GEOTECHNICAL ANALYSIS FOR IDENTIFICTION OF SOLID WASTE DISPOSAL SITE SUTABILITY USING GIS MULTI CRITERIA DATA ANALYSIS IN LILONGWE

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ABSTRACT

Solid waste management is a serious problem in the urban areas because of industrialization, urbanization and population growth. This is the same case for Lilongwe. The main objective of this study was to select potential areas for suitable solid waste dumping sites for Lilongwe district, which are environmentally suitable. The main data used for this study were digital elevation model (DEM) with 30 m spatial resolution,

Lilongwe shapefiles; river, roads, railway, buildings, protected areas, geology, soil, wetlands and tradin

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ACRONYMS/ABBREVIATIONS

USGS: United States geological survey
MASDAP: Malawi spatial data platform
GIS: Geographic information system
CEF: Conserve Energy Future
UNDP: United Nations development program
ADMARC: Agricultural development and Marketing Corporation
DEM: Digital elevation model
MCDA: Multicriteria Data analysis
FAO Classification: food and agriculture organisation classification

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1.0. INTRODUCTION

Solid waste is the non-liquid waste produced by different human activities such as commercial, industrial, domestic, agricultural, and biomedical. Solid wastes in urban areas mostly include wastes of plastics, glass, fabrics, metals, and kitchen waste which have complex composition and late degradable characteristics, creating more harm to the environment (conserve energy future(CEF), 2021).Solid waste management is a cross cutting issue that is facing both developed and developing countries and this has not spared Malawi. The general factors that lead to poor waste management in developing countries include high rate of urbanization, industrialization, population growth, and poor funding. Urbanisation, industrialization and population growth result in production of huge quantity of solid wastes which contribute greatly to environmental degradation. There are different ways of disposing wastes for example incineration, reuse, recycling, reduction and recovery of energy concepts with landfill being the oldest. The disposal of solid waste in landfills is still the most commonly used method in developing countries (Leao, Bishop, & Evans, 2004). Landfills are cheap but if constructed on unsuitable land can cause serious environmental problems including groundwater pollution through seepage making them expensive in the long run. Scientists have developed standard requirements for landfills which are studied physically, using multi criteria data analysis method and other methods. GIS based multi criteria analysis that uses secondary data allows the researcher to select suitable land for dumping wastes in a short time and saves money. The aim of this study is to select suitable sites that can be used as solid waste dumping sites in Lilongwe based on geotechnical factors for example situation of faults and permeability using multi criteria analysis.

1.1. BACKGROUND

Lilongwe is the largest city in Malawi with population 1,170,870 and one of the fastest growing districts in the country, (Namadzunda, 2010) this growth comes with major challenges dealing with waste. Urbanisation also brings pressure on waste management in the city. Lilongwe as a city has a hard time in managing solid waste manifested in polluted rivers and dirty streets and markets. The danger of poor waste management to the people of Lilongwe include increased risk of diseases like cholera, diarrhoea and respiratory infections. In 2018 the city transferred dumping site from Area 38 to Area 24 and 25.The reason they moved the dumpsites was because it was contributing to the spread of cholera in the area (Sangala, 2018). The study for suitable areas to be used as dumping sites in Lilongwe will help city council to open new dumpsites to greatly reduce waste disposal problems as the two dumpsites which were constructed in 2018 were expected to reduce poor waste disposal by 80 percent in the city (UNDP Malawi, 2018). This study will help to avoid encountering the same problems as people in Area 38 did because of location of dumpsite. Dumpsites have negative effects like unpleasant smell and vector for diseases but if well located and managed they are the cheapest way of waste disposal. Since waste management is burning issue in Lilongwe there is need for fast identification of other sites that can be suitable for waste disposal and which are environmental friendly therefore use of GIS based multi criteria analysis based on geotechnical criteria will help to quickly identify the sites.

1.2. PROBLEM STATEMENT

Waste management is a challenge for many countries but also in Malawi and one of the biggest challenges of Lilongwe city. Urbanization, industrialization and population growth has left Lilongwe town streets, drains, rivers, and markets full of wastes (below,





Fig 1 Lilongwe River, wastes dumped on river Bank; source: (Namadzunda, 2010)



Fig 2: KFC restaurant drain Lilongwe; source: (Sangala, 2019)



Fig 3: unauthorised waste disposal Site in Lilongwe; source (Sangala, 2018)

Fig 4: waste disposal depot (Stambuli, 2016)

The effects of these wastes on people and environment include bad smell, polluted water and hygiene diseases such as cholera and respiratory diseases. Since there is

excessive production of wastes this study is critical in the management of wastes as the available dum

1.3. Main objective

To identify suitable solid waste disposal sites that are environmental friendly.

1.4. Specific objectives

1.4.1. To identify potential solid waste disposal areas using multi criteria analysis based on, geotechnical criteria.

1.4.2. To classify potential waste disposal sites into various suitability categories.

1.4.3. To produce waste disposal suitability map of Lilongwe district.

1.5. Research questions

1.5.1. What is the geotechnical criteria and sub criteria for selecting suitable sites for waste disposal?

1.5.2. What suitability categories do the potential sites fall into?

1.5.3. Are there waste disposal suitability maps for Lilongwe district?

1.6. Significance of study

The aim of this study was to identify suitable areas for solid waste disposal in Lilongwe using GIS MCDA based on geotechnical criteria. The project will assist to reduce poor solid waste management and its effects on environment in Lilongwe by fast tracking the identification of suitable potential sites for waste disposal .There is crucial need to strategize on suitability of dumping sites in Lilongwe district, especially due to the high urbanization and population growth. Proper waste disposal site selection is the fundamental step in sound waste disposal and the protection of the environment, public health and quality of life. It determines many of the succeeding steps in the waste disposal process, which, if properly implemented, should ensure against adverse long-term effects on the environment. GIS (geographic information systems) are ideal for preliminary site selection studies because it can manage large volumes of spatially distributed data from a variety of sources and efficiently store, retrieve, analyse and display information.

2.0. LITERATURE REVIEW

Waste management is the collection, transportation, processing or disposal of waste materials usually the ones produced by human activities, in an effort to reduce their effect on human health. There several methods of waste disposal such as recycling, reusing, incineration, chemical, physical and biological treatment and landfills (Conserve Energy Future(CEF), 2021).The cheapest method of waste disposal in the world is landfill/dumps. The main causes of poor waste management include deficient municipal infrastructures, industrial and commercial growths, population growth and lack of financial management and logistics.

2.1. Solid waste management in the world

Around the world, waste generation rates are rising, in 2016 the worlds' cities generated 2.1 billion tonnes of solid waste, amounting to a footprint of 0.74 kilogram per person per day. With rapid population growth and urbanization, annual waste generation is expected to increase by 70% from 2016 levels to 3.40 billion tonnes in 2050 (WorldBankGroup, 2019) .Compared to those in developed nations, residents in developing countries, especially the urban poor, are more severely impacted by unsustainably managed waste. In low-income countries, over 90% of waste is often disposed in unregulated dumps or openly burned. These practices create serious health, safety, and environmental problems. Poorly managed waste serves as a breeding grounds for disease vectors and contributes to global climate change through methane generation. Managing waste properly is essential for building sustainable and livable cities, but it remains a challenge for many developing countries and cities.Until the environmental movement emerged in the 1960s, most unwanted materials were discharged to land, as open dumping, to air, as burning or evaporation of volatile compounds, or to water by discharging solids and liquids to surface or groundwater's or the ocean (Casanova, et al., 2009). There was little regard for the effects on drinking water resources and health of

those living nearby, because disposal was based on the idea that wastes decompose and return to the

2.2. Solid waste management in Malawi

The rapid increase in population and development activities in Malawi has over-stretched the capabilities of local authorities to manage wastes .In 2016 it was found that on average waste generation was 0.5kg/capita/day (Nyirenda, 2016).Dumping is used by cities but also by citizens in Malawi that legally or illegally dump waste in inappropriate places or burn them, thus emitting odorous smokes (Mkwambisi, 2007) .The method of open dumping , was adopted in Malawi because it is relatively cheap compared to other methods of disposal. In 2016 it was established that the city of Lilongwe generates about 109 metric tonnes of waste per day out of which 40% is from residential areas, 25% is from commercial areas, 15% from industries and 20% from hospitals (Nyirenda, 2016) .Since Lilongwe is one of the fastest growing cities in Malawi the levels of waste production have increased due to urbanization, population growth and industrialization putting pressure on waste management system.

2.3. Dumping site selection

As much as dumping is cheap compared to other waste management methods it has high environmental cost if not well situated, therefore need to follow standard criteria when selecting site for dumping. According to World Bank 1996 and 2004 reports respectively dumpsite sitting will depend on the following minimum factors topography, water bodies, protected areas, geology, seismic properties of area and fault status of area, (Cointreau, 2004).A geotechnical analysis will be done where factors like permeability ,geology, faults and seismic condition of area will help to determine its suitability. Geotechnical investigations are done by engineers and geologists to acquire information regarding the physical characteristics of rocks and soils. The purpose of geotechnical investigation is to design earth works and foundation for structures. Geotechnical investigations can be as simple as conducting a visual assessment of site or as detailed as computer aided study .Geotechnical investigations are vast discipline that include geophysical methods, geologic mapping and photogrammetry (geotechnical engineering,

n.d.). Parameters used in geotechnical investigation include faults, seismic conditions, slope or topogr

2.4. GIS Based Multi Criteria Data Analysis (MCDA)

GIS Based multi criteria data analysis process that transforms and combines geographical data and value Judgments (the decision-maker's preferences) to obtain information for decision making. The multi criteria data analysis (MCDA) uses primary as well as secondary datasets .As world's technology is advancing the initial steps for waste disposal sitting can be done on computer and the results found can be verified with field work and experiments. Suitability analysis is a GIS-based process used to determine the appropriateness of a given area (land resource) for a specific use, for example agriculture, forestry, business, urban development, livelihood projects and waste sites.

3.0. METHODOLOGY

3.1. Study area

Lilongwe is located in the central Region Malawi and it is the capital city of Malawi, bounded by -13° 58'00"S latitudes and 33° 47' 14" E longitudes. This area is located on a plateau with an average elevation of 1055.83m. (Geogrphic Coordinates of Lilongwe,Malawi, n.d.). Total area of the district is 6159 km^2 with average temperature of 32.3°C.

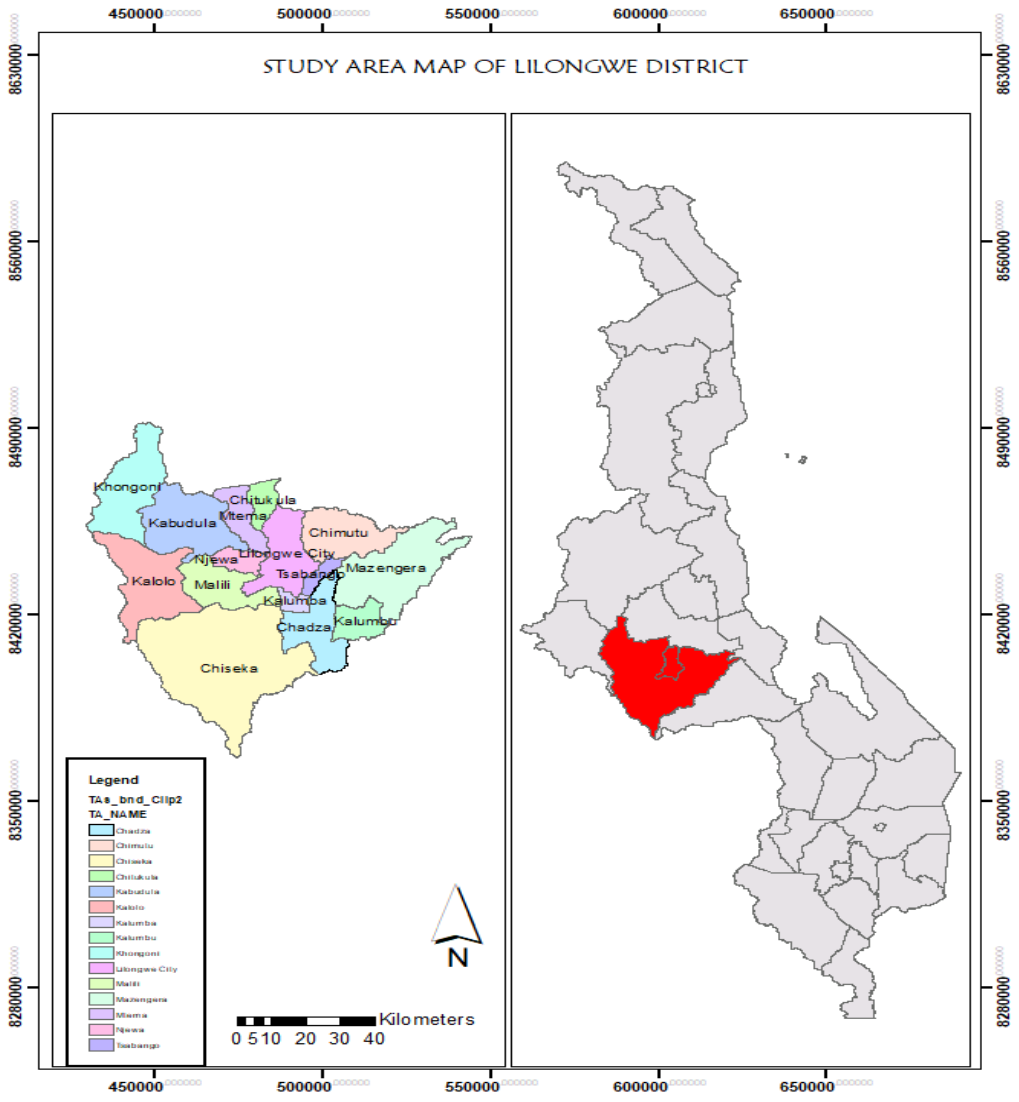

STUDY AREA MAP OF LILONGWE DISTRICT
450000
500000
550000
600000
650000
8630000
8560000
8490000
8420000
8350000
8280000
Khongoni
Chitukula
Mtema
Kabudula
Chimutu
Lilongwe City
Njewa
Tsabango
Mazengera
Kalolo
Malili
Kalumba
Chadza
Kalumbu
Chiseka
Legend
TA's_bnd_Clip2
TA_NAME
N
Kilometers
0 5 10 20 30 40

Fig 5: study area map: Lilongwe district

3.2. Research design

This research is descriptive. Descriptive research aims to accurately and systematically describe a population, situation or phenomena. A descriptive research uses a wide variety of research methods to investigate one or more variables. Unlike experimental research, the researcher does not control or manipulate any of the variables, but observes and measures them (McCombes, 2019).A methodological process called Multi Criteria Data Analysis (MCDA) was used in determining solid waste landfill areas for Lilongwe district and secondary data was used in the study. Decision analysis is a set of systematic procedures for analysing complex decision problems. MCDA is used to deal with the difficulties that decision-makers encounter in handling large amounts of complex information. The principle of the method is to divide the decision problems into smaller more understandable parts, analyse each part separately and then integrate the parts in a logical manner thereby produce a meaningful solution.

3.3. Materials and procedure

First of all, spatial data for identification of the solid waste disposal area was obtained from websites like USGS, MASDAP and ArcGIS 10.4.1 software by ESRI was used to analyse three types of data geological, geotechnical and environmental data. GIS MCDA was conducted, in the following process;

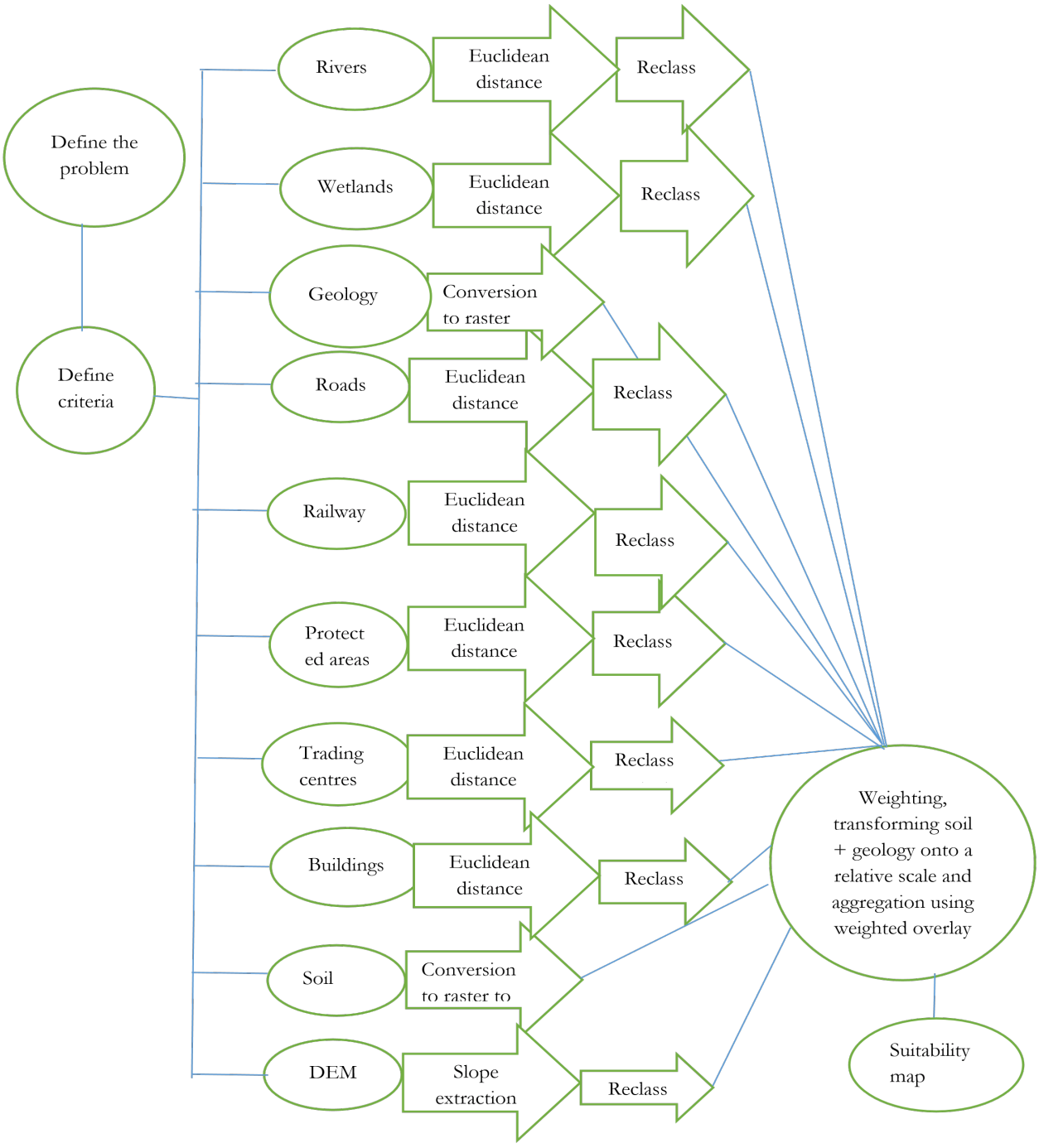

Define the problem
Define criteria
Rivers
Wetlands
Geology
Roads
Railway
Protect ed areas
Trading centres
Buildings
Soil
DEM
Euclidean distance
Euclidean distance
Conversion to raster
Euclidean distance
Euclidean distance
Euclidean distance
Euclidean distance
Euclidean distance
Conversion to raster to
Slope extraction
Reclass
Reclass
Reclass
Reclass
Reclass
Reclass
Reclass
Reclass
Reclass
Weighting, transforming soil + geology onto a relative scale and aggregation using weighted overlay
Suitability map

Fig 6: diagram showing research methodology

In brief the above process can be summarized in 3 steps set the goal/define the problem, determination of criteria and performing analysis. In detail the process started with defining the goal, the goal was to identify suitable solid waste disposal sites that are environmental friendly. Then the criteria (factors/constraints) was determined. The criteria used was adopted from World Bank Environmental requirements of which important factors to be considered for sitting a landfill are: slope, geology, geotechnical factors and other environmental factors (Cointreau, 2004) the limiting factors of the chosen criteria was land use.

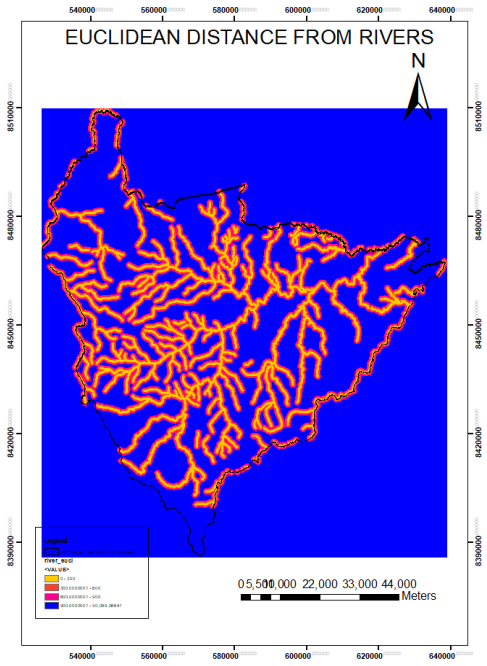
After the determination of criteria, Shapefiles were added to ArcGIS environment. The shapefiles that were added included river,wetlands,railway,protected areas, trading centres,buildings,roads,soil,geology,digital elevation model. Based on recommended distances Euclidean distance for river, wetlands, railway, protected areas, trading centres, buildings and roads was calculated using the Euclidean distance tool in arc tool box. From DEM slope was extracted and soil and geology layers were converted to raster using the raster conversion tool in arc tool box. Then the layers were transformed onto a relative scale using the reclass tool. The layers that were transformed onto relative scale using reclass tool include river, wetlands, railway, protected areas, trading centers, buildings, roads and slope while geology and soil were transformed onto a relative scale during weighted overlay analysis. On the relative scale 1 is not suitable, 2 less suitable, 3 suitable and 4 most suitable. Then lastly using weighted overlay tool weights were assigned to each criteria by rating and the weighted overlay tool run to produce suitability map.

4.0. RESULTS AND DISCUSSION

As earlier stated there are different factors that determine suitability of waste disposal site including distance from restricted areas and characteristics of soil and geology but also the steepness of an area.

4.1. Suitable distance from River

A river shapefile was added to arc GIS and using Euclidean distance tool the distance was calculated from rivers and it gave ten classes. Then classification into 4 classes was done, from 0-300m, 300-600,600 -900, greater than 900 this yielded a Euclidean map .Using reclassification tool the data was turned into raster and the four classes were assigned numbers (transformed onto a relative scale) 1 to 4 with 1 being not suitable, 2 less suitable, 3 suitable and 4 most suitable, another map was produced .The farther lands from river banks got more preferences for solid waste dumping site suitability because they prevent pollution of water sources caused by leachate. (Qureshi.S. et al, 3 March 2021)



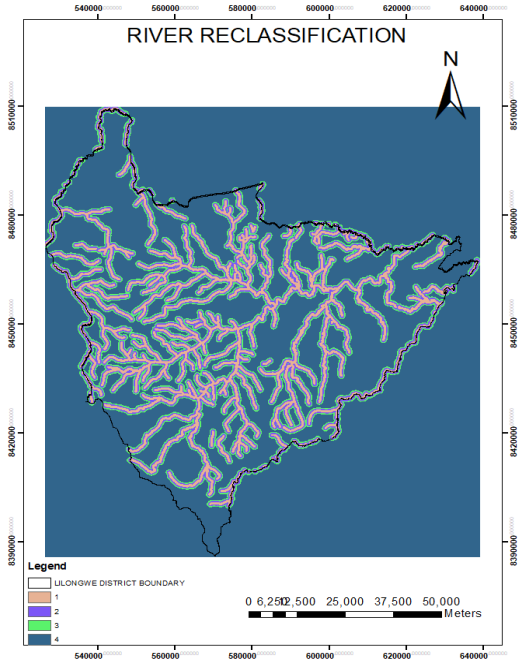


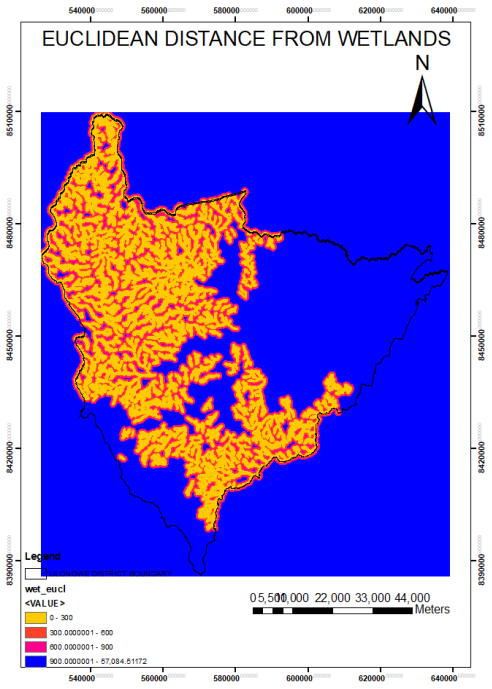
Fig 7 Euclidean distance from rivers

Fig 8: Reclassified river distance

4.2. Suitable distance from Wetlands

A wetland shapefile was added to arc GIS and using Euclidean distance tool the distance was calculated from wetlands and it gave ten classes. Then classification into 4 classes was done, from 0-300m, 300-600,600 -900, greater than 900 this yielded a Euclidean map .Using reclassification tool the data was turned into raster and the four classes were assigned numbers 1 to 4 with 1 being not suitable, 2 less suitable, 3 suitable

and 4 most suitable, another map was produced .



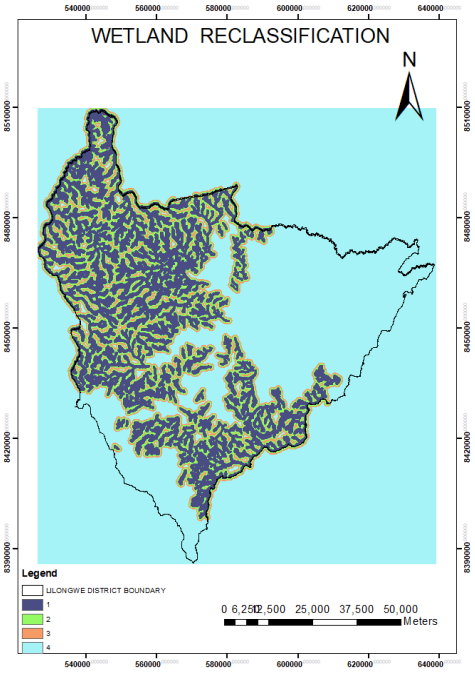
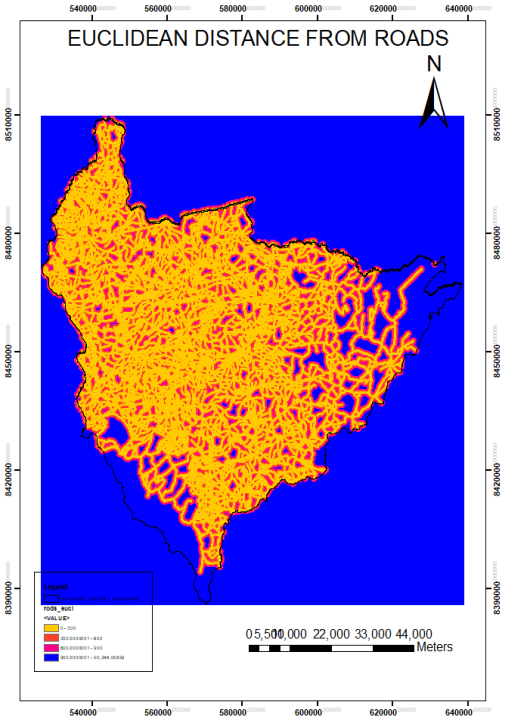


Fig 9 Euclidean distance from wetlands Fig 10: Reclassified wetland distance

4.3. Suitable distance from roads to solid waste dumping site

As the general concept, the landfills shall not be located within 100 m of any major highways, city streets or other transportation routes. Solid waste dumping site must be located at suitable distance from roads network in order to facilitate transportation and consequently to reduce relative costs. The added roads shapefile was classified into 4

classes from 0-300m, 300-600,600 -900, greater than 900 this yielded a Euclidean map .Using reclas



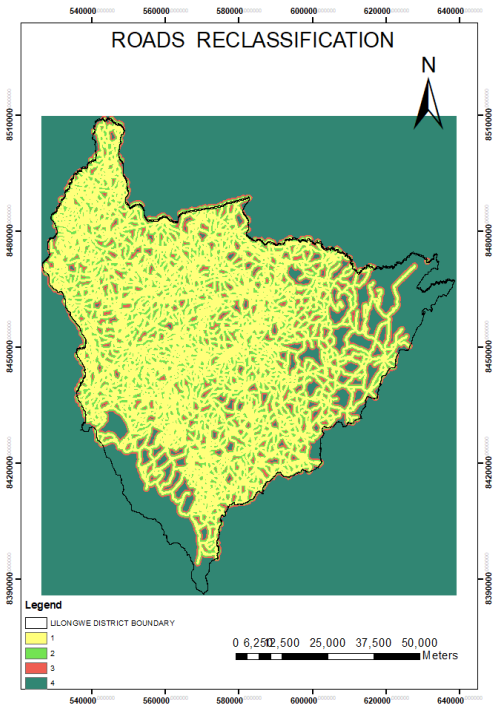


Fig 11 Euclidean distance from roads

Fig 12: Reclassified roads distance

4.4. Suitable distance from railway

As stated in the suitable distance of min roads Solid waste dumping site must be located at suitable distance from roads network in order to facilitate transportation and

consequently to reduce relative costs. The added railway shapefile was classified into 4 classes from

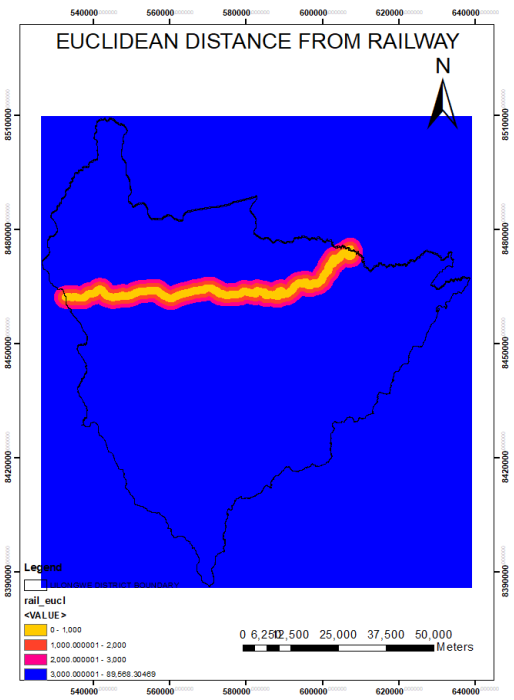


Fig 13 Euclidean distance from railway

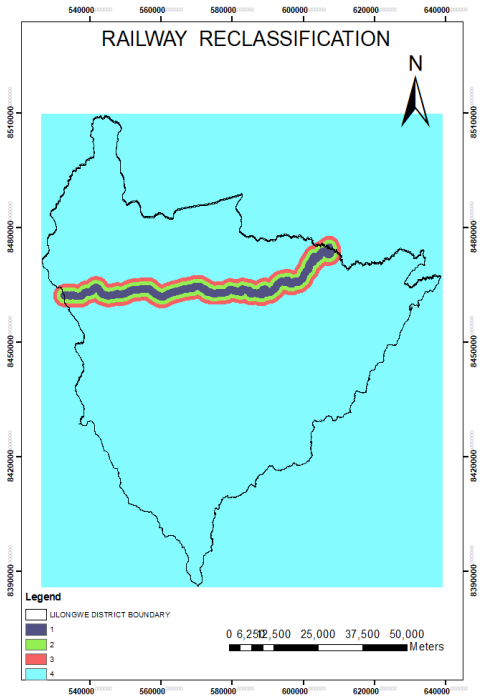


Fig 14: Reclassified railway distance

4.5. Suitable distance from trading centres

Solid waste dumping site must be located at suitable distance from trading centres bad smell and diseases. The trading centres shapefile was added to arc GIS and 10

classes were produced. The added trading centres shapefile was then classified into 4 classes from a

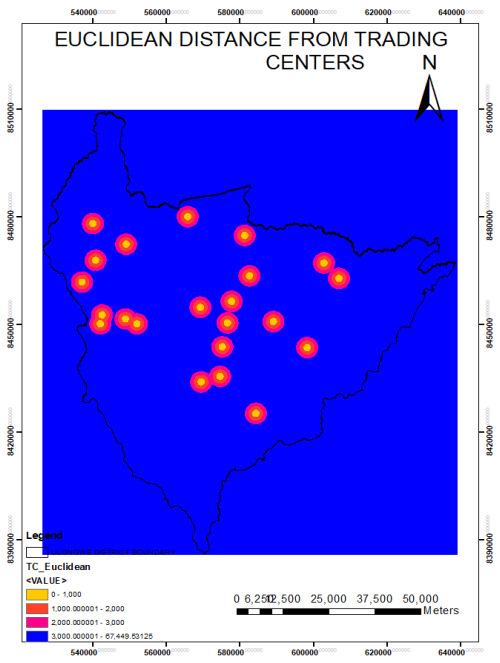


Fig15: Euclidean distance from trading Centres

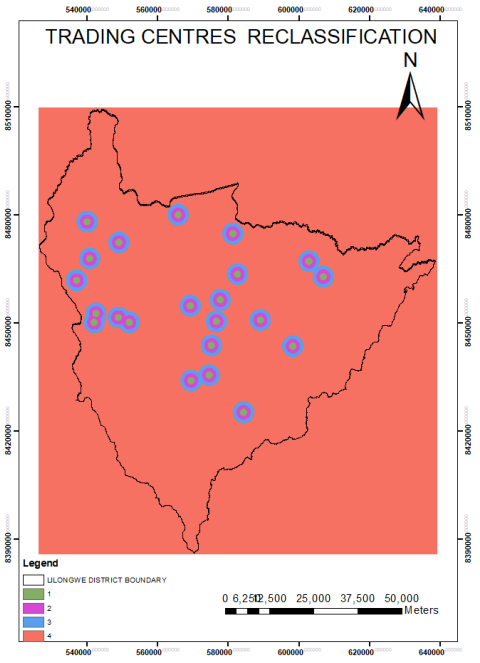
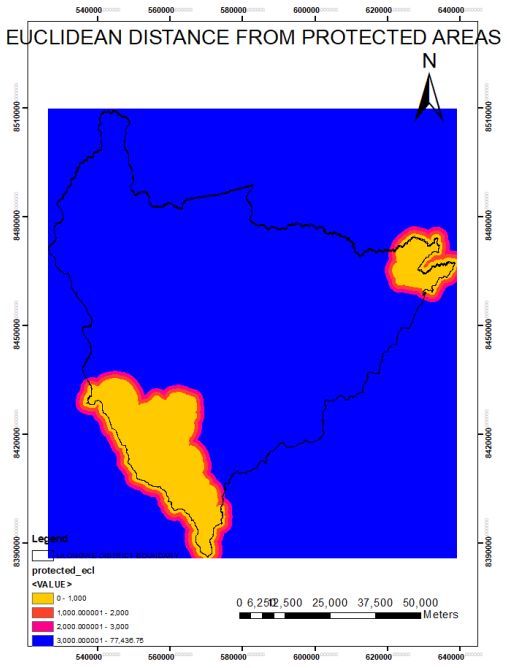


Fig 16: Reclassified trading centres distance

4.6. Suitable distance from protected areas

The protected area in this study includes reserves for example Dzalanyama reserve. The landfill should not be located in close proximity to sensitive areas listed above to limit of 1,000 m Euclidean distance. When the distance increases the suitability also

increases. The reclassified four classes were 1 to 4 with 1 being not suitable, 2 less suitable, 3 suitable



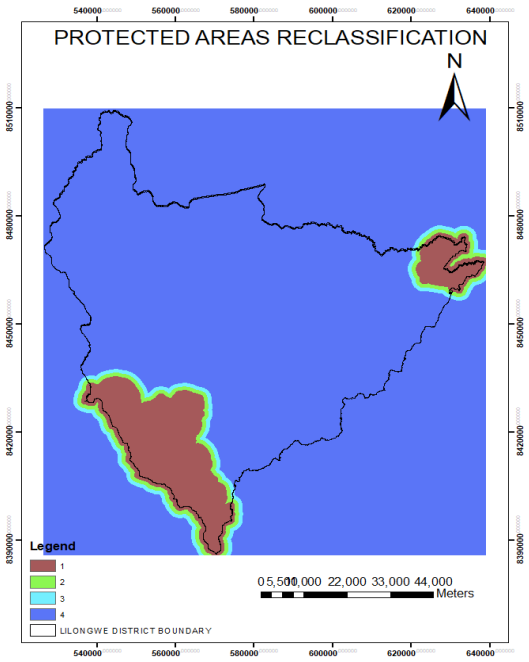


Fig 17 Euclidean distance from protected areas

Fig 18: Reclassified protected areas Distance

4.7. Suitable distance from buildings

The buildings include government buildings like schools, agricultural offices, anti-corruption beau, hospitals, civil offices, ADMARC just to mention a few. The Euclidean

distance was calculated and classified into four classes. The reclass tool in arc tool box was used to a

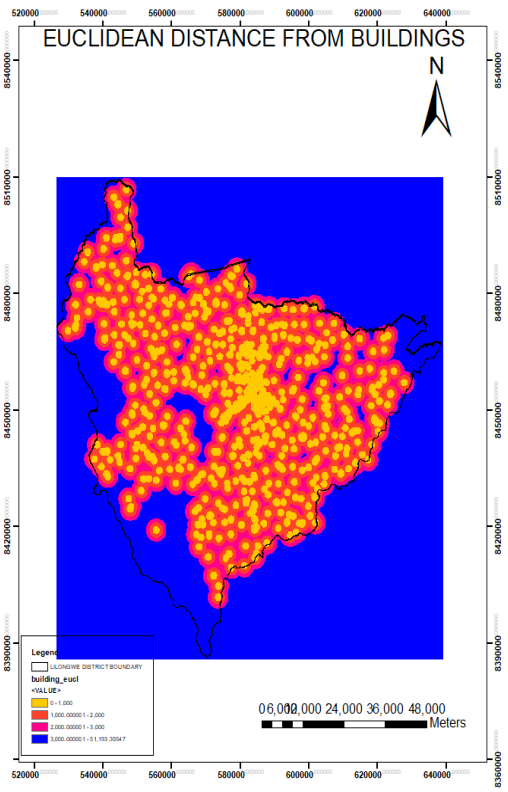


Fig 19 Euclidean distance from buildings

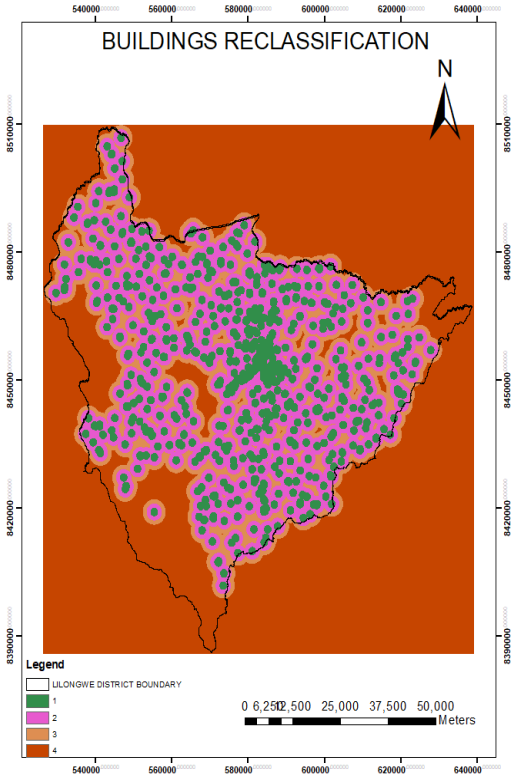
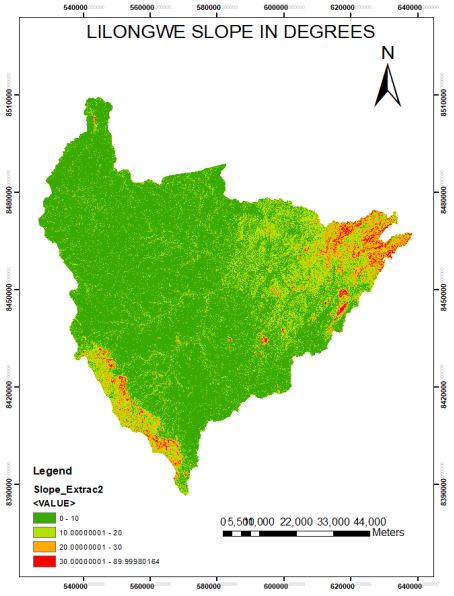


Fig 20: Reclassified buildings distance

4.8. Suitability of slope

This study considered the lower slope more highly suitable than the land with higher

slope. Different research shows that areas with high slopes will have high risk of pollution and potentia



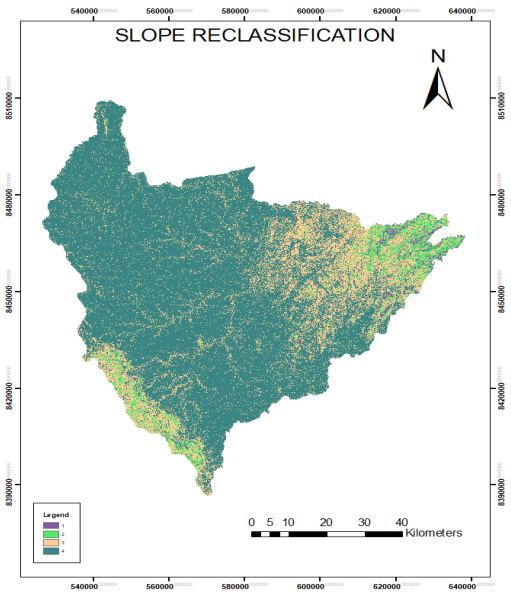


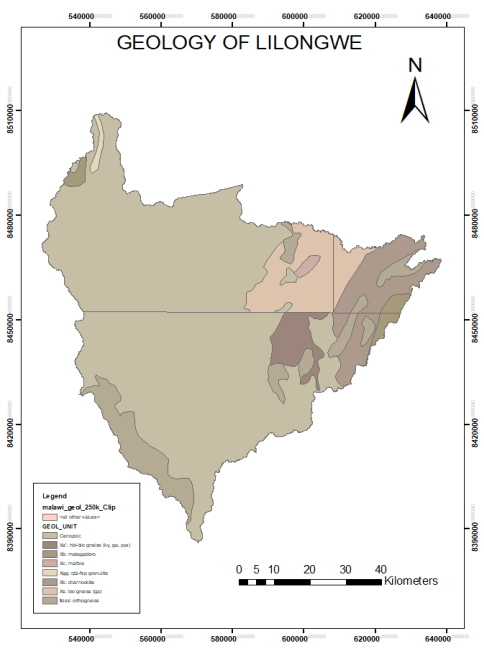
Fig 21: slope extract from DEM

Fig 22: reclassified slope

4.9. Suitability of geology

The analysis of geology included examination of geological formations and geological structures as well especially faults. Based on the geological map there are no faults in Lilongwe. The suitability of geological formations for waste disposal depends on its characteristics .The characteristics are as follows permeability, porosity and weathering. Geological units which have low permeability and are resistant to weathering are suitable for waste disposal site because to avoid seepage but also destabilisation of soil due to

weakening by weathering agents.



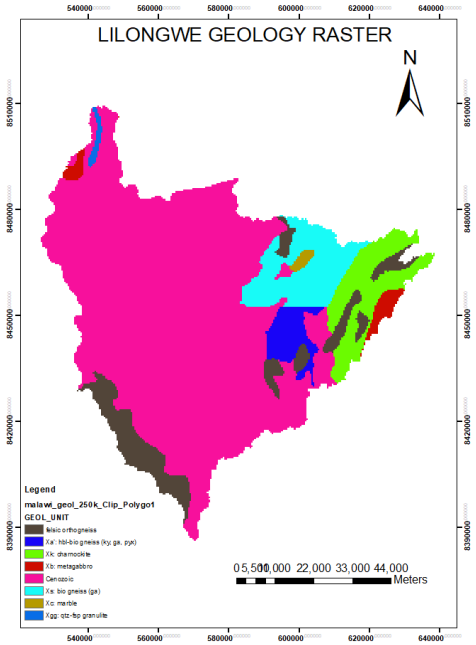


Fig 23: Geology of Lilongwe

Fig 24: geology raster

The table below shows characteristics of geological units of Lilongwe and their suitability

Geological unit	Characteristics	Suitability
Cenozoic	Sungwa comprises buff and brown pebbly sandstones and conglomerates ,chiwondo comprises series	Less suitable

	of dominantly grey and buff marls with sandy horizons of variable col	
Xa:hbl biotite gneiss(ky,ga,pryx)	Metamorphic rock, Impermeable, contains creamy white feldspar, quartz and dark minerals and typical for Lilongwe contains kyanite ,garnet,pryroxene	Suitable
Xb:Meta gabbro	metamorphic rock, contains orthopyroxene and plagioclase therefore weather faster	Not suitable
Xc:Marble	Metamorphic rock, Easily dissolved by water/prone to chemical erosion, major mineral calcite, impermeable	Not suitable
Xgg:qtz-fsp granulite	Metamorphic, Medium to course grained ,impermeable, contains quartz and feldspar	Most suitable
Xk:Charnockite	Metamorphic, contains orthopyroxene	Suitable
Xs:Biotite gneiss(ga)	Metamorphic rock, abundant in mica biotite, Contains garnet	Suitable
Felsic orthogneiss	Metamorphic (from igneous rocks), contains feldspar and quartz.	Most suitable

Table 1 geology of Lilongwe

4.10. Suitability of soils

There are different types of soils but there is specific kind of soil that is suitable for dumpsite .soil that has low permeability is preferred because there are low chances of seepage therefore avoid pollution of groundwater and adjacent soil. The characteristics of soil are listed in the table according to (Food and agriculture organisation(FAO), 2006) and they were studied to classify the soil into most suitable, suitable, less suitable and not suitable.

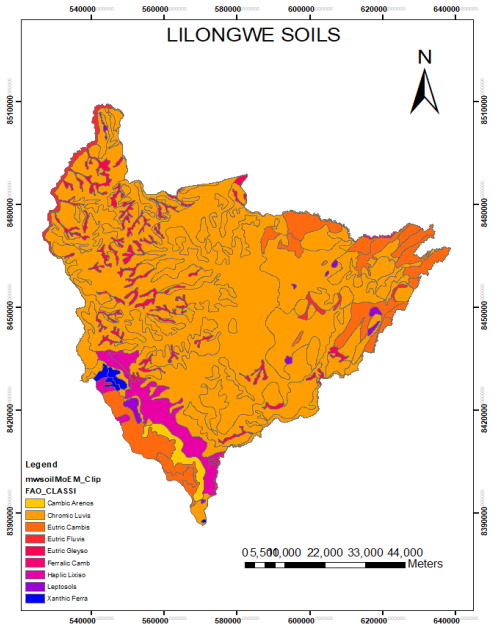


Fig 25 Lilongwe soils according to FAO Classification

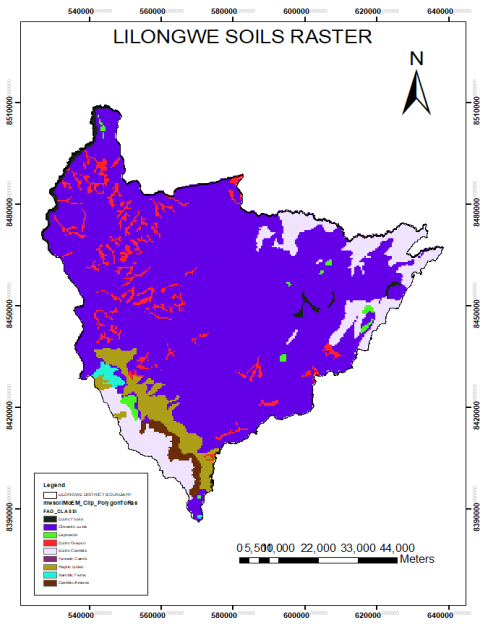


Fig 26: soil raster

Below is FAO soil classification of Lilongwe

Soil type	Characteristics	Suitability
Eutric Fluvis	Imperfectly drained, high chemical fertility (Very deep, poorly drained soils with a wide range in texture and colour. Moderate chemical fertility; pH)	Most Suitable
Chromic luvis	Good internal drainage, moderate stage of weathering, Coarse or medium textured,(Deep, well drained, dark brown, medium over medium to fine textured soils of moderate chemical fertility; pH)	Less suitable
Leptosols	Often contain large amounts of gravel, susceptible to erosion ,desiccation or water logging depending on climate and topography(Very shallow soils (< 30 cm) and/or soils with more than 80 % coarse mineral fragments)	Not suitable
Eutric Greyso	Very deep, poorly to imperfectly drained, grey soils with variable texture and low chemical fertility; pH(Very deep, poorly to imperfectly drained, grey soils with variable texture and low chemical	Most suitable

	fertility; pH)	
Eutric Cambis	Fine textured material, well drained(moderately deep, well drained, brown soils with coarse over medium texture, skeletal subsoil, and low chem	Not suitable
Ferallic Camb	Deeply weathered red or yellow soils.(Moderately deep, well drained, fine textured skeletal soils, of low chemical fertility; pH(0-50 cm)= 5.5-	Not suitable
Haplic Lixiso	Well drained, (Very deep, well drained, coarse over coarse to medium textured brown soils of very low chemical fertility ;)	Not suitable
Xanthic Ferra	Deep, well drained, yellowish brown, medium textured soils of very low chemical fertility; pH upper 50 cm	Less suitable
Cambic Arenos	Coarse textured ,well drained, low chemical fertility(Very deep, well drained, brown, coarse textured soils of very low chemical fertility; pH (0-50 cm) 5.0-6.5)	Not suitable

Table 2 soils of Lilongwe, FAO classification.

WEIGHTED OVERLAY AND IDENTIFYING SOLID WASTE DISPOSAL SUITABLE SITES

In many suitability analyses, some eligibility criteria are more important than others. Often, it is the expectation in a location search to be able to compare several suitable candidates whether, and how strongly, they meet a set of criteria of differing importance this is called weighting. One of the common method of weighting is rating. Here, the ranked criteria receive a score according to their relative importance. The overall score is to be distributed within the chosen criteria. For example, with a total score of 100, criteria could receive the weights 40, 25, 20, 10, and 5 points with decreasing importance. The most important criterion receives the highest score (for example 100) and the insignificant criteria receive a score of 0. This method is good because it is easy and quite popular. It is particularly suitable for problems with a few simple criteria whose relative importance can be estimated with common sense or expertise. However, the distribution of the scores is again subjective and often only poorly justified. (Flitter, Laube, Lüscher, Rogers, & Hägi, 2013) .As explained above the criteria was assigned score by rating as follows the restricting factors; rivers 10%, wetlands 10%, trading centers 10%, roads 10%, protected areas 10%, railways 10%, buildings 10% and determining factors as follows slope 10%, geology 10%, soil type 10% .Each factor has the same score because the used factors are almost equally important in waste disposal selection. After assigning criteria the weighted overlay tool was run and suitability map produced.

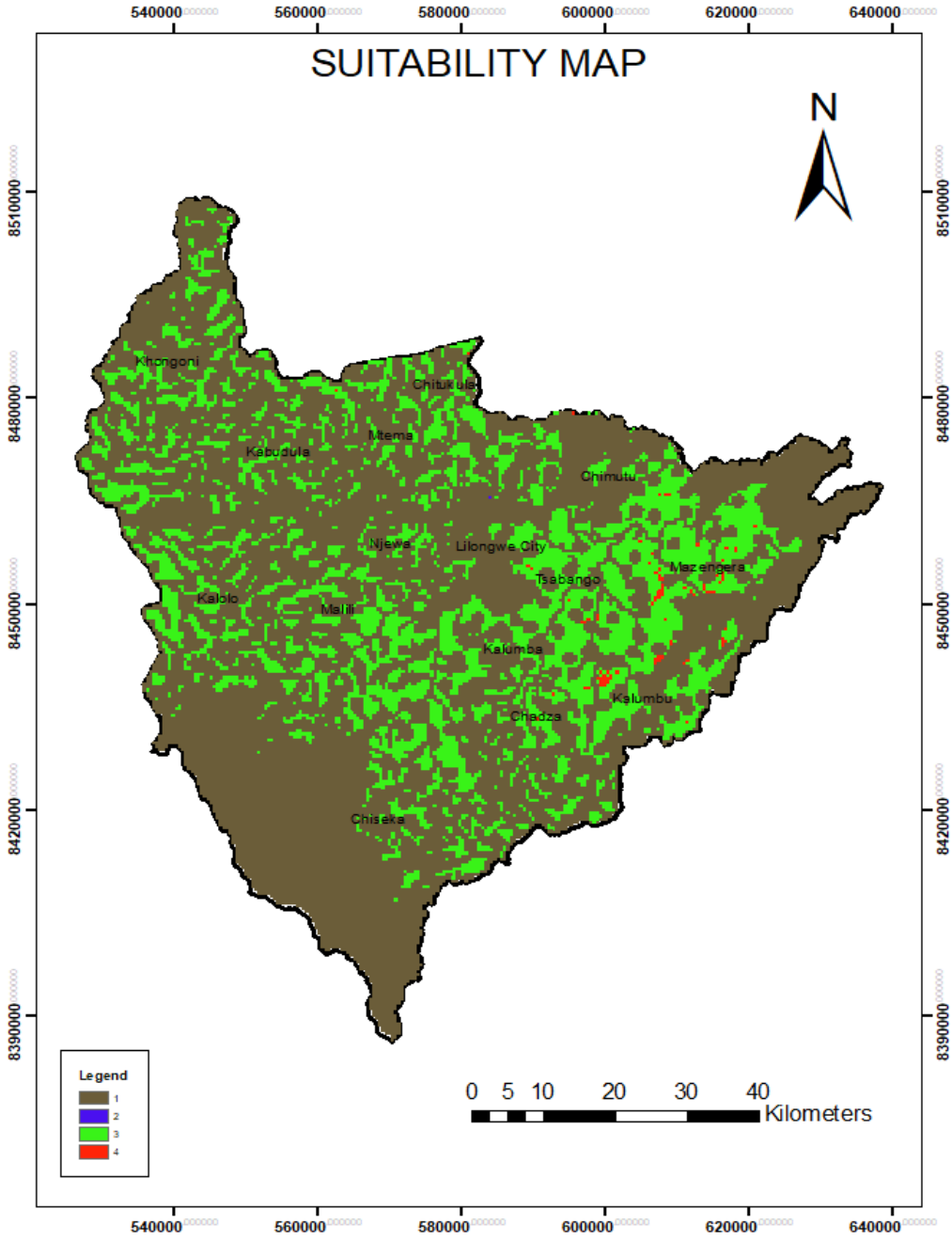

SUITABILITY MAP
N
540000
560000
580000
600000
620000
640000
8510000
8480000
8450000
8420000
8390000
Khongoni
Chitukula
Mtema
Kabudula
Chimutu
Njewa
Lilongwe City
Mazengera
Tsebango
Kabolo
Malili
Kalumba
Kalumbu
Chiadza
Chiseka
Legend
1
2
3
4
0 5 10 20 30 40
Kilometers

Fig 27: suitability map

5.0. CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

Locating a suitable waste disposal site/ landfill or correct locating is most effective method of taking care of the environment .A suitable site to be used as dumpsite has the following favourable characteristics impermeable and weathering resistant geology and soil, located far from faults, easily accessible and located far from hydrology and other water sources (Akbari D , 2011).The findings have shown the ability of GIS and as a tool for analysing the geotechnical criteria for decision support. The analysis has taken land use, slope, water sources, and settlement and transport facilities as deter-mining factor in order to find appropriate site for solid waste dumping site. The suitability map shows that 0.283 % of Lilongwe is most suitable(on relative scale has value 4) for solid waste disposal and 25.751% is suitable(on relative scale has value 3) 0.003% is less suitable(on relative scale has value 2) and 73.962% is not suitable(on relative scale has value 1). From the final map most suitable areas and suitable areas are found in the west part of Lilongwe city between Tsabango (east of Tsabango),Mazengera(south of Mazengera) Chimutu(south east of Chimutu),Kalumba(east of Kalumba),Kalumbu(south of Kalumbu) and Chadza (north east of chadza) traditional authorities. Hence, geotechnical analysis using GIS based MCDA for identification of suitable solid waste dumping site using geotechnical criteria will assist to minimize the environmental risk and human health problems.

5.2. RECOMMENDATION

Suitable areas and most suitable areas are desirable for dumping sites. The most suitable areas should be considered first in making dumpsites/landfills because the sites are easy to access; manage for disposal of solid wastes. These places are far away from any water sources and other variables put into analysis.The GIS geotechnical analysis is

just a preliminary study to fast track the identification of areas that can be used as dumpsites but there

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