

MALAWI UNIVERSITY OF SCIENCE AND TECHNOLOGY NDATA SCHOOL OF CLIMATE AND EARTH SCIENCE DEPARTMENT OF EARTH SCIENCES

ASSESSMENT OF SOIL EROSION AND SEDIMENTS ACCUMULATION IN KAMBENJE VILLAGE, MULANJE

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DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE BACHELOR OF SCIENCE DEGREE IN EARTH SCIENCE

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Date: May 29, 2025

DECLARATION

I Benson Manyenje declare that this research project represents my work and that it has never been submitted to this institution or any other institution for any academic purpose. All sources of information have been appropriately acknowledged.

Signature .....

Date: 29 May 2025

DISSERTATION APPROVED BY:

SUPERVISOR: McDonald Mtonda Signature: 

ASSESSOR: Signature: .....

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ABSTRACT

This dissertation investigates the critical environmental issues of soil erosion and sediment accumulation in Kambenje village, Mulanje district, Malawi, particularly in the aftermath of Cyclone Freddy in March 2023. The cyclone's extensive flooding increased pre-existing conditions of deforestation, unsustainable farming, and climate change, threatening agricultural productivity, water quality, and environmental sustainability. The study area, located in the southern part of Malawi, is characterized by steep slopes and is ecologically significant due to its proximity to the Mulanje Mountain Forest Reserve.The research employs a mixed-methods approach, combining qualitative and quantitative techniques. Field observations, GIS, remote sensing, and geotechnical lab analysis were used to assess the extent of soil erosion. Data collection involved generating a geological map using Arc GIS software, acquiring land use/land cover data from Sentinel-2, deriving slope data from a Digital Elevation Model (DEM), and obtaining annual rainfall data from the CHRS data portal (https://livingatlas.arcgis.com/landcoverexplorer/). Soil samples were collected and analyzed for particle size distribution, shear strength, porosity, and permeability to determine their contribution to soil erosion and sediment accumulation. The study's findings reveal that the soils in Kambenje Village vary in their susceptibility to erosion. Soils with a high proportion of fine particles and low shear strength are more prone to erosion while those with higher porosity and permeability exhibit greater resilience. The slope analysis indicates that steeper areas are at higher risk due to increased runoff velocity. Overall, the combination of factors such as land use practices, topography, and rainfall patterns significantly influence the rate of soil erosion and sediment accumulation in the area. The study concludes that addressing soil erosion and sediment accumulation in Kambenje Village is significant for maintaining agricultural productivity, water quality, and infrastructure integrity. It emphasizes the need for sustainable land management practices to mitigate soil loss and its associated environmental and socioeconomic impacts. Recommendations include a further study of soil erosion and sedimentation to prevent further degradation.

ACKNOWLEDGEMENTS

Firstly, I would like to thank God for granting me wisdom, strength, perseverance and faith to complete this dissertation and I would like to express my deepest gratitude to those who made this dissertation possible with their constant guidance and support, particularly my supervisor, Mr. McDonald Mtonda for his invaluable guidance and unwavering support throughout my research journey. I extend my gratitude to the staff members of the department of Earth Sciences who aided in data acquisition, which helped with completion of this work and MUBAS Lab technicians for conducting a geotechnical test for my samples. I am incredibly grateful for the enduring support and encouragement I got from my family and friends. This provided me with the strength and motivation to go on during challenging times

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Erosion and sediment accumulation present major environmental challenges in Mulanje (Panagos et al., 2024), which was severely affected by Cyclone Freddy in March 2023 reported by the International Federation of Red Cross and Red Crescent Societies (IFRC,2023). The cyclone caused extensive flooding, leading to soil erosion and sediment buildup, which caused considerable damage to water and sanitation systems, agriculture, and housing in Kambenje Village Group Village Head Kukada, T/A Mkanda in Mulanje.

According to a report by the Ministry of Agriculture, Irrigation and Water Development of Malawi, an estimated 40% of the land in Mulanje is affected by soil erosion, leading to loss of fertile topsoil, reduced crop yields, and increased sedimentation in rivers and streams. Kambenje village has experienced soil erosion and nutrient depletion for many years due to deforestation, unsustainable farming practices, and climate change. The region's topography, with steep slopes makes it particularly susceptible to soil erosion and sediment accumulation (Bannari et al..,2016).The flooding of Muluma river a distributary of Thuchila river caused by excessive rainfalls in the south eastern part of the village and the generation of a lot of runoff waters into different distributed streams enhanced the pre-existing soil erosion and sediment accumulation issues in Kambenje and the surrounding villages (Bates et al..,2008). In the upper course of the river, there exists a lot of erosion due to narrow water channel that forces the waters flood excessively on to the closely cultivated lands and they remove the vegetative covers, top and sub soils then deposit the removed soils and sediment downstream on flat surfaces(Duan et al..,2006).

1.1.1 STUDY AREA

The study area for this research is kambenje VillageT/ A Nkanda, in Mulanje district in the Southern part of Malawi. Generally on the eastern part of the village

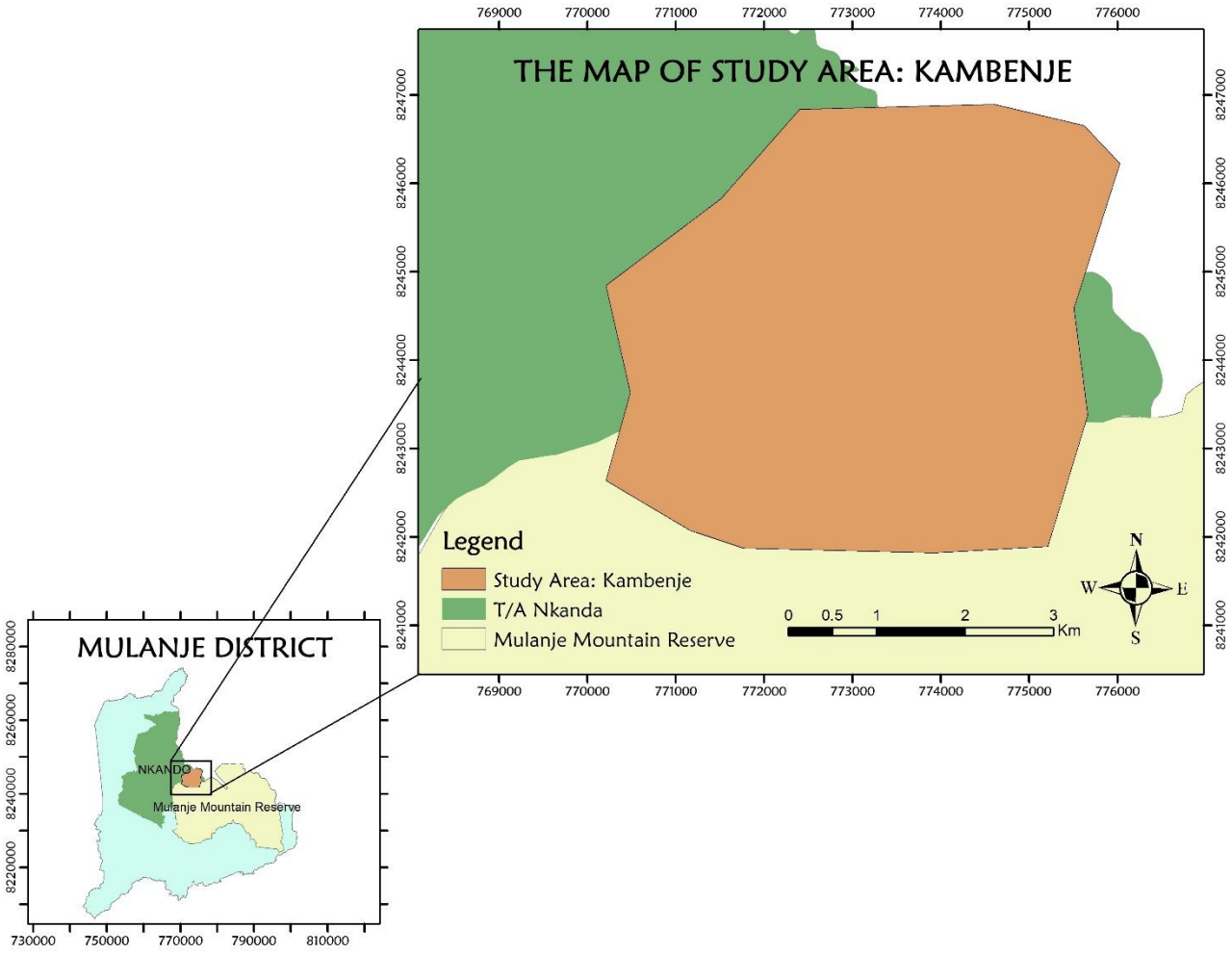


Figure 1 shows a study area Map of Kambenje village

1.2 PROBLEM STATEMENT

The rapid rate of soil erosion and sediment accumulation in Kambenje, Mulanje district poses a serious threat to agricultural productivity, water quality, and overall environmental sustainability in the area. Without proper assessment and management strategies, this issue keeps on increasing leading to negative effects on the local ecosystem and community livelihoods. Kambenje Village's soil erosion and silt buildup are serious environmental issues that need immediate attention and action. The Village is extremely vulnerable to soil erosion and sediment accumulation due to intense rains, steep slopes and poor land cover, which can have a major impact on infrastructure, agriculture, and water quality. Sediment accumulation is degrading the water quality where Sediments do carry pollutants such as heavy metals, pesticides, and nutrients, (Walling, 2006). This can lead to contamination of drinking water sources, harm to aquatic life, and degradation of overall ecosystem health. (Rozanov, 2005).

1.3 MAIN AND SPECIFIC OBJECTIVES

Main objective:

- The main objective of this study is to assess the extent of soil erosion and sediment accumulation in Kambenje Village.

The specific objectives of this study are:

- To analyze the factors contributing to soil erosion and sediment accumulation in Kambenje Village
- To develop a soil erosion model that shows soil erosion and sedimentation distribution in Kambenje Village.
- To encourage sustainable land management practices that can mitigate the impacts of soil erosion and sediment accumulation in the Kambenje Village.

1.4 RESEARCH QUESTIONS

The research questions for this study on erosion and sediment accumulation in Kambenje Village includes:

- What is the extent and severity of soil erosion and sediment accumulation in Kambenje Village?
- How to develop a soil erosion model that shows soil erosion and sedimentation distribution in Kambenje Village.
- How sustainable land management practices can mitigate the impacts of soil erosion and sediment accumulation in the Kambenje Village

1.4 SIGNFICANCE OF STUDY

Assessing soil erosion and sediment accumulation in Kambenje Village can have significant implications for both the environment and human activities. Some of the potential significance includes:

Improved Agricultural productivity as Soil erosion can reduce the fertility of agricultural land, leading to decreased crop yields and economic losses for farmers. By monitoring and addressing erosion, farmers can implement soil conservation practices to maintain soil health and productivity

Minimized Infrastructure and property damage: Soil erosion can pose risks to infrastructure such as roads, buildings, and pipelines, leading to damage and potential safety hazards. By assessing erosion and sediment accumulation, preventative measures can be taken to protect infrastructure and property from erosion-related damage.

Good Water quality: Sediment accumulation in water bodies can degrade water quality by increasing turbidity and nutrient levels, which can harm aquatic organisms and wildlife. By assessing erosion and sediment accumulation, measures can be taken to prevent or minimize these impacts on water quality.

CHAPTER 2: LITERARTUER REVIEW

Soil erosion is a global environmental problem that disturbs the sustainability

Agricultural systems, decreases water quality, and contributes to land degradation. The remove and transport of soil particles by water and wind disturbs the ecosystem, affecting food security and livelihoods (FAO, n.d.). In many developing countries, including Malawi, the problem is increased by a combination of factors such as reliance on rain-fed agriculture, deforestation, and increasing population pressure. This literature review focuses on the assessment of soil erosion and sediment accumulation, specifically in Kambenje village in Mulanje District, Malawi. This area is ecologically significant due to its closeness to the Mulanje Mountain Forest Reserve and faces unique challenges related to its topography and land-use practices. Steep slopes, common in mountainous areas like Mulanje, further accelerate runoff and erosion. Additionally, the weathering of rocks in tropical climates can produce soils that are more susceptible to erosion (Lal, 1990). Understanding the dynamics of soil erosion in this area is important for developing effective land management strategies and mitigating soil erosion and sedimentation (Walling, 1996).

Soil erosion is as the process by which soil is removed from its original location and transported to another location (Montgomery, 2022). The main causes of soil erosion include natural factors such as rainfall, wind, and gravity, as well as human activities such as deforestation, agriculture, and construction (Johnsen et al., 2019; Morgan et al., 2018; Steffen et al., 2018). Deforestation for firewood and agricultural expansion further increases the problem (Climate change and adaptation strategies: a case study of the Mulanje Mountain Forest Reserve and its surroundings Malawi - International Institute for Environment and Development). Sediment accumulation, on the other hand, refers to the deposition of eroded sediment in downstream water bodies, leading to pollution and habitat degradation (Govers et al..., 2022). Both soil erosion and sediment accumulation can have negative impacts on water quality, aquatic ecosystems, and the productivity of agricultural lands (Chipojola et al., 2019).

Several studies have shown the relationships between soil erosion, sedimentation, and land degradation. For example, a study by Smith et al. (2016) found that high rates of soil erosion in agricultural areas led to decreased soil fertility, reduced crop yields, and increased sedimentation in nearby water bodies. Similarly, a study by Jones and Johnson (2018) demonstrated that urban development and construction activities were major drivers of soil erosion and sedimentation in watersheds, resulting in increased flood risks and water pollution.

Slope is a major factor that affects soil erosion. Steep slopes are more prone to erosion as they increase the speed at which water flows over the soil surface, leading to greater erosion. In a study by Montgomery and Dietrich (1994), they found that slope

steepness was the most important factor influencing erosion rates, with steeper slopes experiencing higher rates of erosion.

Rainfall is another key factor that can impact soil erosion. Intense rainfall events can cause soil particles to be dislodged and transported away, leading to erosion. In a study by Wischmeier and Smith (1978), they found that the erosive power of rainfall is influenced by its intensity, duration, and frequency. Areas with high amounts of rainfall are more susceptible to erosion compared to areas with less rainfall.

Land use practices can also have a significant impact on soil erosion. Clearing of forests for agriculture or development can expose the soil to erosion, while improper agricultural practices such as overgrazing and plowing can also contribute to erosion. In a study by Lal (2003), he found that land use changes such as deforestation and agriculture can lead to increased erosion rates.

Geology plays a role in soil erosion as well. The type of rock and soil present in an area can affect its susceptibility to erosion. In a study by Trimble (1974), he found that the geology of an area could influence the erodibility of the soil, with certain types of rock and soil being more prone to erosion.

Another key factor that influences soil erosion is soil porosity. Porosity is the measure of the void spaces within soil, which can affect the movement of water and air through the soil (Dane & Topp, 2002). Soils with high porosity have more void spaces, allowing water to infiltrate more easily and reducing surface runoff. This can help to minimize soil erosion by reducing the amount of water flowing over the soil surface and carrying soil particles with it.

Permeability is another important property that affects soil erosion. Permeability is a measure of how easily water can move through soil, and it is influenced by factors such as soil texture, structure, and porosity (Brady & Weil, 2008). Soils with high permeability allow water to infiltrate quickly, reducing the likelihood of surface runoff and erosion. On the other hand, soils with low permeability may experience more surface runoff, leading to increased soil erosion.

Shear strength is also a critical factor in soil erosion. Shear strength is the resistance of soil to deformation or failure under applied forces, such as water flow or wind (Mitchell, 1993). Soils with higher shear strength are more resistant to erosion, as they are better able to hold their structure and resist movement of soil particles. In contrast, soils with low shear strength are more prone to erosion, as they may easily break apart and be carried away by water or wind.

Using GIS Software Google earth Map, a satellite image was captured where the desired study area was demarcated and digitized using Arc GIS. With the use of Arc GIS A study area Map, slope Map, Geological Map, Land use/cover Map and a Rainfall Map was

produced to analyze how they affect or contributes to soil erosion and a soil erosion Model was produced and key measures to mitigate the impacts of soil erosion was implemented.

This dissertation aims to address this gap by Conducting a comprehensive assessment of soil erosion and sediment accumulation rates in Kambenje, Identifying the key factors driving soil erosion in the area, including land-use practices, topography, and rainfall patterns, Evaluating the effectiveness of current land management practices in mitigating soil erosion, Providing recommendations for sustainable land management strategies to minimize soil loss and its associated environmental and socioeconomic impacts.

CHAPTER 3: METHODOLOGY

3.1 RESEARCH DESIGN

The research employed a Qualitative and quantitative approach, where data was collected through field observations, using GIS and remote sensing and samples were taken for further analysis at the geotechnical lab.

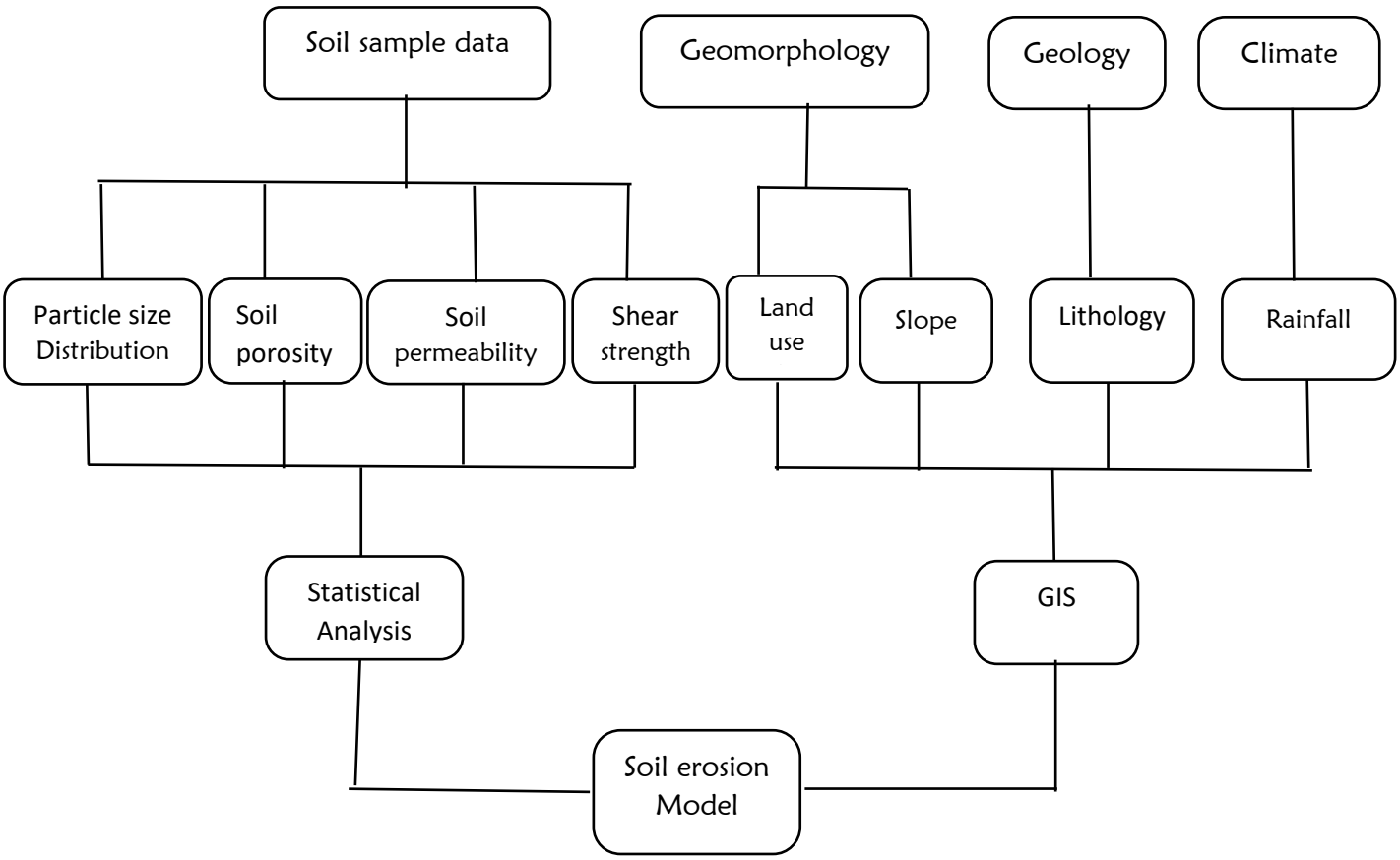


Figure 2 shows a flow chart of the methodology and used parameters

3.2 MATERIAL

- Data Sources and Analysis

This section contains details from various data sources utilized in this dissertation and the methods employed for their analysis, primarily using field surveys and GIS software.

Google earth Map was used to capture satellite image that was used to create a study area map and all the maps produced, and Arc GIS software was used to map the study area and generate a geological map, Rainfall data map, slope map and a land use map to help in identifying the factors affecting or contributing to the erosion and sediment accumulation in the village.

- Primary data collected

Field survey helped in the collection of samples and general characteristics of the area under study. Notable traces of rills and gullies were spotted and generally, the area is used for crops cultivation i.e. maize, legumes and bananas. Trees were partly planted in places that were eroded and deposited with sediments and along the Muluma River.



Figure 4 shows a Trace of a Gully caused by erosion



Figure 3 shows an area with sediments deposited

3.3 METHODS

I. DATA COLLECTION USING GIS

a) Geological Map

A geological map of the study area was generated using Arc GIS software where the desired study area was clipped and digitized to understand the influence of bedrock type on erosion susceptibility.

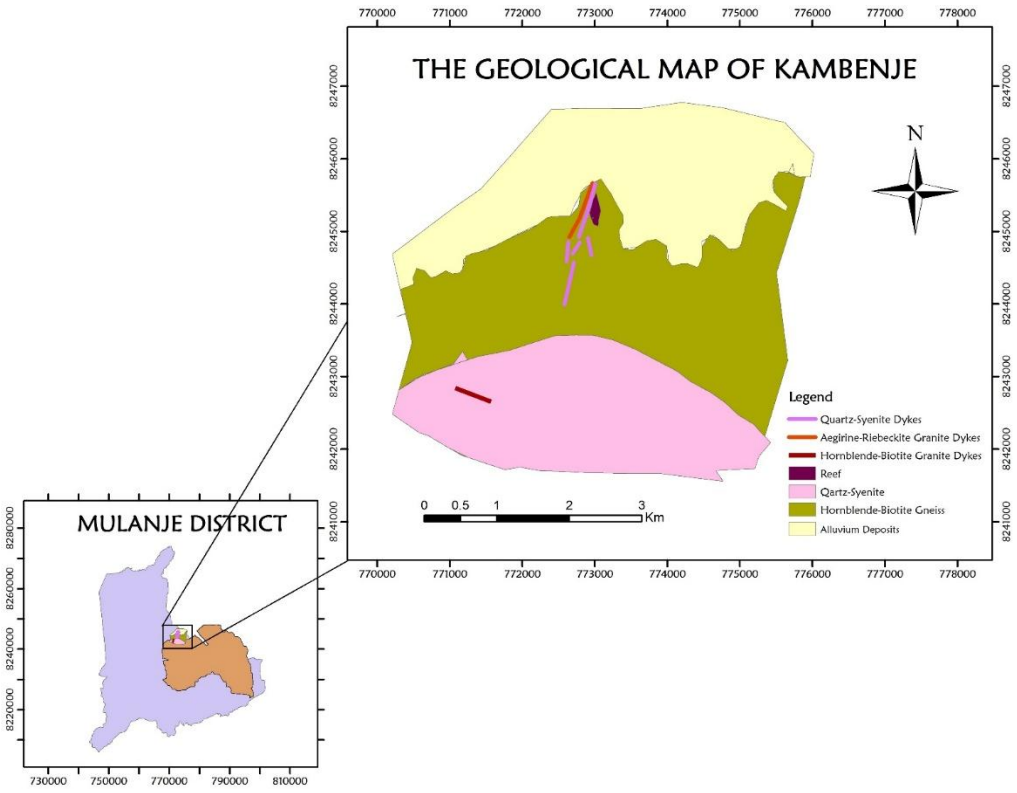


Figure 5 shows a Geological map of Kambenje village

b) Land Use/Land Cover

High-resolution land use/land cover data of the year 2024 for the study area was acquired from the Sentinel-2 10-meter Land Use/Land Cover collection accessible through the Living Atlas of ArcGIS Online (https://livingatlas.arcgis.com/landcoverexplorer/). This data provides land cover classifications at a fine 10-meter resolution. The downloaded tiles were merged using ArcGIS tools to create a seamless land cover dataset for further analysis, which involved clipping and creating the entire map components using the Arc GIS.

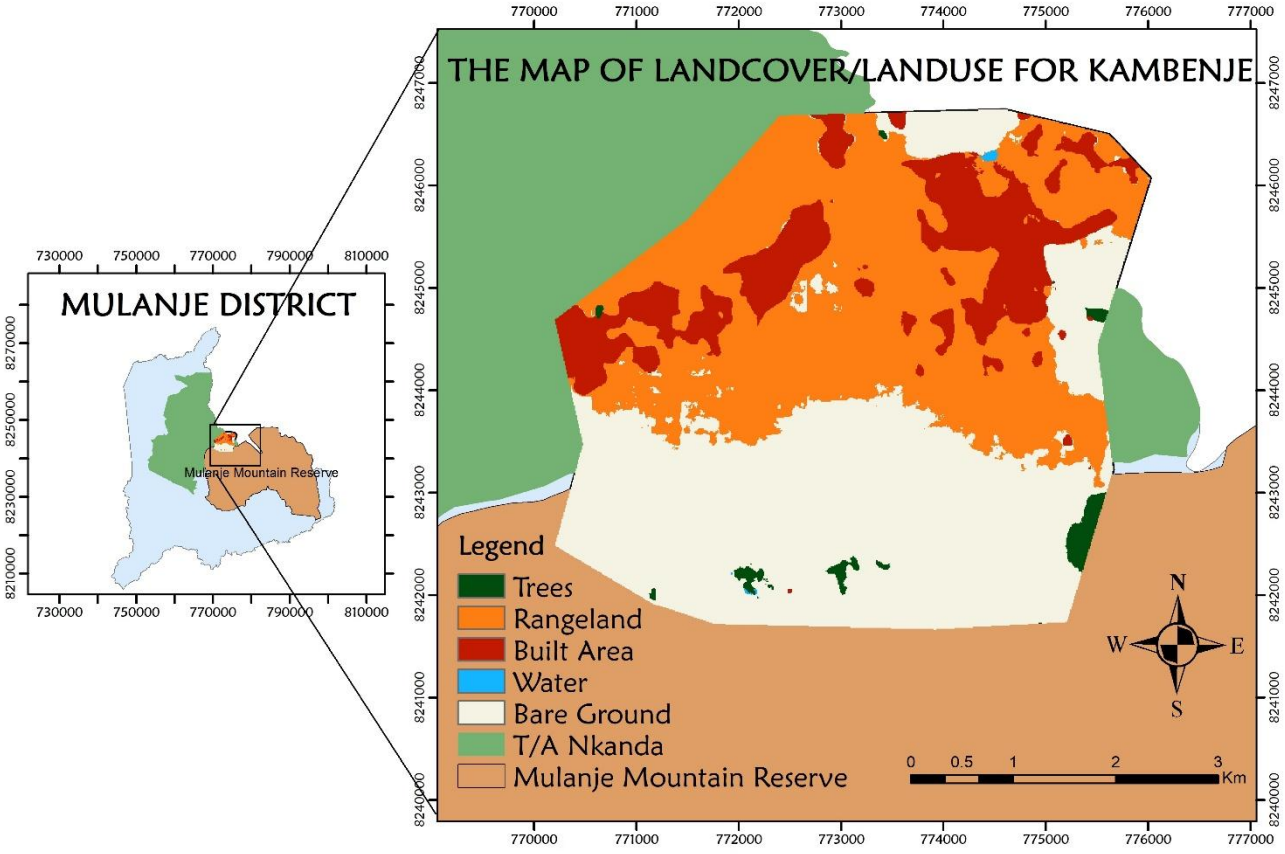


Figure 6 Shows a Land use/cover Map of Kambenje village

c) Slope

Slope data for the study area was derived from a Digital Elevation Model (DEM) using spatial analyst tools in ArcMap. The Slope tool was employed to calculate the gradient for each cell in the DEM, resulting in a raster layer representing the slope inclination across the area.

All data layers were clipped or extracted covering Kambenje Village, and then georeferenced within the Arc GIS software, using the Universal Transverse Mercator (UTM), World Geodetic System (WGS 1984) and 36S Zone Projection Systems. For an easy overlay analysis, Polygon layers were rasterized (soil and geology) and the layers were resampled to match the spatial resolution of land use/ land cover.

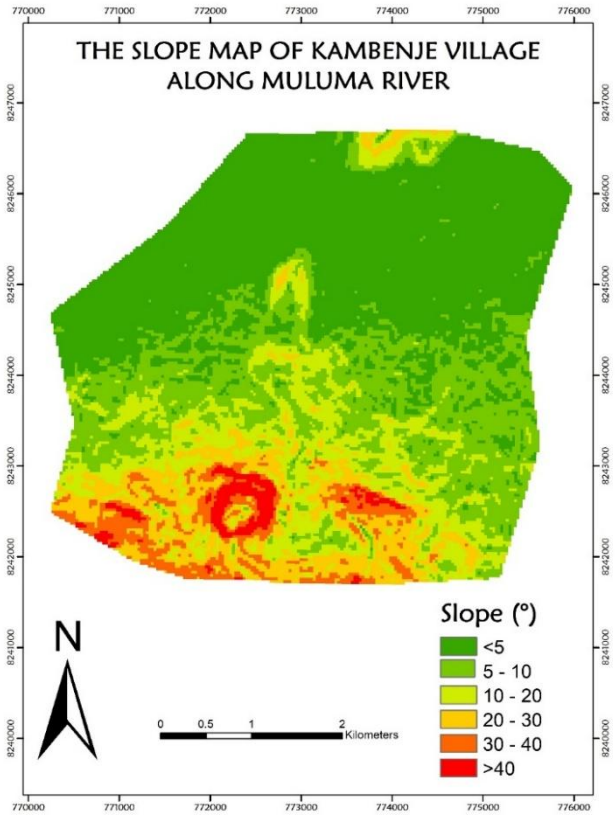


Figure 7 Showing a Slope Map of Kambenje village

d) Rainfall Data

Annual rainfall data from the year 2024 for Mulanje district was obtained from the CHRS data portal (Center for Hydrometeorology and Remote Sensing), (https://chrsdata.eng.uci.edu/) to assess the role of precipitation intensity and duration in driving erosion. The map clearly shows a significant variation in rainfall across kambenje village. The rainfall ranges from 0-0.5 mm/day (lightest blue) to 1.6-2mm/day (darkest blue).

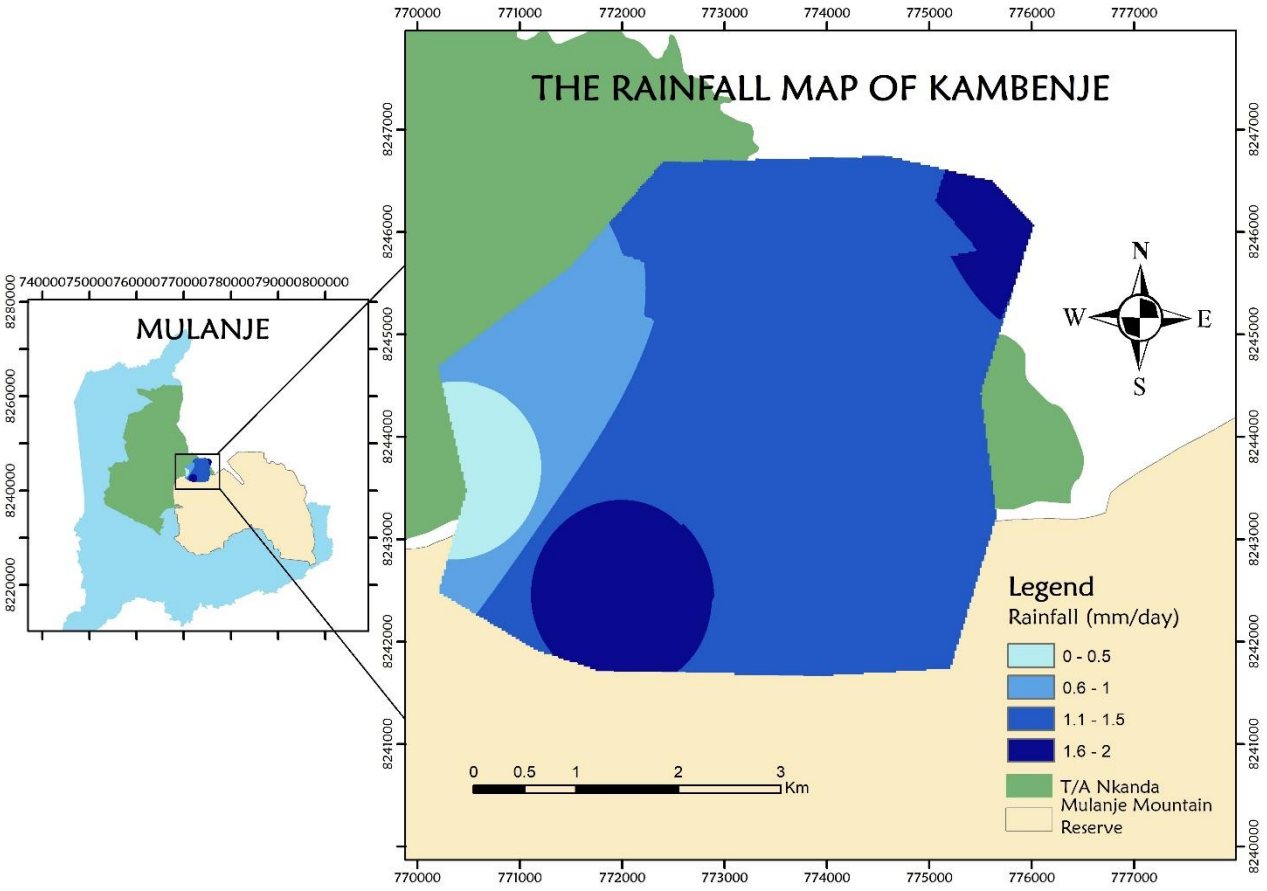


Figure 8 Showing rainfall distribution Map

II. SOIL SAMPLES

Using a GPS, A hand auger and sample bags, 2 soil samples weighing 10kg each were collected (sample A and C) at a 1m depth at two different sample points and been tested at the Lab .





The following parameters were then tested:

i. Particle Size Distribution

Soil particle size distribution refers to the proportion of different sized particles present in the soil. Sieve method was used to determine the size of the particles hence the type of the soil. These particles can range from very large, such as gravel, to very small, such as clay particles. The distribution of these particles can have a significant impact on the soil's ability to resist erosion and sedimentation. In the sieve method, particle size distribution is determined by passing a sample through a series of nested sieves with progressively smaller openings. The sample is initially placed on the top sieve, which has the largest opening, and shaken for a specific amount of time to allow particles to pass through according to their size. The material retained on each sieve is weighed, and the percentage of material passing

through each sieve is calculated. The data collected from the sieving process is used to plot a particle size distribution curve, which shows the percentage of the sample that falls within different size ranges. This curve provides valuable information about the particle size distribution of the sample, including the mean particle size, size range, and overall distribution.

ii. Shear Strength

Shear strength is typically measured in the lab using a method called direct shear testing. In direct shear testing, a sample of soil or another material is placed in a shear box apparatus, which consists of two separate compartments that are pushed together horizontally, creating a shear plane through the sample. A normal force (normal stress) is applied to the sample, which compresses it and creates shear stress along the shear plane. The shear force required to cause the sample to fail is then measured, and the shear strength of the material can be calculated by dividing the shear force by the cross-sectional area of the sample. Direct shear testing is a common method used in geotechnical engineering and soil mechanics to determine the shear strength parameters of soils and other materials

iii. Soil Porosity

Soil porosity is the volume of pore spaces within a soil sample, expressed as a percentage of the total volume of the sample. The saturation method is a common technique used in the lab to measure soil porosity. To measure soil porosity using the saturation method, a soil sample is collected and dried in an oven to remove all moisture and the dry weight of the soil sample is then recorded. Then, the dried soil sample is placed in a container with known volume, and the container is filled with water to saturate the soil sample. The container is then weighed to determine the total volume of the soil sample and water. After that, the container is then drained to remove excess water and the weight of the saturated soil sample in the container is recorded. The porosity of the soil sample is calculated using the following formula; Porosity = (Volume of water / Total volume of the sample) x 100 where this calculation gives the percentage of pore space within the soil sample.

iv. Soil Permeability

Soil permeability refers to the ability of soil to allow water to pass through it. The size, shape, and arrangement of soil particles, as well as the presence of organic matter

determine it. Soils with high permeability allow water to infiltrate quickly, while soils with low permeability cause water to pool on the surface. Permeability ranges with the type of soil. Soil permeability can be measured in the lab using the constant head permeability test method. In this method, a soil sample is placed in a permeameter and water is allowed to flow through the sample under a constant head. By measuring the rate of flow of water through the sample and the applied head, the permeability of the soil can be calculated using Darcy's law. The constant head permeability test involves placing a soil sample of known dimensions is in a permeameter and then constant head of water is applied to the top of the soil sample. The rate of flow of water through the soil sample is measured over a period of time and the permeability of the soil is calculated using Darcy's law, which relates the flow rate, head, and soil properties. Permeability ranges from Gravel and sand: 0.1 - 0.001 cm/s, Silt: 0.001 – 0.0001 cm/ and Clay: 0.0001 – 0.0000001cm/s.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 RESULTS

i. Particle size distribution for Sample A

Below is the graph produced from a sieve analysis of sample A

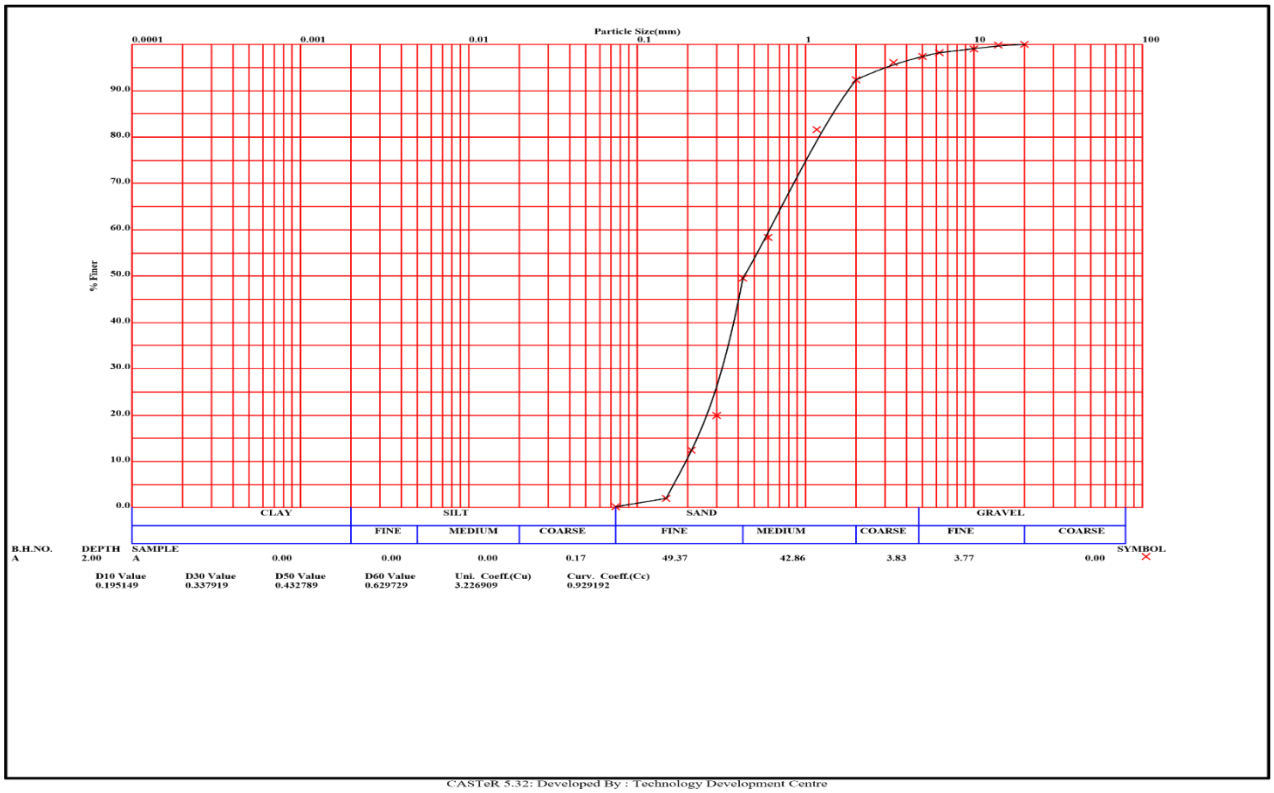


Figure 9 showing a Particle distribution graph

ii. Direct shear strength for sample A

The data and table below represents results for sample A after Lab testing:

Table 1 showing direct shear test for sample A

NORMAL STRESS(N)	PROVING RING READING	SHEAR FORCE(N)	SHEAR STRESS(Kpa)	DISPLACEMENT(mm) (Maximum)
20	17	142.8	39.67	1000
40	19	159.6	44.33	1300
60	22	184.8	51.33	1500

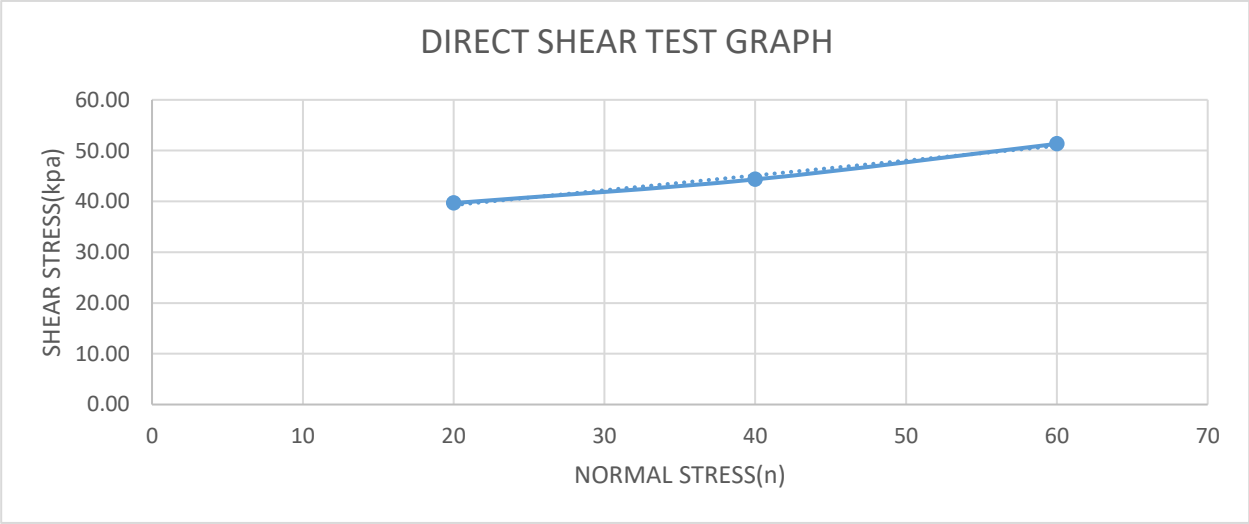


Figure 10 showing a Shear strength graph for sample A

- Cohesion Intercept (C') for sample A is 33 and the Angle of Shearing Resistance (Ø) is 16° where the area (m^2) =0.0036, the volume =0.000108 and the ring factor =8.4

iii. Direct Shear Strength for Sample C

Table 2 below showing direct shear test for sample C

Normal Stress(N)	Proving Ring Reading	Shear Force(N)	Shear Stress(Kpa)	Displacement(Mm)(Maximum)
20	18	151.2	42.00	1100
40	21	176.4	49.00	1200
60	23	193.2	53.67	1400

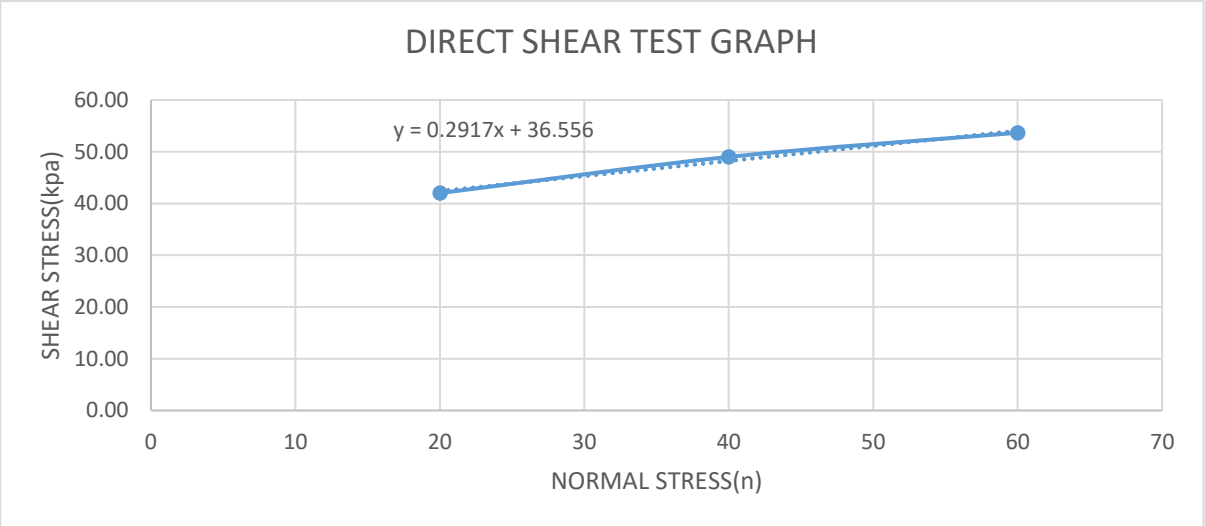


Figure 11 showing a direct shear strength for sample C

- Cohesion Intercept (C') for sample A is 36 and the Angle of Shearing Resistance (Ø) is 16° where the area(m^2) =0.0036 ,the volume =0.000108 and the ring factor =8.4

iv. Soil Porosity

SAMPLE A

Table 3 showing soil porosity test results for Sample A

DETERMINATION OF SOIL POROSITY(SATURATION METHOD)			
PARAMETER	SYMBOL	UNITS	VALUE
Soil core diameter	D	cm	5.0
soil core radius	r=(D/2)	cm	2.5
soil core height	h	cm	10
Total volume of soil	$Vt=r^2h$	cm^3	196
Initial Dry weight of soil	Vd	g	135.44
Water added for saturation	Vw	cm^3	35
Porosity calculation	n=(Vw/Vt)*100	%	17.86

SAMPLE C

Table 4 showing soil porosity test results for Sample C

DETERMINATION OF SOIL POROSITY(SATURATION METHOD)			
PARAMETER	SYMBOL	UNITS	VALUE
Soil core diameter	D	cm	5.0
soil core radius	r=(D/2)	cm	2.5
soil core height	h	cm	10
Total volume of soil	$Vt=r^2h$	cm^3	196
Initial Dry weight of soil	Vd	g	126.03
Water added for saturation	Vw	cm^3	40
Porosity calculation	n=(Vw/Vt)*100	%	20.41

v. Soil Permeability for Sample A

Table 5 below showing measurement of Sample A before permeability test

Length of sample before saturation	L_1(cm)	18	Mass of sample prepare(m_1 g)	2000
Length of sample after saturation	L_2(cm)	17	Dry mass of remainder of sample(m_2 g)	896
Average length of sample	$L(L_1+L_2)/2$ cm	17.5	Manometer (h)	H_1-H_2=h(cm)
Diameter of sample	D cm	7.5	Difference between the grand points(y)	12.5(cm)
Area of sample	A cm^2	44.17		

Table 6: Showing permeability results after test

Test No.	h(cm)	H.GRADIENT (i)	TIME TAKEN (Sec)	PERMEABILITY k=QL/Aht (cm/sec)
1	8.3	0.66	7200	0.0066
2	8.5	0.68	7224.6	0.0065
3	8.7	0.70	7224.6	0.0063
AVERAGE		0.68	7216.4	0.0065

vi. Soil Permeability for Sample C

Table 7 above showing measurement of Sample C before permeability test

L_1(cm)	18	Mass of sample prepare(m_1 g)	2000
L_2(cm)	17	Dry mass of remainder of sample(m_2 g)	886
$L(L_1+L_2)/2$ cm	17.5	Manometer (h)	H_1-H_2=h(cm)
D cm	7.5	Difference between the grand points (y)	12.5(cm)
A cm²	44.17		

Table 8: Showing permeability results after test

Test No.	h(cm)	H.GRADIENT (i)	TIME TAKEN (Sec)	PERMEABILITY k=QL/Aht (cm/sec)
1	7.2	0.66	5419.8	0.0102
2	7.4	0.68	5420.4	0.0099
3	7.6	0.70	5420.4	0.0096
AVERAGE		0.68	**5420.2**	**0.0099**

4.2 DISCUSION

4.2.1 GEOLOGY

The composition of the soil, Drainage patterns and Soil structure is directly influenced by the underlying geology. Rocks that are rich in minerals and organic matter tend to produce more fertile soils that are better at retaining water and nutrients, making them less susceptible to erosion and rocks that are poor in minerals can produce soils that are more prone to erosion. Well-structured soils with good aggregation are better at resisting erosion, as they allow for better water infiltration and root development. In contrast, soils with poor structure are more likely to erode, as they are less able to hold onto water and nutrients.
Based on the map, several key geological units have been highlighted each with varying susceptibilities to soil erosion:

4.2.2 RAINFALL

The areas with higher rainfall (1.1-2mm/day and above) are more susceptible to soil erosion. This is because higher rainfall leads to increased run-off, which can detach or remove soil particles and transport them downhill. The southeastern part of kambenje, with the highest rainfall concentration, is particularly vulnerable. The amount of rainfall determines the amount of water flowing downstream as runoff.

4.2.3 SLOPE

The provided slope map of Kambenje Village along Muluma River illustrates varying degrees of slope across the area, which directly correlates with the potential for soil erosion. The map utilizes a color-coded legend to represent different slope ranges in degrees (°) where Green (< 5°) represent relatively flat to gently sloping terrain, Light Green (5 - 10°) represent Slightly steeper slopes compared to the green areas, Yellow (10 - 20°) represent Moderate slopes, Orange (20 - 30°): Moderately steep slopes, Dark Orange (30 - 40°): Steep slopes and Red (> 40°) represent Very steep slopes.

The areas marked in orange, dark orange, and red are the most prone to soil erosion. This is because steeper slopes increase the velocity of surface runoff, which in turn enhances the removal and transport of soil particles.High Risk (Red and Dark Orange) indicating slopes greater than 40°, are particularly concerning. These areas are likely to experience significant soil loss, especially during periods of heavy rainfalls. The concentration of red in the south-central portion of the map suggests a high risk of erosion in this specific region. The dark orange areas, with slopes between 30-40°, also pose a substantial risk of erosion. Moderate Risk (Orange) representing slopes between 20-30°, are moderately prone to soil erosion. While the risk is not as high as in the red and dark orange zones, these areas still require careful management to prevent excessive soil loss.

4.2.4 LAND USE/COVER

Bare ground are the most critical areas requiring immediate attention to prevent further soil loss. The presence of built areas also necessitates careful management of runoff to avoid erosion in surrounding lands. The extensive rangeland areas need to be managed sustainably to maintain adequate vegetation cover. Monitoring vegetation health and implementing good agricultural practices are essential.

4.2.5 PARTICLE SIZE DISTRIBUTION

Generally, soils with a high proportion of fine particles, such as clay, are more prone to erosion and sedimentation. This is because fine particles are easily transported by wind or water, leading to soil erosion and sedimentation in nearby water bodies. On the other hand, soils with a higher proportion of larger particles, like sand or gravel, are more resistant to erosion and sedimentation.in addition to that, the arrangement of soil particles can also affect erosion and sedimentation in such a way that Soils with a well-structured arrangement of particles, such as granular or crumb structures, are more resistant to erosion and sedimentation compared to soils with a compacted or dispersed structure.

4.2.6 DIRECT SHEAR STRENGTH FOR SAMPLE A AND SAMPLE C

A soil sample A with a cohesion intercept of 33 and an angle of resistance of 16 and sample C with a cohesion intercept of 36 and an angle of resistance of 16 may exhibit some level of resistance to erosion. Cohesion is the measure of a soil's ability to stick together and resist forces trying to pull it apart, while the angle of resistance is a measure of the soil's ability to withstand shearing forces before failing. In this case, the soil sample's relatively high cohesion intercept suggests that it has some level of natural bonding that can help prevent erosion. Additionally, the angle of resistance indicates that the soil has some ability to withstand shear forces, which can also help reduce erosion. However, it is important to note that other factors such as water content, vegetation cover, and slope gradient can also influence erosion rates.

4.2.7 SOIL POROSITY FOR SAMPLE A

A soil sample with a porosity calculation of 17.86% indicates that the soil has a relatively high amount of open space or pore volume, which can be beneficial for water infiltration and drainage. However, this level of porosity can also make the soil more susceptible to erosion, as water and air can easily move through the soil, potentially washing away particles and nutrients.

4.2.8 SOIL POROSITY FOR SAMPLE C

A soil sample with a porosity calculation of 20.41% indicates that the soil has a relatively high level of pore spaces, which can be beneficial in reducing soil erosion. The presence of pores allows water to infiltrate into the soil, reducing surface runoff and the likelihood of erosion occurring. Additionally, the pores provide space for plant roots to penetrate and anchor the soil, further reducing erosion risk. Generally, soil sample with a porosity of 20.41% is likely to have good water infiltration and drainage characteristics, making it more resilient to erosion.

4.2.9 SOIL PERMEABILITY FOR SAMPLE A

A soil sample with a permeability calculation of 0.0065 cm/sec indicates that the soil has a relatively low rate of water infiltration and drainage. This could potentially increase the risk of soil erosion as water may accumulate on the surface, leading to runoff and soil loss. It is

important to take measures to address soil erosion in areas with soils of low permeability, such as implementing erosion control measures and promoting vegetation cover to help stabilize the soil

4.2.10 SOIL PERMEABILITY FOR SAMPLE C

A soil sample with a permeability calculation of 0.0099cm/sec likely has good drainage capabilities, which can help mitigate soil erosion. When soil is more permeable, water is able to infiltrate into the ground more easily instead of running off the surface and causing erosion. This can help reduce the risk of soil erosion by keeping the soil in place and preventing it from being washed away by water.

4.3 DISCUSSION

SOIL EROSION AND SEDIMENTATION MODEL

This map offers a compelling visual analysis of soil erosion and sedimentation within Kambenje village in Mulanje District. It was made by combining or overlaying a geological Map, a slope Map, a land use/cover Map, a Rainfall Map, and a study area map using Arc GIS software where all these datasets were interpolated to come up with this model showing areas with high erosion and sediment accumulation.

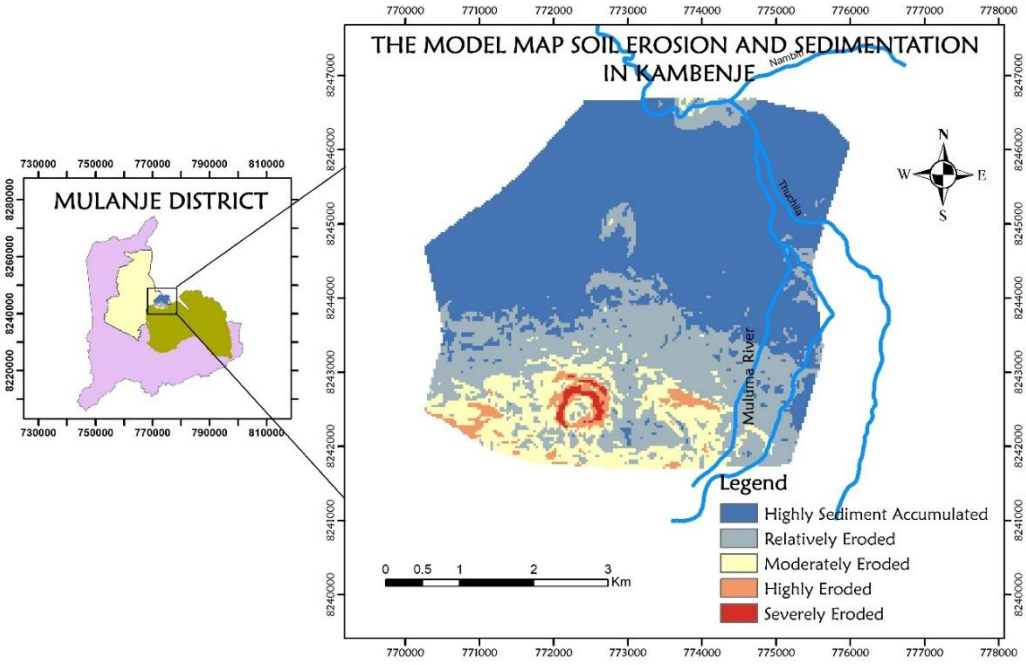


Figure 12 Showing a soil erosion and sedimentation Model Map

The spatial distribution of these colors on the map directly illustrates the varying degrees of erosion and deposition across Kambenje village. The concentrated severe erosion in the

center suggests a focal point of soil loss, while the sediment accumulation along the river indicates where the eroded material is being deposited.

Based on this color-coded detailed model map, it displays a significant variation in soil erosion levels across Kambenje village. Severely Eroded Areas (Red) is evident in the central part of the mapped region. This suggests a location with very steep slopes, poor vegetation cover, or unsustainable land management practices. Highly Eroded Areas (Orange) Surrounding the severely eroded zone and extending towards the south, shows high level of soil loss. Moderately Eroded Areas (Yellow) larger portions of the map, particularly in the western and northeastern sections are classified as moderately eroded. This suggests ongoing soil degradation but at a less critical rate than the highly and severely eroded zones. Relatively Eroded Areas (Light Blue) are Areas with relatively low erosion are scattered across the map, often adjacent to the moderately eroded regions and along the river valleys. These areas likely have better vegetation cover, gentler slopes, or more sustainable land use. Highly Sediment Accumulated Areas (Dark Blue), noticeably, the areas along the Muluma River, particularly in the southeastern part of the map, are classified as having high sediment accumulation. In summary, the Kambenje area within the Mulanje District exhibits a concerning pattern of soil erosion, with a central core of severe erosion and surrounding areas experiencing high to moderate levels of soil loss. The presence of the Muluma River acts as a conduit for this eroded sediment, leading to significant accumulation downstream. This suggests a dynamic landscape where erosion in upland areas directly affects sedimentation in lower-lying regions, particularly along the river and the entire area.

4.4 INTERPRETATION

Kambenje Village's soil erosions is mainly contributed by factors including slope, as the area has a steep slope that favors runoff water indicated on the slope map, poor land cover and use where runoff water get rid of the top soils and carry them downstream. Yearly kambenje Village receives a lot of rainfall that increases the amount of run-off water and flooding of rivers that do also increases the risk of soil erosion and sediment accumulation. The areas sandy soils with high pore spaces and high ability to allow water to pass through them quickly hence high infiltration causes the soils to easily saturate with water hence decreasing the cohesion or the force of attraction between the particles. The soils cohesion and angle of resistance is relatively good but with these conditions on top of it make it susptible to erosion.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The areas general overview i.e. the presence of rills and gullies, poor land cover and poor sustainable farming practices indicates how vulnerable the area is to erosion and the presence of river sand and sediment on cultivated lands and along the river indicates sediment accumulation in the area. The geological map of Kambenje reveals a complex geological setting with varying susceptibilities to soil erosion. The presence of both resistant rock types (quartz syenite, reef) and more erodible materials (hornblende-biotite gneiss, alluvium) suggests that soil erosion is likely a significant issue in the area as the original bedrock influences the formation of the top and sub soils that are the victims of erosion. The distribution of land cover types and the high amount of rainfall in Kambenje village has significant implications for soil erosion. The presence of substantial bare ground and built areas indicates potential hotspots for soil loss and increased runoff. Sustainable management of rangelands and careful land-use planning within Kambenje village are important in mitigating erosion risks. The protection and enhancement of tree-covered areas are vital for maintaining soil stability and overall ecosystem health. Understanding this spatial distribution of land cover and its associated erosion potential is essential for developing targeted soil conservation strategies and ensuring the long-term ecological integrity in Kambenje village. The development of effective erosion control measures and land management strategies to protect the soil resources in Kambenje can help in mitigating soil erosion. Therefore, it is important to take measures to prevent soil erosion, such as implementing erosion control practices like planting cover crops, or establishing terraces to protect the soil and prevent sediment from being carried away by water runoff. Proper soil management and conservation practices can help maintain the soil structure and fertility, preventing erosion and preserving the health of the ecosystem.

5.2 RECOMMEDATIONS

Based on the findings, interpretation and the conclusion, further studies on erosion and sedimentation should be conducted to increase the knowledge and understanding of the factors enhancing soil erosion on a large area that can be easily controlled to mitigate the challenge and hence increase soils fertility, water quality and sustainable ecosystem and environment.

5.3 LIMITATIONS

The research utilizes the use of geotechnical measurement for only two samples that were not fairly enough with respect to the designated study area that could have demanded the use of more than just two samples for a clear overall analysis of the factor contributing to soil erosion and sedimentation. This was due to luck of enough fund to complete the task and make it a success, overall with the provided results, the interpretation was done.

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