Application of GIS in Health Human Resource Deployment to Health Facilities: A Case of Blantyre Health District in Malawi

Eddons C. S. Munthali[a], Patrick A. Chikumba[b*] and Ken C Gondwe[c]

a,b,c University of Malawi, The Polytechnic, Department of Computing and Information Technology

emunthali@poly.ac.mw, pchikumba@poly.ac.mw, kcgondwe@poly.ac.mw

Abstract

Availability of healthcare professionals and accessibility to healthcare facilities are important aspects of health system and has direct impact on the population's health. Applying Geographic Information Systems (GIS) techniques, this study analysed the geographical allocation of health professionals per categories of nurses, clinicians and Health Surveillance Assistants (HSAs) and how GIS could help in distribution of professionals to health facilities. Using Blantyre District Health Office in Southern Malawi as a case study, data on people accessing each health facility and number of health professionals at a facility was collected and analysed. The study found out that applying GIS can help enrich the information required for equitably distributing health human resource. Some health facilities seen to have more personnel were discovered that they still need deployment of additional staff to those health facilities seem to have inadequate number of personnel. Using provider-to-population ratios the research was able to isolate Health Professional Shortage Areas (HPSAs) and Medically Underserved Areas using a threshold based criteria of 1,000:2 as per WHO requirement. The research also adopted gravity model of migration to predict the degree of interaction between two places. Employing gravity model and taking into account population size of two facilities and their distance, the research was able to determine relative strength of the bond between two health facilities and predict where more professionals could be deployed.

Keywords : Geographic Information Systems, Health Facility, Health Professionals, Health Human Resource.

1.0 Introduction

The healthcare plays a very important role for the well-being of the community; it is defined as the prevention, treatment, and management of illness and the preservation of mental and physical well-being through the services offered by the medical, nursing, and allied health professions (KPMG, 2009). The primary healthcare is a crucial element

of national healthcare delivery, especially in developing countries like Malawi where majority of the population living in rural areas. Rural environments present unique challenges for healthcare access such as shortages of medical personnel. Availability of healthcare experts at a health facility is also an important factor for a health system and has a direct impact on the population's health.

Accessibility to the healthcare is concerned with the ability of a population to obtain a specified set of healthcare services. Many factors affect a population's ability to access appropriate levels of the healthcare (Michael et. al., 2004) which are grouped into three categories; availability, accessibility and affordability. Geographic accessibility (often referred to as spatial or physical accessibility) is concerned with the complex relationship between the spatial separation of the population and the supply of healthcare facilities and thus has a strong underlying geographic component (Michael et. al., 2004). It is also intuitive that the level of public health of a population may be affected negatively by the distance to healthcare services (Guagliardo, 2004).

The public sector is the major employer of professional health workers. Hornby and Ozcan (2003) reported that 69 % and 31 % of health workers, in Malawi, were in the public sector and private sector respectively. Malawi has low health worker ratio (Gordon, 2008). There are not enough health personnel in some of the health facilities despite having many graduating each and every year from Health Training institutions and universities. Malawi, like many African countries, is lacking health human resources, preventing it from delivering acceptable quality healthcare services to its population.

The reasons underlying the shortage of health professionals are multiple and include limited output from training institutions, high attrition rates resulting from migration and disease, and increased workloads because of HIV and AIDS (Muula et. al., 2005). It is therefore imperative to look into the equitable allocation of health experts and services into various health facilities and find out if the allocation takes care of the spatial separation of population and number and type of cases referred to a health facility.

Health managers rely on forms and sometimes spreadsheets coming in form of reports from different health facilities to, among others, help them determine personnel deficiency and come up with decisions of allocating health personnel in certain parts of the country. Msiska (2009) argued that spatial dimension offered by GIS is crucial in accessing and allocating health facilities and services. There is also inadequate reporting system which may slow down resource distribution (Oppong, 2011).

The problem of lack of access to health professionals in health facilities could be as a result of uneven distribution of health workers. This can, among other reasons, be attributed to poor reporting formats to help managers make better decisions coupled with unavailability of an enabling tool for spatial analysis of health facilities and services. The

complexity of development tasks such as determining health facility location and health human resource distribution requires the acquisition of up-to-date information to remove uncertainty in decision making. To achieve equitable distribution of health personnel officers and health facilities among population requires the use of perfect knowledge which can only exist where there is accurate and relevant information. Proper knowledge reduces uncertainty in decision making and planning for these important resources in health management systems.

The paper discusses the use of GIS in analysing the geographical distribution of health professionals in the health facilities in Malawi and to determine population's accessibility to healthcare which would help decision makers in distributing health personnel experts. GIS is well suited to measuring spatial accessibility to healthcare as they contain the core components needed for such analysis through data capture, storage, management and manipulation tools for both spatial and attribute data (Michael et. al, 2004). According to Longley et al., (2005, p. 4) "Almost everything that happens, happens somewhere. Knowing where something happens can be critically important."

2.0 Literature review

Despite having limited resources, GIS has proved to be very important in developing countries particularly in Africa. It has found its useful application in traffic and transport, agriculture, allocation decisions, spatial planning (land use), service planning (Education, health and social) and environmental and natural resources (Saugene, 2005). Geospatial applications do not just produce maps, but do carry out a geospatial data analysis as well. Some typical types of analysis include computing of: distances between geographic locations, the amount of area within a certain geographic region, what geographic features overlap other features, the amount of overlap between features, the number of locations within a certain distance of another and many more (Mitchell, 2005). The results of analysis may be shown on a map, but are often tabulated into a report to support management decisions.

The recent phenomena of location-based services promises to introduce all sorts of other features, but many could be based on a combination of maps and analysis. For example, you have a cell phone that tracks your geographic location. If you have the right software, your phone can tell you what kinds of facilities are within walking distance. While this is a novel application of geospatial technology, it is essentially doing geospatial data analysis and listing the results for you (Mitchell 2005).

The tremendous potential of GIS to benefit the healthcare industry is just now beginning to be realized. Both public and private sectors are developing innovative ways to harness the data integration and spatial visualization power of GIS. Parker and Campbell (1998) explain that early applications of GIS in the healthcare research mainly focused on

distribution of health and disease but more lately GIS has been applied to the planning and management of healthcare services. GIS plays a critical role in determining where and when to intervene, improving the quality of care, increasing accessibility of service, finding more cost-effective delivery modes, and preserving patient confidentiality while satisfying the needs of the research community for data accessibility (ESRI, 2009).

Several studies have been undertaken in the use of GIS as a tool in resource allocation. In California, Goulias (2007) argued that assessments of transportation investment from a "social efficiency" viewpoint were absent from transportation policy analysis and marketing practice mainly due to the lack of tools capable to assess the role of transportation infrastructure investment on the provision of activity opportunities to residents of each locality. It was therefore suggested a GIS-based tool as an optimal resource allocation tool for forecasting the travel demands of demographic groups within California.

The tool identified specific locations in an entire state where resource allocation had succeeded in maximizing benefits to the public. In addition, the tool and the GIS maps derived from this tool showed which locations in California failed to be optimal and require their residents to travel excessively to pursue the same amount of activities when compared to other optimal locations around the state where travelling enables better time allocation. The tool showed which demographic segments suffer the most from sub-optimal time allocation and what type of investment is needed to alleviate this suffering. It also showed the distribution of benefits of the transportation system and identified differences in benefits across regions.

In China a GIS-based method was used to determine whether land should be reallocated a new use (Liu et. al., 2006). It was used to assess land suitability in the Qinling Mountains, Shaanxi Province of China through consideration of physical features and current land use. Through interpretation of Landsat TM images and extensive field visits the area was modeled into land types in five altitudinal zones (valleys and gullies, hillsides and terraces, foothills, mid-mountain, and subalpine mountain). Then, a suitability score was assigned to five physical factors: climate, hydrology, topography, soil, and vegetation. Next, their integrated overall suitability value scores were compared with the observed land cover to determine whether it should be reallocated a new use. Implementation of the recommended land reallocations helped to achieve suitable use of land resources and prevent land degradation.

A similar study was also done in China by Wang et al (2005) on optimal water resource allocation in Arid and Semi-Arid areas of Heihe river basin in northwest China. The study developed a dynamic model for equitable distribution of water in water-shortage areas which aimed at optimally satisfying the requirements of each locality, given limited supplies, and to maximise the total economic benefit of the entire area.

In terms of human resource allocation, Massey (2011) explored the use of GIS to examine the regional distribution of human resources for health and related maternal health indicators in Senegal. Results showed that a regional imbalance in the distribution of health personnel and health indicators existed in Senegal. The disparity contributed to the disproportionate burden of disease experienced in the eastern part of the country. Based on a spatial analysis, a priority index was used to identify regions to target for the recruitment and training of midwives.

3.0 Methodology

This research adopted both qualitative and quantitative methods. Qualitative research method was chosen because of the exploratory nature of the research's aims and objectives. Quantitatively, the research was able to calculate the ratios of health human professionals to catchment population. Using GIS prototype tool, the research measured the spatial distance between each health facility and analysed spatial disparities of health facilities and health professionals. The case of Blantyre DHO was used with health surveillance assistants (HSAs), nurses and clinicians as health personnel; and malaria and diarrhea as disease cases.

Data was collected through document analysis and semi-structured interviews. The research demands the knowledge of populations served by the health facilities. Different documents were used to capture information about the catchment area for each health centre. The researchers also used semi-structured interviews to collect information from district health officer and HMIS officers. In addition to these, prototyping was also used to collect data of practical relevance and to gain a practical understanding of using GIS. To facilitate the data collection process an approval was sought from the National Health Sciences Research Committee in Ministry of Health.

The research adopted gravity model of migration which is a model in urban geography derived from Newton's law of gravity, and used to predict the degree of interaction between two places (Rodrigue et. al., 2009). When used geographically in this research, the words 'bodies' and 'masses' are replaced by 'locations' and 'importance' respectively, where importance can be measured in terms of population numbers or other appropriate variables. The gravity model of migration is therefore based upon the idea that as the importance of one or both of the location increases, there will also be an increase in movement between them and farther apart the two locations are, however, the movement between them will be less, a phenomenon known as distance decay (Rodrigue et. al., 2009).

Of particular importance to this research are two points in determining patient migration between two health facilities as well as the number of people in the community likely to use one health facility. The gravity model can also be used to determine the sphere of influence of each central place like a facility by estimating where the breaking point

between the two settlements will be. An example of this is the point at which community or patients find it preferable, because of distance, time and expense considerations, to travel to one facility rather than the other.

A Two-Step Floating Catchment Area (2SFCA) as defined by Luo and Qi (2009) was also used which is a special case of a gravity model of spatial interaction that was developed to measure spatial accessibility to primary care physician. It can also be used to measure other accessibility such as accessibility to healthcare facilities, jobs and others. It was inspired by the spatial decomposition idea first proposed by Radke and Mu (2000). The 2SFCA method is for combining a number of related types of information into a single and immediately meaningful index that allows comparisons to be made across different locations. Its importance lies in the improvement over considering the individual sources of information separately, where none on its own provides an adequate summary.

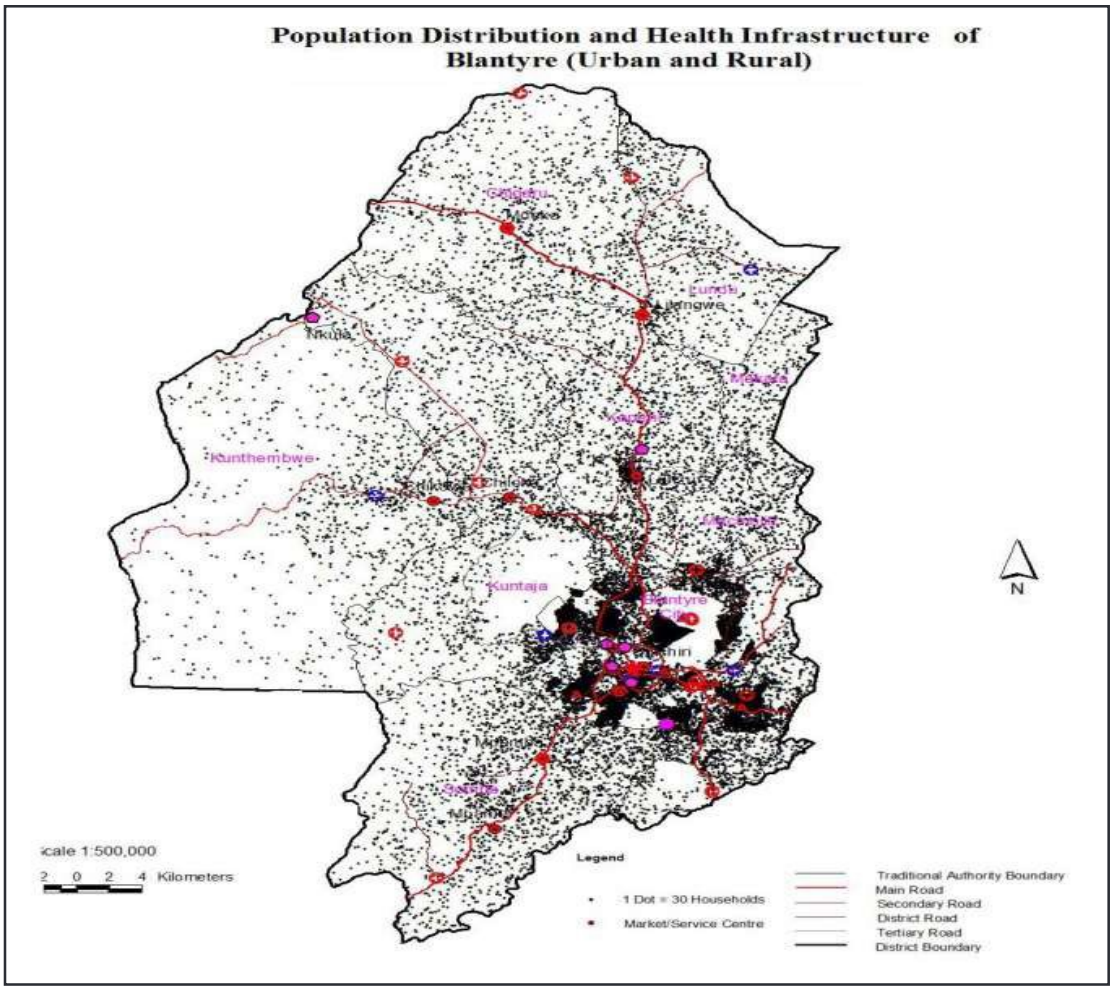

Figure 1: Population Distribution and Health Infrastructure of Blantyre

4.0 Mapping with GIS

4.1 Catchment Area and Provider-to-Population Ratio

In order to plan and monitor the use of services, there is need to know the geographical area and population that a facility is supposed to serve. In this research, GIS prototype was used to map total population per facility (see Figure 1). According to government policy, a health facility is supposed to serve population within 5 km radius. The research regards population within this radius as target population.

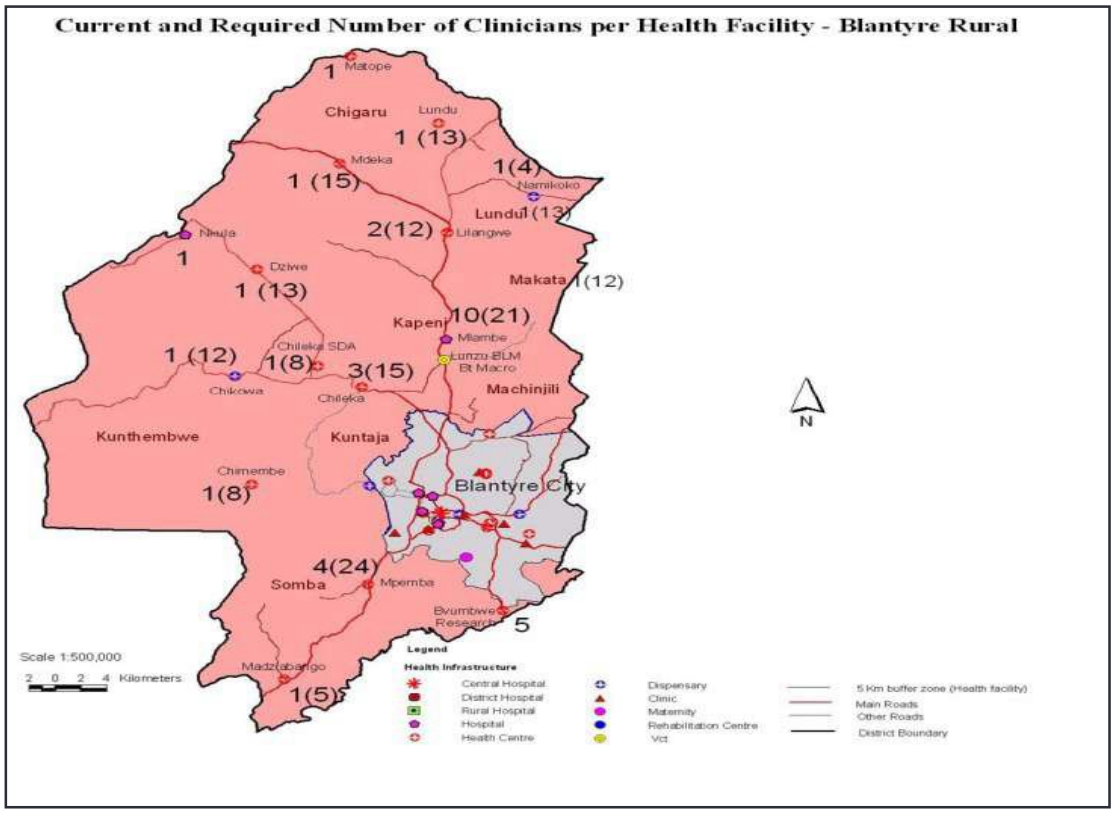

Figure 2: Clinicians per health facility

The provider-to-population ratio was used in this research because of its ease of computation and because it requires minimal data requirements. As such, it can be nicely used as a crude approximation of spatial accessibility. The provider-to-population ratio is also particularly useful to track changes over time as geo-references in historical data are sparse.

The provider-to-population ratio was so important in isolating Health Professional Shortage Areas (HPSAs) and Medically Underserved Areas (MUA). The research adopted the idea from the United State's Department of Health and Human Services (DHHS) where HPSAs were defined using an elaborate system of threshold based criteria. For

geographical area, this research considered areas that exceed a threshold of 1,000:2, as per WHO requirement since WHO determined that countries below a threshold of two (2) to three (3) doctors, nurses and midwives for every 1,000 people are very unlikely to achieve the MGDs (WHO, 2006).

The GIS prototype was used to locate the numbers of the professionals per facility as the actual situation on the ground, as an example shown in Figure 2. The provider-to-population ratio was used to determine the need of professionals per facility. Numbers presented in brackets shows the calculated required number of clinicians per facility using the provider-to-population ratio taking into account the government policy of 2 clinicians and a nurse for every 1000 population.

4.2 Gravity model of migration

The gravity model, as social scientists refer to the modified law of gravitation, takes into account the population size of two places and their distance. Since larger places attract people, ideas, and commodities more than smaller places and places closer together have a greater attraction, the gravity model incorporates these two features. The relative strength of a bond between two places is determined by multiplying the population of city A by the population of city B and then dividing the product by the square of the distance between the two cities as illustrated below:

$$\frac{\text{population}_1 \text{ x population}_2}{\text{distance}^2}$$

Generated from the GIS prototype, Figure 3 shows distances between different facilities within Blantyre. Applying the "how far is it?" feature from GIS software and facility population data to determine the gravitational attraction between two facilities in Blantyre and of course in Malawi, decision makers can determine where to place health professionals to supplement nearby health facilities. After calculating distance between facilities with GIS and using 2011 catchment population data the researchers were able to determine gravitational attraction between facilities. Opponents of the gravity model explain that it cannot be confirmed scientifically, that it is only based on observation. They also state that the gravity model is an unfair method of predicting movement because it is biased toward historic ties and toward the largest population centers.

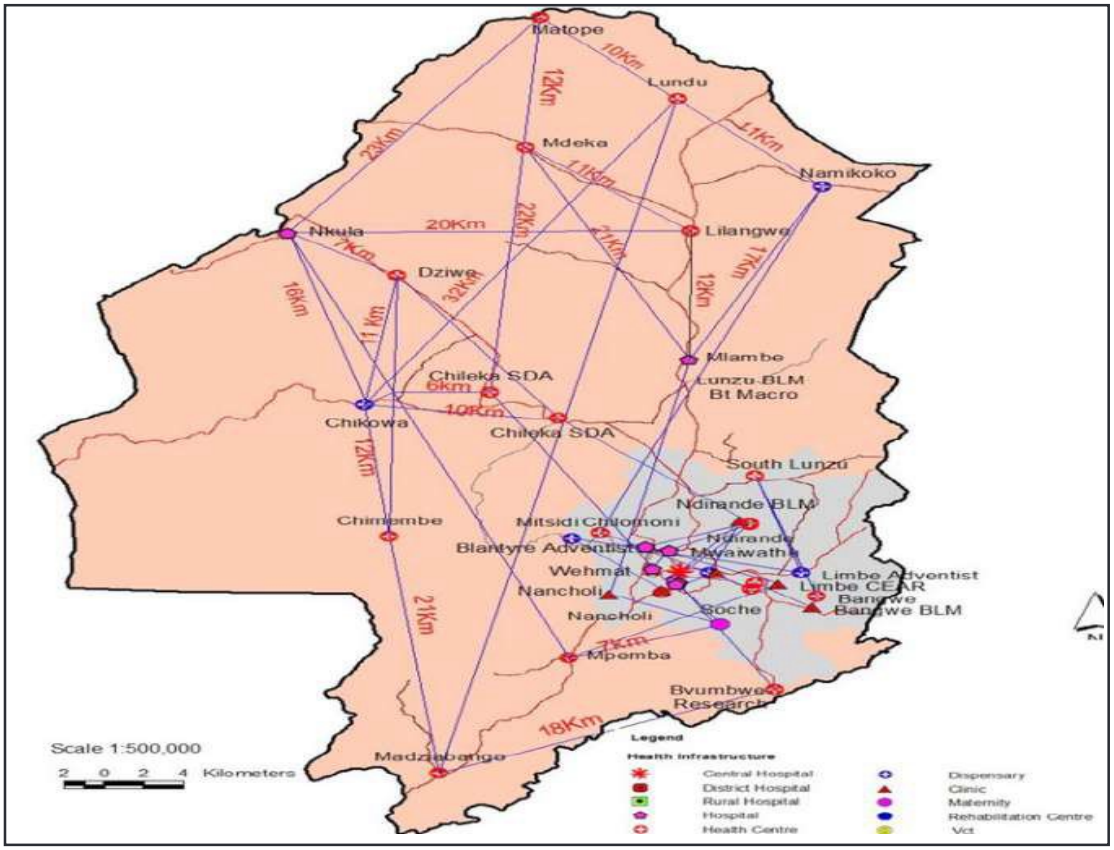

Figure 3: Distance between health facilities

5.0 Application of GIS

Using GIS software in the mapping as explained above, research brought to light geographic distribution of population and the distribution of health facilities in Blantyre health district. After analysing population distribution from the map, it was found out that people are more concentrated in urban than in rural areas. Mapping health facilities and employing the 5 km radius for each health facility that it is supposed to serve, research discovered that Blantyre urban is well covered up with healthcare than Blantyre rural (see Figure 4).

The research recognised that services offered by medical, nursing, and allied health professions play a very important role for the well-being of the community especially in developing countries like Malawi. It also recognised that the availability and ability of a population to obtain a specified set of healthcare services is an important factor for a health system and has a direct impact on the population's health.

The research looked at spatial or physical accessibility, concentrating on the complex relationship between the spatial separation of the population and the supply of healthcare

facilities which has a strong underlying geographic component – geographic accessibility. GIS was applied to analyse geographic distribution of health facilities, services and allocation of health professionals to see spatial separation of population and supply of healthcare facilities. The research findings show that there is low ratio of health professionals to population contrary to WHO requirement of 2:1000.

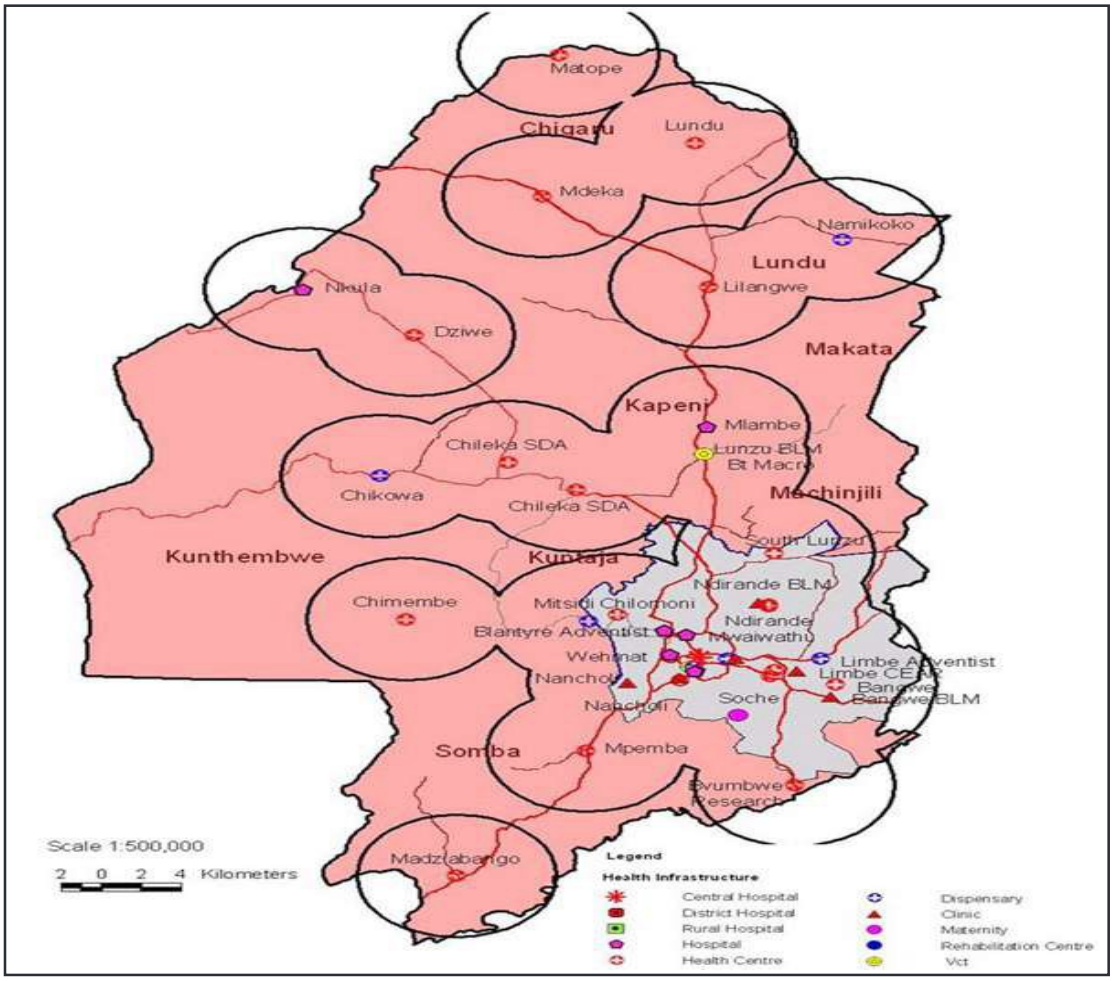

Figure 4a: 5km Radius of Health Facilities in Blantyre Rural

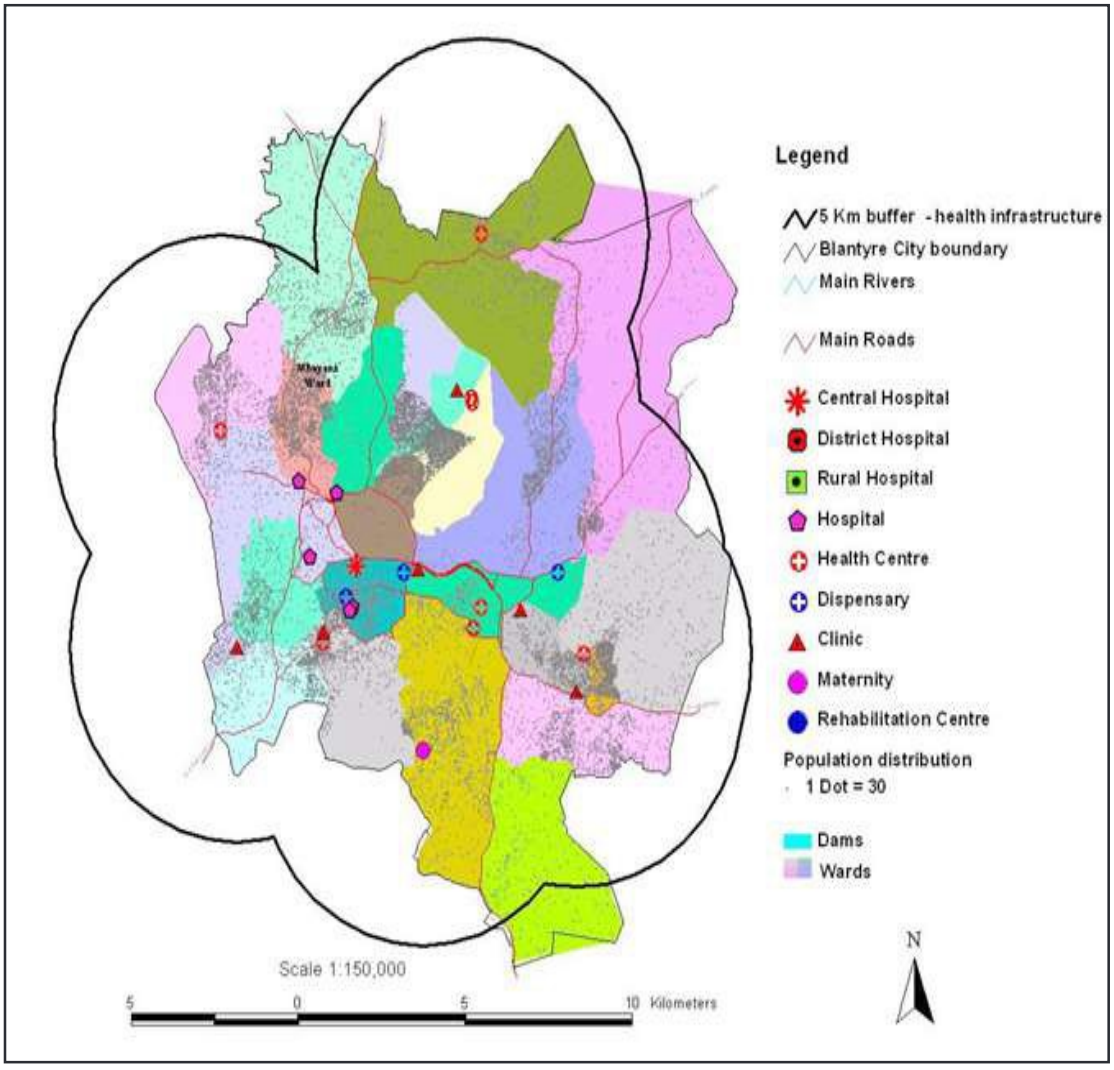

Figure 4b: 5km Radius of Health Facilities in Blantyre

Research findings show that there is the shortage of human resource for health in Blantyre. It was therefore imperative to look into the equitable allocation of health professionals and services into various health facilities and find out if the allocation does take care of the spatial separation of population and number and type of cases referred at the health facility.

The research has explored the application of GIS in analysing the geographical allocation of health professionals and looked at how best GIS as a tool can help health management when making decisions of equitably distributing scarce health professionals into various health facilities in Malawi. Preliminary investigations also indicated that there is inadequate reporting system which slows down health human resource distribution. Concerning this, one of the officers at Blantyre DHO had this to say; "When it comes

to displaying data, we normally use MS Excel. We have GIS software installed in our computers but we don't know how to use it. …you can teach us. …we should easily map health areas, compare the performance of each, and determine if any geographic patterns exist, which is very difficult and time consuming in Excel."

This implies that GIS is well suited to measuring spatial accessibility and can help enrich information which could be used to know how resources, like health personnel, are distributed for maximum utilization. Viewing data in Excel require a health program manager to spend significant amount of time and energy to understand the health service coverage and geographic distribution of services. It has been found that with GIS, managers can easily evaluate both the performance and distribution services through a map. The use of spreadsheet programs for viewing extensive tabular data can make it difficult both to analyse data and to draw valid conclusions.

GIS has got mapping and visualisation tools to communicate the results of analysis. Using GIS, therefore, it was very easy to know where an event had happened because of the geographic coordinates that it uses in relation to spatial and non-spatial data. It can be used to get ground measurement of the geo-referenced objects like health centres, analyse geographical location of the health facilities and enrich the information by displaying it in the form of maps, graphs, charts, and tables for important decision making. It was demonstrated that GIS can easily show how a health service facility relates to the population.

Using GIS therefore helped the researchers to explore, analyse and report the geographical allocation and distribution of health professionals in the health facilities and determine population's accessibility to healthcare which could help decision makers when making decisions of equitably distributing health professionals.

With the capabilities of GIS as explained above, the researchers believe that the results from the research would help the government of Malawi in general and Ministry of Health in particular to make better decisions when it comes to planning the deployment of professionals in to health facilities in a district. The researchers recognised that measuring access to healthcare facilities is very important as it widens understanding of health system's performance and facilitates the development of evidence-based health policies. It is very important that health programs are tailored to the specific needs and unique characteristics of a community or a facility. For example: What is the distribution of those living in the community? What percentage of the population is underserved? GIS allows you to organize and analyze such data geographically. GIS is therefore a very powerful tool when designing health programs and assessing health needs.

6.0 Conclusion

GIS can be an essential tool to understand what is going on. Health managers can use GIS information products which provide a visual framework for conceptualizing, understanding, and prescribing action. GIS is increasingly being implemented as enterprise information systems which go far beyond simply spatially enabling business tables in a database management system. Geography is emerging as a new way to organize and manage organizations. GIS is transforming the way that organizations manage their assets, serve their customers/citizens, make decisions and communicate. In government and many large corporations, GIS can provide a broader context for assets and resource management.

In line with national strategies regarding the development of using Information Technology (IT) in the country, there is a good view for using GIS. Now, most health departments and health organisations have established their ICT departments and are trying to acquire new technology in information infrastructure. It is recommended that this development needs to consider the introduction and application of GIS in these organizations.

It is also recommended that activities have to be done to familiarize managers and decision makers with GIS benefits and improve the level of using it in different aspects of management. With these actions, most organizations, especially organizations related to resource allocation planning and management will identify the vital role of GIS in resource distribution. Much attention should also be paid in the use of GIS in different activities. One of the important actions in this program should be preparing strategies that must dictate the next action of the country for developing spatial data usage.

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