

MALAWI UNIVERSITY OF SCIENCE AND TECHNOLOGY

NDATA SCHOOL OF CLIMATE AND EARTH SCIENCES

DEPARTMENT OF EARTH SCIENCES

ASSESSMENT OF THE LANDSLIDE SUSCIPTIBILITY AT MIDIMA HILL IN MIKOLOGWE AREA, CHIRADZULU, SOUTHERN REGION.

FATSANI KAMPHANGALE

ESC/014/20

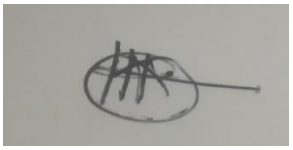
DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE BACHELOR OF SCIENCE DEGREE IN EARTH SCIENCE

SUPERVISOR: MR. RICHARD MVULA

29TH APRIL 2025

DECLARATION

I Fatsani Kamphangale 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: 29th April 2025

DISSERTATION APPROVED BY:

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Mr. Richard Mvula **Signature:** 

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ABSTRACT

The devastating landslides triggered by Cyclone Freddy in March 13–15, 2023 on Midima Hill in Mikolongwe, Chiradzulu District, caused significant damage to crops, farmland, livestock, and infrastructure, highlighting the significant need for landslide risk assessment in the region. Despite the evident threats, no any studies have been conducted to examine landslide triggers or mapped susceptibility zones in this area. This research aimed to fill that gap by assessing key factors influencing landslide occurrence such as lithology, slope gradient, slope aspects, elevation, and land use to create a detailed landslide susceptibility map. This study used GIS to map landslide risks in Midima Hill. Data on slope steepness, lithology, elevation, slope direction, and land use were collected from geological survey of Malawi, satellite images, soil databases, and field surveys. These factors were analyzed in ArcGIS, where each was ranked based on its influence on landslides using a method called AHP (Analytic Hierarchy Process). Finally, a landslide risk map was created by combining all factors, showing areas from very low to very high risk. Findings revealed that weak, foliated rocks like gneiss and fractured rock like migmatite were highly prone to failure, especially on steep slopes at angles greater than 22°, east- and southeast-facing slopes, which receive heavy rainfall. And it also High-elevation zones (>900m) accounted for 70% of landslides due to gravitational forces and slope instability. Land use also played a significant influence on landslide occurrence: bare ground and farmland on slopes were vulnerable because they support erosion and weathering processes, while vegetation provided stability through their roots that anchor the soil and rocks to avoid erosion. The final susceptibility map classified 20.3% of the area as high risk and 13.6% as very high risk, with field validation confirming the model's accuracy through GPS-mapped landslide scars and inventory data. Recommendations to mitigate the risks include avoiding construction in high-risk zones, implementing agroforestry in farms to stabilize slopes, enhancing drainage systems in weak rock areas, and adopting terraced farming to mitigate erosion. These measures aim to reduce future landslide impacts, safeguarding communities and infrastructure.

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ACRONYMS/ABBREVIATIOS

DEM	Digital Elevation Model
GPS	Global Positioning System
AHP	Analytical Hierarchy Process
GSD	Geological Survey of Malawi
ISRIC	International Soil Reference and Information Center
CR	Consistency Ratio
CL	Consistency Index
RI	Random Index
MASDAP	Malawi Spatial Data Platform
QGIS	Quantum Geographic Information

CHAPTER 1: GENERAL INTRODUCTION

1.1 Background

Landslides are among the most destructive hazards in mountainous and highland regions of the tropical world (Petley,2012). Landslides are some of the most widespread geological threats to human lives, and cause destruction of property globally (shano et al., 2020). Globally devastating landslides have been recorded, such as 1920 Haiyuan landslides in China (Zhang & Wang, 2007), the 1999 Vargas Tragedy landslides in Venezuela (Bezada, 2009), and the 1949 Khait landslides in Tajikistan (Evans et al., 2009). In Africa, landslides have been reported in countries like Cameroon, Kenya, Uganda, Rwanda, Tanzania, and Ethiopia (Lukamba, 2010; Broeckx et al., 2018). Several studies consider the East African highlands to be prone to landslides due to their humid climate, steep topography and high weathering rates (knapen et al., 2006; Kitutu et al.,2009). Furthermore, steep slopes, heavy annual rainfall, increasing population pressure, and deforestation, have been identified as the major cause of landslides in the East African Highlands (Glade and crozier, 2005)

Malawi which is located in the southeastern Africa has also faced significant challenges with Landslides, particularly in the southern region (Thiery et al., 2024). Notable events include the Zomba mountain landslide in 1946, the Phalombe landslide in 1991, and the Banga landslide in 1997 (Thiery et al., 2024). Recent landslide events from March 13 to 15, 2023, affected areas like Blantyre, Chiradzulu, Mulanje, and Phalombe, resulting in substantial losses of property and lives. One such event, the Midima landslide in Mikolongwe Area of Chiradzulu, caused significant damage to crops, farmlands, livestock, and infrastructure in the area.

Despite the absence of casualties in the Midima landslide, the event underscores the urgent need for detailed research and susceptibility assessments to understand the preparatory and triggering factors of landslides in the Mikolongwe area. This research aims to determine landslide hazards and devise appropriate mitigation measures to prevent future occurrences or minimize their impacts effectively.

1.2 Problem statement

The recent landslides on Midima Hill triggered by Cyclone Freddy on March 13–15, 2023 have highlighted the area's high vulnerability to such disasters. These landslides caused heavy damage to crops, farmland, livestock, and infrastructure (Thiery et al., 2024), highlighted the need for a deeper understanding of the factors contributing to the disaster. However, no any studies have been conducted in Mikolongwe to assess landslide triggers or map susceptibility zones, leaving the community at continued risk. This research seeks to address this gap by evaluating key factors influencing landslides, including lithology, slope gradient, slope aspect, elevation, and land use, to develop a comprehensive landslide susceptibility map.

Without such an assessment, predicting future landslides or implementing effective prevention measures it will remain difficult. By identifying high-risk areas and analyzing the underlying causes, this study will provide critical understanding to help local communities and authorities mitigate risks and improve land-use planning. The findings will not only fill a significant knowledge gap but also contribute to better disaster management strategies in the region.

1.3 Main and specific objectives

Main Objective:

The main objective is to assess the landslide susceptibility of Midima hill to the community of Mikolongwe.

Specific objectives are:

i. **To evaluate the role of lithology in slope stability** by analyzing the geomechanical properties of quartz-diorite, gneiss, and migmatite and their correlation with observed landslide occurrences.

ii. **To quantify the influence of topographic parameters** (slope gradient, aspect, and elevation) on landslide susceptibility using GIS-based statistical and geospatial modeling.

iii. **To assess the impact of land use/cover dynamics** on slope destabilization by examining the relationship between vegetation loss, agricultural practices, and landslide frequency.

1.4 Research Questions:

II. How does lithology influence landslides occurrence in the study area?

III. How does the topography of the highlands influence landslide occurrence in the study area?

IV. How does land use/cover influence landslides occurrence in the study area?

4.4Significance of the study

Assessing landslide susceptibility in the Midima Hill area of Mikolongwe is very important for the community. By identifying landslide-prone areas, effective strategies can be put in place to reduce risks, thereby protecting lives and property (Rogayan & Dollete, 2020). Understanding landslide risks also helps in planning and building infrastructure in safer locations, preventing damage to farmlands, and other critical structures (Anderson-Berry & King, 2005). Additionally, this assessment helps identify environmentally sensitive areas at risk, allowing focused conservation efforts to

protect natural habitats and reduce further damage. It also helps local communities prepare for future possible landslides, improving their ability to respond in emergencies (Anderson-Berry & King, 2005). Furthermore, assessing landslide risks can reduce economic losses to the community, ensuring stability for local economies and livelihoods affected by such disasters (Holmes et al., 2013).

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Landslides are a form of mass wasting, pose a major global hazard, causing significant damage to infrastructure, loss of life, and environmental harm (Corominas et al., 2013). They happen when a slope becomes unstable, resulting in the downward movement of soil, rock, or debris due to gravity (Arnone et al., 2011). These landslides have different effects on infrastructures, environment and people's lives depending on where and the magnitude of occurrence (Arbanas et al., 2020). According to (Pradhan & Lee, 2010) heavy rainfall and topographic characteristics like slope angle, elevation and slope aspect have an influence of landslides occurrence. Factors that determine the occurrence of landslides in an area are grouped into two categories namely; intrinsic and extrinsic variables. Intrinsic variables are the geologic conditions and the slope structures of the area. The extrinsic variables can be rainfall and human activities that trigger landslides (Huabin et al., 2005). This chapter described in detail landslides processes and classification, the influence of topography, rainfall and geology for the occurrence of landslides.

2.2 Landslides processes and classification

Landslides are a form of mass wasting, pose a major global hazard, causing significant damage to infrastructure, loss of life, and environmental harm (Hock et al., 2022). They happen when a slope becomes unstable, resulting in the downward movement of soil, rock, or debris due to gravity. We can classify Landslides using Varnes classification system, the system categorizes landslides into five main types: falls, topples, slides, spreads, and flows (Davies, 2014).

Falls

Falls refer to the sudden, downward displacement of rock or soil, or a combination of both, which detach from steep inclines or cliffs (Wyllie, 2014). These materials

primarily descend through the air via freefall, bouncing, or rolling (Wyllie, 2014). Such occurrences are characterized by their rapid motion and are typically found in regions with exposed rock faces, cliffs, or steep slopes composed of fractured or weathered rock masses (Manglik, 2024). Falls are triggered by Undercutting of slope by natural processes, including the action of streams and rivers or differential weathering phenomena, such as the freeze/thaw cycle (Manglik, 2024)

Topples

Topples involve the forward rotation out of a slope of a mass of soil or rock around a point or axis below the center of gravity of the displaced mass (Wyllie, 2014). They are Known to occur globally, often in columnar-jointed volcanic terrain, as well as along stream and river courses where the banks are steep (Wyllie, 2017). Topples can occur slowly or rapidly, depending on the geometry of the failing mass and the presence of pre-existing discontinuities (Wyllie, 2017). These events are often triggered by undercutting of the slope toe, weathering, or seismic activity (Wyllie, 2017).

Slides

A slide is a downslope movement of a soil or rock mass occurring on surfaces of rupture or on relatively thin zones of intense shear strain (Wyllie, 2014). These landslides are characterized by a prominent main scarp and back-tilted bench or block at the top, with limited internal deformation (Frampton, 2018). Slides can be further classified into rotational slides, characterized by curved or spoon-shaped failure surface, and translational slides, characterized by a planar failure surface (Zhuang et al., 2016). Slides can be triggered by Intense rainfall or rapid snowmelt this can lead to the saturation of slopes which cause erosion at the base of slopes (Wyllie, 2017).

Spreads

Spreads involve the lateral extension and fracturing of a coherent soil or rock mass, often due to liquefaction or loss of shear strength in the underlying material (Wyllie,

2014). These events are typically associated with gentle slopes or flat terrain and can occur rapidly, causing significant damage to infrastructure (Zhuang et al., 2016). This failure is triggered by liquefaction, where saturated, loose sediments like sands and silts lose their strength and behave like a liquid, often due to earthquakes or human activity (Wyllie, 2017).

Flows

Flows involve the downslope movement of a soil or rock mass in a fluid-like manner, often with high water content (Wyllie, 2014). According to Frampton (2018) Flows can be further classified into debris flows, earthflows, and creep, depending on the material composition and water content. Debris flows are fast-moving mixtures of water, rock, soil, and debris that flow downslope like a fluid (Wyllie, 2014). They are characterized by high velocity, turbulent flow, and the transport of large volumes of sediment and debris (Wyllie, 2014). According to Frampton (2018) Earthflow is a type of mass wasting that involves the slow, downward movement of water-saturated soil and other materials under the influence of gravity. The movement of earthflows is generally slower compared to other mass wasting events like debris flows or, with speeds ranging from a few centimeters to several meters per day (Frampton, 2018). Creep is the informal name for a slow earth flow and consist of the steady downward movement of slope forming soil or rock (Frampton, 2018).

2.3 Topography

Topography plays the most significant role in determine landslide occurrence compared to factors like soil type or landcover (Nandi & Shakoor, 2009). According to Nandi and Shakoor (2009) topography is a key factor in determine where landslides occur and how severe they are. Topographic factors such as, slope gradient, aspect, curvature, roughness, distance from drainage network and discontinuities are the major parameters that influence landslide occurrence (Nseka et al., 2019).

Slope gradient

The angle of a slope is a crucial factor in assessing slope stability. Studies have shown that as the slope angle rises, the shear stress in soil or other loose materials also tends to rise (Thouret et al., 2019). As slopes get steeper, gravity and other forces like shear strength that can cause landslides increase. This affects how materials move downhill controlling how fast they go and how far they travel (Thouret et al., 2019). However, slope angle alone rarely determines landslides potential but it interacts with factors like lithology, soil properties and human activities such as excavation and deforestation (Pangare et al., 2021). The structure of different slopes significantly influences the stability, stress distribution, and deformation characteristics of rock and soil masses (Chen et al., 2025). A dip slope, defined as a slope surface that aligns with the dip direction, is generally considered a high-risk zone for landslides, as the orientation of the rock layers increases the likelihood of developing sliding surfaces due to gravitational forces (Chen et al., 2025).

Aspect

Aspect is a significant topographic characteristic that defines the orientation of a slope in relation to the cardinal directions: north, east, south, and west (Kumar et al., 2023). It is measured in degrees, with 0° indicating north, 90° indicating east, 180° indicating south, and 270° indicating west (Cellek, 2021). The slope's inclination is a critical determinant in various environmental and geological processes, including susceptibility to landslides (Cellek, 2021).

2.4 Lithology

Granite, classified as an igneous rock, serves as a type of parent material that, upon weathering, contributes to significant slope instability, as evidenced by landslide occurrences in regions such as Korea (Wakatsuki et al., 2005) and Nepal (Ibetsberger, 1996). The instability associated with granite is likely attributable to its relatively slow weathering process, which results in the formation of shallow soils characterized by limited water retention and high permeability (Sidle & Ochiai, 2006).

In addition, weak sedimentary rocks, including mudstone and shale, exhibit a pronounced vulnerability to landslides (Pearce & O'Loughlin, 1985; Chigira & Oyama, 1999). The susceptibility of sandstone, another type of sedimentary rock, to landslides is influenced by the presence of specific compounds and oxidation processes. These factors can either weaken the rock or enhance its stability through cementation by iron oxide or hydroxide (Chigira & Oyama, 1999).

CHAPTER 3: METHODOLOGY

3.1 Research design

The research employed a quantitative approach, primarily relying on the collection and analysis of numerical data, generation of thematic maps. This included assigning weights to thematic maps based on their importance in influencing landslides occurrence. Additionally, data layers were potentially reclassified using numerical values. These weights and reclassified data were then utilized in the weighted overlay analysis to produce landslide susceptibility map.

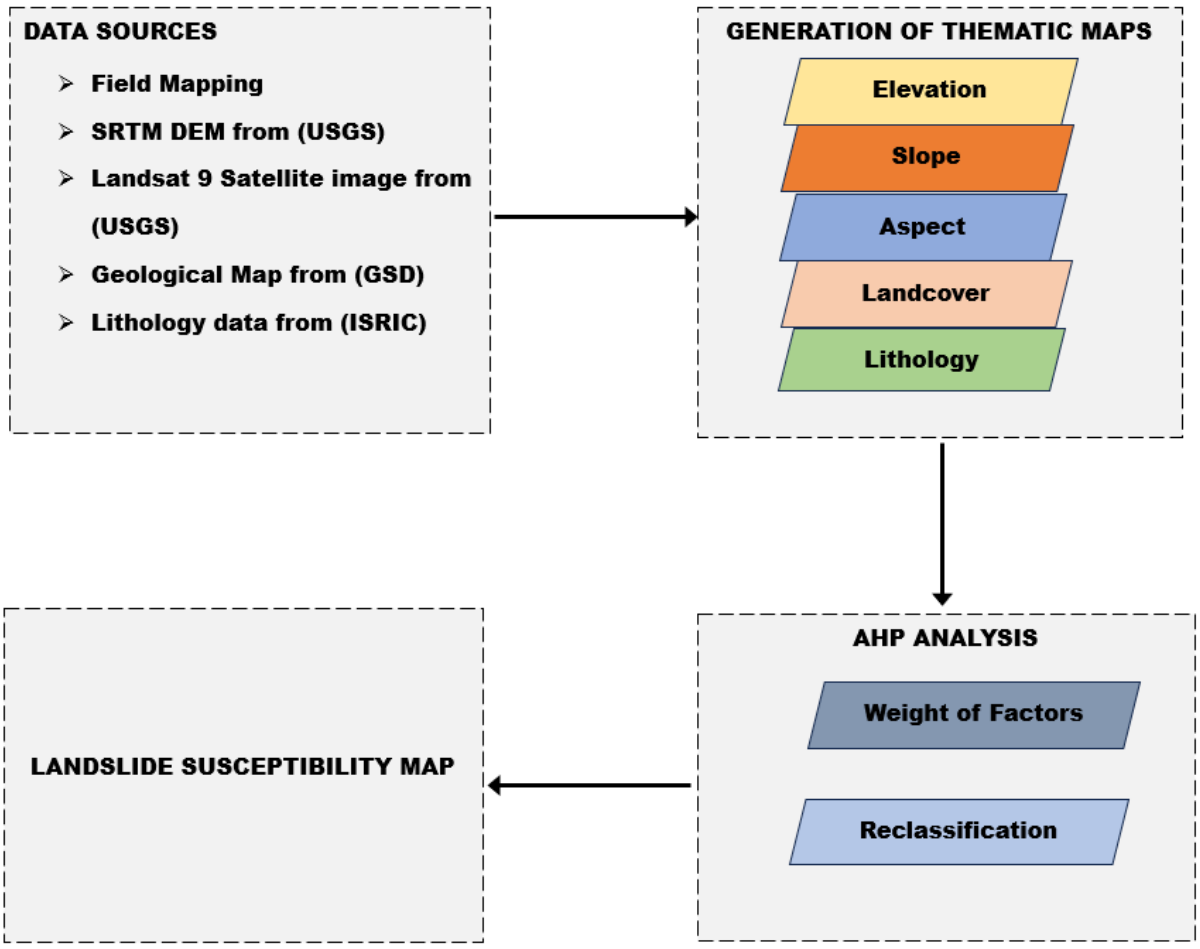


Figure 1 Showing methodological frame work

3.2 STUDY AREA

The study was carried out at Midima hill in Mikolongwe veterinary college, T/A Nkalo Chiradzulu district, southern region of Malawi. The area is part of Phalombe-Thuchira plain which is found to the East side of the district. The area is extended between latitudes -15°52′1.2″ and longitudes 35°13′24.27″ and is approximately 500meters from MUST turnoff. Geologically, chiradzuru District is underlain by the Basement Complex rocks of the Mozambique Belt, which are composed of gneisses, migmatites, granites, and greenstones (Evans, 1965). The Basement Complex rocks are overlain by younger sedimentary rocks, mainly sandstones, shales, and conglomerates of the Karoo Supergroup, which were deposited during the Permian and Triassic periods (Evans, 1965). Understanding the geology of an area is very important, as it can provide information on the types of rocks and their properties, which influence landslides occurrence (Gariano & Guzzetti, 2016). The area experiences a warm tropical climate with mean temperatures ranging from 16°C to 28°C and in exceptional temperatures rise as high as 32°C (State climate of Malawi, 2023). The lowest temperatures experienced in June and July while the highest temperatures are registered between the months of October and November (State climate of Malawi, 2023).

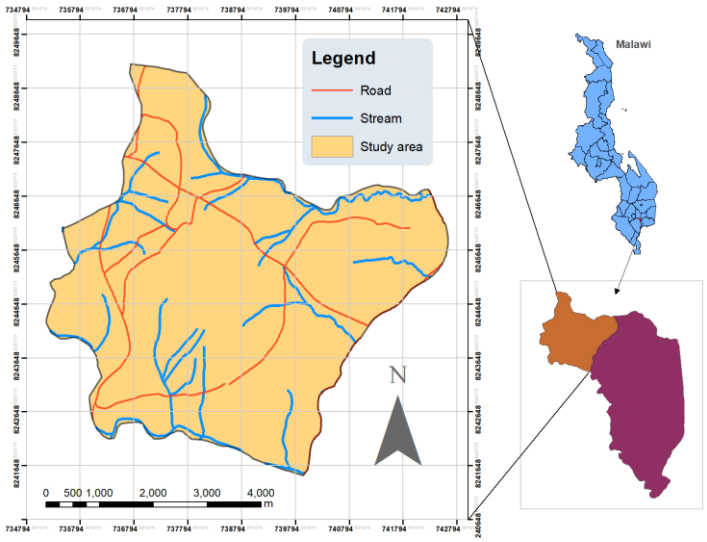


Figure 2 showing study area map

3.3 MATERIALS AND METHODS

Data sources and analysis

This section details the various data sources used in this dissertation and the methods employed for their analysis, primarily using ArcGIS software.

I. Data collection and generation of thematic maps

a. Geology data

A geology data of shire highlands where my study area is, was acquired from the Geological Survey Department located in Lilongwe, Malawi.

b. Lithology data

And lithology data sets of the study area were obtained from ISRIC- World soil information https://data.isric.org/geonetwork/srv/eng/catalog.search#/metadata/60803da0-a15f-4cc5-9cb5-172fa2460af3). The lithology data set was imported into ArcGIS 10.8, where lithology of my study area was clipped to generate lithology thematic map.

c. STRM DEM data

STRM DEM data for Malawi was obtain from Malawi Spatial Data Platform (MASDAP). The data was loaded into ArcGIS 10.8, using add data tool. The DEM was clipped using extract by Mask, this tool requires DEM as the input rater and polygon shape file of the study area boundary to produce a clipped DEM.

d. Creating of thematic maps from DEM Data

The elevation Map was derived directly from the clipped DEM. And the data was classified into meaningful intervals using classified symbology. The slope gradient thematic map was also clipped from DEM, and the steepness of the terrain was

navigated using spatial analysist tool and then classified into slope categories measured in degrees. Finally slope aspect thematic map was extracted from DEM using spatial analysist tool, and then classified into different directions. Then legend, scale bar, and north arrow was added to the thematic maps and exported as image.

e. Land Use/Land Cover

Land Use/Land Cover data for the study area was derived from satellite imagery obtained in Landsat-9. The classification process involved identifying and mapping distinct land cover types, such as vegetation, urban infrastructure, water bodies, and bare soil, resulting in a raster layer representing the physical surface characteristics of the area. Additionally, land use information was inferred by analyzing the purpose or activities associated with each land cover type, such as agriculture, recreation, or urban development, providing insights into human interactions with the landscape.

II. Generation of potential Landslide potential zones

Thematic maps which were generated for this study were reclassified within the ArcGIS 10.8 software. Suitable ranks and weights were assigned to each thematic map according to influence of landslide occurrence. The weights on each thematic map were assigned based on AHP analysis. The Analytical Hierarchy Process (AHP) is a multi-criteria decision-making methodology employed for the development of landslide susceptibility maps. Many researchers have used this approach to assign weights to various factors that influence landslide occurrences (Lin et al., 2020; Ali et al., 2019; Kanwal et al., 2016). AHP operates on the principle of pairwise comparisons, allowing users to determine the relative importance of different factors. Each factor is assigned a score on a scale from 1 to 9(Table 1, Saaty, 1990), reflecting its significance, with higher scores indicating greater impact. The scores are derived from spatial data analysis, and field observations.

IMPORTANCE SCALE	DEFITINITION
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Used to express intermediate values

Table 1: Fundamental Scale for Pairwise Comparisons (Saaty, 1987)

The consistency ratio (CR) works as a mechanism for assessing and mitigating inconsistencies and biases throughout the entire process of evaluating controlling parameters (Ali et al., 2019). The consistency ratio was calculated using the equation 1 below;

$$CR = \frac{CI}{RI}$$

(equation 1)

In this scenario, CR denotes the consistency ratio, CI represents the consistency index, and RI refers to the random index.

CHAPTER 4: RESULTS AND DISCUSSION

3.1 RESULTS

The resulting thematic map of the landslide assessment was grouped into 3 categories, which are; results on lithology, results on topographic factors, and results on land use/ cover.

3.1.1 Results on Lithology

Slope failure is influenced by slope-building lithology. Each lithology responds differently to stresses and therefore affects its susceptibility to slope failure. The Midima hill comprises of variety of lithologies but the area is dominated by quartz-diorite, gneiss and migmatite. Quartz-diorite covers almost 70% of the area, while gneiss and migmatite covers at least 30% of the area.

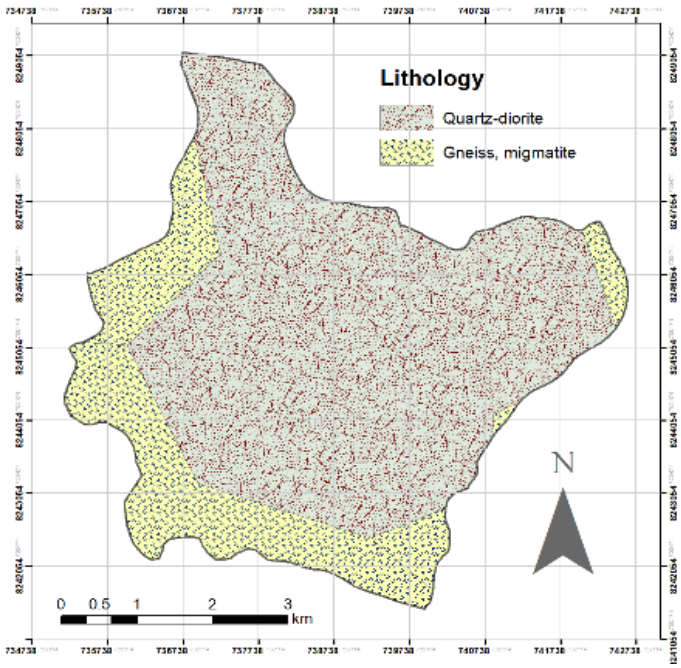


Figure 3 showing Lithology of Midima hill

3.1.2 Results on Topographic factors

The slope angle is an important topographic factor that influences the stability of a slope materials, and it should be taken into consideration when developing landslide susceptibility maps. Steeper slopes are more susceptible to failure as compared to gentle slopes. The study area presents a variation in topography ranging from steep slope to gentle slopes. The slope steepness in the area has been divided into five classes, classified based on statistical analysis. Notably, over 50% of landslides occur within class IV (22° - 31°) and class V (32° - 56°), while the least number of landslide events were recorded in class II and class III. In addition to the slope gradient, aspect and elevation were also identified as significant factors in influencing landslide susceptibility map. However, in my area these parameters appear to have reduced influence on the occurrence of landslides (figure 9).

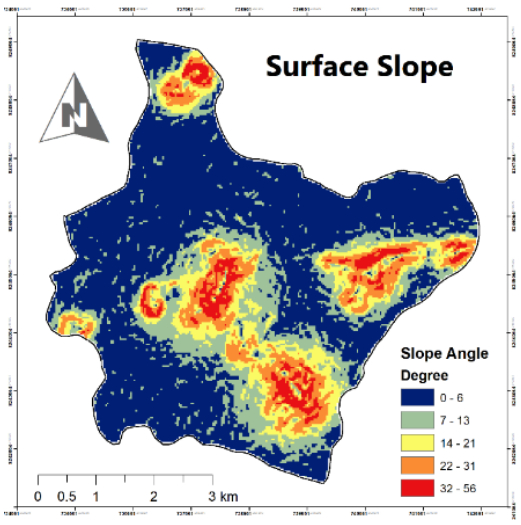


Figure 4 showing slope gradient map

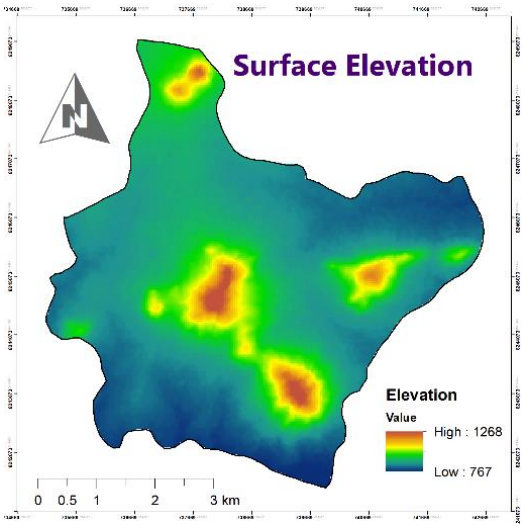


Figure 5 showing surface elevation map

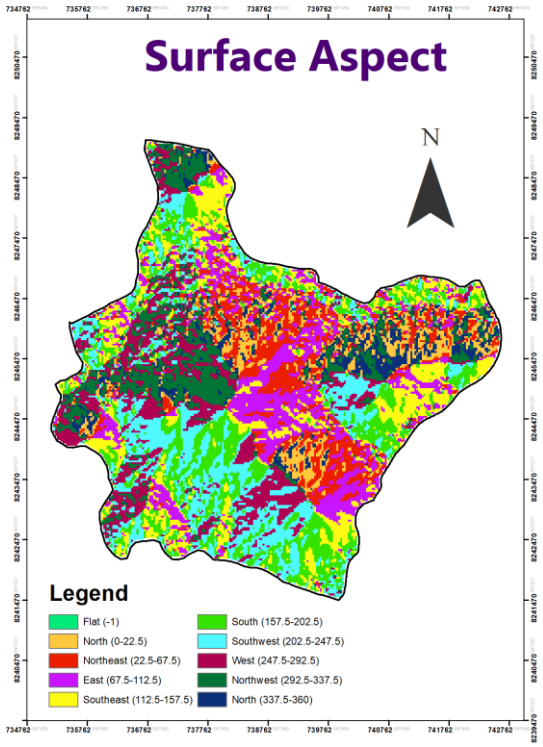


Figure 6 showing surface aspect map of mikolongwe

3.1.3 Results of Land use/cover

The study area's land use was divided into five types: built-up areas, water bodies, farmlands, bare ground, and vegetated land each affecting landslide risk differently. The most vulnerable areas were farmlands (28.5% of the area), built-up zones (17.7%), and bare land (36.6%). In contrast, water bodies (10.2%) and vegetated areas (7.0%) had the lowest landslide risk. Areas with plants and trees were the most stable because roots help hold soil together. However, bare ground and farmlands on steep slopes were more prone to landslides due to exposed soil and erosion. Developed areas, especially those on hillsides, increased landslide risk because construction and poor drainage weaken the ground. Water sources like rivers also contributed to moderate landslide danger nearby, as flowing water erodes banks and saturates the soil.

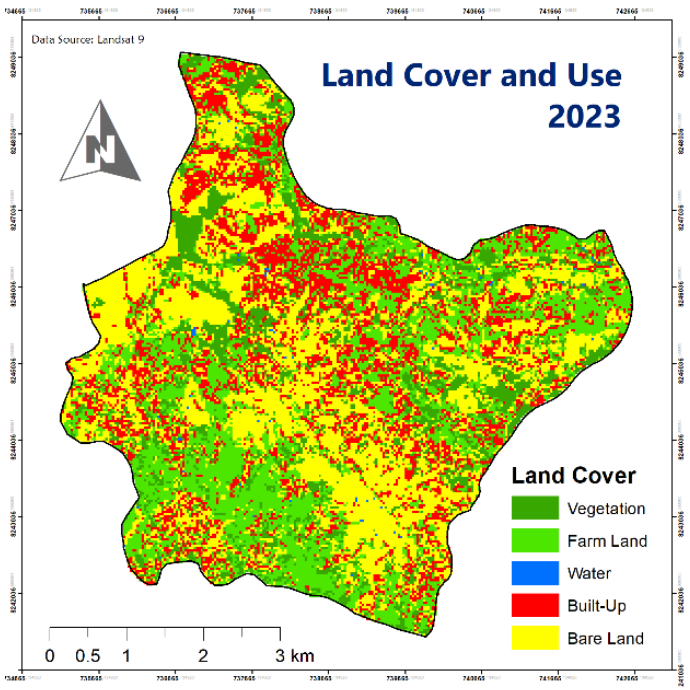


Figure 7 showing the land cover of Mikolongwe area

3.1.4 Landslide susceptibility map

The landslide susceptibility map (Figure 10) divides the study area into five risk levels: very low, low, moderate, high, and very high susceptibility. The analysis shows that about 25.3% of the area has high landslide risk, while 18.6% falls into the very high-risk category. These dangerous zones are mainly found on steep slopes (over 30°), where rocks are heavily weathered, and in bare, unprotected areas. On the other hand, safer areas with low and very low susceptibility cover 20.1% and 15.8% of the region, respectively. These stable zones are mostly flat, with strong bedrock and thick vegetation that helps prevent landslides. The map clearly highlights where landslides are most likely to occur, helping identify areas that need special attention for risk reduction.

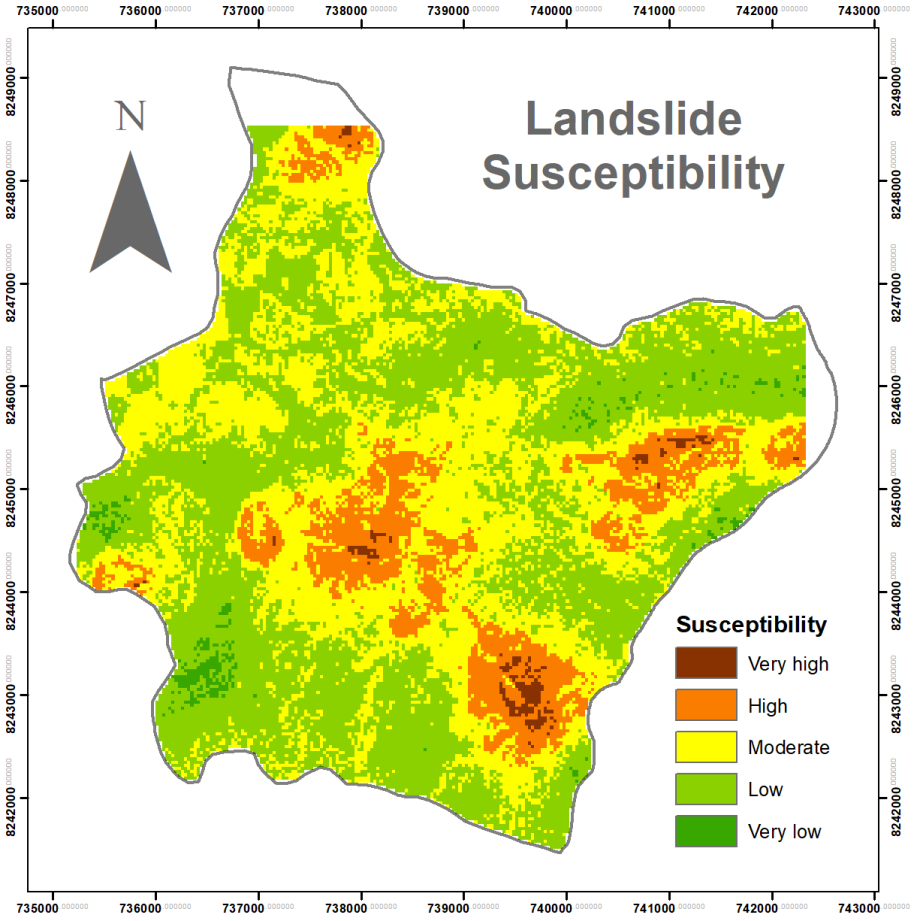


Figure 8 showing landslide susceptibility map of mikolongwe area

3.1.5 Accuracy assessment of the Results

To check the accuracy of the landslide susceptibility map, i conducted field surveys in Midima Hill. i recorded the locations and elevations of past landslide scars using GPS. The data helped us create a detailed landslide inventory map (Figure 13). When i compared the inventory map with the susceptibility map, i found that most landslides scars occurred in areas i had classified as high or very high risk. The main types of landslides i observed were falls, creeping (figure 14), and rock avalanches (figure 15). This field work confirmed that the susceptibility map correctly identified the most dangerous landslide areas in Midima Hill.

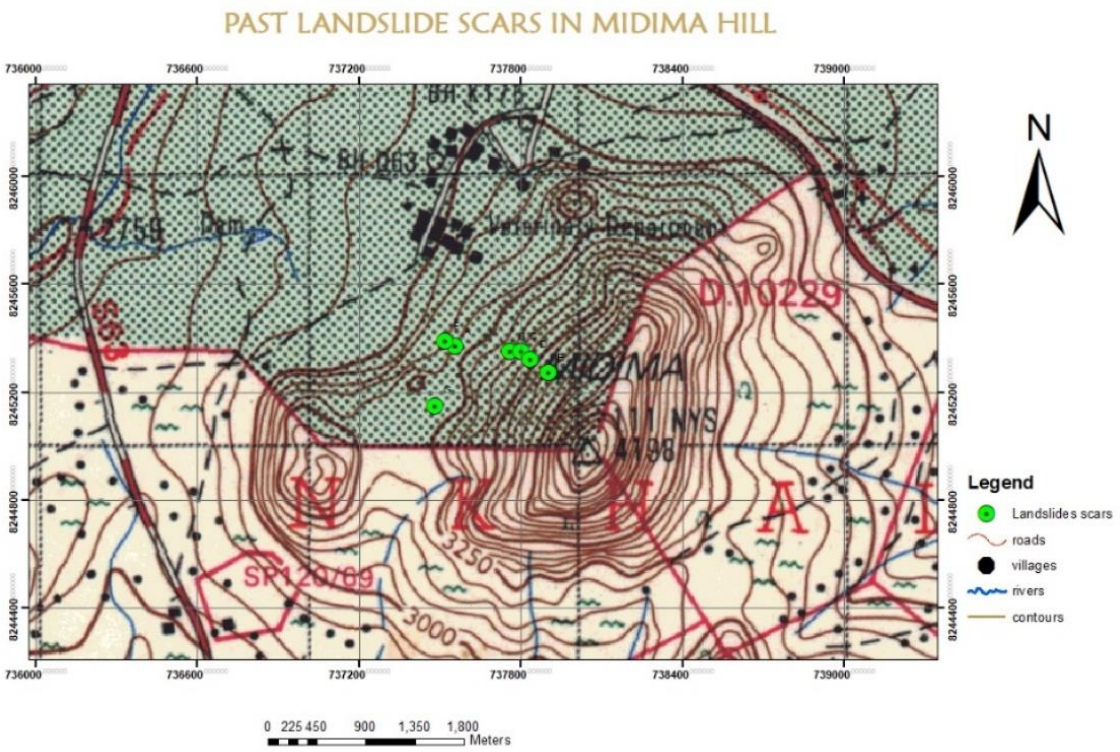


Figure 9 showing inventory map of mikolongwe area



Figure 10 showing rock creeping in Midima Hill



Figure 11 showing rock avalanche in Midima Hill

3.2 DISCUSSION

This study integrated geospatial analysis, field validation, and the Analytic Hierarchy Process (AHP) to assess landslide susceptibility in Midima Hill, Mikolongwe. The findings highlight the interplay between lithological, topographical, and anthropogenic factors in controlling slope instability. The discussion below contextualizes these results within broader landslide science while addressing their implications for risk mitigation.

3.2.1 Lithology

The susceptibility of Midima Hill to landslides is strongly influenced by its underlying lithology. Field observations and GIS analysis confirm that **gneiss** and **migmatite** exhibit higher landslide susceptibility compared to **quartz-diorite**, primarily due to their structural weaknesses. Gneiss, being foliated, promotes preferential water infiltration along planes of weakness, reducing shear strength (Gerrard, 2012). Migmatite, characterized by fracturing and heterogeneous composition, further exacerbates instability under prolonged rainfall (Wu et al., 2022). These findings align with studies in similar tropical highlands, where foliated and fractured metamorphic rocks dominate landslide-prone zones (Donati et al., 2023).

Notably, quartz-diorite, despite its competent nature, still contributed to slope failures where steep gradients (>30°) and weathering-induced jointing were present. This supports the concept that even resistant lithologies can fail under extreme topographical and hydrogeological conditions (Davies & McSaveney, 2009).

3.2.2 Topography

Slope gradient emerged as the most critical topographical factor, with **70% of landslides occurring on slopes >22°**, consistent with global thresholds for shallow landslides (Dai & Lee, 2002). The predominance of failures on **east- and southeast-facing slopes** suggests a climatic coupling: these aspects receive higher rainfall due to orographic effects from

prevailing winds, leading to soil saturation and reduced shear strength (Gariano & Guzzetti, 2016).

Elevation also played a role, with **high-risk zones (>900 m)** correlating with steeper slopes and thinner soils. This pattern reflects gravitational stress accumulation and enhanced weathering rates at higher elevations (Korup et al., 2010). However, the absence of landslides in some high-elevation areas with dense vegetation underscores the modulating role of land cover.

3.2.3 Land use/cover

Land-use practices significantly altered landslide susceptibility. **Bare ground and farmland** accounted for **65% of high-risk zones**, as deforestation and tillage reduced root reinforcement and increased erosion (Kalsnes & Capobianco, 2022). Conversely, vegetated slopes exhibited stability due to root cohesion and interception of rainfall (Xiao et al., 2017).

Anthropogenic disturbances, such as unplanned construction on steep slopes (Appendix), further amplified risks. Poor drainage in built-up areas likely intensified pore-water pressure, a known precursor to landslides (Arbanas & Dugonjić, 2010). These findings echo observations in other developing regions where rapid land-use changes exacerbate slope instability (Klimeš & Blahůt, 2012).

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

3.1 CONCLUSION

This study mapped landslide susceptibility in Midima Hill, Mikolongwe, using a combination of literature review, remote sensing, and field surveys. Six key factors were analyzed: lithology, elevation, slope angle, slope aspect, and land cover. These factors were used to create thematic maps in ArcGIS 10.8, which revealed important patterns in landslide risk.

The results showed that lithology influences landslides in midima hill whereby gneiss and migmatite, have weakness like foliation and are more prone to landslides than quartz-diorite, especially when rainwater seeps into fractures. Slope direction also had a strong influence, with east and southeast-facing slopes experiencing the most landslides of the area because they face rain-bearing winds. Land use further influenced stability, with natural vegetation providing the best protection, while bare ground and farmland on slopes were highly vulnerable.

Using the Analytic Hierarchy Process (AHP), each factor was assigned a weight, and the weighted overlay method combined them into a final susceptibility map. The area was classified into five risk levels: very low, low, moderate, high, and very high susceptibility. The analysis found that 20.3% of the area falls under very high risk and 13.6% under high risk, while about 40% was in low to moderate risk zones.

Field surveys confirmed that **85% of inventoried landslides** aligned with the model's **high- and very-high susceptibility zones**, validating the AHP-GIS approach. Failures primarily manifested as **rockfalls and debris flows** (Figures 10–11), consistent with the lithological and slope conditions identified. Minor discrepancies in low-risk zones may reflect unaccounted micro-scale factors (e.g., localized groundwater seepage), suggesting future refinements with higher-resolution hydrological data.

The susceptibility map provides a actionable framework for land-use planning:

- **Avoid development in high-risk zones** underlain by gneiss/migmatite.

- **Implement slope stabilization measures** (e.g., terracing, agroforestry) on farmed slopes >22°.
- **Enhance drainage systems** in built-up areas to reduce pore-water pressure.

5.2 RECOMMENDATIONS

Based on the findings, the following practical measures must be addressed to reduce landslide risk in Midima Hill:

a. Avoid major construction in zones with gneiss and migmatite bedrock, as these rocks crack easily. In these areas, there is a need to install proper drainage systems to control rainwater and monitor slopes regularly for early signs of movement.

b. There is a need to Improve Farming Practices in the study area, where by agroforestry farming (mixing crops with trees), and Control livestock grazing can help to prevent soil exposure and stabilize the ground.

c. Secure high-risk slopes; whereby steeper slopes at angle greater than 30°, where most landslides occur, must be secured by keeping existing trees and plant more trees in bare ground slopes in order to help hold soil and rocks. And also, the use of terraced farming in these steeper slopes must be done to reduce erosion instead of straight cultivation on these slopes.

5.3 LIMITATIONS OF THE STUDY

Some parts of Midima Hill are remote and hard to reach due to rough terrain. Because of this, I couldn't survey those areas during my fieldwork. These remote spots might have landslide patterns I missed, which could impact how accurate the landslide susceptibility map is.

5.4 Some human activities, like farming and construction, can contribute to landslides. However, it was hard to measure their exact impact on slope stability because the landowners denied me access to the areas for their own personal reasons.

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APPENDIX

1. Pairwise matrix and weights of factors subclasses

CLASS	1	2	3	4	5	6	7	8	%	IMPORTANCE
SLOPE GRADIENT										
(1) 0 - 15	1								3.6	1
(2) 16 - 30	3	1							10.7	3
(3) 31 - 45	9	4	1						44.5	9
(4) 46 - 65	8	3	0.5	1					29.2	7
(5) > 65	5	1	0.25	0.3	1				12.1	3
Lithology										
(1) Quartz-diorite	1								16.9	3
(2) Gneiss	2	1							38.8	5
(3) Migmatite	3	1	1						44.3	7
Landcover										
(1) Water bodies	1								5.6	1
(2) Built-up Areas	2	1							15.1	3
(3) Bare Land	3	1	1						33.2	8
(4) Farm Land	8	3	0.5	1					32.4	7
(5) Vegetation	5	1	0.25	0.3	1				13.6	3
Aspect										
(1) North	1								2.3	2
(2) Northeast	2	1							10.6	3
(3) East	3	2	1						9.5	4
(4) Southeast	6	3	2	1					12.6	5
(5) South	7	4	0.5	1	1				14.3	6
(6) Southwest	8	0.25	3	2	2	1			16.6	7
(7) West	9	5	4	3	2	2	1		27.4	8
(8) Northwest	3	2	1	0.5	0.25	0.25	0.25	1	6.7	4
Elevation										
(1) 767 - 867	1								5.2	1
(2) 867 - 967	2	1							9.4	3
(3) 967 - 1067	3	2	1						24.6	5
(4) 1067 - 1167	6	3	2	1					31.7	8
(5) 1167 -1268	7	4	0.5	1	1				29.1	7

2. pairwise matrix and weights of all controlling parameters.

Controlling parameters	Elevation	Slope	Aspect	Landcover	Lithology	weight
Elevation	1					8.6
Slope	2	1				17.8
Aspect	3	1/2	1			14.2
Landcover	2	1	3	1		20.3
Lithology	3	3	2	3	1	39.1

3. Rock avalanche in Midima Hill





4. Rock creeping in Midima Hill





5. building on slope in high elevated areas in midima hill



6. Impacts of landslides of In Mikolongwe area



