# ASSESSING THE IMPACT OF LAND USE CHANGES ON FLOOD RISK IN URBAN AREAS: A CASE STUDY OF MTANDIRE, LILONGWE DISTRICT, MALAWI

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(DRM-012-21)

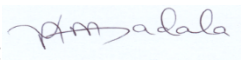
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# ABSTRACT

Rapid and unplanned urbanization is increasingly recognized as a primary driver of elevated flood risk in sub-Saharan African cities, yet localized, evidence-based research quantifying this link remains scarce. This study assesses the impact of land use and land cover (LULC) changes on flood risk in Mtandire, an unplanned informal settlement in Lilongwe District, Malawi. The research was guided by four objectives: (1) to map and quantify LULC changes between 2015 and 2025; (2) to assess how these changes influence surface runoff and flood inundation; (3) to evaluate household perceptions, vulnerability, and coping strategies; and (4) to propose integrated land use and community-based flood mitigation strategies.

A mixed-methods design was employed, integrating remote sensing and GIS-based spatial analysis with quantitative household surveys. Sentinel-2A satellite imagery (2015 and 2025) was classified to quantify LULC changes. Flood susceptibility was modeled using a weighted overlay analysis of key environmental factors elevation, slope, rainfall, distance from streams, and vegetation cover (NDVI). Physical vulnerability was assessed by overlaying infrastructure data with flood susceptibility maps. Social vulnerability and community perceptions were captured through a structured survey of 44 randomly selected households in flood-prone and non-flood-prone zones.

The results reveal a significant LULC transformation over the ten-year period. Built-up areas expanded dramatically, becoming more continuous and dominant, largely at the expense of vegetation and open spaces. NDVI analysis confirmed a marked decline in vegetation density, from moderate-to-dense cover in 2015 (0.415–0.705) to predominantly low-to-moderate cover by 2025 (negative values to 0.67), indicating a shift toward a highly impervious landscape. Flood susceptibility mapping identified that low-lying terrain, gentle slopes (0°–10°), and proximity to drainage channels are key determinants of flood risk, with a large portion of Mtandire classified as falling within high to very high flood susceptibility zones. Physical vulnerability analysis showed that

numerous dwellings and roads are situated within these high-risk areas. Household survey results indicated that flooding is a common experience among residents, yet only 25% of respondents demonstrated adequate awareness of coordinated flood response mechanisms, with most relying on reactive coping strategies.

This study concludes that land use change, specifically the rapid expansion of impervious surfaces and loss of vegetative cover, is a major driver of increased flood hazard in Mtandire. The convergence of physical susceptibility and low adaptive capacity creates a compound vulnerability that heightens flood risk. To mitigate this risk, the study recommends: (1) enforcement of land use zoning to restrict construction in flood-prone areas; (2) upgrading and regular maintenance of stormwater drainage infrastructure; (3) promotion of urban green infrastructure, including re-vegetation and tree planting; (4) community-based education programs to improve flood preparedness and awareness; and (5) the integration of GIS and hydrological modeling into local urban planning processes. The findings provide critical evidence for the Lilongwe City Council and the Department of Disaster Management Affairs (DoDMA) to inform proactive, risk-informed urban development strategies

Table of Contents

ACKNOWLEDGEMENTS ..... v

CHAPTER 1 ..... 1

1.NTRODUCTION ..... 1

1.1 Background ..... 1

1.2 Problem Statement ..... 1

1.3 Research Questions ..... 2

1.4 Research Objectives ..... 2

I. Main objectives ..... 3

II. Specific objectives ..... 3

1.5 Significance Of The Study ..... **Error! Bookmark not defined.**

CHAPTER 2 ..... 4

2. LITERATURE REVIEW ..... 4

2.1 Land Use and Land Cover Change in Urban Areas ..... 4

2.2 Land Use Change and Flood Risk ..... 4

2.3 Flood Risk in Sub-Saharan Africa ..... 4

2.4 Urban Flooding in Malawi ..... 5

2.5 Community Perceptions ..... 5

2.6 Policy and Planning Context ..... 4

2.7 Conceptual Framework ..... 6

2.8 RESEARCH GAP ..... 7

CHAPTER 3 ..... 7

3. METHODOLOGY ..... 8

3.1 Research Design ..... 8

3.2 Materials used for the Study ..... 8
3.3 Study Area ..... 9
3.4 Target Population ..... 10
3.5 Sampling Frame ..... 10
3.6 Sampling Technique ..... 11
3.7 Sample Size Determination ..... 11
3.8 Data Sources and Data Collection Methods ..... 12
3.8.1 Land Use and Land Cover Data ..... 12
3.8.2 Flood Contributing Environmental Factors ..... 12
3.8.3 Topographic Data ..... 13
Elevation ..... Error! Bookmark not defined.
Slope ..... Error! Bookmark not defined.
Aspect ..... Error! Bookmark not defined.
3.8.4 Hydrological Data ..... 14
Rainfall ..... Error! Bookmark not defined.
3.8.4 Distance From Streams and Drainage Channels ..... 14
3.8.5 Land Use and Land Cover ..... 15
3.8.6 Vegetation Cover (NDVI) ..... 15
3.8.7 Vulnerability Data ..... 15
3.9 Data Analysis ..... 16
3.9.1 Flood Susceptibility Mapping ..... 16
3.9.2 Vulnerability Mapping ..... Error! Bookmark not defined.
3.9.3 Physical Vulnerability ..... 16
3.4 Ethical Considerations ..... 17

CHAPTER 4..... Error! Bookmark not defined.
RESULTS AND DISCUSSION..... 18
4.1 Results ..... 18
4.1.1 Land Use and Land Cover Change Analysis ..... 18
Figure 2: The graph shows the land use changes statistics .... Error! Bookmark not defined.
4.1.2 Flood Contributing Environmental Factors.....22
Figure 3: shows the aspect map of mtandire .....26
4.1.5 Flood Vulnerability Assessment ..... Error! Bookmark not defined.
Physical Vulnerability..... Error! Bookmark not defined.
Vulnerability map ..... Error! Bookmark not defined.
Flood risk map .....33
4.2.Discussion.....38
CHAPTER 5..... Error! Bookmark not defined.
5.CONCLUSIONS AND RECOMMENDATIONS ..... Error! Bookmark not defined.
5.1 Summary of Major Findings..... Error! Bookmark not defined.
5.2 CONCLUSIONS..... Error! Bookmark not defined.
5.3 RECOMMENDATIONS ..... Error! Bookmark not defined.
5.3.1 Improved Urban Land Use Planning ..... Error! Bookmark not defined.
5.3.2 Improvement of Drainage Infrastructure..... Error! Bookmark not defined.
5.3.3 Promotion of Urban Green Spaces ..... Error! Bookmark not defined.
5.3.4 Community Awareness and Flood Preparedness .. Error! Bookmark not defined.
5.3.5 Integration of GIS and Hydrological Modelling in Urban Planning ..... Error! Bookmark not defined.
5.3 Suggestions for Future Research..... Error! Bookmark not defined.

REFERENCES .....48

## ABBREVIATIONS AND ACRONAMES

| | |
|---|---|
| DEM | Digital Elevation Model |
| DCCMS | Department of Climate Change and Meteorological Services |
| DRM | Disaster Risk Management |
| FGD(s) | Focus Group Discussion(s) |
| DEM | Digital Elevation Model |
| GIS | Geographic Information System(s) |
| GPS | Global Positioning System |
| HEC-RAS | Hydrologic Engineering Center's River Analysis System |
| IPCC | Intergovernmental Panel on Climate Change |
| KIIs | Key Informant Interviews |
| LCC | Lilongwe City Council |
| LULC | Land Use and Land Cover |
| MUST | Malawi University of Science and Technology |
| NGO(s) | Non-Governmental Organization(s) |
| RMSE | RMSE – Root Mean Square Error |

## LIST OF FIGURES

Figure 1: the figure above is conceptual framework of this study

Figure 3.3: Study area map showing Mtandire settlement in Lilongwe District.

Figure 4.1: The figure above shows the classification of attributes in Mtandire

Figure 4.2: The figure above shows the classification graph based on 4 attributes.

Figure 4.5: shows the pie with the classification tributes

Figure 4.4: Classified land use map for 2025

Figure 4.5: shows the pie with the classification tributes

Figure 4.2.1: Elevation map of Mtandire settlement.

Figure 4.2.2: Slope classification map.

Figure 4.2.3: shows the aspect map of Mtandire

Figure 4.2.5: the above figure shows the distance from stream

Figure 4.2.4: Annual rainfall distribution map.

Figure 4.2.6: Mtandire Normalized Difference Vegetation Index (2015)

Figure 4.2.7: Below the map shows NDVI for Mtandire 2025

Figure 4.3.1: shows the pie chart on gender distribution

Figure 4.3.2: the figure above shows the age range of participants

Figure 4.4.2: the figure above shows the awareness and coordination of the participants

## LIST OF TABLES

Table 3.2: The table above shows the materials required to successfully conduct the research.

Table 4.3.1: shows gender distribution of the participants

Table4.3.2: shows the ae distribution of participants

Table 4.3.3: shows awareness and coordination

# CHAPTER 1

## 1.NTRODUCTION

### 1.1 Background

As cities are growing with unprecedented speed, over half the global population now resides in urban areas, a trend that shows no signs of slowing down (United Nations, 2018). But this rapid urbanization is not without consequence. Planning often lags growth, and the result is a dramatic transformation of our landscapes. Forests, wetlands, grasslands, nature's own flood defenses are being replaced by concrete jungles and rooftops (Fletcher et al., 2013). These impervious surfaces disrupt the hydrological balance, accelerating surface runoff, reducing infiltration, and funneling water into river channels faster than ever before. The outcome? A surge in flood risk. Malawi stands as a stark example of this crisis. Vulnerable to climate-related disasters, the country has witnessed a troubling rise in severe flood events. Lilongwe, its capital, is particularly exposed. Unplanned settlements, poor drainage systems and the loss of natural floodplains converge to create a perfect storm. This study argues that disaster risk management must begin with understanding. In urban contexts, land use change is not just a statistic it's a driver of hydrological hazard. Assessing its impact is essential, not optional. It's a cornerstone of urban resilience and a direct contribution to national development goals and global commitments like the Sendai Framework and Sustainable Development Goal 11.5: reducing the impact of disasters on people and infrastructure. Urban flood risk is not a distant threat it's a present danger.

### 1.2 Problem Statement

The existing body of research on flooding in Malawi has predominantly focused on large-scale, rural, and riverine flooding, particularly along the Shire River Basin and the Lower Zambezi (Phiri et al., 2019; Kaunda et al., 2021). These studies, while valuable, often produce generalized findings that are not directly applicable to the unique micro-dynamics of specific urban neighborhoods. There is a critical gap in localized, evidence-based research

that quantitatively links specific patterns of land use change to increased flood vulnerability at the community level in Malawian cities (Chanza & Mataya, 2020; Manda, 2014).

The community of Mtandire in Lilongwe is a good example. It has undergone rapid and largely unplanned urbanization, characterized by the construction of dwellings in low-lying areas, encroachment on natural drainage channels, and the proliferation of impervious surfaces (Kalindekafe et al., 2022). This has made it increasingly susceptible to flash floods during the rainy season, resulting in recurrent damage to homes, infrastructure, and livelihoods. The community's perception of its risk and its capacity to adapt remains inadequately documented (World Bank, 2021). Consequently, disaster management strategies are often reactive rather than proactive. This research seeks to fill this gap by conducting a detailed case study of Mtandire to quantitatively assess how land use changes have amplified flood risk and to identify pathways for enhancing community resilience.

## 1.3 Research Questions

This study was guided by the following research questions:

1. What are the spatial and temporal patterns of land use and land cover change in Mtandire between 2015 and 2025?
2. How have these land use changes influenced surface runoff generation and potential flood inundation patterns in the area?
3. What are the household perceptions of flood risk, and what coping and adaptation strategies are currently employed by residents of Mtandire?
4. Based on the findings, what integrated land use planning and community-based strategies can be proposed to mitigate flood risk and enhance resilience in Mtandire.

## 1.4 RESEARCH OBJECTIVES

### I. Main objectives

1. To develop evidence-based recommendations for land use planning and community-led flood risk reduction interventions to improve resilience.

### II. Specific objectives

2. To map and quantify the land use and land cover changes in Mtandire over the past 10 years using Geographic Information Systems (GIS) and remote sensing.
3. To assess household vulnerability and adaptive capacity by evaluating community perceptions, experiences, and existing coping mechanisms related to flooding.

- Academic Contribution: It will contribute to the body of knowledge on urban flood risk in Malawi by providing a detailed
- Policy and Planning: The findings will provide critical evidence to inform the Lilongwe City Council (LCC) and (DoDMA) about developing proactive, risk-informed urban planning policies.
- Community Empowerment: the study will produce contextually relevant strategies that empower residents to take ownership of their risk reduction measures.

The research directly supports Malawi's National Resilience Strategy and contributes to achieving SDG Target 11.5. (United nation, 2015)

# CHAPTER 2

## 2. LITERATURE REVIEW

This chapter reviews scholarly literature on land use and land cover (LULC) changes, their influence on hydrological processes, and the implications for flood risk in urban areas. It further discusses urbanization trends in Sub-Saharan Africa.

### 2.1 Land Use and Land Cover Change in Urban Areas

Land use change refers to the alteration of the earth's surface by human activities, including conversion of natural vegetation into built-up areas, agricultural land, and infrastructure (Lambin et al., 2003). Rapid and often unregulated urbanization has emerged as one of the most significant drivers of LULC change, particularly in developing countries where population growth and rural-urban migration are accelerating (Seto et al., 2011). Urban expansion commonly replaces permeable surfaces such as soils and vegetation with impervious materials like asphalt and concrete. Studies have shown that this transition reduces infiltration, accelerates surface runoff, and disrupts natural drainage pathways (Fletcher et al., 2013).

### 2.2 Land Use Change and Flood Risk

The link between land use change and flood risk has been widely established in hydrological and disaster risk literature. Conversion of wetlands and floodplains into settlements or agricultural plots eliminates natural buffering zones, while encroachment on river channels reduces water conveyance capacity (Suriya & Mudgal, 2012).

### 2.6 Policy and Planning Context

International frameworks such as the Sendai Framework for Disaster Risk Reduction (2015–2030) and the Sustainable Development Goals (SDGs) emphasize the need for risk-informed urban planning. In Malawi, the National Resilience Strategy (2018–2030) and

the National Urban Policy call for integrating disaster risk reduction into land use planning and infrastructure development (GoM, 2018). Despite these policy commitments, practical implementation remains weak at local level. (Manda, 2013).

## 2.3 Flood Risk in Sub-Saharan Africa

Sub-Saharan Africa is highly vulnerable to climate-induced disasters, with floods ranking among the most frequent and devastating hazards (UNDRR, 2019). Rapid urban growth in cities has often occurred in the absence of comprehensive land use planning, leading to-settlements in low-lying flood-prone zones (Douglas et al., 2008; UN-Habitat, 2014). Weak governance, poor enforcement of building codes, and limited investment in drainage infrastructure exacerbate the problem.

## 2.4 Urban Flooding in Malawi

Malawi's vulnerability to floods has historically been studied in the context of large-scale riverine flooding in the Shire and Zambezi basins (Di Baldassarre et al., 2010). However, recent decades have seen a rise in localized urban flooding events, especially in Lilongwe, Blantyre, and Mzuzu (GoM, 2019). The 2019 Lilongwe floods, which resulted in loss of life and extensive property damage, highlighted the severity of the problem (Department of Disaster Management Affairs [DoDMA], 2019; UN-Habitat, 2020). Yet, there is limited empirical research that directly links localized land use changes in peri-urban neighborhoods such as Mtandire to their flood risk exposure (Kalindekafe et al., 2022; Chanza & Mataya, 2020).

## 2.5 Community Perceptions

Flood risk is not only a physical phenomenon but also a social one. The perception of risk influences how households and communities respond to recurrent flooding (Wisner et al., 2004). In Malawi, community responses to floods vary by socio-economic conditions. Poorer households often rely on short-term coping mechanisms, such as moving belongings

to higher ground, while wealthier residents may invest in more permanent structural adaptations (Manyungwa-Pasani et al., 2019).

## 2.7 Conceptual Framework

Drawing from the reviewed literature, this study adopts a risk framework where land use change is conceptualized as a key driver of hazard, which interacts with exposure (settlements in flood-prone zones) and vulnerability (limited adaptive capacity) to produce flood risk (Wisner et al., 2004; IPCC, 2014)

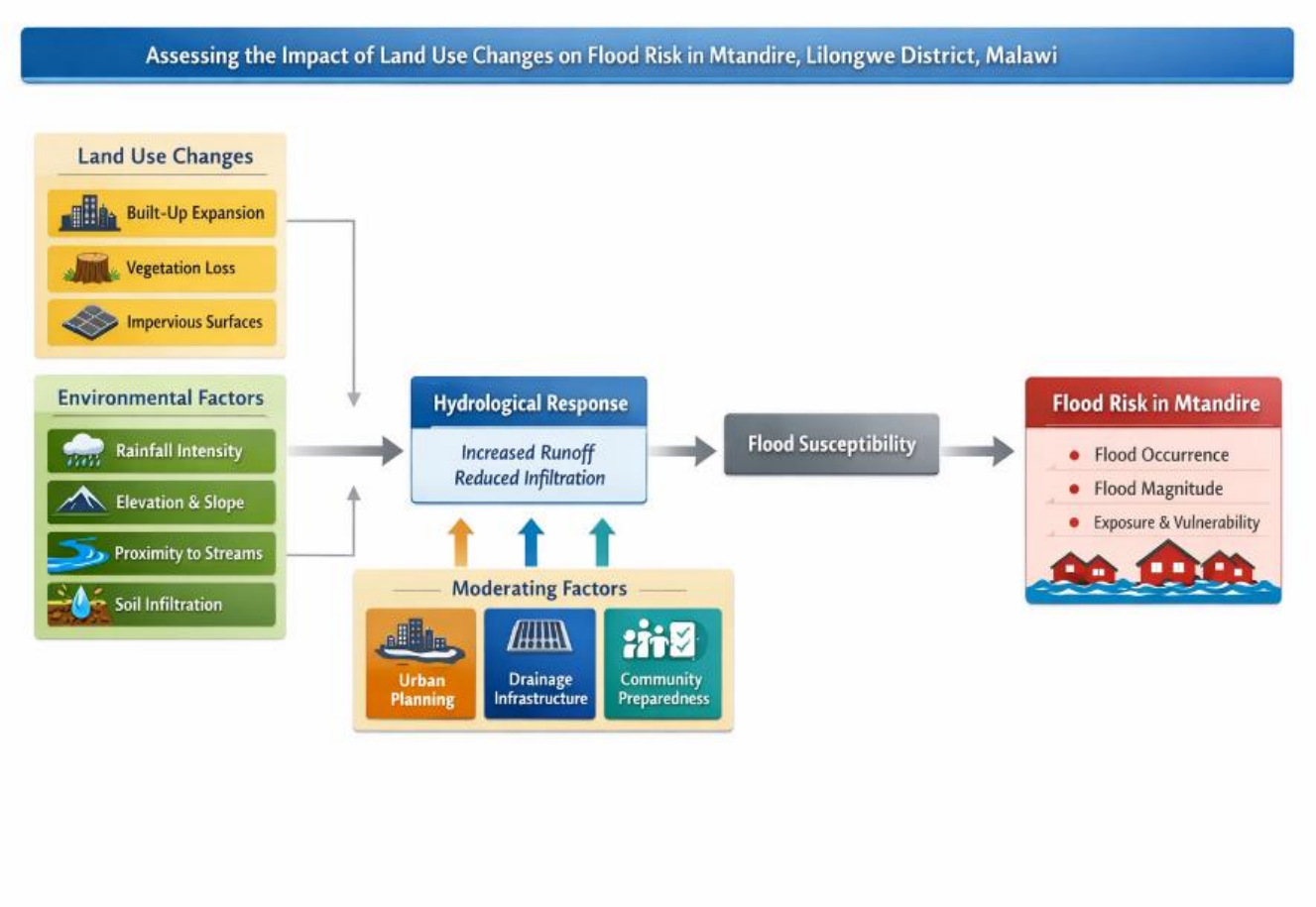



Figure 1: the figure above is conceptual framework of this study.

## 2.8 RESEARCH GAP

Although several studies have examined flooding in Malawi and Sub-Saharan Africa, significant research gaps still exist regarding the relationship between land use change and urban flood risk in informal settlements. Previous studies in Malawi have largely focused on large-scale rural and riverine flooding within the Shire River Basin and Lower Zambezi, providing generalized findings that do not adequately explain localized urban flood dynamics in rapidly growing settlements such as Mtandire (Phiri et al., 2019; Kaunda et al., 2021). Existing literature also demonstrates limited empirical research directly linking urban land use and land cover (LULC) transformation to flood susceptibility at the community level in Malawian cities (Chanza & Mataya, 2020). Furthermore, most studies have treated flood risk either from a physical science perspective focusing on hydrological and environmental factors or from a social science perspective emphasizing household vulnerability and coping strategies, with limited integration of both approaches into a single analytical framework (Wisner et al., 2004). There is also inadequate application of GIS, remote sensing, NDVI analysis, and spatial flood susceptibility modelling in localized urban flood studies within Malawi, despite these tools being critical for understanding how rapid urbanization, vegetation loss, and expansion of impervious surfaces influence runoff generation and flood occurrence (Fletcher et al., 2013). In addition, although policies such as the Sendai Framework, Malawi National Resilience Strategy, and National Urban Policy advocate for risk-informed urban planning, there remains weak translation of these frameworks into practical community-level flood mitigation strategies, especially in informal settlements where unplanned urbanization continues to increase exposure to flood hazards (GoM, 2018; Manda, 2014). Therefore, this study addresses these gaps by integrating GIS and remote sensing analysis with household vulnerability assessment to provide localized, evidence-based understanding of how land use changes influence flood risk in Mtandire settlement, Lilongwe.

# CHAPTER 3

## 3. METHODOLOGY

This chapter outlines the methodological approach used to assess the impact of land use changes on flood risk in Mtandire, Lilongwe District. The chapter describes the research design, study area, materials used in the study, target population, sampling procedures, data collection methods, data analysis techniques, and ethical considerations guiding the research.

### 3.1 Research Design

The study adopts a mixed-methods research design, integrating both quantitative and qualitative approaches to comprehensively assess the relationship between land use changes and flood risk in Mtandire.

The design integrates the following components:

1. Remote Sensing and GIS Analysis – used to map and quantify land use and land cover (LULC) changes within the study area.
2. Household Surveys and Key Informant Interviews (KIIs) – used to capture community perceptions, vulnerabilities, and adaptation strategies related to flooding.

The integration of these approaches enables the study to analyze both the physical drivers of flooding and the socio-economic impacts experienced by communities.

### 3.2 Materials used for the Study

The table presents the materials and tools used to conduct the study and their respective applications.

| Category | Materials/Tools | Application |
|---|---|---|

| | | |
|---|---|---|
| Datasets | Satellite Images | Land use mapping and change detection |
| | Digital Elevation Model (DEM) | Hydrological modelling |
| | Household Survey Data | Assessing community perceptions |
| Software | ArcGIS | Spatial analysis and LULC classification |
| | | |
| | Excel | Data analysis and statistical validation |
| Field Equipment | Smartphone | Household survey administration |
| | Questionnaires | Collecting household data |
| Other Materials | Stationery | Fieldwork documentation |

Table 3.2: The table above shows the materials used to successfully conduct the research.

## 3.3 STUDY AREA

Mtandire is a densely populated informal settlement located within Area 56 of Lilongwe City in Malawi's Central Region. The area lies at approximately latitude -13.9164° and longitude 33.7490°.

Mtandire is characterized by rapid urban expansion, inadequate drainage systems, and high vulnerability to flooding. Many households are in low-lying areas and along natural drainage channels, making the community particularly susceptible to flood events during heavy rainfall periods.

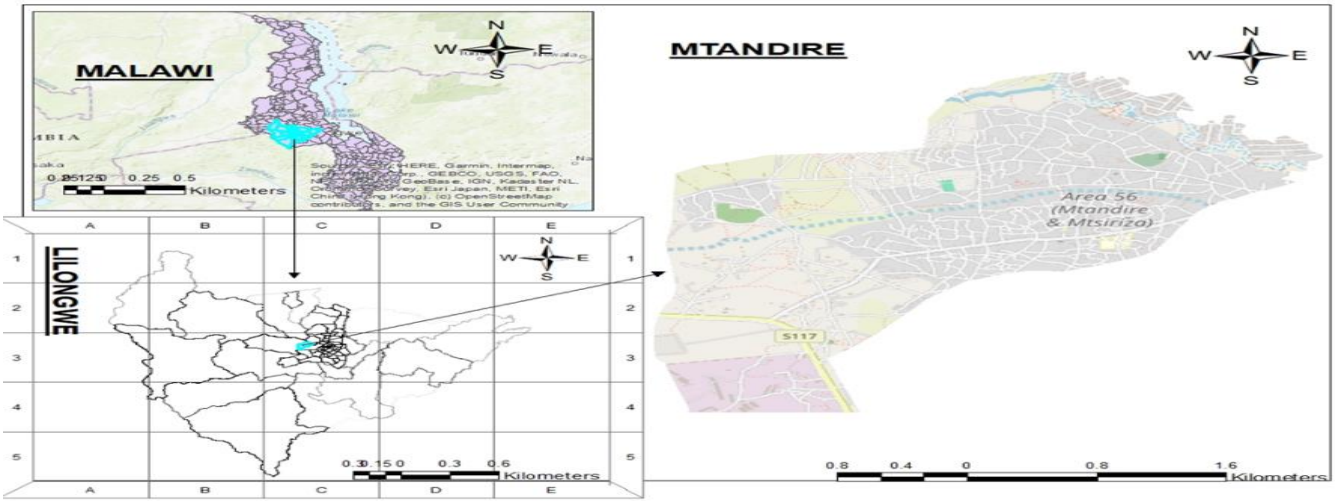



Figure 3.3: Study area map showing Mtandire settlement in Lilongwe District.

## 3.4 Target Population

The target population for this study comprises individuals residing in Mtandire settlement in Lilongwe District. Households are considered the most appropriate unit of analysis because they directly experience flooding events and are affected by land use changes within the area.

Studying households allowed to capture:

- Flood risk perceptions
- Historical flood experiences
- Household Coping and adaptation strategies
- Socio-economic characteristics influencing vulnerability

## 3.5 Sampling Frame

A sampling frame refers to a complete list or source from which a sample is drawn in a research study. It represents all elements within the target population that have a chance of being selected for participation.

In this study, the sampling frame consists of individuals residing in both:

- Flood-prone zones (households located near drainage channels and low-lying areas)
- Non-flood-prone zones within Mtandire settlement.

This classification ensures representation of households experiencing varying levels of flood exposure.

### 3.6 Sampling Technique

The study employed a stratified random sampling technique. Mtandire settlement was first divided into two strata:

1. Flood-prone households
2. Non-flood-prone households

From each stratum, households were selected randomly using a lottery method to minimize selection bias and ensure fair representation of households across different risk zones.

### 3.7 Sample Size Determination

The sample size for the household survey will be determined using Slovin's formula (Slovin, 1960):

$$n = \frac{N}{1 + N(e^2)}$$

Where:

- n = sample size
- N = total household population in Mtandire
- e = margin of error (15%)

Based on preliminary estimates, the study sampled 44 participants from the target population.

## 3.8 Data Sources and Data Collection Methods

This study utilized both spatial and socio-economic datasets to assess the impact of land use and land cover change on flood risk in Mtandire settlement in Lilongwe District. The data included satellite imagery, topographic data, hydrological data, land use data, and household survey information. These datasets were collected from various open-access platforms and field surveys and were analyzed using Geographic Information Systems (GIS), remote sensing techniques and excel.

### 3.8.1 Land Use and Land Cover Data

This research used Sentinel-2A satellite imagery to analyze land use and land cover changes in Mtandire settlement. The satellite images were obtained from the Copernicus Data Space Ecosystem. Two satellite images representing different time periods were used to assess the changes in land use patterns within the study area. The first satellite image representing the earlier land use conditions was acquired in 2015, while the second image representing recent conditions was obtained in 2025. These images were processed and classified using GIS software to identify major land use categories including built-up areas, vegetation, bare land, and water bodies. Image preprocessing techniques such as band combination, and image enhancement were applied to improve the accuracy of land cover classification. Supervised classification methods were then applied to categorize the land use classes within the study area. The results enabled the identification of spatial changes in land cover over time, particularly the expansion of built-up areas which influence surface runoff and flood risk. Field observations were also conducted in Mtandire to validate the classification results and confirm the current land use conditions.

### 3.8.2 Flood Contributing Environmental Factors

Several environmental and physical factors that influence flood occurrence were considered in this study. These factors included topographic characteristics, hydrological conditions, and land cover patterns.

### 3.8.3 Topographic Data

Topography plays a significant role in determining water flow patterns, runoff accumulation, and flood susceptibility. In this study, a 30 m Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) obtained from the USGS Earth Explorer (https://earthexplorer.usgs.gov/) was used to derive important terrain parameters including elevation, slope, and flow accumulation.

#### A. Elevation

Elevation influences how water moves across the landscape and determines areas that are more likely to accumulate water during rainfall events. Low-lying areas tend to accumulate runoff and are therefore more vulnerable to flooding. In this study, elevation values within the Mtandire area were classified into four elevation categories using an equal interval classification method. Areas with lower elevation were identified as zones with higher flood potential because they act as natural drainage basins where runoff accumulates during heavy rainfall.

#### B. Slope

Slope gradient is an important factor influencing the speed and direction of surface runoff. Areas with gentle slopes tend to retain water for longer periods, increasing the likelihood of flooding, whereas steep slopes allow water to flow rapidly downslope. The slope map was derived from the DEM and categorized into five slope classes. Areas with slopes below 5° were considered highly susceptible to flooding because water tends to accumulate in relatively flat terrain. Conversely, areas with steeper slopes were considered to have lower flood susceptibility due to faster runoff movement.

### c. Aspect

Aspect Refers to The Direction That a Slope Faces and Is Measured in Degrees. It Influences the distribution of rainfall, solar radiation, and soil moisture conditions. In hydrological studies, aspect helps to understand the direction of water flow across the terrain.

## 3.8.4 Hydrological Data

Hydrological factors play a crucial role in determining flood occurrence in urban environments. This study considered rainfall patterns and proximity to drainage channels as key hydrological variables.

### A. Rainfall

Rainfall data was obtained from the CHRS Data Portal and used to analyze precipitation distribution within the study area. The rainfall dataset was downloaded in raster format and processed in ARCGIS. The data was first assigned a projected coordinate system and clipped to the study area using the "Extract by Mask" tool. The rainfall raster was then converted into point data using the "Raster to Point" tool. To generate continuous rainfall surface, the Inverse Distance Weighted (IDW) interpolation method was applied. The rainfall distribution was classified into four categories representing varying rainfall intensities within the study area.

## 3.8.5 Distance from Streams and Drainage Channels

Proximity to drainage channels significantly influences flood risk, as areas located near rivers and streams are more prone to flooding during heavy rainfall.

The stream network was derived from the SRTM DEM using hydrological tools in ArcGIS, including flow direction and flow accumulation analysis. Euclidean Distance analysis was then applied to generate distance-to-stream zones. The distances were categorized into

several classes representing areas closest to streams and those farther away. Areas located closer to streams were considered more vulnerable to flooding.

### 3.8.6 Land Use and Land Cover

Land use and land cover play a critical role in influencing flood dynamics in urban environments. Changes such as the conversion of vegetation to built-up areas increase impervious surfaces and reduce infiltration capacity, resulting in increased surface runoff.

### 3.8.7 Vegetation Cover (NDVI)

Vegetation cover was analyzed using the Normalized Difference Vegetation Index (NDVI) derived from Sentinel-2 imagery. NDVI was calculated using the formula:

NDVI = (NIR (band 8) − Red (band 4) / (NIR (band 8 + Red (band 4)).

where NIR represents near-infrared reflectance and Red represents visible red reflectance.

The NDVI values ranged from −0.02 to 0.74 across the study area and were classified into three categories:

- No vegetation (−0.02 – 0.19)
- Moderate vegetation (0.20 – 0.49)
- Dense vegetation (0.50 – 0.74)

Areas with low vegetation cover were identified as having higher flood potential because vegetation helps increase infiltration and reduce runoff.

### 3.8.8 Vulnerability Data

The study assessed flood vulnerability by collecting geospatial data on buildings, roads, bridges, and agricultural areas within Mtandire settlement. Building footprints were

extracted from OpenStreetMap (OSM). Road networks and drainage channels were manually digitized from Google Earth imagery.

This spatial analysis helped determine which infrastructure and land areas were most exposed to flood hazards. To assess social vulnerability, community surveys were conducted among households in Mtandire to evaluate awareness, preparedness, and response to flood events. Questionnaires captured information regarding past flood experiences, knowledge of flood risks, and household coping mechanisms.

## 3.9 DATA ANALYSIS

### 3.9.1 Flood Susceptibility Mapping

Flood susceptibility mapping was conducted using GIS spatial analysis techniques. Several environmental factors including elevation, slope, rainfall, distance from streams, and land use were integrated to identify flood-prone areas within Mtandire.

Each factor was classified into different categories based on its influence on flood occurrence. The thematic layers were then standardized and combined using weighted overlay analysis in QGIS.

The resulting flood susceptibility map categorized the study area into four flood risk levels:

- Low susceptibility
- Moderate susceptibility
- High susceptibility
- Very high susceptibility

### 3.9.3 Physical Vulnerability

Physical vulnerability was assessed by overlaying flood susceptibility maps with spatial data on infrastructure such as buildings, roads, and agricultural land.

## 3.4 ETHICAL CONSIDERATIONS

The study adhered to ethical research guidelines approved by the Malawi University of Science and Technology Research Ethics Committee (MUSTREC). Permission to conduct the research was obtained from local community leaders in Mtandire.

Participation in the survey was voluntary, and respondents were informed about the purpose of the study prior to data collection. Confidentiality was maintained by replacing participants' names with identification numbers.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4. RESULTS

### 4.1 Land Use and Land Cover Change Analysis

Land Use and Land Cover (LULC) change analysis was conducted using Sentinel-2A satellite imagery for the years 2015 and 2025 to evaluate the impact of urban expansion on flood risk in Mtandire settlement. The classified images reveal significant transformations in land use patterns over the ten-year period, characterized by rapid urban growth and a reduction in natural land cover.

The 2015 land use classification (Figure 4.1) indicates that built-up areas were already dominant, reflecting substantial urban development. However, compared to 2025, the built-up surfaces were less dense and more spatially fragmented. Vegetation cover was present in scattered patches, suggesting the existence of small-scale agriculture, tree cover, and undeveloped green spaces. Water bodies were also more visible, particularly in the upper and central parts of the study area, while bare land appeared in limited portions, indicating exposed or unused surfaces

Figure 4.1: Classified land use map for 2015

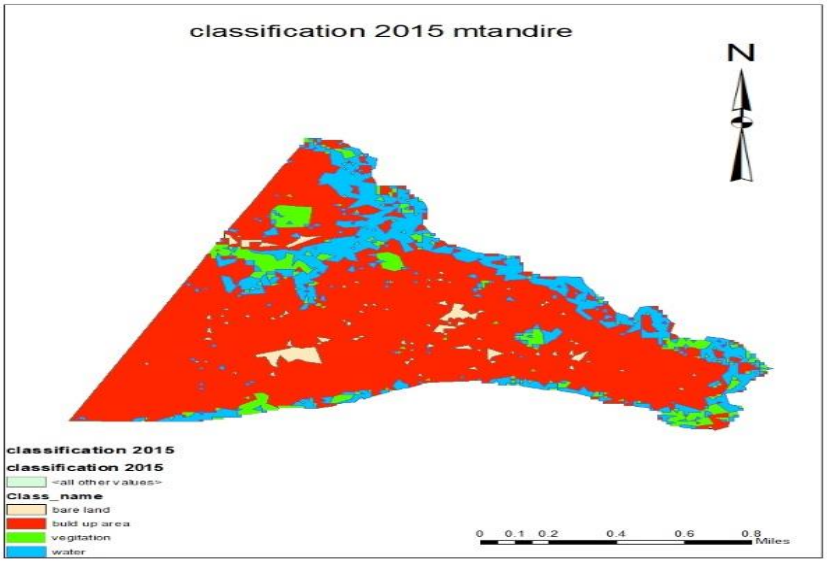



Figure 4.1: The figure above shows the classification of attributes in Mtandire

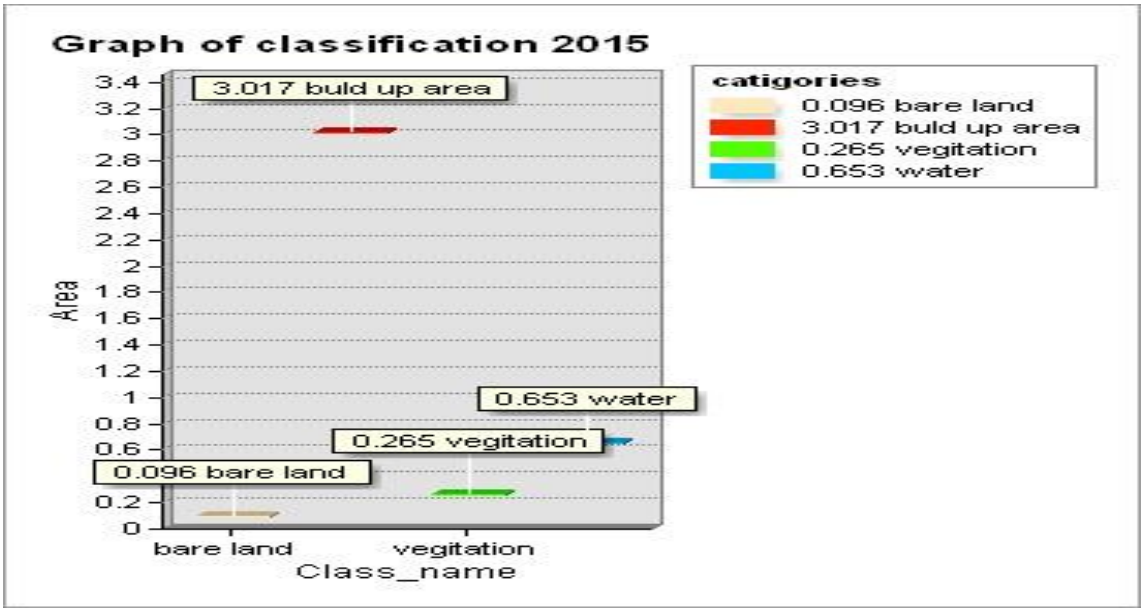



Figure 4.2: The figure above shows the classification graph based on 4 attributes.

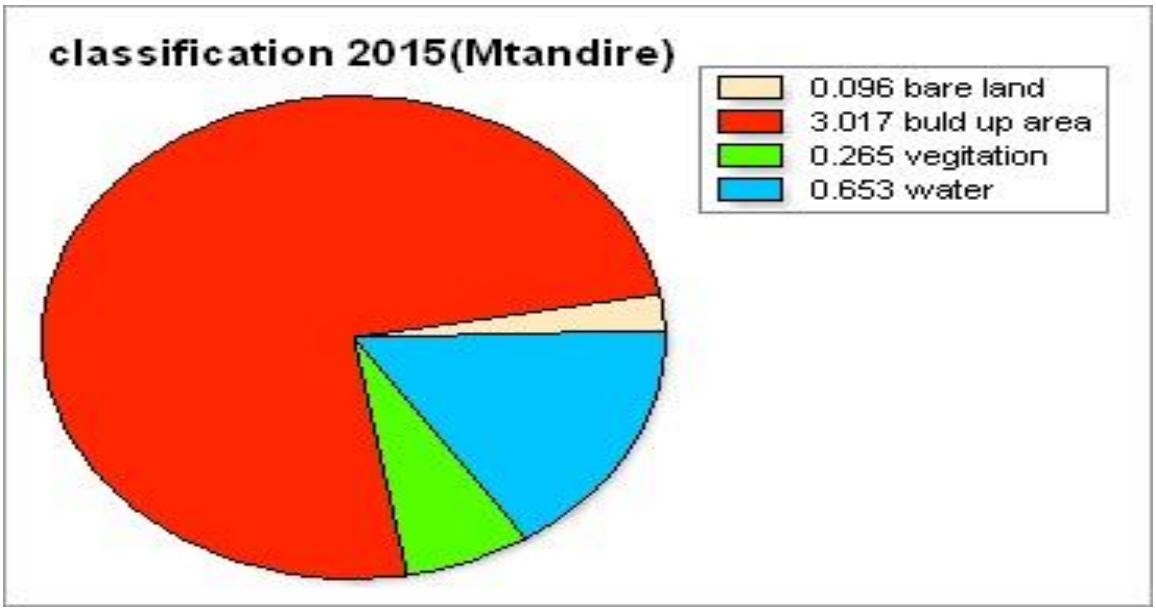



Figure 4.3: shows the pie chart of the 2015 classification based on the 4 attributes.

The figure above shows the land use/land cover classification for Mtandire in 2015.The area is largely dominated by built-up land (red), indicating that urban or residential development was already widespread by 2015. However, compared to later years, the built-up coverage appears slightly less continuous, with more visible patches of other land types.

Other classes include:

- Vegetation (green), which appears in scattered clusters across the map, suggesting the presence of trees, small farms, or undeveloped green spaces.
- Water bodies (blue), which are more noticeable than in the 2025 map, especially in the upper and central parts of the area.
- Bare land (light beige), found in small patches, indicating exposed or unused land.

In contrast, the 2025 classification (Figure 4.2) shows a marked increase in built-up areas, which have expanded both in size and continuity. This expansion has largely occurred at the expense of vegetation and open spaces. The reduction in vegetation cover and

permeable surfaces suggests a decline in natural water infiltration capacity. Consequently, more rainfall is converted into surface runoff, thereby increasing the likelihood and intensity of flooding events.

The graphical and pie chart representations further confirm these changes, illustrating a proportional increase in built-up land and a corresponding decrease in vegetation and other natural land cover types. These findings highlight a strong relationship between urban expansion and increased flood vulnerability in Mtandire

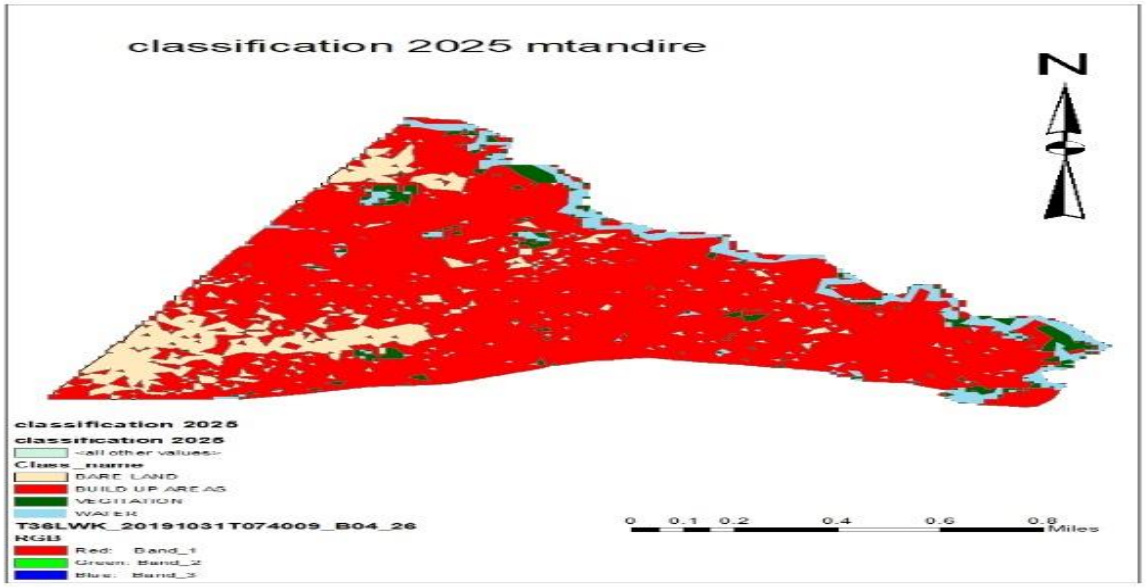



Figure 4.4: Classified land use map for 2025

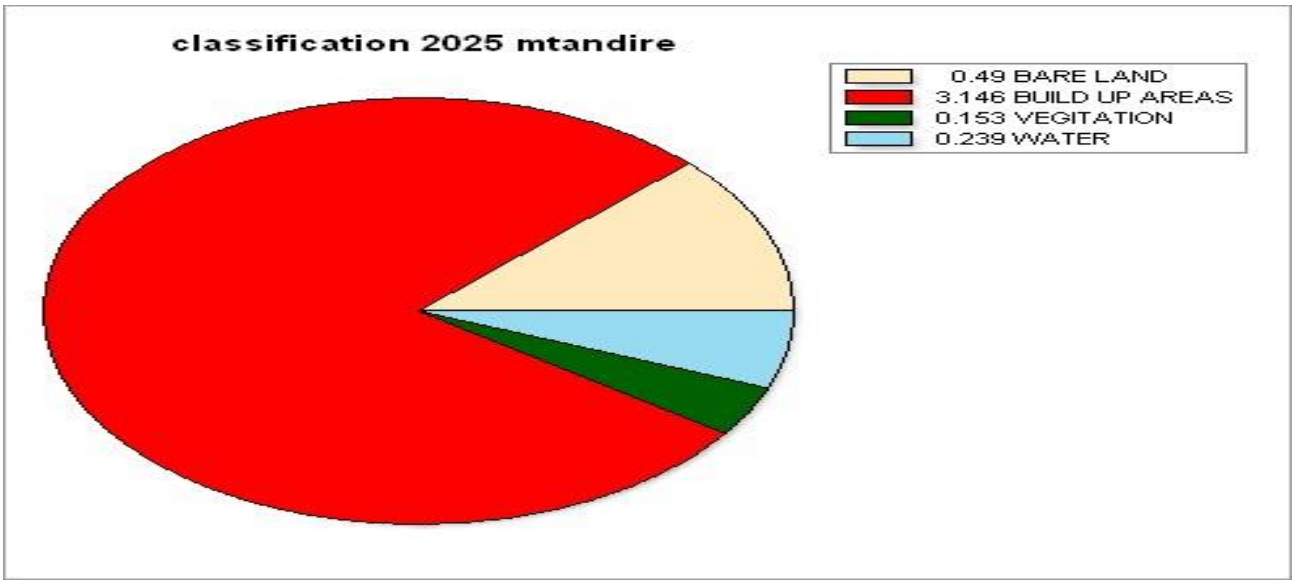



Figure 4.5: shows the pie with the classification tributes

A direct comparison of the 2015 and 2025 land use/land cover classifications shows a clear transformation of the Mtandire landscape, with important implications for flood risk.

In 2015, the map indicates a more heterogeneous land cover pattern. Although built-up areas were already present, there was still a noticeable distribution of vegetation (green patches) and water bodies (blue), particularly along drainage lines and low-lying areas. These vegetated surfaces would have supported infiltration, reduced runoff velocity, and helped regulate local hydrology. Bare land also appeared in smaller, scattered patches, suggesting transitional or less intensively used spaces. By 2025, the classification shows a dramatic dominance of built-up areas (red), which now cover most of the study area. Vegetation has become highly fragmented and limited to small, isolated patches, while bare land appears in reduced but still present pockets. Water bodies or drainage features are less visible or more constrained, likely due to encroachment or modification. This shift reflects rapid urban expansion, likely driven by population growth and informal settlement development.

Relating these changes to flood risk, the increase in built-up surfaces is particularly significant. Built-up areas are typically characterized by impervious materials such as concrete and compacted soils, which drastically reduce infiltration and increase surface runoff. In contrast, the reduction in vegetation also supported by the NDVI results you discussed earlier—means that fewer areas are available to intercept rainfall and slow down water movement. The transition from a mixed land cover system in 2015 to a predominantly built-up landscape in 2025 has therefore altered the hydrological response of Mtandire. Rainfall that would previously have been partially absorbed by soil and vegetation is now more rapidly converted into overland flow. This increases peak discharge, shortens the time it takes for water to accumulate, and raises the likelihood of flash flooding, especially in low-lying or poorly drained zones.

## 4.2 FLOOD CONTRIBUTING ENVIRONMENTAL FACTORS

Flood susceptibility in Mtandire settlement is influenced by several environmental factors, including elevation, slope, aspect, rainfall distribution, distance from streams, and vegetation cover. Each of these factors plays a significant role in determining how water accumulates and flows across the landscape

### 4.2.1 Elevation

The elevation map derived from the SRTM Digital Elevation Model indicates that Mtandire is predominantly characterized by low-lying terrain with minimal elevation variation (Figure 4.3). Lower elevation zones are mainly located along natural drainage pathways, where water tends to accumulate during rainfall events.

These areas are particularly vulnerable to flooding, as they act as natural collection points for runoff. The limited elevation gradient further reduces the ability of water to flow efficiently out of these zones, thereby increasing flood risk

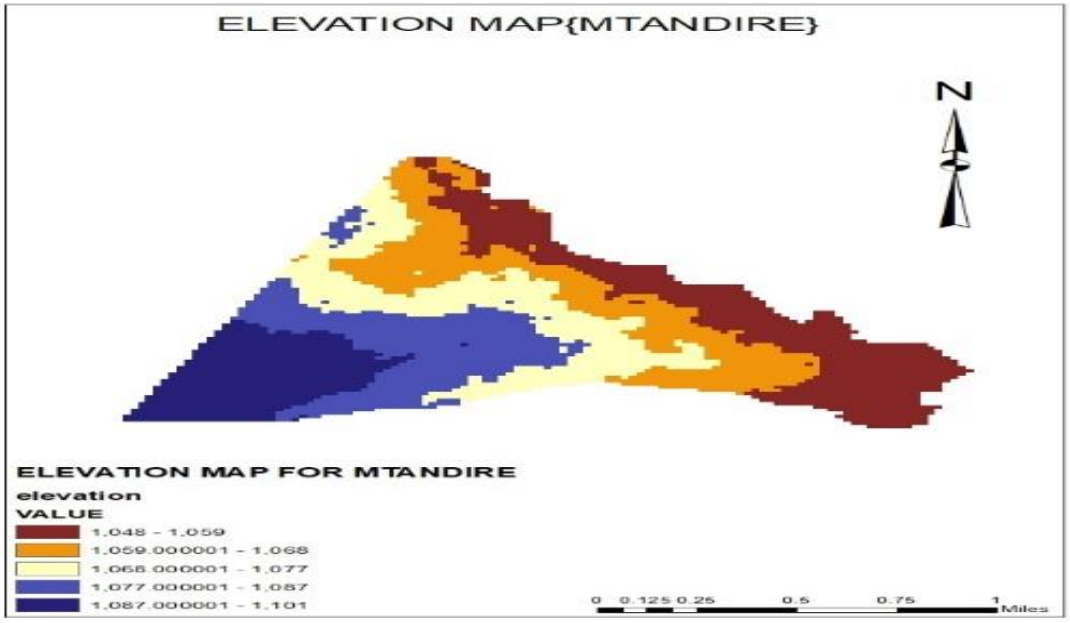



Figure 4.2.1: Elevation map of Mtandire settlement.

### 4.2.2 Slope

Slope analysis (Figure 4.4) shows that most parts of the study area have gentle slopes ranging between 0° and 10°. Gentle slopes slow down the movement of surface runoff, which promotes water accumulation in low-lying areas. As a result, areas with low slope gradients are more prone to flooding, especially where drainage systems are insufficient or poorly maintained. The combination of gentle slopes and increasing impervious surfaces due to urbanization further exacerbates flood risk

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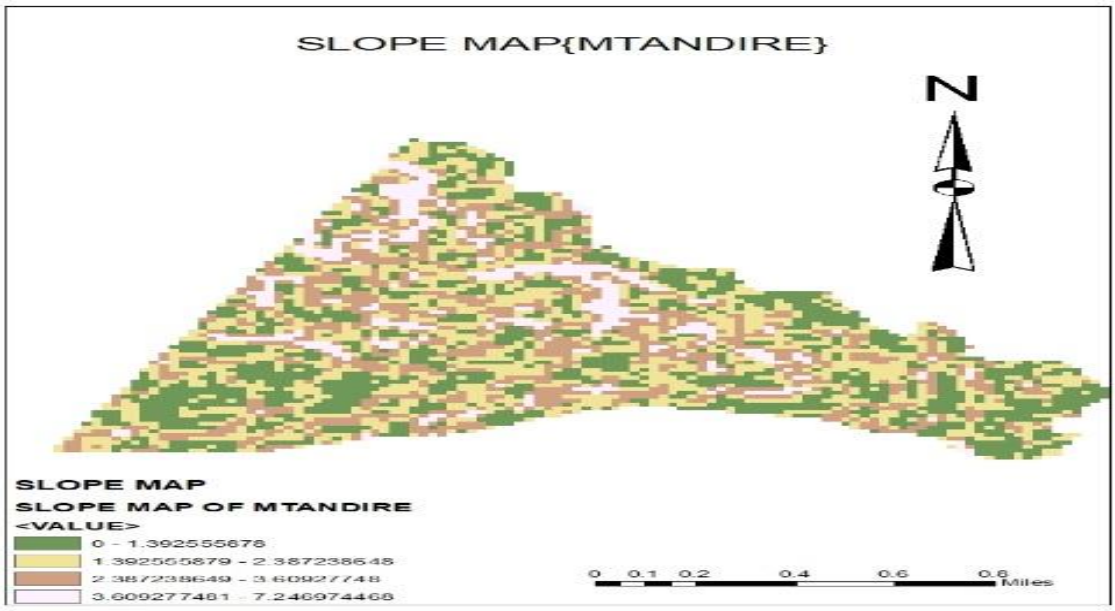



Figure 4.2.2: Slope classification map.

### 4.2.3 Aspect

The aspect map (Figure 4.5) illustrates the directional orientation of slopes within Mtandire. The area is largely dominated by slopes ranging from 0° to 140.3°, representing north- to east-facing slopes.

These slopes generally receive less intense solar radiation, allowing them to retain more soil moisture and support relatively higher vegetation cover. Consequently, such areas are less prone to land degradation and may experience slightly reduced runoff compared to more exposed slopes. However, the influence of flooding is secondary compared to other factors such as land use and slope.

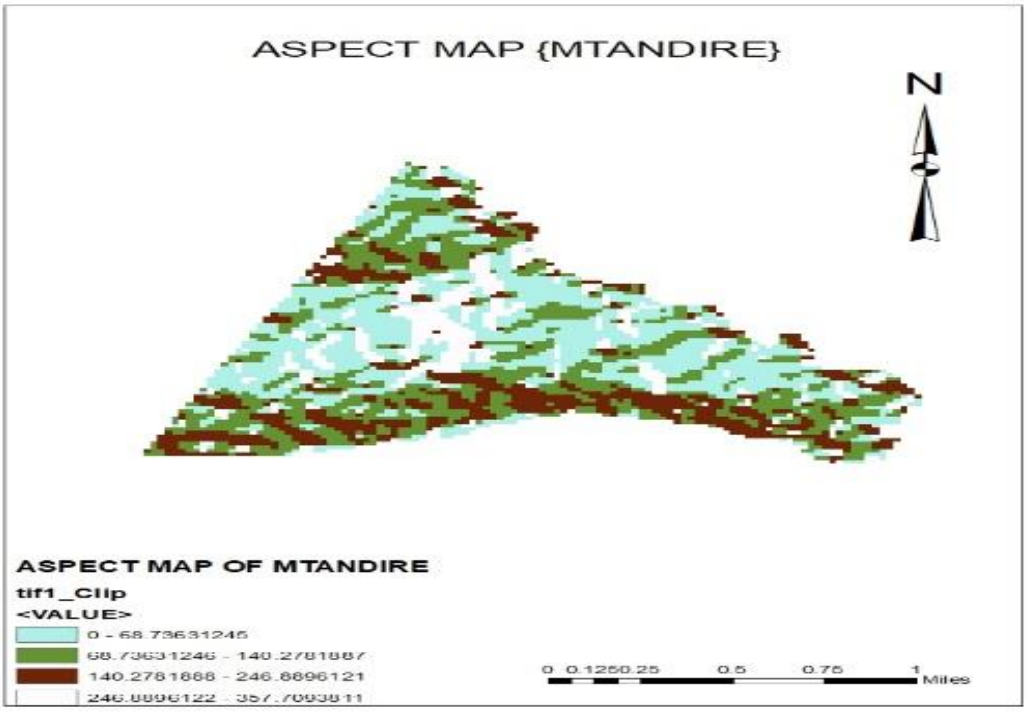



Figure 4.2.3: shows the aspect map of Mtandire

### 4.2.4 Rainfall Distribution

Rainfall data analysis revealed that Mtandire experiences relatively high rainfall during the rainy season, particularly between December and March. High rainfall intensity significantly increases the volume of runoff entering drainage systems. When rainfall exceeds the drainage capacity, flooding occurs in low-lying areas of the settlement.

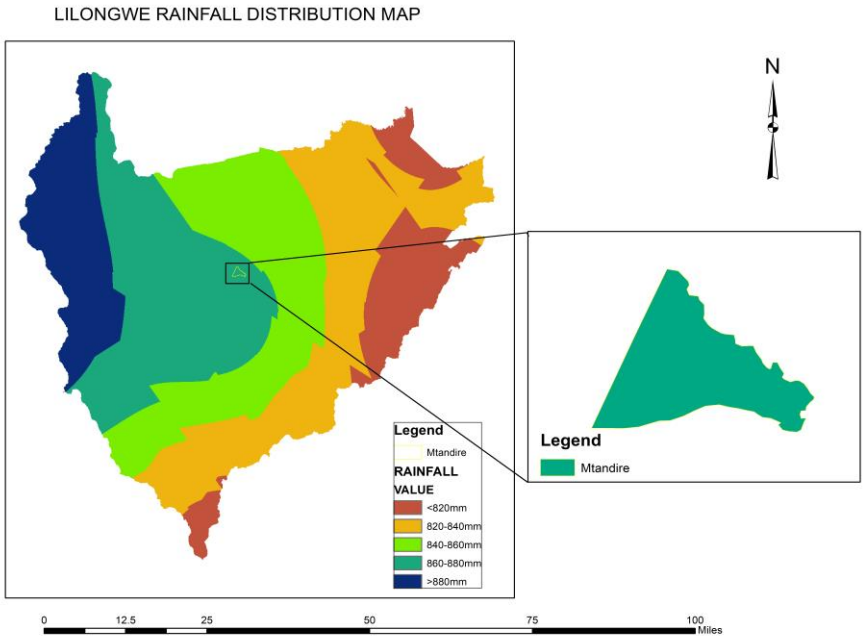



Figure 4.2.4: Annual rainfall distribution map.

### 4.2.5 Distance from Streams

The distance-to-stream analysis (Figure 4.7) shows that areas located close to drainage channels are highly susceptible to flooding. These zones frequently experience overflow during periods of intense rainfall when stream channels exceed their carrying capacity. Settlements located within proximity to streams are therefore at greater risk, particularly in areas where natural drainage has been altered or obstructed by urban development.

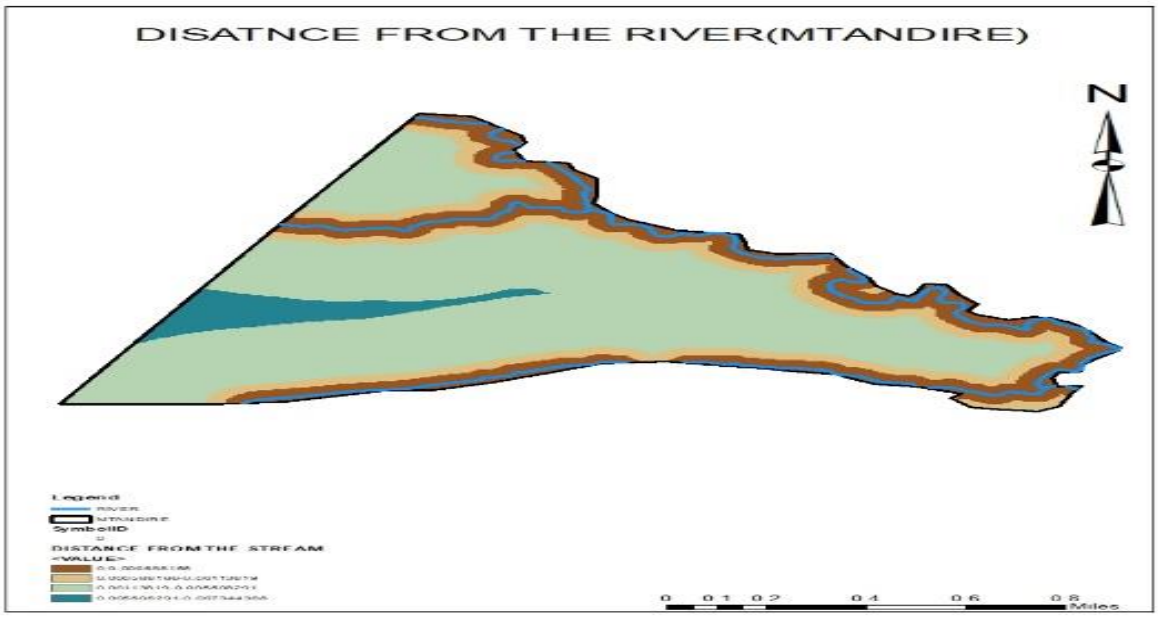



Figure 4.2.5: the above figure shows the distance from stream

### 4.2.6 Vegetation Cover

Vegetation cover was assessed using the Normalized Difference Vegetation Index (NDVI) (Figure 4.8). The results indicate a significant decline in vegetation density, particularly in central parts of Mtandire. Vegetation plays a crucial role in reducing flood risk by enhancing water infiltration, stabilizing soil, and slowing down surface runoff. The observed reduction in vegetation cover has therefore contributed to increased flood susceptibility, as more rainfall is converted into rapid surface runoff. The highest area of vegetation registered 0.705477 and the lowest part of the vegetation registered 0.415867. with the most parts existing between these values.

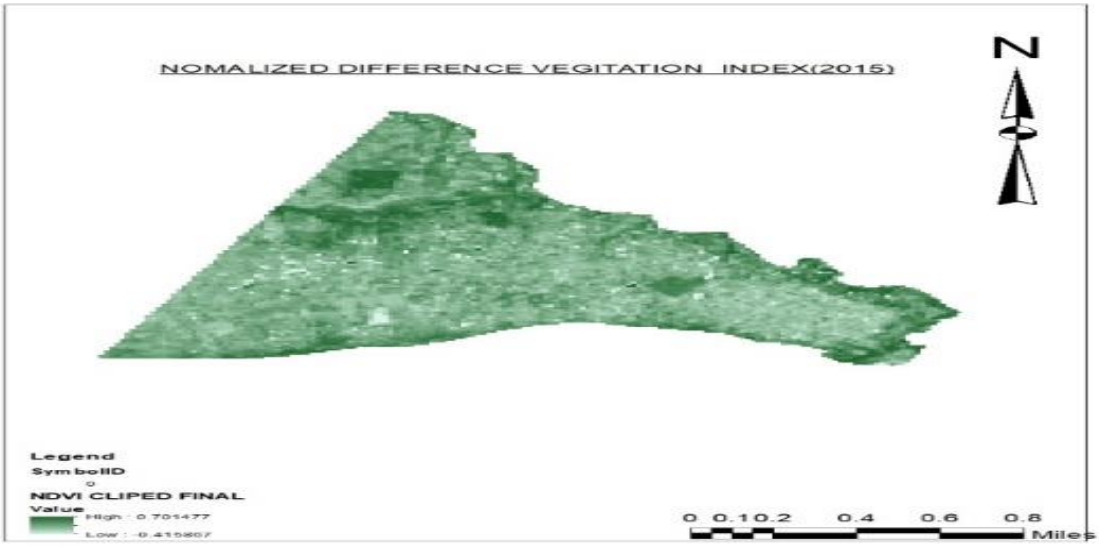



Figure 4.2.6: Mtandire Normalized Difference Vegetation Index (2015)

The 2025 NDVI map of the Mtandire study area, illustrates the spatial distribution and condition of vegetation using a green color gradient, where higher values (up to approximately 0.67) indicate dense and healthy vegetation, and lower values (down to about -0.39) represent sparse vegetation, bare surfaces, or potentially built-up areas. The map reveals a predominantly low-to-moderate vegetation cover across the area, with lighter green tones dominating much of the landscape, suggesting limited biomass or possible land degradation. However, several darker green patches are visible, indicating localized zones of relatively healthier and denser vegetation, which may be associated with favorable environmental conditions such as higher soil moisture or reduced human disturbance. Overall, the observed spatial variability in NDVI values reflects a heterogeneous vegetation pattern, likely influenced by a combination of climatic factors, land use practices, and topographic variation, providing important insight into ecosystem health and land management dynamics within the study area.

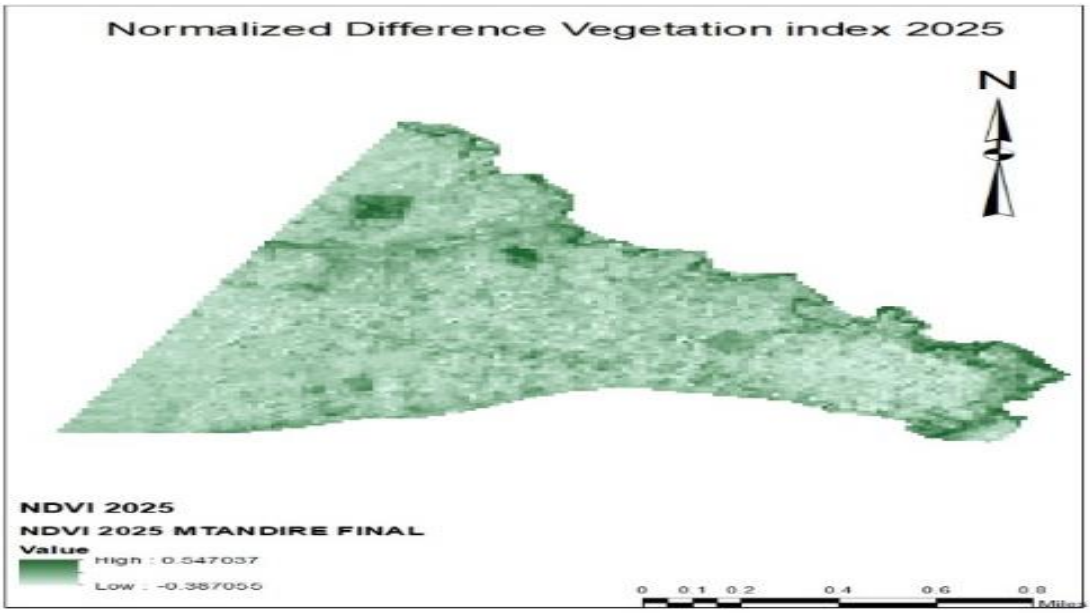



Figure 4.2.7: Below the map shows NDVI for Mtandire 2025

The NDVI analysis for 2015 and 2025 reveals a noticeable decline and spatial fragmentation of vegetation cover in Mtandire. In 2015, NDVI values ranged from approximately 0.415 to 0.705, indicating generally moderate to dense vegetation across much of the area. By 2025, however, the NDVI values show a wider range, extending from negative values (around -0.39) to about 0.67, with most areas dominated by low-to-moderate vegetation cover. This shift suggests a reduction in vegetation density and an increase in non-vegetated surfaces such as built-up areas and bare land. This change is directly linked to land use transformation in Mtandire, where natural vegetation has likely been cleared to accommodate urban expansion, informal settlements, and infrastructure development. Such land significantly alters the hydrological response of the area. Vegetation plays a critical role in intercepting rainfall, promoting infiltration, and stabilizing soil. Therefore, its reduction leads to decreased infiltration capacity and increased surface runoff.

The 2025 NDVI map, which shows predominantly lighter green tones, indicates that much of the study area now has limited vegetation cover. This condition contributes to faster runoff generation during rainfall events, overwhelming drainage systems and increasing the likelihood of flooding. The presence of only a few isolated patches of dense vegetation suggests that the landscape has become hydrologically less resilient, as these patches are insufficient to offset the broader loss of vegetative cover.

In the context of assessing the impact of land use changes on flood risk in Mtandire, the NDVI results provide strong evidence that vegetation loss is a key contributing factor to increased flood susceptibility. The transition from moderately vegetated surfaces in 2015 to more sparsely vegetated and built-up surfaces in 2025 reflects a shift toward land uses that promote rapid runoff rather than water retention. Consequently, areas that experienced vegetation decline are more prone to flash flooding, especially during intense rainfall events.

### 4.2.6 Flood Susceptibility Mapping

The flood susceptibility map was generated using a weighted overlay analysis in GIS, combining the following factors:

- Elevation
- Slope
- Distance from streams
- Land use
- Vegetation cover

The resulting map classified the study area into four flood susceptibility categories:

- Low susceptibility
- Moderate susceptibility
- High susceptibility

- Very high susceptibility

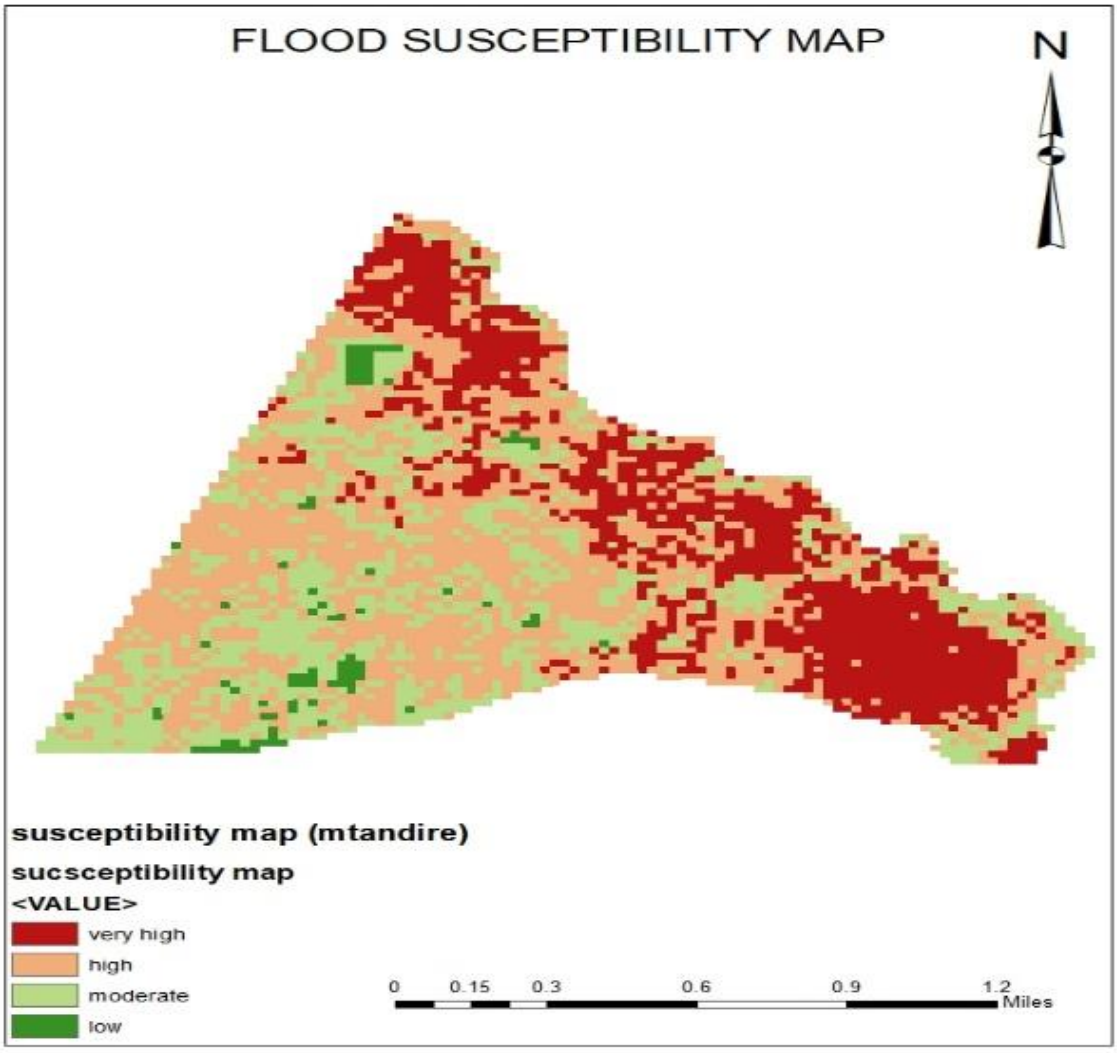



Figure 4.2.6: Flood susceptibility map of Mtandire.

The flood susceptibility map for Mtandire reveals a distinctly uneven spatial distribution of flood risk, with the eastern and central portions of the study area dominated by very high susceptibility zones (red), while the western side is largely characterized by moderate to low susceptibility levels (light to dark green). High-risk areas are also visible in parts of the

north, indicating clusters of vulnerability that are likely associated with low-lying terrain, inadequate drainage systems, or proximity to natural water flow paths. In contrast, the relatively safer western zones suggest better drainage conditions or less exposure to runoff accumulation. Overall, the predominance of moderate to very high susceptibility across much of the area highlights a significant exposure to flooding. This pattern strongly supports the assessment of the impact of land use changes on flood risk in urban areas, as increased urbanization particularly the expansion of impervious surfaces such as roads, rooftops, and compacted soils reduces infiltration and accelerates surface runoff, thereby intensifying flood susceptibility. Consequently, the concentration of high-risk zones in Mtandire can be linked to ongoing land use transformations, emphasizing the need for sustainable urban planning and improved stormwater management to mitigate future flood risks

Flood risk map

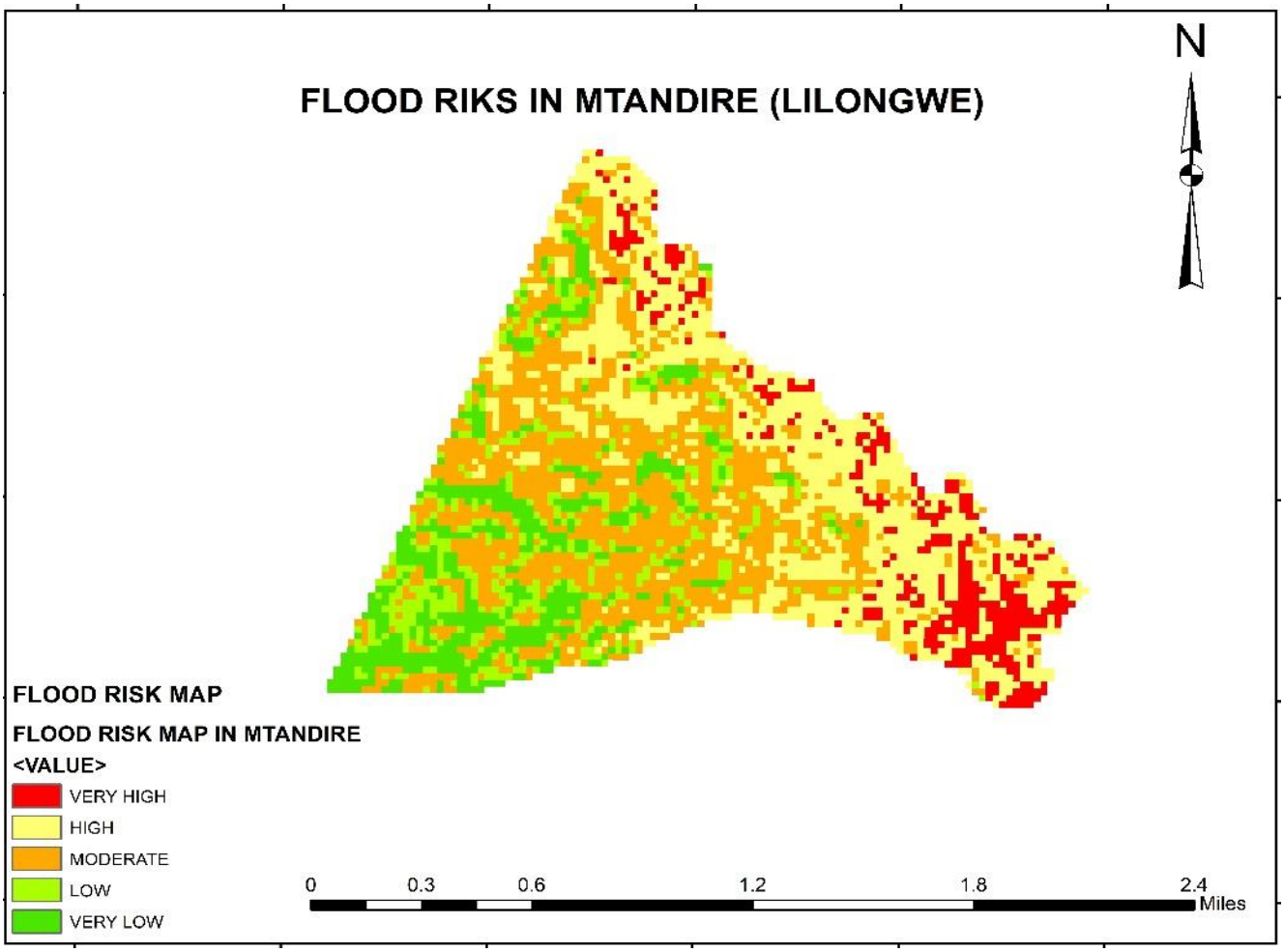



Figure 4.2.6: The figure above shows the flood risk map of Mtandire

The flood risk map of Mtandire reveals a spatially heterogeneous pattern of flood susceptibility that closely reflects the influence of land use dynamics in this rapidly urbanizing area. High-risk zones (shown in red) are concentrated in localized pockets, particularly in densely built-up sections where impervious surfaces such as roads, rooftops, and compacted soils dominate, limiting infiltration and accelerating surface runoff. Moderate-risk areas (orange) are more widespread, indicating transitional zones where mixed land uses such as informal settlements combined with sparse vegetation contribute to moderate runoff accumulation. In contrast, low-risk areas (green) are mainly found on the periphery, where vegetation cover or less disturbed land allows for greater water

absorption and reduced flow velocity. The scattered distribution of medium-to-high risk patches also suggests unplanned urban expansion, where settlement encroachment into natural drainage paths and floodplains has increased exposure to flooding. Overall, the map demonstrates that changes from natural or vegetated land to built-up urban surfaces have significantly heightened flood risk in Mtandire, emphasizing the critical role of land use planning, drainage management, and sustainable urban development in mitigating flood hazards.

## 4.3. DEMOGRAPHIC INFORMATION

The study involved a total of 44 participants,The gender distribution was relatively balanced, with 26 female participants (60%) and 18 male participants (40%).

### 4.3.1 GENDER DISTRIBUTION

Table 2: Gender Distribution

| Category | Count (n) | Percentage (%) |
|---|---|---|
| Female | 26 | 60% |
| Male | 18 | 40% |
| | | |
| Total | 44 | 100% |

Table 4.3.1: shows gender distribution of the participants

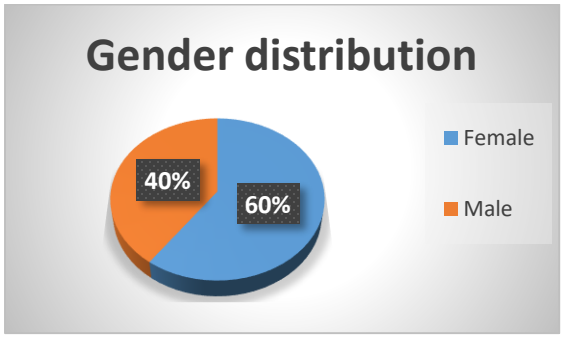



Figure 4.3.1: shows the pie chart on gender distribution

In terms of age distribution, the sample represented a broad generational span. The largest segment consisted of individuals above the age of 35 (; 45.5%). Younger participants under the age of 18 accounted for 22.7% of the sample. The remaining 14 participants (31.8%) fell within the 20–30 age bracket, providing a diverse perspective across different life stages.

### 4.3.2 AGE DISTRIBUTION

| Age | Count (n) | Percentage (%) |
|---|---|---|
| Below 18 | 10 | 22.7% |
| 20 – 30 | 14 | 31.8% |
| Above 35 | 20 | 45.5% |
| Total | 44 | 100% |

Table4.3.2: shows the ae distribution of participants

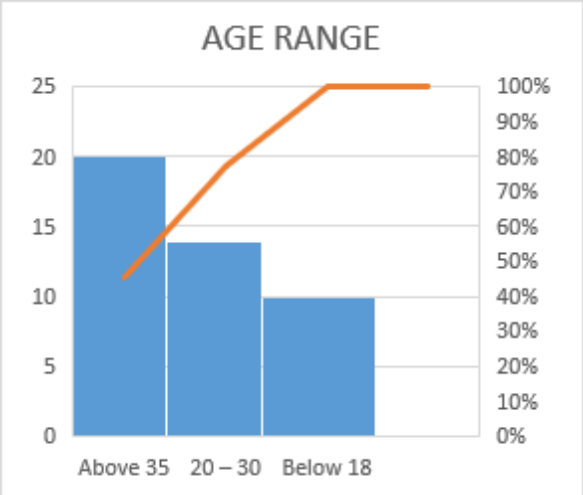



Figure 4.3.2: the figure above shows the age range of participants

4.3.3: Assessment of Awareness and Coordination Levels

This table illustrates the participants' proficiency in awareness and coordination, which are critical indicators of developmental or social integration.

| Awareness & Coordination Status | Percentage (%) | Interpretation |
|---|---|---|
| Poor Awareness and Coordination | 75% | Significant lack of situational awareness or cognitive coordination. |
| Adequate Awareness and Coordination | 25% | Demonstrated standard or high levels of awareness and coordination. |
| Total | 100% | |

Table 4.3.3: shows awareness and coordination

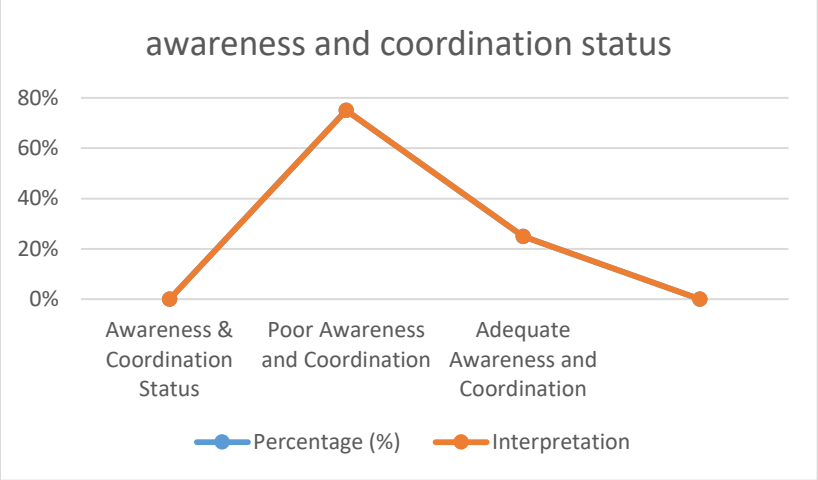



Figure 4.4.2: the figure above shows the awareness and coordination of the participants

The demographic profile of the study population reveals a significant educational divide and a concerning trend regarding cognitive or physical coordination. As shown in Table 1, exactly half of the respondents (50%) have not progressed beyond primary-level education. This high percentage of "Below Secondary" attainment suggests potential barriers to advanced schooling, such as economic constraints or lack of local infrastructure. Conversely, the remaining half is split equally between those who completed secondary school (25%) and those who pursued tertiary education (25%). While a 25% tertiary

attendance rate is notable, it is overshadowed by the fact that 75% of the total population lacks a post-secondary degree.

Furthermore, the data in Table 2 highlights a critical deficit in functional awareness and coordination. A substantial majority, three-quarters of the population (75%), exhibits "poor" levels in these areas. This disproportionate figure is statistically significant; it suggests that the lack of higher educational attainment may correlate with lower exposure to structured environments that foster these skills. Alternatively, this may point toward underlying systemic issues, such as lack of community-based developmental programs. The 25% who demonstrate adequate awareness likely represent the segment of the population with higher educational or professional exposure. These findings underscore an urgent need for targeted interventions aimed at both educational reform and specialized coordination training.

# DISCUSSION OF RESULTS

The findings of this study provide good evidence that land use change is a primary driver of escalating flood risk in Mtandire settlement. This discussion interprets the key results within the context of existing literature, examines the implications for urban flood management, and addresses the study's limitations.

## 5.1 Land Use Transformation as a Hydrological Driver

The observed expansion of built-up areas from 2015 to 2025, accompanied by the fragmentation and reduction of vegetation cover, represents a fundamental alteration of the landscape's hydrological functioning. This finding aligns with established research demonstrating that urbanization replaces permeable surfaces with impervious materials such as concrete, asphalt, and compacted soils (Fletcher et al., 2013; Suriya & Mudgal, 2012). In Mtandire, the conversion of vegetated areas to built-up land has reduced infiltration capacity, accelerated surface runoff generation, and shortened the concentration time the period between rainfall onset and peak flow reaching drainage channels.

The NDVI results are particularly instructive. The decline from moderate-to-dense vegetation values (0.415–0.705) in 2015 to predominantly low-to-moderate values (negative to 0.67) in 2025 indicates not merely a reduction in vegetation quantity but a qualitative shift in landscape condition. Negative NDVI values observed in 2025 correspond to water surfaces or extremely sparse vegetation, while values approaching zero represent built-up or bare surfaces. This transformation has practical consequences: vegetation intercepts rainfall, promotes evapotranspiration, and creates macropores for infiltration. Its loss means that rainfall previously absorbed by soils now flows rapidly overland, overwhelming drainage systems that were not designed for such runoff volumes. Comparable patterns have been documented elsewhere in Sub-Saharan Africa. In Accra, Ghana, Amoako and Frimpong Boamah (2015) found that unregulated urban expansion onto floodplains and the removal of natural drainage corridors intensified flooding. Similarly, Douglas et al. (2008) observed across multiple African cities that poor households

are disproportionately forced to settle in flood-prone areas due to land affordability constraints, creating a cycle of vulnerability that Mtandire exemplifies.

## 5.2 The Role of Topographic and Environmental Factors

The spatial analysis identified low elevation, gentle slopes, and proximity to streams as critical determinants of flood susceptibility in Mtandire. The predominance of slopes between 0° and 10° is geomorphologically significant because such gradients lack the hydraulic energy to transport runoff efficiently. Water accumulates in low-lying areas rather than draining rapidly, particularly when drainage channels are blocked by sedimentation or solid waste conditions frequently observed during fieldwork.

The distance-from-stream analysis revealed that settlements located within 50 meters of drainage channels experience recurrent inundation. This finding is consistent with hydrological principles: during intense rainfall, channel capacity is exceeded, causing water to spill onto adjacent floodplains. However, unlike natural floodplains that accommodate flooding without significant damage, Mtandire's floodplain has been extensively built upon, meaning that overflow directly inundates dwellings. This encroachment on drainage corridors is not accidental but reflects Lilongwe's broader challenge of informal settlement growth outpacing planning enforcement (Manda, 2014; Kalindekafe et al., 2022).

Elevation analysis showed minimal topographic variation across Mtandire, which is both a physical constraint and a policy challenge. Without significant elevational refuges, floodwater has few naturally safe areas to drain toward. Engineered solutions such as properly graded roads functioning as drainage channels or constructed retention basins become essential, yet these remain largely absent or poorly maintained.

## 5.3 Vulnerability, Awareness, and Adaptive Capacity

The social vulnerability findings reveal a concerning disconnect between flood experience and preparedness. While residents readily identify heavy rainfall, poor drainage, and low-lying settlement locations as flood causes, only 25% demonstrated adequate awareness of coordinated response mechanisms. This gap between risk perception and action is well

documented in disaster literature (Wisner et al., 2004) and has specific manifestations in Mtandire.

Several factors explain this low preparedness. First, flooding in Mtandire is typically shallow and short-duration characteristics that may lead residents to normalize risk rather than mobilize transformative adaptation. Second, household survey data indicated that most affected residents rely on reactive coping mechanisms such as moving belongings to higher ground or constructing small sandbag barriers. These responses, while locally rational given resource constraints, do not address the structural drivers of flooding identified in this study. Third, the absence of functioning early warning systems and community disaster preparedness committees means that even when residents recognize risk, coordinated action remains difficult.

The gender distribution (60% female participants) is noteworthy given that women in many African contexts bear disproportionate responsibility for household water management and experience differential impacts during floods, including disrupted access to water, sanitation, and hygiene facilities (Manyungwa-Pasani et al., 2019). However, the survey instrument did not explicitly disaggregate flood impacts by gender, representing an analytical limitation.

## 5.4 Integration of Physical and Social Findings

A distinctive contribution of this study is the integration of physical flood susceptibility mapping with social vulnerability assessment. The flood risk map shows high-risk zones concentrated in eastern and central Mtandire areas that coincide with informal housing clusters, limited drainage infrastructure, and the NDVI-identified vegetation loss. This spatial convergence means that the most physically hazardous areas are also those occupied by households with the lowest adaptive capacity, a classic manifestation of compound vulnerability.

Conversely, the western portion of the study area, characterized by moderate-to-low flood susceptibility, represents a relative safety gradient. Understanding why this area has remained less developed whether due to land tenure arrangements, topography, or

historical settlement patterns could inform strategies for guiding future urban expansion toward lower-risk locations.

# CHAPTER 5

# CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the key conclusions drawn from the study and provides recommendations based on the findings. The study assessed the impact of land use changes on flood risk in Mtandire settlement in Lilongwe District, Malawi. It integrated Geographic Information Systems (GIS), remote sensing analysis, hydrological modelling, and household survey data to evaluate how urban expansion has influenced flood occurrence and vulnerability.

## 5.1 Summary of Major Findings

The findings of this study highlight a strong relationship between land use change and increasing flood risk in Mtandire.

First, the land use and land cover (LULC) analysis revealed significant transformation between 2015 and 2025. Built-up areas expanded considerably, becoming more continuous and dominant across the study area. This expansion occurred largely at the expense of vegetation and open spaces, which became fragmented and reduced in size. The NDVI analysis further confirmed a decline in vegetation density, with 2025 showing lower and more variable vegetation values compared to 2015. This indicates a shift toward a more urbanized and less permeable landscape.

Second, the study identified key environmental factors influencing flood susceptibility, including elevation, slope, rainfall intensity, distance from streams, and vegetation cover. Low-lying areas and zones close to drainage channels were found to be highly vulnerable, as they naturally accumulate runoff. Additionally, the predominance of gentle slopes (0°–10°) across Mtandire limits the speed of water movement, increasing the likelihood of water accumulation during heavy rainfall events.

Third, the reduction in vegetation cover has significantly weakened the natural hydrological functioning of the area. Vegetation plays a critical role in intercepting rainfall, promoting infiltration, and reducing runoff velocity. Its decline has therefore contributed to increased surface runoff and reduced water retention capacity.

Fourth, flood susceptibility mapping showed that a large portion of Mtandire falls within high and very high flood risk zones. These areas are characterized by a combination of unfavourable topographic conditions, proximity to streams, increased impervious surfaces, and inadequate drainage systems.

Fifth, the vulnerability assessment revealed that many buildings and infrastructure are located within high-risk flood zones, particularly near drainage channels. This increases exposure to flood hazards and disrupts mobility and emergency response during flood events.

Finally, household survey results indicated that flooding is a common experience among residents. While most respondents identified heavy rainfall, poor drainage, and settlement in low-lying areas as major causes of flooding, a significant proportion of households lack adequate preparedness and awareness. The findings also revealed low levels of awareness and coordination among residents, which further increases vulnerability.

## 5.2 CONCLUSIONS

Based on the findings, the study concludes that land use change is a major driver of increased flood risk in Mtandire settlement.

The rapid expansion of built-up areas between 2015 and 2025 has significantly altered the natural landscape by increasing impervious surfaces and reducing vegetation cover. This transformation has disrupted natural hydrological processes, resulting in reduced infiltration and increased surface runoff. Consequently, rainfall is rapidly converted into overland flow, increasing flood frequency and intensity.

The study also concludes that environmental factors such as elevation, slope, and proximity to streams play a critical role in shaping flood susceptibility. Low-lying areas with gentle slopes and locations near drainage channels are particularly prone to flooding due to their limited drainage capacity and tendency to accumulate water.

In addition, unplanned urban development has intensified flood risk. The construction of houses in flood-prone areas, combined with inadequate and poorly maintained drainage systems, has increased both exposure and vulnerability of the population.

The hydrological and spatial analyses further confirm that continued urbanization without proper planning will exacerbate flood risk in the future. The decline in vegetation cover, as shown by NDVI results, has reduced the landscape's resilience to flooding, making the area more susceptible to rapid runoff and flash floods.

Overall, flood risk in Mtandire is the result of an interaction between land use changes, environmental conditions, and socio-economic factors. Addressing this challenge requires a comprehensive and integrated approach that combines land use planning, infrastructure improvement, and community-based strategies.

## 5.3 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

### 5.3.1 Strengthening Urban Land Use Planning

Urban planning authorities should enforce land use regulations to control settlement expansion in flood-prone areas. Zoning policies should restrict construction near drainage channels and low-lying zones. Planned urban development should prioritize safer locations and incorporate flood risk assessments into planning processes.

### 5.3.2 Improvement of Drainage Infrastructure

There is a need to upgrade and expand stormwater drainage systems within Mtandire. Properly designed drainage networks will improve water flow and reduce flooding during heavy rainfall. Regular maintenance, including clearing of blocked drains and removal of solid waste, is essential to ensure system efficiency.

### 5.3.3 Promotion of Urban Green Infrastructure

Efforts should be made to restore and protect vegetation within the settlement. Tree planting, urban green spaces, and community-based greening initiatives can enhance infiltration, reduce runoff, and improve environmental sustainability. Integrating green infrastructure into urban design can significantly reduce flood risk.

### 5.3.4 Community Awareness and Flood Preparedness

Community education programs should be implemented to improve awareness of flood risks and preparedness strategies. These programs should focus on early warning systems, emergency response, and household-level mitigation measures. Strengthening local disaster management committees can improve coordination and response during flood events.

### 5.3.5 Integration of GIS and Hydrological Tools in Planning

Urban planners and policymakers should incorporate GIS and hydrological modelling tools into decision-making processes. These tools can help identify high-risk areas, simulate flood scenarios, and support evidence-based planning. Their use will improve the effectiveness of flood risk management strategies.

## 5.4 Suggestions for Future Research

While this study provides valuable insights, further research is recommended in several areas. Future studies should examine the impact of climate change on rainfall patterns and flood frequency in Lilongwe. There is also a need to evaluate the effectiveness of different flood mitigation strategies, such as green infrastructure, retention basins, and improved drainage systems.

Additionally, expanding the study to cover larger urban areas would provide a broader understanding of flood dynamics in rapidly growing cities in Malawi. Further research could also explore socio-economic resilience and community adaptation strategies to flooding.

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