Irrespective of agro-ecological zone, the average potential yield for hybrid maize is 8625 kgha^{-1} (MoAFS, 2012). For the growing season 2010-11 the maximum yield was

4293.18kgha^{-1} and this occurred in less than 5 EPAs out of the 35 EPAs from which this data was obtained, Figure 11. This just shows that less than 14% of the EPAs in MZADD are able to produce just about 50% of the potential yield for hybrid maize.

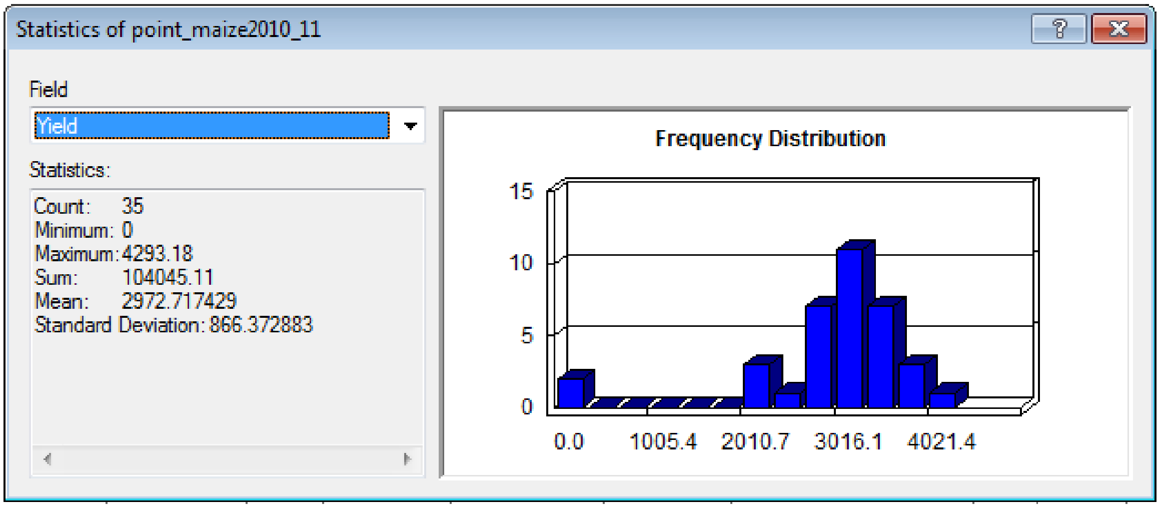

Figure 11 Frequency for Hybrid maize yield

In this study following the suitability model as stated by McCoy (2004), the elements for several layers that represent relevant factors for maize production are reclassified then analysis on the factors is performed followed by use of Raster calculator in ArcGIS Analyst to run the model and produce a map showing areas which are likely to produce potential yield for hybrid maize. Each element is reclassified on a scale of 1 to 10 with 10 being the most suitable for maize production and 1 being the least suitable. A category was excluded from analysis by being reclassified as NoData.

There are various factors that have to be considered to realize potential yield for hybrid maize, among them are land use and type of soils. In his manual of area specific fertilizer recommendation for hybrid maize grown by smallholders, Benson (1999) argues that conditions or natural fertility of the soils is one of the most important factors for one to obtain potential yield in hybrid maize. Soils texture (sandy, loam and clay) is an important indicator that affects the level of yield in response to fertilizer. Sandy soils are less fertile however they respond well to fertilizer in good weather conditions. Loams and clays are less responsive to fertilizer but have a less risk when fertilizer is used on them since they are less affected by droughts and fertilizer does not leach readily in heavy rains. Thus loams and clays are preferred soils for fertilizer usage in Malawi. On land use ‘dambos’ have small packets of fertile soils and water logging prevents a maize crop from surviving (Benson, 1999).

In suitability analysis, elements necessary to produce potential yield in various areas are weighed on the level of their importance in influencing an area to produce potential yield for hybrid maize when all other factors are held constant. With the help of 3 crops officer, each element of a factor is weighed on a scale of 1 to 10, the weighted value of 1 means that the element is less likely to influence an area to produce potential yield for hybrid maize and 10 means that the element is likely to be influential

Table 12. The weighed elements are reclassified in ArcGIS. On a scale of 1 to 10 rainfall is reclassified so much so that rainfall figure far below or above 792 mm annual rainfall are not ideal for hybrid maize and have been given a weight value of 1 and those close to the ideal rainfall ,792mm, have a value of 10, Figure 12.

Table 12: Factors and their elements in essential for potential Maize hybrid yield

Factors	**Elements**
Land Use	Grass lands
	Marshes
	Rain fed cultivation
	Dimba cultivation
	Wetland cultivation
	Plantation
Soil	Clay loam
	Loamy sand
	Sand
	Sandy Clay Loam
	Sand Clay
	Sandy Loam
Rain Fall	From minimum value to the maximum value
Maize Hybrid Yield figures	From minimum value to the maximum value

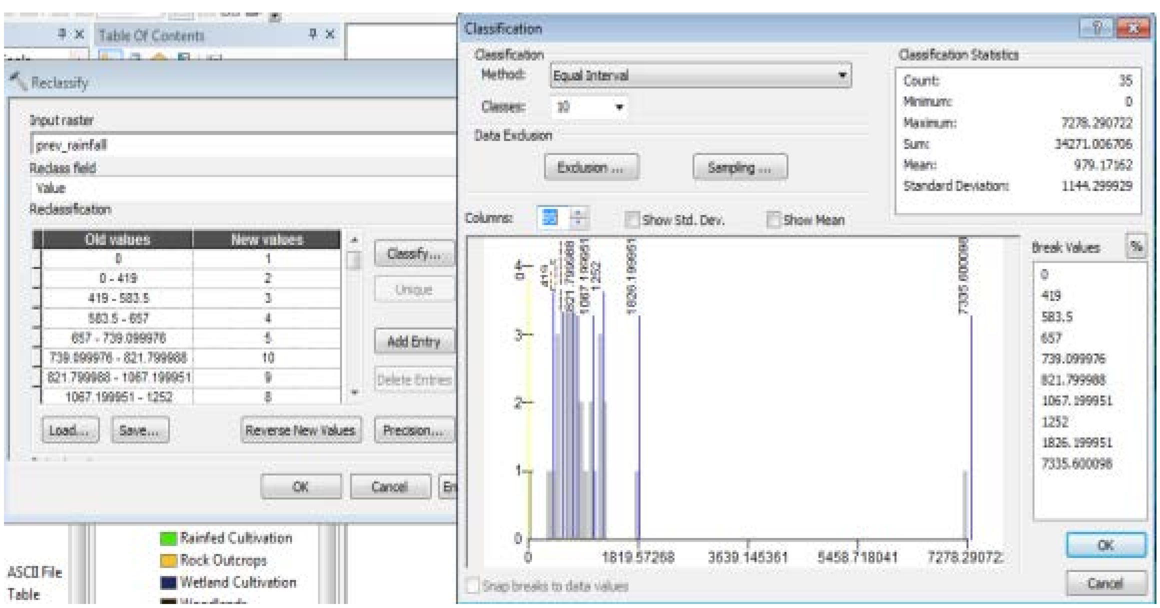

Figure 12 Reclassification of rainfall figures

Reclassifying yield for hybrid maize in 2010-11 growing period area with high yield figures were considered most likely to produce potential hybrid maize yield thus they were given a weight of 10 and those with low figures were give a weight of 1, Figure 13. Before reclassifying rainfall and yield figures each raster file for rainfall and yield that was converted from the point shape file of MZADD EPAs was interpolated using the natural neighbour method present in ArcGIS, this was done so as to predict values for rainfall and yield in areas that did not have figures for the same.

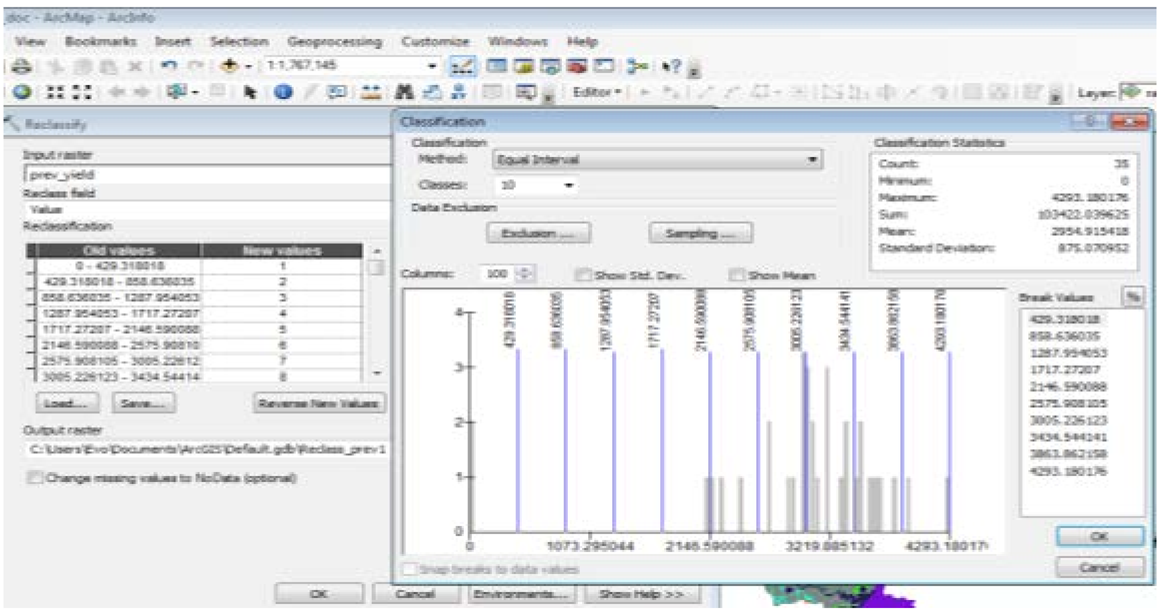

Figure 13 Reclassification of maize yield figures

The weights for reclassifying land use elements were obtained by finding the average of the total weights which were supplied by 3 crops officers. Figure 14 displays the weights for the elements of land use as being influential factors in the production of potential hybrid maize yield in an area with all other factors held constant.

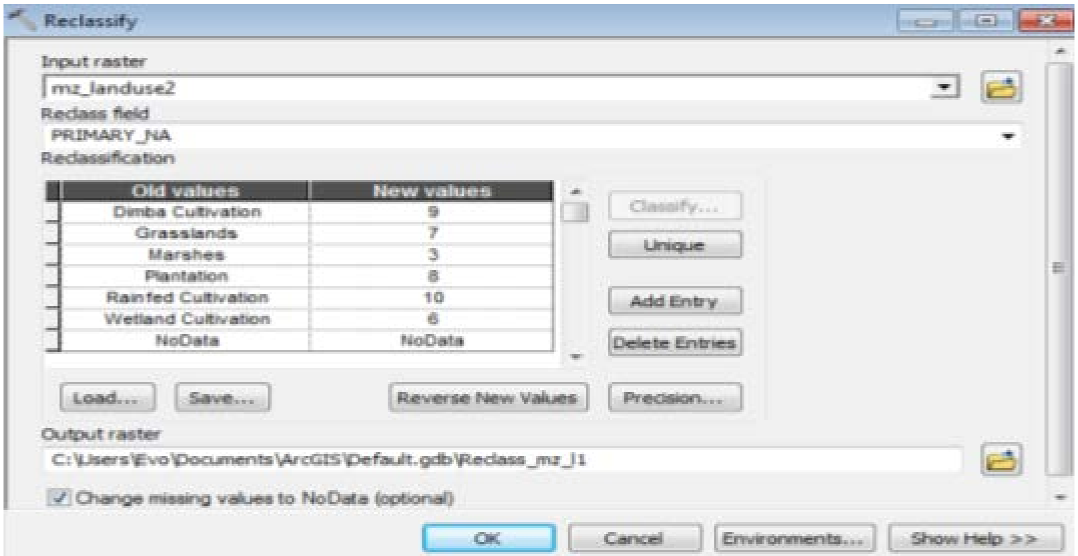

Figure 14 Reclassification of Land Use elements

Similarly weights for reclassifying soil texture elements were obtained by finding the average of the total weights which were supplied by 3 crops officers. Figure 15 displays the weights for the elements of soil texture as being influential factors in the production of potential hybrid maize yield in an area with all other factors held constant. However the officers advised that yields for hybrid maize are better determined by the cropping pattern, mulching, intercropping, crop rotation or mono cropping.

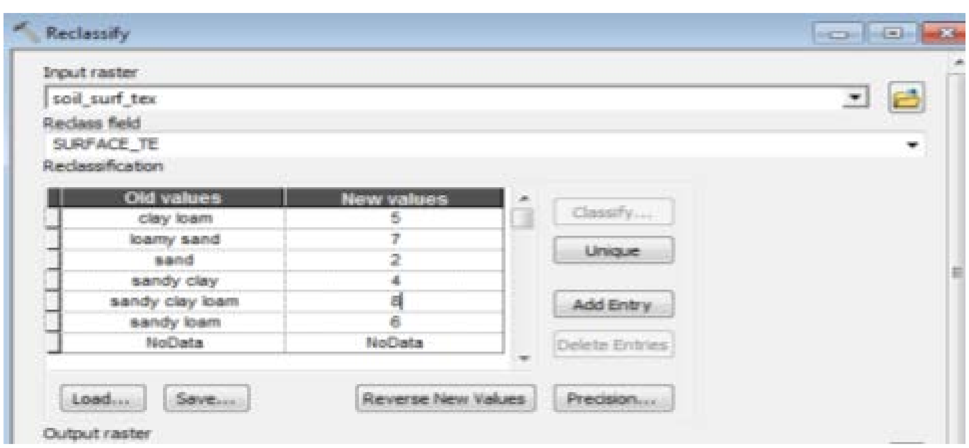

Figure 15 Reclassification of elements for soil texture

Not only the elements of factors but also the factors themselves also have varying weights in influencing an area to be a potential hybrid maize yield producer, using the product of each factors weight and the factor then summing these in the raster calculator produces a map displaying areas which are likely to produce potential yield. In this study, the weights for the factors are calculated using Analytic Hierarchy Process (AHP) (Saaty, 1980). AHP is conducted in three steps to determine the weight of each factor in influencing the likelihood of an area in producing potential yield. In the first step factors are paired to determine the most influential factor in a pair, then a matrix table is constructed using the weighed values from the pairing and then normalization and determination of each factor's weight is done. To check the consistency of paring and to determine the reliability of the weights obtained a Consistency Ratio (CR) is calculated. A CR of less than 0.1 (CR<0.1) means that the results are acceptable and can be relied up on. The weights of pairs have to be revised until an ideal CR is achieved (Saaty, 1980).

In conducting AHP factors are paired and weighed, each pair is weighed while holding other factors constant. The weighing of the pairs was initially done by the 3 crops officer and the average of their weights was considered the weight of a pair, but revision had to be done since CR was greater than 0.1. The weights were obtained on a scale of 1 to 9, where 1 means the factors have equal influence in yield production and 9 means that a particular factor is extremely influential compared to the other. From the discussions the influence of the selected factors on maize production is not really significantly large though differences are there, effects of soil texture on yield take longer to be noticed. If land is poorly used soil texture will be affected thus leading to low yields. Rainfall and soil texture do not interact much to determine yield. Figure 16 below is a revised detailed pairing of weights that achieved a consistency ratio of 0.1.

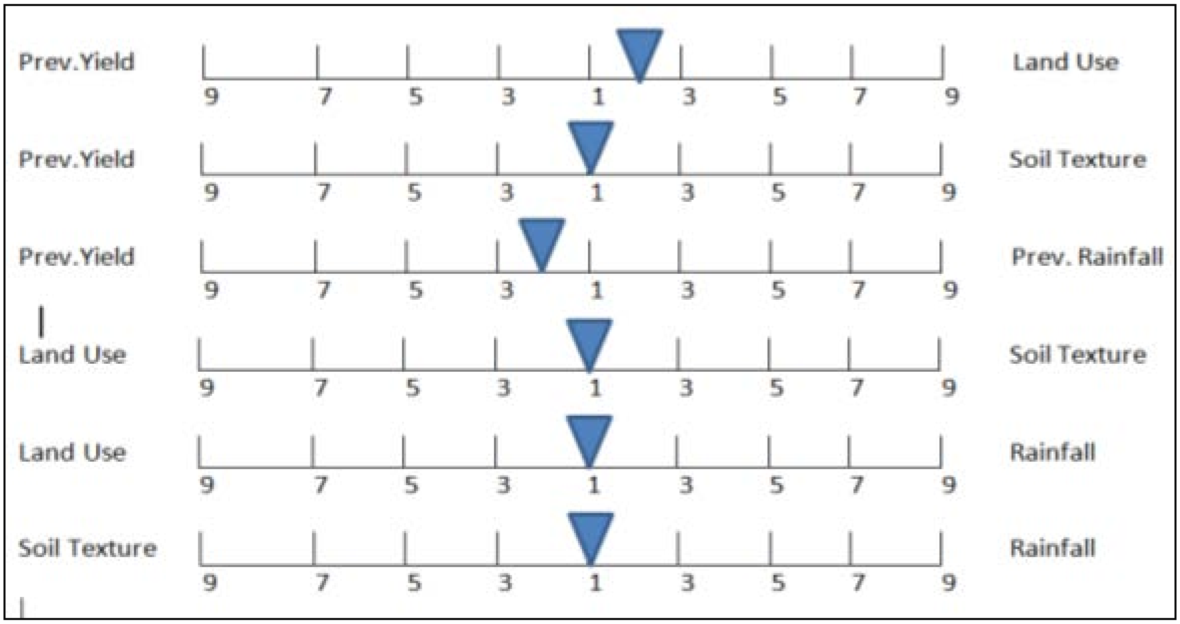

Figure 16 Weights of paired factors in stage one of AHP

Once the factors have been paired, a compared matrix of the factors is constructed. In filling the matrix, if the judgement value is on the left side of 1, the actual judgement value is filled in the cell and for the judgement values on the right side of 1 the reciprocal value is filled in the cell (

Table 13). Values in bold in the matrix table are reciprocal.

Table 13: Matrix of compared factors

Factors	**Prev. Yield**	**Landuse**	**Soil Texture**	**Prev. Rainfall**
Prev. Yield	1.00	0.50	1.00	2.00
Landuse	**2.00**	1.00	1.00	1.00
Soil Texture	**1.00**	**1.00**	1.00	1.00
Prev. Rainfall	**0.50**	**1.00**	**1.00**	1.00
Total	4.50	3.50	4.00	5.00

To conduct normalization and determine weights of the factors which will be used to produce the map through the raster calculator the values for the cells are normalized by dividing the value by its column total (Table 13) and the weight is calculated by finding the mean of the row Table 14.

Table 14: Normalization and determination of weight

Factors	**Prev. Yield**	**Landuse**	**Soil Texture**	**Prev. Rainfall**	**Weight**
Prev. Yield	0.22	0.14	0.25	0.40	**0.25**
Landuse	0.44	0.29	0.25	0.20	**0.30**
Soil Texture	0.22	0.29	0.25	0.20	**0.24**
Prev. Rainfall	0.11	0.29	0.25	0.20	**0.21**

To check on the acceptability of the results, the value of CR is calculated as in Equation 2.

$$Consistency\ Ratio = \frac{Consistency\ Index\ (CI)}{Random\ Consistency\ Index\ (RI)}$$

Equation 2

$$CI = \frac{(\lambda_{max} - \mathrm{n})}{\mathrm{n} - 1}$$

$$Where\ \mathrm{n}\ is\ the\ number\ of\ factors\ and\ \mathrm{n} = 4$$

$$\lambda_{max} = \sum \begin{matrix} Sum\ of\ product\ between\ each\ factor's\ weight\ (\text{Table 14}) \\ and\ the\ column\ totals\ (\text{Table 13}) \end{matrix}$$

Equation 3

Random Consistency Index (RI) for small number of factors according to Saaty (1980) is given as in Table 15.

Table 15: Random Consistency Index (RI)

N	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

From Equation 3 Consistency Index is (CI) 0.06369, Random Consistency Index (RI) from Table 15 with n equal to 4 is 0.90. Thus this gives a Consistency Ration (CR) of 0.070767 which is less than 0.1 meaning that the weights are reliable.

To produce a map displaying areas in MZADD most likely to produce potential yield from the stated influential factors a calculation is done using the raster calculator to compute the sum of the product of the factors (Table 13) and their weights (

Table 14) as shown in Figure 17

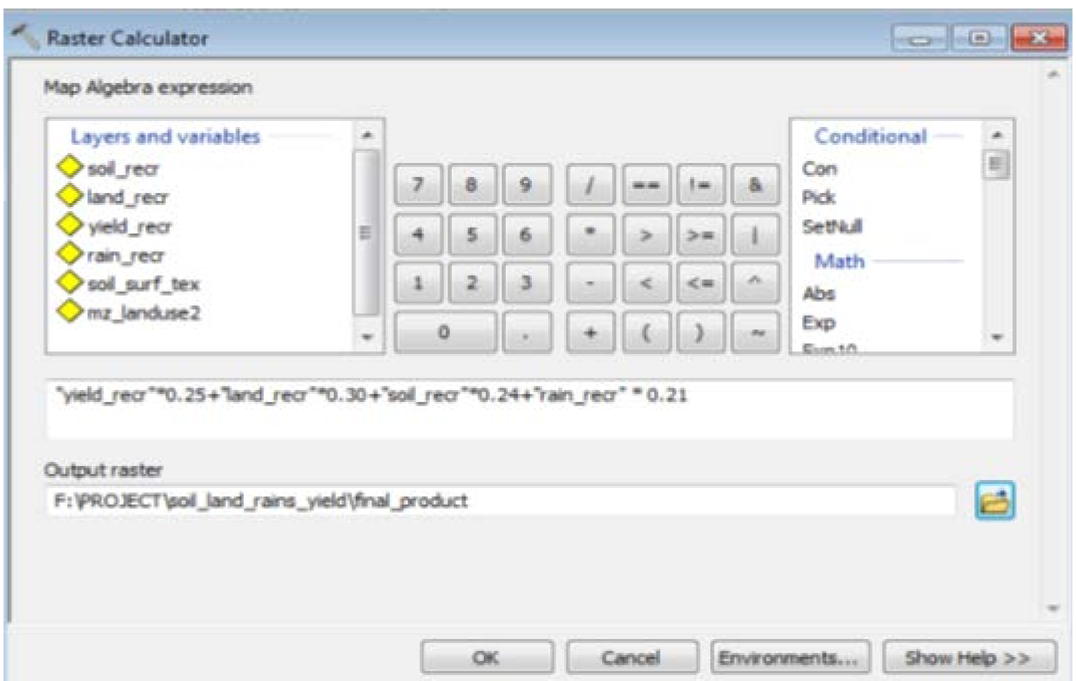

Figure 17 performing raster calculation

Using these factors (land use, soil texture) and taking into account the 2010-11 growing season yield data and rainfall figures the most likely areas to have the potential yield for hybrid maize are those in Nchenachena, Mhuju, Chikwina and Kazomba and areas that are less like to have potential hybrid maize yield are parts of Mzenga, Emsizini, Bolero and Malidade (Figure 18).

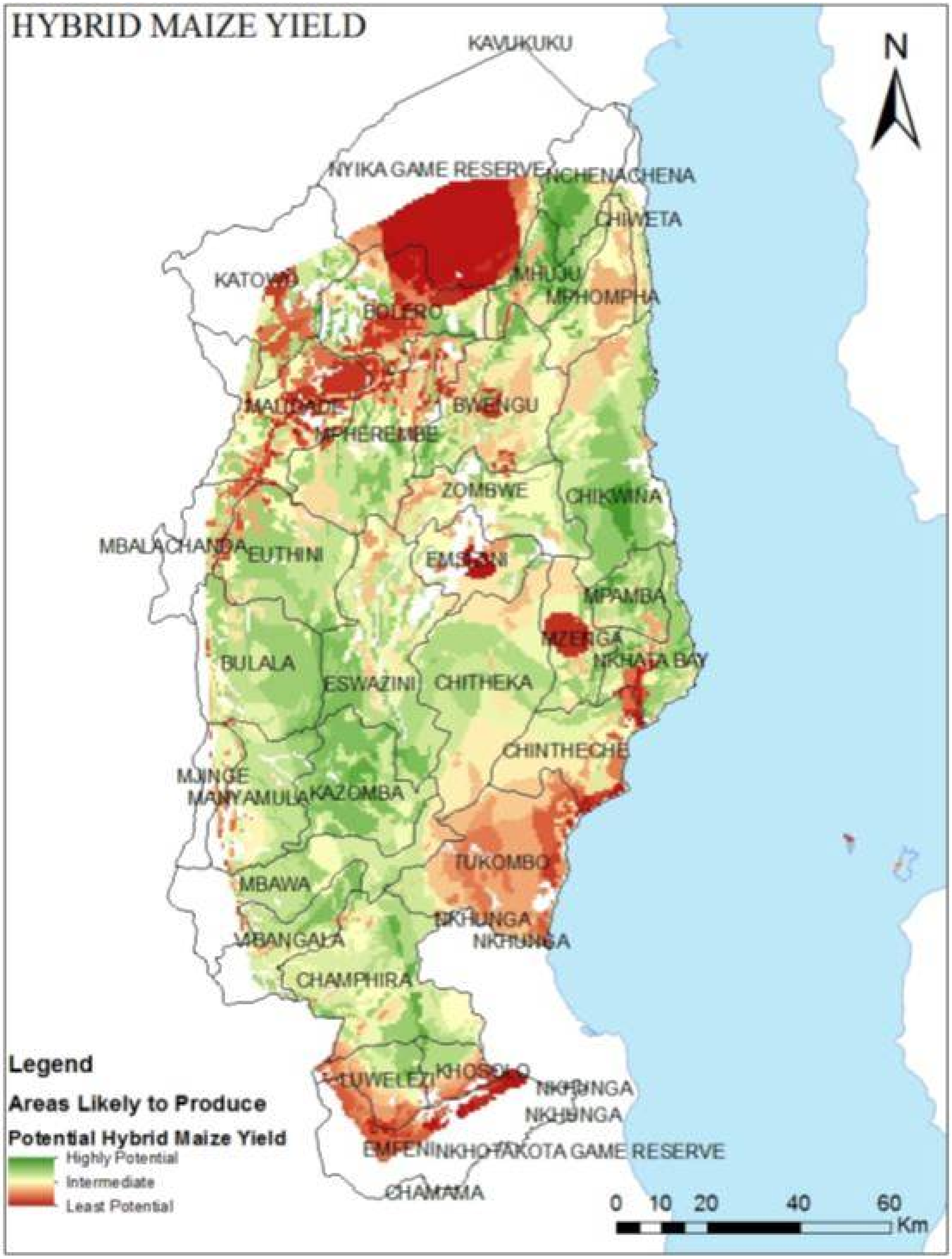

Figure 18 map of MZADD areas most likely to produce potential yield for hybrid maize

Using this information subject matter specialist can visit areas to verify the results and from there take appropriate action in assisting farmers especially in areas which are less likely to produce potential yield for hybrid maize. From this study it can further be deduced the importance of most factors in influencing the production of potential yield is almost equally the same.

4.3 Implications of Institutional Client-Server GIS

4.3.1 Workforce Implications

For a successful implementation of a client-server GIS application there is need for a workforce that has at least basic skills in computer usage and that is willing to share data. When sharing data adequate information about the data need to be provided for people viewing the data to quickly see the relevance of the data. With a client-server GIS application like Geonetwork, the workforces that exist in the technical departments (Land Resources, Crops, Extension and Livestock) suffice in availing spatial and non-spatial data for sharing across MZADD despite the need for further training on the capabilities of a computer and in GIS. However, the application requires an administrator.

The administrator must be knowledgeable in database management, networking and general system management. General system management can be user management, local integration of the Geonetwork with locally available desktop GIS application and spatial enabled database. The Administrator must be resourceful in identifying remote Geonetwork nodes and databases to have a rich resource of spatial and non-spatial data available for the institution.

In the institution the policies and structure are not affected in any way at the inception of a client-server GIS application, in fact they are reinforced. A user of a client-server GIS application like Geonetwork can be configured as an editor, registered user, content reviewer, user administrator, or Geonetwork administrator. A user administrator can be the head of the department. The head of the department can appoint personnel within the department to publish departmental data (content reviewer) or departmental members who can just view the data available in the Geonetwork. The departmental data can be configured to allow other departments to view, download or edit it by the content reviewer. This in a way keeps in check what is published to the public and it is only published with personnel with that responsibility, thus ensuring security and integrity on data.

4.3.2 Technology Implications

Client-server GIS application has the following technological implications for an institution: centralized data storage, reliable network, installation of desktop GIS application, linking to other spatial data providers. Although there was provision for a centralized repository which was readily accessible to all computers on LAN, users were not motivated to utilize the application because of the power outages, intermittent connectivity from Administration block and Veterinary block and users being on different networks (Figure 5). The high mobility of staff that often worked away from the office also contributed to low contribution to the prototype.

Wireless connectivity to Administration block and Veterinary block is intermittent (Figure 5). The configuration of the devices usually change on their own thus rendering the two blocks disconnected from the main server block. When internet is down, most respondents use mobile doggles which renders them to be outside the MZADD LAN, thus unable to access the server from their computers.

Just having the client-server GIS application is not enough, there is need to have readily available and accessible repository which implies steady power supply and dependable connectivity (Laudon & Laundon, 2006). To modify or edit the downloaded spatial data users must have desktop GIS installed on their computers that have high processing power which most desktop did not meet.

Limited supply of spatial data that meet departmental specific needs can be a hindrance to uptake of new technology. This study has revealed that for the institutional client-server GIS application to be useful it needs to have plenty of spatial data available to its users which was not available at MZADD. Even though Geonetwork can be configured to get data from other remote Geonetwork nodes and spatial enabled databases, poor internet connectivity constrained the potential of harvesting data from remote computers online.

The manual recommends the use of apache web server over the embedded jetty server, in this study, configuring Geonetwork with apache web server proved to be a challenge thus jetty server was used. But for the production environment Apache web server is recommended. Geonetwork did not give provision to monitor who has logged in and what activities they have been doing whilst logged in, this was a challenge as data of usage was obtained from word of mouth and observations where word of mouth was difficult to verify the interactions the only way to notice user activity was when data was uploaded.

4.3.3 Data Management Implications

When Geonetwork is implemented the roles of data collectors remain the same. The data that is collected will have a centralized repository readily available to anyone on MZADD LAN. The data is stored in such a way that it can easily be searched and one can measure its relevance by just reading the metadata that is stored with the data. Geonetwork being the cataloguing software, users use metadata templates to describe resources they have uploaded this easily helps data seekers to see the validity of the data they are looking for.

When uploading data Geonetwork has a choice of templates from which users can choose for filling the metadata. Most templates have many fields that are required to be filled. This proved to be a challenge in this study. Respondents wished if only there were asked to give a name and brief description of the data uploaded. Neither the manual nor the help from the application fully describes what each template is for and how different it is from the others. Users have to make an intelligent guess on their use. The available online Geonetwork installation manual only recommends the use of one template just as it did on the use of apache web server.

4.4 MZADD Adoption of Client-Server GIS Application According to TOE

Technology Organization Environment (TOE) framework is used to study technology adoption at an organizational level. This framework looks at three contexts as key for a technology to be adopted at an organizational level (Lippert & Govindarajulu 2006; Scott 2007; Oliveira & Martins 2011; Shemi & Proctor 2013). These contexts are technology, organization and environment. In this study the context of technology has been sub categorised into accumulation of technology and Availability; the context of organization has been subcategorised into communication process and quality, and availability of human resource; and the context of Environment has been subcategorised into competitive pressure and supplier

Introduction of a client-server GIS application is not a replacement of any existing technology but rather an enhancement of the technologies that are already in existence. The application is implemented on an already installed LAN, server computer and accessed on individual computers which are already in use. From the study, MZADD LAN connectivity is intermittent from other building blocks. This in away posed the difficulties in the availability of client-server application. Information on client-server was not accessed whenever it was needed due to loss of configuration settings in the wireless connectivity in the building blocks and also electricity failures. Under technology context an innovation is likely to be adopted if it can be implemented without much changes to the existing technology and if it is available whenever it is needed (Lippert & Govindarajulu, 2006; Scott, 2007, Lin & Ho, 2008).

From this study, MZADD can be said to have a means of communication that is in place. Information readily flows from one department to the other and among individuals. The ADD at times has ad hoc activities which are not tied only to one department but are cross cutting, in a way instilling in members of staff the vision and mandate of MZADD, which is "to contribute to agricultural productivity and sustainable management of land resources to achieve food security, increased agro-based incomes and ensure sustainable socio-economical growth and development" (Mzuzu Agricultural Development Division, 2012). The benefit of a client-server GIS application is to enhance the sharing of spatial data among other data that can be shared. Availability of spatial data can encourage individual to have a GIS mind-set in delivering agricultural services to farmers. As demonstrated in this study GIS can help in telling which areas are less likely to produce potential yield thus help subject matter specialist to provide the necessary interventions in these areas for a bumper yield. leadership influences change in an organization by changing the mind-set of the workforce, perceived benefits encourages adoption of an innovation (Scott, 2007).

Despite the intermittent connectivity of computers, MZADD is more likely to adopt client-server GIS application as in enhancement in its agricultural service delivery to the farmers for the following reasons; (1) it has the necessary infrastructure in place like the server as a central repository and most of the computers are already connected on the local area network all that needs to be done is to train members of staff in basic computing and GIS that is closely related to their field of work, (2) introducing client-server GIS will not change much on how the ADD carries its activities, (3) the competitors of MZADD are other ADDs who in actual sense are just complementing each other in hunger reduction in Malawi, if MZADD is to implement the client-server application it will be the first and an example to other ADDs, and (4) the immediate environment, headquarters and the districts (not EPAs) are already technologically aware, so implementing a client-server GIS application will not be a surprise to them.

5.0 CHAPTER 5 - CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This dissertation has examined the implication of introducing an institutional client-server GIS application. The framework being used to understand the client-server GIS has been guided by the frame-field experiment approach. The results in this dissertation reveal that MZADD has a weak matrix organization which facilitates interactions among members of staff and departments which ensure that all members of staff are aware of the vision and mandate of the ADD. According to Scott (2007) interactions of such are necessary in an organization's intentions and actual adoption of an innovation. It has been found that institutions, in particular MZADD, offer numerous opportunities for the application of client-server GIS but can be faced with challenges beyond individual organization's mandate. The findings also reveal that within organisation intermittent connectivity and internet connectivity plus not being connected to the office internet when one works out of the office can be a hindrance in adoption of a technology this thus makes an innovation unreliable (Lippert & Govindarajulu 2006).

Although MZADD has necessary human resources and technology, it does not have the necessary combination of capabilities that can be used to put into operation the client-server GIS application. Evidence from the current practices of institutional organization, data gathering and sharing, MZADD can be described as a highly departmentalized such that technical departments often times use internet facilities to communicate within individual departments as compared to wider MZADD.

Based on the findings this study concludes that spatial data utilization is at its infancy stage as such GIS is not fully integrated in day-to-day decision making. This situation may have implication on adoption of client-server GIS introduced in this dissertation in addition to power outages and multiple internet connectivity.

5.2 Current Information Sharing Practice at MZADD

Data gathered at MZADD originates from districts structures. The main mediums of data transmission are electronic and hard copy reports. The flow of data is mainly in one direction from districts to MZADD and central government. It has been argued that MZADD does not have centralized computer data storage. Flash drives and personal email accounts are the most used means of data sharing. Data sharing depends on staff availability, network coverage, data management culture on individual computers and perceived virus security threats by officers.

5.3 An Institutional Client-Server GIS Application as an Alternative of Sharing Spatial Data in an Institution

This dissertation has demonstrated prototyping of Geonetwork. It has outlined critical steps and requirements for setting up a Geonetwork based on OSGeo manual. The configured system has the capabilities to handle spatial data, word documents, Excel documents and Portable Documents File (PDF). The platform also offers potential for data storage, editing and sharing.

Despite Geonetwork accommodating users (including non-GIS experts), it is not user friendly because of its long requirement on filling of metadata templates. The designed system's harvested spatial data cannot be easily downloaded and used for further analysis in desktop GIS.

5.4 Opportunities and Challenges of Introducing Institutional Client-Server GIS Application.

MZADD provides an enabling environment for client-server GIS because of some investments which are already in place such as internet connectivity, LAN and wireless facilities. In addition, each department has the initiative of data sharing among staff members in-line with the existing efforts by MZADD to have centralized data management system. Finally, MZADD has staff with basic computer literacy and well vest in internet usage though there were some skills gaps that need investing in.

This study finds some challenges associated with introducing a client-server GIS application in MZADD that are technological. Technologically the client-server GIS application is challenged with frequent power outages which did not only affect the server but even connectivity of LAN at MZADD. Furthermore, unreliable connectivity between the wireless access points from the server block to administration and veterinary blocks was a challenge.

Workforce implications of introducing a client-server GIS include staff attitude towards new innovation of data management and competencies among staff that demand having an administrator who would manage users, connectivity and data harvesting.

5.5 Use of GIS in identification of potential hybrid maize areas

Through spatial analysis, various layers and there attributes were combined and calculated to produce a map displaying areas in Mzuzu ADD that are more likely to reach potential yield for hybrid maize and those which are less likely. This was done by some of the factors which can affect yield which are land usage and soil type this information was combined with yield data and rainfall figures for the growing season 2010-11. But land usage and soil type are not the only factors that can affect yield levels (Benson, 1999), there is need to have a comprehensive list of all factors and their associated data so that subject matter specialist can be well informed and assist the farmers in their agricultural production.

5.6 Recommendations

MZADD has all it takes in terms of technology infrastructure to use Geonetwork as a platform for spatial data and non-spatial data sharing. However if the inception of Geonetwork is to be accepted by members of staff at MZADD (1) there is need to have the institution to be fully knowledgeable about integrating the new technology in its program delivery; (2) there is also need to empower members of staff with the general computer skills; and (3) there is need to have a reliable cooperate network that should enable members of staff to access company resources even when they are out in the field. A reliable cooperate network can entice external projects to exist on the same network as MZADD thus contributing to its data resource unlike how the present situation is where data is stored on personal computer rendering absent of the project data once the project finishes.

There is need to have members of staff trained in GIS however, GIS trainings should be specific to participants' specific area of work. In this case, the trainings should be department specific. GIS presents itself as a reliable tool to help subject matter specialist when assisting farmers through say combining factors necessary for a bumper yield one can know which areas farmers require more assistance.

This study has looked at sharing of spatial data at an institutional level, a proposition of a future study would be where there is a look at different institutions implementing their own Geonetwork and having these Geonetwork linked to facilitate spatial data sharing among the different institutions. The Technology-Organization-Environment model used in this study opens for further investigations through empirical testing to confirm the direction of client-server GIS adoption.

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APPENDIX 1 - FIRST SET QUESTIONNAIRE

This questionnaire seeks to gather information for the use of the study IMPLICATIONS OF INTRODUCING INSTITUTIONAL CLIENT-SERVER GEOGRAPHIC INFORMATION SYSTEMS: A CASE OF MZUZU AGRICULTURE DEVELOPMENT DIVISION. The information gathered will only be used for this study. Names of individual will not be used in the study. Recording may be used as a part of data collection. Your participation is highly appreciated.

Department name ………………………………………………

GIS Applications in use …………………………………………

Departmental Questions

1. What data does the department collect in the field?
2. What are some of the tools used in data collection?
3. In what form is the data kept?
4. Where is it kept?
5. How is the data shared among departmental members? (If not shared, why not?)
6. (individual) What are the challenges faced in accessing data collected in the field?
7. Why is GIS application not used in the department? (If the department does not have any GIS application)

GIS Questions on Individual Basis

1. Have you ever been in any GIS training? (if no, go to 4)
2. How many times?
3. (If GIS application available)

    a. How do you use GIS application on you day to day work activities?
    b. Do you share spatial information with any of your colleagues?
    c. If yes How?
    d. What are the challenges you face in the use of GIS application? (go to SDI Questions)
4. Why not?

APPENDIX 2 - SECOND SET QUESTIONNAIRE

This questionnaire seeks to gather information for the use of the study IMPLICATIONS OF INTRODUCING INSTITUTIONAL CLIENT-SERVER GEOGRAPHIC INFORMATION SYSTEMS: A CASE OF MZUZU AGRICULTURE DEVELOPMENT DIVISION. The information gathered will only be used for this study. Names of individual will not be used in the study. Recording may be used as a part of data collection. Your participation is highly appreciated.

Questions for Prototype Interaction

1. Were you able to interact with the application comfortably?
2. In what ways do you find the application useful?
3. What were some of the challenges you faced in interacting with the application?
    - Data inadequate.
    - Application complication.
4. How do you think these challenges can be addressed?
5. If you have not been using GIS in the past, has this application motivated you in any way?

APPENDIX 3 - REQUEST FOR MZADD RESOURCES

Ref No-MZ/IT/01/13 7th January, 2013

From: Systems Analyst/Programmer
Mzuzu ADD
Box 131
Mzuzu

To: The Program Manager
Mzuzu ADD
Box 131
Mzuzu

Approved
THE PROGRAMME MANAGER
MZUZU A.D.D.
2013-01-11
P.O. BOX 131
MZUZU
Jan 2013

Dear Madam

REQUEST TO USE MZADD RESOURCES IN CONDUCTING A STUDY

I am conducting a study entitled IMPLICATIONS OF INTRODUCING INSTITUTIONAL CLIENT-SERVER GEOGRAPHIC INFORMATION SYSTEMS: A CASE OF MZUZU AGRICULTURE DEVELOPMENT DIVISION. In order for this study to be conducted it requires the use of the MZADD resources which include; server computer, local area network, personal computers and the time of the employees who would be will to participate in the study.

This letter therefore has been submitted for your approval.

Sincerely

D. Nkosi

Systems Analyst/Programmer

APPENDIX 4 - INFORMED CONSENT FORM

Chancellor College

Consent to Participate in Research Study

INTERVIEW AND OBSERVATION

STUDY TITLE: **Implications Of Introducing Institutional Client-Server Geographic Information System: Case Of Mzuzu Agriculture Development Division**

RESEARCHER: Daniel Nkosi **TELEPHONE:** 0995434640

MAIN SUPERVISOR: M. Tembo

SUPERVISOR: P. Chikumba

INTRODUCTION

You are invited to consider participating in this research study. Please take as much time as you need to make your decision. Feel free to discuss your decision with whomever you want, but remember that ***the decision to participate, or not to participate, is yours***. If you decide that you want to participate, please sign and date where indicated at the end of this form and return the form to Daniel Nkosi, you can slid it under the door.

If you have any questions, you should ask Daniel Nkosi.

BACKGROUND AND PURPOSE

This study is being done in order to find the challenges and opportunities that can arise in introducing a client-server GIS application at an institution (i.e. MZADD) where some departments

are using stand alone GIS application and some are not when they can as well be using. The study should assist in sharing of spatial data and encourage spatial related decision making at high level.

STUDY PLAN

You are being asked to take part in this study because you are in the technical department/support department of the Mzuzu ADD, your office has a computer that is on a network and that your department is currently using GIS application or have potential to do so. At least fourteen (14) people will take part in this study at Mzuzu ADD Management Unit.

If you decide to participate in this study, you will take part in learning about the Spatial Data Infrastructure which will be installed at the ADD, one on one interview and a focus group discussion. Prior to everything you or any member of your department, who decides to take part in the study, will be asked questions pertaining data requirement of the department.

The learning session should take somewhere around 45 minutes, the interview should last around 30 minutes and the focus group discussion should take approximately 45 minutes.

<table>
<tr><th>Week Beginning</th><th>Activity</th><th>Location Where Activity will Take Place</th><th>Types of Questions to expect</th></tr>
<tr><td>1st April 2013</td><td>Gathering data of Departmental data requirements</td><td>Participants’ respective offices</td><td rowspan="3">In general the type of questions will be related to place and information of things, objects that occur at the place, i.e. spatial data and its attribute. The information will be related to the work done at the ADD.</td></tr>
<tr><td>8th April 2013</td><td>Introduce Participants to the Spatial Data Infrastructure application. To be done in form of a classroom like setup.</td><td>Mzuzu ADD Conference room or the room at the Communications department.</td></tr>
<tr><td>15th April 2013</td><td>One on One interview.</td><td>Participants’ respective offices</td></tr>
</table>

22nd April 2013	Group discussions.	Mzuzu ADD Conference room or the room at the Communications department.	

You will be in the study for about 8 days.

The interviews and group discussion will be recorded. The recorded information will be kept by the research and will be destroyed at the end of the study.

You can stop participating at any time. However, if you decide to stop participating in the study, it is encouraged to talk to the researcher first.

RISKS

There are no risks associated with participating in this study.

BENEFITS

If you agree to take part in this study, there will be no direct benefits to you. However, information gathered in this study may *provide insight into* Institutional Spatial Data Infrastructure which might be a basis for the National Spatial Data Infrastructure. The developed Infrastructure will aid management to make decisions that are related to spatial data.

The Spatial Data Infrastructure will provide the ADD with a comprehensive database. The database will have data that is collected by all departments.

CONFIDENTIALITY

Every effort will be made to keep any information collected about you confidential. However, it is impossible to guarantee absolute confidentiality.

In order to keep information about you safe, steps that will be taken to protect data, include study data will be kept in a password-protected file on the researcher's personal computer which only the researcher can access, study data will be kept in a locked drawer in the researcher's office .

Your name or other identifiable information will not be included in the final thesis. Please note that, even if your name is not used in publication, the researcher will still be able to connect you to the information gathered about you in this study.

Chancellor College will be allowed to access the study records if there is any need to review the data for any reason.

YOUR RIGHTS AS A RESEARCH PARTICIPANT

Participation in this study is entirely voluntary at all times. You can choose not to participate at all or to leave the study at any point. If you decide not to participate or to leave the study, there will be no effect on your relationship with the researcher or any other negative consequences.

If you decide that you no longer want to take part in learning the Spatial Data Infrastructure, interviews or the focus group discussions you are encouraged to inform the researcher of your decision. The information already obtained through your participation will be included in the data analysis and final report for this study.

QUESTIONS OR CONCERNS?

If you have questions about the study, you may contact Daniel Nkosi on 0995434640 or danielnkosi@gmail.com.

STATEMENT OF PERSON OBTAINING INFORMED CONSENT

I have fully explained this study to the participant. I have discussed the study's purpose and procedures, the possible risks and benefits, and that participation is completely voluntary.

I have invited the participant to ask questions and I have given complete answers to all of the participant's questions.

____ ____________________

Signature of Person Obtaining Informed Consent Date

CONSENT OF PARTICIPANT

I understand all of the information in this Informed Consent Form.

I have gotten complete answers for all of my questions.

I freely and voluntarily agree to participate in this study.

I understand that I will be photographed and audio recorded as a part of this study.

Please indicate whether you agree to be photographed and or audio recorded as a part of this study.

☐ **YES** *(If you change your mind about this at any point, please let the researcher know)*
☐ **NO**

____ ____________________

Participant Signature Date

____

Printed Name of Participant