

SELECTING SUITABLE SITE FOR CONSTRUCTION A WATER RESERVOIR FOR IRRIGATION IN KASUNGU DISTRICT USING GIS MODEL BUILDER

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July, 2021

DECLARATION

I TAMANI MAKAWA declare that this research project represents my own work and that it has never been submitted to this institution or any other institution for any academic purpose. All source of information has been appropriately acknowledged.

Signature……..T.Makawa

20 JULY 2021

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ABSTRACT

Farming is one of activity happen in Kasungu district and most crop grown in this area including tobacco, Chitete, Kamwana, Mangazi and Nkhulande area the villages where I was study in order to selecting a suitable area for constructing suitable site for water reservoir. Water problem in Kasungu is one of the problems the farmer faces since Kasungu district depend on farming like tobacco. Just because tobacco required a lot of water starting from nursery up to the time when will be transplanted therefore Kasungu district does not have enough water for the farmer to irrigate their crops. The main objective of the study was to selecting suitable site for constructing a irrigation dam using geographic information system (GIS) and remote sensing as well as spatial analysis. After the site has selected and the irrigation dam has constructed it help to solve a lot of problem that the farmer facing due to lack of enough water for their irrigation.

This study involved the use of various datasets both raster and vector data from different sources like download from NASA website. Computer with ArcGis software installed should be needed and some data like digital elevation model (DEM). There are some factors that was consided when choosing a suitable site for constructing a water reservoir like terrain, condition of the soil, land cover, land use, transport condition, river as the source of water.

All the data was collected both qualitative data and all the information will be loaded into the arcgis software in order to analysis the condition of that area in order to come with planning, analysis, data conversion where vector can be converted into raster data.

ACKNOWLEDGEMENTS

Firstly, my heartfelt appreciation goes to my family, starting with my Dad and Mum. Mr and Mrs Makawa for all the financial and material support that they have been providing in my education, you people have done so much in my life and without your support I couldn't have attend tertiary education. May the good Lord give you a long and healthy life as He continues showering you with blessings. Another heartfelt appreciation goes to my beloved sister, Mrs. M. Chadza, the strongest woman I have ever known you are such an inspiration in my life. God bless you.

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TABLE OF CONTENTS

Contents

INTRODUCTION 1
1.1. BACKGROUND 1
1.2. PROBLEM STATEMENT. 2
1.3. MAIN AND SPECIFIC OBJECTIVE 2
1.3.1. MAIN OBJECTIVES 2
1.3.2. SPECIFIC OBJECTIVES 2
1.4 RESEARCH QUESTIONS 3
1.4. SCIENTIFIC SIGNIFICANT 3
1.5. JUSTIFICATION OF THE STUDY 4
2.0 LITERETUTRE REVIEW 5
2.1 Existing situation 5
2.2 LOCATING THE BEST IRRIGATION DAM SITE 6
2.2.1 IN ETHOPIA (JANUARY 2019) 6
2.2.2 IN ISRAEL 8
2.2.3 IN MALAWI WATER BOARD 8
3.0 METHODOLOGY 10
3.1 STUDY AREA DISTRIPTION 10
3.2 Structure of Methods Used. 11
3.2 DATA USED 12
3.3 DESCRIPTIONS OF DATA USED 12
3.4 METHODS 15
3.4.1 CONVERSION OF DATA TO RASTER 15
3.4.1.1 PROXIMITY FROM THE RIVER SIDE 15
3.4.1.2 Proximity to Existing Road 16
3.4.1.3 DEM PROCESSING 18
4.0 WEIGHTING OF FACTORS USING AHP MULTI-CRITERIA DECISION ANALYSIS (MCDA) 20
4.1 DETERMINATION OF THE STRUCTURE OF AHP DECISION MAKING TREE 21
4.2 ASSESSMENT OF RELATIVE IMPOTRANCE OF EACH CRITERA WITH ONE ANOTHER 22
4.4 CALCULATING PRIORITY WEIGHT USING PAIR-WISE COMPARISON 25
NORMALIZATION AND WEIGHT DETERMINATION 26
4.6 ASSESSMENT OF CONSISTANCY 26
4.7 Determination Of Random Consistency Index 27
5.0 DATA RECLASSIFICATION 27
5.RESULTS AND CONCLUSSION 31
5.1 Analysis of the results 31
5.2 Discussion 34
6.0 CONCLUSION AND RECOMMENDATION 35
6.1 Conclusion 35
6.2 Recommendations 36
References 37

1.ACRONYMS/ABBREVIATIONS

2.GIS: GEO-INFORMATION SYSTEM

3.RS: REMOTE SENSING

4.DEM: DIGITAL ELEVETION MODEL

5.MCDA: MULTI-CRITERIA DECISSION ANALYSIS

6.AHP: ANALYTIC HIERARCHY PROCESS

7.WSM: WEIGHTED SUM METHOD

8.LCLU: LAND COVER AND LAND USE

9.ARCGIS: ARCHITECTURE GIS

10.QGIS: QUANTUM GIS

11.WHO: WORLD HEALTH ORGANISATION

LIST OF FIGURES

Figure 1 showing study area location.

Figure 2 showing soil data.

Figure 3 show the data of river before converted into raster.

Figure 4 showing the river after converted into raster.

Figure 5 showing road centerline before converted into raster.

Figure 6 showing proximity to road side after converted into raster.

Figure 7 showing Kasungu Digital Elevation Model.

Figure 8 showing Kasungu raster Elevation Model.

Figure 9 showing AHP structure.

Figure 10 showing Model Builder as method used for selecting suitable site.

Figure 11 showing suitability map.

Figure 12 showing pie-chart for suitability site.

Figure 13 showing a suitability map.

Figure 14 showing demarcated area for highly suitability.

Figure 15 showing demarcated area for suitability sites.

LIST OF TABLES

Table 1 showing data used.

Table 2 showing intensity of importance.

Table 3 showing order of importance.

Table 4 showing pair-wise comparison.

Table 5 showing Normalization and Weighted determinations.

Table 6 showing Random Index Value.

Table 7 show the summary of the selected ranks

INTRODUCTION

Malawi is one of the country in Africa where many people depend on farming like growing of tobacco and vegetables. Farming in Malawi depend on the availability of enough water in order to irrigate their crops and also for domestic purpose like drinking and also using for some industrial use. The aim of this research was to selecting a suitable site for constructing a reservoir using geographical information system model builder in ArcGis where this model can be used in any place here in Malawi if a person input the data for that area which is the conditions for constructing reservoir.

The construction of a reservoir in this country will help to conserve water which help for different purpose around the whole Malawi. Construction of the dam require different technique of GIS and Remote Sensing in order to select the suitable site for constructing a permanent and perfect water reservoir.

1.1. BACKGROUND

This study was conducted in central part of Malawi in Kasungu district where the area is very slope and steepness and most of the time the land become dry. The aim of the research was to selecting the suitable site for constructing reservoir to store water using GIS model builder in ArcGis where Kasungu district is my study area where many people growing tobacco but they don't have enough water for irrigating their crops and even.

Model Builder is a visual programming language for building geoprocessing workflows. Geoprocessing models automate and document your spatial analysis and data management processes. The construction of this model builder required knowledge and data in order to come up with good quality water reservoir where they come up with some condition and factors necessary for the constructing this reservoir using different method of geographical information system model builder using software like ARCGIS.

1.2. PROBLEM STATEMENT.

Construction of the reservoirs for central region Kasungu was an important solution to curbing water problem for both domestic and irrigation purpose but according to my research the main target was irrigation purpose since the people from Kasungu depend on farming and even the whole Malawi will be helped to increase the economy of the Malawi and also well standard of people here in this country due to drought, floods and population growth.

Lack of enough water reservoir in Kasungu district makes a lot of people to suffer since these people they grow tobacco and tobacco require a lot of water starting from nursery up to the field. Even though many Non organization Government come to bring their own project like Iradi where they provide schemes to the people but still it was not enough to provide water to all farmers, some other farmer was difficult to have access to the water. Through this project will help people around Kasungu district to have enough water to irrigate their crops.

The main problem for this constructing a reservoir in this area was the use of effective, inefficient, accurate method of reservoirs site construction selection that will provide accurate terrain investigation and provide adequate information on selecting site for proper planning and design but this has been be solved through application of capabilities of Geographical information system through the use of model builder in order to come up with a good site so that people and even the government can construct a reservoir in order to store and conserve water for different purpose in that particular area.

1.3. MAIN AND SPECIFIC OBJECTIVE

1.3.1. MAIN OBJECTIVES

To investigate the use of geographical information system (GIS) through the process of model builder by the use of ArcGIS software inorder to selecting and locate good site to construct water reservoir in Kasungu district and the whole Malawi.

1.3.2. SPECIFIC OBJECTIVES

A. The specific objective was to determine a selection criterion for reservoirs site selection and establish the specific method used in that particular area

inorder to construct a good water reservoir which help a people around Kasungu and Malawi to use for their farming and domestic use.

B. To perform the analysis using ArcGis in order to come up with good quality water reservoirs in district where the conditions necessary for reservoir construction is available.

1.4 RESEARCH QUESTIONS

In order to achieve the intended objectives, this study attempted to answer the following
questions.

A. How significant is the selecting site for constructing water reservoir to the people of Kasungu and to the national of Malawi?
B. What are some of the factors required for selecting site for constructing water reservoir?
C. When will this project be achieved inorder for the people to use and benefit for them?
D. Why the study of this area important and how the people will be benefit from it?

1.4. SCIENTIFIC SIGNIFICANT

Water is very important all over the world and each and everything need water inorder to survival. Selecting a site for constructing water reservoir was another important method for storing and conserver water where many people use for different purpose. Since many people here in Malawi depend on farming for example tobacco, maize and tomatoes like in rural area will be able to use for irrigation.

Kasungu district is one of the districts here in Malawi where a lot of people growing crops like tobacco. Tobacco is one of the crops which require a lot of water of water starting from the nursery up to the field, but why tobacco require a lot of water.? Many farmers start their preparation during the dry season like September and October where the land has dry so during that time farmer sow the seedling to the nursery and start to irrigate until it germinates. The farmer needs a lot of water during this time. Through the construction of water reservoir will help

both farmer and the government. To have enough water for where they grow their crops and sell them and get money after selling their produce will help to assist their family and also the economics of the country.

1.5. JUSTIFICATION OF THE STUDY

Before selecting a water reservoir location, it is important to consider the watershed properties and land characteristics of the study area. This property was discovered primarily through the use of techniques such as research on a Digital Elevation Model (DEM), which are used by GIS specialists to select reservoir sites using contours and topographical maps.

The watershed analysis and ground characteristics for the area by integrating geographical information system will be intent for the purpose of the research. Suitability map specifying a suitable location for water reservoirs constructing in Kasungu district and also in Malawi will be provide when the project end. This research will benefit the nation because the water crisis will no longer exist, and as a result, more people will be able to practice irrigation farming because water will be available.

2.0 LITERETUTRE REVIEW

2.1 Existing situation

The selecting suitable site for construction water reservoir in Kasungu district benefic a lot of people around in that area and even the whole Malawi. During the process of constructing a reservoir severe factors must be considered before starting the process which include physical characteristic of the site as well as the economic factors. Terrain, land cover and catchment area are the most factors for constructing dam in Kasungu according to water conservation source (2015) here in Malawi.

The use of GIS help to analysis the data through the use arcgis software material.

The situation in Kasungu district is really hard since many people depend for agriculture farming like tobacco. Since Kasungu district has no enough river to use so that people should use for their farming but in the past years many were complaining about lack of enough water to irrigate their crop like tobacco and according to statistic tobacco needs much water starting from nursery up to the time, they transplant it to field. Surface area and the contour line for that particular area shows that some area are steepness while other are flat but not much flat due the way DEM show.

GIS and remote sensing techniques in water reservoir site selection through application of remote sensing and GIS techniques in hydrology is today one of the most effective approaches.

Recently, remote sensing has provided valuable datasets to examine hydrological variables and morphological changes over large regions at different spatial and temporal scales (e.g. MSR-E, TRMM, GSMAP, ASTER, SAR and several others). Many researchers over the past 20 years have focused on satellite imagery applications in hydrology [5-9].

GIS and remote sensing can provide a huge amount of valuable data in spatial and temporal resolutions for areas where ground data are not easily available.

In 2008, GIS and remote sensing techniques were applied by Forzieri et al. to assess the suitability of sites for the installation of small dams for the purpose of water harvesting in arid areas.

The selection criteria are defined both in a qualitative way. Qualitative criteria imply the identification of suitable valleys, wadi physical characteristics, based on satellite images interpretation – mainly DEM – and large-scale available cartography; other qualitative selection criteria concern the distance from settlements and infrastructures.

2.2 LOCATING THE BEST IRRIGATION DAM SITE

The success of constructing water reservoir is primarly centered on locating best for the

water reservoir. As revealed by Dorfeshan, Heldarred and Bo (2014), selecting a suitable site calls for thorough consideration of several factor which include the physical characteristic of the site and economic factors among others. In particular, slope data and the physical characteristic of the area the most influence factor is as they determine the inundation behaviour of area of study.

Generation and analysis of DEM facilitates automatic accomplishment of the task such as planning, designing, constructing and monitoring of reservoirs which serves as the substitute to using topographic maps as seen by Ouma(2016)

Early investigation as described by Thonoon and Ahmed(2015), demonstrated that application of GIS significantly enhance the value of spatial analysis in the land use administration as well as automatic declination of drainage system and fundamental catchments from DEM, based on the investigation , it was conclude that automatic the method for obtaining the spatial presentation of drainage system and fundamental catchment is important since these entities are terrain objects which connects different aggregation level of hydrographic information.

2.2.1 IN ETHOPIA (JANUARY 2019)

The high dependency on rain-fed and the incessant erratic rainfall during the main growing seasons in Ethiopia pose a huge threat to agricultural production and

productivity. Multi-criteria irrigation land suitability analysis and mapping can play an important role not only in sustainable use of scarce resources, but also in overcoming the global problem of water scarcity and crop production caused due to the high degree of rainfall variability and unreliability.

The objective of this study was to determine suitable sites for surface irrigation along the Erer Watershed of East Hararghe Zone, Ethiopia. The study employed GIS-based multi criteria land suitability evaluation method considering fifteen factors, namely, soil pH, soil type, soil drainage, soil depth, AWSC, impermeable layer, ECE, CEC, phase, organic carbon, texture classes, obstacle to root, land use /land cover, slope, and distance from the river outlets to find suitable land for surface irrigation.

Each factor was standardized to a common measurement scale so that the results represent numeric range giving higher values to more suitable and lower values to less suitable attributes. Using the Weighted Overlay tool, the values of each dataset were weighted and combined to find the most suitable location for irrigation using the ArcGIS environment.

The results of the study revealed that about 386,731ha (11.7% of the watershed area) is highly suitable while 140,308 ha (36.3% of the watershed area) is not suitable for surface irrigation. The remaining suitability classes placed within the marginally and moderately suitable categories were about 151,120 ha (39.07%) and 50,223 ha (12.98%) of the watershed area, respectively. The findings drawn from this study can play an indispensable role in boosting irrigable land and crop production in the study area by considering suitable irrigable lands in terms of the fifteen factors described.

A site that was less than 0.5 km distance to agricultural activities was considered appropriate for the dam site. The distance to agricultural activities was very small so as to have access to water for farming purposes and close to the roads to provide enough access to the route networks [19] (Figure 8 and Figure 9). The

results indicate that dam number one is within the appropriate category while the rest of the dams are within the category inappropriate for distance from agricultural areas.

2.2.2 IN ISRAEL

Jordan is located in an arid to semi-arid region where around 90% of its land receives an average annual precipitation of less than 100 mm while only 3% of the land receives an average annual precipitation of 300 mm or more. Jordan is characterized as a "water scarce" country because the current per capita share of water is estimated to be of the order of 140 m3 per year which is well below the 1000 m3 threshold. Rainwater harvesting is the accumulating and storing, of rainwater. It has been used to provide drinking water, water for livestock, water for irrigation or to refill aquifers as a groundwater recharge. GIS has been widely used in selecting the best sites for water harvesting schemes.

This research aims at selecting optimum sites for water harvesting schemes in the Jordan arid lands (Badia) using indigenous knowledge and geoinformatics. To achieve this aim, a community-based research and desktop investigating is applied. The community-based research focused on consulting with 200 stakeholders form local communities where they provided knowledge on opportunities and constrains form their experience on water management in the arid lands where they live and interact. Also, they provided information on potential location for water collecting sites that has been used for ages to provide water to humans and livestock.

2.2.3 IN MALAWI WATER BOARD

There are five water boards, Northern, Central, Lilongwe, Blantyre and Southern, reconstituted by an Act of Parliament, the 'Water Works Act' No. 17 of 1995. They are responsible for the provision of water supply services including for example in the case of Lilongwe, to "manage the source of raw water, abstract and treat water in full compliance with regulatory bodies such as World Health Organization (WHO) and Malawi Bureau of Standards (MBS); and provide adequate and reliable water supply to the residents of the City of Lilongwe that meets customer needs. They serve designated urban and peri-urban areas and are intended to be self-financing, raising revenue from domestic, institutional, industrial and commercial customers. They describe themselves on the websites in a number of ways including "Parastatal Organization", "Statutory Corporation", "Public commercial-statutory corporation" and "wholly owned by the Government of Malawi". They operate in

a similar way to Scottish Water but without the benefit of independent financial regulation. Hence, they are constrained in their financial planning by government and short-term focused political influence in setting fees and tariffs. In addition, their status as corporations prohibits support from many donors for water development funding. Key challenges include rapid population growth from migration from rural to urban and peri-urban region, which leads to pressure on existing water sources, inadequate distribution systems comprising limited networks that include pipes that are too small for the increased flow rates that are now required, and pipe failure in system that lack ring mains. In addition, aging infrastructure has high leakage rates and there are incidents of cholera in Lilongwe from cross contamination from aging sewer systems. Investment in infrastructure is severely constrained by tariff levels that are set by the Government on a socio/political basis and non-payment of or late payment of water bills by public sector clients. Water scarcity has a huge impact on food production. Without water people do not have a means of watering their crops and, therefore, to provide food for the fast-growing population.

Water scarcity has a huge impact on food production. Without water people do not have a means of watering their crops and, therefore, to provide food for the fast-growing population. According to the International Water Management Institute_, agriculture, which accounts for about 70% of global water withdrawals, is constantly competing with domestic, industrial and environmental uses for a scarce water supply. In attempts to fix this ever-growing problem, many have tried to form more effective methods of water management.

One such method is irrigation management. Irrigation is a method of transporting water to crops in order to maximize the number of crops produced. Many of the irrigation systems in place do not use the water in the most efficient way. This causes more water than necessary to be used or for there not to be enough water to ensure healthy crops. According to the World Bank, irrigation management works to upgrade and maintain irrigation systems, such as groundwater irrigation, that are already in place and expands the areas of irrigation to increase the amount of crops being produced.

3.0 METHODOLOGY

3.1 STUDY AREA DISTRIPTION

Malawi is divided into twenty-eight districts divided into three regions, one of which is Kasungu District in the Central region. It is bordered on the west by Zambia, on the south by Mchinji, Dowa, and Lilongwe district, on the north by Mzimba, and on the east by Nkhotakota and Ntchisi district.

It is the only district in Malawi that has more district boundaries than the rest of the region. Malawi's capital, Lilongwe, is about 127 kilometers from the district headquarters (NSO Atlas, 2002). Kasungu district is home to many tobacco farmers and occupies 7,878 square kilometers, accounting for 8.4% of Malawi's total land area. Farming but due to the condition of the area its dry and many peoples, they struggle to irrigate their crop due lack of enough (Kasungu SEP, 2013).

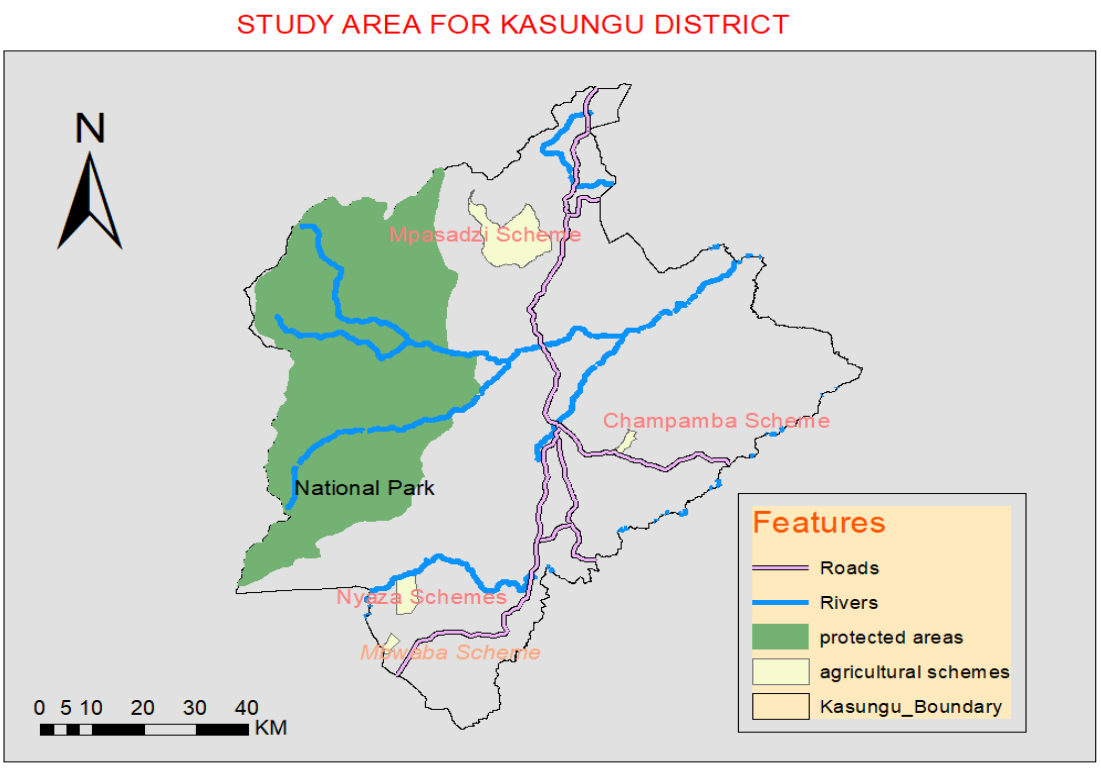
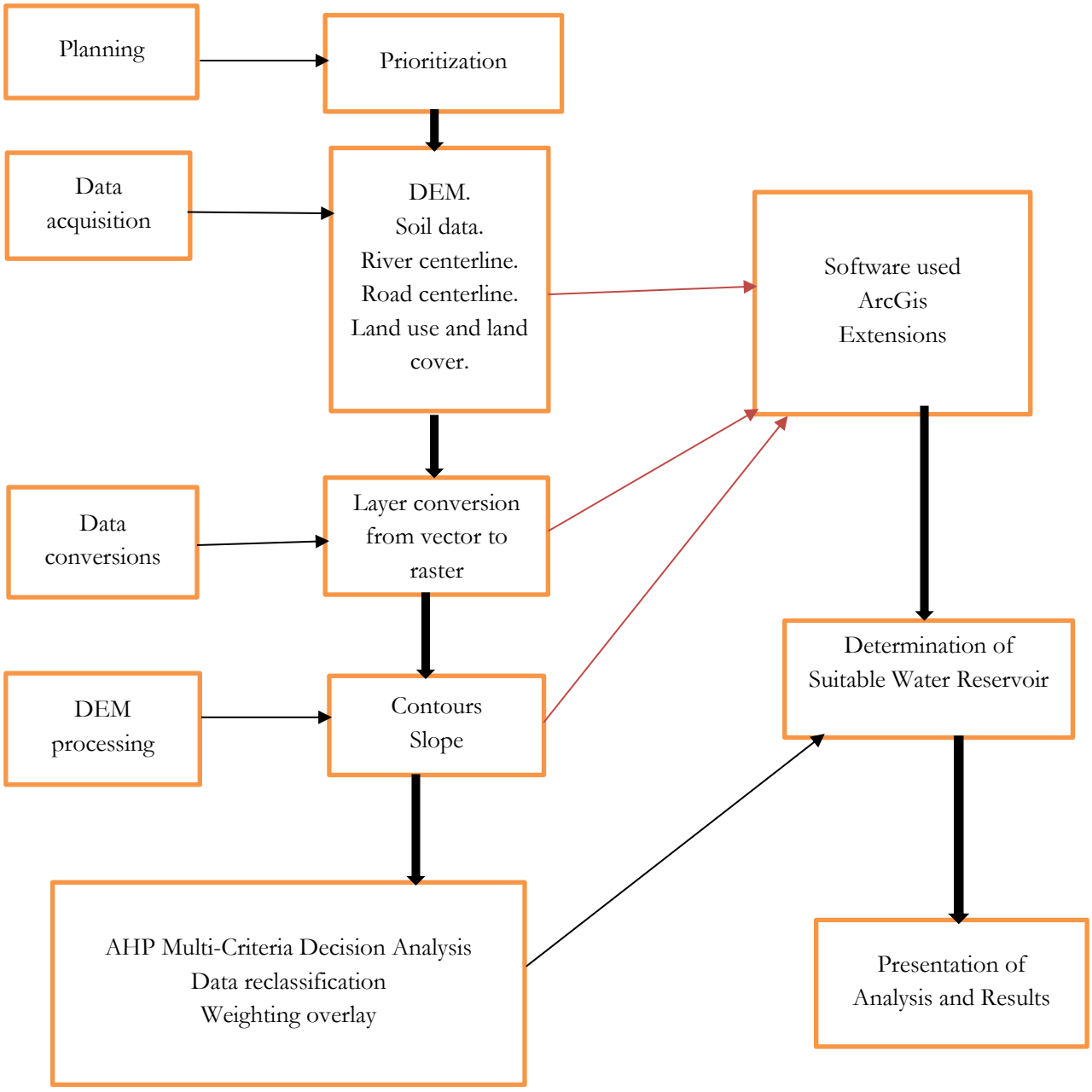


Figure 1 showing the study area location

3.2 Structure of Methods Used.

The methodology used for data collection as well as data analysis are as follows.

Chart 1 show the methods used



3.2 DATA USED

Table 1 show the data used.

NO	DATA	EXPLANATIONS
1	DEM	Data set used for generating DEM, slope and hydrological layer.
2	River centerline	The main source of water for the dam site
3	Road centerline	This will used to calculate proximity of the dam to the existing main roads.
4	Soil data	This dataset illustrates the distribution of the various soil categories with the study area.
5	Land cover	This showed the current pattern and use of the land within the study area.

3.3 DESCRIPTIONS OF DATA USED

i. Elevation. Kasungu was given a digital elevation model (DEM) with a resolution of 30 meters and an elevation raster ranging from 0 to 413 meters (above sea level). Since it affects water retention and movement, the DEM has an effect on the dam's best position. Since the risk of accumulating precipitated water as well as groundwater is greater at a lower level, a low elevation has been deemed ideal for water reservoir construction. Slope attributes can also be extracted using a Digital Elevation Model (DEM).

ii. Slope. The slope degree parameter affects water velocity for surface and ground water. The lower the slope, the higher the possibility of water accumulation. As with elevation, a slope map was also obtained from the DEM at a 30 m resolution. For Kasungu, the slope ranged up to 58 degrees. Water velocity is directly proportional to slope. A slope under 5% is suitable

for the water holding capacity of the proposed dam construction for irrigation. Slope is one of the factors that influence the safety of the dam since large degree of the slope has high risks on landslides and give more pressure on the foundation of the buildings.

iii. Major fracture Euclidean distance. For Kasungu district and the whole Malawi, major fractures are mostly concentrated in the mountainous regions. The stream flow depends on the major fracture and moves from higher to lower elevations. A distance of 100 m from the tectonic faults and fractures should be at least considered for considering suitable locations for dam construction. Areas with faults should be excluded from the consideration of dam site suitability.

iv. Soil type will be obtained from harmonized World SOIL Data (HWSD). All the type of the soil will be selected then choose like loam soil, clay soil, dump soil, sand soil. Clay soil will be considered more suitable because of their permeability and great water-holding capacity.

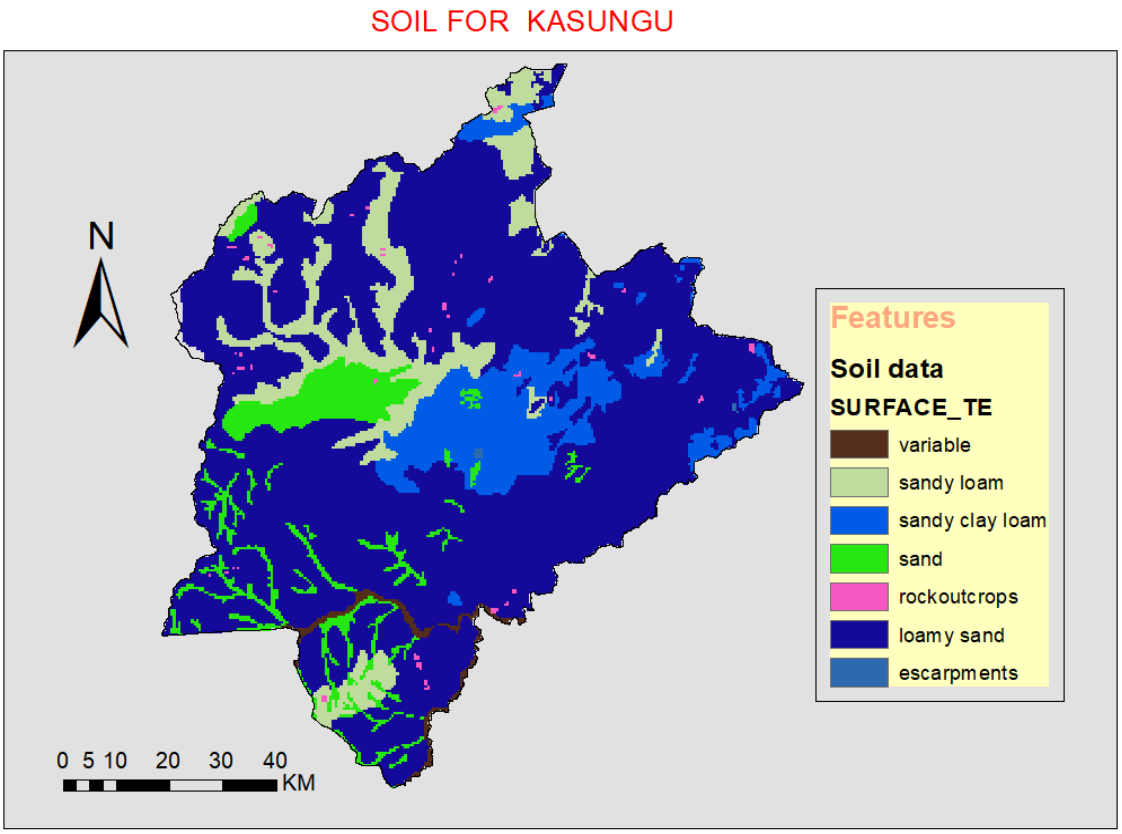
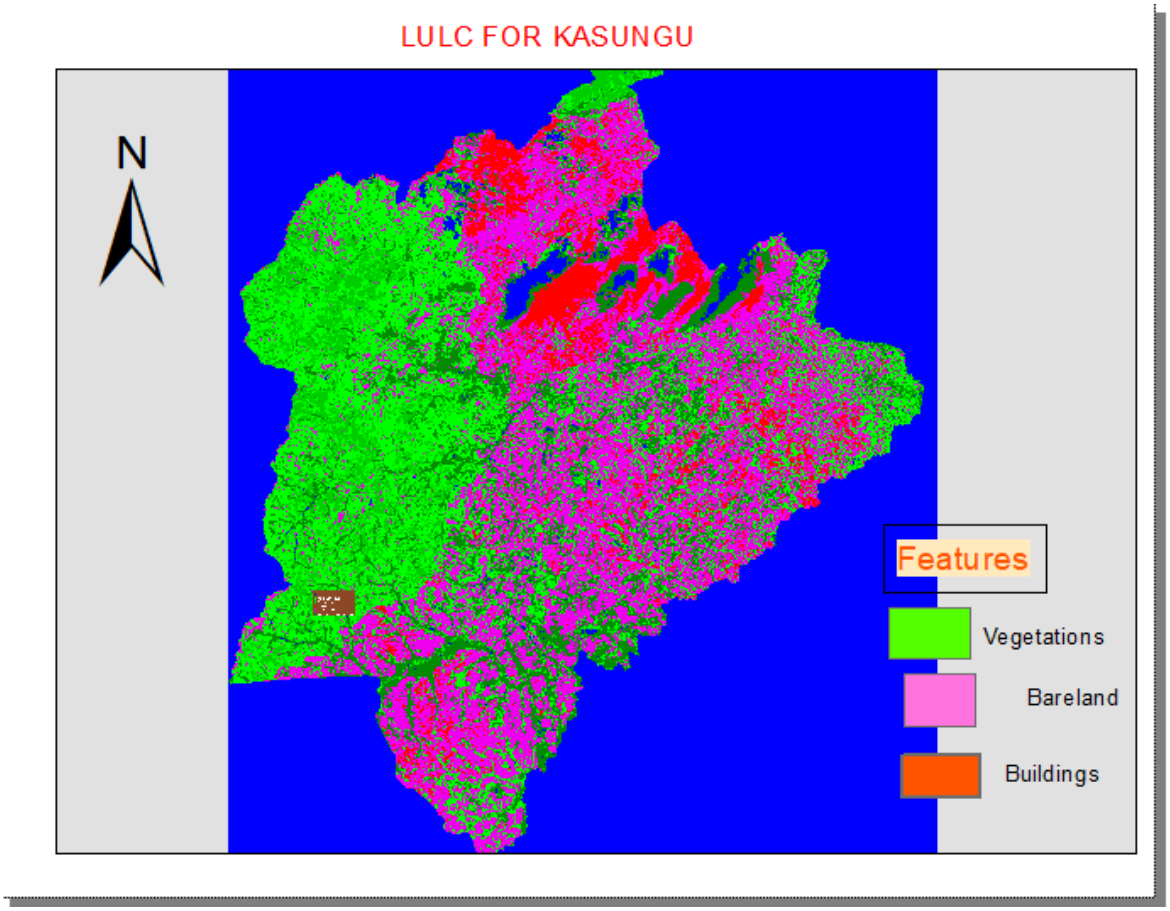


Figure 2 showing soil data.

v. Land cover is also another factor to consider when selecting a suitable site for water reservoir construction. Firstly, land cover plays a greatly important rule to affects rainfall which help to cover the land and prevent soil erosion and high soil erosion are make a weak for foundation of water reservoir construction (Baban $ Wan-Yusof 2003). Classification will be conducted which is supervised classification using the support vector machine algorithm prosed to describe the seven major land cover classes include trees, bare land, water, roads, buildings, forest and mountain using Landsat image with spatial resolution of 30m.



3.4 METHODS

3.4.1 CONVERSION OF DATA TO RASTER

3.4.1.1 PROXIMITY FROM THE RIVER SIDE

This was done by the creating Euclidean distance by using spatial analysis tool in Arcgis. Suitable water reservoir site should be within one kilometer corrido from the centerline. More than one kilometer may result in several challenges which would include financial.

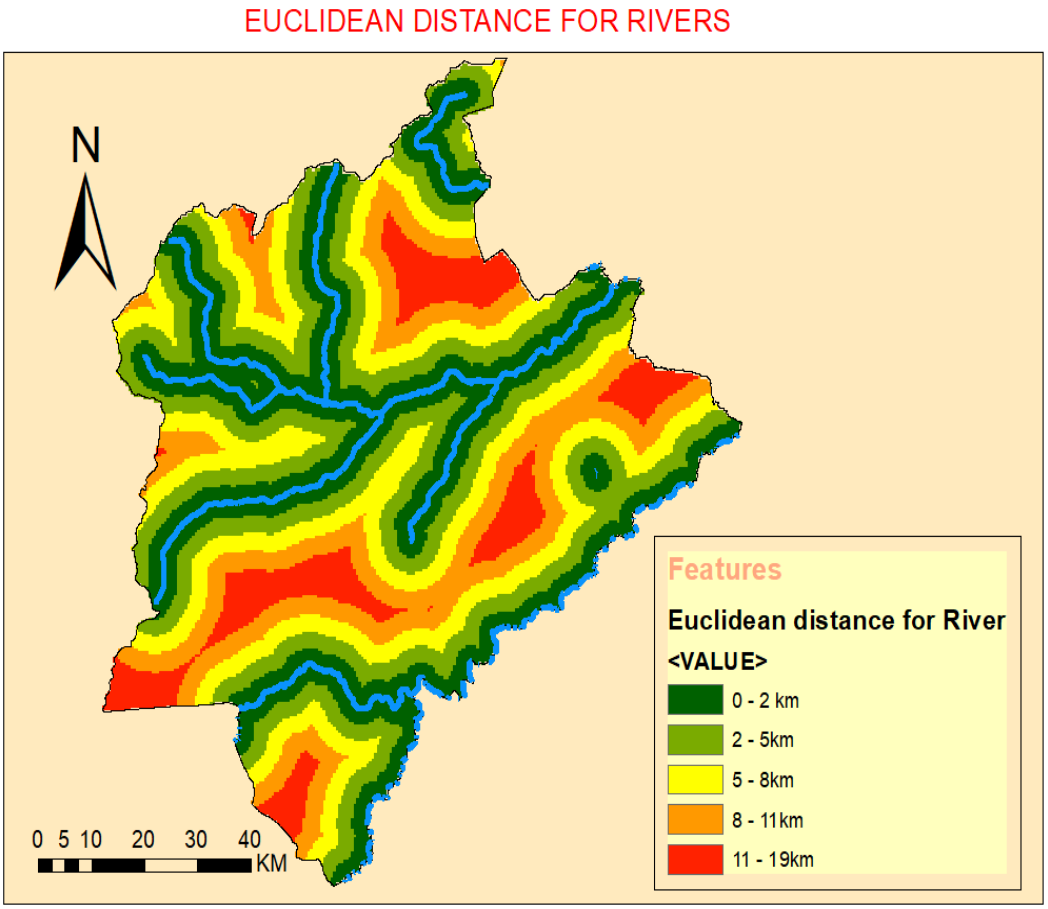


Figure 3 show the data of river before converted into raster.

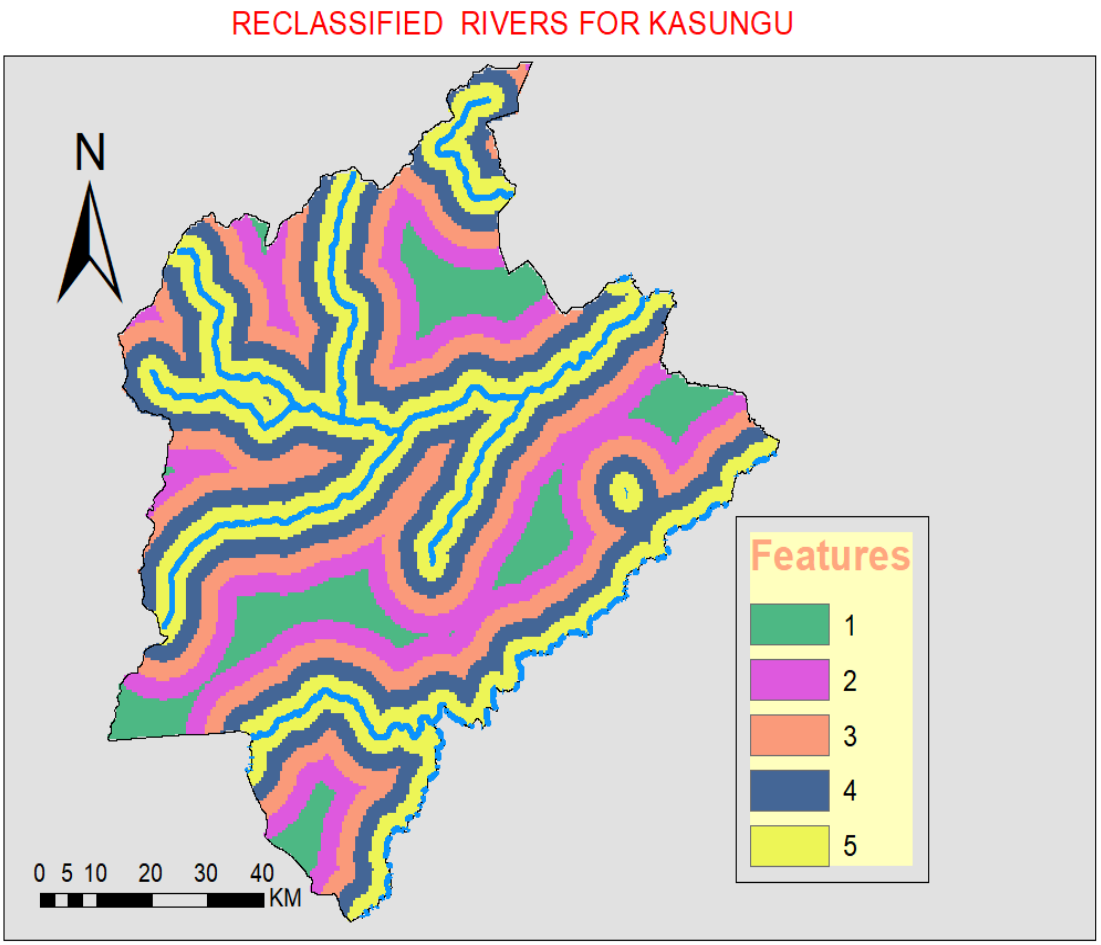


Figure 4 show the river after converted into raster.

3.4.1.2 Proximity to Existing Road

This was done by using spatial analysis tool in ArcGis to create Euclidean distance. The water reservoir should be as near as possible to the existing road. Existing literature reveals that a distance of a kilometers to the main road is recommended. Figure show the output result from road proximity analysis.

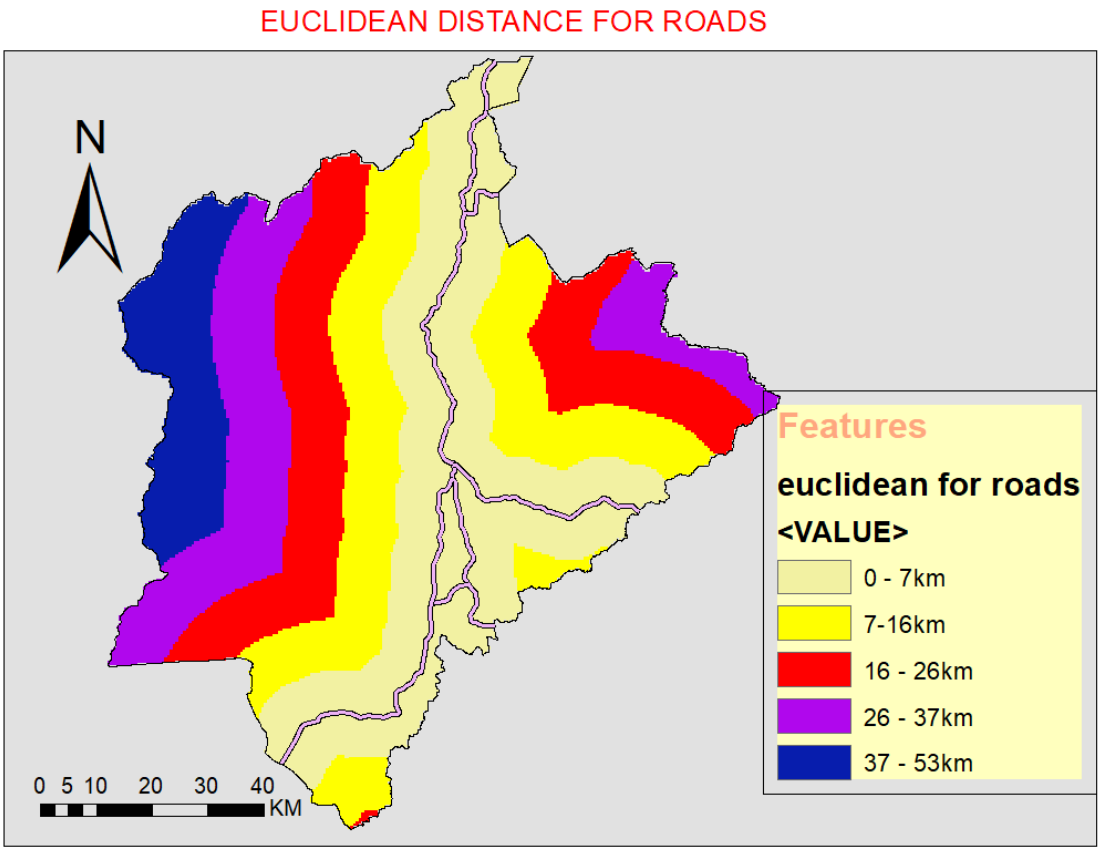


Figure 5 Road centerline before converted into raster.

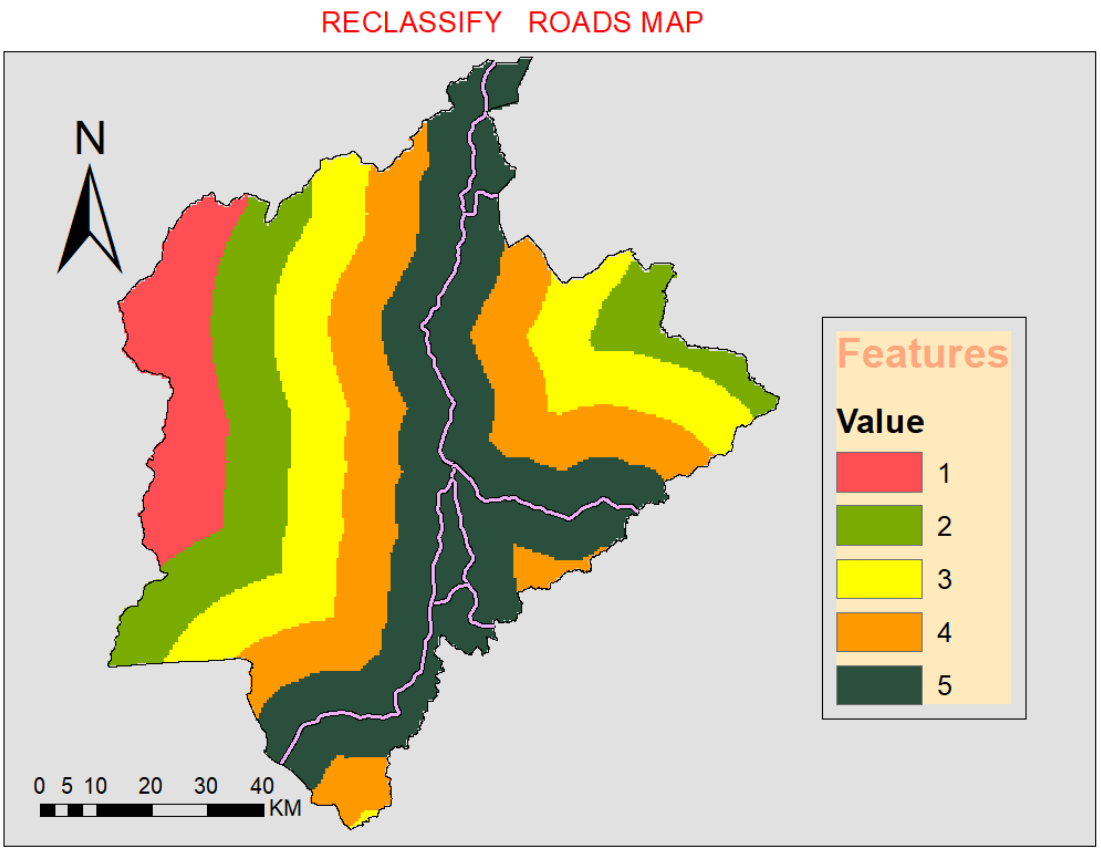


Figure 6 proximity to road side after converted into raster.

3.4.1.3 DEM PROCESSING

Elevation, slope, and contours are among the layers formed by the DEM. In global mapper, the elevation layer was generated using an ASTER DEM. The slope in ArcGis 3D analysis extension was used to measure the maximum gradient between a cell and its neighbouring cells using elevation as the input. The output raster included contours as well as a slope percentage.

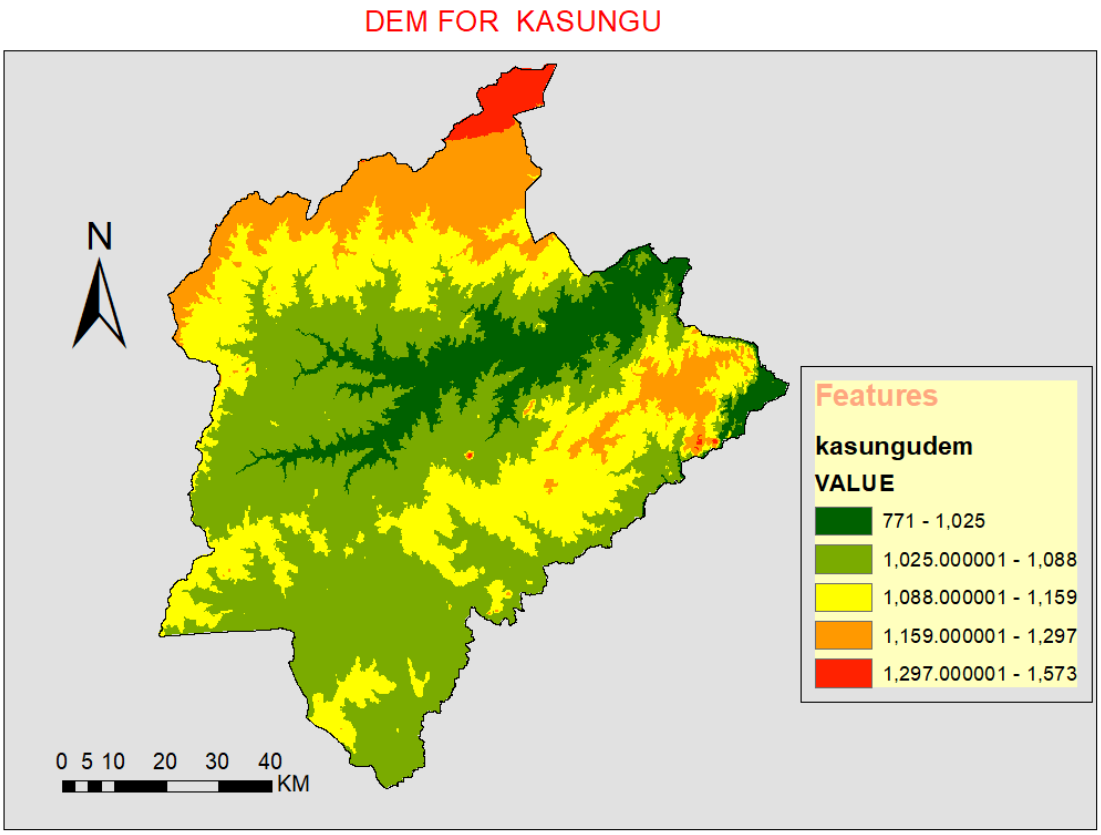


Figure 7 Kasungu elevation

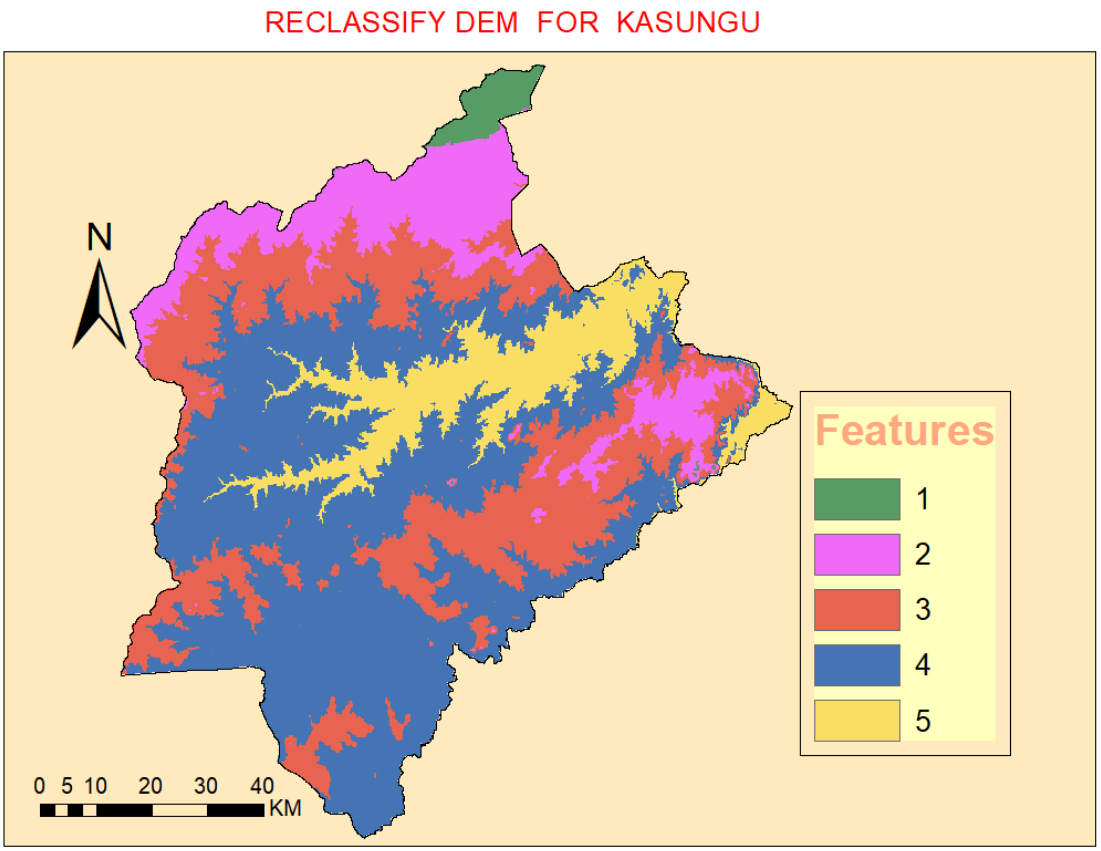


Figure 8 Kasungu raster elevation

4.0 WEIGHTING OF FACTORS USING AHP MULTI-CRITERIA DECISION ANALYSIS (MCDA)

Weighting was a important part of this study. Each factor was assigned a weight which determine their significant of the projects. The weighted displayed way the study was conducted in view of the economic factors which minimize the production cost project viability based on physical factors of the study area as well as the overall benefit it will be to the district of Kasungu and the whole Malawi. Several methods are applied for weight determination of each contributing factors. Among widely used is the pair-wise method AHP by Saaty (1977) where in the basic of their significant factors are weighted and compared against each other hence this study applied pair-wise comparison method.

According to Saaty (2008), a matrix is created in which each criterion is compared to each other on a scale of 1 to 9 in terms of its significance. The calculated

weighted approximation is then used to calculate the pair-wise comparison's consistency ratio (CR). If the consistency ratio is greater than 0.10, it's time to look at some pair-wise values. The procedure is repeated until the acceptable value of consistence ratio is less than 0.1 is achieved.

The main stages were involved as follow

I. Determination of the structure of AHP decision making tree
II. The evaluation of the relative important of each criterion with one another
III. The assessment of consistency done with pair-wise comparison to assign the consistency ratio.
IV. Computing the principle, consistency index CI computation and calculating CR.

4.1 DETERMINATION OF THE STRUCTURE OF AHP DECISION MAKING TREE

From the literature review the specific condition of the Kasungu district and even the whole Malawi the availability of data, the analysis utilizes seven different map layer as input in the suitability slope, soil type, proximity to river side, proximity to road side, digital elevation model. The decision-making tree was constructed as described by Dorfeshan Haidarnejad and Bo (2014). This formed the structure of the multi-criteria decision analysis. The problem was decomposed into a level of hierarchy consisting crucial elements of the decision problem. First layer indicates the goal of the decision making, the second layer containing the criterion to be used and the third layer show the decision-making attribute.

AHP figure

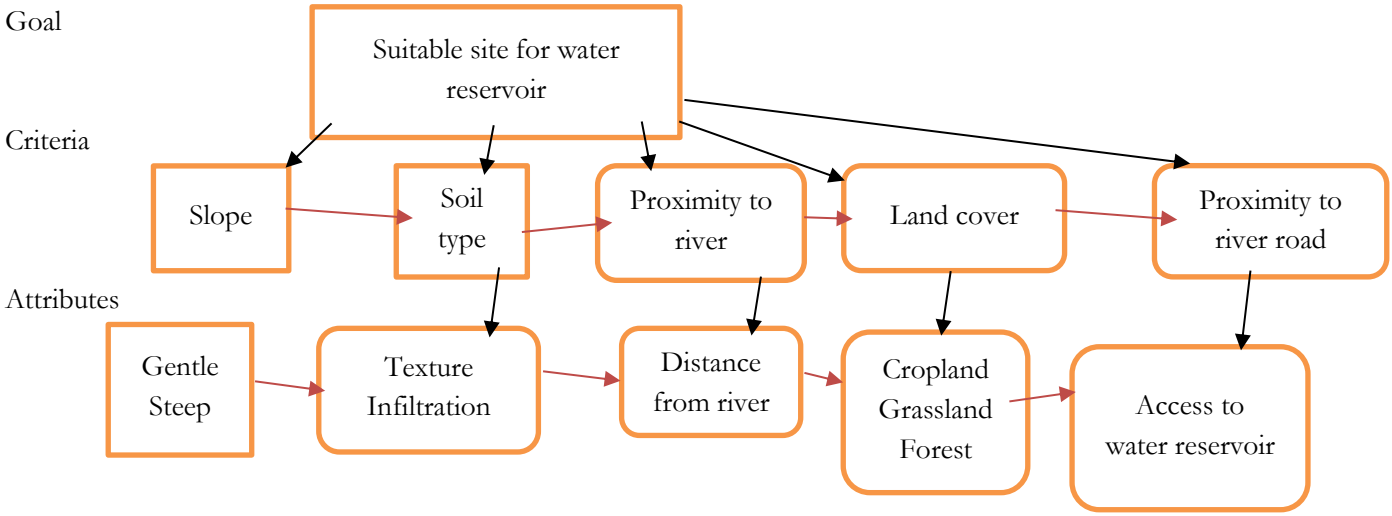


Figure 9 showing AHP structure.

4.2 ASSESSMENT OF RELATIVE IMPOTRANCE OF EACH CRITERA WITH ONE ANOTHER

During this phase, important technological aspects based on the requirements were considered. Saaty (2008) used a scale of 1-9 to allow for an equitable comparison of the intensity of suitability, with 1 denoting factors of equal preference and 9 denoting factors of extreme preference over the other.

Table 2, intensity of importance.

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equal to the objects
3	Somewhat more importance	Experience and judgement slightly favor one over the other.
5	Much more importance	Experience and judgement strongly favor one over the other.
7	Very much more important	Experience and judgement very strong favor one over the over. Its importance demonstrated in practices.
9	Absolute more importance	The evidence favoring one over the other of the highest possible validity
2,4,6,8	Intermediate values	When compromise is needed.

The table below show the order of importance which was already done by many people in the past.

Table 3 Order of importance

Factors	Order of importance	Arguments
Slope	1	Slope influence water reservoir safe since higher slope have more risks of landslide and give pressure to the foundation.
Soil type	2	Difference soil type have different infiltration ratio which usually influence the mostly flowing of water reservoir.
Land cover	3	This is useful for examination of land that have different economical cost depending.
Proximity to river	4	A suitable water reservoir site should be within a buffer of the one kilometer from the river centerline. This was considered an economic suitability distance from the river centerline (Expert's opinion)
Proximity to roads	5	The water reservoir site should be easily accessible, so that it can be economically connected to the required population (Engineering Articles 2017)

4.4 CALCULATING PRIORITY WEIGHT USING PAIR-WISE COMPARISON

As shown in table 2, the weight was calculated on a scale of 1 to 9. Pair-wise comparison was used to calculate the weight of each factor, as shown in table 4. The matrix was built according to Saaty's (1977) recommendations, in which a criterion was compared to other criteria on a scale of 1-9 to determine its significance.

where

1= Two factors of each preference.

9=Extremely favor factors over the other.

COMPLETE MATRIX

Table 4, Pair- wise comparison

Factors	Slope	Soil type	Land use	Proximity to river	Proximity to road
Slope	1	5	7	9	9
Soil type	1/5	1	3	5	7
Land use	1/7	1/3	1	2	2
Proximity to river	1/9	1/7	1/3	1	2
Proximity to roads	1/9	1/5	1/2	1/2	1
Total	1.543	6.976	12	17.5	21

After comparison between all possible criteria pair-wise is completed, the weight (W) of criteria i is calculated using equation 1 (Dai, 2016). The formular below for calculated weight (W)

$$Wi = \sum_{i=1}^{n} Pij / (\sum_{i=1}^{n} Pi \sum_{i=1}^{n} Pj) \quad \text{equation.....1}$$

Equation 1 calculation of weight (source Dai 2016)

Where Pij=relative importance in pair-wise comparison of criterion i compared to criterion j, n= Number of factors, i and j =criterion and w=priority weight.

4.5 NORMALIZATION AND WEIGHT DETERMINATION

Table 5 show the Normalization and weight determination

	Slope	Soil type	landcover	Proximity to rivers	Proximity to roads	Weight (W)
Slope	0.6480	0.7167	0.5833	0.5142	0.4286	0.5781
Soil type	0.1296	0.1433	0.25	0.2857	0.3333	0.2283
Landcover	0.09258	0.0477	0.0833	0.11428	0.0952	0.0866
Proximity to rivers	0.0720	0.0204	0.0416	0.0571	0.0952	0.0573
Proximity to roads	0.720	0.0286	0.0416	0.0571	0.0476	0.0437
Total	1.002	0.9567	0.998	0.998	0.999	0.994

4.6 ASSESSMENT OF CONSISTANCY

As expressed by Dai (2016) the values used for pair-wise comparison usually relies on subjective judgement which could lead to arbitrary results with bias. To evaluate the consistency of pair-wise comparison matrix, a numerical index called consistency ratio is used. Consistency ratio show the ratio of the consistency index (CI) to the average consistency index.

CR=CI/RI

Calculate of the consistency ratio

CI=max-n/n-1

Where n is the number factors

Max= the summation of the products between each element of the priority vector and column totals.

= (1.543*0.57814) + (6.976*0.2284) + (12*0.0866) +(17*0.05726) +(21*0.04366)

=0.8921+1.5933+1.0392+1.0021+0.9169

=5.4436

CI= (5.4436-5)/ (5-1)

0.4436/4

0.1109

4.7 Determination Of Random Consistency Index

As proposed by Saaty (1977), the RI used depends on the number of criteria. This study has five criteria hence the RI used was 1.12 as indicated in table 6 below.

Table 6 Random Index Value (source: Saaty (1977))

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

CR= CI/CI

0.1109/1.12

0.099

According to Saaty (1977), the value of CR is compared to 0.1 which is the maximum CR value for acceptable pair-wise comparison. The resulting CR for this analysis is 0.099 which is less than the acceptable maximum CR value recommended in AHP and therefore this consistency is accepted.

5.0 DATA RECLASSIFICATION

Decision on features to include or exclude for analysis usually require a quite measurable field knowledge combined with modeling.

Classification was done with help of the spatial analysist Tool in ArcGis. During the classification the rank for each criterion was given based on its estimate application in site selection. Each input layer has potential different ranges of values as well as diverse styles of the numbering systems, which necessitates reclassification or transformation into a common ratio scale before they are combined for the analysis.

To perform the reclasification each raster dataset was reclassified into a common scale of 1 to 9 with 5 being more favorable and 1 with the lowest influence classification of geological factors mainly depended on the permeability thickness and strength of rock foundation at the area of interest stronger foundation was given the highest scale of 5 while weak was given the lowest scale of 1.

Water reservoir construction requires a topography of a well-drained, gently sloping site. This is best as it minimum instruction cost, gentle slope was given the highest scale of 5 steep slope was given the lowest of 1.

The ranking of soil was done on the soil infiltration rate. As describe by the Djokin (2012) the smaller the soil particles the slower the water infiltration rate. To ensure minimum loss of water through seepage soils must be impermeable with more than 20% clay. Therefore, clayey soil was given the highest scale of 5 and the sandy soil was given the lowest scale of 1.

The closer the water reservoir to the river the better for economical purpose. The closes distance of 500m buffer from the river centerline was given the highest scale of 5while distance beyond 3 kilometers were given lower scale of 1.

The near the water reservoir to the transport networks, the better the accessibility (Dorfeshan, Heidarnejad $Bo, 2014). Thefore, short distance was given the highest scale of 5 and long distance were given the lowest scale of 1.

Table 7 show the summary of the selected ranks

Factors	High rank (5)	Low rank (1)	Reasons (experts' opinion and other existing literature)
1 Soil type	Low Infiltration rate	High Infiltration rate	The low the infiltration rate the better the soil type.
2Topographic	Well-drained gently sloping site	Steep and flat land	Gentle slope minimizes amount of cost.
3 land cover	Low soil erosion area	High soil erosion area	Land cover prone to soil erosion are less conducive for water reservoir.
4 Transport networks	Near distance	Far distance	The close the water reservoir.
5 proximities to river side	Lower distance	High distance	The short the distance the better.

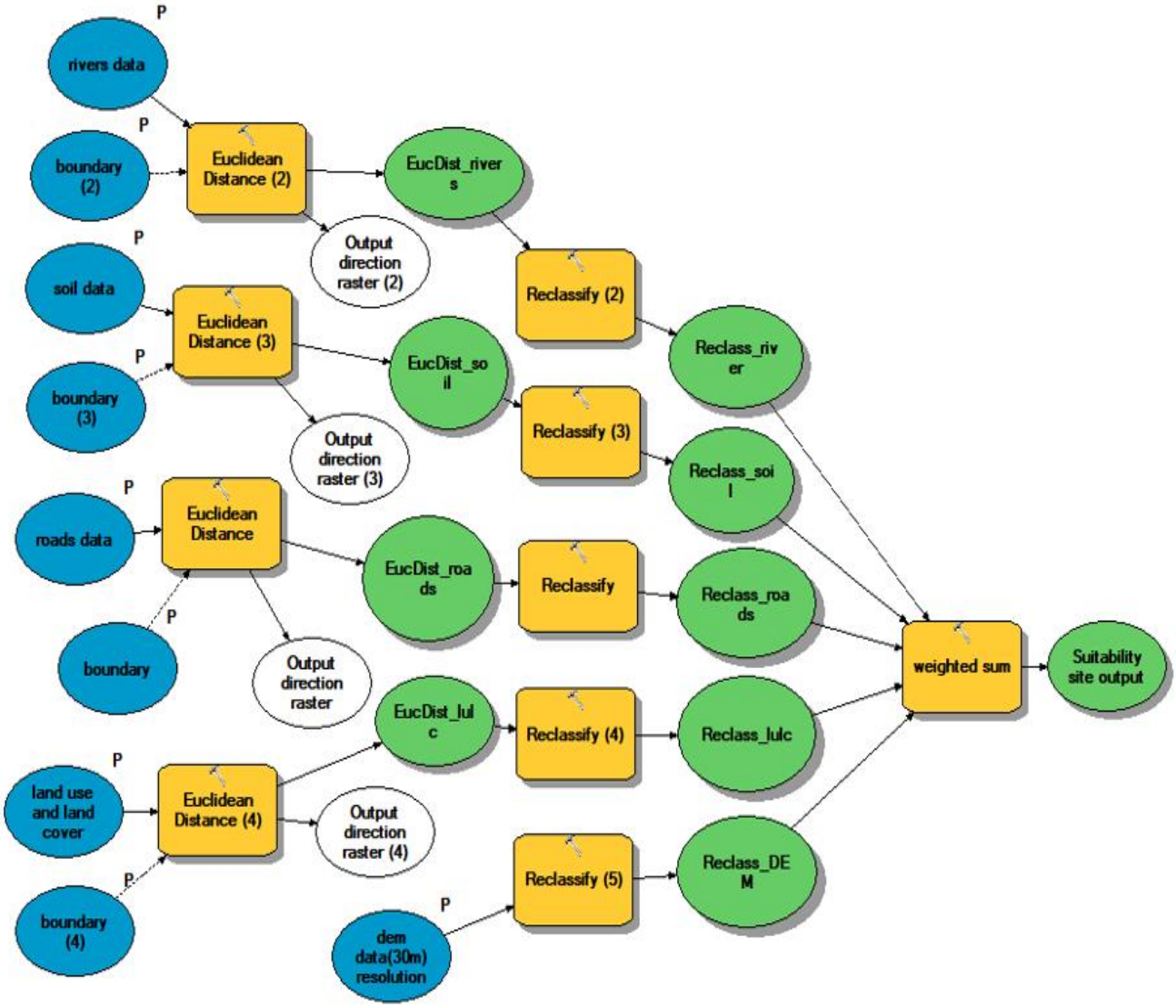


Figure 11 Model Builder as a method for selecting suitable site.

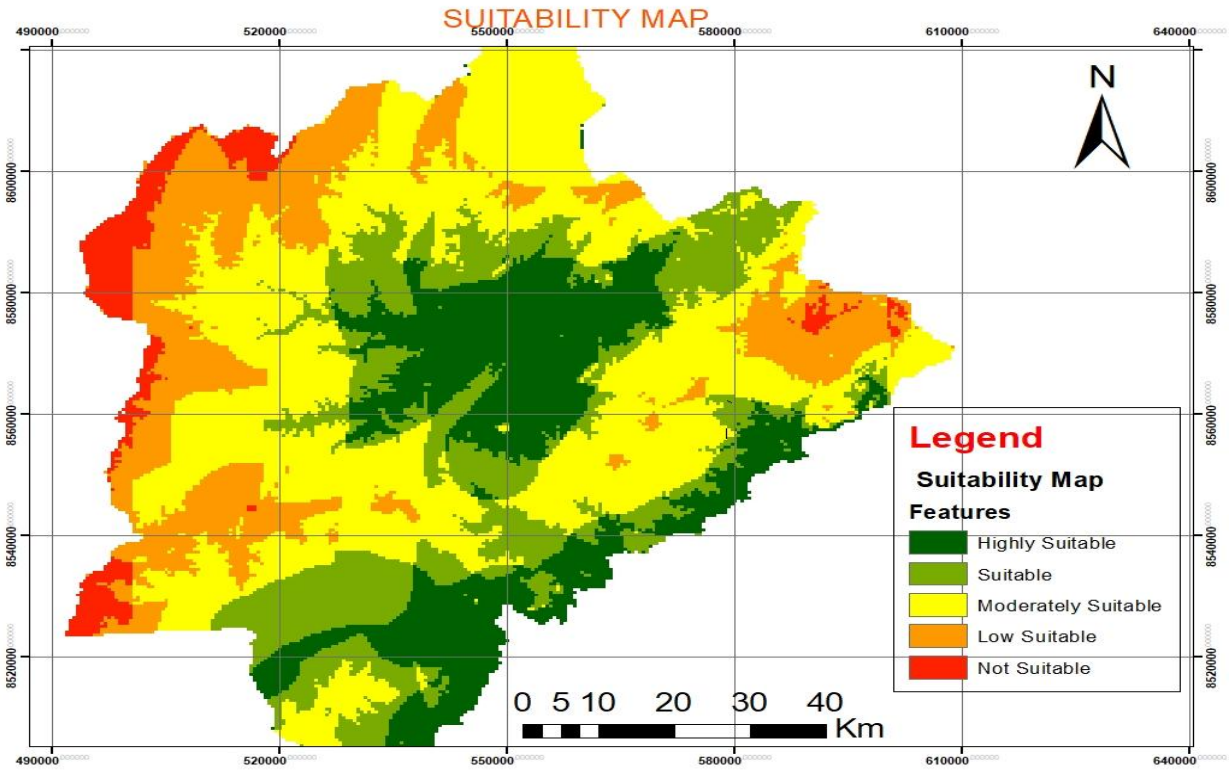


Figure 11 Showing final suitability map.

5.RESULTS AND CONCLUSSION

5.1 Analysis of the results

As suitability map specifying suitable location for water reservoirs in Kasungu district central region of Malawi was produced as shown in figure 9.The map was reclassified into five classes of different colours. Green colour represents the land which is the highly suitable, green colour represent land which is suitable, orange colour represent land which is moderate suitable, yellow colour represent land which low suitable and Red represent land which is not suitable for water reservoir. and percentage for various suitability levels was produced.

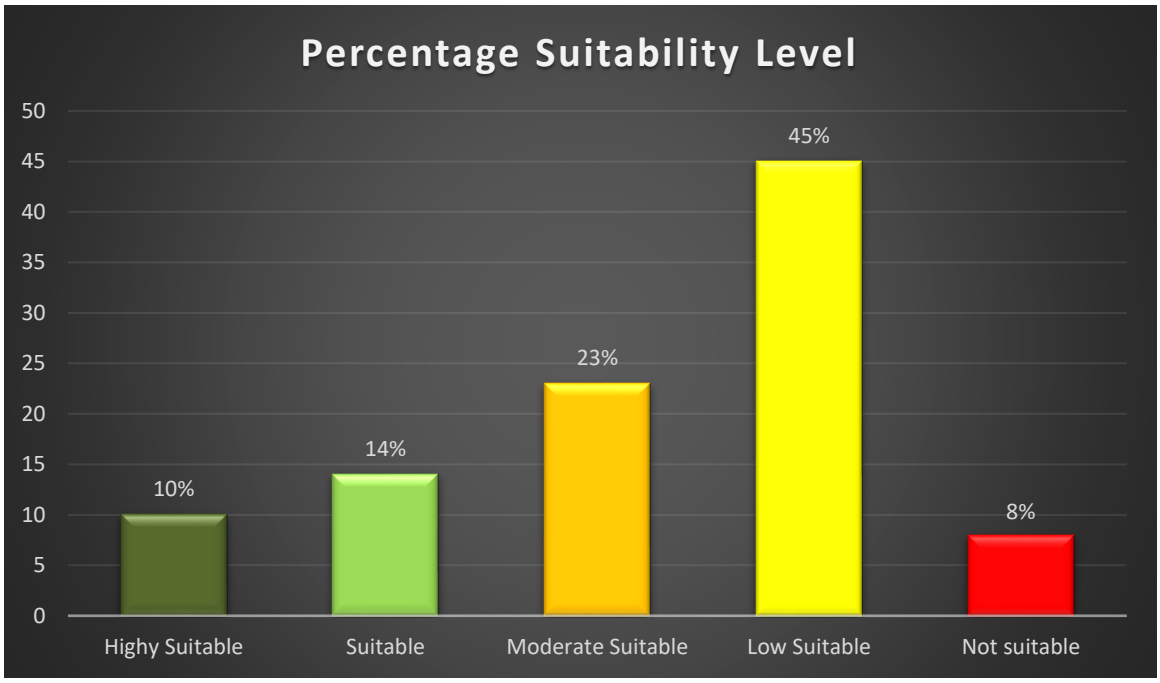


Figure 12 Showing graph for suitability levels.

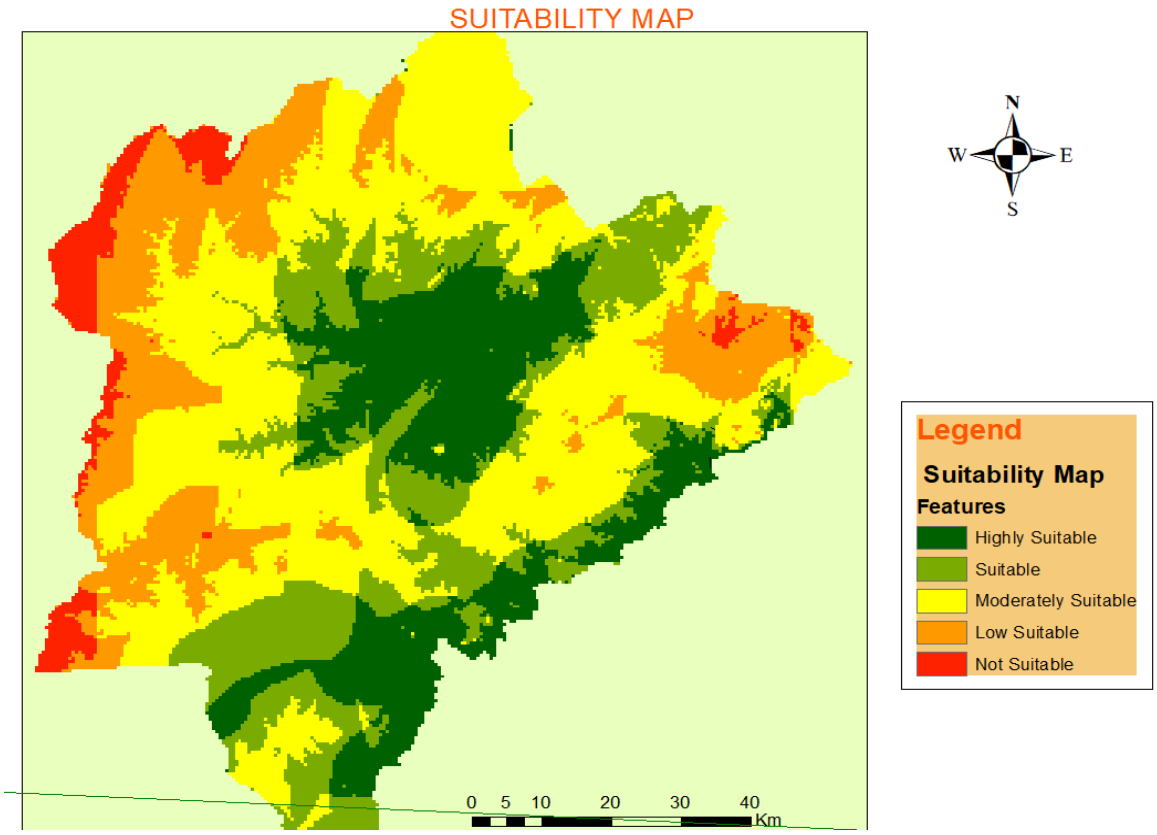


Figure 13 showing suitability map.

A

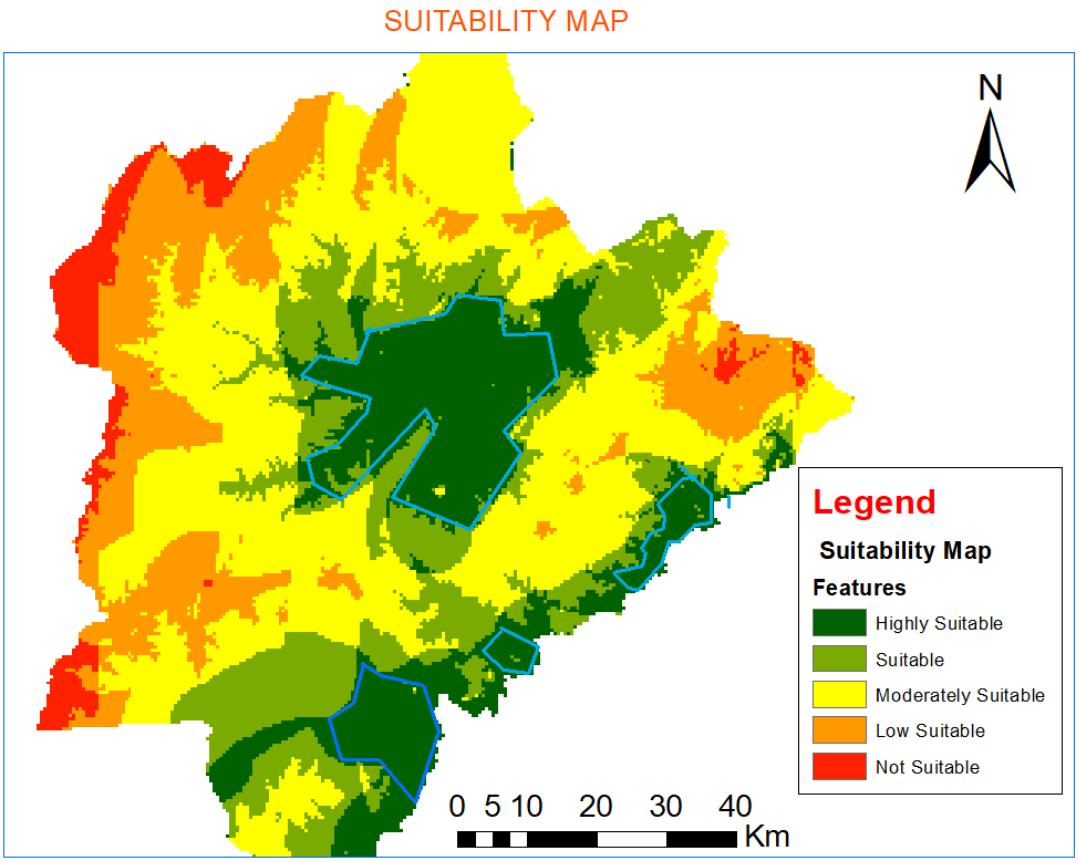


Figure 14 showing demarcating area for highly suitable site.

Highly suitability site has been divided into more than four parts. The biggest site or area showing that the area is good for water reservoir according to the condition necessary for water reservoir site selection. Farmers from Kasungu district can construct their dam for irrigation since people from Kasungu district depend on farming like tobacco. Those area that has demarcated by blue are area which are highly suitable for water reservoirs.

Map below on figure 15 also showing suitable area where people from Kasungu district can construct their water reservoirs but is not much better than the one above. Area which has demarcated by purple colour is suitable for water reservoir.

Area from the west map of Kasungu district is not suitable for water reservoir according to the conditions and also that area is protect area where there is

Kasungu national park. Therefore, there is no much settlements as showing in my land use and land cover map above on figure 3.

B

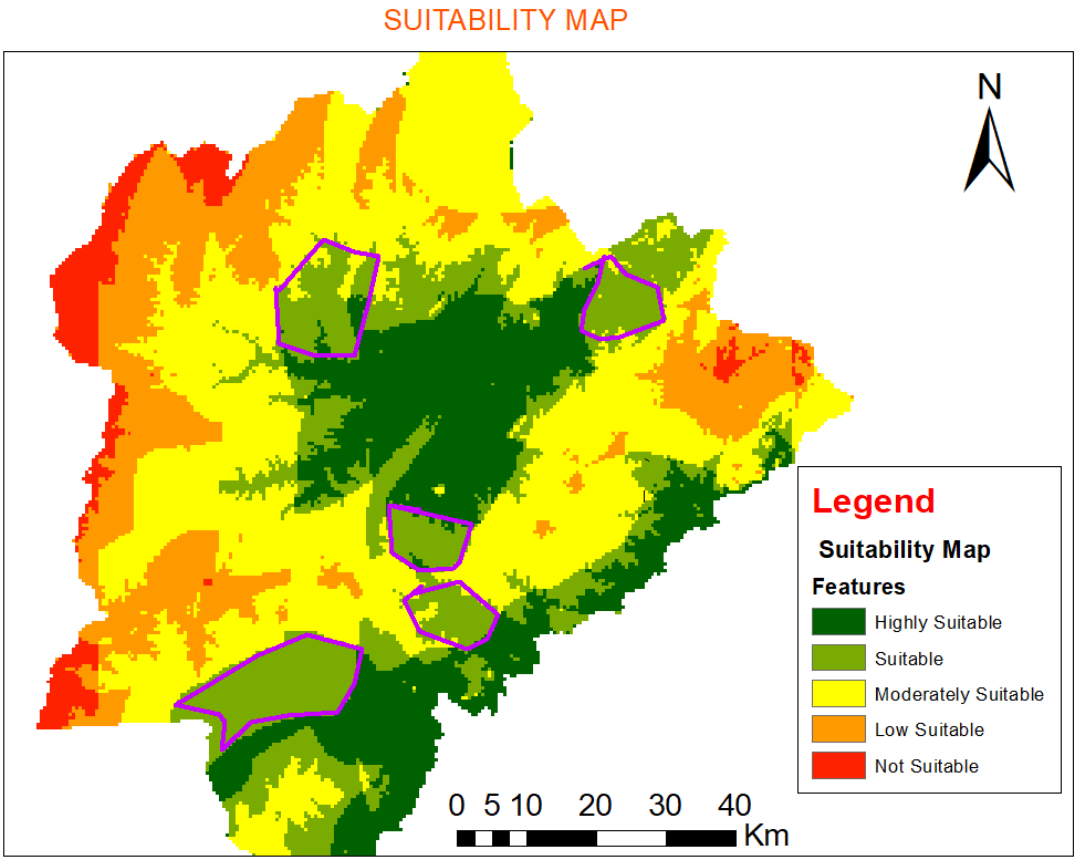


Figure 15 showing a demarcating site for suitable reservoirs.

5.2 DISCUSSION

The elevation within the study area ranges between 638 to 1798m above sea level. After comparing the suitability map with elevation map. The highy suitability areas lies within fair flat elevation of the between 856-950m as well as well as within area of gentle slope between 2-9%.

The suitability area also lies within the drainage basin meaning the reservoir will be able to get water from the all-possible catchment within the available drainage

area, depicting steep slope within the area which are not suitable for water reservoir construction.

The main objective of this study has been achieved in such that suitable site for water reservoir site location has been analysed. The integration GIS and AHP has been successfully and a final suitability map has been produced. The success of the final results mainly depended on the accuracy of the DEM used since this was the main dataset. Aster DEM was used with a horizontal accuracy of 30m resolution. This was detailed enough to meet the requirements for a medium scale study such as this study, where area was approximately.

In general integration of GIS with AHP has been helpful in arriving at a suitable location for a water reservoir site selection. Therefore, both area proficient and supportive tools for decision-making process.

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In the view to support policy makers to come up with conclusive and dependable decision on a suitable location to construct water reservoir for Kasungu district in central region. I selected a methodology of integrated GIS and AHP, one of the popular multi-criteria Decision Analysis tools.

Having determine the criteria and their respective weights, ARCGIS extensions, 3D Analysis, Spatial Analysis were used obtain a final suitability map. The entire process demonstrate that this is a reliable and precise method of dam site selection, even though it has some few limitations. which requires future improvement.

The results indicates that integration of GIS with AHP multi-criteria Decision Analysis for a water reservoir site selection is feasible and effective. Powered by GIS analytical capabilities and Geospatial technologies, water reservoir site selection and planning can be done in a more effective and scientific way. This is contrary to manual methods of reservoir site selection using topographic maps and contours

without consideration of terrain properties which can only be discovered by GIS analysis.

6.2 Recommendations

Based on the limitation of this study as well as the future perspective, there are parts of the study which requires improvement in future studies of the same nature. In the AHP weight determination, there is no standard for rank order of criteria. High resolution DEM especially the LiDAR DEM should be used in future to increase the accuracy of the results LiDAR DEM can be of as high resolutions one meter and as high point density as 3 to 4 points per meter square.

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