

VULNERABILITY ASSESSMENT OF AREAS ALONG MULUNGUZI RIVER TO POTENTIAL DAM FAILURE FLOODS, ZOMBA CITY

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ABSTRACT

The study aimed at assessing the vulnerability of areas along the Mulunguzi river to potential floods influenced by dam failure. Provention Consortium (2007) defined vulnerability as the potential to suffer harm or loss, related to the capacity to anticipate a hazard, cope with it, resist it and recover from its impact. Both vulnerability and its antithesis, resilience, are determined by physical, environmental, social, economic, political, cultural, and institutional factors. The study is centred on the warning which was issued by the Department of Disaster Risk Management Affairs on the potential failure of the Chagwa Dam on Zomba Plateau. The failure of the dam could result in inundating areas along the Mulunguzi river. Therefore, recognizing that vulnerability differs among individuals and communities, the study focused on assessing the levels of vulnerability in prone areas and not excluding their causes. Furthermore, identifying elements at risk and their susceptibility to adverse impacts of the hazard based on exposure.

It was identified that among the areas along Mulunguzi river, Matawale is more vulnerable due to various underlying causes of vulnerability for instance peoples' livelihood, nature of houses constructed, land use, and so forth. Whereas Mangasanja is less vulnerable to DFF floods. Various elements at risk were determined and later classified e.g. roads, people, buildings, environment, and many more.

The study was conducted by field visits, desk study, and flood vulnerability mapping. A field visit was after identifying elements at risk and ground-truthing. Desk study involves various statistical operations to determine the level of socio-economic and physical vulnerability. Whilst mapping was done to determine and exhibition the level of vulnerability in all prone areas and to show levels of susceptibility to adverse impacts based on proximity to the river.

ACKNOWLEDGEMENT

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ACRONYMS/ABBREVIATIONS

ACPC'S: Area Civil Protection Committees

DEM: Digital Elevation Model

DFF: Dam Failure Floods

DoDMA: Department of Disaster Management Affairs

DRM: Disaster Risk Management

EWAS: Early warning system

NSO: National Statistical Office

VCPC'S: Village Civil Protection Committees

UNISDR: United Nation International Strategy for Disaster Reduction

NY: New Yolk

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1. GENERAL INTRODUCTION

1.1. Background

Every dam represents a certain threat due to the possibility of its failure, which may lead to a dam-break flood downstream area (Ríha, Kotaška , & Petrula, 2020). The challenging situation is the vulnerability of people who are exposed to the flood hazard since vulnerability is directly linked to disasters. A dam is an engineering structure constructed across a valley or natural depression to create a water storage reservoir. Unfortunately, most dams are subjected to failure due to overtopping, seismic failure, and foundation defects. Dam failure often leads to catastrophic events in which sudden, rapid, and uncontrolled release of impounded water is devastating to surrounding communities. This results in losses in lives, injuries, extensive economic damage, and environmental damage. In the USA, the deadliest dam failure resulted from the 1889 failure of the South Fork Dam on the Little Conemaugh River in Pennsylvania, which occurred as a result of flood-induced overtopping and caused the Johnstown Flood in which more than 2,200 people died (DeNeale et. al, 2019).

Malawi is often hit by floods of hydro-meteorological origin e.g. drought and floods. Government of Malawi (2015) highlighted that from 1979 to 2010, natural disasters cumulatively affected nearly 21.7 million people and killed about 2,596 people. Disasters play a significant role in defining household poverty and national economic growth trends through economic losses and shocks to livelihood systems. Over the past five decades, Malawi has experienced more than 19 major floods (Malawi Government, 2019). This has been influenced by rapid population growth, unsustainable urbanization, climate change, and environmental degradation. However, the degree of losses from a disaster depends on the susceptibility of the community which is determined by physical, social, economic, and environmental factors.

Zomba city has magnificent dams; Mulunguzi and Chagwa which supply water and support the ecosystem. However, in 2019, the department of disaster management affairs issued a warning of a potential failure of the Chagwa dam which could result in flooding of the Mulunguzi river affecting thousands of households. This could affect Mangasanja, Old Naisi, Mulunguzi secondary, Matawale, and other areas along the Mulunguzi river banks (Malikwa, 2019). Although experts were entangled to reduce

the water volume while working on lasting solutions, still the risk is there. However, assessing the strength of the dam is not a topic of interest in this study rather the vulnerability of stated communities at risk.

In this paper, vulnerability is understood from three different viewpoints: those vulnerable due to exposure, those vulnerable due to the level of socio-economic standing in society, and finally from the point of expected damages due to dam failure floods (structural/physical vulnerability). Most importantly, the interaction of these three factors and their role in worsening overall vulnerability to floods are assessed. A vulnerability assessment will aid decision-making in hazard mitigation, prevention, preparedness, and response to a potential hazard. Hence, eradicate losses and damage due to disasters.

1.2. Problem statement

DRM policy states that given the range of hazards Malawi is exposed to, both rural, as well as urban areas, are vulnerable (Government of Malawi, 2015). Despite that Zomba is often hit by flood disasters mostly of hydro-meteorological origin. For instance, in 2019, Zomba was amongst the worst-hit districts, with more than 50,000 people affected by flooding due to heavy rains. This was during cyclone Idai (Reliefweb, 2019). The city has no historical record of flooding resulting from dam failure hence excessive fear of possible devastating impacts. In addition to that, due to rapid population growth and urbanization people tend to reside in disaster-prone zones besides poverty, lack of knowledge, and scarcity of affordable safer areas. Although technological advancement has increased the safety of dams, but then a full non-risk guarantee is not possible and accidents can occur, triggered by natural hazards, human actions, or loss of strength capacity of the dam due to its age (Viseu & Almeida, 2009).

On 22nd March 2019, DoDMA issued a warning of the potential failure of the Chagwa dam (Malikwa,2019). This was due to cracks observed on the dam. The warning brought a lot of fear to the areas exposed to the hazard. Although engineers were involved to reduce the volume of water in the dam while working on lasting solutions, still more, the risk exists. The threat to potential failure was said to be influenced by erosion caused by heavy rains. Although vegetation is vastly protected by law, deforestation on the Zomba plateau could have a negative contributing impact. Those

living in hazard-prone areas are to some extent vulnerable whether in physical, social, economic, and environmental circumstances. However, the vulnerability of areas along the Mulunguzi river to flood hazards has not yet been studied and published. Assessing the vulnerability of floods triggered by dam failure helps to ascertain underlying root causes, areas of high risk and develop cost-effective flood mitigation and adaptation strategies.

1.3. Objectives

This study aimed at assessing the flood vulnerability triggered by a dam failure in areas along the Mulunguzi river.

The following were the specific objectives:

- To establish and analyse underlying causes of vulnerability in hazard-prone areas.
- To identify the vulnerable groups of people in the study areas.
- To identify and classify the elements at risk along the Mulunguzi river.
- To generating an exposure map in ArcMap for areas along the Mulunguzi river.

1.4. Research questions

The study answered the following questions:

- Which areas along the Mulunguzi river are most vulnerable to dam failure flooding?
- What are the underlying causes of vulnerability in the prone areas?
- Which groups of people are more vulnerable to the adverse impacts of the hazard in areas along the Mulunguzi river
- Which elements are at the risk in an event of DFF.

1.5. Significance of study

United nation Sendai Framework for disaster reduction calls for all parts of the world to engage in a better understanding of the disaster risk for which vulnerability is fundamental. This is one of the priority areas in the current framework in use (United Nations, 2015). Basically, over the past years, most initiatives by the government to cope with floods and other disasters have been response (emergency relief), short-term, and heavily donor-dependent. However, to cope with disaster it demands more pre-

disaster initiatives. There has been a gap in determining the vulnerability of communities in this country. The vulnerability assessment will show the susceptibility of areas at risk and those along the Mulunguzi river to adverse impacts of flood hazards. It will also show the degree of losses in risk areas by identifying elements at risk hence highlighting the need for risk reduction measures. The assessment will also benefit the areas at risk by increasing the knowledge base of the hazard and vulnerability. Therefore, this will influence the community and other relevant stakeholders to intensify coping capacity by developing an early warning system, improving emergence management, constructing buildings that can withstand the hazard, and so forth. In so doing, attaining recommended flood mitigation and adaptation measures. Lastly, this assessment will help various stakeholders and government agencies to mainstream disaster risk reduction in development ventures in areas along the Mulunguzi river.

2. LITERATURE REVIEW

2.1. Dam failure disaster

Dams play a tremendous role in flood control, water supply, hydropower generation, irrigation, navigation, and recreation benefits. However, because of the water storage problem, huge potential energy in form of flooded water can be generated and has a great threat to the downstream (Peng & Zhang, 2019). Dam failure can take several forms, including a collapse of, or breach in, the structure. While most dams have storage volumes small enough that failures have few or no repercussions, dams storing large amounts can cause significant flooding downstream (Association of State Dam Safety Officials, 2016). Dam breach produces a large number of devastating floods and results in loss of lives, injuries, and damage to properties and the environment.

In recent years, there have been many serious dam breach accidents. On 24 July 2018, at least 20 people had been killed and more than 100 were missing in the floods caused by the collapse of an under-construction dam, which is part of the Xe-Pian Xe-Namnoy hydroelectric power project in Southeast Laos. In another dam failure, twenty people were killed and eight were missing because of the dam breach of Sheyuegou Reservoir in Xinjiang, China on 1st August 2018 (Wu et., 2019). The failures also engrossed devastating losses in properties. Consequently, the risk consequences of dam breach have always attracted the attention of researchers. National Research Council of 1985 stated that in some cases, the failure of the dam could produce flood rates and damages greater than would have been experienced if the dam had not been built. (DeNeale et. al, 2019). The deadliest US dam failure resulted from the 1889 failure of the South Fork Dam on the Little Conemaugh River in Pennsylvania, which occurred as a result of flood-induced overtopping and caused the Johnstown Flood in which more than 2,200 people died and huge property damage. Over the ensuing 80+ years, many other disastrous dam failures occurred, and hundreds of lives were lost. It is noted that dam failure has catastrophic impacts on the population. However, all these losses are due to exposure and susceptibility of people to withstand or cope up with the hazard, since if the vulnerability is reduced, people can possibly withstand adverse impacts of the hazard.

Even though dams be subjected to frequent maintenance and environmental conservation, we need to be prepared so much for what mother nature can throw at us (Nassivera, 2018). Mother nature contributes a lot to dam failure. Rainstorms come in all sizes, and some come with more water than are expected, as well as more than what our dams are prepared to handle. Excessive rainfall is among the main contributors to high discharge which often leads to the overflow that leads to erosion, pipe breakage, and eventually floods due to dam failure. Although there are many other causes of dam failure that result in different levels of damage, vulnerability determines the severity of the disaster damage. Disasters can also increase the vulnerability of the community as articulated in national disaster risk management policy (Government of Malawi, 2015). In such a way that, disasters increase the poverty of rural and urban households and erode the ability of the national economy to invest in key social sectors which are important to reducing poverty. It is, therefore, important to address disaster risks for the socio-economic development of the country (Government of Malawi, 2015). The issue of Vulnerability is deeply uttered in the Sendai framework for action since it determines the disaster risk.

2.2. Flood Vulnerability

Vulnerability is defined as the characteristics and circumstances of the community, system, or assets that make it susceptible to the damage effects of a hazard(United Nations International Strategy for Disaster Reduction (UNISDR), 2009). UNISDR stresses that characteristics of the community or society determine the level of vulnerability to adverse impacts of the hazard. United Nations described flood vulnerability as the degree of damage to given items at risk caused by flood with the determined amount and expressed as a scale from 0-1 (no damage to total damage) (United Nations NY, 1982). There is a need to develop a scientific understanding of vulnerability since it is understood that vulnerability is the root cause of disasters. Despite the recent increase in knowledge about vulnerability, flood risk is still very widespread. Researchers have developed many methods to assess flood vulnerability (Nasiri & Shahram , 2013). Flood vulnerability in an area depends on some environmental, economic, social, and even political factors, therefore, it is difficult to measure vulnerability. That means vulnerability is influenced by several factors including

human settlement conditions, infrastructure, authority's policy and abilities, social imbalances, economic patterns, etc.

In previous works, the vulnerability was assessed using the following methods: Vulnerability index system, vulnerability curve method, and disaster loss data. Each of these methods has its advantages and disadvantages. However, the flood vulnerability index is used as an instrument to link a multidisciplinary subject with a large number of components in a straight way and also can provide a good review of vulnerability in three scales that is river basin, sub-catchment, and urban area. Hence it is useful in action plans to manage floods and can improve local decision-making practices with appropriate measures to reduce vulnerability in different spatial levels. Nasiri & Shahram (2013) stated that the FVI can be used in combination with other decision-making tools and participatory methods with people in vulnerable communities.

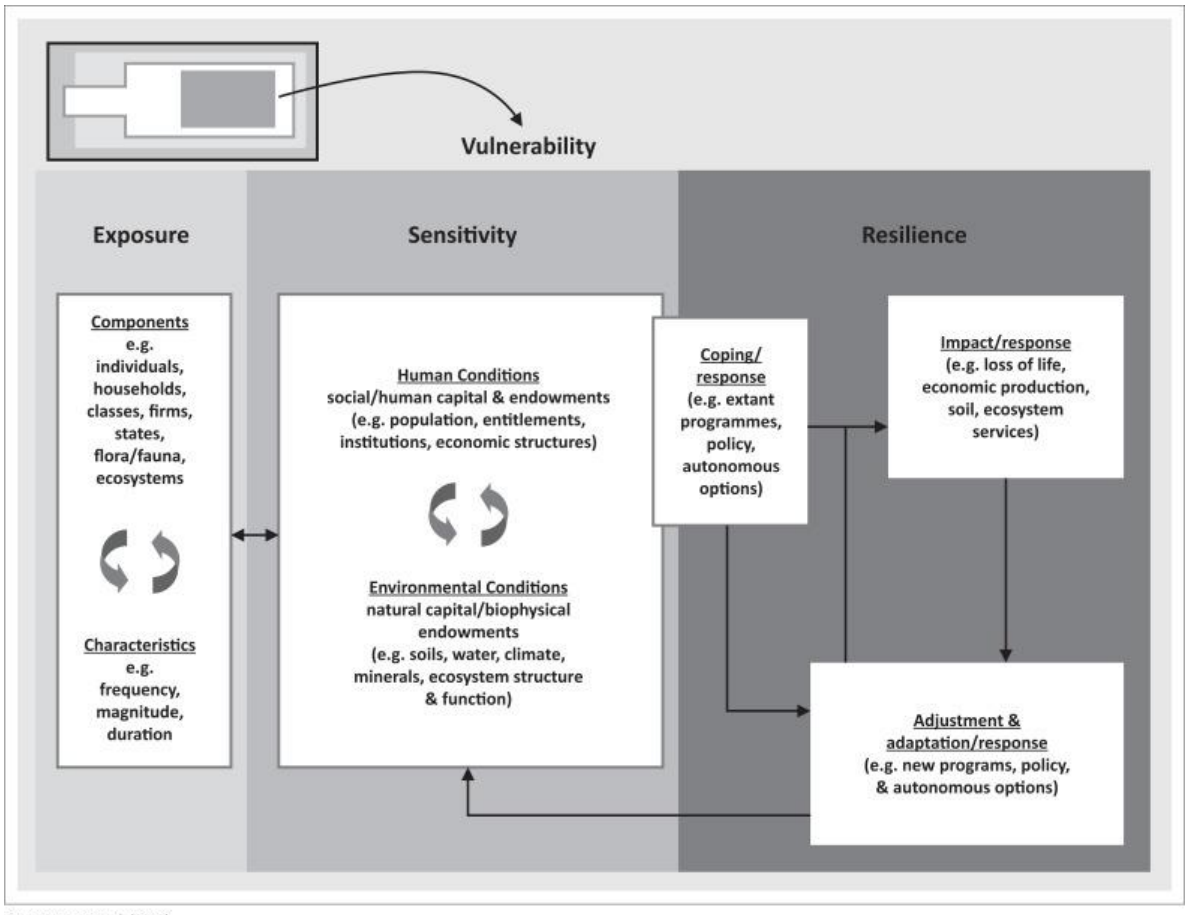
GIS can also be used in vulnerability assessment. A study that addressed flood vulnerability and risk in the Bénin Niger River Valley including the two municipalities Karimama and Malanville. A GIS-based mapping and theory-driven indicator approach were applied. The assessment revealed that almost 90% of the district is located in a flood hazard footprint and is consequently exposed to high flood risk. However, the municipalities are not exposed to the same degree of flood risk due to their different degrees of vulnerability. This demands the use of spatial data sets which are not readily available. Although such is the case, there is a need for field surveys to complement the mapping. In Niger river flood vulnerability mapping, field surveys were carried out to obtain more detailed information about the flood exposure of the communities and to complete vulnerability indicators chosen from the census data. This required use of articles, theses, official government documents, and reports was utilized (Behanzin, Thiel, Szarzynski, & Boko, 2015). This can spring a need for GIS techniques in flood vulnerability assessment in the study. In addition to that, field study will help to have a successful vulnerability assessment

In Benin, Niger River valley's vulnerability assessment method follows an indicator-based approach where vulnerability is seen as physical, social, economic, environmental characteristics and conditions that make people or communities susceptible to the damaging effects of a flood. This form of vulnerability assessment has been recognized

internationally and is strongly stressed in the Hyogo Framework for Action. This uses statistical data of which in other circumstances is unavailable hence complicating the method since socio-demographic data is expensive and time-consuming to obtain.

Mwape (2009) stressed that vulnerability plays such an important part in why natural hazards become human disasters, it is worth spending time to examine the characteristics of vulnerability. Conditions of vulnerability are a combination of factors that include poor living conditions, lack of power, exposure to risk, and the lack of capacity to cope with shocks and adverse situations.

Munyai, Musyoki, Nethengwe (2019) adopted a conceptual framework of Turner et al. (2003) which depicts that vulnerability is a function of exposure, sensitivity, and adaptive capacity as shown in the illustration below.



Source: Turner et al. (2003).

Figure 2. 1: Conceptual model of vulnerability by Turner et al.

Figure 2.1 above illustrates that exposure, sensitivity, and resilience are the key factors of vulnerability. Exposure is the degree to which elements at risk are exposed to adverse impacts of the hazard. Sensitivity is related to human and environmental conditions that determine the response and coping capacity. Resilience is the ability of society to bounce back to normal functioning after suffering distress. In this study, the vulnerability will be grounded on these key factors.

According to Zomba city's social-economic study, it is identified that vulnerability causes can be specified as follows: There are several factors behind the increased vulnerability of communities over time. High population growth with a total fertility rate (TFR) at 5.41 creates pressure on the natural resources and reduces landholding size per household. This acts as a push factor for people to cultivate in marginal areas like mountain slopes, riverbanks, and forest reserves thus resulting in weakened soils and making the areas susceptible to flooding. The HIV and AIDS scourge has led to losses in the productive age group (15 to 64 years old) which has reduced the much-needed labour force for sustainable development. In addition, gender inequalities in rural communities pose challenges in addressing disaster risks, and over-dependence on chemical fertilizers negatively affects the soil structure leading to low agricultural production per hectare over time (Zomba District Assembly, 2009).

2.3. Elements at risk

Westen, Kingma, & Montoya (nd.) highlighted that elements at risk are the population, properties, economic activities, including public services, or any other defined values exposed to hazards in a given area. They are also referred to as “assets”. Notably, elements at risk have spatial and non-spatial characteristics. The way the amount of elements-at-risk is characterized (e.g. several buildings, number of people, economic value, or the area of qualitative classes of importance) also defines how the risk is presented to the end-users (i.e. decision-makers, emergency personnel, and the general public). The interaction of elements at risk and hazard defines the exposure and the vulnerability of the elements at risk. Exposure indicates the degree to which the elements at risk are exposed to a particular hazard. The spatial interaction between the elements at risk and the hazard footprints is depicted in a GIS by a simple map overlaying the hazard map with the elements at risk map. The element at risk mapping

aims to build up a database for the evaluation of the vulnerability of the elements at risk for certain hazards.

Although elements at risk information may be derived from existing data sources such as census data, there is always a need to collect additional data to characterize the elements at risk for vulnerability assessment. Mapping of elements at risk can also be done using the participatory method. In which mapping of large areas can be done by selected people from the local community, which are trained to do the survey. Interestingly, these local people can aid in the identification of variables contributing to social vulnerability in relation to this study.

2.4. Vulnerable groups

Fekete (2018) states that the lives of people are not determined by a single factor such as poverty only. Several human conditions determine one's vulnerability, for instance, social status, downward social mobility, low to middle level of education, the highest ratio of unemployment. Therefore, individuals and communities are differently exposed and are vulnerable to floods because of socio-economic factors, such as wealth, education, race, ethnicity, religion, gender, age, class, disability, and health status.

AsRoder et al.(2017) highlighted that the spatial identification and the inclusion of vulnerable people into the risk management planning process have been widely discussed and fostered in the Sendai Framework for Disaster Risk Reduction. It emerged that it could enhance effective mitigation plans aimed at increasing social capacities serving as a communication tool among all the actors involved in the disaster management framework, from academic communities.

3. METHODOLOGY

The vulnerability was assessed by both qualitative and quantitative methods, mapping, and field observation.

3.1. Study area

Zomba is located in the southern region of Malawi. Its coordinates are 15.3766°S and 35.3357°E (Brinkhoff, 2019). Zomba has a wonderful plateau, On this plateau is where the dam system was constructed in 2001 although the whole project started in 1997 (World Bank, 2013). Chagwa dam is located in Zomba next to Mulunguzi dam and it has 0.43Kilometres length. However, the Mulunguzi dam is the main dam that supplies water to most of the areas in Zomba city. Chagwa dam is mainly made of mud and has been in existence for many, many years. The surrounding area has been logged and this amongst other things, has led the soils to be degraded and erosion to occur. With the recent heavy rains, the dam has suffered further degradation (Zomba Forest Lodge, 2019). Unfortunately, the dam is at risk for failure which could result in devastating floods in the Mulunguzi river affecting areas along the river. Zomba has a population of 851,737 people and 105,013 staying in the city. (National Statistical Office, 2018). The district is 923m above sea level and receives about 906mm of annual rainfall (Climate-Data.org, 2021). The study was done in four residential areas along Mulunguzi river which are located in Zomba municipality, namely; Old Naisi, Matawale, Mangasanja, and Mulunguzi Secondary School.

Figure 3.1 shows a detailed map for the study area:

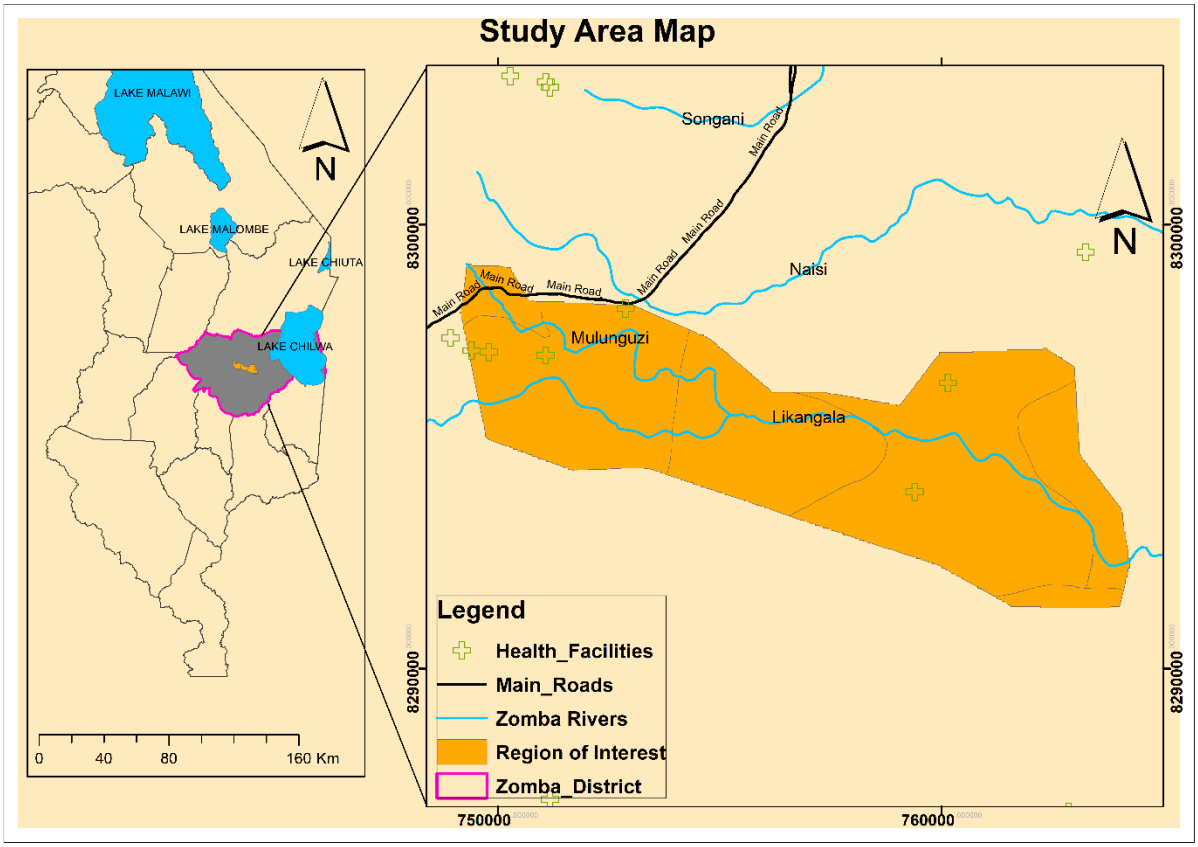


Figure 3. 1: The dam system on the Zomba Mountain plateau

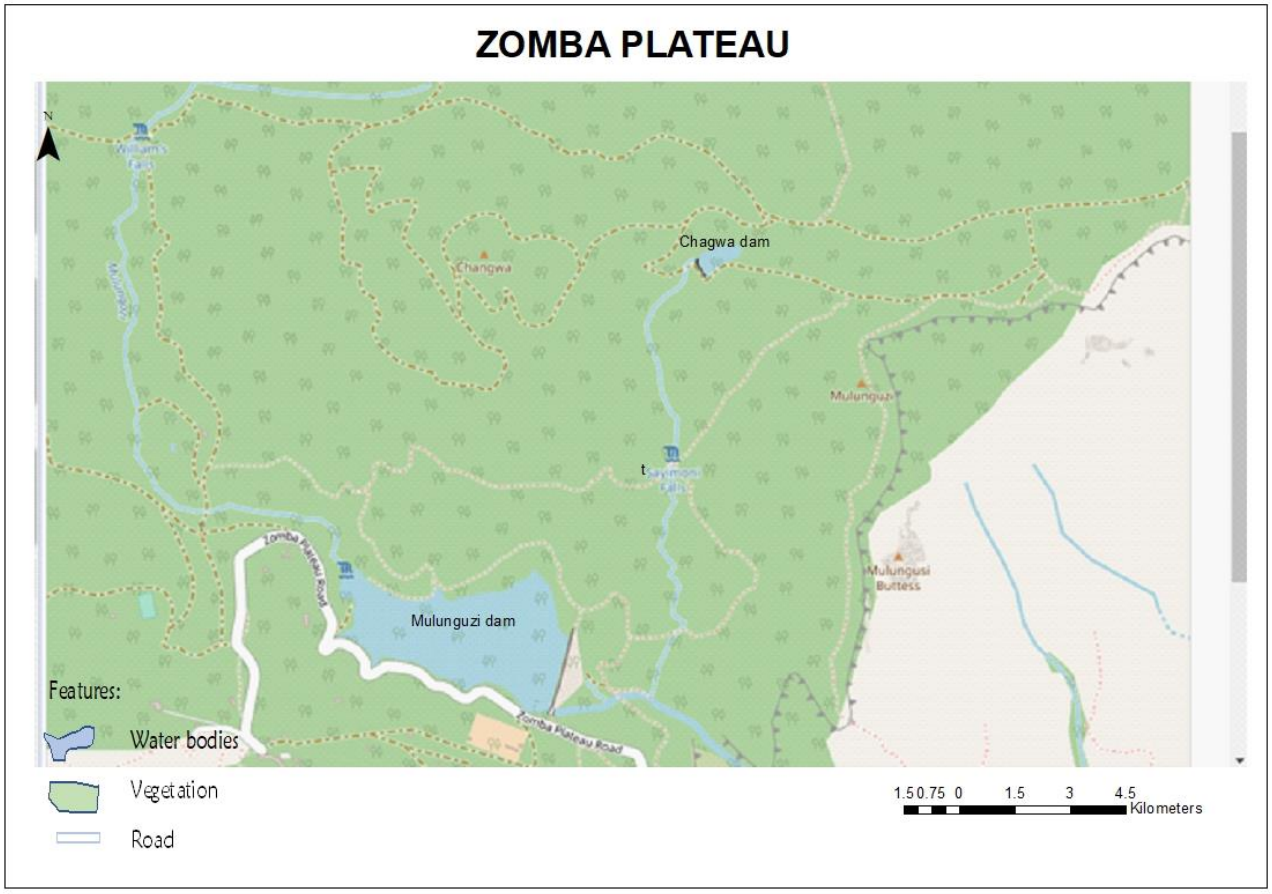


Figure 3.2 shows that the Chagwa dam connects to Mulunguzi river after Mulunguzi dam. Water in Mulunguzi dam is much monitored and controlled, unlike Chagwa dam. Despite that Chagwa dam is small as shown in the figure, in the unlikely event of failure, water overflow would undeniably inundate areas along Mulunguzi river which has small width and height.

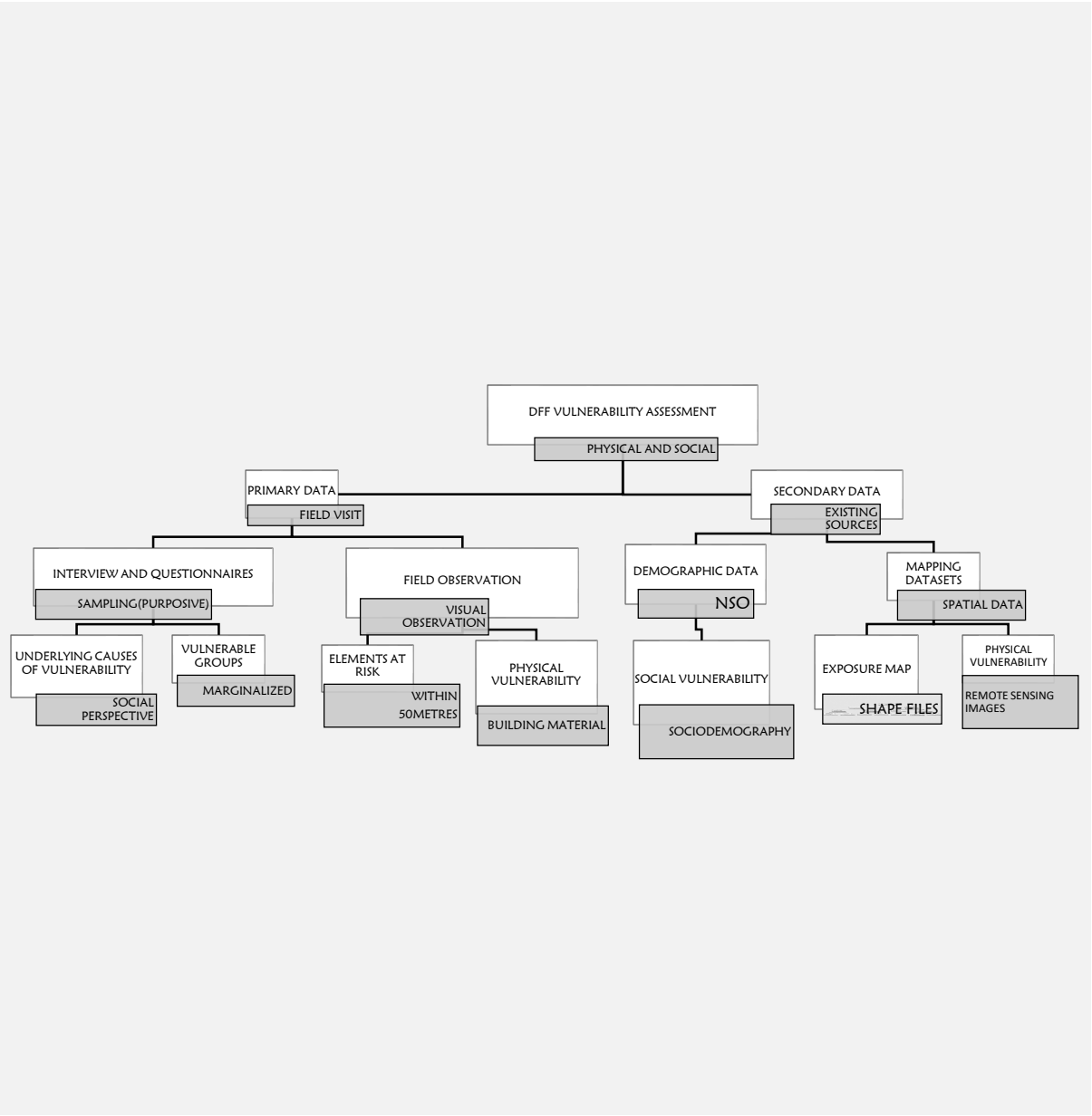
3.2. Research design

The study assessed vulnerability by employing both qualitative and quantitative methods. Data collection was done using a purposive method of sampling in three risk areas (Matawale, Mangasanja, and Old Naisi) since the selection of participants was based on judgement. That is only those staying within 100metres from the river, adults and those who have stayed in the area for more than 2 years were chosen to participate. A total of 45 individuals were selected and responded to questionnaires due to limited resources. Furthermore, interviews were conducted with the Area civil protection committee chairman and Mulunguzi secondary school Headteacher. Questionnaires

and interviews aimed at better understanding respondents' perceptions of vulnerability and their capacities to cope with adverse impacts that dam failure hazards can instigate. In addition to the above modus operandi, field observation was also executed to identify elements at risk and determine the potential physical vulnerability based on the nature of buildings and proximity to the river.

Maps were produced to display elements at risk and their susceptibility based on proximity to the river (exposure). Lastly, secondary data from NSO was used to calculate sociodemographic vulnerability.

Figure 3. 2: General flow diagram.



3.3. Materials and Methods

The following materials were used from the data collection stage to the interpretation stage: ArcMap, QGIS, Satellite Image, NSO data, Questionnaires, Phone recorder, Excel, SPSS, published reports, books, and journals.

The following data was obtained and used in the DFF vulnerability assessment presented in table 3.1 below

Data	Acquisition	Source
Remote sensing images	2 July 2021	Google Earth Pro
Demographic data	2018 census	National Statistical office
Interview data and questionnaires	12 to 15 May 2021	Field visit

Table 3. 1: Data used in DFF vulnerability assessment.

3.4. Methods

3.4.1. Establishing and analysing underlying causes of vulnerability

The data for analysing and establishing underlying causes of vulnerability encompassed questionnaires and interviews.

Questionnaires were administered to only selected samples based on the researcher's judgement. A purposive method of sampling was used to determine individuals to participate in the process based on proximity to the river (that is those living along the river within 100metres distance. Therefore, 15 individuals were selected in each of the following study areas, Mangasanja, Matawale, and Old Naisi. Thus a total of 45 respondents. The collected data was entered in the Statistical Package for Social Science (SPSS) spreadsheet wherein data was ready for analysis. Later, tabulated data from questionnaires were analysed under legacy dialogs as summaries of separate variables. Thereafter bar graphs were produced in SPSS to display the extent to which a factor is responsible for causing vulnerability in the stated study areas.

In addition to that, demographic data signified the social vulnerability of areas along Mulunguzi river. The obtained data from National Statistical Office was entered in excel whereby percentages of females, persons with disabilities, children, and elderly were calculated. The calculated percentages were tabulated in the table. Bar graphs presented social vulnerability for Mangasanja, Old Naisi, and Matawale. In other instances, the

underlying causes of physical vulnerability were analysed from field observation and remote sensing images obtained from Google Earth Pro. Later potential levels of physical vulnerability for all risk areas were deduced based on the nature of buildings and building materials, and their proximity to the river.

3.4.2. Identification of vulnerable groups

Interviews were conducted to identify vulnerable groups of people in the study areas. The selected 45 individuals were asked additional open-end questions in form of interviews to identify the most vulnerable groups of people in their respective communities. This data was coded and themes were generated manually from the interview transcript upon thorough analysis. In addition to that, interviews were also conducted with the headmaster for Mulunguzi secondary school, area civil protection committee chairperson for Mwambo Tradition authority, and village civil protection committee for Chogojo and Mindano villages in Matawale. The data obtained had to go through the same process of qualitative data analysis stated above. In addition to that, the proportions of vulnerable groups in the study areas were calculated from National statistical office (NSO) Data under sociodemographic. It must be emphasized that the participants were given consent forms in which their participation was voluntarily their own choice.

3.4.3. Identifying Elements at risk

Field observation was done to identify elements at risk. These elements were those which are very close to the river and those poorly constructed buildings, old buildings, public and private facilities. The elements were recorded in the notebook and later classified in the results and discussions.

In addition to field observation, elements at risk were identified and mapped using mapping techniques. In QGIS, spatial features which in this interest were elements at risk were digitized online, a technique known as heads up digitizing with the aid of open layers' plugin. The spatial features include buildings at risk, schools, Mulunguzi river, roads, etc. These features were then loaded in ArcMap 10.5 for map final production. In ArcMap, a geoprocessing tool known as buffer analysis was conducted in which 3 levels of vulnerability were created. Mulunguzi river as the central point of reference, buffers of distances 50m, 100m, and 200m were created whereby they were

given names and colours as very high exposure to floods, high exposure to floods, and low exposure to floods respectively.

4. RESULTS AND DISCUSSIONS

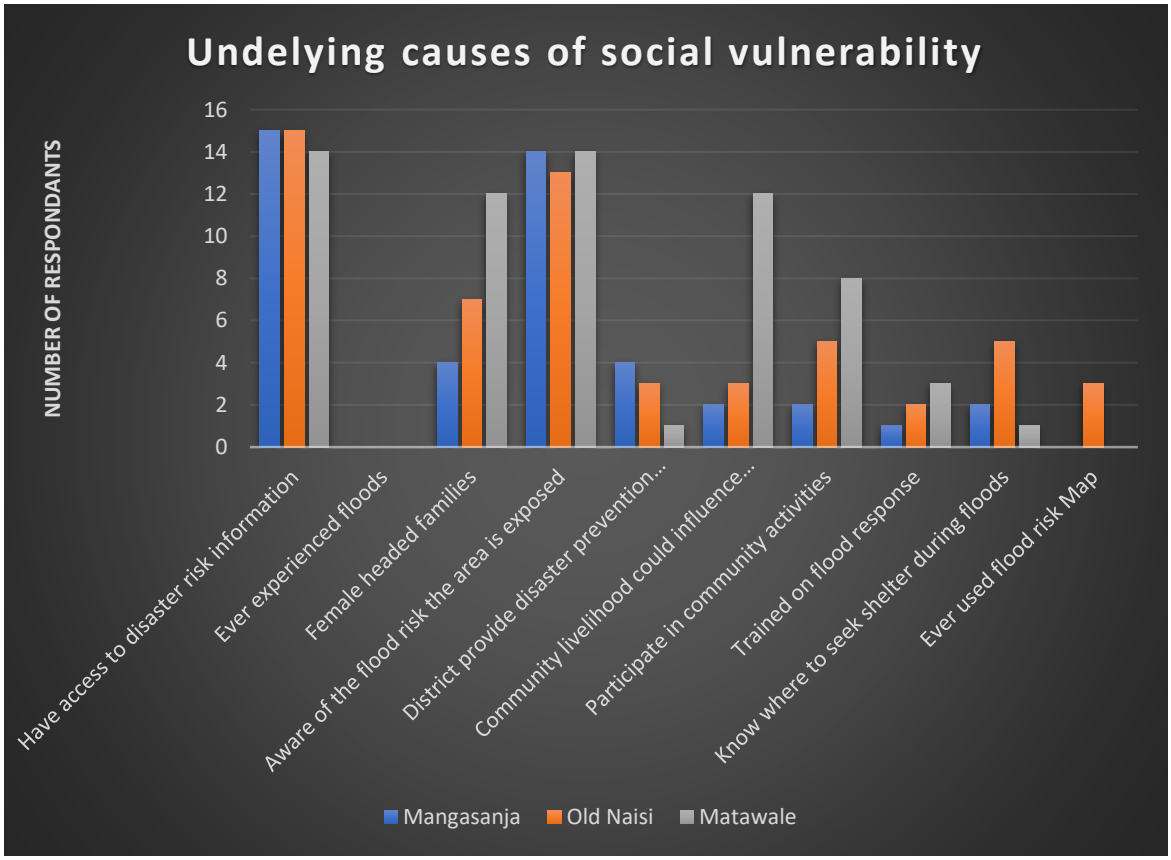
The study focused on assessing the vulnerability of areas along the Mulunguzi river to potential dam failure floods in which was done by field study (data collection and field observation) and later mapping in the GIS environment. The data were analysed and this section presents the obt0ained results.

4.1. Underlying causes of Vulnerability

The underlying causes were analysed in social and physical vulnerability contexts. This was done in each of the study areas separately as discussed below.

Firstly, social vulnerability context:

Figure 4.1 showing social vulnerability for Mangasanja, Old Naisi, and Mangasanja.



4.1.1. MANGASANJA

As shown in the graph above Mangasanja's level of vulnerability can be characterized by the following factors: limited disaster-related knowledge, absence of disaster

training/ drills, socially separated community in terms of people's interaction, presence of female-headed families, and lack of experience in handling an extreme event. Since residents are above the poverty line, households can easily cope up with the adverse impacts of the DFF to some extent. It can also be pointed out that disaster risk governance is not well organized in the area hence attributing to the susceptibility of the area. The graph also shows that majority have access to disaster information, are aware of the DFF hazard the area is exposed to and their livelihood activities don't have an influence on the hazard.

4.1.2. OLD NAISI

As shown in the graph above, it can be established that people in Old Naisi have limited disaster-related knowledge, disaster training drills not yet conducted, no flood experience, no disaster risk reduction measures provided, minimal community involvement due to socially separated households, and presence of more female-headed families. Those factors materialize their social vulnerability in such a way that, females have limited access to assets, limited participation due to triple roles in the society, and females are most victims of gender-based violence. In addition to that, behaviour response during floods can be a challenge due to lack of experience and simulation drills. However, the community have access to disaster information and they are aware of the flood risk the area is exposed

4.1.3. MATAWALE

There is a lot to be desired in Matawale as shown in the graph where most of the factors are directly influencing vulnerability. The community doesn't have access to disaster-related information and training, limited understanding of disasters, no disaster management measures provided, socially separated community, presence of female-headed families, and peoples' involvement in disaster activities is a problem. Just as in other communities as explained above disaster risk governance is also a challenge as the majority of people in risk-prone areas aren't aware of their VCPCS AND ACPCS. It can be pointed out that, community livelihood activities could increase the intensity of DFF since they practice farming along the river. In addition to that, more female-headed families could increase their vulnerability due to limited access to resources, poor

participation of women due to their triple roles in society and they are mostly victims of gender-based violence during a disaster.

4.1.4. Mulunguzi Secondary School

At this institution, upon conducting interviews with the headmaster it was learnt that there are many underlying causes of vulnerability. Notably, the institution being close to the Mulunguzi river of which vegetation is jeopardized for construction activities despite prohibition due to urbanisation. The school has 47 students with disabilities in terms of agility and hearing impairment representing 7.42% and 38.39% of females as shown in appendix 1. Students are not trained on how to respond to flood hazards, no designated evacuation point and they can't use flood hazard maps. It was also hinted that the institution has no trusted access to disaster information from the district council or community level. Those can affect their behavioural response during a disaster.

4.1.5. Sociodemographic

Demographic data obtained from NSO is presented in appendix 1. It was observed that DFF risk areas have some marginalized groups of people which increases their level of vulnerability. The results were presented as shown in the graph below.

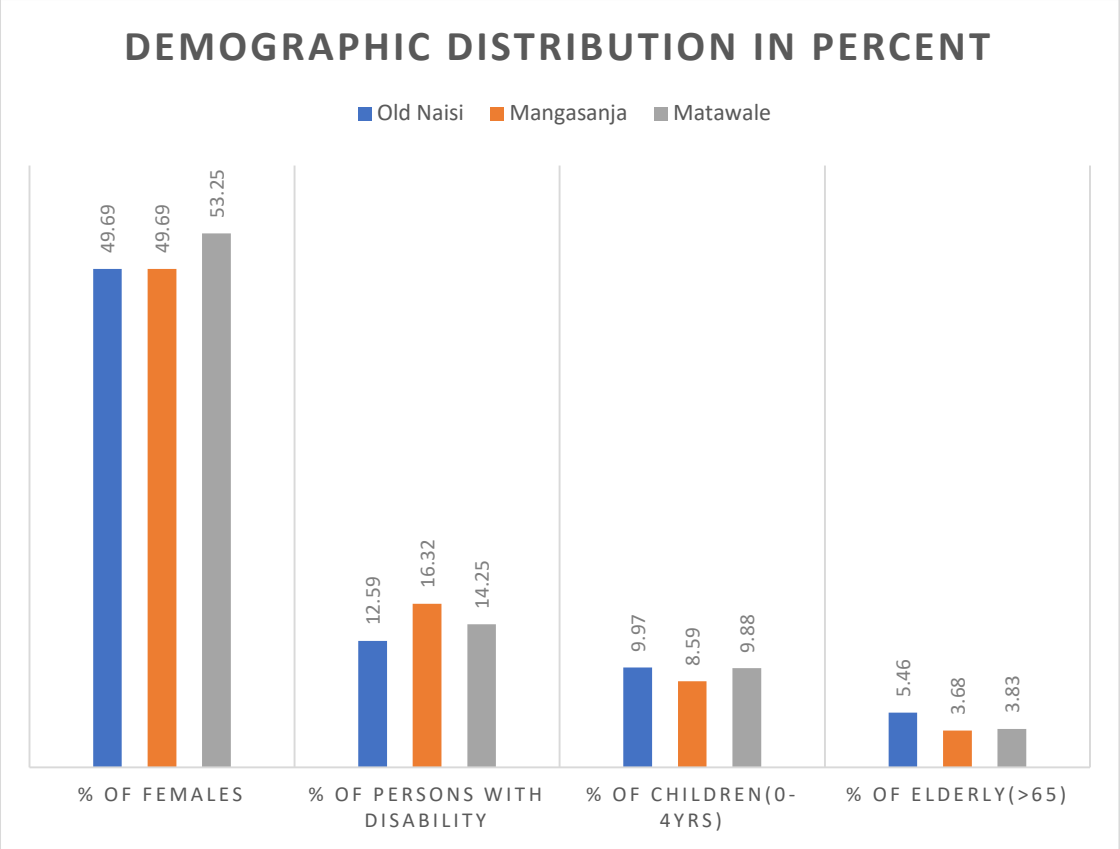


Figure 4. 1: Demographic distribution in percent.

As presented in figure 4.4 above, Matawale has more females (53.25%), a high percentage of people with disabilities are in Mangasanja (16.32%) and lastly, Old Naisi has a high percentage of children and Elderly (9.97 and 5.46 respectively). These groups of people are highly affected during a disaster as they have challenges in responding and coping up with the adverse impact of the hazard.

4.1.6. Building types and materials

In physical vulnerability context: type of buildings and nature of building material, and proximity to the river determine the level of damage during a flood disaster. The potential of physical vulnerability was assigned and presented in table 4.2 below.

DFF HAZARD PRONE AREAS	PHYSICAL VULNERABILITY
Mangasanja	Very low
Old Naisi	Low
Mulunguzi secondary school	Low
Matawale	High

Table 4. 1: probable physical Vulnerabilities.

The probable levels of vulnerabilities presented in table 4.2 above are results observed through field visits by characterizing the nature of buildings and their proximity to the river. It was complemented with remote sensing products by calculating the number of buildings. The images obtained from Google Earth Plus shown were presented in appendix 2.

It was observed that 100% of buildings in Mangasanja were constructed with bricks and cement that is strong building material. Although over 50% are old buildings constructed decades ago. Despite being on the upper part of the Mulunguzi river, houses are not so close to the river (the level of proximity is low). Therefore, it can be concluded that the potential physical vulnerability is very low in Mangasanja.

In Old Naisi, 100% of the houses were observed to be constructed with bricks and cement. However, 23 buildings were constructed very close to the river but then built with strong building materials. Geographically, Old Naisi is located on the upper to the middle part of the Mulunguzi river. In addition to that, trees along Mulunguzi river are prohibited from cutting, thou, more new buildings were observed to be constructed within the area and this encompasses removing the vegetation. This can be due to rapid population growth, urbanization, and poor disaster risk governance. Therefore, a low value of vulnerability was signed.

Mulunguzi secondary school has buildings constructed with bricks and cement. Despite its proximity to the river as observed through remote sensing images and field observation, it was constructed on elevated ground and covered with vegetation. Therefore, low vulnerability can possibly be assigned.

In Matawale, there is high physical vulnerability due to the presence of poorly constructed houses. This can be explained by the presence of over 20 houses constructed with mad rather cement and unburnt bricks. In addition to that, most of the new buildings are constructed within 50metres from the river despite being constructed with bricks and cement. Geographically, Matawale is located on the lower part of Mulunguzi river where agricultural activities along the river are heavily practiced and this also increases the potential of vulnerability. Even the extent to which the vegetation is being destroyed is a great concern.

4.2. Elements at risk

Field observation revealed that several public and private facilities are at risk. This was determined by their proximity to the river and ground elevation. These include bridges, houses, botanical gardens, Lutheran Church, and Zomba ESCOM station. In addition to that, buildings which are being constructed close to the river, old buildings, people staying in those buildings, and farms which are along the river.

These elements at risk can be classified using the ADPC method (Asian disaster preparedness centre) as shown in table 4.3.

Physical elements	**Societal elements**
Houses	Low-income groups in Matawale
Bridges	Elderly people
ESCOM offices	Proportion of females
Mulunguzi secondary	Female-headed families
Lutheran Evangelical church	
Economic elements	**Environmental elements**
Farming	Botanical Gardens
	Naisi Spar

Table 4. 2: Classification of elements at risk.

Furthermore, these elements at risk can be quantified in the following ways:

Using Google Earth Plus 74 residential buildings were identified to be constructed within 100metres away from the river. The operation was done using a ruler tab to determine if the building is within 100 metres from the river. A total of 136 buildings were calculated. But the figure was reduced to 89 for residential buildings upon ground-truthing.

The fifth integrated household survey report indicates that the average household size for Zomba is 4.5(National Statistical Office, 2019). therefore,

Total population at risk = 89 × 4.5 = 400.5, thus approximately 400 people are highly exposed to the DFF hazard.

The Exposure maps for elements at risk were produced based on proximity to the Mulunguzi river. Those buildings within 50 metres from the river were marked high exposure that is more vulnerable to DFF hazard and so forth. The maps below show elements at risk however, some elements might be missing due to resolution since the digitizing was done online and not more detailed. The buildings in the red zone are more vulnerable to flooding comparing to those in yellow and green zones.

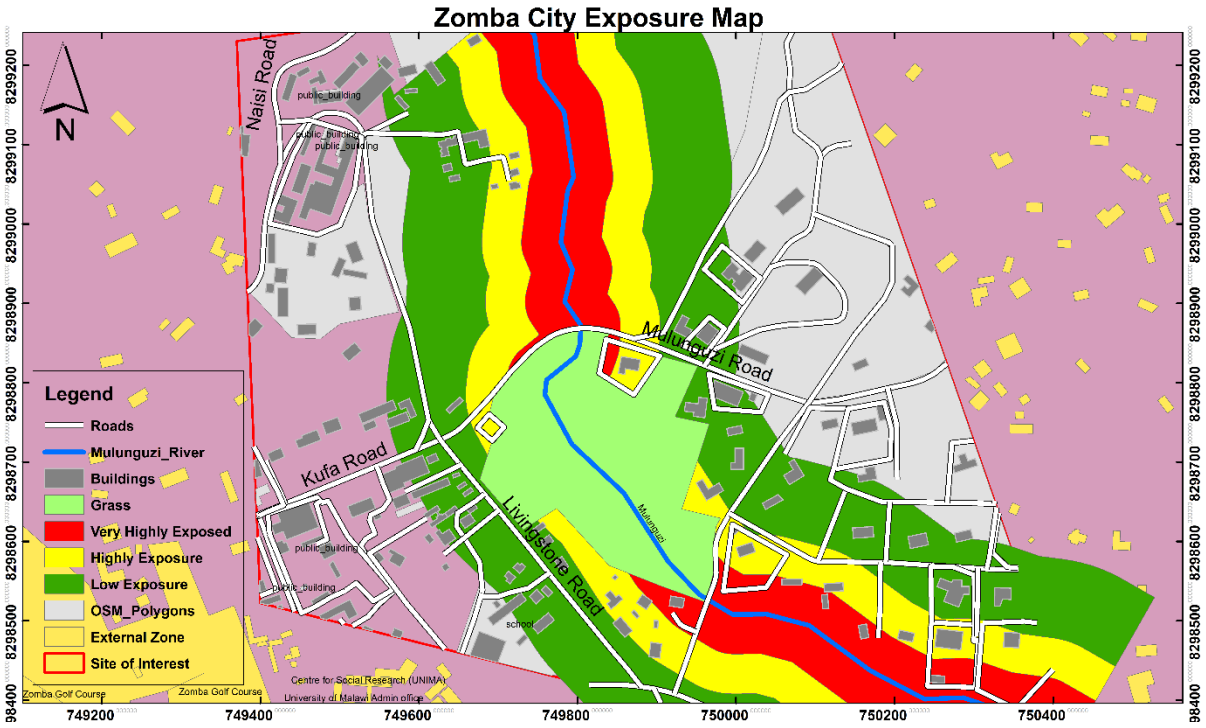


Figure 4. 2: Susceptibility of elements at risk to adverse impacts of the hazard in Mangasanja and Old Naisi based on exposure.

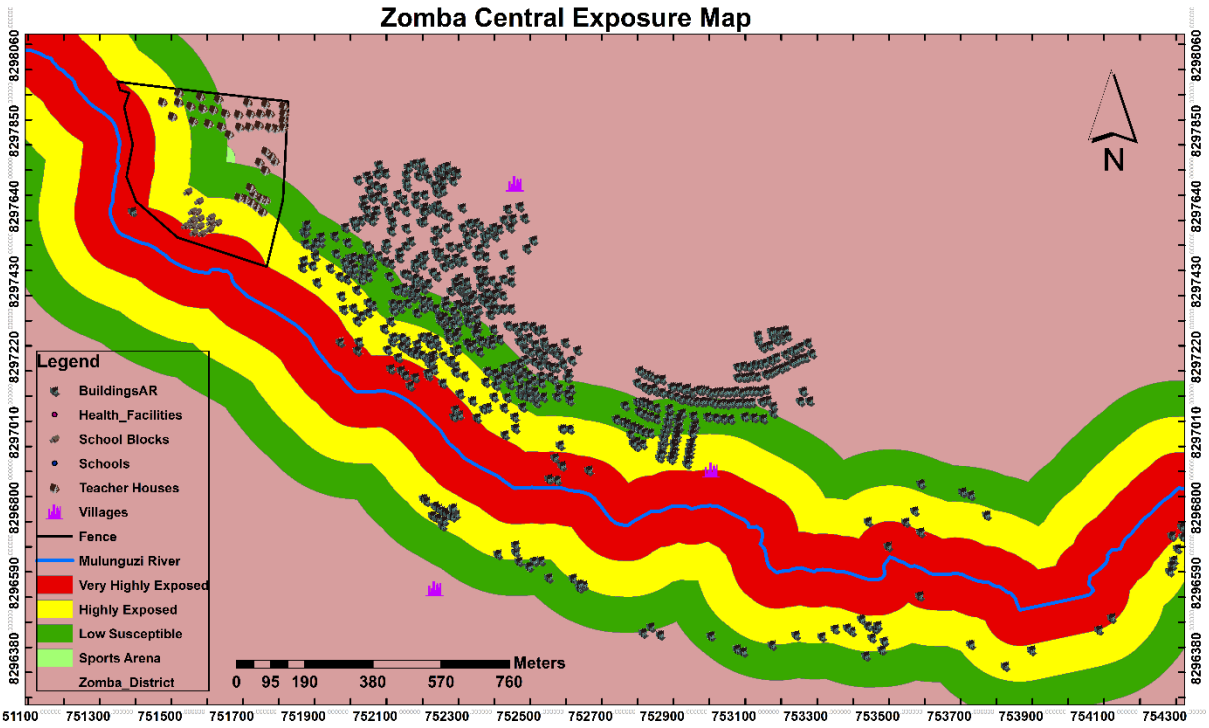


Figure 4. 3: Susceptibility of elements at risk to adverse impacts of the hazard in Matawale and Mulunguzi secondary school based on exposure.

4.3. Vulnerable groups

All areas along the Mulunguzi river have vulnerable groups of people e.g. the poor, people with disabilities, female-headed families, and children. However, based on the sociodemographic distribution in percent provided above. Matawale has more females who are vulnerable to lack of assets, limited participation, and most victims of gender-based violence. Mangasanja has a high percentage of people with disabilities and these have challenges during disaster response. Old Naisi has more infants and Elderly who mostly have difficulties coping with disaster events and their limited agility impact the evacuation process. Lastly, Mulunguzi secondary school has female students and students with a disability who needs special consideration during disasters.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Vulnerabilities of areas along Mulunguzi river were assessed in a physical and socioeconomic context. It was identified that Matawale is more vulnerable compared to other prone areas. This is due to proximity to the river, social-economic factors, and nature and type of buildings. In addition to that flood vulnerability map was produced in ArcMap with the aid of spatial data sets although data availability was a challenge.

In addition to that, elements at risk were identified in all prone areas and a susceptibility map was produced. However, they are exposed differently to the adverse impacts of the hazard. This can be associated with the presence of vegetation, proximity to the river, altitude, and whether they are in the lower or upper part of the river. Furthermore, vulnerable groups were identified and these include: elderly, minority groups, handicapped, female-headed families, and children. However, everyone in hazard-prone areas are vulnerable to some extent regardless of their economic status.

Policymakers must prioritize reducing the vulnerability of Matawale by introducing measures/strategies to improve the livelihood activities of people, intensify awareness campaigns, reduce poverty, and regulating land use. Furthermore, the district disaster risk management office must establish a liaison and rapport with people in prone areas for effective disaster risk reduction initiatives.

An early warning system (EWAS) can be designed and installed so that water level changes are monitored, information is disseminated through a trusted source, and timely and effective response is adopted. This must involve various stakeholders to design an effective and efficient early warning system to save losses in lives and properties. This could be achieved by designing a community-based early warning system in which the community members are the core of everything. Since it empowers the community to better protect and prepare themselves hence achieving disaster resilience. Lastly, indigenous knowledge must also be incorporated in designing the EWAS.

5.2. Recommendation

I recommend studying the stability of Chagwa Dam since it has been 2years since the warning was issued. Of course, engineering measures were said to be taken to improve the stability of the dam but then there is a lot to be desired. In addition to that, a risk assessment can be conducted for Mulunguzi river since this study emphasized vulnerability which is one of the steps in Risk Assessment.

5.3. Study limitation

This study has faced some challenges that may be taken into consideration when conduction the same project in the future, these challenges: data availability, the time factor, and availability of financial resources. Data availability was an immense limitation whereby socioeconomic statistical data at the area level was not accessible. These include income and education levels for Matawale, Old Naisi, and Mangasanja. On the same issue of data availability, mapping some elements at risk was impossible due to the resolution of obtained datasets. Time for the study was limited since everything was against time, however, the study was demanding more time to survey a good number of households. Lastly, limited financial resources to understand the vulnerability in general in which thorough field verification of mapping-related findings was a challenge.

6. APPENDIX

6.1. Appendix 1: NSO data

Demographic data for Mangasanja

	Population	Persons with Disability	0-4	Elderly (60+)
Mangasanja	815	133	70	30
Male	410	67	46	21
Female	405	66	24	9

Demographic data for Matawale

	Population	Persons with Disability	0-4	Elderly (60+)
Matawale	3,369	480	333	129
Male	1,575	201	164	60
Female	1,794	279	169	69

Demographic data for Old Naisi

	Population	Persons with Disability	0-4	Elderly (60+)
Old Naisi	1,795	226	179	98
Male	903	95	85	52
Female	892	131	94	46

Percentage demographic data for Old Naisi, Mangasanja and Matawale.

Area	% of Females	% of persons with disability	% of children(0-4yrs)	% of elderly(>65)
Old Naisi	49.69	12.59	9.97	5.46
Mangasanja	49.69	16.32	8.59	3.68
Matawale	53.25	14.25	9.88	3.83

Demographic data for Mulunguzi secondary school

Total number of students	633
Total number of females	243
Total number of those with disabilities	47
Percentage of females	38.38863%
Percentage of those with disabilities	7.424961%

6.2. Appendix 2: Remote sensing images

The following images were obtained on Google Earth Pro to identify elements at risk.

Mangasanja



Image:1

Old Naisi



Image:2

Matawale



Image:3



Image:4



Image:5

Mulunguzi secondary school



Image:6

DAMS



Image:7

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