PROJECT ZIMBABWE

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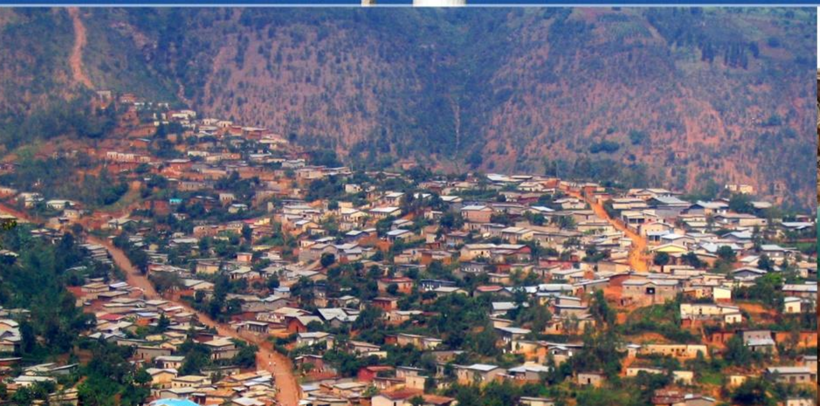


Table of Contents

1.0 Introduction

The lack of access to healthcare in Zimbabwe can be detrimental for maternal women as they require constant checkups to ensure the health of their child. The sparsity of nearby healthcare facilities was found be a factor in rural Zimbabwe that has caused neonatal and child mortality rates to result in 83 deaths per 1,000 live births (UNICEF 2015). In sub-Saharan Africa alone maternal mortality is 12 times higher than in many developing countries (Makate & Makate, n.d.). There is an urgent need to develop interventions to improve the services of obstetric complications. GIS applications can assist in the reducing the maternal mortality rates by increasing the accessibility to healthcare facilities (Wilkinson, D., & Tanser, F., 1999). GIS can identify areas requiring increased attention and help in finding the ideal location for construction of a new healthcare facilities using different Geographic Information Systems (GIS)-based measures. The proximity to the health facilities are likely to promote adherence to maternal care and the better maternal outcomes for the pregnant women.

In this project the in ideal location for the construction of a new healthcare facility will be found in southwest Harare, Zimbabwe. This will be done using GIS applications and GIS-based measures. Factors that will be included: existing road networks, proximity to existing infrastructure, and elevation. Analysis will be done on these factors and resulting spatial outputs will be constructed. This project may not represent the true optimal locations as it is based on only a couple factors, but it is useable to assist in future research to identify key locations. Because of this project it was found that the ideal location would in a region southwest of Turf Town, near the center of the study area.

The most important implication of this study is to be the stepping stone in the further research of this area. This increased attention to issues in global health will optimally increase the support in underrepresented regions such as rural Zimbabwe. In turn this study will help reduce maternal and infant mortality rates.

2.0 Background Information

Zimbabwe is a landlocked country located in southern Africa, between the Zambezi and Limpopo Rivers. It is bordered by South Africa to the south, Botswana to the west and southwest, Zambia to the northwest, and Mozambique to the east and northeast. The area is also known as Sub-Saharan Africa where mobility is severely constrained by lack of transport infrastructure (D.F.Bryceson, T.C.Mbara, D. Maunder; 2002).Through the data posted by

World Bank in 2016, the country has an estimated population of 15.6 million (15,602751) in 2015, of which approximately 50% live in urban or suburban areas. The total GDP in 2015(nominal) of the country is 14.419 billion US dollars and 814.56 US dollar per capita. Moreover, it is a country with very low HDI which is only ranked 154th in the world.

2.1 Zimbabwe Health Care Situation

Per the paper written by Neil Thomson, emergency medical services in Zimbabwe are of a very variable standard, and exist in many forms:

- Reasonably well-developed urban emergency medical services systems mixed with very poorly resourced and under-developed rural services.
- Very high patient workloads, with severely ill medical patients and a large proportion of major trauma and multiple-casualty situations (public safety is given a low priority, and public transport is poorly regulated).
- Long emergency response times and patient transport distances.
- Somewhat under resourced and underdeveloped emergency departments, with large numbers of critically ill acute patients, as well as many non-emergency/chronic patients who have no other access to appropriate health care.

The World Health Organization estimates its life expectancy at birth at 37.9 years in 2005; the child mortality rate (probability of dying under 5 years of age, per 1000) is 111. The very high prevalence of HIV is the most likely cause of this (Neil Thomson, 2005). The number of maternal mortality has increased from 555 to 960 per 100,000 live births from 2006 to 2011 (Crofts, J. F., Mukuli & Wilcox, H., 2015). The national review of maternal deaths mention that 82% of those women who died of pregnancy-related complication. They also claim that there were 47% of maternal deaths could be avoidable if those pregnant women receive good maternal health service in time. Although health care in Zimbabwe, once considered to be good, has been in a steady decline, with deteriorating facilities, increasing demand on resources and the high cost of disposable and capital equipment contributing to this. Despite national policies of ‘health for all by the year 2000’ in the 1980s, health care for the public has become substandard and unaffordable (Neil Thomson, 2005). Since travel time to health facilities is a known determinant of both access to maternal care and better maternal outcomes. If a pregnant woman receives regular antenatal care in time in the period of pregnancy, the problem of maternal complication will be detected and cured easier. Therefore, the potential locations of maternal health facilities for those women of childbearing age become a determining factor.

Overall, the problem of maternal mortality rates have not improved significantly within sub-Saharan Africa especially in Zimbabwe and the situation even get worse for some reasons such as deteriorating facilities and increasing demand on resources. Maternal Mortality Rate in Zimbabwe have declined drastically in the rest of the world within the past decades following actions from the Millennium Development Goals (MDG) and Sustainable Development Goals (SDG) acted by the United Nations (Ng'anjo Phiri et al., 2014). As a consequence, this project is trying to establish a database in order to alleviates the seriousness of the problem.

2.2 Current Data on Zimbabwe

There is not much in available data for Zimbabwe. There is limited road network data only provided by OpenStreetMaps which is present inconsistencies. There are also locations of healthcare facilities as well as a DEM data. The creation and growth of OSM has been motivated by restrictions on use or availability of map information across much of the world, and the advent of inexpensive portable satellite navigation devices. OSM is considered a prominent example of VGI.

Other scientific information are referenced by several journal articles on the health care situation in Zimbabwe and Sub-Saharan Africa, and the latest research result of how to solve the problem by using Geographic Information Science.

3.0 Objectives

The object of our project is to create a geodatabase for the spatial modeling, and finally potential investigate the optimal locations of health facilities in Zimbabwe, to mitigate the maternal mortality problems in the country (particularly the study region). This is planning to be done in 3 parts:

1. The creation of geodatabase
2. Spatial analysis the road network data
3. Comparative analysis between the optimal locations and the current locations of health facilities.

Through the establishment of geodatabase, the platform for analysis can be created. The digitalization of road networks and the classification of the road networks will be implemented in the Open Street Map system. After that, road network analysis and other Geographic Information analysis such DEM and service areas will be done in ArcGIS and IDRISI Terrset. With an adequately completed geodatabase spatial analysis and multi-criteria evaluations can be done to determine the ideal locations for new health facilities. Moreover, with the completion of this data, a comparative analysis can be done to understand where the current health facilities are providing inadequate coverage, and where they should be ideally located instead. The result will help the improvement of regular or emergency maternal care and gain better maternal outcomes in the country (particularly in the study region).

The study area is located between Highway NO.5, Highway No.4 and Highway No.17 and is bordered by the city of Harare to the North, the city of Kadoma to the West and the city of Gweru to the South. The extent map of the study area can be seen in figure 1.

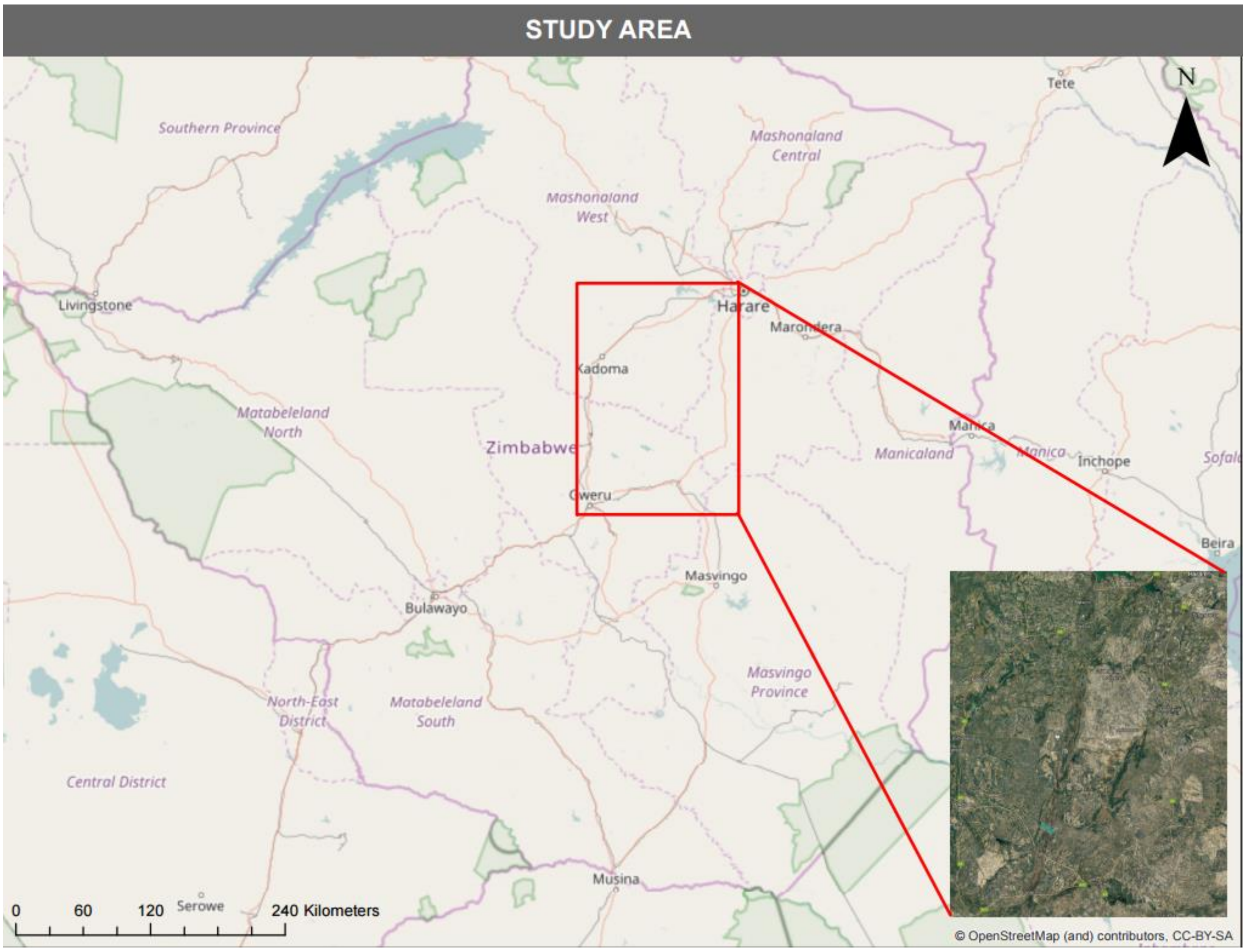

Figure 1. Study area of southwest Harare, Zimbabwe

4.0 Literature Review

The study of medical science and health research and the study of geography are two subjects that are both closely intertwined with each other and, there are many areas in which they can mutually benefit each other. Geography, especially in the areas of mapping and geographic information has proven to be crucial in the research of diseases, the ways in which they spread and the health of individuals across space and time (Srinath 2013). The research done by the Physician John Snow in 1854 is one of the most famous examples in which geography was used to locate the origin of the cholera epidemic that broke out in London. (Mcleod 2000) More recent advances in technology has led to the rise of Geographic Information Systems(GIS) and as well as Geographic Information Sciences(GISci) which have both proven to be highly applicable to many different facets of health research. The use of GIS in the planning of healthcare facilities and services is one that has become much more prevalent within the recent decades due to the decreased cost of such software as well as the increased capabilities of GIS. A GIS as a tool can allow for researchers to aggregate different layers of information into one system to figure out the relationships between multiple factors that might affect the provision and access of healthcare (Fradelos 2014).

While GIS is a very comprehensive tool that can allow for the organization and management of various spatial and non-spatial data, when it comes to utilizing this technology there is one major obstacle and that is the ability to access the appropriate levels of data. National maternal mortality rate (MMR) as a statistic has been used by some governments within their planning policy, however this aggregate approach to MMR effectively hides the growing disparities at local and regional scales between the urban and rural communities (Atuoye et al., 2015). High resolution road network data is crucial in the mapping of accessibility especially when looking at the local and regional scale as roads are the main avenues of transport that individuals will be travelling along. While such data might be readily available in some higher income countries, this is usually not the case for many developing countries across the world where there is a lack of data in this field (Jha, M. K. 2007). In a developed nation, the mapping of road networks is also a much simpler task as roads are well defined as they are generally paved in one way or another. However, in developing nations, the term “roads” might hold very different connotations depending on where its located. Within the urban core you might define roads as areas of concrete that one can travel along, but within rural communities, roads might simply be patches of dirt connecting one location to another (Schürenberg-Frosch, 2014). Transportation barriers also negatively affect referrals, which has been outlined as crucial for emergency healthcare delivery (Atuoye et al., 2015). Referrals are defined as a request for a patient to seek out health services made by an Healthcare professional and in maternal health care it has been found to reduce stillbirth by 27%, neonatal deaths by 18% and maternal deaths by 50% (Pattinson 2011). One major factor in influencing referrals depends on geographic factors. Distance from facilities is the main deterrent in causing many referrals to be rejected since healthcare facilities cannot uphold them as they simply do not have the financial capability to transport women in pregnancy across long distances (Atuoye et al., 2015). It has been found in some cases 70% of referrals cannot be upheld with the main factor being attributed to high transportation costs (Atuoye et al., 2015). Typical transportation within Sub-Saharan Africa for rural communities can be broken down into three main categories, by bicycle, foot or to wait for the "market day truck" (Atuoye et al., 2015). The first method, while incapable of transporting women in maternity, is used frequently when travelling to and from clinics for other medical needs. Walking being often the other alternative is especially difficult for women in maternity, and when the travel distance is upwards to 10km it is not feasible for them to be carried that far. Relying on the market day truck also fails to address the issue as in Ghana such trucks might come only once every five days and cannot be relied on in case of medical emergencies (Atuoye et al., 2015). Ways in which distances to medical facilities can be reduced will be imperative; along with the management of an efficient transportation system.

It is important to note however, is that the use of GIS as an assessment approach can tend to simply reveal the need within a region and not the fundamental problem (Foley, 2002). While GIS analysis can determine the location of least access it cannot however, be solely used to determine the reason of why said area has so little access. What is revealed by a GIS through its map output is strictly bound by its data inputs therefore further study into the context of the situation and phenomena is required to truly delve into further societal issues.

4.1 Uses of VGI for Scientific Research

Volunteer Geographic Information (VGI) is a term coined by Goodchild (2007) and he argues that VGI is increasingly playing a role in geographic information for geographers. One such platform for VGI is Open Street Maps (OSM). is an online geospatial database that is freely available for use by anyone with a internet connection. OSM first began in 2004 as a way for individuals to gather and share their geospatial information and to upload it onto a shared database that is openly available. Much like how Wikipedia operates, OSM simply requires the user to register an account before they can begin uploading and editing data within the database. Therefore, the question of how useful such a database can be must be asked. Wikipedia as a source of information within the academic sphere is one that is commonly frowned upon as it is not considered a credible source even by the website itself (Wikipedia 2017). The freedom for anyone to edit the information within Wikipedia results in many cases where misinformation is spread. OSM and volunteer geographic information are areas that have been put under heavy scrutiny by researchers and many research works have been done in analyzing the quality of such datasets (Forghani 2014). Foody (2015) argues that VGI is fundamentally flawed due to the nature of how it is created. The lack of a standard classification within VGI between different users as well as the lack of any means of distinguishing between contributors results in a dataset that is incredibly difficult to discern the validity of the information (Foody 2015). Studies into the quality of OSM data has been carried out in several different countries including the UK, Ireland, Germany and France (Forghani 2015) and the conclusion of these research articles reveal that it is extremely difficult to say with certainty that OSM data is accurate enough for all research purposes. To judge the validity of OSM data for a project the use and application of the data must be considered (Foody 2015).

5.0 Methods

The determination of the suitable area for the installation of a new health facility was found using distance and elevation maps, literature reviews, and qualitative methods. The study area was determined due to the lack of spatial representation in that area.

5.1 Data Collection and Digitization

Manual digitalization of the road network was done using OpenStreetMaps API (OSM). Road classifications were based on the operator discretion and the relative classifications of already digitized nearby roads. Roads were classified to either: Minor/unclassified road, unmaintained track road, or path.

The data was collected using OpenStreetMaps API (OSM). The OSM data was pulled on March 26th, 2017 using QGIS software. Polygon and point data were filtered to only show pharmacies, clinics, and hospitals. Polygon data were then converted to point data to allow for consistent symbology. Road network data was filtered to remove errors and N/A entries.

Road map data was then run on ArcGIS and processing tools to reconnect nodes to the road were done. All point data of hospitals, clinics, and pharmacies were categorized as health facilities.

5.2 Suitability map

There are four data suitable to use in our suitability map. It is based on electrical lines, roads, elevation and existing health facilities. The DEM data we have used is Zimbabwe SRTM 30 Meters (DEM elevation .tif) from RCMRD GEOPORTAL. The main purpose of the Shuttle Radar Topography Mission(SRTM) 30 meters' resolution DEM is one of the factors to create a suitability map to define which places is the most suitable to build new health facilities based on Multi Criteria Evaluation(MCE).

5.2.1 Pre - processing in ArcMap

Add all the data into ArcMap. Set the environment as same as the Road Data to clip the study area. We used "Euclidean Distance" the spatial analysis tool to find the distance to roads, health facilities and electrical lines using the cell size of 0.005. Then use ArcMap conversion tool "From Raster to ASCII" to convert all Raster map to ASCII. Then we converted all shapefiles into raster files using cell size of 0.005.

5.2.2 Data Analysis in IDRISI

First, import DEM .tif file to Terraset as a Raster map. Import the all ASCII by using Terraset. For roads, electrical lines and health facilities data, import them(.shp) by using "SHAPEIDR" function. Import DEM by using "ArcRaster", select ArcInfo raster ASCII format to Idrisi. After that, Spatial Decision Modeler as seen in figure 2 was used S to establish the MCE Model.

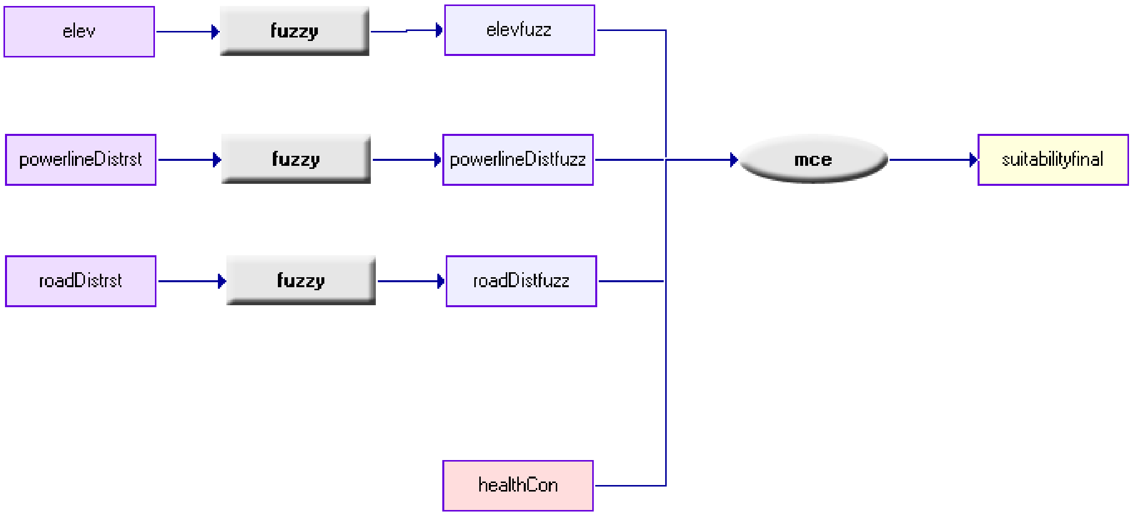

Figure 2. The spatial decision model used to determine the factors for the suitability map

Then the criteria were determined. Major Roads, electrical lines, elevation are factors and healthcare facilities is the constraint, it is because it cannot be built within 2.5 km of an existing health facilities. Vancouver as an example, approximately 2.2 km from one to another (takes 27-30mins to walk) Zimbabwe, it was chosen to use 2.5km as well. Then the factor scores were standardized and set the suitability values of the factors to a common scale to make comparisons possible. Fuzzy membership functions were used to standardize the criterion scores. Following the weights of each factor was determined by using Pairwise comparison, Analytical Hierarchy Process (AHP) the results can be seen in table 1.

Necessary

1. Compare the factors

2. Fill in the matrix

3. Normalization & weight determination

4. Check the Consistency Ratio

The Weighted Linear Combination was used aggregate the criteria and get the result on the map.

Table 1. Pairwise Matrix

	elefuzz	powerline Dist fuzz	road Dist fuzz	Eigenvector Weights
elefuzz	1	2	2	0.1985
powerline Dist fuzz	2	1	1.5	0.3469
road Dist fuzz	2	1.5	1	0.4546

Consistency ratio = 0.02

Consistency is acceptable.

5.3 Distance map

The distance to nearest health facility map was done using the data collected. This includes the road network data pulled from OSM and the point data of health facilities. The network analysis was done in ArcGIS and used the service area tool. The service distances used were: 10km, 25km, 50km, 75km, 100km. The distances were determined using a literature review on the average walking distances of facilities in rural Zimbabwe and the use of Google maps (Mehretu & Mutambirwa, 1992). 10km was the maximum walkable distance. 25km was the distance immediate drivable service distance. 50km was the moderate drivable service distance. 75km was the further drivable service distance. 100km was the boundary limit in which it would surpass an approximated 1 hour travel time by car under optimal conditions.

The resulting layers were then run through the process of “Erase (Analysis) Tool” to prevent overlapping of layers and the distortion of colors. The map was color coded accordingly and shows the service regions of the health facilities in southwest Harare.

6.0 Results

6.1 Suitability map

The suitability map made up the 3 factors as seen in figure 3,4, and 5. The resultant suitability map (figure 6) is using continuous data which assigned a suitability value per class using a scale of 0 to 1 (0 = least suitable, 1 = most suitable).
It is intended to assist in finding the optimal location for new Healthcare facilities in rural Zimbabwe.

The suitability map clearly displayed where it is possible to build new healthcare facilities in southwest Harare. In the city of Harare, it is not a good place to build a new health facility based on the factor we calculated due to there was a lot of existing healthcare facilities located in that area. The southeast of Turf Town is not a suitable place to build a new health facility due to lack of electrical lines and roads.

Per the suitability map, the range of Turf Town within 25km -50km diameter would be the most optimal areas to build new healthcare facilities.

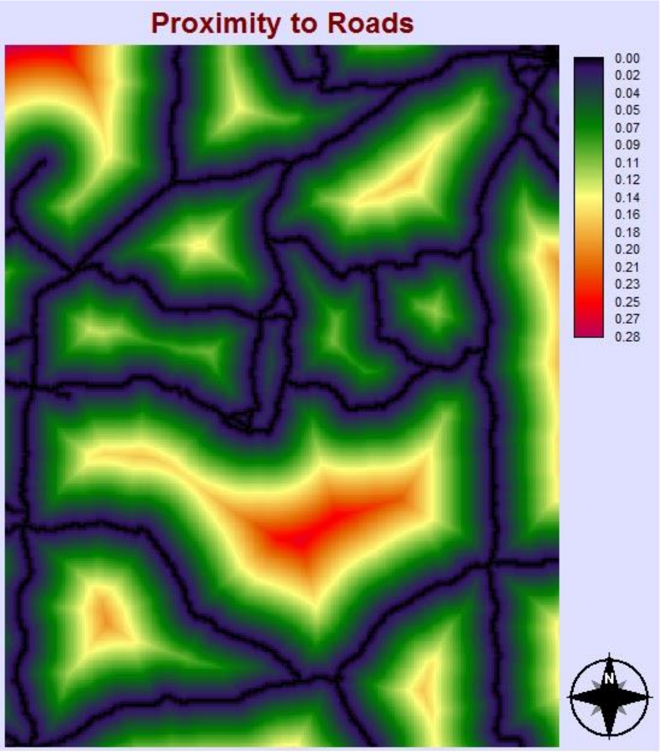

Figure 3. The proximity to roads based on Euclidean Distance

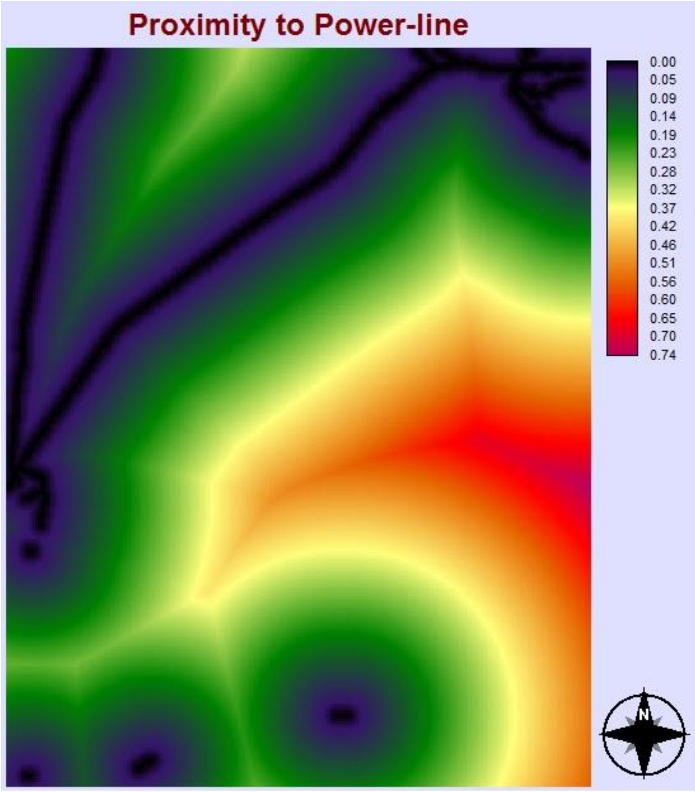

Figure 4. The proximity to electrical lines based on Euclidean Distance

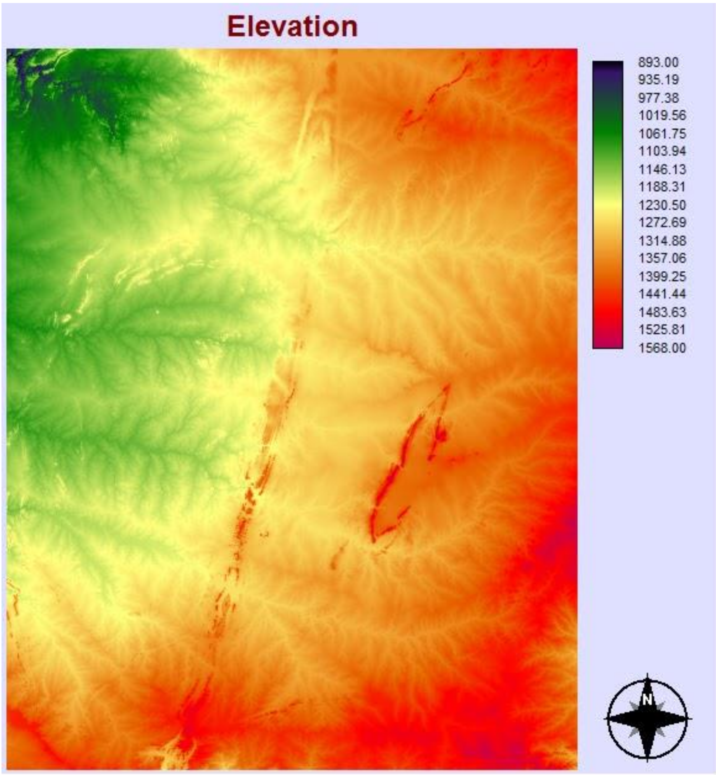

Figure 5. Elevation of the study area

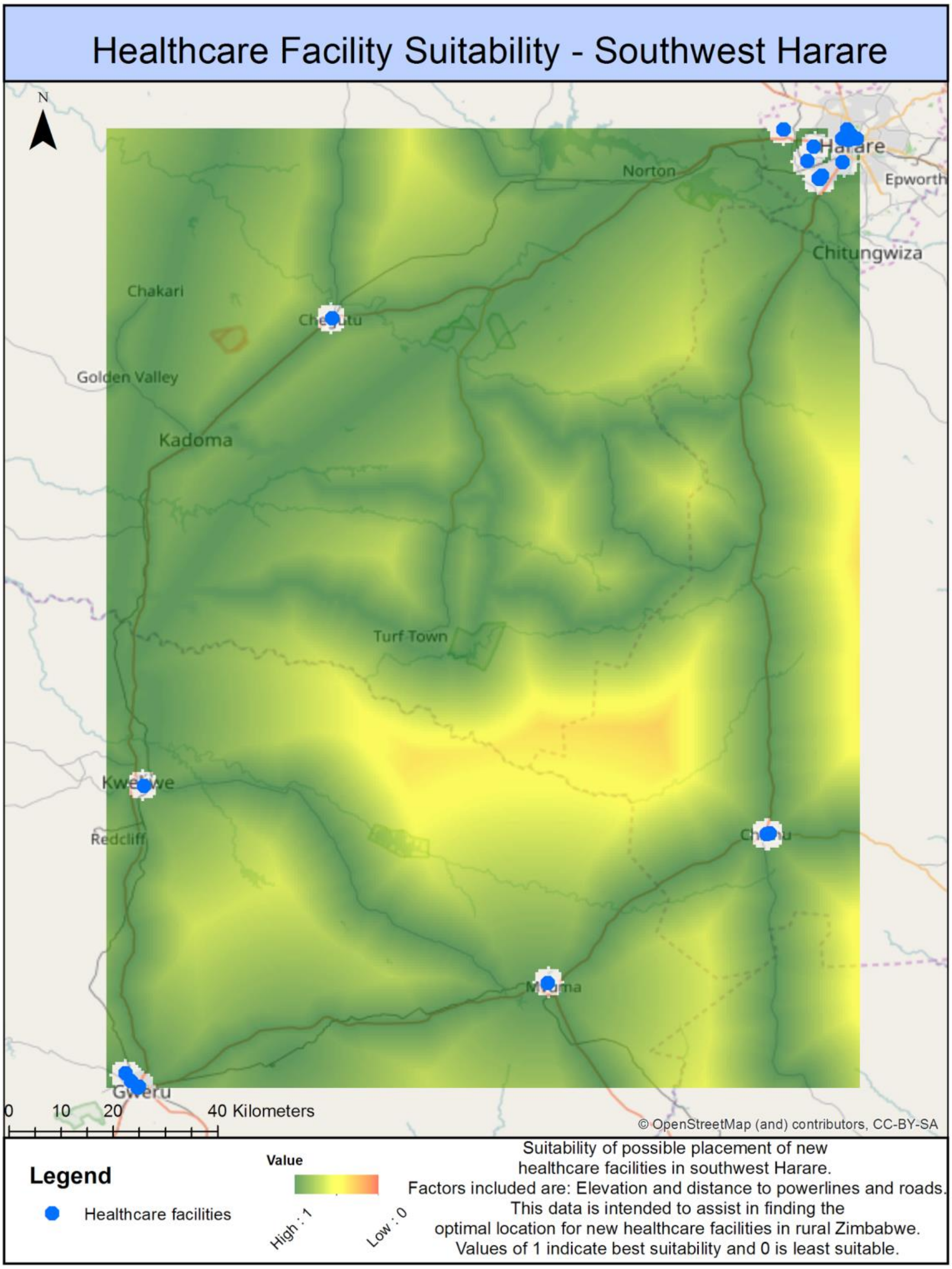

Figure 6. Suitability map of the optimal locations for new healthcare facility construction

6.2 Road Network Map

The distance to the nearest health facility map provided clear indications of the service area southwest of Harare. It was evident that Harare being the capital city of Zimbabwe had the most health facilities in the region. 20 out of the 27 health facilities were located in the city of Harare. The remaining 7 health facilities were in other nearby urban centers. It was found that every single facility was situated along a major road network or highway. The area with no direct highway access fell outside the 50-km moderate service area. The highway was the clear conduit between each city and the skewness of the 50km service areas shows this.

The area near Turf Town in the center of the study area as seen in figure 7 was the primary region furthest from any healthcare facilities. Most of that region fell in the 100km service area in which it would take more than 1 hour travel time to reach the nearest healthcare facility. The new healthcare facility would need to be built to service the areas that are within the 100-km areas this is where there is the least amount of accessibility for rural families. There were holes in the study area in which no road network data was collected or represented errors in the building of the road network. Thus, these areas were left blank and not analyzed.

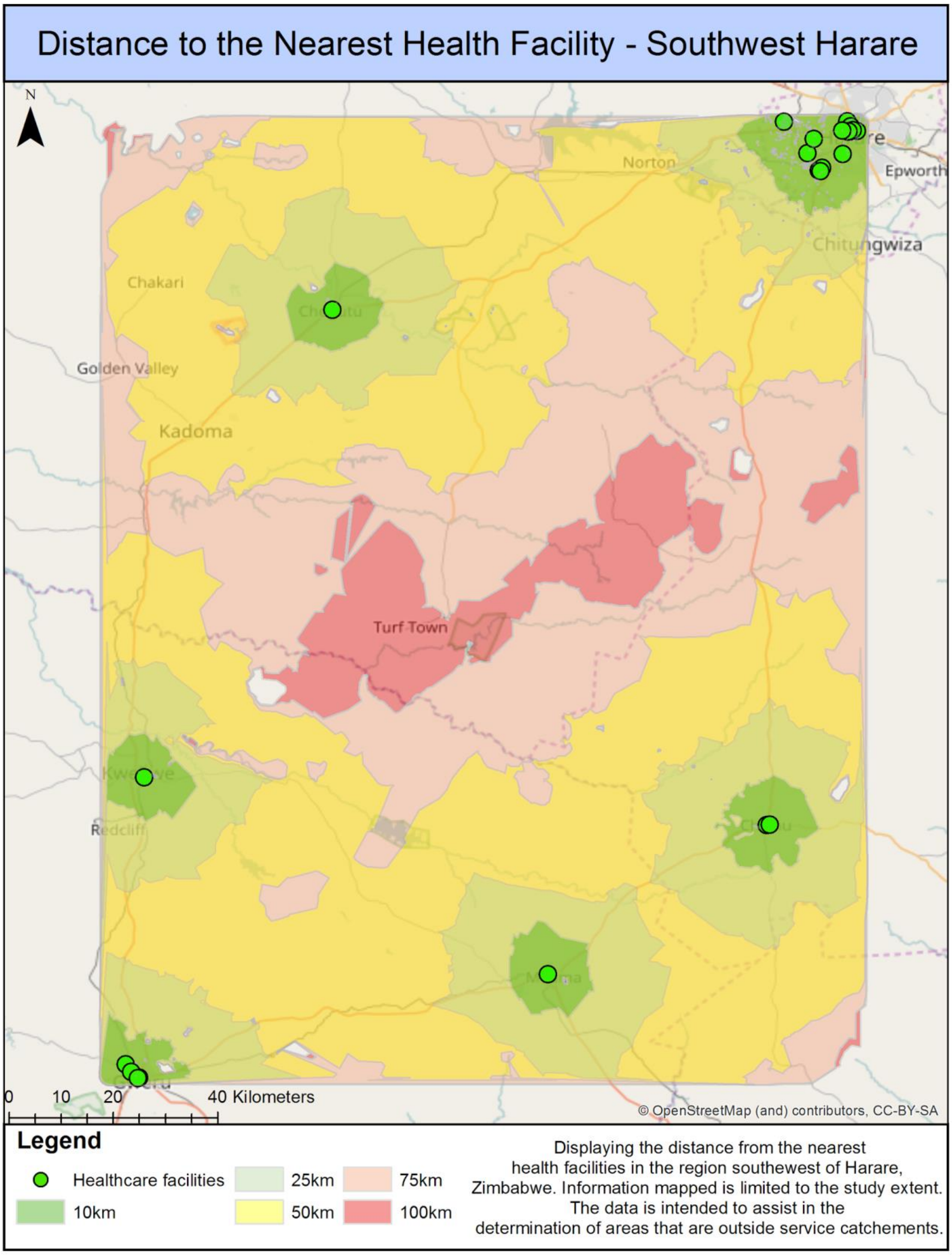

Figure 7. Road network map indicating the distances from the nearest healthcare facility in southwest Harare.

7.0 Discussion

Based on the two points of data, distance and elevation provided by the maps, ideal placement locations for new healthcare facilities were evident. The elevation suitability map indicated that the further west of the study area the better suitable the land elevation becomes. While the combination of the DEM and proximity to existing infrastructure indicated that west is indeed the most suitable.

When looking at the service areas of the current healthcare facilities it was clear that the center had the least service. Specifically, the least serviced area was near Turf Town and northeast of there; they were more than 100 km from a healthcare facility. Through this understanding it was found that the ideal location would in a region southwest of Turf Town, where elevation is the most suitable but is still in a region 100 km from a healthcare facility. This combination of parameters would allow the ease of construction due to the lower elevation, but that the same time be in an effective position to better service the region.

However, the exact ideal location is yet to be accurately determined as this result only considers road distances, infrastructure distances and elevation. This leaves room uncertainty to the accuracy of the results, and as such would require more factors to be considered to make responsible decisions. Further research on this topic could include investigating the population densities of the region. By incorporating population density, finding the ideal location based on how many will be serviced can be determined. Apart from this research into the different modes of transportation and speed analysis could be done. This will increase the precision and accuracy of the distance map as well as the ability to create a friction map. Lastly, further digitization of road network data would be beneficial to the overall future projects as the main component of this project is the road network data.

There are several limitations within this study that directly hampered the assessment of Zimbabwe's Healthcare accessibility. Firstly, due to time constraints coupled with the overall lack of accessible data for the country of Zimbabwe, it was not possible to create a comprehensive outlook of Zimbabwe's healthcare situation. Having to rely on the manual digitization of road networks greatly increased the time needed to create an extensive road network for analytical purposes. Several problems also arose when this data was exported into ArcGIS from within OpenStreetMaps. To properly run the "Network Analysis" tool within ArcMap, the road network it was required for the road network data to have true connections at every road junction, however it was found to be not the case in the exported data. Thus, an additional step of processing was required to fix this issue but through this process the attribute data associated with each road polyline was lost. This did not raise any issues with the creation of a distance map but when it came to doing further analysis with various velocities and road conditions would require manually adding attribute data back to each individual line segment.

Secondly, to create a Multi-Criteria Evaluation suitability map for a new healthcare facility, thorough datasets on infrastructure and population data is required. However, the only information that could be obtained for our study area was the extent of the power grid along with the OSM digitized road network. Optimally, a client database that has the locational data of families within the region would be needed to find the prime location in which a facility should be built. Furthermore, aside from electricity infrastructure, data for Zimbabwe's water supply and sanitation are also crucial in the construction of a healthcare facility but this data was not openly available.

7.1 Future Research

The analysis presented in this project provides an overview of the current distribution of healthcare within our selected study area and it could reveal major rural areas in which healthcare was inaccessible. However, there is much more work that can be done to improve upon our study. This study only encompasses a small region of the rural landscape in Zimbabwe therefore through simply enlarging the study area a more comprehensive look at healthcare inaccessibility can be created. Furthermore, assessment and validation of the OSM data used as well as the data created would greatly improve the accuracy of future analysis. This would require collaboration with groups working within Zimbabwe and if possible, the use of GPS trackers as a method of mapping out rural roads instead of manually digitizing them.

8.0 Conclusions

While the maternal mortality rates have decreased over the past decade across the globe they have not improved significantly within sub-Saharan Africa (Phiri et al., 2014). The infant mortality rate in Zimbabwe alone is nearly 1.18 times that of other sub-Saharan countries (UNICEF 2015). This increased mortality rate increases the need to for adequate access to medical facilities for maternal women and neonatal care. Using spatial analytical methods and OSM data possible locations for new healthcare facilities were determined for southwest of Harare. DEM and distance analysis gave indications to the region most suitable for construction. The DEM model informed on the low-lying areas in which construction would be best suited. The distance analysis gave information on the service areas of the current health facilities and the areas that lacked adequate service. The distance analysis also provided insight on the distance from roads and powerlines, which would also assist in reducing construction costs. From these the best suited location for construction would be in a region west to southwest of Turf Town, as it is low-lying and not within the moderate catchment area of any healthcare facility.

However, this result may not be the true ideal location as lack of data proved to cause issues with uncertainty. Apart from this the incorporation of only 3 influences: Elevation, existing road network, and infrastructure distance. These may not explain all the factors that would result in the most optimal location. Future research should be done to incorporate more factors as well as increasing the accuracy and amount of data available.

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