TOWARDS A FRAMEWORK FOR FLOOD VULNERABILITY ASSESSMENT FOR RURAL AND URBAN INFORMAL SETTLEMENTS IN MALAWI: A STUDY OF KARONGA DISTRICT AND LILONGWE CITY

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MZUZU UNIVERSITY, MALAWI

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A Thesis Submitted to the Faculty of Environmental Sciences, Department of Water and Sanitation in Fulfilment of the Requirement for the Award of a Doctor of Philosophy Degree in Water Resources Management and Development

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August 2023

DECLARATION

I hereby declare that this thesis, titled "***Towards a Framework for Flood Vulnerability Assessment for Rural and Urban Informal Settlements in Malawi: A study of Karonga District and Lilongwe City***" is my original work undertaken at Mzuzu University. This thesis has been submitted to the Faculty of Environmental Sciences, Department of Water and Sanitation in fulfilment of the requirement for the award of a Doctor of Philosophy (Water Resources Management and Development). It was prepared under the supervision of **Associate Professor Mtafu Manda** and **Professor Cosmo Ngongondo.** All matters and opinions embodied in this thesis remain my sole responsibility. The use of all materials from other sources has been properly acknowledged. This thesis has not been submitted for any other degree or any University and/or would not be presented to any other institution for any award like this one.

Isaac Kadono Mwalwimba

18/08/2023

Students name & Signature **Date**

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CERTIFICATE OF COMPLETION

We, the undersigned certify that this thesis, titled ***Towards a Framework for Flood Vulnerability Assessment for Rural and Urban Informal Settlements in Malawi: A study of Karonga District and Lilongwe City*** is the original work of the candidate. It has been prepared according to the Mzuzu University prescribed thesis format.

We, recommend the thesis for being accepted as fulfilment of requirements for the award of the degree of Doctor of Philosophy (Water Resources Management and Development) of the Mzuzu University.

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ABSTRACT

Flood vulnerability assessment (FVA) is a significant step for developing flood mitigation plan. However, there is lack of FVA that proposes a framework to support flood mitigation and preparedness in rural and urban areas of Malawi. This informed the need to assess households' flood vulnerability (HFV) in Mtandire ward of Lilongwe city (LC) and Traditional Authority Kilupula of Karonga district (KD) in order to propose a FVA framework for rural and urban informal settlements in Malawi. Analysing spatial-temporal flood vulnerability (FV), predicting HFV, assessing perception of HFV and evaluating household adaptive capacity were the focus of this study. These were attained using flood frequency analysis (FFA), indicator-based method and hazard, vulnerability and capacity assessment (HVCA) approach. Baseline data was collected from Departments of Water Resources and Disaster Management Affairs in the Ministries of Water and Sanitation and Natural Resources and Climate Change respectively. A household survey was used to collect data from a sample of 545 households' participants, 17 key informants and 21 location points. Statistical methods (Gumbel, R and SPSS), ArcGIS 10.8, Multiple Correspondence Analysis (MCA), Artificial Neural Network (ANN) and qualitative data analysis (QDA) miner level 6.0 were used for data analysis. The Flood Vulnerability Index (FVI) was applied to determine HFV. The results found a higher expected floods for Lingadzi compared to Lufilya catchments in LC and KD respectively at different return periods. The results further show a higher flood risk in T/A Kilupula of KD (6) compared to Mtandire Ward in LC (2). The FVI revealed high HFV on Enviro-Exposure Factors (EEFs) (0.9) in LC and (0.8) in KD, followed by Eco-Resilience Factors (ERFs) (0.8) in KD and(0.6) in LC and Physio-Exposure Factors (PEFs) (0.5) in LC besides 0.6 in KD. The findings show that perception of household flood vulnerability is significant by age (0.0065), education (0.0045) and marital status (0.0085) in LC, while only occupation is significant in KD. The findings revealed high (3), medium (2) and low (1) for the respective of physical, social organisation and economic livelihoods adaptive capacity measures. The study developed the framework with a reconstituted equation as sum of UVFs, VCs, hazard (H) and (-) adaptive capacity (AC). The FVA reveals variations of causes that contribute to households' flood vulnerability. The study recommends that FVA framework can be applied in promoting resilience of communities to mitigate flood risks and key component for planning and decision-making process.

Key words: *Vulnerability, Floods, Mtandire, Kilupula, Karonga, Lilongwe city, Malawi*

DEDICATION

To Georgina, my wife, my love, my entertainer.

To Hillary Meagan, my daughter.

To Rhoida, my mother, my promoter of Faith! "**God should help you**"

To late father, Fraction Kadonosha Mwalwimba. ***You died a great man! You believed in speaking the truth and died by the truth. Rest in eternal peace***.

To my beloved brothers and sisters who gave courage throughout this PhD Thesis process. Thank you all!

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ABBREVIATIONS AND ACRONYMS

ACPC	Area Civil Protection Committee
CCPC	City Civil Protection Committee
CEO	Chief Executive Officer
CSF	Cultural Susceptibility Factors
DC	District Commissioner
DCPC	District Civil Protection Committee
DFID	Development for International Development
DLMD	Disaster Loss Models Data
DODMA	Department of Disaster Management
DPR	Disaster Preparedness and Relief
DRI	Disaster Risk Index
DRM	Disaster Risk Management
DRMP	Disaster Risk Management Policy
DRR	Disaster Risk Reduction
EEF	Enviro-Exposure Factors
EEI’s	Enviro-Exposure Indicators
ERF	Eco-Resilience Factors
ERI’s	Eco-Resilience Indicators
ERVF	Elements at Risk in the Vulnerability Factors
EWS	Early Warning Systems
FFA	Flood Frequency Analysis
FVA	Flood Vulnerability Assessment
FVAF	Food Vulnerability Assessment Framework
GOM-NDRM	Government of Malawi National Disaster Risk Management
GPS	Geographic Position System
IDNDR	International Decade for Natural Disaster Reduction

KDC	Karonga District Council
LCC	Lilongwe City Council
MGDS	Malawi Growth and Development Strategy
MZUNIREC	Mzuzu University Research Ethics Committee
NAPA	National Adaptation Program of Action
NCP	National Contingency Plan
NCPC	Neighborhood Civil Protection Committee
NDPRC	National Disaster Preparedness and Relief Committee
NDRF	National Disaster Recovery Framework
NDRM	National Disaster Risk Management
NGO	Non-Governmental Organisation
NRP	National Resilience Policy
NSO	National Statistics Office
PASSA	Participatory Approach for Safer Shelter Awareness
PCA	Principal Component Analysis
PEF	Physio-Exposure Factors
PEI’s	Physio-Exposure Indicators
SEP	Socio Economic Profile
SVF	Social Vulnerability Framework
SVI	Social Vulnerability Index
SWAT	Soil and Water Assessment Tool
UNDP	United Nations Development Program
UVF	Underlying Vulnerability Factors
VA	Vulnerability Assessment
VC	Vulnerability Components
VCPC	Village Civil Protection Committee
WCDR	World Conference on Disaster Reduction

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CHAPTER 1: INTRODUCTION

1.1 Background Information

In recent years, the world has deviated from flood hazard control to flood vulnerability assessment (Ndanusa et al., 2022; Rana et al., 2018). Vulnerability induces floods to become disasters (Below et al., 2012; Nong et al., 2020; Salami et al. 2017). Therefore, vulnerability assessment is a primary component of flood hazard mitigation, preparedness and management (Ndanusa et al., 2022; Zhou et al., 2015). However, studies have attempted to assess flood vulnerability, but they have used single dimensional indicators (Munyani et al., 2019; Salami et al., 2017). Those that have combined the indicators (Karagiorgos et al., 2016; Mwale, 2014; Nazeer et al., 2020) have not gone further to propose FVA frameworks to support decision making. While this is so, floods affect many people worldwide (Ndanusa et al., 2021; Zarekarizi et al., 2020). The Emergency Events Database (CRED, 2019) indicates that 50,000 people died and approximately 10% of the world population was affected by floods between 2009 and 2019 (Moreira et al., 2021).

Indeed, the level of vulnerability differs between the developed and developing nations, but floods recently, have shown vulnerability of all the regions with numerous effects (Kron, 2014; Li Qiong et al., 2014; Munyai et al. 2019; Parvin et al., 2022). In the developed world, the Germany floods in July 2021 (Haoyu & Garside, 2022), the destruction of Louisiana in USA (Salami et al., 2017), the 2001 floods in the city of Kempsey in Australia (Dube, 2017) and the occurrence of floods in China (Li Qiong et al., 2014) and Poland (Parvin, 2022) are among the key examples that reveal flood vulnerability. According to statistics provided by the National Centers for Environmental Information (NCEI), the average annual cost of flooding from 1980 to 2022 in the United States is approximately $4.0 Billion US Dollars (Smith, 2022).

Developing countries such as Benin, Nigeria, Senegal and Sudan have recently experienced severe flooding leaving considerable number of human casualties and thousands displaced (Salami et al., 2017). In the sub-Saharan Africa (SSA), floods and droughts account for 80% and 70% disaster related deaths and economic loss respectively (Mwale et al., 2014; Ndaruzaniye et al., 2013). In Southern Africa, the cyclone Eline induced floods of 2000 resulting in huge loss for communities of the Zambezi Basin (Dube, 2017). About 700 people died, over 500,000 people were left homeless and damage to infrastructure of over US$ 1 billion was incurred (Dube, 2017). Further, the 11-13 April 2022 floods in South Africa left 448 people dead and 40,000 people displaced (Serradinho et al., 2022). Similarly, in January 2011, floods caused death of 11 and 2 people in Luanda Providence in Northern Angola and Madagascar respectively (Dube, 2017). Statistics for the reported economic losses due to natural disasters in Africa, for the 1970 – 2019 period, revealed that the cost of floods is around 13.09 billion U.S. Dollars (Tramblay et al., 2020). Undoubtedly, people in developing countries have the limited capacity to resist the impact of hazards such as floods (Salami et al. 2015). According to Mwale (2014), this is the major reason to undertake flood vulnerability assessment (FVA) in developing countries.

In Malawi, floods are the most frequent natural hazards causing devastating impacts in both rural and urban areas. For instance, between periods of 2015-2023, about four major floods induced by tropical cyclones have affected communities. The most destructive were floods of 11-13 March 2023, influenced by tropical cyclone Freddy (TCF) which was developed in the Western Indian Ocean and moved eastwards (GOM, 2023). The TCF caused multiple flash floods and landslides which killed about 679 people, injured 2178 people, displaced 563,602 people, and about 511 people were reported missing, including causing several other damages and loss in sectors such as agriculture, infrastructure, food security and health (GOM, 2023).The response to this catastrophic, including the previous floods tailored more on rescue and relief operations (GOM, 2023). While these are critical to save lives and to provide immediate relief and short term support, but they cannot provide long terms solutions for programming current and future floods impacts resulting from these cyclones. As such, the application of FVA can provide practical indicators for programming current and future flood mitigation measures in a sustainable and long term process.

FVA provides a significant opportunity towards identifying factors leading to flooding losses (Lidiu et al., 2018; Nazeer et al., 2020; Ndanusa et al., 2022). FVA is an impetus in which science may help to build resilient society (Ran et al., 2018; Birkmann et al., 2013). FVA provides metrics that can support decision-making process and policy interventions (Mwale et al., 2015; Ndanusa et al., 2014). FVA is a proactive task for pre-hazard management and planning activities (Parvin et al. 2022). Nazir et al. (2013) maintains that FVA provides an association between theoretical conceptions of flood vulnerability and daily administrative process. Mwale (2014) maintains that vulnerability must be quantified and analysed to identify specific dimensions of vulnerability. Birkmann et al. (2013) stipulates that the need to understand vulnerability is a primary component of disaster risk reduction at household and community level and culture of building resilience. Iloka (2017) highlights that measuring vulnerability helps to determine immediate impacts on lives as well as future impacts of the future affected households and communities.

The Sendai Framework (2015-2030), an international policy for disaster risk reduction (DRR) also emphasises on vulnerability assessment as a tool for minimising the impact of hazards (UN/ISDR, 2017). It posits that vulnerability assessment (VA) should be conducted to understand risk in all dimensions of vulnerability, capacity, exposure of persons, hazard characteristics and the environment (UN/ISDR, 2017). Birkmann et al. (2013) maintains that conducting vulnerability identification and assessment is a first step towards improving risk reduction and disaster preparedness. Development of framework for measuring vulnerability is a prerequisite to reduce the impact of any natural hazard (Birkmann et al., 2013).

1.2 Study Setting

SSA, in particular, Malawi is faced with numerous floods impacts due to intertwined households' vulnerability patterns (Chawawa, 2018; Munthali, 2022; Mwale, 2014). Floods have escalated poverty levels, leaving many Malawians trapped in the cycle of poverty and vulnerability. Salami et al. (2017) state that poverty is a factor in vulnerability analysis because it generates conditions such as crime, inadequate housing and poor health. In Malawi despite the formulation of disaster risk management (DRM) policies, theoretical debates on the connectivity of disasters, hazards and vulnerability appear to be limited. This is also compounded by limited comprehensive vulnerability assessment (DoDMA, 2015). This therefore, cannot negate the notion that the disaster risk management is slowly integrating proactive measures (Wright et al., 2017). Practice also shows that disaster risk management is focusing on relief support (Wright et al., 2017). For example, similar to the 1991 Disaster Preparedness and Relief Act (DPR Act, 1991), the new developed DRM Law (DRM, 2023), which has replaced DPR Act is also tailored much on response and relief activities than vulnerability assessment that can support disaster risk reduction. More importantly, it is observed that the DRM Law (DRM, 2023) does not articulate properly the link between DRR and VA, and this has implication in flood risk mitigation.

Every time Malawi experiences the landed Tropical Cyclones in Mozambique-Indian Ocean, the outcome is either the declaration of a "State of disaster" induced by floods or the neglect of the declaration of "disaster" at the expense of loss of life and the magnitude damage of infrastructure. As such, understanding of factors that trigger peoples' underlying vulnerabilities and negative consequences is necessary for managing flood risks efficiently (Oyedele & Vyonne, 2022). This would further contribute to identification of indicators which can be useful for developing FVA framework, and thereby supporting decision makers to mitigate floods caused by these cyclones. According to Ndanusa et al. (2022), the assessment need to be holistic in order to provide data that can be used to inform decision makers and stakeholders when creating mitigation and preparedness strategies for at risk communities. This informed the need to undertake FVA through a combination of underlying vulnerability factors (UVFs)-physical-social-economic-environmental and cultural with vulnerability components (VCs)-exposure-susceptibility and resilience.

FVA has been emphasised by the research community as the right step towards mitigating floods impacts (Birkmann, 2014; Hossain et al. 2015; Nasiri et al., 2016; Ndanusa 2022; Rajan et al., 2020; Salami et al., 2017). Though this acknowledgement, FVA has received little attention in both rural and urban areas in Malawi (Chawawa, 2018; Mwale, 2014). Yet, the significant loss of life from flood hazards is triggered by the vulnerability of communities living in the flooded areas (Munthali et al., 2022). Instead, sporadic studies have been carried out in either rural or urban areas in addressing various issues surrounding the causes, impacts and management of floods (Kita, 2017; Manda et al., 2015). However, despite the huge contributions of these studies, up till now, tailor made indicators for FVA in rural and urban areas in Malawi are limited. Though, rural people are supported with decisive institutional and legal frameworks for disaster risk management (DRM) programmes, their vulnerabilities to floods is still high (Chawawa, 2018; Manda et al., 2017; Mwale et al., 2015). The problem is aggravated by the fact that many people consider floods to be part of life (Chawawa, 2018). Most of them have beliefs and practices that events from flood hazards are inevitable, acceptable and cannot be disputed (Chawawa, 2018).

The problem is further heightened in urban areas where a complete neglect of FVA has been observed with very limited studies (Banda, 2015; Kita 2017; Manda et al., 2017) not even directly aiming at developing flood vulnerability assessment frameworks. Kita (2017) and Manda et al. (2017) observed that flood impacts in cities have been attributed to building in risky areas, poor follow-up on physical planning guidelines, and poor enforcement of laws against illegal occupants, failure to provide plots in the right time, unplanned development, poor land use and rapid urbanization. Some of these impacts can be attributed to the slow adoption of DRR to mitigate flood effects by government and other stakeholders in cities (Kita, 2017). The major reason is that DRM strategies have not targeted urban areas (LCDRMP, 2017). The DRM focus is on village and district levels (Manda et al., 2017). The majority of urban people have even shown little cooperation to move their households from the danger zones.

The problem experienced in flood vulnerability assessment in rural and urban areas of Malawi is also supported in literature (Chawawa, 2018; Salami et al., 2017; Wisner et al., 2014). Wisner et al. (2014) cited an example of the "Flood Response study" in an article "Stopping Floods is not the same as reducing Vulnerability", conducted in Bangladesh. The study found that the affected people had their own priorities for flooding and showed very little interest to evacuate and stopping floods altogether. Chawawa (2018) in the study of smallholder farmers self-perceived flood vulnerability in Blantyre rural and Nsanje district found that farmers have accepted floods as an inevitable natural phenomenon to be endured. Salami et al. (2017) states that most African people are vulnerable to floods usually because they have lesser capacity to recover from the shocks of floods disasters as a result of failure of governments to build human security for the residents. According to Ndanusa et al. (2022), lack of FVA contributes to question the efficiency and effectiveness of the DRR programmes being implemented. This also, contrasts the arguments of various studies that acknowledge the significance of developing frameworks to measure vulnerability and coping capacity to flood hazards (Nasiri et al., 2016; Nazir et al., 2022; Rajan et al., 2020). Arguments have been presented in literature that floods interventions can only be implemented when the vulnerability of people has been assessed (Mwale, 2014; Nazir et al., 2022; Oyedele & Vyonne, 2022; Rajan et al., 2020). This can be looked at as a strong shift from reactive approach to flood risks management to proactive planning and preventive approach (Ludin et al., 2018). The crucial point in regard to the concerns and nature of this problem is the need to assess household flood vulnerability for rural and urban areas in

Malawi which can support policy and decision makers to understand different dimensions of peoples' vulnerabilities. This would act as critical step towards implementation of resilience and DRR strategies aimed at decreasing human suffering and damage to infrastructures. As such, in this study, the concept of vulnerability is operationalized as conditions that predispose households or systems to incur loss based on interaction of underlying vulnerability factors (physical, social, economic, environmental, cultural) and vulnerability components (exposure, susceptibility and resilience).

1.3 Problem Statement

Scientific studies have confirmed that FVA is a step towards reducing flood hazard impacts (Birkmann, 2013; Hossain et al., 2015; Nong et al., 2020). It constitutes a step in the process of measuring vulnerability to identify vulnerable areas in all aspects of multi-dimensional measures such as physical, social, economic, environmental (Ludin et al., 2018; Ndanusa et al., 2022) and exposure, susceptibility as well as adaptive capacity (Mwale, 2014). It is a primary component of disaster risk reduction (Ndanusa et al., 2020; Zhou et al., 2015). However, in Malawi, FVA has been rarely understood (GOM, 2015; Kamanga et al., 2022). This is compounded by lack of comprehensive and standardised flood vulnerability assessment tools and guidelines (GOM, 2015). While floods occurrences are common in both urban and rural areas of Malawi with varying impacts on households and infrastructure, few studies have been conducted targeting either urban areas (Kita, 2017; Manda, 2014) or rural areas (Chawawa, 2018; Munthali, 2022; Mwale et al., 2015) of Malawi. This implies that there are limited studies that support a comparison of flood vulnerability assessment in rural and urban settlements. For example, across the world, majority of the studies (62.1%) focused on the neighbourhood followed by 14.7% in the city (Moreira et al., 2021). Indisputably, there is a neglect to develop FVA framework, which would guide vulnerability assessment in rural and urban informal settlements. The Malawi National Disaster Risk Management Policy (GOM-NDRM, 2015) maintains that vulnerability assessment has not been done in a comprehensive manner. This is another huge notable gap in vulnerability assessment to hazards like floods. While this is the case, the Social Vulnerability Index (SVI) ranks Malawi with high vulnerability of 0.6 arbitrary units of societal vulnerability (Vincent, 2004). As such, the need for comprehensive analysis of vulnerability to particular hazards like floods in order to increase assessment methods of flood vulnerability, which can support decision makers in flood hazards management is required. Doing so, would unveil the real trigger causes of vulnerability that make the majority of Malawians to suffer from flood hazards in rural and urban informal settlements.

Lack of FVA studies that compare rural and urban vulnerability, negatively impact on the development of vulnerability assessment framework that could be utilised in national policy and planning making for effective disaster risk management. It also makes Malawi to lack a strategy to invest its scarce resources to minimise the damage related to flood disasters (DoDMA, 2015). It further makes the DRM to be characterised by post-event humanitarian actions and relief activities. It also makes the country to lack scientific data and framework that could be utilised to compare households' vulnerability to floods between urban and rural settlements. Finally, it makes the achievement of priority area 3 aimed at *ensuring comprehensive disaster risk identification, assessment and monitoring system is established and functional* in the NDRM policy to be practically difficult. Hence, this study conducted flood vulnerability assessment in rural and urban informal settlements in Malawi in order to compare household vulnerabilities and propose a flood vulnerability assessment framework. Otherwise, lack of studies like this, one prevent the country from identifying best measures for strengthening communities' resilience to flood hazards and disasters.

1.4 Aim of the Study

1.4.1 Main Objective

The main objective of this study was to assess households' flood vulnerability in Karonga district and Lilongwe City in order to propose FVA framework for rural and urban informal settlements in Malawi.

1.4.2 Specific Objectives

Specific objectives of the study were:

i. To analyse spatio-temporal flood vulnerability trends in Karonga district and Lilongwe city.
ii. To predict factors that determine household flood vulnerability in Karonga district and Lilongwe city
iii. To assess the perception of household on flood vulnerability in Karonga district and Lilongwe city
iv. To evaluate household adaptive capacity on flood vulnerability in Karonga district and Lilongwe city.

1.5 Significance of the Study

This study is an integral part in responding to the implementation of Malawi National disaster Risk Management Policy (2015) in all its priority area 2 "*establishment of comprehensive systems for disaster risk identification, assessment and monitoring*" (p.6). This study further responds to Malawi 2063 in its policy enablers "environmental sustainability" where it spell out that "Malawi shall *develop a system to break the cycle of environmental degradation and increase resilience through integration of disaster risk reduction and financing into sustainable development and planning*" (MW2063). It also responds to National Water Policy (2023) in policy priority area 3 "disaster risk management" with more emphasis on policy strategy 6 "*use scientifically validated data for floods and droughts mitigation* (p.21). In addition, this thesis is contributing to the most required work for researchers to unveil the vulnerabilities of communities to floods, which can assist policy makers to do a commendable work to people, who put trust on them.

Significantly, this study contributes to provide new knowledge in flood vulnerability studies in Malawi, with which the flood vulnerability assessment framework for rural and urban informal settlements has been proposed. This flood vulnerability assessment framework could be a supportive tool for benchmarking the formulation of disaster risk management policy frameworks such as National Disaster Risk Management Policy (NDRM), National Resilience Policy (NRP), National Contingency Plan (NPC), City and district Disaster Risk Management Plans and other policies such as National Water and Sanitation Policy, Malawi Growth and Development Strategy (MGDS). This FVA framework provides useful scientific data and information to be utilised by policy makers in disaster management. It further responds to the overall priority 3 of the National Disaster Risk Management aimed at *ensuring comprehensive disaster risk identification, assessment and monitoring system is established and functional* (GOM-NDRMP-2015).

Lastly, this study provides data that can assist Malawi to build back better in order to achieve priorities 1, 2 and 4 of the Sendai Framework (2015-2030)-an international disaster risk reduction blue print. Specifically, this study through the FVA framework, provides data in the aspects of in its disaster risk reduction for resilience building, understanding disaster risk and enhancing disaster preparedness for effective response.

1.6 Scope of the Study

In the ardent of developing a framework for flood vulnerability assessment in rural and urban areas of Malawi using Traditional Authority (T/A) Kilupula in Karonga district and Mtandire ward in Lilongwe city as study areas, vulnerability was augmented as connectivity of hazards and disasters based on a social science (social vulnerability) perspective and technocentric/physical science (Physical/natural/engineering) perspective. Both views are significant to be used in the analysis of floods and to understand how floods turn into disasters. Iloka (2017) stipulates that disasters are a product of hazards and vulnerability. Wisner (2016) disasters cannot occur if vulnerability to the hazards does not exist. While this study applied both views to undertake flood vulnerability assessment, however, the emphasis was on the social science (social vulnerability). Similarly, this thesis considered all the creative tensions and debates regarding vulnerability to natural hazards (Birkmann et al., 2013). These creative debates include complexity versus simplicity (taking into account issues like cultural, livelihood, institutional and mathematical illustrations), understanding versus/implementation (focusing on main issue of vulnerability understanding as starting point for DRR implementation), nomothetic versus ideographic goals (establishing laws versus/ developing concrete actions/ideas to raise consciousness of risks, mobilizing local in preparedness) and cacophony versus polyphony (full understanding of vulnerability may involve a large team).

This thesis focused on the social science as it keenly looks at the production of social vulnerability as a key factor for the communities to become vulnerable to hazards like floods (Ludin et al., 2018). The extent to which communities or group of people exposed to floods for instance, disaster situation may (may not) occur to the community depending on their level of societal conditions that may generate vulnerability. Further, this study opted for this approach because it provides a room in which policy and decision makers may introduce measures, mechanisms, institutional set up and interventions for the present and future flood hazards response (Ndanusa et al., 2021). Unlike the technocentric, this approach responds to a number of international policy documents, which have a shift from reactive to proactive planning and preventive in the work of disaster risk management in the contemporary period.

Similarly, the reliance on the social production of vulnerability was because the assessment was rooted in the theoretical framework of the Pressure and Release (PAR) model (Wisner et al., 2004). This framework gives much emphasis on the social production of vulnerability in understanding vulnerability variability in aspects such as physical, social, economic, environmental and cultural. The model explains that the progression of vulnerability is generated based on three stages classified as the underlying root causes, dynamic pressures and unsafe conditions. Therefore, all the issues of vulnerability and adaptive capacities were evaluated based on this framework with more attention to social sciences vulnerability approach.

Similarly, this study considered the techno-engineering approach as it provides some solutions that are critical in flood management such as construction of dykes, earth dams among others. However, because of its reactivity in dealing with natural hazard impacts (Ciurean et al., 2013), emphasis was not highly elucidated for this approach. Particularly, the approach is critical in the sense that engineering solutions though termed reactive and leave out policies as well community involvement, they are important to control floods. Therefore, the fact that this study looked at changes in river systems through the analysis of spatial-temporal trends of floods, technocentric solutions would have been not left out as they formed as key part of recommendations to assist people in the affected areas.

Furthermore, this study employed urban flood vulnerability assessment framework (Salami et al., 2017), Pressure, and Release Model (PAR model) (Wisner et al., 2004) to assess household vulnerability to floods. The urban flood vulnerability framework was selected since it defines exposure, sensitivity and resilience as (coping response, impact response and adaptation response) part of vulnerability. It has indicators which integrate very well with PAR model (Winser et al., 2004) to understand vulnerability in all factors and components. It is important to note that the variables of measurement in all the issues were assessed only from flood hazards perspective and not any other kind of hazards. Finally, the PAR model (Winser et al., 2004) was selected because it provides a vivid picture on the progression of vulnerability.

1.7 Ethical Consideration

Ethical research protocol approval (appendix 1.1) was sought from the Mzuzu University Research Ethics Committee (MZUNIREC) and a letter of support to collect data was obtained from the Head of Department-Department of Water and Sanitation (DWAS) (appendix 1.2). The MZUNIREC research protocol approval and letter of support with a covering letter were submitted to the Lilongwe city council (LCC) and the Karonga District Council (KDC). The LCC and KDC approved to conduct the study through the District Commission (DC) and Chief Executive Officer (CEO) for Karonga district Council and Lilongwe City Council respectively. Before the data collection, the aim, purpose and importance of the research were explained to the participants (appendix 1.3). As obligation for ethical consideration, the participants were assured of anonymity and confidentiality. They were also informed that they could either accept (or decline) to take part in interviews in case the questions were not meeting their interest. Participants were assured that the information gathered was neither for some purpose, nor would the information reveal their identity in any way. Participants were also assured that the research was causing no harm to them by explaining the purpose of this study. Lastly, participants were requested to sign the consent form if they aged being interviewed (appendix 1.3)

1.8. Outputs of the Study

This thesis assessed household flood vulnerability in Karonga district and Lilongwe city order to propose a framework for rural and urban informal settlements in Malawi. Based on this main aim, the output from this thesis are (a) three journal articles and (b) four conferences and seminars.

a. Journal articles online (Preprint)

These journal articles include:

- **i.** Measuring Vulnerability to Assess Households Resilience to Flood Risks in Karonga District, Malawi (Journal of Natural Hazard).
- **ii.** Towards a Flood Vulnerability Assessment Framework for Rural and Urban Informal Settlements in Malawi (Modelling Earth Systems and Environment).

iii. A metric-Based Prediction of Flood Vulnerability Assessment in Lilongwe City and Karonga district, Malawi (Environmental Modelling & Assessment).

a. Conferences and Seminars

i. National Water Conference: Building Resilience Faster, Nkopola Lodge, Mangochi (29-30th September, 2021): presented a paper titled: **The Role of Indigenous Knowledge in Climate Change and Water Resources Management.**

ii. 5th Biennial Southern Africa Society for Disaster Reduction (SASDiR) Conference (26-28 October, 2022) presented a paper titled: **Measuring Vulnerability to Assess Households Resilience to Flood Risks in Karonga District, Malawi.**

iii. Seminar at the Catholic University of Malawi under the Department of Geography and Environmental Studies in the Faculty of Science (May, 2022) presented a paper titled: **A Metric Based Prediction of Household Flood Vulnerability in Lilongwe city and Karonga district, Malawi.**

iv. Food Security Seminar at University of Malawi (30th August 2023) presented a paper titled**: Towards a Framework for Flood Vulnerability Assessment Framework for Rural and Urban Informal Settlements in Malawi.**

1.9 Limitations of the Study

Largely, this study has provided comprehensive indicators of FVA since it has linked all factors and components. In this way, future researchers and policy makers can adopt the FVA framework to replicate vulnerability assessment at all levels in the country. It is very important to note that the disagreements that exist in the selection of indicators for vulnerability assessment might in one way affected the outcome of the results. The selection of these indicators tends to be based upon the study context and purpose. However, this study used different tools to analyse the data in order to ensure that the indicators were selected from an informed process. Relatedly, the application of variance independent factor (VIF) helped to select indicators which had limited correlation inflation problems to predict flood vulnerability in the binomial multiple logit regression model. Furthermore, lack of current data on flow rate, precipitation and run-off from the Water department, meant that the study used old baseline water resources data between 1984-2006 in Lilongwe City and 1984-2006 in Karonga District. Despite this challenge, the data was justified to meet the purpose of this study because the intention was to show the evidence of food trends in the area so that household flood vulnerability could be predicted. Disaster profile data collected from DoDMA complimented this flow rate and precipitation data to show the evidence of flooding. Other challenges encountered during data collection include: people mind set about humanitarian relief on disaster response. Many households were very eager to be interviewed and even those not selected during random sampling were demanding to be interviewed hoping for disaster relief handouts. This challenge was explained to the participants that the purpose of the study is purely academic, which would be used for policy interventions by stakeholders in flood risk management and disaster risk reduction.

1.10. Chapter Summary

This chapter focused on introducing this research study. It outlines various issues underpinning household flood vulnerability assessment at global, regional and national level. The need for vulnerability assessment in relation to flooding situations and their impacts in Malawi were presented. Lack of vulnerability assessment with special attention to rural and urban informal settlements were revealed. The objectives, significance, scope, ethical issues, outputs and limitations of the study were fully presented. The major outcome of this chapter is that a comprehensive flood vulnerability assessment should agglomerate the underlying vulnerability factors (UVFs) and vulnerability components (VC) in a multicollinearity analysis in order to predict households' vulnerability and identify indicators for decision making process.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter provides a discussion of the literature related to this study. The discussion mainly focused on first, conceptualisation of vulnerability; second spatial temporal flood vulnerability trends; third, factors that determine household flood vulnerability; fourth, household perception of flood vulnerability; firth, household adaptive capacity on flood vulnerability and finally summary of the chapter.

2.2 Conceptualisation of the Concept of Vulnerability

The concept of vulnerability emerged in the 20th century with a new face and outlook to explain natural hazards leading into disasters (Jain et al., 2018). It was introduced by social scientists who questioned the hazard centric disaster (Iloka, 2017; Ludin et al., 2018). In other words, it was a simple rejection of the past hazard oriented thinking. Iloka (2017) states that the vulnerability paradigm was a counter argument to the tenet that disasters cannot be avoided. The key point is that natural hazards cannot be avoided, but its impacts can be minimised by reducing vulnerability, thereby resulting to avoiding a disaster. The term vulnerability is defined from different schools of thought such as geographical development, poverty research, hazard and disaster risk reduction research, climate change science and research in adaptation (Jana et al., 2018). Despite differences in the interpretation of the concept of vulnerability, it has, however, been used to address particular issues of the potential impacts of disasters (Birkmann, 2013; Ludin et al., 2018).

Vulnerability refers to the extent to which the population, communities, country, regions systems or structures are prone/susceptible to damage or injury from hazards (Hamis, 2018). Coppola (2011) defined the term as a measure of the propensity of an object, area, individual, group, community, country, or other entity to incur the consequences of a hazard. Susman (2011) describes vulnerability as the degree to which different classes of society are at risk. Wesner et al. (2016) define vulnerability as characteristics of a person or group in terms of their capacity or ability to anticipate, cope with, resist and recover from the impacts of a hazard. Birkmann et al.

(2013) looked at vulnerability as exposure to contingencies and stress, and difficulty in coping with them. In this case, Birkmann et al. (2013) indicate that vulnerability has thus two sides: an external side of risks, shocks and stress to which an individual or household is subject; and an internal side that is, defencelessness meaning, a lack of means to cope without damaging loss (Fekete, 2010). Wisner et al. (2016) states that vulnerability has been defined as the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. Kron (2014) maintain that vulnerability is a multi-layered and multi-dimensional social space defined by the political, economic, and institutional capabilities of people in specific places. Birkmann et al. (2013) maintains that scientific discussion about the concept itself is still evolving. This demonstrates that the field is still unsettled (Birkmann et al., 2013). For this fact, Ciurean et al. (2013) argues that the definition of vulnerability for the purpose of scientific assessment should depend on the purpose of the study. Rana (2018) looks at vulnerability as a degree to which an individual, group or system is susceptible to harm due to exposure to a hazard or stress, and the (in)ability to cope, recover, or fundamentally adapt.

The concept has also been referred to as the magnitude of harm that would result from a particular hazardous event (Kissi et al., 2015). In this case, the term considers that household or people in the community/society may differ in their susceptibility to a particular level of hazard due to differences in age, knowledge, warning, organisation, decision-making, sex etc. (Ndanusa et al., 2022). Hinkel (2011) states that the diversity in definition is accompanied by similar diversity of methodologies for assessing vulnerability. This study defines vulnerability as conditions that predispose an individual or system to incur loss based on interaction of underlying vulnerability factors (physical, social, economic, environmental, cultural) and vulnerability components (exposure, susceptibility and resilience). Though "vulnerability" has been used differently by various communities and disciplines, it has, however, allowed a strong social science perspective (social vulnerability) on disaster and natural hazards (such as floods) to be established (Kumar et al., 2014; Rana et al., 2018). It is a fact that identifying, assessing and establishing vulnerability reduction strategies is one of the key steps towards flood disaster risk reduction and resilience building (Ndanusa et al., 2022; Rana et al., 2018). Birkmann (2013), states that vulnerability provides important insights for understanding differential impacts and consequences of societies exposed to natural hazards.

Literature reveals that before the emergence of the concept "vulnerability", there was a range of views, none of which dealt with the issue of how society creates the conditions in which people face hazards differently (Wesner et al., 2016). Now, the use of the term vulnerability to explain disasters has dominated most academic work and policy documents (Barret et al., 2021; Dodman et al., 2013; ISDR, 2014; Mwale et al., 2014; Rana et al., 2021). In a vulnerability viewpoint, disasters are not "natural", neither in the sense of being from nature or in the sense of being normal and acceptable (Iloka, 2017). Jain et al. (2018) stipulate that hazard become disasters only when the likelihood of a hazard and the vulnerability of the community increase the risk of being affected. Significantly, they argue that in a disaster risk the social production of vulnerability needs consideration with at least the same degree of importance that is devoted to understanding and addressing natural hazards. In this scenario, it is imperative to consider that the underlying factors and root causes embedded in everyday life give rise to dynamic pressures affecting particular groups resulting in specifically unsafe conditions (Wisner et al., 2016). In a vulnerability viewpoint the implication is that there cannot be disasters if there are hazards but without vulnerability or if there is vulnerable population but without hazardous event (Iloka, 2017; Jain et al., 2018). This approach puts much emphasis on the social science (social vulnerability) as key to explain the causes of disasters in the context of differing hazards (Kissi et al., 2015; Kumar et al., 2014). It links physical, social, economic, environmental, cultural and institutional vulnerability to analyse the underlying causes of societal vulnerability to a particular hazard (Rana et al., 2018). Worth noting is that any hazard for example, flood, earthquake or drought which is a triggering event along with greater vulnerability (inadequate access to resources, sick and old people, lack of awareness, condition of settlement and infrastructure, etc.) would lead to disaster causing greater loss to life and property (Wesner et al., 2016). Thus, a natural disaster is only a disaster because people are in wrong place at the wrong time, had no choice but to be in the way of a disaster or were caught unawares when it struck (Iloka, 2017).

2.2.1 Approaches to the Study of Vulnerability

Vulnerability has been understood into two major perspectives. The first perspective being the techno-engineering sciences-oriented or simply technocentric approach. This perspective attributed disasters to natural forces (Ciurean et al., 2013; Garran et al., 2018). It neglects the role of human systems in mediating the outcomes of hazard events. Proponents of this perspective viewed disaster as departure from state of normalcy to which society returned to on recovery (Garran et al., 2018). The arguments of this framework, provided technocentric solutions aimed at resisting natural forces. This study attempts even to argue that the solutions of this perspective were not disaster risk reduction and management inclusive for all the phases of pre-response and post disaster. The solutions focused on providing post disaster relief which resulted in increased dependencies of the victims because they were provided with ready-made solutions. Further, the approach called upon stakeholders to concentrate on reconstruction of shelters and infrastructures. Garran et al. (2018) states that the infrastructures were even unsustainable and increased disaster vulnerability. The other notable challenge was that it led to top-down command and control in dealing with disasters. That is to say, local structures like community-based disaster risk management initiatives were not promoted. As such, issues that could incorporate elements of resilience, adaptive capacity and policy formulations were lacking. In the same way, this approach, did not take into account limited resources in developing countries to undertake capital intensive measures (Garran et al., 2018).

The setbacks of the technocentric approached, a new face and outlook of disasters appeared in the social sciences perspective (Garran et al., 2018). This uses the social vulnerability as a starting point for risk reduction. This perspective centred on societal response to disasters. It provided an explanation as to why people face the impact of hazards in different ways. In this way, it provided a good picture of how people end up being in a disaster situation. This takes into account various factors and parameters that influence vulnerability, such as physical, social, economic, environmental, and institutional characteristics (Ciurean et al., 2013). It also tends to look at specific vulnerabilities of various groups of people such as female, children, elderly, disabled, economically poor (Garran et al., 2018). The approach gives a good starting point to conduct analysis by identifying underlying factors and root causes embedded in everyday life that give rise to dynamic pressures affecting a particular group of people (Wisner et al., 2014). Therefore, while techno-engineering solutions cannot be completely left out, the concentration of this study is on the social sciences perspective (social vulnerability). This is because it helps to analyse vulnerability of urban and rural poor in the developing world who have little access to the resources, power and choice mechanisms needed to radically change their life circumstances. Furthermore, the social vulnerability correlates with the argument of this study that disasters caused by flood hazards for example, are not only natural in themselves but rather they are also strongly induced by the social production of vulnerability that operate to generate disasters. The Yokohama Conference (1994) also supports this where the social aspects of vulnerability were given a serious consideration.

2.2.2 Classification of Vulnerability

Various classifications of vulnerability exist in literature (Birkmann, 2013; Coppola, 2015; Hamis, 2018). Birkmann (2013) highlights three classifications of vulnerability namely physical/material vulnerability (focus on visible entities such as land, climate environment, health, skills and labour); the social/organisational vulnerability and capacity (focuses on the organisation of the society) and the motivational/attitudinal vulnerability (prioritising mostly on how people view themselves and their ability to affect the environment in which they live). Vulnerability is further classified as tangible and intangible. The tangible/material vulnerability are those that are easy to see and values that can be determined (Rana et al., 2021). On the other hand, the intangible/non-material are those that are difficult to see and values that cannot be determined (Rana et al., 2021). The tangible are further associated with characteristics like people (lives, health, security, living conditions); property (services, physical property loss and loss of use); economy (loss of products and production); environment (water, soil, air, vegetation and wild life) and the intangible are associated with characteristics such as social structures (family and community relationships); cultural practices (religious issues); cohesion (disruption of normal life) and motivation (government and community response strategies).

Coppola (2015) classifies vulnerability in four ways. The first way is the physical vulnerability that is defined as the built environment. The second way is the social vulnerability that measures the individuals, societal, political and cultural factors that increase or decrease a population propensity to incur damage because of a hazard. The third way being the economic vulnerability which is based on financial means of individuals, towns, cities, communities or whole countries to protect themselves from the effects of hazards and the fourth way is the environmental vulnerability which is based on health and welfare of the natural environment whether it increases or reduces their proneness over hazards.

The above classifications, however, make the classification of vulnerability to be a vexing issue because literature is not straightforward. This puzzle is also supported in literature as Birkmann (2013) indicates that scientists are dealing with a paradox concept since it is aimed at being measured yet it cannot be precisely defined and systematised. A closer analysis indicates that tangible and intangible classes can be regarded as types of vulnerability instead of classes of vulnerability. Furthermore, physical, social, economic and environmental aspects are grouped classes yet these are the causes of vulnerability (Mwale, 2015). Similarly, the cultural aspects of vulnerability are mixing in the classification system, yet cultural values are very significant to increase or reduce vulnerability of people from a particular hazard (Iloka, 2017). Based on these challenges, this study maintains that the classification of vulnerability should be based on tangible and intangible aspects with all other aspects mentioned in the physical, social, environmental, economic and cultural factors being the characteristics which should define the tangible and intangible vulnerability classes. Furthermore, this study finds it critical to assess cultural attributes in the analysis of vulnerability because culture consists of beliefs, attitudes, values and their associated behaviours, that are key for disaster risk and vulnerability reduction (Clarke, 2018; Iloka, 2017).

2.2.3 Theoretical Frameworks of Vulnerability

Vulnerability is viewed through the lens of multiple contexts, dimensions and spatiotemporal scales (Rana et al., 2018). It is pointed out that there is no universal theory or model for measuring vulnerability (Jamshed et al., 2017). Birkmann (2013) argues that measuring vulnerability can help to develop indicators that can reduce vulnerability of societies at risk. Mwale (2014) maintains that measuring vulnerability provides opportunity for identifying vulnerabilities of specific people and specific areas. Many contemporary vulnerability theories and frameworks have been developed in the context of disaster resilience in order to develop methods of measuring vulnerability (Ludin et al., 2018; Mwale, 2014). They include; Sustainable Livelihood Framework (DFID, 1999) (Appendix 2.1), Hazard of Place Framework (Curter et al. 2003) (Appendix 2.2), Birkmann, Boarguard and Cadona –BBC model (Birkmann, 2006) (Appendix 2.3), ISDR Framework for disaster risk reduction (Appendix 2.4) and Turner et al. (2003) Vulnerability Framework (Appendix 2.5). The Sustainable Livelihood Framework (DFID, 1999) looks at vulnerability as failure to access and maintain livelihoods (Joakim, 2008; Mwale, 2014). It measures the accessibility and availability of livelihood capitals such as human, natural, social, physical and economic. The hazard of Place Framework (Curter et al., 2003), it stresses that vulnerability is based on geographical and specific conditions of an area. Therefore, it emphasizes that each place needs to be examined based on its uniqueness. It acknowledges the combination of biophysical and social vulnerability for risk creation. Similarly, BBC Framework (Birkmann, 2006), underscores vulnerability as a function of exposure, susceptibility and coping capacities. It argues that identification of interventions to reduce vulnerability could be crucial to reduce the potential risks that might be created by the hazards. It further emphasises that vulnerability should be analysed from a social, economic, environmental perspective (Mwale, 2014). Last, but one, the ISDR Framework for disaster risk reduction (ISDR, 2004) separates vulnerability from hazards. It argues that vulnerability is a standalone entity of the hazard, and thereby risks originate from two different phenomena. The framework conceptualises vulnerability as having four dimensions; social, economic, environmental and physical (Mwale, 2014). Finally, the Turner et al. (2003) Vulnerability Framework, views vulnerability as result of exposure, susceptibility and responses (coping responses, impact responses, adaptation responses). It argues that the linkages of human and biophysical processes contribute to vulnerability. In this study, these frameworks were deductively assessed in order to identify indicators of flood vulnerability assessment which could be used to benchmark and compare with the indicators of FVA framework. However, for inductive assessment, the selection of indicators in this study focused much on the Pressure and Release model (Wisner et al., 2004) and urban flood vulnerability framework (Salami et al., 2017) as key theoretical frameworks.

2.2.4 The Pressure and Release (PAR) Model

The PAR model is a compound of two models; the Pressure (Crunch) model and the Release model (Wisner et al., 2004). Though the model is explained as one, this study provides a separate explanation. The main reason for separating is due to the fact that the model has fully portrayed the theoretical underpinnings that define the generation of vulnerability (pressures) (Mwalwimba, 2020). On the other hand, the underpinnings that define the reduction of vulnerability (release) have not fully been articulated (release) (Mwalwimba, 2020). Capacity assessment (CA) was undertaken to engage community members in jointly identifying coping strategies, individual, household, and village-based resources and capacities, and social assets to help address their vulnerabilities.

The Pressure (crunch) model is based on the idea that a number of factors influence vulnerability to disaster (Hing et al., 2010; Muller et al., 2011; Mwale 2015). The model views disaster as the intersection of the processes generating vulnerability and natural hazard event (Iloka, 2017). The model underlines how disasters occur when natural hazards affect vulnerable people (Wisner et al., 2004). The framework stresses that the cause of vulnerability can be traced back from the unsafe condition through economic and social (dynamic) pressures to underlying root causes. The model is used to assess vulnerabilities and their interaction with developmental processes and disasters with respect to internal and external factors that raise the disaster risks of community (Wisner et al., 2004). Importantly, the Pressure Model outlines a hierarchy of causal factors that together constitute the pre-conditions for a disaster (Rana et al., 2018). The model is based on the commonly used equation:

$$Disaster\ Risk = (Hazard\ \times high\ Vulnerabiity)/(Low\ capacity)$$

(Wisner et al., 2004). ***(Equ.1)***

The model defines vulnerability within three progressive levels: root causes, dynamic pressures and unsafe conditions (Figure 2.1).

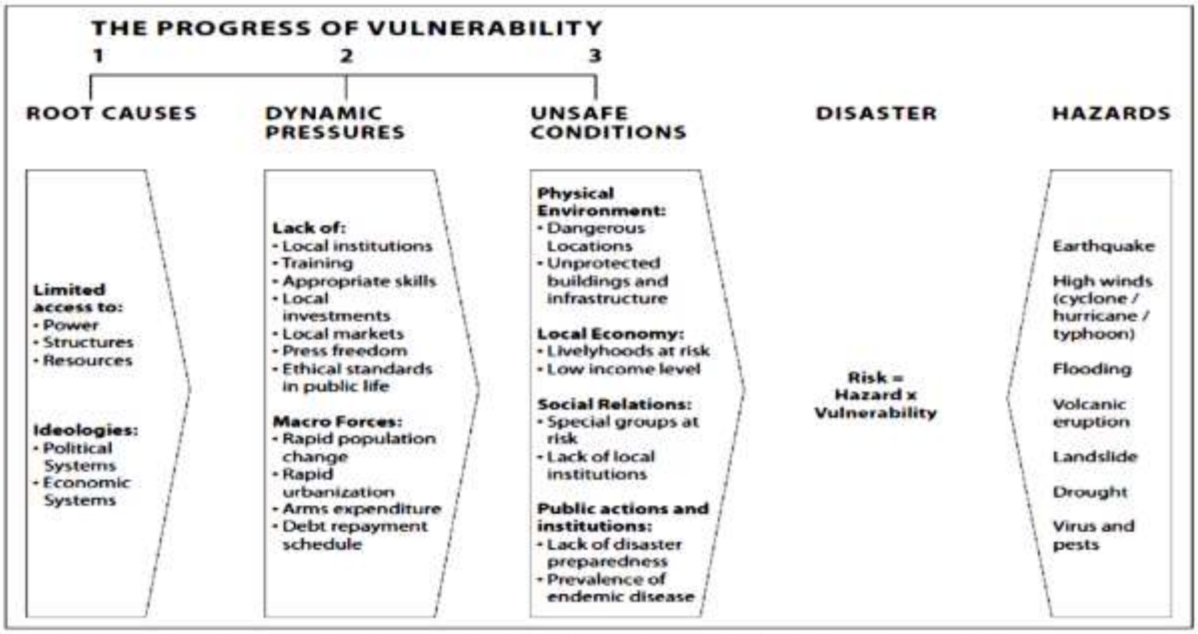


Figure 1: The Pressure and Release model proposed by Blaikie at al. (1996). Root causes lead to dynamic pressures, which lead to unsafe conditions. Risk is the combination of hazard and vulnerability (Wisner et al, 2004).

Figure 2.1 The Pressure Model: Source Wisner et al. (2004).

The Release model arises from the realisation that to release the pressure that causes disaster, the entire underlying factors that generate vulnerability need to be addressed right back from the root causes to the unsafe condition of vulnerability (Figure 2.2) (Hing et al., 2010; Mwalwimba, 2020). In this case, the model focuses on identifying measures that reduce vulnerability to a hazard. It gives the measures that could be undertaken to build adaptive capacity to increase resilience of communities to hazards (Hassan et al. 2019). This model analyses the progression of safety toward disaster risk reduction on by identifying means to address the root causes and dynamic pressures, and achieve safe conditions. It is a model that incorporates capacity assessment (CA) in order to engage households in jointly identifying and clarifying the coping strategies and village-based resources and local capacities and social assets that help address their vulnerabilities within their locations. The model is founded on the equation:

$Disaster\ Risk\ Reduction = Hazard\ \times Low\ Vulnerabiity/high\ capacity$ (Wisner et al., 2004). ***(Equ.2)***

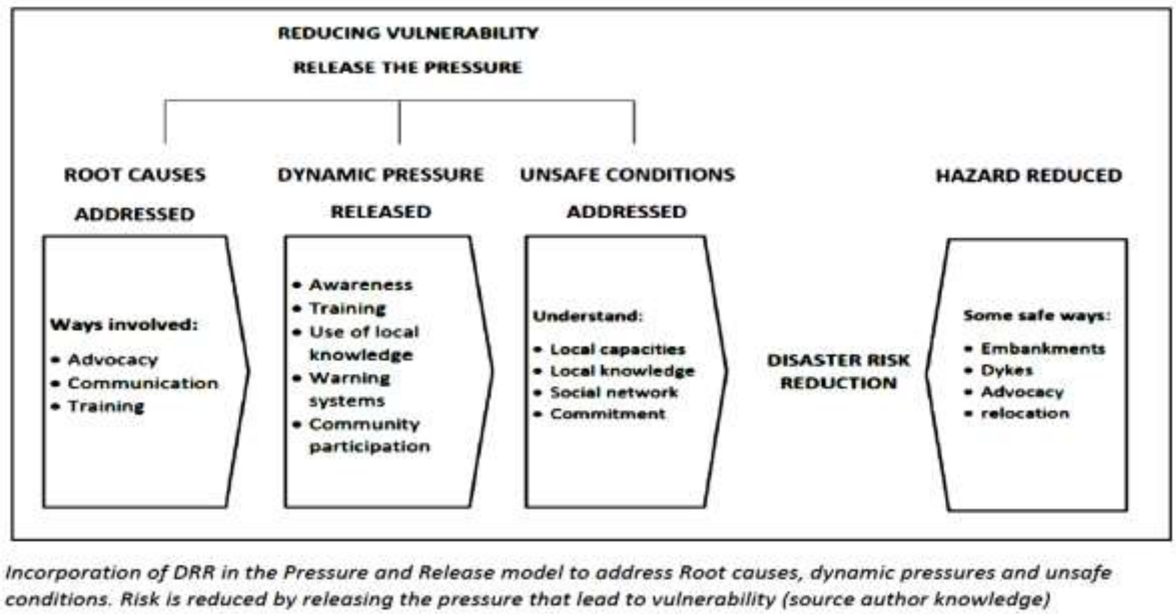


Figure 2.2 Incorporation of DRR Pressure and Release mode (Source: Hing et al., 2010)

Rationale for the PAR Model

This study considered the PAR model because it is one of the best-known conceptual frameworks worldwide that focuses on vulnerability and its underlying driving forces (Hing et al., 2010; Iloka, 2018; Mwale et al., 2014). It is useful in identifying the factors that contribute to the generation of vulnerability thereby leading to disaster situations (Iloka, 2017; Kushe et al., 2018). Moreover, this model gives a real situation as to why people are affected differently by the impact of flood hazards occurring in the same place with the same magnitude and intensity and in the same location. Likewise, based on Birkmann (2013) opinion, this model is adopted because it is an important approach, which goes beyond identification of vulnerability towards addressing its root causes and driving forces embedded in the human-environment system. The model provides indicators that can be used to analyse and assess vulnerability of communities to a particular hazard (Rana et al., 2018). This model is essential because it is useful in identifying vulnerabilities to natural hazards that are linked to the different capacities of individuals, households, and institutions (Kissi et al., 2015).

Weaknesses of PAR Model

Critics argue that the model puts much emphasis on the national and global levels although many dynamic pressures and unsafe conditions might also be determined by local conditions. Other studies further state that the framework exaggerates the separation of hazard from social processes in order to emphasise the social causation of disasters (Fekete et al., 2010). This study also finds that the PAR model does not clearly define and separate the underlying conditions that generate vulnerability from those that can release the pressure in order to reduce vulnerability. In this way, it lacks the ability of incorporating disaster risk reduction to address a comprehensive mix of factors contributing to vulnerabilities.

This study further establishes that the PAR model seemingly ignores to explain the other part of the model (Release part). It is centric to the Pressure (Crunch) model. It does not explain how Release model can be used to release the pressure that causes disaster in the entire chain of causations that needs to be addressed right back to the root causes and not just the proximate causes or triggers of the hazard itself, or the unsafe condition of vulnerability (Kumar et al., 2014). The model does not specify the set of variables that should define vulnerability reduction as part of releasing the pressure that is generated from the three stages of vulnerability.

With the above shortcomings, this study maintains that while the model is critical, it should incorporate the release aspects (1) addressing the root causes (2) reducing the dynamic pressures and (3) achieving the unsafe conditions (Figure 2.2). In this way, the model would have provided the room for community members to identify solutions that would be rooted in their traditional beliefs and systems consistent with their local and indigenous adaptation strategies.

2.2.4 Urban Flood Vulnerability Framework (UFVF)

The Urban Flood Vulnerability Framework (UFVF) is an outcome of the study titled "urban settlements' vulnerability to flood risk in African cities (Salami et al., 2017). The UFVF explains the interaction that exists between urban settlements in African cities with the natural and human induced hazards. It posits that flood vulnerability is a result of social processes emanated from underlying root causes, dynamic pressures and unsafe conditions (Salami et al., 2017). In this scenario, the framework adopts three stages for the progression of vulnerability. It entails that the progression of vulnerability in African cities triggers from root causes and dynamic pressures (i.e., differential access to livelihood income, environmental injustices, climate change, lack of flood risk understanding, rapid urbanization tenure security, poor governance, urban growth and demographic pressures) to unsafe conditions (living in hazardous areas, deficient housing and infrastructure). The framework further states that flood disaster risk reduction and management interventions such as structural and non-structural can reduce flood vulnerability through the application of result-oriented flood risk management (FRM) tools (Salami et al., 2017). The framework adopts five components of vulnerability drivers through which different variables and indicators can be evaluated to understand the vulnerability as well as detailing the vulnerability profiles (Table 2.1).

Table 2.1 Urban Flood Vulnerability Indicators

Variables		
Physical/environment	**(a) Housing** • Housing type • Roofing material • Land use cover • Building codes • Road network and transport	**(b) Flooding** • Elevation of settlement above sea level • Proximity to the river • The frequency of flood occurrence • Intensity of flood • The extent of damage
Economic	• Source of income • Level of education • Occupation • Access to insurance	**Institutional** • • Trust in local risk management • Protection and response • Warning system • Development control • Evacuation plan and route • Collaboration with NGOs and CBOs • Participatory decision making
Attitudinal	• Past flood experience • Flood risk awareness • Flood perception • Level of preparedness • Adaptation mechanisms • Social network	**Social** • Employment status • Community participation • Local resource base

Source (Salami et al., 2017)

2.2.5 Conceptual Framework on Vulnerability

This study developed a conceptual framework based on the understanding that a disaster occurs as an intersection of vulnerability and hazard (Iloka, 2017; Wisner et al., 2004). Significantly, the framework was developed with consideration of the social science (social vulnerability) and technocentric (physical/engineering) perspectives. The use of both helped to identify social and physical vulnerability solutions that can promote adaptive capacity and increase community resilience to flood hazards. Further, this approach deviates from the dominant views that focused on one side of vulnerability assessment either social science or physical science. Using both perspectives means that this study contributes to widen the methodologies of assessing vulnerability in SSA. Mwale (2014) alluded to that studies in SSA have mainly been focusing on one dimension. This conceptual framework considered the physical, social, economic, environmental and cultural domains on one end and on the other end, it considered exposure, susceptibility and resilience domains.

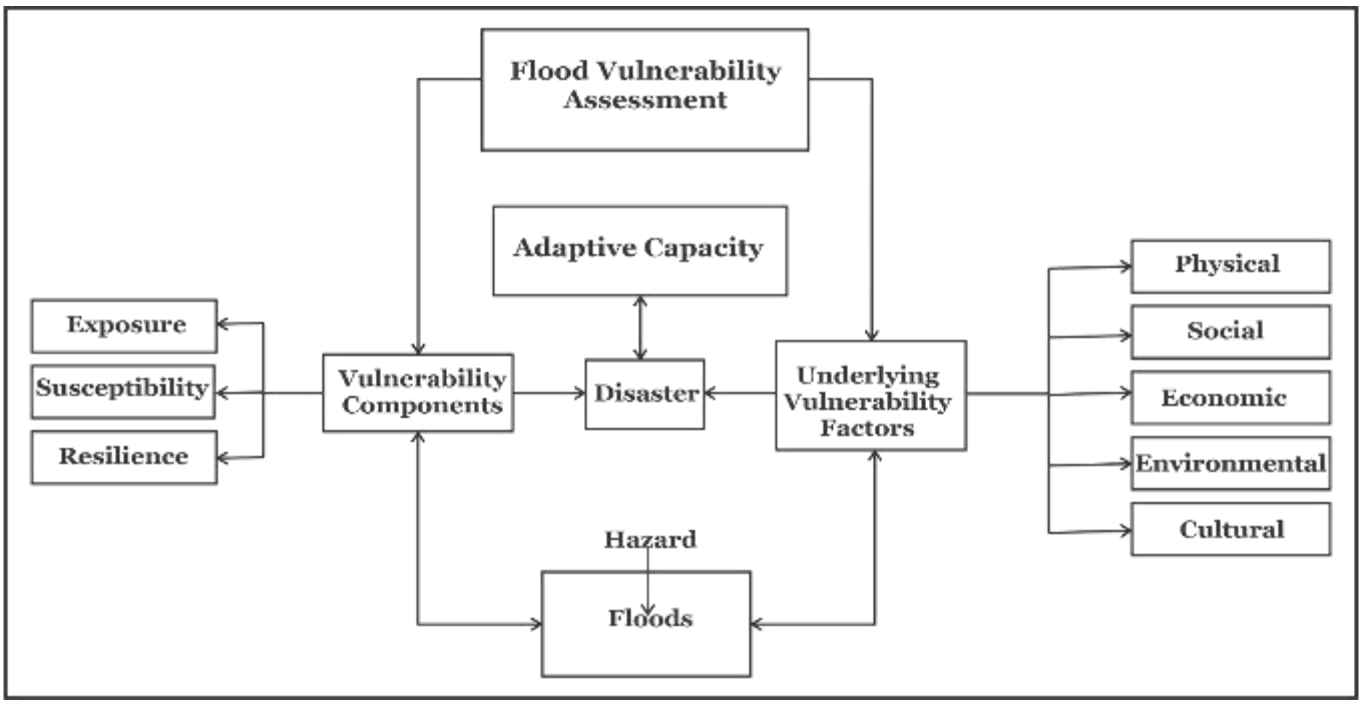


Figure 2.3 Conceptual Framework: Source (Mwalwimba, 2021)

This conceptual framework indicates that two forces create vulnerability of households/communities to floods. First, households can be vulnerable to floods when subjected to the underlying vulnerability factors (physical, social, economic, environmental and cultural causes). Each of the causes, physical-social-economic-environmental-cultural, have the indicators that are used to identify households' vulnerability to floods. Depending on variations that exist among these indicators in terms of their scores, percentages, inertias and probability values, households may be determined and/or predicted their vulnerabilities. The determination and prediction can be based on flood vulnerability index (FVI) scale range 0 to 1 (Balica et al. 2012).

The second force is determined by vulnerability components (exposure, susceptibility and resilience) (Kissi et al., 2015). Households are vulnerable to floods if they are exposed and susceptible to it and have less resilient to withstand its impacts (Rana et al., 2018). In this study, exposure is portrayed as the extent to which an area that is subject to an assessment falls within the geographical range of the hazard event (Nazeer et al., 2020). This implies that exposure looks at possibility of flooding to impact people and their physical objects (Nazeer et al., 2020) in the location they live. Hence, exposure was linked with physical and environmental vulnerability factors to predict household vulnerability. Furthermore, susceptibility means the predisposition of elements at risk (social and cultural) to suffering harm resulting from the levels of fragility conditions (Birkmann et al. 2013; Kablan et al., 2017; Nazeer et al., 2020). Therefore, susceptibility was linked to social and cultural vulnerability factors during the assessment in this study. In the same vein, resilience of households is evaluated based on the capacity of people or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure (Ndanusa et al., 2022). This is determined by the degree to which the social system is capable of organising itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures as well as to recover from the impact of natural hazard (Birkmann et al., 2013; Nazeer et al. 2020). It can be argued that resilience is a measure of insufficient resources to withstand the hazardous situation. As such, in this study, it was related to economic vulnerability during assessment. Iloka (2017) states that low incomes, lack of resources, and unemployment are some of the factors that make vulnerability leading to disasters.

This study’s conceptual framework highlights the scenario that the occurrence of hazards (floods) in a community (Lilongwe city and Karonga district) where households are subjected to many characteristics in the vulnerability factors while at the same time the households are exposed and are susceptible to floods, the condition may turn floods to become disasters. It is only when the households have enough resilience and adaptive measures that they can either cope up with or respond quickly to the hazard (floods). Similarly, if the households are not resilient and have fewer adaptive measures, a situation that may increase vulnerability of households to the hazard impact resulting in a devastating disaster. Therefore, lack of adaptive capacity means that the community may be limited to respond to the disaster in a timely manner thereby their vulnerability will be always high.

This conceptual framework gives a basis that flood vulnerability assessment therefore should examine factors that predict household vulnerability to floods and linking them to the composite indicators of vulnerability, including understanding their adaptive capacity that would help them to cope with flood impacts. The assessment, using this framework should analyse several indicators from the underlying vulnerability factors and components of vulnerability to fully identify which of these conditions contribute to vulnerability in a specific location to generate standardised indicators of flood vulnerability assessment.

2.3 Spatial-Temporal Flood Vulnerability Trends

The frequency of floods are increasing across the world, resulting into the most serious and devastating natural threats to lives, properties, and living environments (Moreira et al., 2021; Ndanusa et al. 2022; Zhang et al., 2020). Flood hazards are associated by spatial characteristics such as nature (types of forces associated with it), intensity (potential destructive), extent (geographical distribution), predictability (ability for reduction, mitigation, prevention of impact) and manageability (ability to reduce and manage the impacts). The temporal characteristics of flood hazards include frequency, duration, speed of onset and forewarning systems. Therefore, understanding these characteristics in flood vulnerability assessment is a crucial step to reduce the impacts of flood risks (Fuchs et al., 2012).

2.3.1 Conceptualising Flood hazards

Flooding is one of the most dangerous natural hazards in the world (Liu et al., 2022). A flood is the overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, storm surges, and glacial lake outburst floods (Field et al., 2012). The main causes of floods are intense and/or long-lasting precipitation, snow/ice melt, a combination of these causes, dam break (e.g., glacial lakes), reduced conveyance due to ice jams or landslides, or by a local intense storm. The shocks arising from flood hazards are felt by the poor. Poor households are more unable to cope than the non-poor households (Nong et al., 2020). The poor own fewer productive assets, are more likely to reside in hazardous locations and in substandard housing, and are primarily dependent on their own labour to meet their livelihood needs (Kron, 2014). For many years, these conditions were attributed to rural people (Gracian et al., 2018). Yet today, floods and risks with limited institutional support mostly affect urban informal settlements (Ndanusa et al., 2022).

Floods are the manifest of increased total volume of water due to high rainfall. It occurs when a body of water raises to overflow some land which is not usually submerged (Nazir et al., 2022). As such, water has a negative vulnerability face and consequently a threat to life (UN Water, 2013). The increased people's vulnerability patterns generate flood hazards to have a higher impact on human life and their livelihoods (Moreira et al., 2021). Munyai et al. (2019) states that floods have caused losses to various communities around the world. Flood hazards are a global issue which must be planned and prepared for at international, national and local levels (Moreira et al., 2021; Munyani et al., 2019). A flood is further understood in the perspectives of geomorphology, water resources management and hydrology. While these disciplines look at floods in different insights, there exists commonality within the term. All the disciplines attribute floods as overflow of water in the riverbanks. This study, however, relies much on the hydrological definition of a flood, defined as an upward condition of water levels in coastal areas, reservoirs, streams and canals (Abah & Clement 2013).

In the current period, floods have increased in occurrence and magnitude across the globe (Moreira et al., 2021). Their impacts have accelerated and raised vulnerability of people causing widespread destruction in all aspects of human life such as the physical, social, economic, environmental and cultural domains (Koks et al., 2015; Nasiri et al., 2016). Rajan et al. (2020) in a study of geospatial approach for assessment of vulnerability to floods, maintain that the increase in occurrence of floods necessitates the use of flood vulnerability assessment to identify flood mitigation strategies. Similarly, literature reveals that floods across the globe will continue to increase based on intertwined factors like climate change, population growth, unplanned urbanization and land use changes (Hirsch et al., 2015; Leung et al., 2019). For instance, from

2000, 2007, 2014 and 2015, this catastrophic natural hazard has struck many people worldwide (Nasiri et al. 2022). The same study by Nasiri et al., (2022) indicates that between 2010 and 2020, floods affected almost 3.6 billion people comprising 56 per cent of the world total population. In the same study through a systematic review, the term “flood” listed frequently in the international database than any other hazard. For example, in Taylor and Francis Journal, the term appears 160,247 times; Springer Link 83157, Science Direct 244,408, Sage Journals 39319 and JSTOR 399,417 (Nasiri et al., 2022). Floods can destroy critical infrastructure, buildings, roads, and bridges; tear out trees; devastate agriculture; cause mudslides; and threaten human lives (Carreño et al., 2019). Africa is exceptionally vulnerable to climate variability and change compared to many other regions (State of the Climate in Africa, 2020). Floods represent a major natural hazard in Africa (Tramblay et al., 2020) and have strong impacts on the population and their activities, claiming a large toll in terms of fatalities and economic damage (Tramblay et al., 2021). EM-DAT data revealed over 32 000 deaths and approximately 8.7 million affected people in over 1 100 flood events from 1927 to 2022 (Tramblay et al., 2021). The negative impacts of floods, as evidenced in the literature remains critical indication that floods are the frequent natural event that calls for serious interventions to minimise their impacts to people and their belongings. The mitigation of the effects of floods requires monitoring of location, extent, time, and depth of the floods. To achieve this, FVA is a necessity for developing successful flood mitigation measures. Oyedele and Vyonne (2022) argue that VA is significant for understanding society’s and exposure to environmental hazards.

2.3.2 Flooding Situation in Malawi

The increase of extreme climatic and weather events such as floods are frequently affecting various parts of Malawi. Rural and urban are equally devastated by the impacts of these climatic related events. The country has experienced over twenty-five disasters associated with severe rainfall events in the last decade (GOM, 2023). For instance, between a periods of 2015-2023, about four major floods induced by tropical cyclones have affected communities. The most destructive were floods of 11-13 March, 2023, influenced by tropical cyclone Freddy (TCF), which killed about 679 people, injured 2178 people, displaced about 563,602 people, and about 511 people were reported missing, including causing several other damages and loss in sectors such as agriculture, infrastructure, food security and health (GOM, 2023). A “state of disaster” was declared on the 13th March in the districts that were affected by the cyclone namely; Blantyre city and district, Chikwawa district, Chiradzulu district, Mulanje district, Mwnza district, Neno district, Phalombe district, Nsanje district, Thyolo district and Zomba city and district. Relatedly, in January 2022, the passage of tropical storm named “Ana” over southern Malawi with heavy rainfall caused rivers overflow, floods and landslides. The flooding affected 19 districts in the southern region and mong the heavily affected districts were Chikwawa, Mulanje, Nsanje and Phalombe. The event caused 46 deaths, 206 injuries, 152, 000 people were displaced with several infrastructural damages. The country also experienced a worst cyclone Idai that originated from Mozambique in 2019. This cyclone induced floods which killed 60 people as well as affected 975,000, displaced 86,976 and injured 672 people (PDNA, 2019). In January and February 2015, over 1 million people were affected and about US$ 335 million was incurred on infrastructural damage (PDNA, 2015).

The Sentinels-4-African DRR rank Malawi position 11 out of 53 African countries affected by floods from 1927-2022 with statistics of 42 events, 948 deaths and 3,531, 145 people affected (Danzeglocke et al., 2023). Similarly, the 2011 Climate Change Vulnerability Index by the British Risk Analysis Firm Maplecroft ranks Malawi 15 out of 16 countries with extreme risks to climate change impacts in the world. It is one of the only four African countries classified in this category. Floods have been categorised as occurring wide spread in terms of geographical area. For instance, Malawi National disaster profile that dates from 1946 indicates frequent severe floods occurring in the country (Table 2.2).

Table 2.2 Frequency of flood Occurrence in Malawi (Source: DoDMA 2014)

Location	Period of occurrence
Zomba	1946,2023
Lowershire (Chikwawa & Nsanje)	1956, 1984,2012, 2015 ,2019, 2022
Nkhatabay	1957
Phalombe	1991, 2023
Lilongwe city	2017, 2029, 2020
Salima	2012, 2010, 2019,2021,2022,2023
Karonga	2001, 2012, 2013, 2015, 2023

Interestingly, floods have been largely perceived as a rural manifestation during the past years (Chawawa, 2018), with district councils taking the lead in flood management through development of disaster risk management strategies and policies (Manda et al., 2017). This neglect made disaster management policies and strategies to be limited to cities as compared to rural areas. Recently, there has been increase in the occurrence of floods in cities with devastating impacts (Rana et al., 2018). For example, from 2012 to 2020, Lilongwe city experienced numerous flooding with varying impacts of damage in schools, health centres, shops, houses and loss of lives (LCDRMP, 2017). This increased occurrence and devastating impacts calls for putting measures in place to protect people living in the flood prone areas, including flood risk reduction, prevention, mitigation and management. However, strong measures cannot be put without vulnerability assessment that is a cornerstone for disaster risk reduction (Munyai et al., 2019; Nazeer et al., 2020; Nong et al., 2020).

DoDMA (2015) indicates that floods cause huge loss of life, damage and destruction of the environment, property, agricultural and livestock systems. For instance, DoDMA (2023) reported that the damage and loss resulting from floods induced by TCF had highest impact on agricultural sector with a total of 2, 267,458 people equivalent to 523,564 households lost their crops and livestock. It was further found that food security was the second highest impacted sector with 901,466 households being food insecure. Shelter came third with 882,989 households had their houses either partially or completely damaged. Looking at all the consequences that floods have on people, the Malawi Government in partnership with local and international developmental organisations (such as the World Bank (WB) and the United Nations Development Programme (UNDP) developed developmental policies that incorporate risk information (NDRMP, 2015). This is done as a way of reducing risks from disasters on the rate of development. There are some efforts taken by the Government of Malawi and stakeholders to reduce the impacts of flood disasters. For instance, the Disaster Preparedness and Relief (DPR) Act (1991) aimed at promoting proactive approach as a transit from reactive approach of addressing disaster issues in the country (NDRMP, 2015). However, the DPR Act has been reactive in dealing with disaster issues in the country. The Act mainly focussed on response and relief activities than in DRR (Wright et al., 2017). At the time of this study, the new Bill was published on 5th March 2023 as “Bill No.9” of Disaster Risk Management in a “Gazette

Extraordinary Supplement” in Parliament. The Disaster Risk Management Bill seeks to repeal DPR Act (1991) and replace it with a new Act (DRM Law 2023) in order to align the law with developments in the area of disaster preparedness, risk reduction, and response and recovery (GOM, 2023). While the Bill (now to be the new DRM Law 2023) has incorporated issues of risk reduction which were missing in the DPR Act (1991), the process of disaster risk management policy formulation would still be attributed as a “centric symbol of disaster enterprise”. This is because the first Act (1991) was formulated after the Phalombe flood disaster in 1991, and this new Bill has been influenced by the 2023 floods induced by TCF. Yet stakeholders and expert called for this Law to be operational for long time. Therefore, this study through FVA, is setting a proactive pace in which future DRM policies and Acts must be formulated.

2.3.3 Flood Frequency Analysis

The increase in flooding events calls for flood frequency analysis (FFA) in catchment area of flood plains in order to predict and understand the trends in the river regimes. FFA provides better practices on flood prevention, protection and mitigation (Grek, 2020). It assists in designing hydraulic structures and estimation of flood hazards (Jain et al., 2014). It is also crucial for evaluating design flows in ungauged basins, and can complement existing time series in gauged sites and transfer them to ungauged catchments (Machado et al., 2015). FFA can be done through statistical analysis from data obtained on stream discharge at a gauged station for a specific period (Silva et al., 2012). The analysis of this data is subjected to different techniques such as Geographic Information System (GIS), Soli and Water Assessment Tool (SWAT) (Grek, 2020).

Various studies which have conducted flood frequency analysis exist in the literature (Grek, 2020; Machado et al., 2015; Ngongondo et al., 2020). However, most of them have paid much attention on catchment management, water resources management and in general, understanding hydrological issues in the river regimes. Ngongondo et al. (2020) carried a study on an evaluation of integrated impacts of climate and land use change on the river regime in Wamkulumadzi river basin in Malawi. This study assessed how the CC and LUC affect the flow regime of Wamkulumadzi. The study used both remote sensed imagery using a supervised image classification systems and Soil Water Assessment Tool (SWAT). The study used images of 1984 to 2015 on part of understanding land use changes and gauged data on the same years to understand the hydro climatology. The results of the supervised classification of landsat images from the years of 1989, 1999 and 2015 demonstrated a lot of land use changes in the Wamkulumadzi catchment. The results showed that agricultural land had covered 30.66% in 1989 but had decreased to 7.62% in 1999 before increasing to 15.14% (Ngongondo et al., 2020). It further revealed that urban area increased rapidly between 1989 and 1999 followed by a slight decrease in 2015 (Ngongondo, et al., 2020). What is not clear on this analysis is whether the changes of land use are due to flooding. In fact, the paper attributes the main cause of this change to rapid population growth. However, the paper did not highlight any influence of the floods on land use change and other human displacement within the area. It is for this fact that this study focused on understanding the spatial and temporal trends of floods in the Lingadzi and Lufilya catchments using baseline gauges and hazard data and field survey data, collected by GPS receiver from the catchments. The use of field survey (location points) collected in the catchments provided a good visualisation of what exactly is happening in the context of flooding in the area of study rather than depending on image satellites and existing hydroclimatology data which may give results of some parameters based on assumptions.

Furthermore, the results did not link properly how flood trends impact on people surrounding the catchment. This in turn, means that limited knowledge could be realised from the study in terms of the mitigation and preparedness strategies that authorities can take to assist people surrounding the catchments. Noting this gap, this study therefore used GPS to collect the coordinates of the catchments. This was to ensure that recent and update information was collected to profile the river catchments to see the changes that have occurred in spatiotemporal scale (Rana et al., 2018). Hence, this study quantified the land gained/lost through floods in the catchments of the studied area. Further, this study predicted future profiles or trends of the river regimes. In this case, the study provides a tool for the flood warning in terms of evacuation and relocation. Finally, this study provides a basis of understanding the amount of harvests that people in the area loose through floods because of loss of agricultural land as well as the amount of land lost for settlement with passage of time. Further to this, the study conducted flood frequency analysis using return periods, flow rate, runoff and precipitation from the river catchments to show the flood trends in the catchments. In this scenario, the study demonstrated how the flooding trends are impacting people on their livelihoods. The findings helped to provide explanation of the social and physical vulnerability solutions on the category of adaptive capacity.

Other hydrological studies have used artificial neural networks (ANN) in flood modelling (Ludin et al., 2018). ANN helps to solve problems of uncertainty in inputs and produce outputs from incomplete data (Kia et al., 2011). This method uses rainfall and run-off parameters as the input and output (Ludin et al., 2018). However, this method can take other factors to assess the causes of floods (Fritzsche et al., 2014). Ludin et al. (2018) noted that studies that used ANN in FVA revealed similar predicted values with using hydrological data records (Brown et al., 2017). Ludin et al. (2018) concluded that ANN has the potential to be applied in FVA estimation. In the study of flood vulnerability assessment in Muar Region, Malaysia, three factors (topography, distance of residents between rivers and population density) were analysed using ANN (Ludin et al., 2018). The results of the ANN generated FVA map which showed the spatial variability of FVA with a range between 0 - 0.85 (Ludin et al., 2018). The results further revealed that more vulnerable areas (>0.8) were found in areas with characteristics such as low-lying areas (<30m), residents living close to the river (<8.3km), high population density (>10 people per grid cell of 10km). On the other hand, lower vulnerability (<0.4) was characterised by high topography areas (>90m), residents living away to the river (>16km) and low population density (<1 per grid cell of 10km). This study therefore used ANN method to understand the relationship of variables of UVFs and VCs to explain the variability of contribution to households flood vulnerability in urban and rural areas.

2.4 Factors that Determine Household Flood Vulnerability

The conceptual framework, on the one, gives the UVFs and on the other hand, provides the VCs as major sets of flood vulnerability assessment. Wisner et al. (2016), indicates that vulnerability involves a combination of underlying factors that determine the degree to which life, livelihoods, property and other assets are put at risk by a discrete identifiable event in nature and in society. Therefore, this section presents the review of literature based on four components namely underlying vulnerability factors (UVFs), linkage of UVFs and demographics, drivers of vulnerability components (VCs) and methods of measuring flood vulnerability.

2.4.1 Underlying Vulnerability Factors (UVFs)

Iloka (2017) maintains that vulnerability is the combination of numerous factors that determine the level of risk to people's lives and livelihoods. Ndanusa et al. (2022) highlights that assessment of flood vulnerability has not been holistically conducted. Studies have assessed flood vulnerability either using physical or social components (Ndanusa et al., 2022).Therefore, this study indicates that the physical, social, economic, environmental and cultural factors in which an individual, a household or a community live can increase (or decrease) the degree to which life, livelihoods, property and assets are put at risk. Therefore, the conditions in these underlying factors must be assessed to understand flood vulnerability drivers in order to select effective flood response techniques. Within the underlying vulnerability factors, it is important to assess the vulnerability of the elements at risk-defined here as those materials (both tangible and intangible) that are important to support people's lives. Ndanusa et al. (2022) argues that a breakdown of these materials poses a serious communities' vulnerability. A review of literature reveals various conditions within the factors that lead to the progression of communities' vulnerability to floods as discussed in sections 2.4.1.1 to 2.4.1.5.

2.4.1.1 Physical Vulnerability Factors (PVFs)

Physical vulnerability incorporates indicators of the physical and structural sensitivity (Ndanusa et al. 2022). The physical conditions relate to the infrastructures to be damaged or damaged by flooding events (Ndanusa et al., 2022). Key identified components of the physical vulnerability are topography, proximity to the river flood water, depth of building, condition and material made up of the building (Balica, 2012). Birkmann (2013) also highlights that physical vulnerability refers to the physical characteristics of a country that can be classified according to three components: geography, infrastructure and population. Ndanusa et al. (2022) states that the physical components which have shaped the physical vulnerability condition comprise geo-morphological and climatic characteristics of the system and different infrastructures like buildings, dams and levees. This study, considered the elements of infrastructure (such as type of construction materials, nature of buildings) to define the physical causes of vulnerability. Utilisation of physical indicators like these ones has been supported in literature. Birkmann (2013) indicates that physical dimension of vulnerability depends on the exposure and fragility of ecosystem services that people depend on such as water systems and infrastructures. In this regard, physical causes of vulnerability should be particular selected based on material objects of the physical environment that may be affected by location. Iloka (2017) as cited in Edger et al. (2004) indicates that physical infrastructures are indicators of vulnerability that can be utilised at community level.

2.4.1.2 Social Vulnerability Factors (SVFs)

Birkmann (2013) states that vulnerability patterns are not universal but often depend on specific context conditions and development processes in the respective country or region. Therefore, social vulnerability refers to the impact of disasters on the social structure of a society (Iloka, 2017). The most common social factors that increase people's vulnerability include limited access to health, education and housing (Asharose et al., 2015). Other studies in literature put emphasis on poverty, social marginalisation, social networks and powerlessness as key social causes of vulnerability (Aldrich et al., 2015; Davies et al., 2013). Birkmann (2013) indicates that the social causes of vulnerability include among other aspects as justice, social differentiation, societal organisation and individual strengths. Most people residing in flood prone areas face health, education and housing problems. They lack access to knowledge and information on health, have low levels of education and inadequate access to shelter and safety (Iloka, 2017). Moreover, vulnerability among these people increases because they stay in very remote and risk-prone areas (Mwalwimba, 2020). Often these areas are difficult for emergency services to access them easily. It is also noted that the remoteness of the location of people results in challenges for the delivery of relief and recovery assistance during disaster (Barbier, 2012). Birkmann (2013) provides several characteristics that define social vulnerability like livelihoods and resilience, self-protection, social protection, social networks. Iloka (2017) as cited in Adger et al., (2004) highlights that social conditions such as health and nutrition, education and illiteracy contributes to vulnerability of community to hazards and disasters (Iloka, 2017). In other studies, social flood vulnerability is described as information pertaining to losses incurred due to characteristics of population which include age, health, gender, poverty and employment (Ndanusa et al, 2022).

Social vulnerability in this study is measured by the characteristics of availability of health services, ability to cope, access to social services and information.

2.4.1.3 Economic Vulnerability Factors (EVFs)

Economic vulnerability is related to the number of economic resources in the country (Ndanusa et al., 2022). It relates to the ability of the country to support itself in the face of a disaster and the susceptibility of a country's economy to disasters (Birkmann, 2013). A country's economic stability and the amount of money allocated to disaster management determine economic vulnerability (DIFD, 2015). People are regarded to be more vulnerable to economic challenges due to their levels of economic wellbeing (Iloka, 2017). In most cases local, people are marginalised from the economic mainstream and they live in poverty. Poverty is generally recognised as one of the most important causes of economic vulnerability (Iloka, 2017), because the poor tend to have much lower coping capacities. Poverty bears a disproportionate burden of the impact of disasters (ISDR, 2011). Iloka (2017) further stipulates that dependency on limited resources and agricultural production contribute to vulnerability to hazards in the absence of cautions to households and communities. It is also revealed by studies that limited access to resources, wealth and poverty, country resource base and technological advancement determine variations of vulnerability and exposure (Iloka 2017: Kushe et al., 2018; Winser et al., 2012; Winser et al., 2016). Ndanusa et al. (2022) indicate that economic vulnerability to floods include indicators that are associated with monetary flood losses. It further relates to the income or issues which are inherent to economies that are predisposed to be affected by floods (Ndanusa et al., 2022). This study considered economic vulnerability parameters such as poverty, lack of alternative livelihoods, and income generating activities to determine households' vulnerability to floods.

2.4.1.4 Environmental Vulnerability Factors (EnVFs)

Environmental vulnerability refers to the natural environment in which a society is located and the impact of environmental degradation (Birkmann, 2013). It is a fact that environmental change affects everyone; however, this phenomenon has adverse impact on people whose lives remain entirely tied to the land and who depend largely on the environment for food. Environmental damage affects well-being of the local peoples in that the availability of traditional foods and medicines is diminished because of environmental degradation (Barbier et al., 2012). Ndanusa et al. (2022) relates environmental vulnerability to indicators such as degraded area, forest change rate, percentage of the urbanized area, groundwater level, percentage of land use for economic activity and natural reserve. Balica (2012) suggests that agriculture, urbanization, deforestation and enhanced environmental degradation create environmental vulnerability. Ndanusa et al. (2022) argues that most environmental threats are induced by rainfall, topography and soil characteristics.

2.4.1.5 Cultural Vulnerability Factors (CVFs)

Chawawa (2014) defines cultural vulnerability as systems of beliefs regarding hazards and disasters. There are various cultural factors contributing to vulnerability (Iloka, 2017). McEntire (2011) identifies "public apathy towards disasters, defiance of safety precautions and regulations and dependency and absence of personal responsibility" as such factors. People have beliefs and practices that event from natural hazards are inevitable and humanity should accept the fate without dispute (Chawawa, 2018; Iloka, 2017; Kushe et al., 2018). It is argued that failure to recognise culture of people may increase vulnerability to hazards. According to Iloka (2017), culture is a way of life and a means through which knowledge is gathered. Therefore, local knowledge plays a key role in the management of hazards (Iloka, 2017). This may increase their vulnerability if the area is susceptible to a disaster. Wisner et al. (2014) further states that due to certain religious and cultural beliefs people may not attempt to prevent, reduce or deal with hazards causing disaster.

Within the cultural/human causes, this study found that it was justifiable to look at political influence on vulnerability. Beck et al. (2012) defines political vulnerability as limited access to political power and representation. Politics also has a serious influence on the vulnerability of local people or communities at large. This vulnerability occurs when people lack political voice. According to McEntire (2011) he identified political factors such as "minimal support for disaster programs among elected officials, over centralization of decision making and uncoordinated disaster related institutions". When resources are allocated politicians and governments may give priority to the influential sector of society who has the power to vote for them (McEntire, 2011).

2.4.2 Underlying Vulnerability Factors and Demographics

The underlying vulnerability factors have been widely studied by connecting to demographics such as age, marital status, gender, physical status of individuals, occupation, and education among others (Kushe et al. 2018; Munthali et al. 2022; Rana et al. 2018). Most of these studies link these demographics in the realm of the UVFs. For example, Ndanusa et al. (2022) indicates that social vulnerability factors (SVFs) describe information pertaining to the losses incurred due to characteristics of population which include age, individual health, sex and employment. Barbier (2012), states that an individual’s physical characteristics also influence the individual’s vulnerability to death or injury from natural hazards. The characteristics include age, gender, linguistic ability and background, ethnicity, race, and state of physical and mental health. An individual’s state of health includes physical mobility, speed of reaction, intelligence and medical history. Elderly people are more susceptible to diseases. This puts them to be more vulnerable to injuries during the occurrence of natural hazards such as floods, storms and earthquakes.

Additionally, elderly people are more vulnerable to some biological hazards than younger people are, because they also have decreased mobility that increases vulnerability to rapid onset hazards (Hing et al., 2010). As a person’s state of health declines due to old age, physical mobility is impaired, linguistic ability may regress, and the ability to respond appropriately to warnings or situations may be compromised (Beck et al., 2012). These increase the vulnerability of aged people in situations of rapid response due to decreased mobility (Help Age International, 2014). Furthermore, individuals who do not understand warnings and safety instructions due to their educational background, youth or age, hearing impediments, intelligence, or linguistic background different from the language of the community are more vulnerable to rapid-onset hazards such as storms and flash floods (Birkmann et al., 2010). Individuals who do not understand the language in which a warning about an impending disaster is issued may be more vulnerable to that hazard due to their lack of understanding and comprehension of the hazard (Mwalwimba, 2020).

The above articulated demographics are used in most studies to explain physical-social-economic-environmental vulnerabilities to specific hazards (Kushe et al., 2018; Munthali et al., 2022; Ndanusa et al., 2022). However, these demographics are used as explanatory variables to the constructed underlying vulnerability factors. These elements were used with the demographic variables to explain vulnerability of households to floods in Lilongwe city and Karonga district.

2.4.3 Drivers of Vulnerability Components

Literature reveals that exposure, susceptibility and resilience are the most widely used measure of flood vulnerability (Nazeer et al., 2021; Oyedele & Vyonne, 2022). These measures are classified as vulnerability components (Oyedele & Vyonne, 2022). They are further regarded as three interrelated factors that generate flood risk (Oyedele & Vyonne, 2022). However, despite huge emphasis on these measures, still, there is a missing gap to combine the VCs and UVFs, which might have implications on designing flood vulnerability reduction measures. For instance, Oyedele and Vyonne (2022) in Nigeria carried a study to understand flood vulnerability in local communities of Kogi State using index-based approach. The study constructed 16 indicators based on VCs. The study used flood vulnerability index (FVI) to measure VCs. The study revealed that susceptibility contributed most to flood vulnerability, followed by lack of resilience and exposure. However, the study did not clarify the selected 16 indicators as whether they were based from the UVFs (physical, social, economic, environmental or cultural), rather it described as drivers of FVI and its underlying factors.

Furthermore, Hui-Hsuarg Yang & Dargee (2018) in Taiwani the area of Krosa conducted a study analysing social vulnerability factors of floods. The study used Social Vulnerability Framework (SVF) proposed by Li et al. (2017) to identify factors that were to be analysed based on indicators which were selected from the three VCs. The framework included three dimensions to look at; maximum loss of household properties, household resistance to flood disasters and household self-recovery ability. The study targeted the heads of households living in the flood prone areas. The analysis of factors was based on the risk perception as either high or low. The risk perception of variables was compared using ANOVA. The study found out that gender, elders living alone (above 61 years) and disabled individuals were significant with high-risk perception in the susceptibility indicators. The study had some useful tools that are partly used in this study to measure vulnerability to floods, more especially, a framework dimension of maximum loss of household properties. Although the study analysed the vulnerability factors and found out the significant factors based on the level of risk perception, the study did not analyse what reduced or raised the risk perception of the variables. This is where someone has to analyse vulnerability of households to floods taking into account exposure, susceptibility and resilience as a component of flood vulnerability assessment that can be linked to underlying drivers of vulnerability (physical, social, economic, environmental and cultural).

Aliyu Baba Nabegu (2013) also conducted a study aimed to assess vulnerability to floods in Kano State, Nigeria. The study explored households' characteristics before and after flood disasters, looked at coping mechanisms and analysed the infrastructures such as schools, roads, bridges, hospitals and markets. The study used human Security Index proposed by Plate in 2002 in order to determine the time a household would need to recover from property damage. The study also used vulnerability index in order to determine the level of coping capacities among the three zones under the study. The study reported that damages to properties appeared to be the common feature in all the three zones. The reason behind that was that the housing could not withstand flood based on the age, material used, structured integrity and construction type and quality. Out of those houses built of mud, only 0.9% survived, 82% were destroyed and 12.1% were damaged compared to those made with concrete. Sex also was considered the factor of vulnerability because regarding the dead, 72% were female and 28% were males. While, the study provided metrics for floods, still, it did not look at flood vulnerability in the dimension of VCs in relation to UVFs.

Mtembenuzeni and Kushe (2018) assessed the theoretical and practical understanding of vulnerability in flood disaster prone areas of Chikuse. The assessment was reviewed in relation to Pressure and Release model (PAR) and the access model. The research used qualitative data collected through interview of key informants and focus group discussion. The study reported that the impacts of floods in the area varied between individual and families. The reasons behind the variation were reported as lack of access to land, wealth, natural and social resources and linkages that lead to more vulnerability conditions. Just as many other studies mention the significance of exposure, susceptibility and resilience, not all of them tried to measure vulnerability in the context of the same variables in of vulnerability factors. Though it is significant to look at vulnerability from a qualitative view, vulnerability using both quantitative and qualitative approach provides a good picture of unveiling the mix of factors that contribute to household vulnerability to floods; there is a need as well to understand the situation quantitatively. That is one of the reasons this study considered using both approaches to assess households' vulnerability to floods in Lilongwe city and Karonga district.

Mwale (2014) carried a study on contemporary disaster management framework quantification of flood risk in rural lower shire valley in Malawi. The study obtained flood risk by integrating hazard and vulnerability. Flood hazard was characterised in terms of flood depth and inundation area obtained through hydraulic modelling of the catchment with Lisflood-FP, while the vulnerability was indexed through analysis of exposure, susceptibility and capacity and linked to social, economic, environmental and physical perspectives. The implementation of the entire analysis was carried in GIS environment which enabled the visualisation of spatial variability in flood risk in the valley. The study found that vulnerability was dominated by a high to very high susceptibility component largely because of the high to very high socio-economic and environmental vulnerability (Mwale, 2014). Furthermore, the study established that economic and physical capacities were predominantly low but social capacity was significantly high, resulting in overall medium levels of capacity-induced vulnerability. Though the study quantified the vulnerability, it did not provide indicators for measuring vulnerability in Malawi. The study focused on developing methodology for reconstructing hydro-meteorological data and advancing the understanding of the flood risk of rural communities in SSA. However, this study is beyond the contribution of the earlier study in the sense that it quantified vulnerability for rural and urban areas. Furthermore, it has proposed a framework for measuring and systematising flood vulnerability for rural and urban areas. The study further provides adaptive capacity specific for the different dimensions of vulnerability. Above all, the study demonstrated the flood vulnerability trends through hydrologic, GIS and remote sensing assessments.

The significant part of the contemporary disaster management framework quantification study (Mwale, 2014) is that it accords to different arguments that are articulated in this study. For example, both studies agree on the fact that research in the literature in SSA is missing in terms of (1) linking hazard and vulnerability (2) quantification of vulnerability and (3) limited indicators on vulnerability. Hence, both studies emphasise the need to have indicators that can be utilised in policy and decision making process for promoting disaster risk reduction and to build household resilience. Above all, the study was premised similar to the current study since it indexed vulnerability through analysis of exposure, susceptibility and capacity and linked to social, economic, environmental and physical perspectives. The only missing aspect in the linkage was cultural perspective, which has been added in this current study.

Chawawa (2018) conducted a study that critically explores how smallholder farmers perceive their vulnerability to floods in Nsanje district and Blantyre rural in Malawi. The study investigated the factors and processes that motivate smallholder farmers to live in the flood prone areas. It also examined the realities and dynamics of local adaptation in the flood prone areas in Malawi through opportunities, challenges, barriers and limitations. The research used 57 in-depth interviews, a household survey involving 227 households, participant observations and 12 focus group discussions with smallholder farmers. The study revealed that smallholder farmers are not ready to abandon their land and relocate upland because floods are part of their lives and livelihood strategies. The study further found that power dynamics at household and community levels based on gender roles and culture need to be understood and accounted for in local adaptation strategies in order to effectively enhance local adaptive capacity. In addition, the study found that social networks and interdependence between the smallholder farmers living in flood prone areas and those living in upland areas play a significant role in the adoption of local adaptation strategies and adaptation to floods and droughts through temporary migration. The study also revealed that the perception and extent of vulnerability to floods is dynamic and differentiated based on several factors such as gender, age and marital status. The problem with this earlier study, which has been addressed in the current study is that it relied much on qualitative dimension of understanding vulnerability. In this way, the study did not provide indicators of measuring vulnerability other than just identifying casual factors, impacts and coping strategies of vulnerability.

2.4.4 Methods of Measuring Flood Vulnerability

Vulnerability and its components must be understood to reduce flood risks (Rana et al., 2018). Assessing vulnerability is a crucial task (Barret et al., 2021) and is advancing in the current global trends (Moreira et al., 2021; Ndanusa et al., 2022; Rana et al., 2018). However, its systematic review and measurement is not easy and straightforward (Moreira et al., 2021; Mwale, 2014; Smith, 2013). Moreira et al. (2021), states that though there is an increasing body of research on flood vulnerability, methods in the construction of vulnerability indices are still lacking. Nazeer et al. (2019) states that vulnerability has no single universally "best" methodological approach for the formulation of indicators because of its data-specific nature of each single study. However, this can be complimented by using approaches such as data rescaling, weighting and aggregation (Nazeer et al., 2019). The UN (2014), also stresses that the assessments are often sporadic, isolated and that they lack standardised methodologies. The literature has been even contradictory to some extent. For example, Leon (2013) has argued that some social scientists and professionals have stated that vulnerability cannot be measured at all and only proxies can be used to present it. Nevertheless, Hinkel (2011) argues that the diversity in definitions of vulnerability is accompanied by a similar diversity of methodologies for assessing vulnerability. Moreira et al. (2021) indicate that the most common methods are min-max normalisation (30.5%), equal weighting (24.2%) and linear aggregation (80.0%). This indicates that no one has a clear idea as to what exactly this concept means in operational terms. Birkmann (2013) noted that 'we are still dealing with a paradox: we aim to measure vulnerability, yet we cannot define it precisely'. Mwale (2014) outlines seven challenges that are encountered when measuring vulnerability (1) human ecological interactions (2) multiple stressors to which a system is subjected to (3) multiple outcomes manifested by vulnerability (4) the dynamic nature of the different component in a system (5) the inclusiveness of variables (6) the qualitative nature of the social variables and (7) the need for threshold.

Mwale (2014) as cited in Cutter et al. (2003) indicates that Social Index (SoVI) has been used in measuring vulnerability in the USA around 2060-2008. SoVI uses thresholds for vulnerability ranking. It identifies dominant vulnerability factors from a large set of social vulnerability factors using Principal Component Analysis (PCA). PCA determines vulnerability using a scale of $\geq +2$ for high vulnerability and ≤ -2 for low vulnerability (Mwale 2014). The scale is obtained from the vulnerability variables after being computed in the Minitab-PCA. While, this study did not use PCA, it used Multiple Correspondence Analysis (MCA), another type of Minitab. This helped to determine variability of vulnerability factors in terms of contribution to increase or decrease vulnerability in the studied areas.

Nasiri (2013) stipulates that a methodology of measuring vulnerability involve critical infrastructure and sectors assessment. The emphasis of this method is based on the ground survey of the exposure and susceptibility of basic infrastructure services and facilities such as hospitals and schools (Nazeer et al., 2020). This measurement method is based on quantitative approaches and set along three dimensions- geographical level, sector and components (Nasiri, 2013). In order to assess vulnerability, this method focuses on the dimension of the components. It employs vulnerability indicators, which make use of arbitrary set weights to combine different elements. Though expert judgments tend to be employed, some still question the selection of numerical weights (Birkmann et al., 2013; Munyani et al., 2019).

Another method considered significant in measuring vulnerability has been community-based assessments (CBA) (Mwale. 2014). CBA involves the use of active participation of local communities in identifying the hazards, vulnerabilities and risks through such methods as transect walks, risk mapping, asset inventories, livelihood surveys, focus group discussions or key informant interviews. They have been particularly used in developing countries by Non-Governmental Organisations (NGO) as a means to foster their relationships with communities and as a basis for the design and operation of their projects (Izumi & Shaw, 2012; Mwale, 2014). Outputs from CBA have also been used in index-based vulnerability assessments, e.g., Kienberger (2012).

It is further argued that using indicators-based method has emerged as a prominent trend in the measurement of vulnerability in contemporary disaster management (Mwale, 2014; Nelson, 2010). According to Birkmann (2013), this method requires the most attention to explore the various vulnerabilities of different social groups. This method involves the use of the in-depth questionnaire survey to allow better understanding and estimation of vulnerability and address spatially specific features of vulnerabilities to floods. Tate (2012) defines "indicators as quantitative variables intended to represent a characteristic of a system of interest". According to Mwale (2014), the indicator method provides three advantages in the assessment of vulnerability.

These advantages include; (1) summarise complex data in simple figures (2) it is easier to understand especially those that are non-experts and (3) provide various range of variables which give the opportunity to identify the root causes of vulnerability. According to Nazeer et al. (2019), indicator-based approach is largely practiced from a policy point of view through use of composite indicators. Moreira et al. (2021) noted that most of the indicators used, focus on the socio-economic aspects such as population density, illiteracy rate, gender).

The multi-dimensional model approach has been also recommended as significant methodology for assessing flood vulnerability (Ndanusa et al., 2022). The model gives a holistic approach to flood vulnerability assessment (Rana et al., 2018). It quantifies vulnerability indicators using the participatory approach though application of flood vulnerability index (FVI). For example, Ndanusa et al. (2022) conducted flood vulnerability using multi-dimensional model by applying FVI. The multi-dimensional model flood vulnerability found an index of 0.65 with high flood vulnerability from all the dimensions; economic (0.71), physical (0.66), social (0.62) and environmental (0.57). Though this study quantified vulnerability, this study finds that the earlier study concentrated only on one dimension of assessing vulnerability through the use of four lens; physical, social, economic and environmental. Similarly, Rana et al. (2018) assessed vulnerability through the lens of five dimensions: social, economic, physical, infrastructure, institutional and attitudinal. The study excluded cultural vulnerability yet it is an important dimension in the analysis of vulnerability (Iloka, 2017).

Other studies use both qualitative and quantitative methods to assess vulnerability (Chawawa, 2018). In this case, the vulnerability assessment involves conducting risk assessment. According to ISDR (2014), risk assessment considers potential hazards, estimating the likelihood or probability of those impacts actually occurring and the consequences or potential harm that would result. The process involves both the science of measurement and the art of judgment in order to determine the acceptability of a particular risk (ISDR, 2014). The vulnerability risk matrix is used to express the qualitative and quantitative values in which word and numerical values are assigned to qualitative and quantitative data respectively.

Nasiri (2013) gives three main methods of assessing vulnerability namely the vulnerability index system (VIS), vulnerability curve method (VCM) and disaster loss models data (DLMD). The VIS method is commonly used in flood vulnerability because it is able to incorporate complex indices and has ability to allow the weighting of their indicators (Rana et al., 2018). Normally, the VCM is found on real damage investigation, but it takes a lot of time and resources (Moreira et al., 2021). Finally, the DLMD focuses on demonstrating the losses in simulation analysis. It encounters the problem of low validity of data shortage in most of the country or region (Ndanusa et al., 2022). Therefore, this study applied the VIS method because which was linked with the indicator-based approach derivation of flood vulnerability indicators using binomial logistical regression model and Minitab-multiple correspondence analysis (MCA).

2.4.5 Policy Initiatives Shaping Vulnerability Assessment

Vulnerability assessment is an important component of DRR. Therefore, several international and national initiatives emphasize on vulnerability assessment. The Sendai Framework for Disaster Risk Reduction (SFDRR), calls upon national governments to base policies and practices for disaster risk management on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characterisation and the environment (SFDRR, 2015-2030). The Hyogo Framework for Action (2005-2015) focused on building the resilience of nations and communities to disasters. Member governments and agencies agreed to the Hyogo framework for Action 2005-2015, which aimed at promoting the strategic and systematic approach of reducing vulnerability and risks to hazards. The International Decade of Natural Disaster Reduction (IDNDR, 1990-1999) emphasised the need to conduct national risk and vulnerability assessments, developed national and/or local prevention preparedness plans, and implemented global, regional and national warning. Yokohama Strategy and Plan of Action for a Safer World (1994) stressed that every country has a sovereign and primary responsibility to protect its people, the infrastructure and the national, social and economic assets from the impact of disasters. It further emphasised that community involvement and active participation should be encouraged in order to gain greater insight into individual and collective perception of development and risk, and a clear understanding of the cultural characteristics of each society as well as its behaviour and interactions with the physical and natural environment (ISDR, 1994). Government of Malawi (GOM) through the Malawi

Growth and Development Strategy (MGDS III) seeks to build a productive, competitive and resilient nation by reducing vulnerability and enhancing the resilience of its population to disasters and socio-economic shocks (GoM, 2017). GOM has developed enabling policy frameworks to enhance vulnerability assessment, risk characterisation and knowledge management in disaster risk management. Among the key framework relevant to this thesis, include; (1) Malawi National Disaster Risk Management Policy, 2015. The policy acknowledges the significant role of vulnerability assessment to reduce the disaster risk. Disaster Preparedness and Relief Act, 1991 (now the new Disaster Risk Management Bill to replace the old Act). The Act provides the creation of structures to assist the implementation of disaster risk reduction programmes from village level to national level. It creates the legal and institutional framework for addressing disaster in Malawi. The established institutional mechanisms include the National Preparedness and Relief Committee (NDPRC), National Preparedness and Relief Technical Committee (NDPRTC) and other technical committees such as Village Civil Protection Committee (VCPC), Area Civil Protection Committee (ACPC) and District Civil Protection Committee (DCPC).

2.5 Household Perception of Flood Vulnerability

The increased household flood vulnerability could be accentuated by the limited understanding of perception of flood risks. Risk perception can be understood as intuitive judgement about the potential risk and its consequences that individual or group holds (Bixler et al., 2021; Rana et al., 2020). To promote strategies that reduce household vulnerability, requires a critical assessment and understanding of perception of household flood vulnerability. This is geared toward establishing household preparedness and mitigation measures to deal with flood risks (Okaka & Odhiaambo, 2019). According to Shan et al. (2022) states that perception plays an important role in household vulnerability and resilience. It is an important component that must be included in DRR as well as climate change adaptation. Its assessment may help people to understand their own risks and thereby assisting decision makers to provide best solutions of dealing with such risks. Shan et al. (2022) argues that lack of data or information regarding flood risk perception would make it more difficult to effectively communicate flood risks. This also may negatively impact on the community to have strong faith in its government for better preparedness to deal with flood disasters (Shan et al., 2022). Iloka (2017) in the study of perceptions of ethnicity, local knowledge and sustainable livelihoods in relation to DRR in Nsukka , South-East Nigeria found that communities are aware of different hazards but they are continuously affected by the way they perceive the hazards. Key among the factors that shape perception and influence vulnerability are population growth, socio-economic structures, culture, scientific and local knowledge and approach to climate change (Iloka, 2017).

Perception contributes to shape the way people look at natural hazards that lead to disasters. Therefore, actions aimed to deal with hazards and disasters must consistently consider household perceptions of their own risk. Toan et al. (2014) states that knowledge on vulnerable peoples' perception of flood risk can help policy makers to develop communication strategies for engaging the communities to deal with their own risk. It is important to understand that, while, studies confirm that disasters are a product of interaction of hazards and vulnerability, some people still perceive disasters as the "act of God" (Iloka, 2017). In this regards, it cannot be negated that faith and religion influence the vulnerability of households or communities to the impact of hazards. Significantly, faith and religion are inherent of cultural beliefs and values that are perceived by the holders as right or wrong. Iloka (2017) argues that several areas that are affected by disasters, religion in an inherent part of their cultural identity and therefore it should be duly considered in the disaster management process. Importantly, cultural factors such as beliefs and norms impact the response to adverse events (Iloka, 2017). Barriers such as increased corruption in government, lack of trust in the political system and non-commitment of relevant stakeholders increase vulnerable conditions in the local communities (Iloka, 2017).

Understanding of perception on flood risks may help in the identification of appropriate DRR interventions aimed at reducing vulnerability. These DRR measures such as mitigation, preparedness and advocacy can only be fully implemented when peoples' perception of flood vulnerability has been understood. Okaka and Odhiambo (2019) maintain that perception of vulnerable households to flood risks play significant role for the developing effective long-term adaptation strategies. For instance, for households to take some form of mitigation measures to strengthen their resilience aimed at reducing vulnerability, it depends on how those households perceive flood risks. Jain et al. (2018) states that mitigation means "to make less severe", these are measures undertaken to reduce the impact of flood events, to avoid damage to personal property, avoid loss of life, and to decrease or diminish overall damage (Bixler et al., 2021; Brody et al., 2017). They include structural and non-structural measures such as institutional reforms, education awareness, financial planning and potential commitment, introduction of new agricultural practices and relocation of settlements. However, these measures to be successful, it will depend whether households understand their own risks so as they can select appropriate measure to mitigate those risks. According to Brody et al. (2017) states that various factors can influence household to pursue flood mitigation actions. These include: hazard experience, hazard intrusiveness, location, in relation to physical risk, risk perception, and socio-economic (demographic) characteristics. Bixler et al. (2021) concurs that victims of flood events possess a unique awareness of their vulnerabilities and associate different emotions with floods, making them more likely to implement mitigation measures than non-victims.

Perception of household flood vulnerability can help households to strengthen their capacity to withstand, respond to and recover from hazards. Shan et al. (2022) argues that managing and communicating flood risks necessitates a strong understanding of how people perceive risk. This can be supported through establishment of speedy preparedness plans and appropriate interventions. Preparedness in this scenario entails establishing contingency plans and evacuation plans to ensure a speedy and effective response to before, during and after the emergencies. Preparedness plans can be established at a number of different levels including village or community, local authority and central government. However, the effectiveness of these preparedness plans will depend on the understanding of risks associated by the communities or households. In the view points of Shan et al. (2022), risk perception is a critical strategy to implement effective DRM measures.

The assessment of flood risk perception has been centralized based on socio-economic variables. Okaka and Odhiambo (2019) in the study of households perception of flood risk and health impact of exposure to flooding in flood prone informal settlements in the coastal city of Mombasa in Kenya used socio-economic variables such age, gender, education and income to measure perception on flood risks. This study revealed that majority of respondents’ perceived future flooding as high risk or severe with high negative health impacts. The study further revealed that despite this, many households showed low willingness to vacate their homes because of lack of alternative places to move to. Shan et al. (2022) in the study of flood risk perception and its attributes among rural households under developing country conditions in Pakistan used socio-economic inputs to measure perception on flood risk. The study established that flood risk perception is strongly linked socio-economic variables such as age, education, house ownership, family size, past flood experience and distance from the nearest river sources. Furthermore, the results revealed that institutional factors such as access to credit and extreme weather forecast information contributes to influence flood risk perception. The findings highlighted that flood risk perception were varied among households based on education, age (greater than 40 years perceive high flood risk) and monthly income (lower monthly income group perceived high flood risk).

The use of socio-economic variables in the studies of Okaka and Odhiambo (2019) and Shan et al. (2022) ignore other important variables of measuring and assessing perception of household flood vulnerability. Determinants such as place/location, temporal characteristics (such as frequency, duration, speed of onset, and forewarning), permanent characteristics (such as knowledge of the hazard, intensity, geographical coverage, predictability, and manageability) and impacts of floods on essential activities (such as education, farming etc) could be key determinants that may influence perception of households flood vulnerability. The importance of these variables have been acknowledged in the Hazard of Place Model (Cutter, 1996). The model depicts that hazards occur to specific places and have different impacts based on peoples' vulnerability and resilience (Joakim, 2008). In this equation, the argument that can be made is that a place may influence perception of household flood vulnerability because the inhabitants of the place attribute a strong identity character and meaning from the social, economic, political as well as biophysical processes occurring in the area. Therefore, the fact that people hold these values for their places, it would be practically difficult to achieve priority 4 of the Sendai Framework for Disaster Risk Reduction (2015-2030) which states that "there is a need to enhance disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction". More specifically target "l" which emphasize on relocation of public facilities and infrastructures to areas outside the risk range and target "m" which focuses on strengthen the capacity of local authorities to evacuate persons living in disaster prone areas

(SF-DRR-2015-2030, P. 22). Similarly, Wachinger et al. (2013) identifies a broad set of factors influencing risk perception such as: scientific factors, information factors, personal factors, and contextual factors. According to Bixler et al. (2021) these factors are fundamental to understanding and mitigation actions taken by individuals and governments to deal with flood vulnerability. To take account non-socio-economic variables to determine perception, Bixler et al. (2021) associated flood impacts as predictors of flood risk perception with social vulnerability. The results of the association revealed that impacts of floods have had a significant and positive effects on risk perception (0.35, $P<0.01$) and mitigation behaviour (0.88, $P<0.01$). These results imply that households who have been more severely impacted by flood have higher risk perception compared to those who have experienced flooding but had little or no impact to themselves, their family or their belongings (Bixler et al., 2021).

2.6 Household Adaptive Capacity on Flood Vulnerability

Improving measures for vulnerability reduction is complex enterprise. Vulnerability reduction requires measures that can increase resilience of households to climate change events. These measures can be generated within the community through households' adaptive capacity or outside the community through institutional support (Bixler et al., 2021). Therefore, this study maintains (as highlighted in the conceptual framework) that adaptive capacity is an inherent part of vulnerability assessment. It helps to comprehend and give a picture of how the households respond to climate change shocks such as floods. That is to say, adaptive capacity of a system (for example, a city government), population (for example, a low-income community in a city) or individual/household to undertake actions that can help to avoid loss and can speed recovery from a hazard (Dodman et al., 2013). Availability or lack of adaptive capacities to cope with floods impact can reduce or increase vulnerabilities of households to floods. For example, low-income households are often hit hardest by extreme weather because of greater exposure to the hazards (Dodman & Satterthwaite, 2013). Carter et al. (2015) maintains that adaptive capacity can help to reduce disaster risk by reducing vulnerability. It is further highlighted that adaptive capacity is determined by the characteristics of communities, countries and regions to adapt (Iloka, 2017).

Literature gives vexing views on what exactly adaptive capacity means. Reviews of various studies indicate that adaptive capacity is similar to coping capacity, adaptability, conflict management and resilience. However, a close look at the application of these terms does not sound the same. IPCC (2011) states that adaptive capacity means the ability of a system to adjust to extreme events in order to moderate potential damages and to take advantage of opportunities or to cope with the consequences. While this definition widens the conception of adaptive capacity, it leaves the key concepts of adaptation and resilience in constituting the term adaptive capacity. Wilson et al. (2020) observed that the concept of adaptive capacity is complex as it has been defined differently by different disciplines. Bixler et al. (2021) relates the concept as a vector of resources and assets, surrounded by four sets of interconnectedness resources: economic/financial, social, information and community (Barnes et al., 2020). In disaster resilience literature, the concept is used to mean the counteracting influences that reduce the effects of hazards exposure and susceptibility to the hazard (Bixler et al., 2021). The complexity of the term also necessitated this study to define it as a set of actions and resources taken and used by households to withstand a hazard that has interacted with vulnerability resulting to a disaster, in the pre-disaster, trans-disaster and post-disaster phases. In simple term, adaptive capacity are actions that people take to reduce vulnerability so as to be able to adapt, absorb and cope with a hazard event. Understanding the concept in this way, has prompted this research study to reconstructed adaptive capacity in three major groups as follows: physical/infrastructure measures, social organisation measures and economic livelihood measures.

Carter et al., (2015) include the components of adaptive capacity such as access to information, access to resources and role of institutions. It is also highlighted that the aspect of barriers that hinder communities to adapt to natural hazards should be included as part of adaptive capacity (Carter et al., 2015). Iloka (2017) states that adaptive capacity are influenced by variations such as awareness to natural hazards, mobility, socio-economic status, duration of residences and the extent of community support. Despite these variations, it significant to note that people in the community have their own adaptive measures to respond to natural hazards and these must be tapped. Mtembenuzeni and Kushe (2018) noted that communities in flood prone areas of Malawi are adapting to floods but their adaptive capacity remains unknown.

Therefore, this study maintains that measuring adaptive capacity of households to floods is an important part to understand people's level of preparedness, response and recovery. Once these levels have been understood, the work of flood risk management by decision makers may include proactive activities in all phases of pre-floods, trans-floods and post-floods. However, the evidence on these appear to be limited because indicators for measuring adaptive capacity have not been systematised and not yet known (Mtembenuzeni & Kushe, 2018). This makes different studies to adopt the indicators based on the purpose of the study, particularly from the field of the expert conducting the study. However, Yobe (2012) suggested determinants for adaptive capacity (Table 2.3).

Table 2.1 Indicators for Measuring Adaptive Capacity

Code	Indicator/determinants
1	The range of available technological options for adaptation;
2	The availability of resources and their distribution across the population;
3	The structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed;
4	The stock of human capital, including education and personal security;
5	The stock of social capital, including the definition of property rights;
6	The system's access to risk-spreading processes, e.g., insurance;
7	The ability of decision makers to manage information, the processes by which these decision-makers determine which information is credible and the credibility of the decision-makers, themselves

Source: Yobe (2012)

Iloka (2017) highlights that adaptive capacity is different from community to community and from household to household. This means that adaptive capacity trigger factors might range from resources availability and its disposal. According to Iloka (2017) outline seven key factors influencing adaptive capacity namely availability of funds, roles of politics and polity, human relations, level of managerial skills, access to relevant technologies and information, type of infrastructure and adaptation environment. Thanvisitthpon et al. (2020) argues that there is lack of consensus on ways to assess flood adaptive capacity, as such proposes to establish a framework for assessing flood adaptive capacity of residents of different locations. According to Thanvisitthpon et al. (2020) there are six components of flood adaptive capacity: economic resources, social capital, awareness and training, technology, infrastructure, and institutions.

Based on the study that Thanvisitthpon et al. (2020) conducted to understand adaptive capacity of Phetchaburi Municipality in Thailand using these components of adaptive capacity, the study revealed that adaptive capacity of the Municipality to flooding was found to be high in economic resources and infrastructure components and low in social capital, technology, institutions and training and awareness. Relatedly, Bixler et al. (2021) in the study of unpacking adaptive capacity in urban environments in Austin, Texas, United States of America (USA), associated social capital measures (such as neighbood cohesion, flood protection behaviours, trust and network) with social vulnerability to understand adaptive capacity of the residents. The results revealed significant effect of social capital on flood mitigation as adaptive measures. Tembo (2013) in the study of dynamic assessment of adaptive capacity to climate change, a study of water management in Makondo, Uganda, found that adaptive capacity is shaped with access to power, complex relationships, gender-based village level water governance, context based strategies, application of local knowledge and sharing of seasonal diversification of livelihoods. According to Tembo (2013), these are mechanisms that limit how future adaptive strategies will develop.

The Participatory Approach for Safe Shelter Awareness (PASSA) can assist to strengthen adaptive capacity (International Red Cross, 2014). PASSA is method of disaster risk reduction (DRR) related to shelter safety. The overall aim of PASSA is to develop adaptive capacity to reduce shelter related risk by raising awareness and developing skills in joint analysis learning and decision-making at community level (International Red Cross, 2014). Basically, PASSA is a bottom-up approach which emphasises much on people to identify the risks and their own capacities to overcome the risks and their shortfalls or problems that need attention from other appropriate authorities either government, non-governmental organisations and other partners. The international Red Cross and Red Crescent (2014) indicates that this is a win-win situation between communities and government because communities understand their own risks related to shelter and government prioritises choices based on real needs.

2.7 Chapter Summary

This section, in discussing the concept of vulnerability, focused on vulnerability conceptual framework, the approach of vulnerability, underlying and theoretical factors of vulnerability, vulnerability assessment methods, and approaches to reduce vulnerability. The study reviewed the literature on study objectives which include: spatial-temporal flood vulnerability trends, factors determining household flood vulnerability, perception of household flood vulnerability and household adaptive capacity on flood vulnerability. All in all, vulnerability is a concept that is multi-faceted. Its application is varied for different sectors and disciplines. Therefore, for assessment purposes, one has to select tools that must help to respond to the objectives of the study. Key factors for identifying the tools may include availability of resources, work a heard of the assessor, time, and knowledgeability of the tools. Though literature reveals multiple contemporary vulnerability frameworks, no single framework has agglomerated the UFVs and CVs. Hence, the conceptual framework for this study has merged the UVFs and VCs to provide the road map and a new thinking as well as approach for flood vulnerability assessment. This research understands that the analysis of all the four objectives is a necessary step of building and generating comprehensive data to support the development of FVA framework for rural and urban informal settlements; and giving the framework a new outlook in relation to a call for multi-hazard vulnerability assessment (MHVA).

CHAPTER 3: MATERIALS AND METHODS

3.1 Introduction

This chapter discusses the materials and methods used in this study. It highlights all the strategies and indicator-variables that were employed to achieve the objectives of this study. It gives the procedures and analysis that were performed to develop FVA framework (Figure 3.1). The chapter is divided into eight sections. The first section is about the study approach and design. The second section is about description of the study area. The third section is about description of the study methods on flood vulnerability assessment (quantitative and qualitative). The fourth section is about methods of flood vulnerability determination and prediction. The fifth section deals with the methods of flood frequency analysis (FFA). The six section deals with data analysis tools for spatiotemporal flood vulnerability trends. The seventh chapter highlights the procedures involved in the development of FVA framework. The last chapter deals with data management, knowledge translation, validation and dissemination.

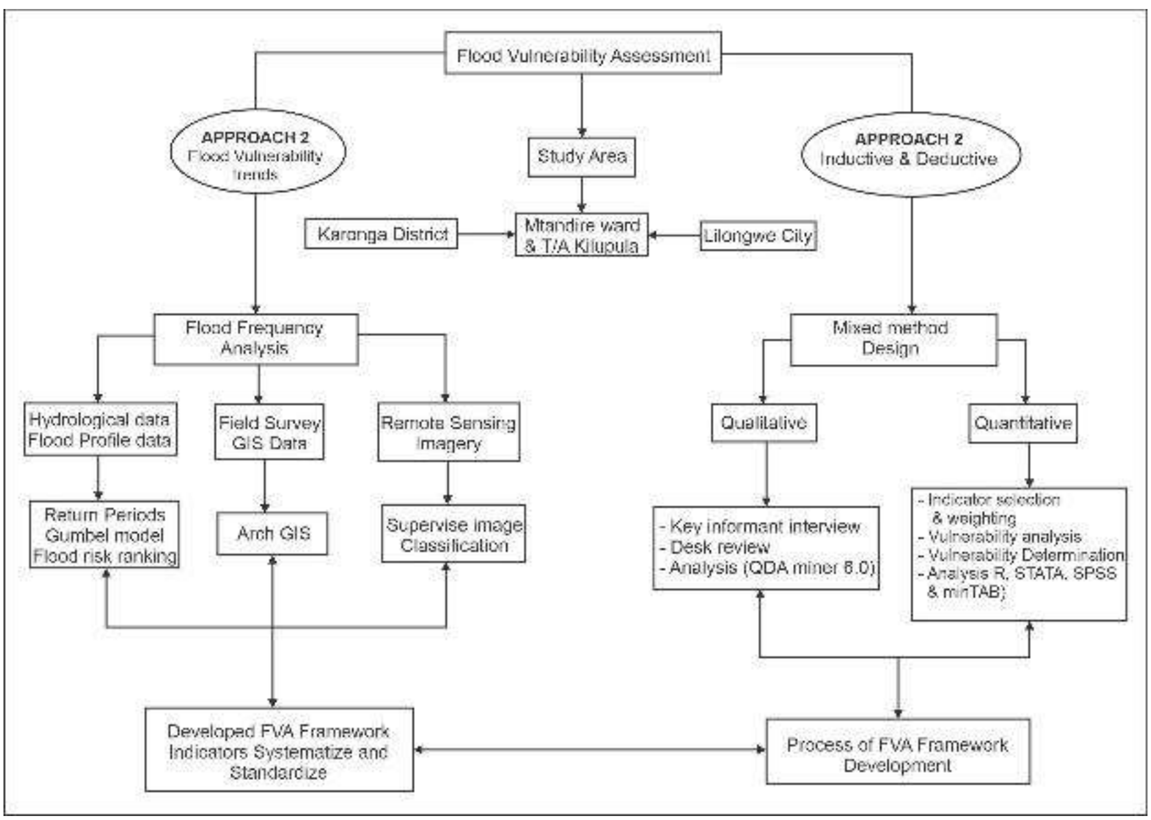


Figure 3.1: Methodology Layout

3.2 Study Approach and Design

3.2.1 Study Approaches

This study carried flood vulnerability assessment (FVA) using two approaches. Firstly, it employed inductive and deductive approaches (Abass, 2018; Kissi et al., 2015; Mwale, 2014). Secondly, it used flood vulnerability trend (FVT) approach (Tanaka et al., 2017). The FVT was implemented through flood frequency analysis (Kissi et al., 2015; Pawar et al., 2019; Samantaray et al., 2020) (Figure 3.1). The use of inductive approach allows the study to apply statistical techniques that helped to isolate variables and indicators that were significant (Broeken et al., 2018; Mwale, 2015; Nazeer et al., 2020). Inductive approach also allowed the study to relate a larger number of variables to vulnerability in order to identify the factors that are statistically significant (Kissi et al., 2015). On the other hand, deductive approach was used to understand vulnerability and capacity (Munthali et al., 2022) through application of Hazard, Vulnerability, Capacity Assessment (HVCA) (Hing et al., 2010). FFA was substantial to assess evidence of flood trends in order to predict household flood vulnerability. It also helped to select indicators based on relationship from theories and conceptual frameworks (Kissi et al., 2015). Machado et al. (2015) indicated that FFA improves the estimation of flood return period. Kissi et al., (2015) state that flood frequency and magnitudes analysis determine the frequency of occurrence.

3.2.2 Study Design

The inductive and deductive approaches adopted a descriptive design which was implemented through mixed methods (Munthali et al., 2022; Kita, 2017). Data was obtained through cross sectional survey using quantitative and qualitative methods (Kita, 2017). The method was opted based on the premise that it allows the researcher to validate the findings (Creswell, 2013). It further helped to evaluate multiple vulnerabilities indicators from the context of flood risk (Munthali et al., 2022; Mwale, 2014). It was also employed to improve the quality of the research based on; firstly, making use of triangulation, which refers to the use of quantitative research to corroborate with qualitative research findings and vice versa (Creswell, 2015). Secondly, it involved use of facilitation that arises when one research strategy is employed in order to aid research using another method (Creswell, 2015). Lastly, it offered complementary when two research strategies are employed in order that different aspects of investigation can be dovetailed (Munthali et al., 2022).

3.3 Study Area

This study was carried out in Lilongwe City and Karonga District in the central and northern regions of Malawi respectively (Figure 3.2). The target population in Lilongwe city were the households in Mtandire ward, specifically in two Group Village Headmen Chibwe and Chimombo of Senior Chief Ligomeka. The target population in Karonga district were households of GVH Matani Mwakasangila and Mujulu Gweleweta in Traditional Authority (TA) Kilupula.

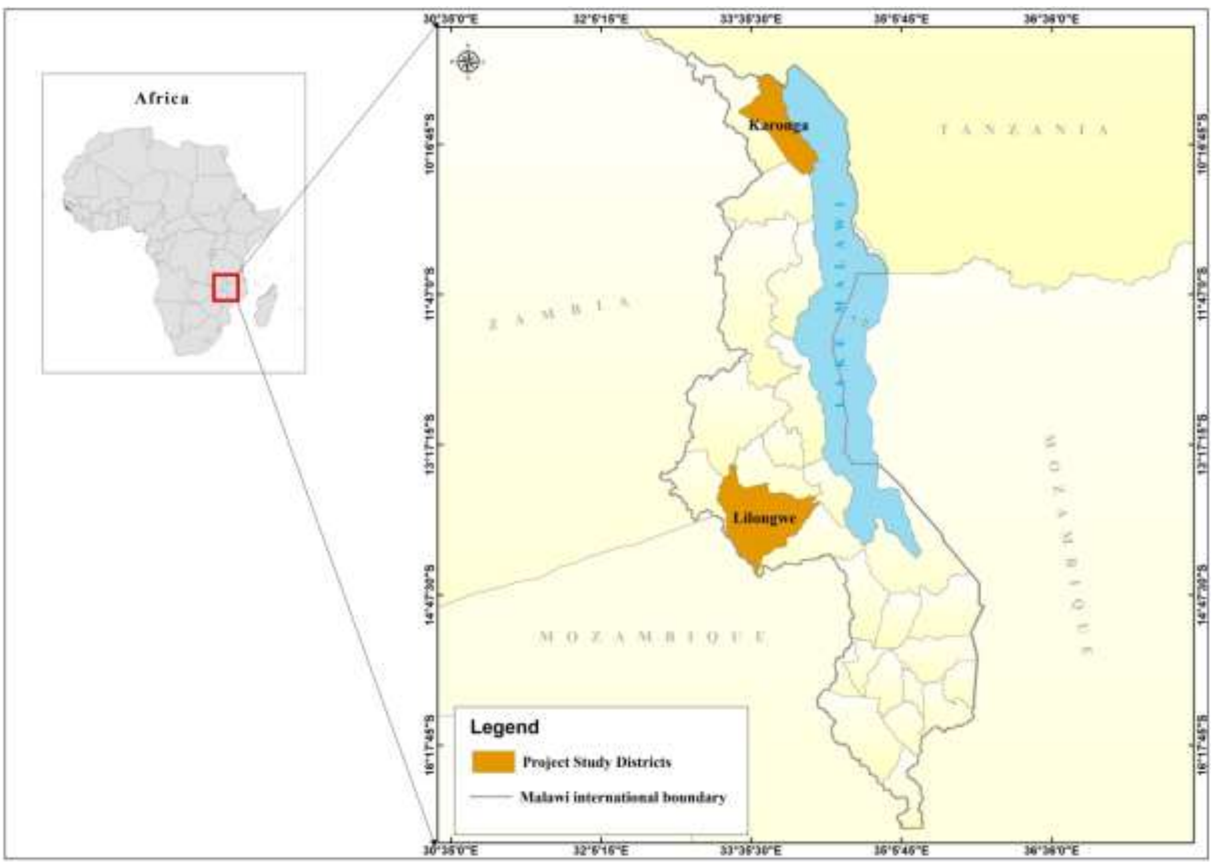


Figure 3.2: Map of Malawi Showing Location of Lilongwe and Karonga

3.3.1 Description of Lilongwe City

Lilongwe district hosts the capital city of Malawi. The district became the host of the Capital city in 1975 after it was relocated from Zomba. The district owes its name from Lilongwe River, which flows across the centre of the district (SEP, 2017-2022). The city has grown tremendously from 2005 when the government relocated all the head offices from Blantyre (SEP, 2017). This growth has been also amplified by the presence of numerous opportunities in the city like access to socio-economic services and availability of markets for the produced products. This growth has contributed in generating a lot of vulnerable conditions of people to hazards such as floods, accidents, fires, droughts, environmental degradation and disease epidemics (LCDRM;2017) because of increased environmental degradation, increased conversion of agricultural land into urban infrastructural development. Though hazards in the city overlap and interact in cause and effect, floods are the most frequently occurring hazards that affect many parts of the city (SEP, 2017). As a category related to water and weather, floods, mostly affect areas like Mtandire, Kauma, Kaliyeka, Chipasula, Kawale, Nankhaka, Area 22, Kauma, New Shire, Area 25, Kawale, and Mgona in the city (LCDRM, 2017).

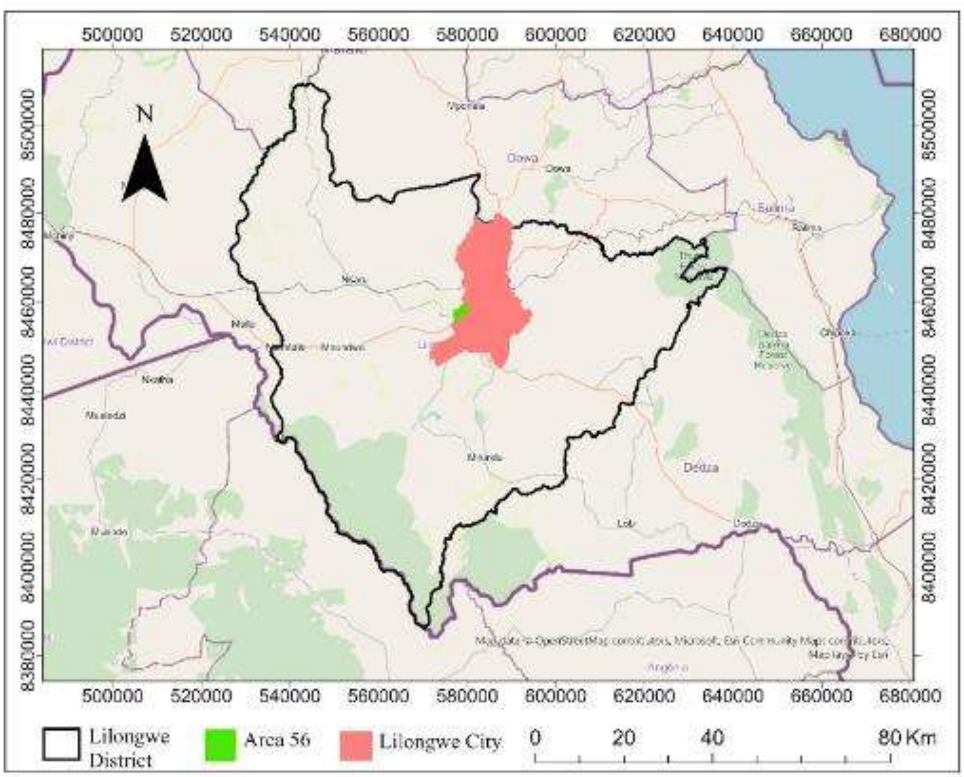


Figure 3.3: Map of Lilongwe City in Lilongwe District (Source: Author)

The city started experiencing the occurrence of flooding in February 2012 in areas of Kaliyeka and Mchesi. The 2012 flooding resulted in the collapse of 6 and 4 houses in Kaliyeka and Mchesi areas respectively. The records indicate that floods repeated in 2013, 2014, 2015, 2016 and 2017. Data indicates that in February 2017, floods caused a magnitude of the disaster which caused great damage; more than 4000 people were affected including loss of people's lives. The affected areas were Mtandire, Kauma, New Shire, Area 25, Kawale, Nankhaka and Mgona. (Figure 3.4).

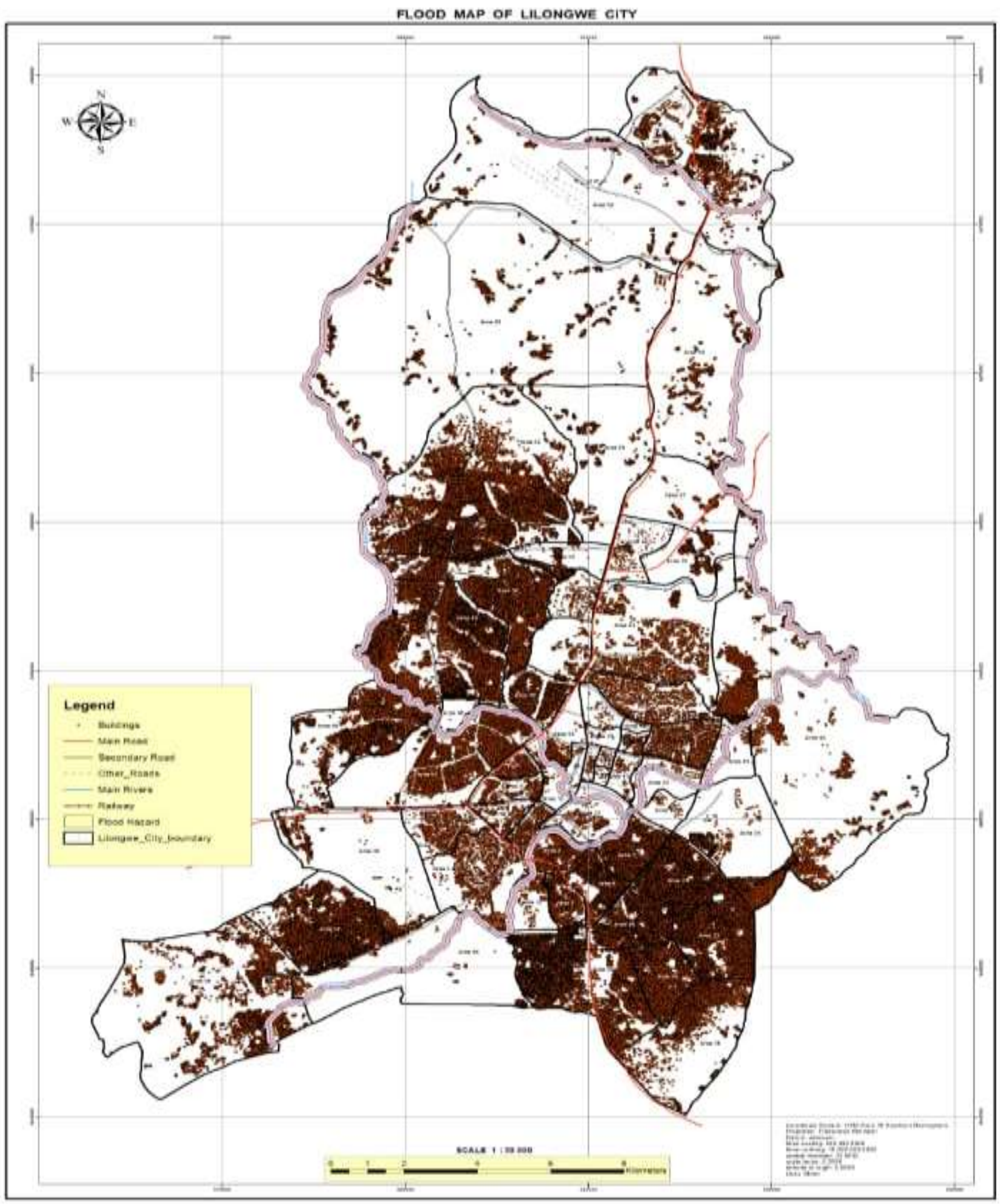


Figure 3.4 showing Flood Map of Lilongwe City

The topography of the entire district is characterised by landform which ranges from extensive plains lying at mid-altitude between 1,000-1,400m above sea level, with isolated inselbergs rising above this level. Ngala hills (1,600 m) and Bunda Hill (1,500m) are the most dramatic, soaring almost sheer from the plain and providing the best-known landmarks in the south of Lilongwe. Similar features are also developed along Lilongwe River (SEP, 2017-2022). These include the Chiwamba, Nkuyu and Nguli hills lying about 1,125m and 1,189m above sea level (SEP, 2017-2022).

The general hydrology of the district is composed of four rivers which drain into the district. These are Lilongwe, Lingadzi, Diamphwe and Bua (Table 3.1).

Table 3.1: Major Rivers in Lilongwe District

Lilongwe	This river runs from the Dzalanyama mountains across the district to merge with the Linthipe river, which forms the border with Dedza district, at the north-eastern tip of Lilongwe district.
Lingadzi	The Lingadzi river runs from the north and merges with the Lilongwe river in Lilongwe city.
Diamphwe	The Diamphwe river runs from the Dzalanyama mountains into the Linthipe river, to form the border with Dedza district
Bua	This river forms the border with Kazungu in the north east of Lilongwe district.

Source: SEP-2017-2022

The geology of the district consists of volcanic and metamorphic rock. The most important rock species are gneiss, granulites and schist as well as important developments of pegmatite rocks (SEP.2017-2020). All these are assigned to what is called 'the Malawi Basement Complex'. In some 5 places these hard rock formations surface, forming mountain ranges and Inselbergs. In the east of the District for example, the hard rock formation is very close to the surface, which challenges drilling for groundwater. In the centre and west of Lilongwe however, the rock formations are masked by a variety of superficial deposits ('soil'), which in some places are of considerable thickness.

The soil of the district is made up of superficial layers, deposited by rivers, streams and wind are referred to as soil and vary in type, depth and maturity (SEP, 2017-2022). The Lilongwe Catena is representative of the ferruginous soil pattern covering the central part of the Lilongwe plain (SEP, 2017-2022). The district is also composed of dark red sandy clay or clay, possessing typical properties of ferruginous soil which dominate the district's flat lying plain, commonly known as the Lilongwe Series (SEP. 2017-2022).

In terms of climate and climate change, Lilongwe district has a warm tropical climate with a mean annual temperature of about 210 Celsius (SEP-2017-2022). The lowest temperatures are experienced in July, ranging between 3.50 C to 12.50 C and the highest temperatures in October-November rising up to 390 C (SEP, 2017-2022). The district experiences three seasons namely the cool dry season from April to July, the hot dry season from August to October and the hot wet season which generally starts from November to mid-April.

Lilongwe district has three meteorological stations which record rainfall on a regular basis. These are Kamuzu International Airport, Chitedze Research Station and Malingunde. Rainfall data from these stations gives clear evidence of rainfall variability over the rain season. Table 1.4 below presents the monthly average rainfall figures recorded at Kamuzu International Airport over from 2013 to 2017 as a typical example of rainfall variability.

Table 3.2: Monthly Rainfall Trends in Lilongwe District from Selected Met Stations

Year/ Season	Recorded average rainfall per month (mm)						
	October	November	December	January	February	March	April
2013-2014	-	38.4	202.0	318.2	227.9	32.2	69.5
2014-2015	2.4	4.7	235.9	206.7	131.8	26.7	47.0
2015-2016	-	32.2	216.1	204.3	159.3	136.5	24.9
2016-2017	26.6	2.4	68.8	286.2	227.0	110.8	2.3

Source: Lilongwe District Council Socio-economic profile: 2017-2022

Table 3.2 shows that Lilongwe district has over the past five years been experiencing significant variations in amounts of rains (Table 3.2). For instance, the 2013-2014 season, had more rains but the rainfall season was very short. The rains started in November and ended in mid-March. In comparison, the 2016-2017 rainfall season was longer with rains starting in October and ending in April. Such unpredictability in the rainfall patterns are affecting people's livelihood activities, particularly agricultural activities.

This research study was carried out in Mtandire ward (area 56) due to informal settlements which have the existing vulnerability conditions that have potential to put households at risk to flood hazards and disasters.

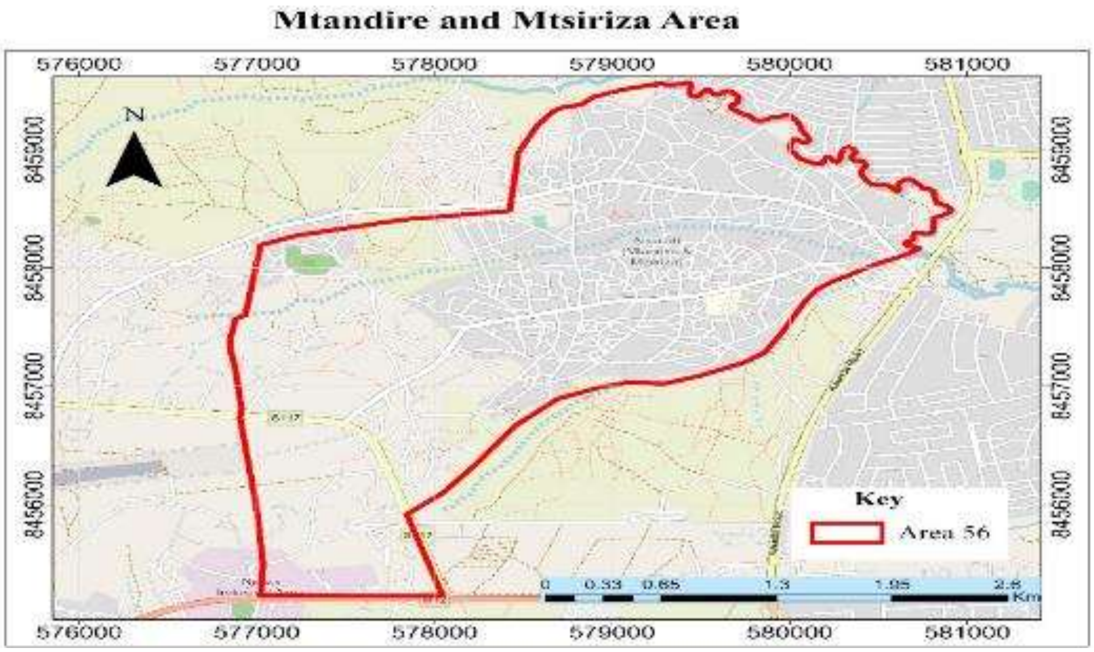


Figure 3.5: Map of Mtandire and Mtsiriza Area in Lilongwe city

Mtandire Ward is an informal settlement which is found in Senior Chief (SC) Chigoneka. Therefore, this study targeted households in Senior Chief (SC) Chigoneka of Mtandire Ward. The area of SC Chigoneka is bounded by Lingadzi drainage system (Figure 3.6). This river system is prone to flooding, making the residents susceptible to disasters. This increased flooding in the area is shocking many people in the sense that floods have been perceived a rural manifestation for a long period in the country. However, an observation that was made in the area is that there are intertwined vulnerabilities existing among the residents that trigger floods to become disasters. Key among these are dilapidated houses, weak materials that people use to construct their homes and lack of protective measures in the riverbanks, land use and human occupancy, sand extraction and brick making among others.

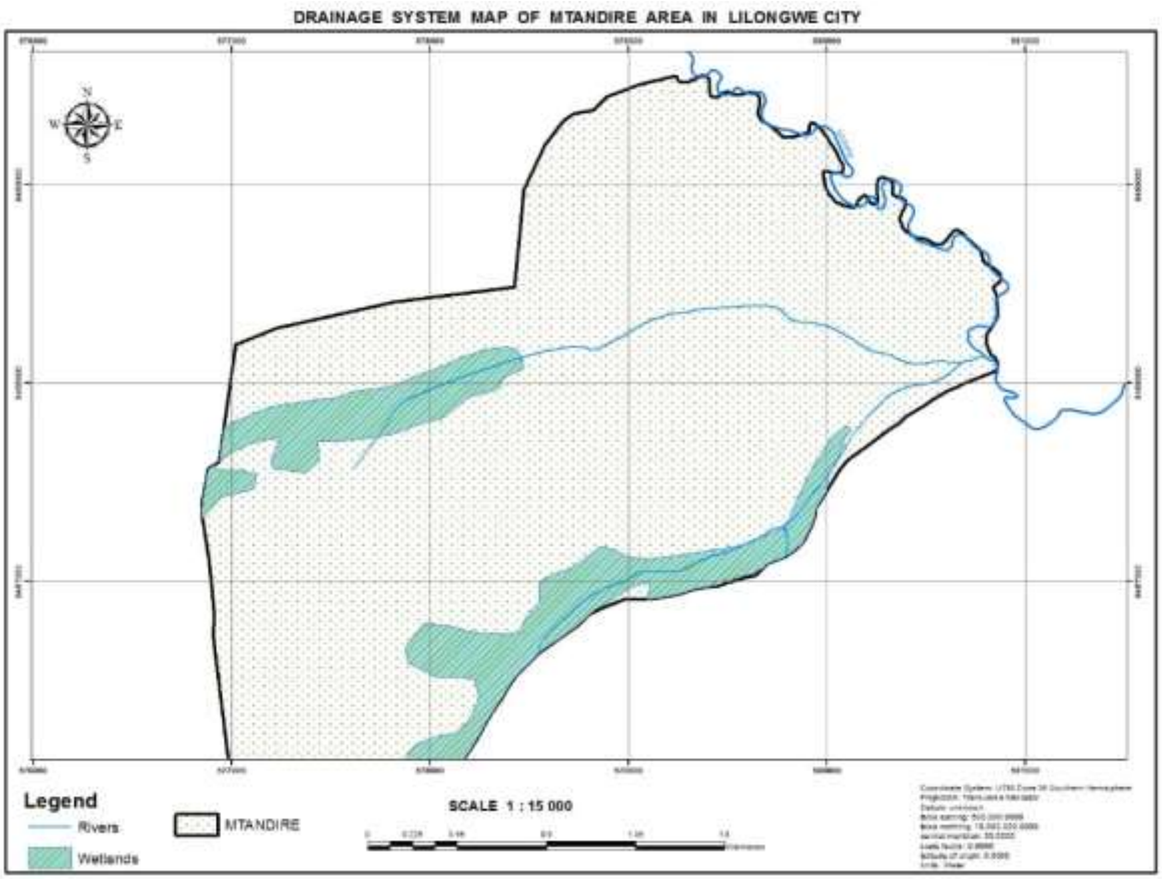


Figure 3.6 Map showing the Drainage System of Mtandire Ward in Lilongwe City

3.3.2 Description of Karonga District

Karonga lies between latitudes 09º E and 10º S along 33º longitude (District Environmental Outlook, 2015). The district covers an area of 3,355 Km^2, which is about 3.5% of national total land area (94,274Km^2) (Socio-economic profile (SEP), 2013-2018). Its main topographic features are the flat rift valley plain along the lakeshores 500meters to 600metres, the rift valley escarpment zone 601metres to 1400metres and the high hills and plateau zone 1401metres to 2000metres above sea level (SEP, 2009-2012). The district has an estimated population of 307,216 (NSO, 2012) now estimated at 365, 028 (NSO, 2018) people which represent 2.08% of the total population of Malawi (SEP, 2013-2018).

The proposed demarcation of the district as a "municipality" include areas of Paramount Chief Kyungu T/A Karonga and as a "district council" include T/As Wasambo, Mwirang'ombe

Kilupula and Mwakaboko (SEP-2013-2018). In the traditional setup, the district is also subdivided into 39 Group Village Heads (GVH) with 50 Village Development Committees (VDC) and 336 Villages (SEP, 2013-2018).

The elevation of the district ranges from 400m at the lake shore to 2400m at the high Nyika Plateau (SEP-2013-2018). The district is predominantly hilly, especially west of Lake Malawi. The most outstanding landforms in the district are divided into three zones: a) the High Hills and Plateau, b) the Rift Valley Escarpment and c) the Lake shore Plain (Kushe et al. 2015). The high hill zone ranges from about 1400m to 2000m above sea level and is characterised mostly by the Nyika Plateau (SEP-2013-2018). The rift valley escarpment zone ranges from about 600m to 1400m above sea level (SEP, 2013-2018). The Lake shore Plain is relatively a flat zone covering an area of an altitude between 500m to about 600m above sea level (SEP, 2013-2018). The area consists of largely alluvial plains, valley flood plains and marshes that extend from 4 km to about 20 km in width. It is characterised by hills with moderate to steep slopes rising above the Lakeshore.

The district experiences warm temperatures with a mean annual temperature of 24°C. Mean minimum temperatures range from 17°C to 23°C and occur between June and July. Mean maximum temperatures range from 27°C to 33°C and are registered between October and November (Karonga Met Office, 2021). The mean annual rainfall for the district is about 1400 mm. The highest rainfall in the district is experienced around Mwangulukulu (Traditional Authority Kilupula) area where normally annual rainfall of around 3000 mm is experienced due to the topography (Karonga Met office, 2021). Most of the rains in the district fall between March and April when the main rain bearing system, Inter Tropical Convergence Zone (ITCZ) is anchored within the district as it progresses northwards (Karonga Met office, 2021). This triggers high intense rainfall that results in floods in the low lying areas of the district (Karonga Met Office, 2021).

The Lake shore Plain has been characterised by occurrence of high magnitude and increased frequency of floods causing disasters (SEP-2013-2018). The district is made up of weathered ferralitic soils, lithosols and undifferentiated soils, alluvial soils, often calcimorphic soils (SEP, 2013-2018). The low lying areas which are usually prone to flooding are also characterised by fertile alluvial soils (SEP-2013-2018). This soil makes the households to have little interest for relocation as a way of promoting DRR and reducing vulnerability (Mwalwimba, 2020).

Though flooding is not limited to a particular geographic area, the areas hardest hit includes those of T/A Kilupula and Paramount Chief Kyungu (DODMA, 2022). Karonga town is also the hardest hit by flooding in the jurisdiction of Paramount Kyungu (Manda et al., 2017). However, this study considered T/A Kilupula because of its historical background in terms of flood occurrence which provided a good comparison between a rural area and urban area. T/A Kilupula was further considered because it is classified as rural under Karonga District Council (Karonga District Classification, 2022). Therefore, because definition of what is rural depends on perception, this study defined the area as rural, based on the district council classification system. As such rural in this study means an area that by geographical demarcation has been administratively designated as a rural area and looks upon the district council to provide the needed resources and support to the citizenry.

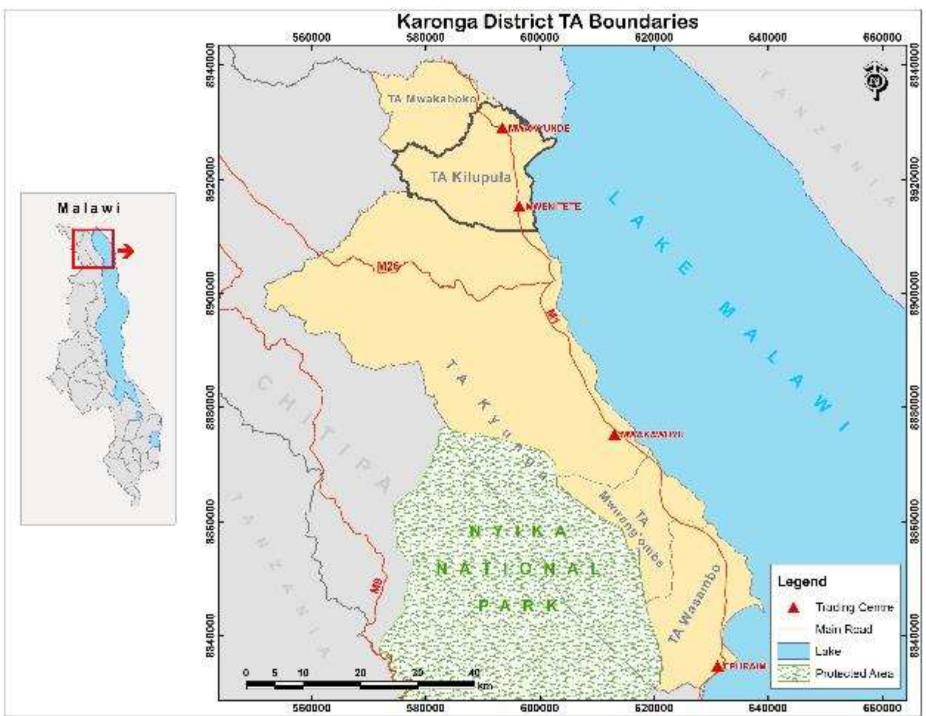


Figure 3.7: Map of Karonga District showing location of Traditional Authority Kilupula

The documented evidence of vulnerability to floods in Karonga district dates back to the early 1960s (Manda et al., 2015). However, by 1981 records about floods started to be seriously documented following a major flooding disaster which destroyed most of the old town along the lakeshore in 1980s (Lunduka et al., 2013). Macheyeki et al. (2014) indicate that in 1979/80, floods occurred because the water level in Lake Malawi rose from 471 m above Karonga reference level in 1915 to 477m in 1980. Kushe et al. (2014) noted that the rise of the lake induced flooding damage to the old town and led to relocation of the commercial centre to the current site in 1987. As a response to the Gitec Consult feasibility study that showed that Karonga town was at risk mainly due to out bank of North Rukuru River, dykes had to be constructed to control any recurring flood occurrences. Despite the development of dykes, the recorded data on floods since 1974 (Table 3.3) indicates that the north (in T/A Kilupula) and north west (in Paramount Kyungu) are affected by various types of floods which are common along rivers Rukuru, Lufilya, Songwe, Kyungu and Lake Malawi. The wide range of river networks means that the swelling of rivers due to heavy rains has devastating effects to the livelihoods of the people living close. The trend of floods from 1974 to 1992 shows that Karonga South and Central did not experience much flooding because the environment was not much degraded (DFEP, 2016) (Figure 3.8)

Table 3.3: Trends of Floods and Affected Areas in Karonga District (1974-2020)

Year	**Rivers/ Lake**	**Areas Affected**
1974	Rukuru and lake Malawi	North, North West
1978	Rukuru, Lufilya and Songwe	North, North West
1983	Rukuru, Lufilya and Songwe	North, North West
1988	Rukuru, Lufilya and Songwe	North, North West
1992	Rukuru, Lufilya and Songwe	North, North West
2010	Songwe and Kyungu	North and Central
2015	Rukuru	North and Central
2020	Various rivers	North, Central and South

Source (District Flood Evacuation Plan, 2019)

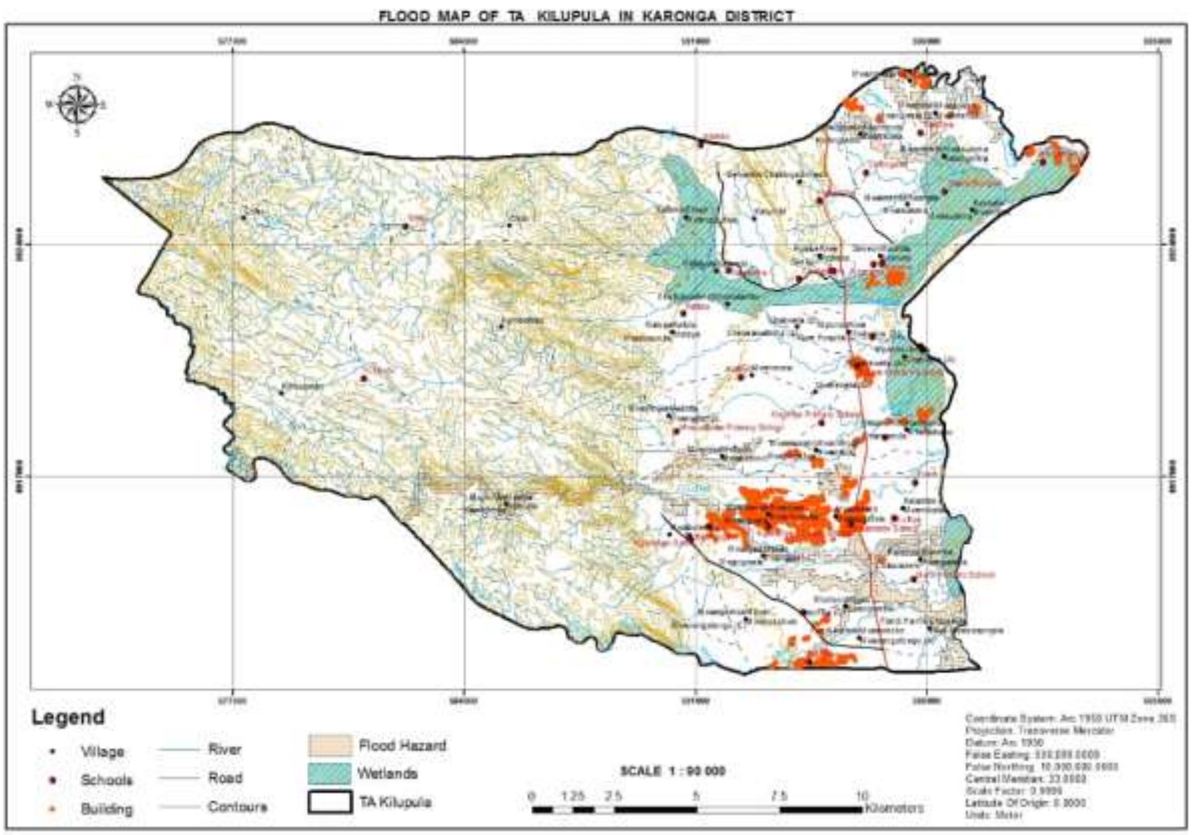


Figure 3.8: Flood Map of T/A Kilupula in Karonga District

This study targeted two group village headmen (GVH) in T/A Kilupula of the northern part of Karonga district. These include GVH Matani Mwakasangila and Mujulu Gweleweta in Traditional Authority Kilupula (Figure 3.8)

The area of GVH Matani Mwakasangila is found in T/A Kilupula located about 16 km north of Karonga town. GVH Matani Mwakasangila has five Village headmen (VH) namely Eliya Mwakasangila, Matani Mwakasangila, Chipamila, Shalisoni Mwakasangila and Fundi Hamisi. The greater part of the area - Eliya Mwakasangila, Chipamila and Matani Mwakasangila, are bounded by Lake Malawi to the eastern side and M1 road-Songwe-Tanzania border to the Western side. The other two villages Shalisoni Mwakasangila and Fundi Hamisi are to the Western side of the M1 road. The area has numerous networks of rivers such as Lufilya, Kasisi, Fwira, Ntchowo, and Kasoba. The area has two primary schools (Maro and Ntchowo) and one health post at Miyombo in VH Fundi Hamisi. The main hospital for the area is Kaporo Rural Hospital located at latitude (0595943) and longitude (8920187) in GVH Gweleweta. Serious cases are referred from Kaporo Rural Hospital (KRH) to Karonga District Hospital (KDH), which is the referral hospital in the district. The area has no Flood Evacuation Centre such that during floods, victims are forced to camp in classroom blocks and sometimes others temporarily stay on the main road and churches

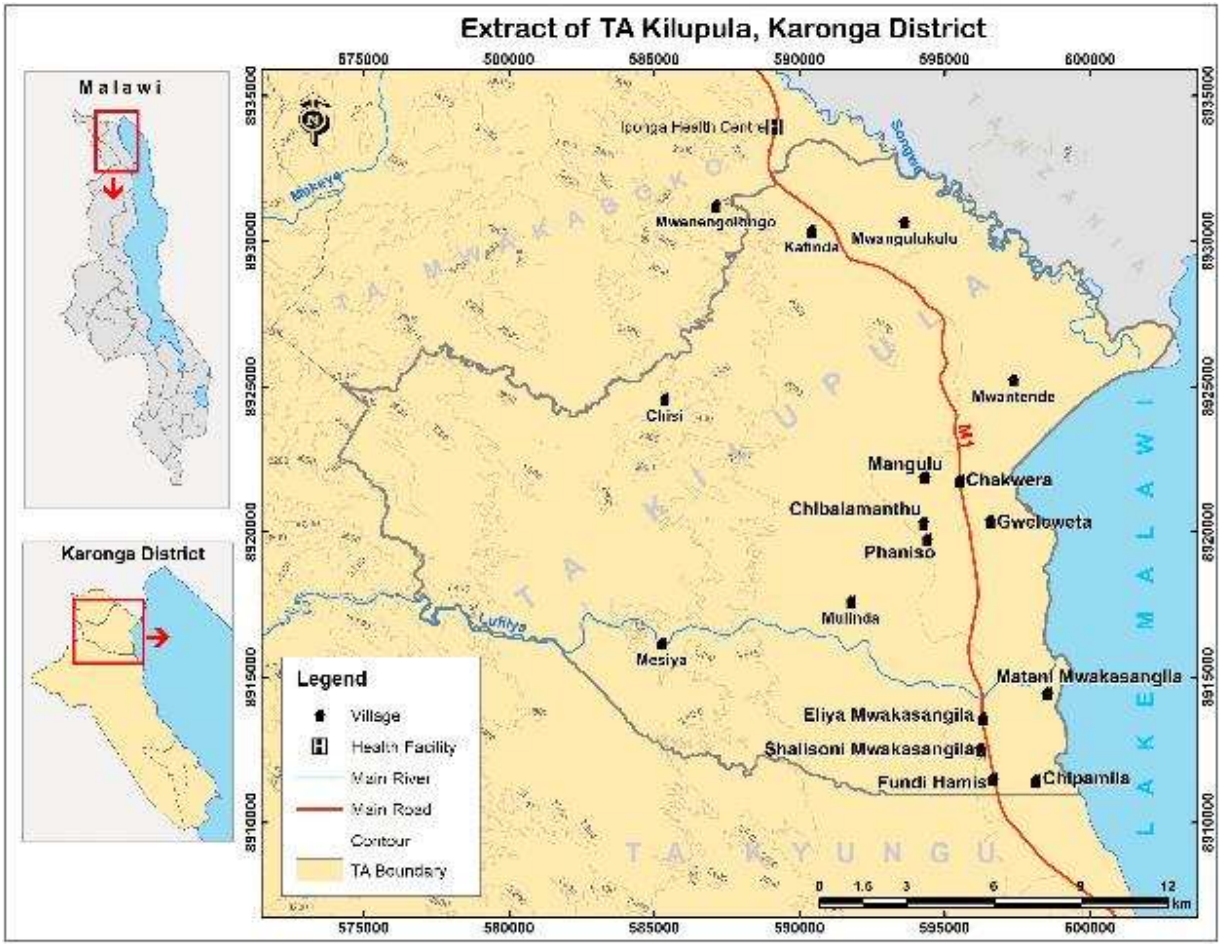


Figure 3.9: Location of GVH Matani Mwakasangila and Gweleweta in Traditional Authority Kilupula. Source (Author: 2022)

Similarly, the area of GVH Mujulu Gweleweta is found in T/A Kilupula located about 22 km north of Karonga town. GVH Mujulu Gweleweta has seven Village headmen (VH) namely James, Gweleweta, Chakwera, Chimalabanthu, Mangulu, Yarero and Phaniso. Five villages (Phaniso, Chimalabanthu, Chakwera, Mangulu and Gweleweta) were chosen because these are the most vulnerable villages to floods. Two villages within the GVH (Chakwera and Gweleweta) are bounded by Lake Malawi to the eastern side and M1 road –Songwe- Tanzania boarder to the Western side. The other three villages; Chimalabanthu, Phaniso and Mangulu are to the Western side of the M1 road. The area has numerous networks of rivers such as Kiwe/Kaundi, Mayofya, Wiloye, and Ngalamu (Figure 3.9). The area has two primary schools (Kiwe and Kaporo) and one hospital that is Kaporo Rural Hospital. During floods, victims are camped at a Church that is used as rescue centre located in VH Chimalabanthu at latitudes (0594345) and longitudes (8920197) with height above sea level as 496 metres.

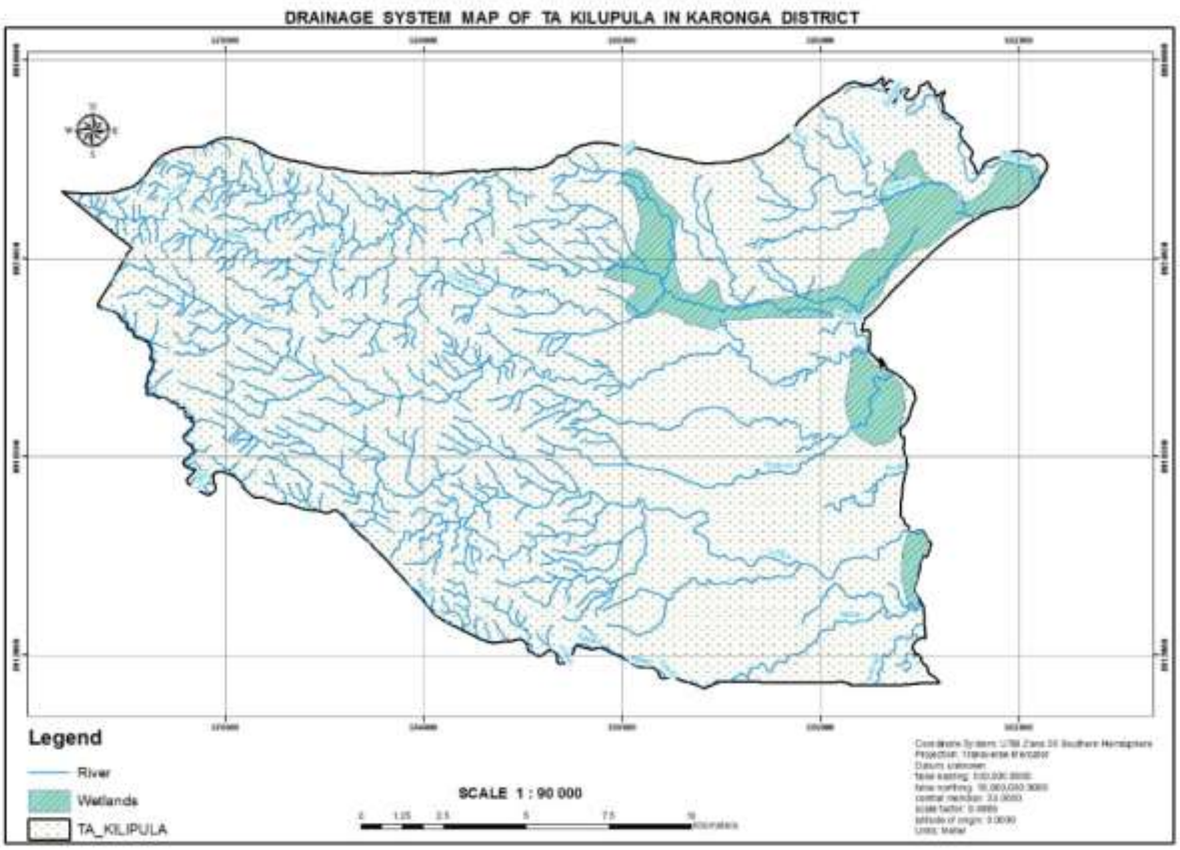


Figure 3.10: Map showing drainage Systems of T/A Kilupula in Karonga District

The two areas (under GVH Matani Mwakasangila and Mujulu Gweleweta) were chosen because the nature of their locations is prone to flooding (Mwalwimba. 2020; SEP-2013-2018). This makes the residents vulnerable to flood hazards that cause disaster every year (SEP, 2013-2018). Secondly, the areas are dominated by flood plain along the shores of Lake Malawi (SEP-2013-2018). These areas are flat and low-lying areas as such this becomes the pre-requisite to flooding in the event of a heavy downpour (Karonga Met Office, 2021). Thirdly, the choice of these two areas is due to high population growth rate and issues of culture that have forced the people to occupy dangerous areas and even occupy the protected areas rendering them vulnerable to the effects of flooding (Mwalwimba, 2020). Lastly, the last flood in these two areas occurred recently in 2021; that was easy to be verified from officials responsible for flood management

(DODMA, 2021). Moreover, the fact that flooding in these areas occurred more recently implies that respondents could easily remember their flood experiences.

3.4 Spatial-Temporal Household Flood Vulnerability Trends (STFVT)

Flooding trend analysis is an important component of flood vulnerability assessment (Kissi et al., 2015). It is of assistance in water resources management and provides better ways of preventing events that cause harm to people. Therefore, to achieve this objective, this study carried out a flood frequency analysis (FFA) using three methods namely hydrological assessment, GIS and Remote Sensing.

3.4.1 Data Collection

The methods employed to carry out the FFA was constituted in a three-phased process as follows:

3.4.1.1. Hydrological Assessment

Hydrological assessment to analyse flood vulnerability trends used baseline hydrological and disaster profile data. Hydrological data was collected from Department of Water Resources in the Ministry of Water and Sanitation for the period of 1980-2006 (Lingadzi River) in LC and 1980-2006 (Lufilya River) in KD. The data that was collected included annual water flow rate, annual discharge and annual precipitation from the gauging stations of Lingadzi and Lufilya River. The collected data was used to work out the return period, annual peak discharge, expected floods, probabilities of flood occurrences and trends in the hydrologic parameters such as annual precipitation, flow rate and run-off. Kissi et al. (2015) state that insights into flood frequency is provided by the return period analysis.

3.4.1.2 Geographical Information System (GIS)

Geographical Information Systems (GIS) provide powerful tools for dealing with space data. They are very effective for archiving, displaying, analyzing and modeling geographic data. These tools are useful for supporting decision-making processes (Suárez et al., 2019). GIS analysis can be used for modeling the magnitude of flood risk areas with rainfall, elevation and slope, drainage network and density, land use, land cover and soil types (Wang, 2015). The technique can help to build strong preparedness and mitigation measures during flood event, pre and post stages hazard control. Realising this significance, this study collected spatial data using Geographic Positioning (GPS) from Lingadzi and Lufilya catchments. 21 location points, 9 from Lingadzi and 13 from Lufilya were collected using GPS receiver (Figure 3.10a and b).

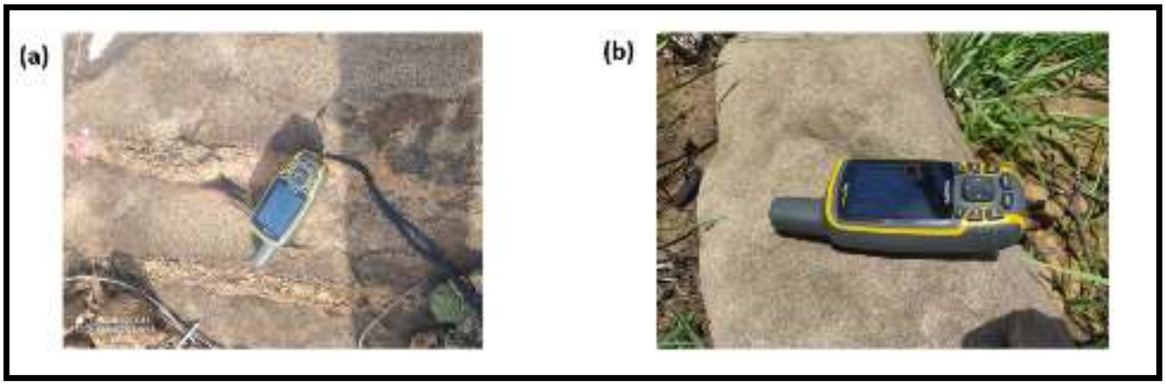


Figure 3.11: GPS Receivers used for data collection

The use of Digital Elevation Model (DEM) in ArchGIS with Geo Spatial Stream Model Extension such as HEC GeoHMS provides a powerful strategies for flood mapping as well as river profiles. However, this study used GPS receivers collected information relating to profiles of Lingadzi and Lufilya rivers within their catchments in order to show evidence of flooding for vulnerability prediction. The spatial data (coordinates) were collected at each point of the river meander. The difference between selected location points in Lufilya and Lingadzi was based on the size of the distance covered by the households that were selected during the survey. In addition, the chairperson of the VCPC helped to locate the profiles where the river was passing by in the past years (Table 3.4). Furthermore, observation was used to crosscheck the profiles of the river in order to collect coordinates in the proper location for analysis and interpretation. Google Earth was used to download the base map image (OpenStreetMap) of the old profiles of Lingadzi and Lufilya rivers. The image used was a baseline polyline of the rivers. From the polyline image, coordinates were collected in all the profiles that were created by the flooding events.

Table 3.4: Sample Matrix Used to collect Location Points

Point target	Selection method	Data source	Data collection tool
River meander	• Transect walk • VCPC guides • Profile of a river	Field survey OpenStreetMap	GPS

3.4.1.3 Remote Sensing

Rapid delineation of spatial extent of flooding is great important for dynamic assessment of flood evolution and corresponding emergency strategies (Zhang et al., 2012). Remote sensing provide valuable information on flood extent and dynamics (Yu, 2019). It provides chance to delineate flood extent, and estimate flood damage as well as risk analysis and mitigation. Therefore, this technique to understand catchment morphology of Lufilya and Lingadzi rivers. The technique involved using datasets like Landsat images, administrative boundaries for Malawi, and other shapefiles, in particular, rivers. 30m spatial resolution satellite images of the study were obtained from USGS Earth Explorer under Landsat Collection 1 Level 1 archive. The USGS provides some satellite image archives free of charge ranging from 1970s to present (Wulder *et al.*, 2016). The vector shapefiles of the study area were downloaded from MASDAP website and pen-source website respectively. The method involved the use of supervised image classification (Figure 3.12).

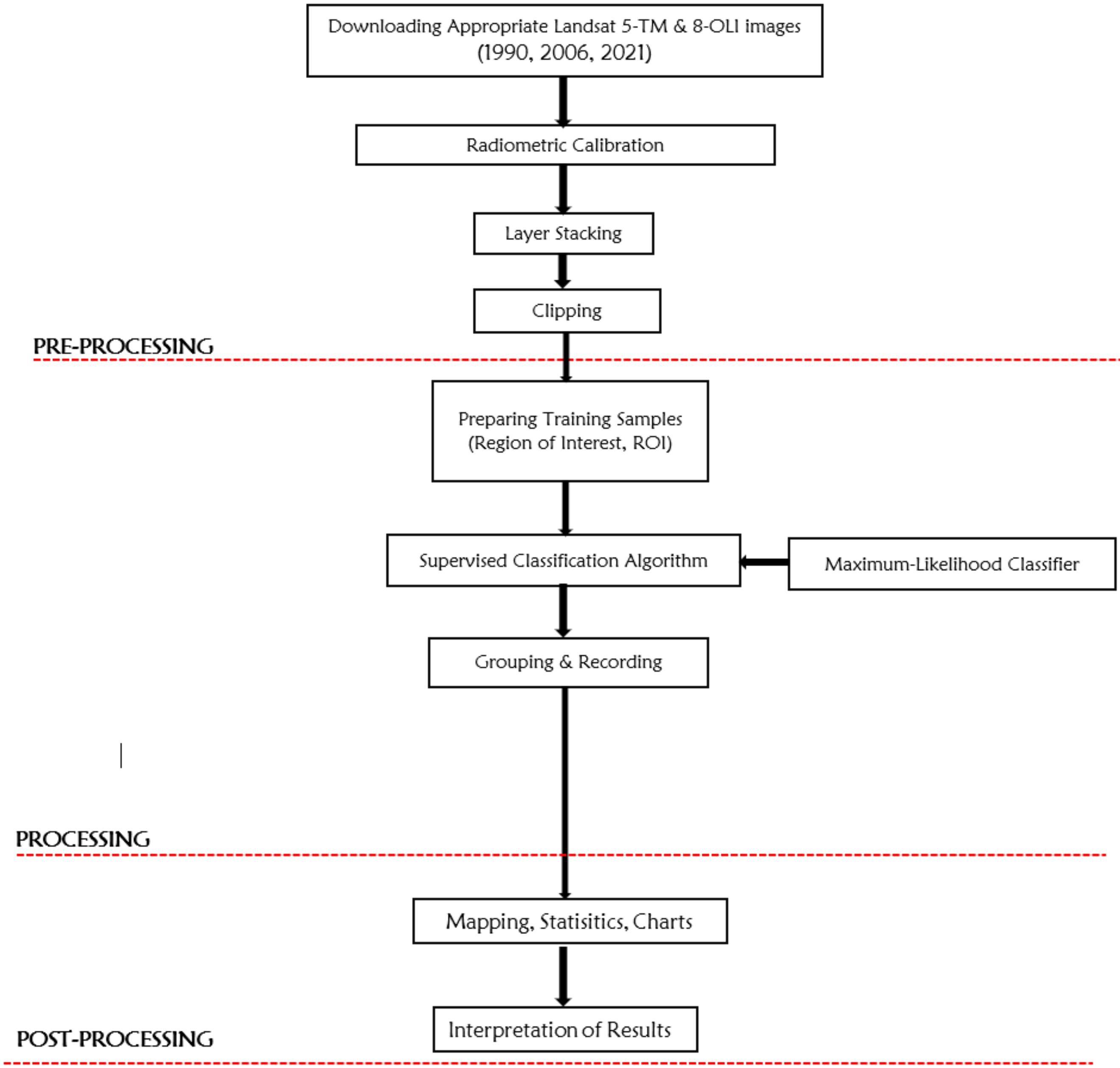


Figure 3.12: Methodology Flow Diagram for Supervised Image Classification

In this study, the satellite images downloaded were from the same season of the year and with the same spatial resolution for the study periods 1990, 2006, and 2021. Thus, images ranging from September to November were obtained for the reason that a couple of images from this period had little or no clouds. The images were extracted to Tiff formats for processing and the details of image properties acquired (Figure 3.12).

Table 3.5: Utilised Metadata of the Satellite images

Year	Satellite	Acquisition Date (yyyy, mm, dd)	Path/Row	Spatial Resolution	Study Extent/Subset
1990	Landsat 5 TM	1990-10-06	169/067	30m	TA Kilupula
	Landsat 5 TM	1990-10-15	168/070	30m	Mtandire ward
2006	Landsat 5 TM	2006-09-16	169/067	30m	TA Kilupula
	Landsat 5 TM	2006-08-24	168/070	30m	Mtandire ward
2021	Landsat 8 OLI	2021-11-12	169/067	30m	TA Kilupula
	Landsat 8 OLI	2021-10-04	168/070	30m	Mtandire ward

This study used six satellite imagery data for a study period between 1990 and 2021, at 16- and 15-year intervals for Lilongwe city and Karonga district (Table 3.5). Every image was subjected to Radiometric Calibration in order to convert Digital Number Values to Reflectance. The term "Digital Number" or "DN" refers to pixel values that have not yet been calibrated into physically meaningful units, whereas "reflectance" refers to the ratio of incident radiation to reflected radiation (de Keukelaere et al., 2018). To calibrate the pixel values and adjust for faults in the values, radiometric correction is used. The method increases the quality and interpretability of remotely sensed data. When comparing numerous data sets across time, radiometric calibration and corrections are very crucial (Humboldt State University, 2019). This calibration process was carried out using sensor-specific data (MTL file). The metadata file saved with the image bundle downloaded provided the essential information to perform Radiometric Calibration in the case of Landsat data.

Landsat images span huge areas; one Landsat 8 OLI scene, for example, covers 185 km by 180 km. The raster files were enormous in terms of disk space (about 1GB), and processing might take a long time. The actual region of interest was frequently substantially smaller. As a result, Landsat images were clipped and the exact extent that only included the area of interest, Lilongwe city and TA Kilupula, were acquired using respective vector shapefile for each study area. This resulted in a reduction in both disk space and processing time. The Landsat dataset was successfully clipped using ENVI 5.3 Software. This procedure resulted in the creation of a new dataset including solely the Landsat image data subset.

Satellite bands were composed in different ways to identify surface features in the study area. For instance, true colour composite is usually known as RGB 321 combination where band 3 reflects red colour, band 2 reflects green and band 1 reflects blue colour for Landsat 5 TM except for Landsat 8 OLI where true colour composite corresponds to RGB 432. This was the case since different satellite sensors have different spectral properties. Another composite called "false-colour composite" which uses an RGB combination of 432 and 543 for Landsat 5TM and Landsat 8 OLI respectively were employed. In this band combination band 4 represents the Near Infrared (NIR), band 3 belongs to red, and band 2 to green for Landsat 5 TM. Whereas in Landsat 8 OLI, band 5 represents the NIR band, band 4 belongs to red, and band 3 green. False-colour image band combination gives better visualisation in identifying vegetation that looks red given NIR, Red and Green bands RGB combination. Figures below illustrates images of each study area generated using the false-colour 432 (Landsat 5 TM) and 543(Landsat 8 OLI) band combination, where vegetation is seen as red and dark red, water correspond to shades of blue, while the built-up area is seen as cyan (light blue) and bare land as brownish.

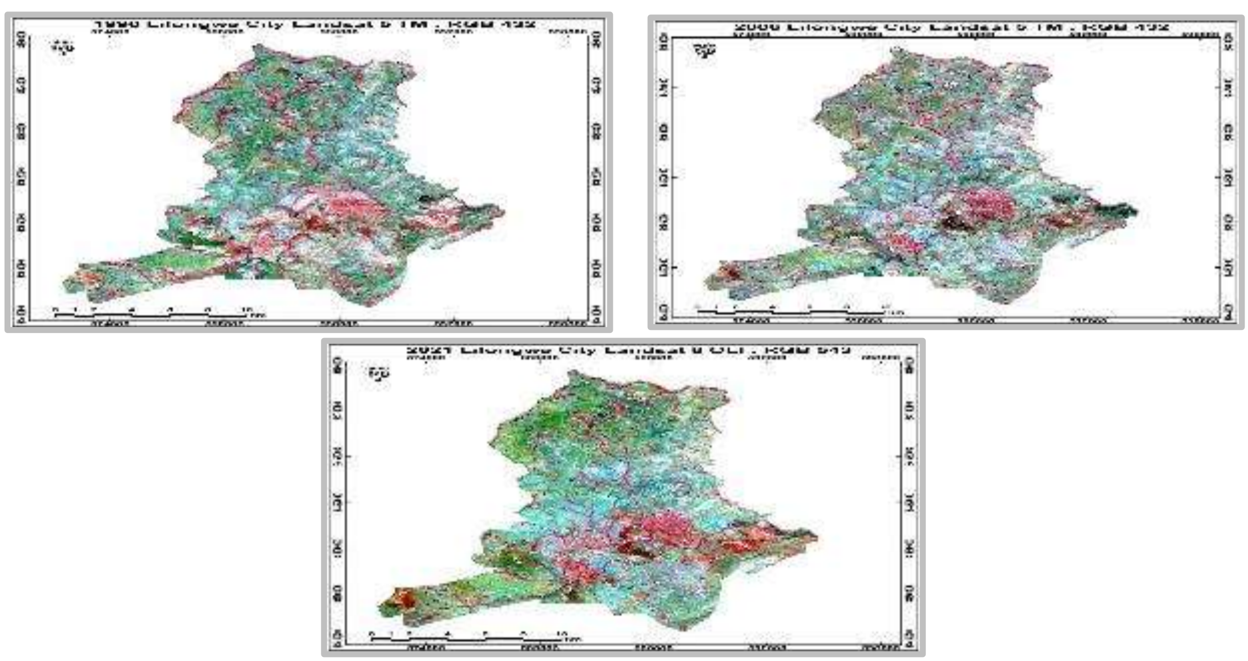


Figure 3.13: Lilongwe City RGB False Colour Composites of the Landsat Images

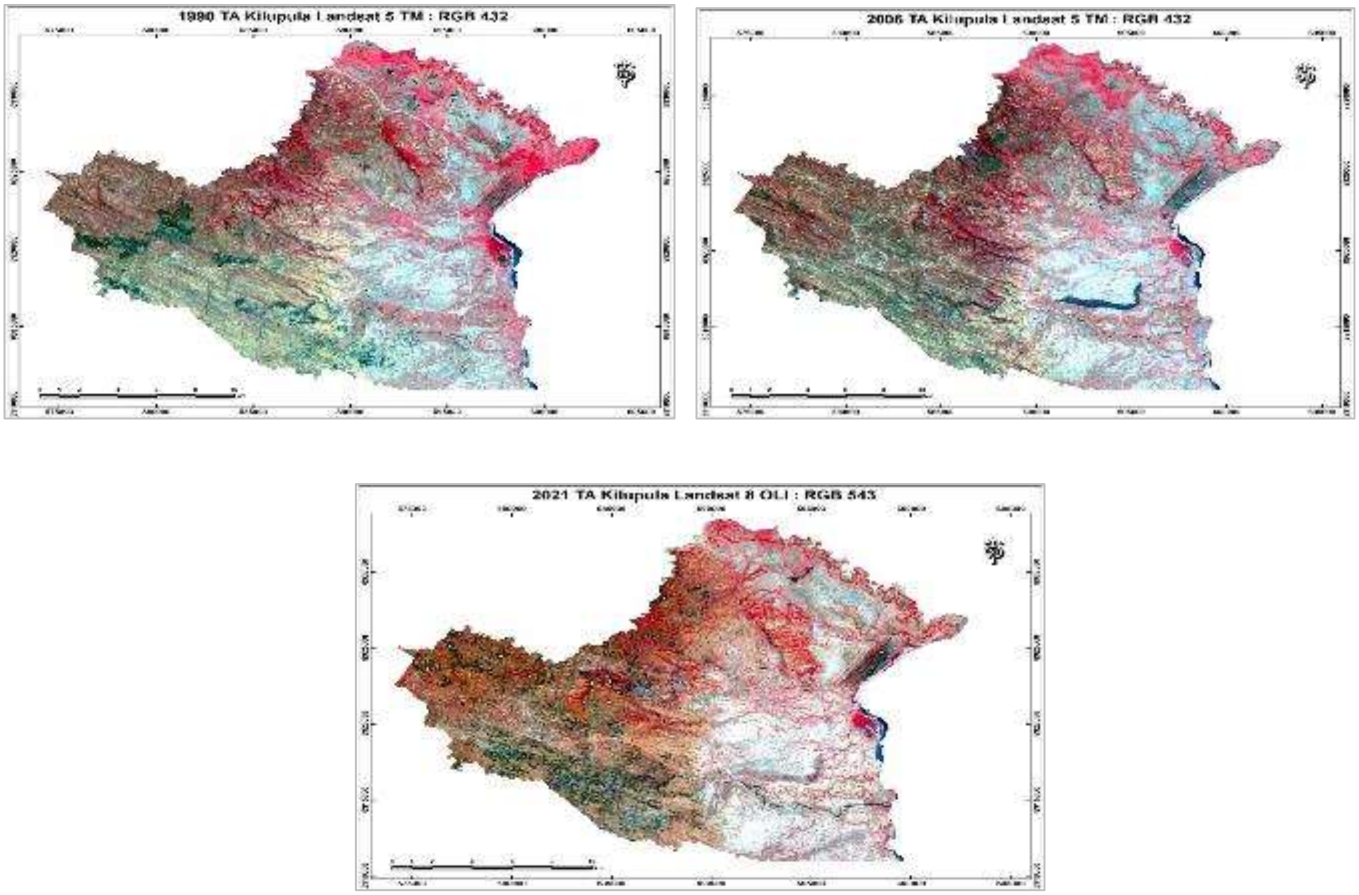


Figure 3.14: TA Kilupula RGB False Colour Composites of the Landsat Images

3.4.2 Data Analysis

Floods estimation provides better practices on flood prevention, protection and mitigation (Jian et al., 2014). It can be useful for designing hydraulic structures and estimation of magnitude of possible future floods (flood design) (Ngongondo et al., 2011). Therefore, applying modern methods to established and estimate floods have been recommended as practical solutions to estimate floods (Grek et al., 2020; Machado et al., 2011; Silvia et al., 2012). This study therefore, used three sets of datasets (hydrological from gauged stations, GIS field survey and remote sensing imagery) as discussed in sub sections 3.4.2.1-3.4.2.3.

3.4.2.1 Hydrological Analysis

Rainfall analysis in the catchments of Lufilya and Lingadzi was performed using Excel to determine descriptive statistical values of mean, maximum, minimum and median in the category of averaged annual precipitation, flow rate and run-off for the period of 1980-2006 in both catchments (Lufilya and Lingadzi). The determination of higher or low precipitation and flow rate was based on the modified Fournier index (MFI), which expresses the sum of the average monthly rainfall aggressiveness index at a location (Dimitriou, 2013). The MFI uses the scale of low to high rainfall aggressiveness in the catchment as follows: <100, moderate aggressiveness: 100–300, high aggressiveness: 300–400, and very high aggressiveness: >400. Therefore, this study checked the averaged summation of precipitation, flow rate and run-off to determine the catchment with higher rainfall aggressiveness. Run-off was calculated based on the curve number method (CNM). The CNM is based on the recharge capacity of the watershed. The recharge capacity is determined by antecedent moisture conditions and by the physical characteristics of the watershed.

Flood frequency analysis (FFA) was used to determine flood vulnerability trends for Lingadzi and Lufilya catchments in LC and KD. FFA was done using Gumbel statistical distribution test (Samantaray et al., 2020). The test is used to obtain flood return periods, discharge and exceedance probability (Bhat et al., 2019; Parhi, 2018). The test is further used to obtain mean, variance, standard deviation, probability (percentage) and discharge (Pawar et al., 2018; Sraj et al., 2015). Similarly, this study used the test to calculate return periods employing 2, 5, 10, 25, 50, 100 and 500 years to forecast expected floods in LC and KD using Lingadzi and Lufilya river catchments. Then floods of various return periods were correlated with household responses in order to understand household flood vulnerability. Machado et al. (2015) stressed that FFA improves the estimates of the probabilities of rare floods by using interval of return periods. Though literature presents varied methods of undertaking FFA (Grek et al., 2020; Jian et al., 2014; Machado et al., 2020), this study applied the statistical methods using Gumbel statistical distribution model (Samantaray et al., 2020).

In Gumbel statistical distribution, calculation of return periods (T) corresponding to the exceedance probability (Samantaray et al., 2020) and is calculated as follows:

$$T = \frac{1}{1-P}$$

(Equ. 3)

Where T=return period (years) and P= exceedance probability

Samantaray et al. (2020), further highlight that predicted discharge (Q_p) in Gumbel method is calculated with standard normal distribution formula for different return periods expressed as:

$$Q_{p=\mu+K_t}\varphi$$

(Equ.4)

Where $Q_{p=}$ Predicted discharge, µ=standard mean φ =standard deviation

Furthermore, the exceedance probability (q_i), probability was evaluated in percentage using the Gringorten et al. (2019) plotting position formula as:

$$\boldsymbol{q}_{\boldsymbol{i}=\frac{\boldsymbol{i}-\boldsymbol{a}}{\boldsymbol{N}+\boldsymbol{1}-\boldsymbol{2a}}}$$

(Equ.5)

Where q_i= Exceedance probability association with a specific observation
N= Number of annual maxima observations (in this case 37 for Lingadzi catchment and 35 for Lufilya catchment)
i= Rank of specific observation with i=1 being the largest to i=N being the smallest (appendix. In column … for Lingadzi and Lufilya respectively).
a=constant for estimation =0.44 using Gringorten's method.

This study used Microsoft Excel to determine the return period, exceedance probability and discharge by applying Gumbel statistical formulas mentioned above. Furthermore, excel was used to draw tables and graphs which showed the expected floods, exceedance probabilities and discharge. Also, graphs of flood trends for discharge (Q), flood peaks and return periods for specific years (1980-2006) in Lingadzi catchment and (1980-2006) in Lufilya catchment were plotted in Microsoft excel. According to Machado et al. (2015) the use of long historical records is an important source of information about extreme events. It establishes a reliable flood return frequency (Machado et al., 2015). Correlation was observed between monthly discharges. Salgueiro et al. (2013) proposes that a strong correlation (r) should be observed between negative monthly NAO index and flood discharges above $400m^3s^{-1}$. Finally, graphs for annual average precipitation, flow rate and run-off were plotted for Lingadzi and Lufilya catchments. All these helped to determine the nature of floods in order to predict flood vulnerability in the studied areas.

3.4.2.2 Flood Risk Ranking

Flood risk ranking was carried out in order to determine vulnerability and capacity of households' floods. The ranking was done based on flood frequency using baseline data of 1934-2021. This baseline data was collected from the Department of Disaster Management Affairs (DODMA) in the Ministry of Natural Resources. The hazard (flood) exposure to the assessed areas was ranked based on the adopted and modified scale of Hing et al. (2010) of less frequent (1), frequent (2) and more frequent (3). A less frequent flood was determined with the frequency of less than 10 times in terms of occurrence in the area. A frequent flood was determined with a frequency of $\geq 10 \leq 30$ in terms of occurrence. A more frequent flood was determine with the frequency of ≥ 30 times. All the ranges were determined at the time interval of 10 years for the baseline data collected from DODMA. Vulnerability and capacity were ranked as low (1) medium (2) and high (3). The vulnerability rank was determined based on the output of the multiple binomial logistical regression computed using the methodology discussed in Table 3.13. A mean value of PEFs, SSFs, ERFs, EEFs and CSFs was computed and compared to the developed scale by Hing et al. (2010) of 0.1-0.39 (low=1), 0.4-0.69 (medium=2) and 0.7-1 (high=3). On the other hand, capacity was determined by the output of physical/infrastructural adaptive strategies, social organisational adaptive strategies and economic adaptive strategies (Mwalwimba, 2020). The scale range was placed at 1 (low), 2 (medium) and 3 (high). Finally, risk to flood was done through the formula adopted by Hing et al. (2010) as proposed by Winser et al. (2004):

$$Risk = hazard\ (flood) \times vulnerability/capacity$$

(Equ.6)

Then, the final determination was interpreted as: 1-2.9 (low flood risk), 3-5.9 (medium flood risk) and 6-9 (high flood risk) as indicated in Table 3.6.

Table 3.6: Flood Risk Ranking Matrix in Mtandire Ward (Lilongwe city) and T/A Kilupula (Karonga district)

Flood	1=less frequent	2= frequent	3= More frequent
Vulnerability	1=low	2= Medium	3= High
Capacity	1= low	2= Medium	3= High
Flood risk Ranking	1-2.9	Low flood risk	
	3-5.9	Medium flood risk	
	6-9	High flood risk	

Source: Hing et al., (2010) modified by Author (2022)

3.4.2.3 GIS Field Survey Analysis

GIS field spatial data of location points collected from the Lingadzi and Lufilya catchments (Table 3.7) focused on the analysis of river profiling (Lingadzi and Lufilya), land use change due to floods and changes in settlement patterns due to floods. All these were determined using GIS desktop 10.8 as outlined in (Table 3.7). GIS helped to model hydrological parameters such as river morphology, including properties such distance of households from rivers, stream profiling and loss of land due to floods.

Table 3.7: Analysis Matrix of GIS Field Survey for Lingadzi and Lufilya River Catchments

Point Target	Data	Analysis focus	Data source	Analysis Tool
River Meander	Spatio	• Catchment profiling. • Land patterns in the catchment • Flooding and changing settlement patterns	Field survey (GPS)	GIS desktop 10.8

Source: Author (2022)

The spatio data was entered in Arch GIS desktop 10.8 to create Geodatabase using Arch catalog. Then tables were created for the entered data. The database contained four tables and four profiles for Lufilya catchment while two tables and two profiles for Lingadzi catchment. Then data from the database was displayed using Arch Map as points. The points were converted from to polylines. Later on, the polylines were converted into line feature using geoprocessing features. This process was followed by the displaying of the base map (openstreet map) to check if the points landed in the actual location of the catchments from which they were obtained. Using this base map (openstreet map) satellite image, all the points were digitized. Then the geoprocessing tasks like area of profiles, distances of households to the river profiles (both current and old profiles), land gained or lost and extent of settlement displacement were calculated. The significance of knowing these parameters is that they can inform flood responders to plan for relocation in terms of the available land that people need to get where they are being relocated (Hing et al., 2010). Furthermore, it assists in checking the amount of land that people lose from floods, thereby providing insights on the amount of yields that is lost in the process.

3.4.2.4 Supervised Image Classification System

The land cover classes were known before gathering training samples, which made categorisation easier. For supervised image classification, training samples, also known as areas of interest (ROIs), were gathered for each image, followed by post-classification smoothing methods to provide accurate and precise land cover maps for the research periods. The land cover classes used for supervised classification are summarised in Table 3.8.

Table 3.8: Land Cover Classes

Land Cover Class	Description
Built-Up Area	Consists of Urban, Industrial, commercial, and transport units, dump, and construction sites.
Bare Land	Open spaces with little or no vegetation, beaches, dunes sands, bare rocks, sparsely vegetated areas
Vegetation	Forests, Shrub and herbaceous vegetation association, Arable land, Permanent crops, Pastures, and Heterogeneous agricultural areas.
Water Bodies	Watercourses, dam areas,

Polygons were drawn (that had to be closed, that is, no open ends) and ROI names were assigned once it was evident that each training region was defined as a class (this is very similar to an onscreen digitizing procedure in a GIS). A significant number of points were collected for each ROI, allowing the classifier to accept it. As a result, this strategy aimed for as many points per training region as possible as long as the sample remained representative. In general, the more training pixels a statistical classifier has, the more accurate its outputs will be. This did not, however, imply that ROI was built around a whole feature, as this would defeat the purpose of a representative.

Land cover maps were created for this study using different procedures based on pixel-based supervised classification. The first phase involved gathering a set of training samples for each land cover class, which were typically representative of the land cover classes described previously. These samples were gathered based on the researcher's own experience and understanding of the study area's physiography. For a better determination of land cover classes, image enhancement and false-colour band composition were also used. For each Landsat image, roughly 80 training samples were obtained using these methods. Finally, a supervised image classification, in particular Maximum-Likelihood Classifier was applied to determine land cover changes in the studied areas.

3.5 Determination of Household Flood Vulnerability

Vulnerability is a complex concept and includes diverse components (Rana et al., 2018). Therefore, vulnerability requires a comprehensive methodology which can help to reveal various components (Moreira et al., 2021). Rana et al. (2018) stipulate that there is lack of integrated methodology that fuses all the components together. This study used indicator based approach to quantitatively assess household flood vulnerability. The determination was based on flood vulnerability index (FVI) (Balica et al., 2012; Kissi et al., 2015; Ndanusa et al., 2022). As accorded by ISDR (2014), quantitative approach was useful to establish indicators of FVA framework. Chakraborty et al. (2014), Hudrikova (2013), Kablan et al. (2017), and Nazeer et al. (2020) agree that quantitative indicators are used to predict flood vulnerability. However, variation exists on the selection of the quantitative tools (Kissi et al., 2015). For instance, Nazeer et al. (2020) applied Pearson’s correlation to predict flood vulnerability. Kissi et al. (2018) used deductive and inductive approaches to select flood vulnerability indicators. This study used binomial multiple logistical regression to predict household flood vulnerability. The use of this method allowed to agglomerate the indicators of the UVFs and VCs.

3.5.1 Data Collection Procedure

The procedure for the determination of household flood vulnerability involved undertaking various steps namely (1) framing flood vulnerability indicators, (2) sampling determination, (3) questionnaire design and administration (4) indicators derivation, normalisation, weighting and aggregation.

3.5.1.1 Framing Flood Vulnerability Indicators

Flood vulnerability indicators were selected based on a thorough review of contemporary frameworks (Appendices 2.1-2.5), but with more emphasis on PAR model (Winser et al. 2004) (Figure 2.1) and Salami et al. (2017) FVA framework (Table 2.2). Data variables were classified into two parts namely the UVFs and the VCs (Figure 2.3). The study used demographic characteristics variables (age, gender, marital status, education and occupation) to provide explanation of the variability of UVFs and VCs on household flood vulnerability using descriptive and inferential statistics. Since there is no general acceptable way of selecting vulnerability indicators (Kablan et al., 2014; Nazeer et al, 2020), this study considered the indicators based on a cut-off point of probable value zero to one where zero represents minimum and one indicates maximum values (Kissi et al., 2015; Nazeer et al., 2020; Ndanusa et al., 2022).

3.5.1.2 Study population and Sampling Determination

The target flood prone area of TA Kilupula in KD was selected based on frequency of floods occurrence. Kissi et al. (2015) indicates that the magnitude of an extreme event is inversely related to its frequency of occurrence. Whilst, Mtandire Ward in Lilongwe city was chosen because it is an informal settlement. Household's participants in Mtandire ward, were those specifically in two Group Village Headmen, Chibwe and Chimombo of Senior Chief Ligomeka. These villages are located along Lingadzi River opposite area 49 (New Gulliver). This study used a total of 10 headmen (VH). The choice of the VH was based on proximity to Lingadzi River. Mtandire has total population of 66,574 people, but 5000 people are reported to be at risk to floods (MDCP 2010-2021; MPHC, 2018). Relatedly, the target population in Karonga district were households of GVH Matani Mwakasangila and Mujulu Gweleweta in Traditional Authority (TA) Kilupula. These household villages share a network of water systems such as Lufilya, Mberere, Ntchowo and Fwira (Mwalwimba, 2020). This study used a total of 10 village headmen (VH), five from each GVH. The choice of five VH in each GVH was based on the fact that each

GVH in T/A Kilupula has minimum number of five Village Headmen (Karonga Chief Classification, 2016). T/A Kilupula has a total population of 78,424 people, with approximately 9,500 households at risk to floods (KD-SEP 2013-2018; MPHC, 2018).

The sample size (n) for this study was calculated using the formula in Fisher et al. (2010) as shown in the equation (4). The formula in the equation (2) returns the minimum sample size required to ensure the reliability of the results.

$$n = \frac{z^2 p\, q}{d^2}$$

(Equ.7)

In equation (7), Z is confidence level (1.96 for 95%), p is proportion of the target households, q = is the alternative (1-P) and d is the power of precision (d = 0.05 at 95%). The formula require to know the target population (P) and it also assumes "P" to be 0.5 which is conservative. Therefore, the fact that the number of households prone to floods in T/A Kilupula and Mtandire ward are known, using this formula, 384 and 246 households were obtained from Mtandire ward and T/A Kilupula respectively. The study used 0.5 (50%) to represents "P" in Mtandire Ward and 0.2 (20%) to represents "P' in T/A Kilupula. The reason for differentiating the "P" was that in Mtandire ward the whole area was selected while in T/A Kilupula not all the GVHs were selected and involved in the survey. Furthermore, unlike in T/A Kilupula where the population is sparsely distributed and households were selected based on location to flood prone areas, in Mtandire ward 50% was used as conservative because of high population density such it was possible to interview many households. During data collection, the researcher managed to collect data from 345 and 200 household participants, representing 90% and 81% of the total sampled in Mtandire ward and T/A Kilupula respectively. The reason for not completing the actual sample size was that the household survey interviewed houses along the buffer zones of Lingadzi and Lufilya rivers and the whole area of the buffer was randomly selected. Therefore, continuing interviewing every household in the buffered area would have meant interviewing every household. This would have worked against the rule of simple random sampling strategy and survey ethics (Kissi et al., 2015).

3.5.1.3 Questionnaire Design and Administration

This study used a structured household questionnaire survey. Key variables in the questionnaire were aligned based on the conceptual framework (Figure 2.3). This questionnaire captured information that provided the linkages of households' vulnerability factors, exposure, susceptibility and resilience. Associations of vulnerability factors have been supported in literature (Kissi et al, 2015; Mwale, 2014; Nazeer et al., 2020). Nazeer et al. (2020) argues that the issue of double counting of the indicators is an important step to be considered in the formation of composite indicators. The household questionnaire survey was coded in KoBoToolBox. The household questionnaire survey was administered face- to-face with household participants who were above 21 years old. Age parameter was controlled in the KoBoToolBox environment such that the interviewers could not proceed administering the questionnaire if this question was not answered even if the age entered was below 21. It is also important to note that the attributes to variable age were not coded because it is a continuous variable hence the RAs asked the ages directly from the participants to type manually in the system of KoBo. Finally, the household questionnaire survey was pretested and piloted in Mchesi and Mwanjasi in LC and KD respectively. Before pretesting and piloting, RAs were trained to have a common local understanding of the terms that were contained in the questionnaire, specifically vulnerability, floods, resilience, susceptibility, adaptive capacity and exposure.

3.5.1.4 Indicators Derivation, Normalisation and Aggregation

The indicators of the vulnerability factors were categorised based on conceptual framework as generated from a thorough review of the theoretical frameworks such as PAR model (Winser et al., 2004), Salami et al. (2017) frame1work and studies of various scholars. Wisner et al. (2004) in the Pressure and Release (PAR) Model provides three stages for the progression of vulnerability namely (1) underlying root causes (like lack of access to institutional support, education) (2) dynamic pressures (like environmental degradation, conflict over land, deforestation) and (3) unsafe conditions (dangerous locations, livelihood at risk, income levels, food insecurity). Similarly, Urban Flood Vulnerability Framework (Salami et al., 2017) provides indicators of measuring flood vulnerability in the category of (1) physical/environment (like housing, house type, roofing material, flood intensity, proximity to the river), (2) economic (like source of income, level of education, occupation), (3) institutional (like trust on local risk management, protection and response, warning system), (4) altitudinal (like past flood experience, flood risk awareness, flood perception, level of preparedness), (5) social (like employment status, local resource base). Birkmann et al. (2013) designed a framework "Methods for the Improvement of Vulnerability Assessment in Europe" (MOVE) for measuring vulnerability, risk and adaptation in the basis of exposure, vulnerability and lack of resilience to calculate risk. Hing et al. (2010) classify the indicators based on housing materials, vulnerable zones (rice fields and settlement), weak institutional organisations and risk elements on economic, social, and political aspects as key drivers to vulnerability.

This study constructed two major categories of indicators for measuring flood vulnerability namely UVFs and VCs. First, two sub-sets indicators of the UVFs were employed for determining household flood vulnerability using a weighting scale (Nazeer et al., 2020; Rodger et al., 2017). The first sub-set involved the indicators of the vulnerability factors (Table 3.9) and the second were the indicators of elements at risk (Table 3.10). Nazeer et al. (2020) states that using two driven data provides an opportunity for rescaling, weighting and aggregation. Therefore, supplication of these might have a significant impact on the results of the flood vulnerability (Nazeer et al., 2020).

Table 3.9: Underlying Vulnerability Factors

Vulnerability Factor	Indicators	Data source	Weighting scale
Physical	• No construction codes and standards • Infrastructural built without DRR • Substandard building materials	**Field survey**	0= Not important 1=Less important 2= Important 3= Very important
Social/institutional	• Lack of Knowledge and skills in DRR • Poor access and source of drinking water • Limited/absence of institutional support	**Field survey**	0= Not important 1=Less important 2= Important 3= Very important
Economic	• No credit unions • Lack of income generating activities • Poverty • No alternative livelihoods	**Field survey**	0= Not important 1=Less important 2= Important 3= Very important
Environmental	• Pressure on land • Residing in prone areas • Scarcity of energy • Poor drainage systems	**Field survey**	0= Not important 1= Less important 2= Important 3= Very important
Cultural	• Traditional beliefs • Cultural conflicts • Defiance to safety measures • Absence of ownership of resources	**Field survey**	1= Not important 1=Less important 2= Important 3= Very important

Indicator Source (PAR Model: Wesner et al. 2004; Salami et al. 2017) Modified by Author (2022)

This study constituted a measuring weighting scale of less important (1), important (2) and very important (3) in the category of underlying vulnerability determinates (Mwalwimba, 2020). The indices (Table 3.9) relate to the ones in the Community Based Disaster Risk Index (CBDRI) developed by Bollin et al., 2003) as cited by Mwale (2015). However, in this study, the indices (indicators) for the UVFs were comprehensively selected compared to the ones applied in the CBDRI.

The study measured the level of the vulnerability of the elements at risk in all the underlying vulnerability factors (Table 3.10). These were evaluated based on the constructed scale which modified the Balica et al. (2012) and was calibrated as (0-0.2) very low vulnerability; (0.2 -0.49) moderate vulnerability; (0.5 to 0.59) vulnerability (0.6-0.79) high vulnerability and (0.8-1) very high vulnerability. However, in the actual data collection tool (household questionnaire survey), adopted Mwalwimba (2020) measurements scale of "not vulnerable", "slightly vulnerable", "vulnerable", "severe vulnerable" and "do not know" were used and later the percentage obtained during univariate analysis were computed and compared to the weighting scale constructed (Balica et al., 2012) (3.10). Ndanusa et al., (2022) argued that a breakdown of the elements at risk pose a serious threat to communities vulnerability and prosperity.

Table 3.10: Elements at Risk

Elements at Risk in UVFs	Indicators	Description	Weighting scale
Physical	• Houses • Toilets • Roads and bridges	% houses affected % toilets affected % roads damaged	0.-0.2 very low vulnerability 0.2-0.49 moderate vulnerability 0.5-0.59 Vulnerability 0.6-0.79 high vulnerability 0.8-1 very high vulnerability
Social/institutional	• Health posts • Schools • Warehouses • Electricity cables	% health posts affected % schools affected % warehouses affected % electricity cables affected	
Economic	• Farm crops • Livestock • Trading & business • Loss of employment	% farm crops affected % livestock lost % trade and business affected % loss of employment	
Environmental	• River channels • Forest cover • Land and soil quality • Drainage systems	% river channels affected % forest cover affected % loss of land & soil fertility % of poor drainage systems	
Cultural	• Social networks • Cultural systems and heritage • Loss of important cultural artefacts	% of loss of social networks % loss of cultural systems % loss of cultural artefacts	

Indicator Source (PAR Model: Wesner et al. 2004; Salami et al. 2017) Modified by Author (2021)

Second, indicators of vulnerability components (exposure, susceptibility and resilience) are the widely used in the assessment of flood vulnerability (Kissi et al., 2015; Ndanusa et al., 2022; Rana et al., 2018). In most studies, these components are not linked to the UVFs, implying that there is limited literature that has combined the variables in a single study. Available studies that attempted to combine the variables (Mwale, 2014) did not compute flood vulnerability using FVI which allows comparing overall vulnerability of one place to another place (Kissi et al., 2015). Furthermore, the study of Mwale (2014) did not further develop indicators for measuring vulnerability in rural and urban informal settlements in Malawi. Therefore, these three vulnerability components (Table 3.11) were aligned to the five vulnerability factors to compare household vulnerability to floods between urban and rural areas. This helped to reveal indicators which combined the UVFs and VCs to develop a flood vulnerability assessment framework for rural and urban informal settlements (Figure 6.1). Measuring vulnerability using these components has been supported in literature (Hamidi et al., 2022; Kablan et al., 2017; Kissi et al., 2015; Nazeer et al., 2020). Hamidi et al. (2022) provided an integrated analysis of the flood exposure and social vulnerability through the analysis of indicators constructed under exposure, susceptibility and resilience. Mwale (2014) also used exposure, susceptibility and resilience to link with physical-social-economic and environmental factors to quantifying flood vulnerability. Nazeer et al. (2020) applied Pearson correlation (r) using minimum-maximum method for scaling vulnerability indicators. Data indicators were transformed to zero and one, where zero represents minimum and one indicates maximum values for an indicator.

Table 3.11: Vulnerability Components

Vulnerability components	Indicators and Associated UVFs	Description	Data Source
Exposure	**Physical**		
	Extent of damage	% HHs partially/fully damaged houses	Structured Field survey
	House type	% of house type categories	
	Environmental		
	Surrounded by forest	% Yes=1 and % No=2	Structured Field survey
	Geography	% Yes=1 and % No=2	
	River banks	% Yes=1 and % No=2	
Susceptibility	**Social**		
	Floods risk awareness	% Yes=1 and % No=2	Structured Field survey
	Communication accessibility	% Yes=1 and % No=2	
	Adaptation mechanism	% Yes=1 and % No=2	
	Warning systems	% % Yes=1 and % No=2	
	Cultural/Human		Structured Field survey
	Trust in local authority.	% Yes=1 and % No=2	Structured field survey
	Protection and response	% Yes=1 and %No=2	
	Prediction method	% None=0, % Scientific Knowledge =1, % Indigenous knowledge =2	
Resilience	**Economic**		
	Source of income	% HHs source of income	Structured field survey
	Education	% HH participants level of education	
	Employment	% HH participants employed	
	Occupation	% type of occupation of participants	

Indicator Source (PAR Model: Wesner et al. 2014; Salami et al. 2017) Modified by Author (2021)

The vulnerability component indicators (Table 3.11) were normalised to have a comparable set of indicators, the study adopted the Min–Max normalisation to convert the values to a linear scale (such as 0 to 1) (Balica et al, 2012; Erena et al., 2019; Kissi et al., 2015; Nazeer et al., 2021; Ndanusa et al., 2022). Vulnerability increases with an increase in exposure and susceptibility, and it decreases with an increase in Resilience (Kissi et al., 2015; Mwale, 2014; Munyani et al, 2019; Nazieer, 2021). Therefore, normalisation was based on the assumptions that:

(a) Vulnerability (V) increases as the absolute value of the indicator also increases. In this case, where the functional relationship between the indicator and vulnerability is positive, the normalised indicator is derived using the following equation (Oyedele and Yyonne, 2022).

$$X_1 = \frac{X_a - X_{Min}}{X_{Max} - X_{Min}}$$

(Equ. 8)

(b)Vulnerability (V) decreases with an increasing absolute value of the indicator. Here, when the relationship between vulnerability and the indicator is found to be negative, the data are rescaled by applying the equation (Oyedele and Vyonne, 2022).

$$X_1 = \frac{X_{Max} - X_a}{X_{Max} - X_{Min}}$$

(Equ. 9)

Where:

Xi = normalised value;

Xa = actual value;

XMax = maximum value;

XMin =minimum value for an indicator i (1, 2, 3. . . n) across the selected communities.

Furthermore, no weight was assigned to the indicators of vulnerability components. The reason for not including weights was that most of responses during the stakeholders' engagement were contradictory and highly inflicting. Therefore, to avoid an index value that will mislead the end users, the normalised indicator was aggregated into its respective sub-indices for final flood vulnerability index.

The additive arithmetic function was employed in the aggregation of the indicator into its respective sub-indices (exposure, susceptibility, and lack of resilience) using equation (Kissi et al., 2015; Nazeer et al., 2021; Oyedele & Vyonne, 2022)

$$SI = \frac{\sum_{i}^{n=} 1 \ X_i}{n}$$

(Equ.10)

The overall flood value of the vulnerability index was computed with equation (4), an additive function (Nazeer et al., 2019; Lee and Choi, 2018; Oyedele and Vyonne, 2022).

$$\text{FVI} = \frac{1}{3}(\mathbf{SIE\ +SIS+\ SLoR})$$

(Equ. 11)

Where SIE means sub-indices exposure, Susceptibility (SIS), and lack of resilience (SILoR) for "n" numbers of indicator in each component of vulnerability.

3.4.2 Data Analysis

The analysis of household flood vulnerability was carried at three levels. The univariate analysis looked at descriptive statistics such as percentages of households' participants in order to determine how the participants view the generation of vulnerability from the physical, social, economic, environmental and cultural factors. It was further used to analyse the indicators of the vulnerability components (exposure, susceptibility and resilience). The results from the univariate analysis were grouped and presented in the form of tables and bar graphs.

In bivariate analysis, this study looked at the significance levels between demographics and vulnerability factors using the single Chi-square test and a combinedPvalue analysis package. The categorical variables (education, gender, marital status, and occupation) against each categorical variable per each vulnerability factors (physical, social, economic, environmental and cultural) were analysed. Then, the resultant p-values from each variable in the vulnerability factors were combined to come up with a single p-value using the "combinedPvalue" package in "r" environment. Furthermore, for categorical variables (vulnerability variables in each factor) against continuous variable (age) were analysed using two-way anova in the same "r" environment. Then, all the p-values from the two-way anova were blocked to test them against age using a "combinedPvalue" package in order to come up with a single p-value for age against vulnerability factors. The results were presented in figures that depicted only the significant combined p-values. Cross tabulations of demographic variables (especially sex and marital status) and vulnerability factors were done for those that were statistically significant in the combined p-values. Adjusted Residual (AR) was used in the cross for the tabulations to check the variability of the influence of UVFs and demographics per variable/indicator in each UVF. This was further used were used to determined significance levels of variables in UVFs and VCs. Those that were significant were selected for further post analysis in the multivariate level.

A post analysis of computed results was carried using artificial neural network (ANN). ANN is a machine learning method that stands more independent in comparison than statistical methods (Ludin et al., 2018; Parvin et al., 2022). Several studies have used ANN to predict specific events (Abaryhouei et al. 2013; Mwale 2014; Ray et al. 2020). Due to its predictive ability, this method was applied in this study as a post analysis to predict the causes of flood vulnerability of the variables which were statistically tested using combined Pvalue package between UVFs and VCs. ANN comprises several nodes and interconnected programming elements (Mwale, 2014; Parvin, et al. 2022). It contains input layers, hidden layers and output layers (Ahmadi, 2015) (Figure 3.15).

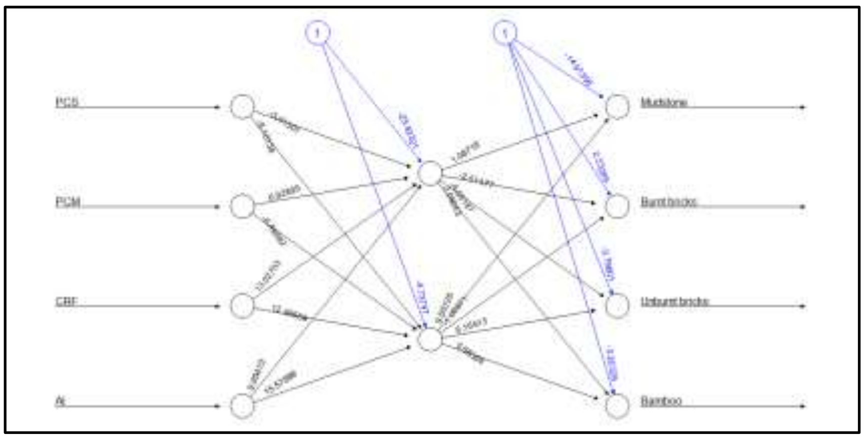


Figure 3.15: Example of ANN using MLP

It uses different applications, but in this study, a multi-layer perceptron (MLP) with a back propagation algorithm was used (Figure 3.15). In this study, input layer denotes the number of neurons which are the variables from the UVFs, hidden layers indicate the number of neurons from the UVFs and VCs and output layers were those variables from the VCs (house type, geography, income of household and communication accessibility). In the final results, the neurons of input which revealed positive results were used to describe their contribution to household flood vulnerability. In the situations where all the network of neurons revealed negative results, the lower negative results were used to explain the less contribution of each indicator to flood vulnerability. The outcome of the ANN was presented in tables with corresponding inputs weight (Parvin et al., 2022).

To farther determine variations among the indicator variables of UVFs for the predicted factors, a Minitab statistical test called Multiple Correspondence Analysis (MCA) was computed in multivariate level. MCA produced two outputs called "Indicator Analysis Matrix" and "Column Contribution table". The column of contribution is used to determine the variations that exist between indicators (Husson, 2014). On the other hand, the total inertia in the Analysis of Indicator Matrix (AIM) was averaged for all the five UVFs in LC and KD to obtain a single inertia which was used to determine a multi-correspondence variations of vulnerability factors (MIHVF). Table 3.12 shows the features of MCA including their meanings and interpretations.

Table 3.12: Key Features of MCA's Meanings and Interpretations

MCA Key features	Meaning	Interpretation
Axis	Principle component	Evaluate the component that account for most of the variability.
Inertia for component	The mount of variation a component explains	Evaluate the component that account for most of the variability in the data
Inertia (Inert) for column	Proportion of the total inertia contributed by each category	Evaluate the principle component that deviates most from its expected value.
Qual. (Quality)	It is the squared distance of the point from the origin in the chosen number of dimensions.	Help to determine the proportion of inertia represented (0-1) larger quality values indicate that the category is well represented by the component. Lower values indicate poorer representation.
	Correlation value (measured 0 to 1)	Interpret the contribution to the column inertia. Values close to 1 indicates that the component accounts for a higher amount of inertia. Values close to 0 indicate that the component contributes little to the inertia.
Contr (contribution)	It assess the contribution to the principal component	To assess which categories contribute most to the inertia of each component.

Source: Husson (2014)

Based on the features in Table 3.12, this study utilised four features namely; quality (Qual.), inertia (inert), correlation (Corr) and contribution (Contr) to determine variability of different variables that were analysed based on UVFs. According to Husson (2014), these measures help to assess associations between the categories of variables under the assessment. The variables (indicators) that showed more contribution to the inertia were selected for flood vulnerability assessment framework. More the indicator variables helped to explain farther the differences of factors that were predicted to generate household flood vulnerability using binomial logistical regression and based on FVI (Balica et al., 2012). Lastly, in this study an indicator in the quality column was chosen at a cut level of 0.5 (50%). This helped in checking the contribution to inertia, which was used to describe variation in vulnerability.

Lastly, the multivariate level analysis used the binomial multiple logit regression model to predict the factors that determine household's vulnerability to floods. This utilised a paired comparison model (Chen et al., 2013; Hamidi et al. 2020), in which each UVF was linked with a selected vulnerability component (exposure, susceptibility and resilience). This link is accorded in the studies of Wallen, et al. (2014) and Mwale (2014). This model generated the significance levels of physical-exposure, social-susceptibility, eco-resilience, enviro-exposure and cultural-susceptibility. Then, Flood Vulnerability Index (FVI) was applied to determine which factor contributes vulnerability (Balica et al., 2012; Kissi et al., 2015). The FVI uses a probability range 0 to 1 (Balica et al., 2012). Using equation 12, the paired attributes were run in r environment through the modified binomial logit multiple regression (Eq.12). However, it would have been significant to use logit ordered regression since vulnerability has certain order (Kissi et al., 2015; Hamidi et al., 2020). Consequently, this study modified binomial logit multiple regression formula developed by Israel (2013) as depicted in Eq.12. This binomial logit multiple regression was used because the data for this study was dominated by categorical variables.

$$y_j = \sum_{i=1}^{i=n} \beta_i \, \delta_i^{O_i} + \epsilon_j \qquad \textbf{\textit{(Eq. 12)}}$$

Where y_j is a predictor variable (i.e., as selected from exposure, susceptibility and resilience) β_i is intercept (values generated by the equation after extraction in r- environment, δ_i is response variable (selected from physical, social, economic, environmental and cultural), O_i operator (i.e., measurement scale, less important and very important which considered by the model), ϵ_j is an error. Table 3.13 provides an implicit relationship showing the predictor and response variables. It also highlights the measurement and expected relationship of the predictor and response variables.

Table 3.13: Relationship Matrix of VCs and UVFs Using the Binomial Regression (Eq.12)

VC	Predictor (y)	UVF	Response (δ_i)	Measurement (R Software)	Expected theoretical Relationships
Susceptibility (S)	Communication accessibility (ca)	Social	• Human rights (HR) • Health services (HS)	Equ. 12 (R)	S_{ca}=$\sum[\beta_i + (-)HR_{int} + (-)HS_{vint}]$ (Equ. 13)
		Cultural	• Local norms (LN) • Local behaviour (LB)	Equ. 12 (R)	S_{ca}=$\sum[\beta_i + (-)LN_{int} + (-)LB_{vint}]$ (Equ. 14)
Exposure (E)	Housing material type (hmt)	Physical	• Poor construction (PC) • Lack of construction materials (CM)	Equ. 12 (R)	E_{hmt}=$\sum[\beta_i + (-)PC_{int} + (-)CM_{vint}]$ (Equ. 15)
	Geography (ge)	Environmental	• Cultivated land (CL) • Environmental mismanagement (EM) • Poor land management (PLM) • In appropriate use of resources (AUR)	Equ. 12 (R)	E_{ge}=$\sum[\beta_i + (-)CL_{int} + (-)PML_{vint}]$ (Equ. 16)
Resilience (R)	Income of household head (ihh	Economic	• Poverty (PV) • Alternatives livelihood (AL)	Equ. 12 (R)	R_{ihh}=$\sum[\beta_i + (-)PV_{int} + (-)AL_{vint}]$ (Equ.17)

Source: Author (2022)

The binomial multiple logit regression model was used based on three assumptions which implied that:

(a) The indicators for UVFs should be measured as a proportional value of household participants involved during the survey. The percentage values should be generated using a scale range with operator of "*less important" (Int)*; "*important*" (int) and "*very important*" (vint) to contribute to flood vulnerability". However, for flood vulnerability determination, a cut-off point should be placed at greater or equal to 50% for each indicator from the operator of the scale range of "important" and "very important". In this case, all the values generated in the scale of "less important" as responded by the participants should be left out during determination and selection.

(b) The linkage of UVFs and VCs should be based on statistical tests using P-values or correlation (r) or simply any statistical test applicable by the researcher. The values that are significant at certain confidence level (i.e. 0.05 in this study) should be selected to be included in the framework for specific combination like Physical Exposure Factors (PEFs), Socio-Susceptibility Factors (SSFs), Eco-Resilience Factors (ERFs), Enviro-Exposure Factors (EEFs) and Cultural-Susceptibility Factors (CSFs). Furthermore, those values significant at an appropriate confidence level should be considered as factors generating flood vulnerability in the studied areas.

(c) Multicollinearity of the UVF and VC variables should be check using variance independent factor (VIF) to assess the level of correlation in the regression model. It is assumed that a variable with VIF ≥ 10 has higher variance inflation in influencing other response variance and is redundant with other variables. As such, that variable should be dropped. In this study, the VIF process was done in SPSS.

Flood vulnerability index (FVI) was used in the determination of household flood vulnerability based on the output of the analysis of the results. A summarized was compared flood vulnerability index (FVI) probability scale 0 to 1 (Balica et al. 2012) has been presented in table 3.14.

Table 3.14: Interpretation of Flood Vulnerability Index

Index value	Description	Designated Colour
0.32-0.40	Very low vulnerability	Light Green
0.41-0.49	Low vulnerability	Dark Green
0.50-0.59	Moderate Vulnerability	Yellow
0.60 to 0.79	High vulnerability	Orange
0.8 to 1	Very high vulnerability	Red

Source: Adapted from Balica et al., (2012) and Modified by Author (2022)

Results were presented on spatial distribution maps, computed in ArcGIS 10.8 Desktop. Shapefiles for Malawi administrative boundaries were downloaded from MASDAP (Malawi Spatial Data Application Portal). Then excel was used to generate the tabulated information and pie charts and later exported the output to ArcMap. The Maps were coloured to show the contribution of each variable to households flood vulnerability.

3.6 Perception of Household Flood Vulnerability

Vulnerability is a socio-economic condition which may be accentuated by perceived factors such as population growth, scientific and local knowledge (Iloka, 2017). These factors shape the perception of individuals towards hazards and disasters (Iloka, 2017). According to Wisner (2016), location, ethnic groups, social affiliations, wealth, occupation gender, among others contribute to vulnerability.

3.6.1 Data Collection

Data on perception of household flood vulnerability was collected at two levels. At the first level, a household questionnaire was used to capture data aimed at assessing the perceptions of households flood vulnerability in rural and urban informal settlements" with a focus on perception determinants (Table 3.15). Key informant interviews (KII) were further employed to obtain in-depth understanding of the perspectives of key informants on household vulnerability to floods. The methods were conducted to ascertain the perspectives of key informants on the differences that exist between rural and urban flood vulnerability. Munthali et al. (2022) and Plummer et al. (2012) maintain that using qualitative methods help to better understand respondents' own perceptions of vulnerability and capacities to cope with the hazardous event.

3.6.1 Data Analysis

Data from household questionnaire survey was analysed using both univariate and bivariate analysis levels, specifically descriptive statistics such as percentages were used in order to understand the perception of household's participants based on the selected factors that shape perception of individuals on their vulnerability to hazards and disasters. Then, the chi-square rest was performed to determine the implications of the demographic characteristics on perception of households' floods occurrence. All the demographic variables (age, gender, marital status, education and occupation) were associated with categories of household participants flood occurrence as a rural problem, urban problem and/or both rural-urban problem. Relationships between these demographics were computed using p-values and significant level 0.05. This kind of determining the relationship is supported in literature (Clarke, 2018; Mortreux et al., 2017; Moser et al., 2014). Clarke (2018) used various indicators to measure perception of people on transformative adaptation from flood risks. Key findings which were statistically significant were revealed and included illiteracy, norms and cultural beliefs, occupation of people and other social issues (Clarke, 2018).

Table 3.15: Indicators of Perception

Perception category	Variables
Location	1= Rural 2= Urban
Demographics	1=Age 2=Sex 3=Education 4=Marital status 5=Occupation
Impact	1=Education 2=Housing 3=Livelihood
Time	1=Past 2=Present

Source: (Author)

3.7. Household Adaptive Capacity on Flood Vulnerability

This objective was achieved through quantitative and qualitative methods. Quantitatively, key data obtained included those activities that people in community do before, during and after the floods (Munthali 2021; Mwalwimba 2020). These were grouped as social organisation measures, infrastructure measures and economic measures. Other issues which were assessed in relation to adaptive capacity were early warning systems, relocation and community participation. These parameters were assessed because studies reveal that there is a need of more effort in risk reduction and preparedness oriented approach (Wright et al., 2017).

The qualitative methods were used to gain a wider understanding of factors determining households' vulnerabilities to floods, linkages between household's vulnerability and adaptive capacity. The target population in Lilongwe City were officials from Government Departments and Non-governmental organisations (NGOs) ward councillors block leaders, city council officials, Ward Civil Protection Committee (WCPC) and Neighbourhood Civil Protection Committee (NCPC) and the City Civil Protection Committee (CCPC). On the other hand, the target population in Karonga District were officials from Government Departments and Non-governmental organisations (NGOs), indigenous leaders (Chiefs and elders), Area Civil Protection Committee (ACPC), Village Civil Protection Committee (VCPC), the District Civil Protection Committee (DCPC) and these were selected using purposive sampling.

Qualitative data were collected using literature review, unstructured and key informants interviews. The unstructured and key informant guides were designed based on HVCA. The HVCA process, first, involved flood hazard assessment (FHA). According to Hing et al. (2010), hazard assessment helps to better understand the nature and behaviour of the hazard. Based on this reason, FHA helped to underscore the scope and magnitude of floods (Iloka. 2017). The flood hazard assessment matrix (Table 3.16) was used to generate key information on flood hazards, including hazard factors, warning signs, speed of onset and frequency.

Table 3.16: Sample of Hazard Assessment Matrix Used

Hazard	Hazard factors/forces	Warning signs	Frequency	Timeline	Duration
Flood	Heavy rain	Indigenous and scientific signs	Two times per year	January-March	3 days

Source: Adapted from Hing et al., (2010) and Modified by Author (2021)

Second, in terms of vulnerability, the assessment was set based on physical, social, economic, environmental and cultural factors (Table 3.16). This was conducted by engaging key informants in order to gain their perceptions on the causes of vulnerability in the studied areas. Hing et al. (2010) accords this kind of assessing vulnerability by arguing that it tackles the root causes of vulnerability on economic, social, and political aspects.

During assessment also involved the analysis of Capacity Assessment (CA) by talking to key informants. Key issues that were tackled in a CA process were adapted from Hing et al. (2010) (Table 3.17). This approach allowed the researcher to systematically select and record local adaptive capacities that help to reduce household’s vulnerability. According to Hing et al. (2010) maintains that this approach help to obtain data that is vital to understand household vulnerabilities and their capacities to respond to flood hazards.

Table 3.17: Sample Categories of Analysis for Capacity Assessment

Infrastructure/ physical	Social organisation	Economic livelihoods
Houses built with support initiatives	• Community ability to organise, access to communication, access to warning systems, trust on warning systems	• Diversify their livelihoods • Involved in income generation activities
Perception/motivational	• Villagers help each other. • Adoption of technologies	

Source: Adapted from Hing et al., (2010) and Modified by Author (2021)

Finally, the information collected using the HVCA was validated with the information obtained using household structured questionnaire survey (Appendix 3). In terms of flood hazard assessment, information on appendix 3 (Section C) helped to determine the nature of flood hazards in the studied areas. Vulnerability assessment was validated with information presented in appendix 3 (Sections D1, 2, 3 and 4).

3.7.1 Data Analysis

The univariate analysis looked at descriptive statistics such as percentages of households' participants in order to determine what activities do the people in the area perform before, during and other floods so that they are able to adapt. The p-values were computed to determine the significance levels between resilience variables (ability to make decision, warning system, trust on the warning system and ability of people to organise themselves).Also, the scores of the key adaptive capacity in the categories of physical/infrastructural, economic livelihood and social organisation were computed using a scale adapted from Hing et al. (2010) and modified by the researcher of low (1) in the percentage category 0-25% , medium (2) 26-49% and high (3) above 50%. Finally, the overall adaptive capacity for physical/infrastructural, social/organisation and economic was ranked "1" implying not insufficient (low), "2" sufficient and (medium) "3" very sufficient (high) to promote adaptive capacity.

Finally, qualitative data from key informants through HVCA was analysed using qualitative data analysis (QDA) miner level 6.0. This is a qualitative data analysis software for coding textual data graphical, annotating, retrieving and reviewing coded data and documents (Lewis et al. 2014). It has the ability to combine numerical and categorical information to generate inferences from the observed data (Lewis et al. 2014). This software provides a wide range of exploratory tools to identify patterns in coding and relationships between assigned codes and other numerical categorical properties (Smith et al. 2019). It can import and export documents, data and results in numerous file formats (MS word, WordPerfect, RTF, HTM, XML, MS Access, Excel, Paradox, dBase, QSR, N6. Atlas.ti, HyperResearch, Enograph, and Transana Transcriber) (Smith et al., 2019). In this study, it provided a unique integration with the quantitative results and thereby broadening the explanation of the causes of households flood vulnerability in different categories of assessment. Lewis et al. (2014) argues that through the use of applications such as content analysis text mining (WordStat) and statistical analysis (SimStat) tools, QDA provides an easy combination and integration of qualitative and quantitative methods.

3.8 Data Management, Validation and Dissemination

Information from every Research Assistant in a tablet was checked to see if questions were responded correctly. Households' and village codes were checked. The data was later interpolated in a laptop saved household survey questionnaire. Furthermore, stakeholder validation was carried with selected team of participants who were involved in the survey. Moreira et al. (2021) noted that in most flood vulnerability studies, there is inadequate or inexistent validation of the results. In a systematic review of flood vulnerability assessment, Moreira et al. (2021) found that only 13.7% of the 89 articles which were reviewed had conducted validation. This is a huge gap in flood vulnerability assessment. Hence, this study conducted stakeholder validation to gather additional inputs on the study findings and to confirm the results. Their inputs further helped to reshape and refine the results and discussion. Finally, the results were disseminated during a seminar organised by Department of Geography in the Faculty of Science at the Catholic University of Malawi on 25 May 2022. The researcher further disseminated the results at Mzuzu University on 21 July 2022 as part of preliminary progress report. Furthermore, the results were presented at the National Conference for Environmental Health Association on 17 July 2022. Finally, the results were disseminated at the fifth Biennial Conference under Southern Africa Society for Disaster Reduction.

3.9 Chapter Summary

This section has described the study design, study area, sampling methods, data collection procedures, and data collection tools and/or instruments as well as data analysis procedures based on the study that was conducted in LC and KD. The research used various methods of data collection to ensure construct validity and reliability. The use of various methods was also to ensure the indicators of the FVA framework captures were comparable with other contemporary frameworks. Furthermore, it helped to ensure that the indicators were selected from an informed decision. In this case, this study provides the needed data for decision making process. For example, lack of flood vulnerability quantification of the causes and indicators of vulnerability may result in decision makers to making poor choices in the design and interventions to protect people who put trust on them.

CHAPTER 4: STUDY RESULTS

4.1 Introduction

This chapter presents the results of this study as unfolded from the analysis. The results have been presented in four sections. Section one is about spatiotemporal flood vulnerability trends. Section two deals with prediction of households' vulnerability to floods. Section three focuses on factors that determine perception of households' vulnerability to floods. The last section presents the results of households' adaptive capacity to respond to floods in the studied areas.

4.2 Spatio-temporal Flood Vulnerability Trends

This study presents the results of the spatio-temporal flood vulnerability trends in three categories. The first category presents the results of the hydrological assessment in terms rainfall analysis (precipitation, flow rate and run-off) and flood frequency analysis (return periods, annual peak discharge and trends of precipitation, flow rate and run-off). The second category deals with results of the field survey (spatial data). The last category presents results of the supervised image classification systems for the studied areas of Mtandire ward in Lilongwe city and T/A Kilupula of Karonga district.

4.2.1 Hydrological Regime Assessment

The hydrological assessment was performed at two levels. The first level involved rainfall analysis in the catchments using basic descriptive statisitcs. The second level used flood frequency analysis through return periods and exceedance probability.

- **Rainfall Analysis in the Catchments**

The results of rainfall assessment for Lufilya and Lingadzi catchments in T/A Kilupula and Mtandire ward respectively, involved analysis of basic descriptive statisitcs such as sum, mean, median maximum and minimum. These were used to understand precipitation, flow rate and run-off parameters of the Lufilya and Lingadzi catchments (Table 4.1 and 4.2).

Table 4.1. Basic Statisitcs of Precipitation, Flow Rate and Run-off for Lufilya (1980-2006)

Statistic category	Precipitation (mm)	Flow rate (cumecs)	Run-off (mm)
Sum	2549.31	6660.84	4698.27
Mean	98.05	256.17	180.72
Maximum	182.35	475.95	337.55
Minimum	32.29	84.25	59,75
Median	86.07	256.17	159.05

Table 4.2. Basic Statisitcs of Precipitation, Flow Rate and Run-off for Lingadzi (1970-2006)

Statistic category	Precipitation (mm)	Flow rate (Cumecs)	Run-off (mm)
Sum	940.24	2252.32	2478.49
Mean	36.16	86.63	95.33
Maximum	110.87	284.65	306.73
Minimum	2.43	6.38	6.87
Median	38.87	90.66	100.07

The results in table 4.1 and 4.2 show that the sum of annual precipitations, flow rates and run-off are in the scale of "very high aggressiveness">400 in both catchments. However, the results are very much higher for Lufilya catchment compared to Lingadzi catchment. The results indicate that Lufilya catchment receives higher amount of water compared to Lingadzi catchment.

Table 4.3: Hydrological Assessment for Lingadzi and Lufilya Catchments

Category	Flood Peak of Lingadzi Catchment (LC): (1970-2006)	Flood Peak Lufilya Catchment (KD): (1980-2006)
Mean	(73.67)	(189.32)
Standard deviation	(36.68)	(127.09)
	Discharge (Q (cumecs)) of Lingadzi	**Discharge (Q(cumecs)) of Lufilya**
Minimum	11.8 (2001)	26.9 (1992)
Maximum	166.0 (1970)	480 (1984)

The results show that Q for both rivers increased during the past years 1970 and 1984 for Lingadzi and Lufilya catchments in LC and KD respectively. In terms of flood peak, Lufilya has both a higher mean and standard deviation compared to Lingadzi River. The results demonstrate that the catchment of Lufilya receives higher water compared to the catchment of Lingadzi which eventually contributes to higher flood peak.

- **Flood Frequency Analysis**

The results of the expected floods for return periods (in years) and relationship between exceedance probability and expected floods are presented in Figures 4.1a and 4.1b for Lingadzi river catchment in LC.

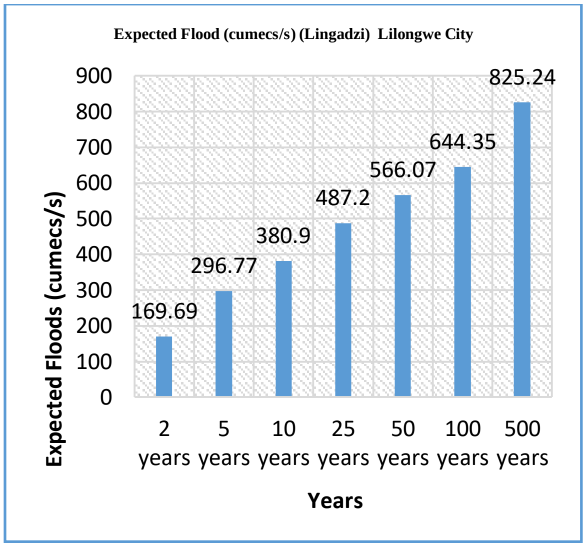


Figure 4.1a: Lingadzi River Catchment: Data Source: Department of Water Resources (1970-2006)

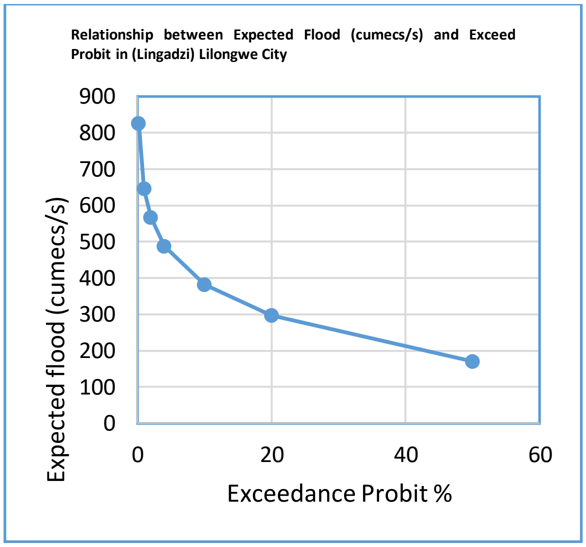


Figure 4.1b: Lingadzi River Catchment: Data Source: Department of Water Resources (1970-2006)

The results show the trend of a higher return period (T in years) corresponding to a higher expected flood floods (Cumecs/s) for Lingadzi river catchment of LC (Figure 4.1a). The results, indicate that at a return period of 500 years, the expected flood is at 825.24cumecs/s while at the return period of 2 years, the expected flood is 169.69cumecs/s (Figure.4.1a). The results further show that the higher the return period, the lower the probability for the flood to occur in the catchment (Figure 4.1b). The result revealed that at a return period of 500 years, the exceedance probability for the flood to occur is 0.2% and vice versa.

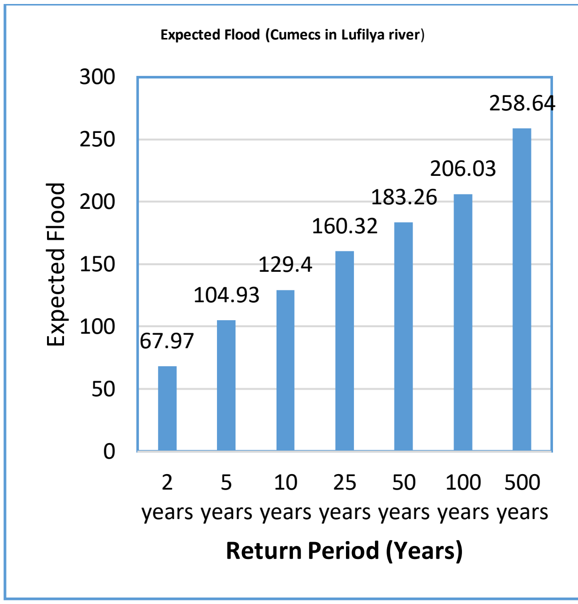


Figure 4.2a: Lufilya River in KD: Data Source: Department of Water Resources (1970-2006)

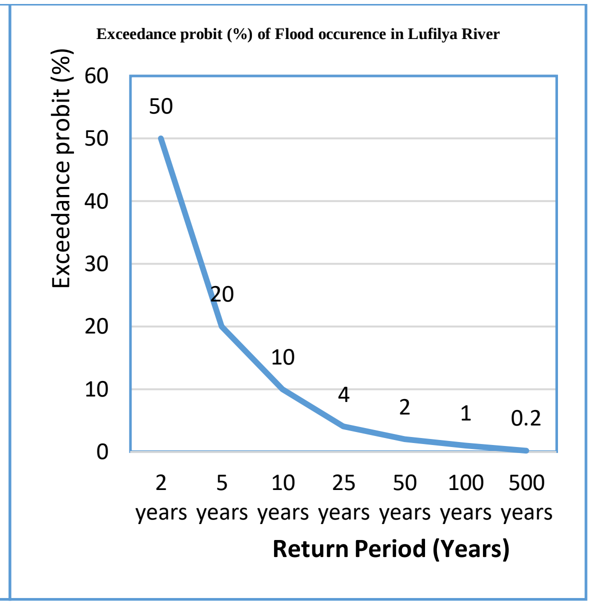


Figure 4.2b: Lufilya River in KD: Data Source: Department of Water Resources (1980-2006)

The results show the trend of a higher return period (T in years) corresponding to a higher expected flood floods in Lufilya catchment of KD (Figure 4.2a). At the return period of 500 years, the expected flood is at 258.64 cumecs/s while at the return period of 2 years, the expected flood is 67.97cumecs/s (Figure.4.2a). The results further show that the higher the return period, the lower the exceedance probability for the flood to occur in the catchment (Figure 4.2b). The probability of flood occurrence is higher at a return period of 2years (50%) while lower at return period of 500 years (0.2%) (Figure 4.2b).

However, the results in figures 4.1a and 4.2a, show that Lingadzi river catchment has higher expected floods for all the return periods compared to Lufilya river catchment. The results show that a return period of 5 years has an expected flood of 296.77m^3/s for Lingadzi river catchment greater than expected flood of 258.64m^3/s for a return period of 500 years for Lufilya river catchment.

- **Hydrological regime trends for Lingadzi and Lufilya river catchments**

Table 4.4: Flood Trends in Lingadzi Catchment

Year	Q max(cumecs)	Flooding peak	Return Period (T)
1980	480	480	38.0
1981	164	442	19.0
1982	185	434	12.7
1983	320	409	9.5
2006	71	11.8	1.0

The results in Table 4.4 further show that the trends in terms of relationship between discharges (Q), return period (T) and flooding peak is decreasing (1980 to 2006) for Lingadzi catchment. The results also show that (T) was very low in 2006 compared to 1980. This result depicts that there is more likelihood for the floods to occur in these recent times compared to past years (1980s).

Table 4.5: Flood Trends in Lufilya Catchment

Year	Q max(cumecs)	Flooding peak	Return Period (T)
1980	41.6	166.0	38.0
1981	44.0	153.4	19.0
1982	127.0	127.0	12.7
1983	166.0	112.9	7.6
2006	61.3	27	1.4

The results in Table 4.5 further show that discharge (Q) is increasing from 1980 to 2006, flooding peak and return period are decreasing between the same years in the Lufilya river catchment. The results also show that T was very low in 2006 compared to 1980. This result depicts that there is more likelihood for the floods to occur in these recent times compared to past years (1980s).

The results in Tables 4.4 and 4.5 reveal that there is no difference for the livelihood of flood occurrence during the selected years in the Lingadzi and Lufilya river catchment. However, Lingadzi river catchment had experienced higher Q and flood peak compared to Lufilya river catchment.

- **Annual Peak Discharge (APD) in the Lingadzi and Lufilya river Catchment**

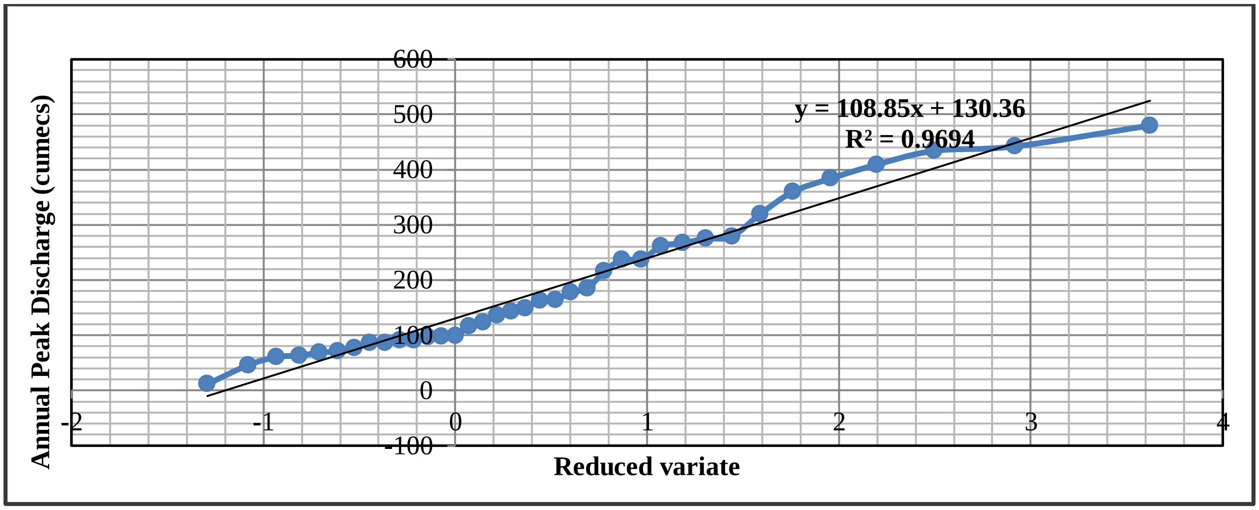


Figure 4.3: Relationship of Annual Peak Discharge and Reduced Variate in Lingadzi Catchment

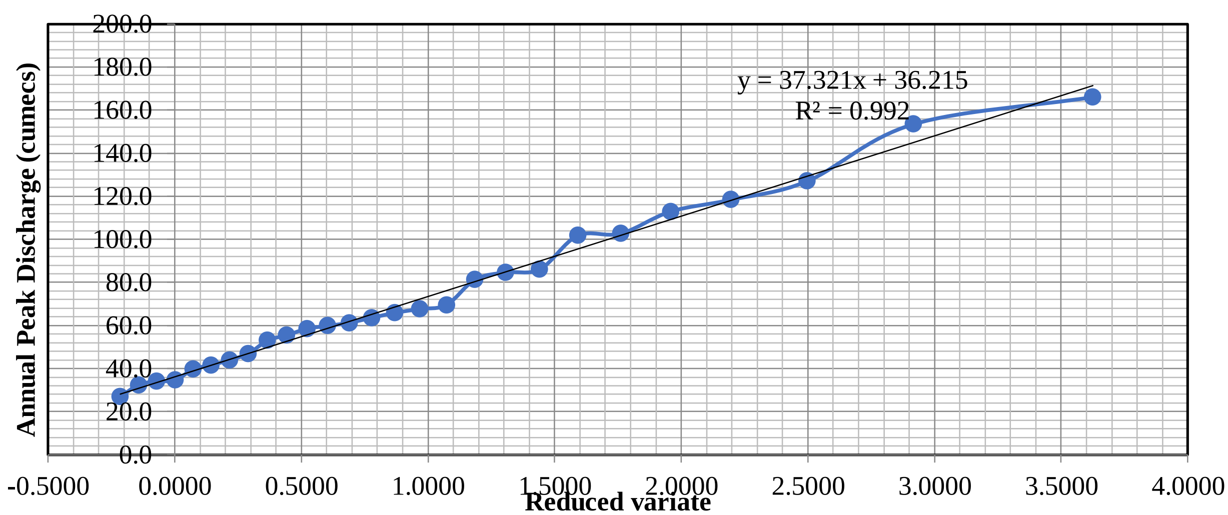


Figure 4.4: Annual Peak Discharge and Reduced Variate for Lufilya Catchment

The result show that discharge of Lingadzi and Lufilya river catchment is very high with a value of R^2 = 0.9694 for Lingadzi river catchment in LC (Figure 4.3) and R^2 = 0.992 for Lufilya river catchment in KD (Figure 4.4). The results further show that the Lingadzi river catchment recorded a higher APD from 1970-1988 with high flood peaks (1970-1992) (Figure 4.5). These results also show the corresponded decrease in annual precipitation (Figure 4.10), annual flow rate (Figure 4.11) and annual run-off (Figure 4.12). However, in the Lufilya river catchment, the results show high flood peaks from 1980-1986 with a high Q around 1982, 84,89.98.99,2000, and 2003 (Figure 11). The results further show that run-off and flow rate increase and decrease based on the trends of precipitation in the catchment areas (Figures 4.7; 4.8 and 4.9).

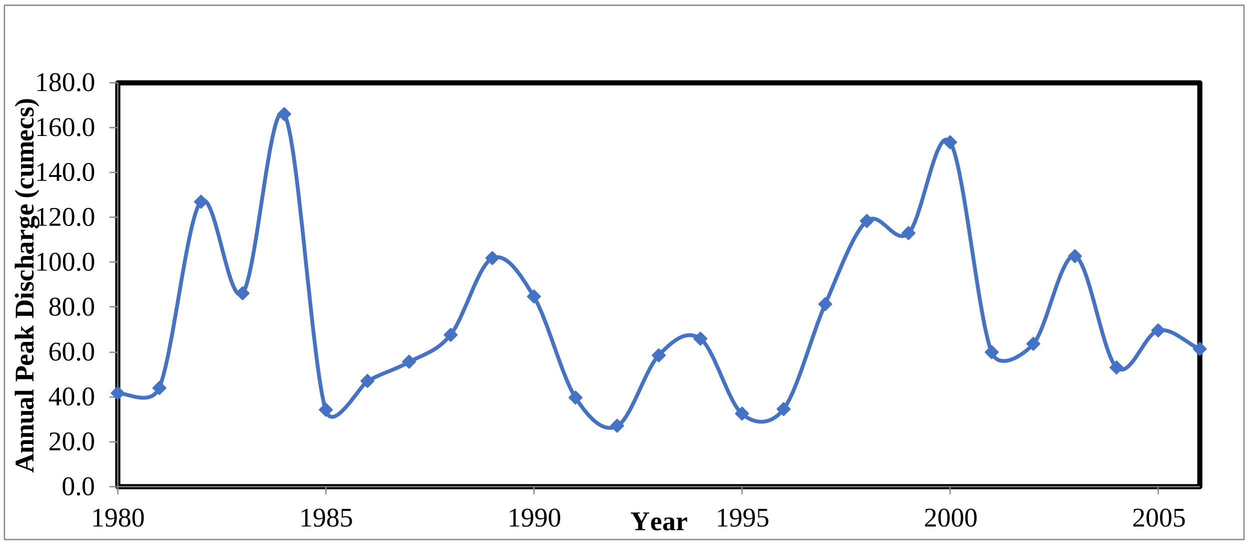


Figure 4.5: Annual Peak Discharge for Lufilya Riverd

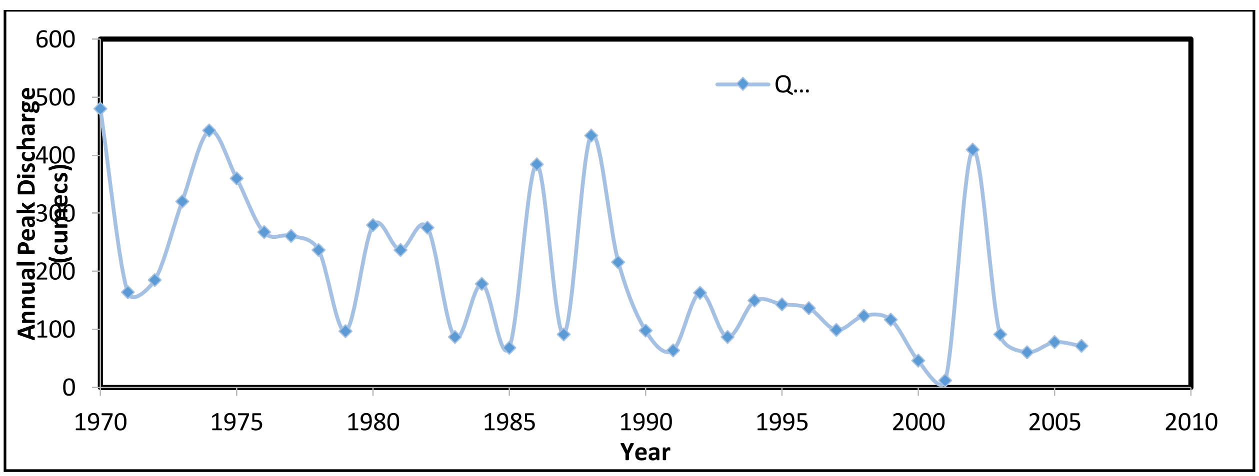


Figure 4.6: Annual Peak Discharge for Lingadzi River

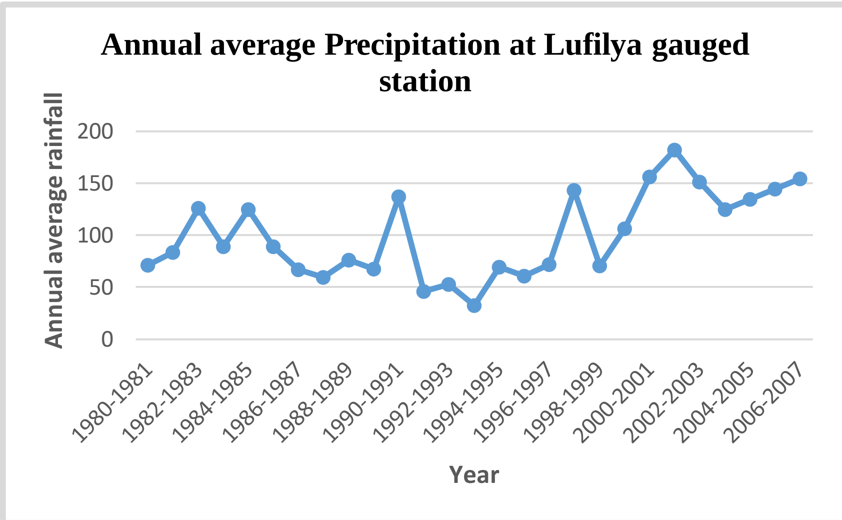


Figure 4.7: Annual Precipitation at Lufilya Gauging

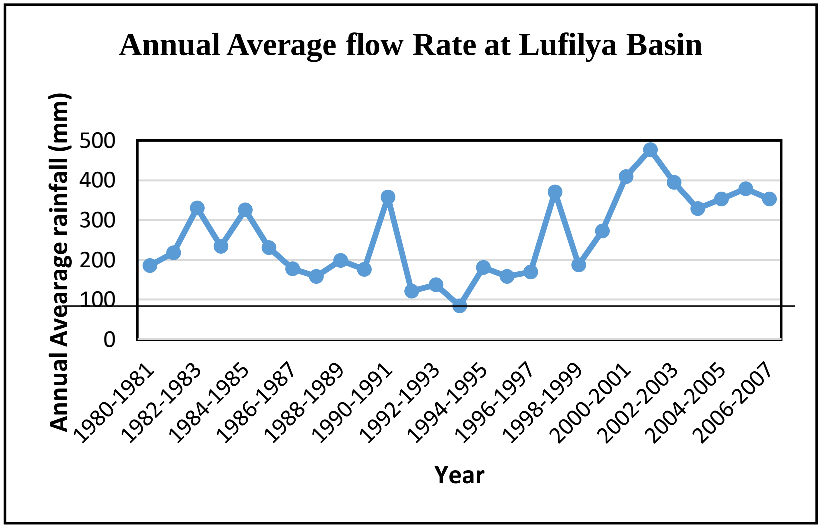


Figure 4.8: Annual Avg. Flow Rate for Lufilya

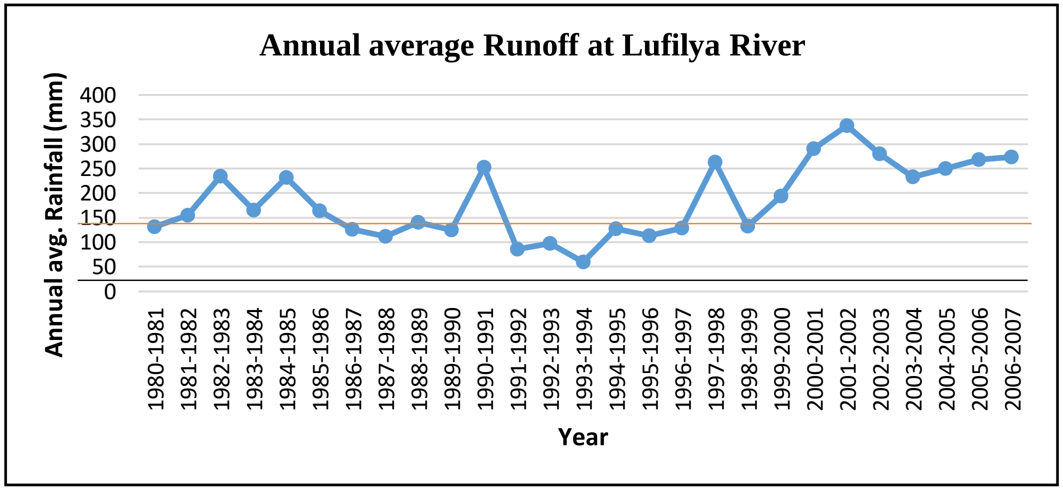


Figure 4.9: Annual Avg. Runoff for Lufilya River

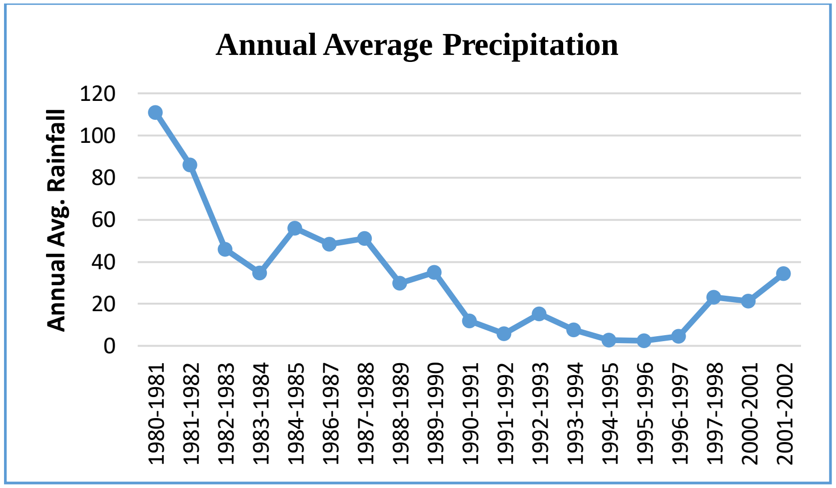


Figure 4.10: Annual Precipitation at Lingadzi station

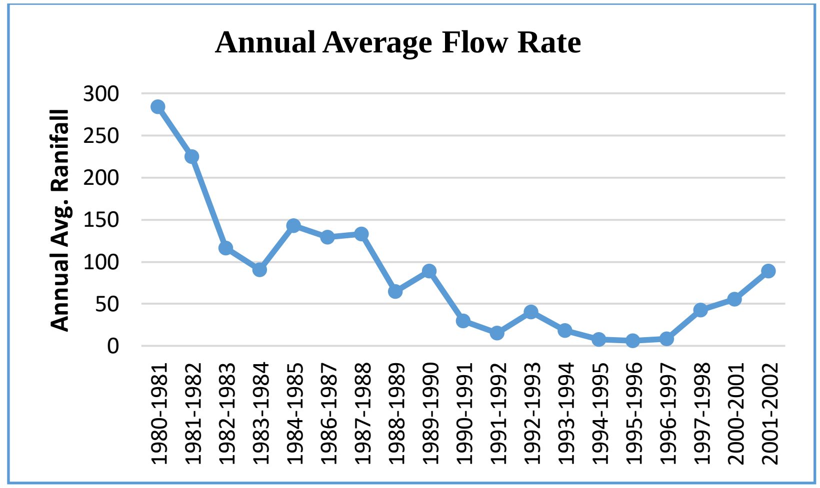


Figure 4.11: Annual Flow Rate at Lingadzi station

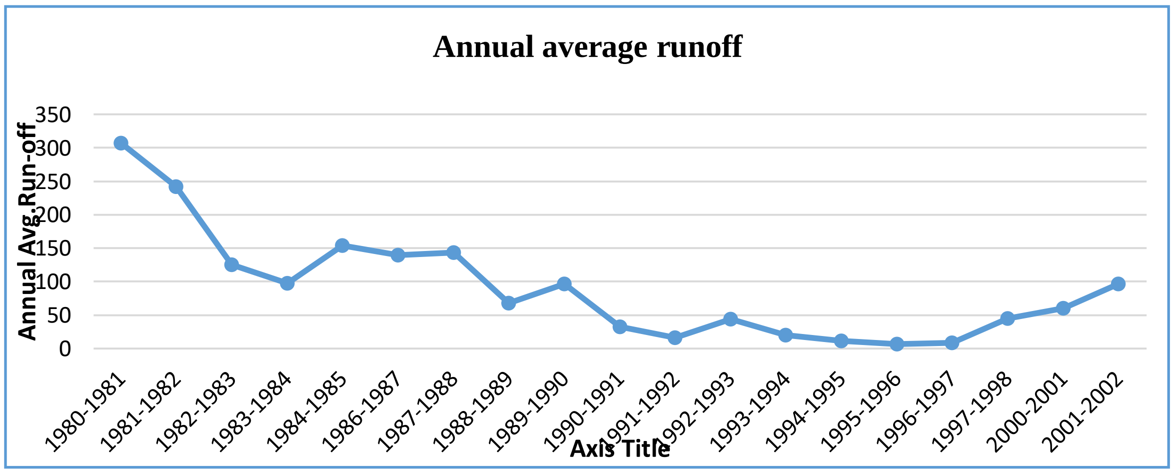


Figure 4.12: Annual Average Runoff

4.2.2 Flooding Occurrence in the Catchments

The results of the baseline data collected from DODMA, community leaders and key informants in a participatory HVCA process are presented as follows**:**

- **Frequency of Flooding in the Assessed Areas**

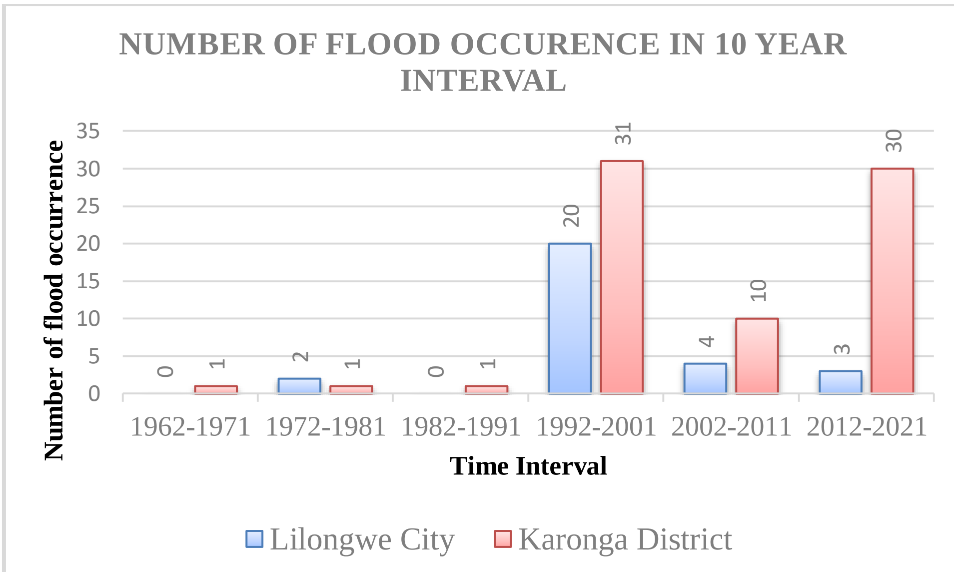


Figure 4.13: Number of Flood Occurrence (Data Source: DODMA 2022)

The results revealed that in the 10 year interval (1992-2001) Lilongwe city and Karonga district experienced flooding 20 and 31 times respectively. The result further revealed that between 2012-2021, Karonga district continues to experience more flooding events compared to Lilongwe city (Figure 4.13). During participatory process in the HVCA, key informants revealed that the floods have been happening in the Lilongwe city in the past but not to the current magnitude. Key informants further reported that the recent floods were more devastating compared to the past floods. One key informant said:

> "*We are in difficulties time! We never experienced the floods with devastating impacts like the flooding of 2017. We know the cause to be the people who have built their houses close to Lingadzi River. I informed the Vice President who came to see us about this*

condition which has been created by those people who have built their houses in the risk areas." KII #1 26 July 2021).

- **Overall Flood Risk Ranking in the Study Areas**

The overall flood risk ranking used the average means of vulnerability in Mtandire ward of Lilongwe city and T/A Kilupula of Karonga district. The value in Mtandire was computed to be 0.488 and T/A Kilupula was 0.508. Using these values (as discussed in the methodology of section 3.4.2.2), both areas were classified in the category of medium vulnerability (2) with low capacity on economic measures (1). However, flood frequency was revealed to be 1 in Mtandire and 3 in T/A Kilupula. The results of the probability of flood risk were calculated using the equation presented in section 3.6.3. The calculations revealed the results as presented in Figure 4.14.

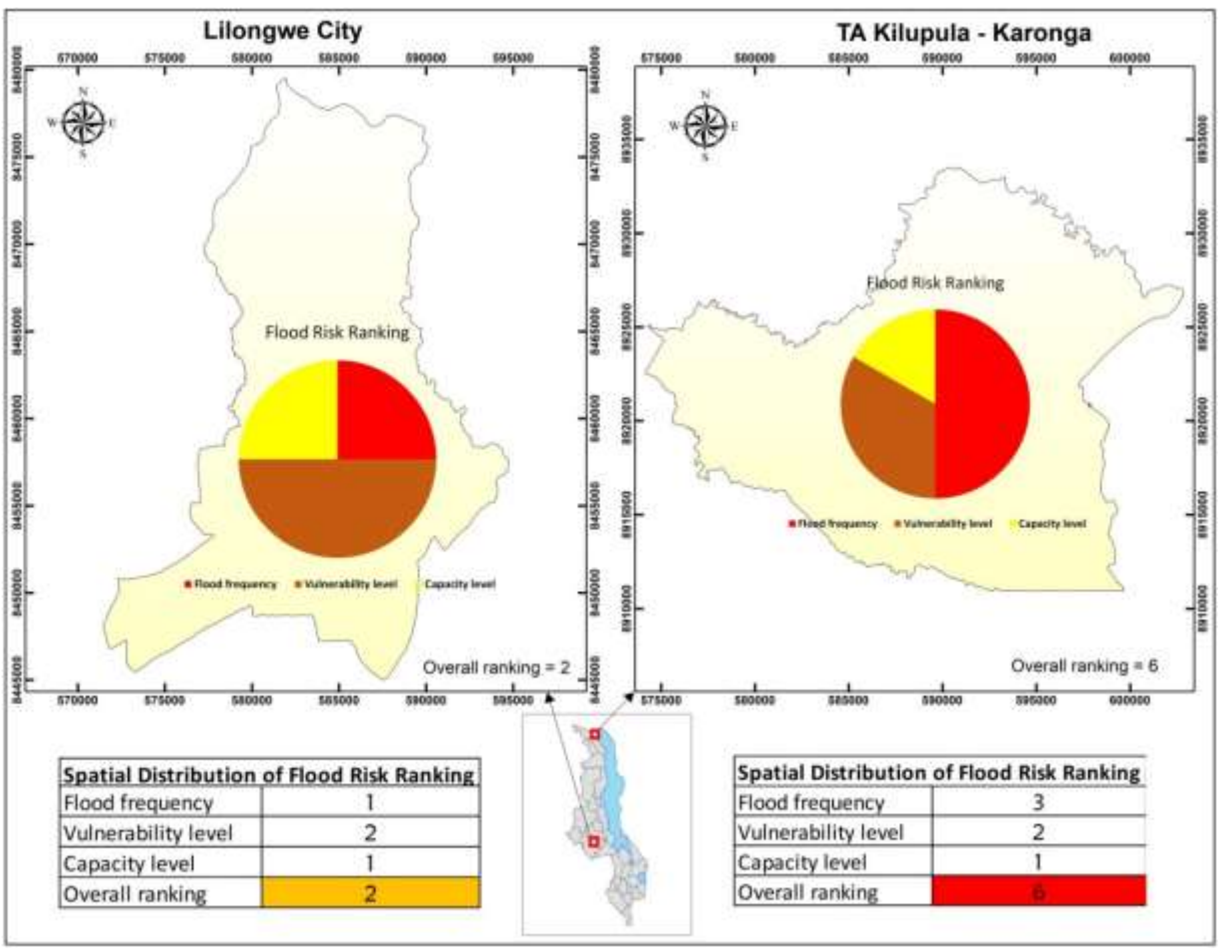


Figure 4.14: Flood Risk Ranking in LC and KD

The computed results revealed a high overall flood risk in T/A Kilupula of KD (6) compared to Mtandire ward of LC (2). The major outcome of these results is that there is high probability of floods occurrence in T/A Kilupula of Karonga compared to Mtandire Ward of Lilongwe city. This outcome accords to the analysis of results of the baseline data collected from the Department of Disaster Management Affairs (DODMA) showing the occurrence of floods in LC and KD (Figure 4.14).

4.2.3 Morphology and Land Patterns in the Lufilya and Lingadzi River Catchments

This section presents the results of the field survey collected using GPS receiver. The results are divided in two themes. The first theme is about catchment morphology of Lufilya and Lingadzi rivers and the second theme is about flooding and changing patterns of land and settlements. The results of these themes were determined using GIS desktop 10.8 and flood hazard Assessment carried out during a participatory process as discussed under the HVCA methods.

4.2.3.1 Catchment Morphology of Lufilya and Lingadzi Rivers

The results show that the profile of Lufilya river catchment is not homogenous. Its channels is widened and has changed its directions into several river courses. The results show that the catchment has developed four profiles (channels) (Figure 4.15) deviating from the original river profiles which was depicted by the based map of the “image satellite” (Profile 1). The results show that the river has changed its shape from the old profile portrayed by the satellite. The results further show that there is no main channel to direct proper water flow in the river.

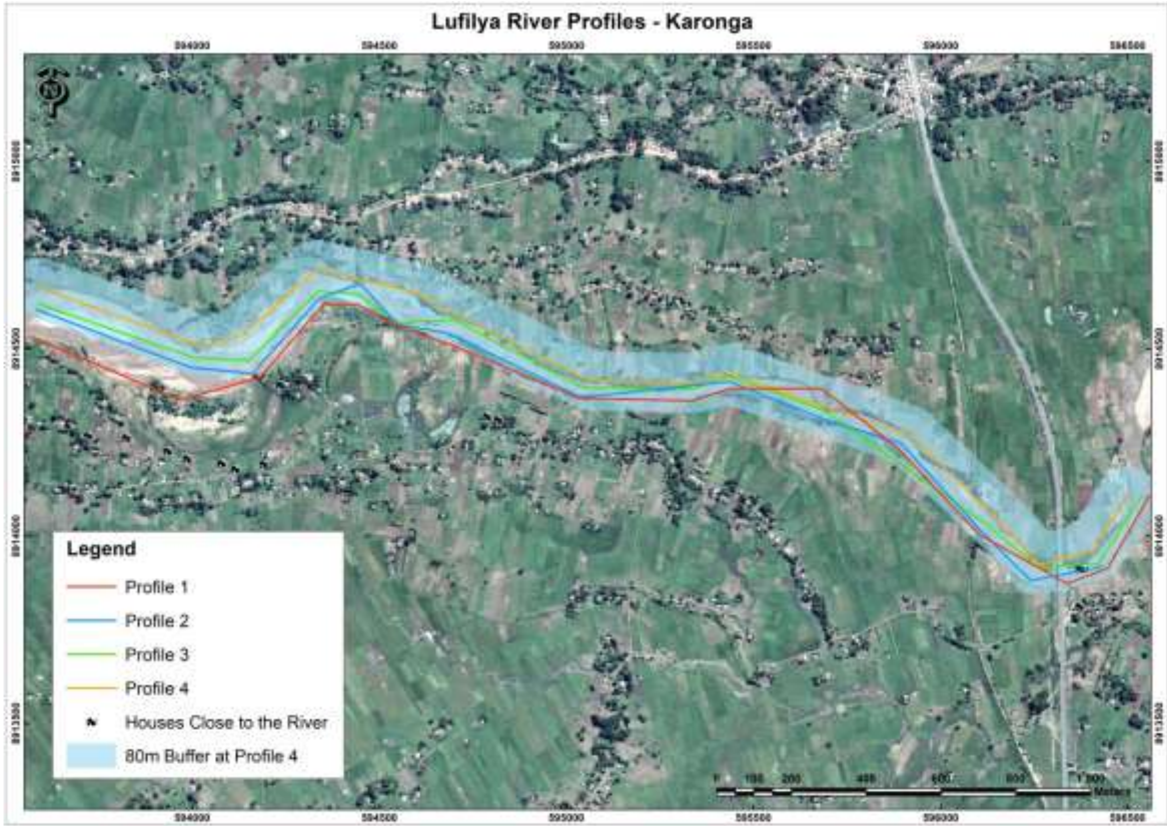


Figure 4.15: Profiles of Lufilya Catchment

In a participatory hazard assessment, a community member commented that vulnerability is high in the villages because most people's farm lands get destroyed by floods. A community member further reported that people are not certain about the river direction since the river tends to flood everywhere due to lack of banks and buffer zones degradation. The reporter narrated that, "*We are not certain who is to be displaced as the river is not stable and every time it floods, we see new direction in water flow*" (KII# 9:18th July 2021). Another key informant indicated that:

> "*Our big problem here is about lack of focus to deal with these floods. When the river started changing in different directions, people accused each other of witchcraft, accusing some people to have caused the problem in order to become rich*" (KII# 8: 19th July 2021).

It was reported that some gentlemen were accused to have installed local medicines in the river to cause troubles to others and thereby become rich.

However, in Lilongwe city, the results revealed that Lingadzi River catchment has maintained its channel with some minor modifications from the original points as it is depicted from the satellite image (Figure 4.16). In flood hazard assessment, key informants attributed the intense causes of catchment change to human settlements, brick making, and sand extraction. A member of the WCPC alluded to that youths in Mtandire ward have nothing do and thereby have resorted to brick making and sand mining in the river.

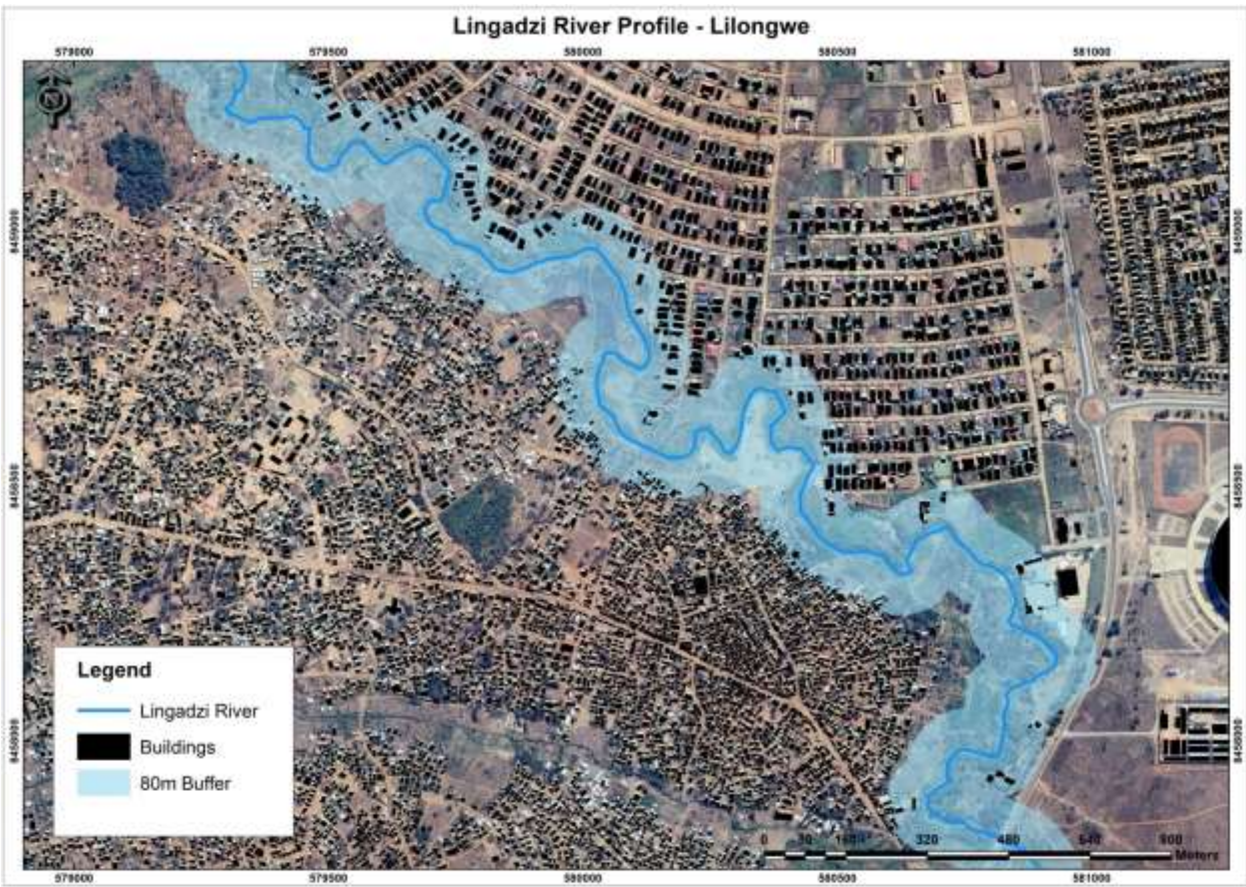


Figure 4.16: Profile of Lingadzi Catchment

In the same flood hazard assessment, one response further said: "*These floods existed but not to the magnitude we see today*! We *are experiencing these floods because people have built houses in risk areas and they have bypassed authorities who also seems that they are not doing their work as required" (*KII 13; 27 July 2021*).*

4.2.3.2 Flooding and the changing land and settlements patterns

- **Land Availability**

The geospatial analysis determined the area of the land that was available between the households and the image satellite of Lufilya River before the river began changing from profile 4 (original channel) and profile 1 (Figure 4.17). The results show that about 0.920970km^2 or 920,970.180m^2 of land area was available before flooding events changed the profile of the Lufilya River in KD. The results also show that households' settlement which were very far from the image satellite of Lufilya River are now very close to the river (Figure 4.17). This was observed to be one of the main causes of households' vulnerability to floods.

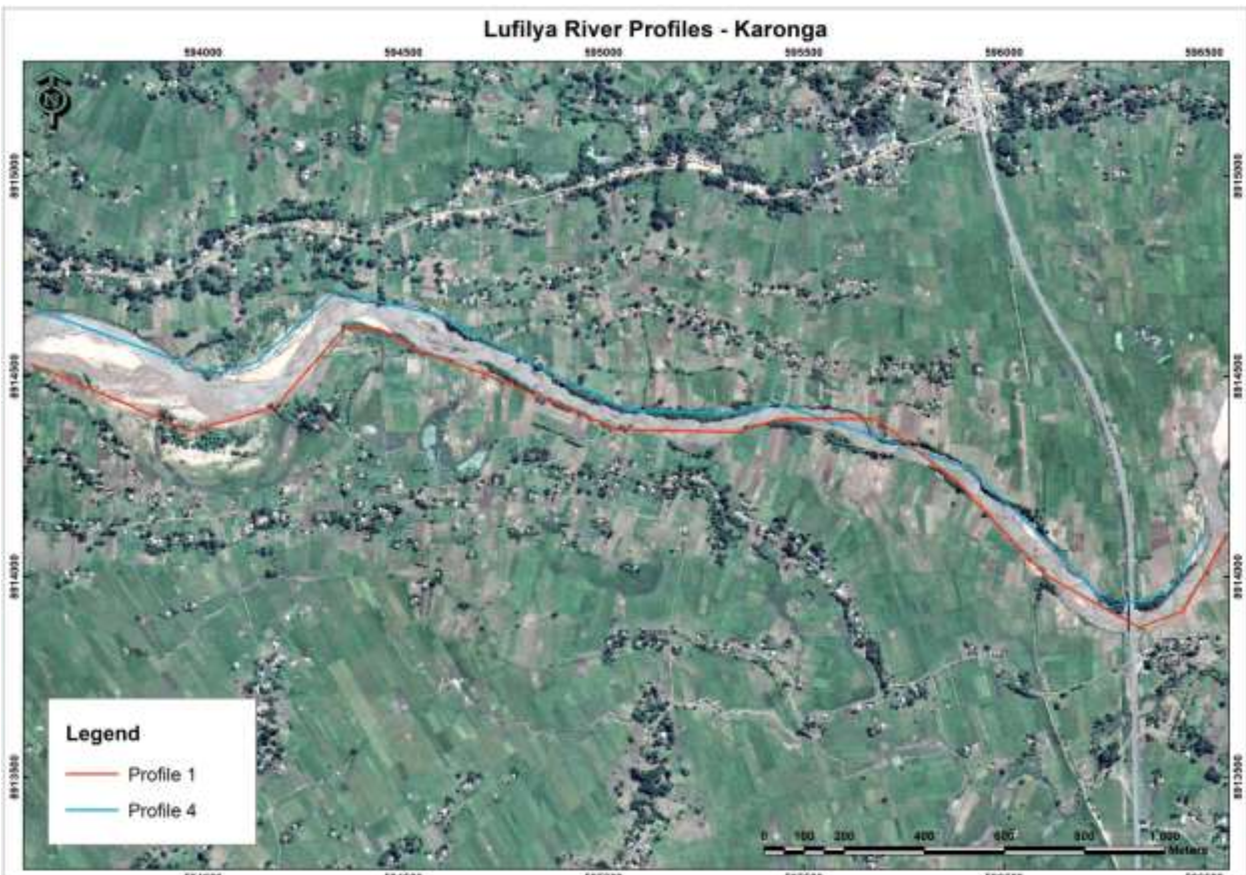


Figure 4.17: Land Area of affected households along Lufilya Catchment

The results further revealed that the changing river profile due to flooding regime has contributed to the reduction of agricultural land were people used to cultivate maize, groundnuts and pigeon peas. The calculated results show the available land of about 0.534148km^2 (Figure 4.17). The results revealed the loss of land due to flooding of about 0.386822km^2 (0.920970km^2-0.534148km^2). The results further revealed a distance of 84.64m between profiles 1 and 4. This distance is an indication that the land which households used for other activities is being depleted thereby making people become landless.

During HVCA, key informants and communities leaders perceived the scale of damages resulting from floods to be huge. One key informant indicated that "*our vulnerability is increased because people continue losing their cultivated lands, planted crops, livestock and household properties*" (KII#7: 16 July 2021).

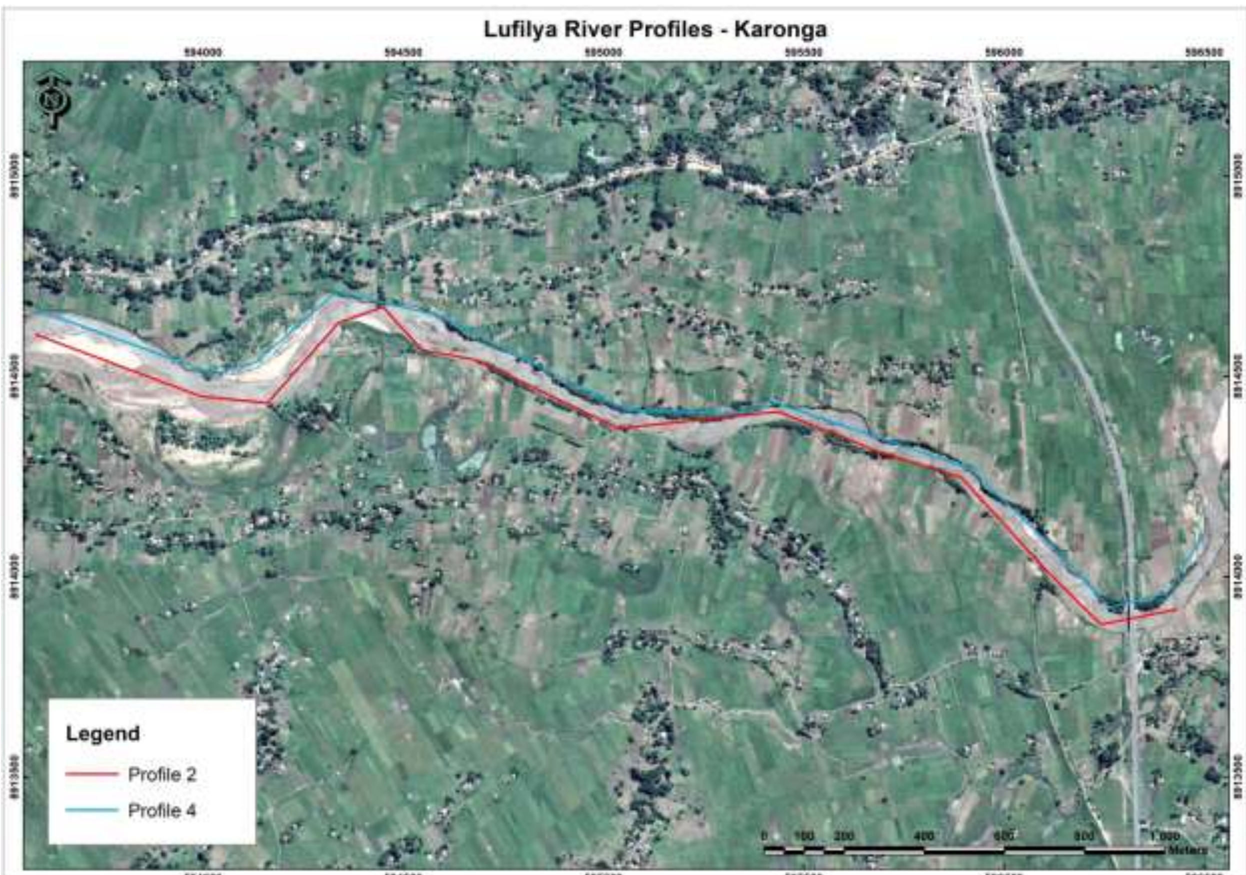


Figure 4.18: Land Area of Affected Households along Lufilya Catchment

The results further revealed a distance of 74.63m between profiles 2 and 4. This distance is an indication that the land which households used for other activities is being depleted thereby making people become landless.

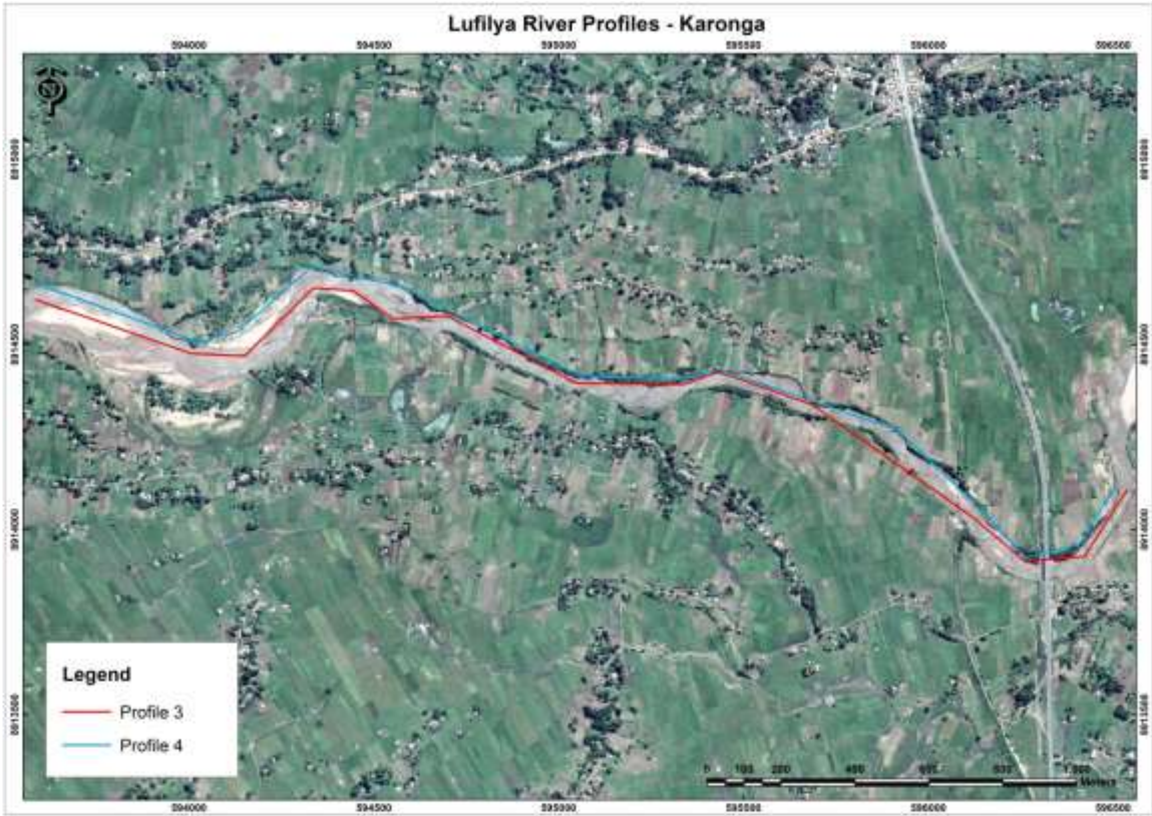


Figure 4.19: Land Area of Affected Households along Lufilya Catchment

The results further revealed a distance of 64.43m between profiles 3 and 4. This distance is an indication that the land which households used for other activities is being depleted thereby making people become landless.

- **Flooding and Settlement Patterns**

The results of the distances from the households to the river profiles show that households that were very far from the river (profile 4) are now very close to the newly formed profiles (Table 4.6).

Table 4.6: Distances of Households to Different Profiles of Lufilya Catchment

Code	Profile 1	Profile 2	Profile 3	Profile 4
H1	200.65	285.40	307.51	349.45
H2	161.63	252.01	276.14	197.25
H3	151.53	246.55	275.37	192.744
H4	161.45	243.21	269.74	310.51
H5	199.73	247.60	278.27	445.96
H6	226.73	260.44	292.70	477.88
H7	231.26	269.36	309.11	544.90
H8	83.52	112.44	145.79	374.01
H9	145.59	160.01	209.19	283.63
H10	146.71	161.53	200.96	274.55
H11	75.55	102.59	102.59	198.68

The results revealed that household with code **H8** which had a distance as far as 374.01m^2 from the original satellite of Lufilya river catchment is now at 83.5m^2 (Table 4.6). The results show that household with **code H11** was far to the original satellite (198.68m$^{2)}$, now the distances has fluctuated in profiles 1, 2 and 3. In some instances, the household is gaining land with distances of 252.01m^2, 276.14m^2 and 317.56m^2 respectively. Significantly, the short distance of the settlements located along Lufilya river catchment contribute to the increase in household vulnerability to floods. On the same, households that were very far from the river as depicted by the satellite image (544.9m) are now getting closer to the Lufilya River.

Relatedly, the results of the digitized flood maps overlayed with surveyed households' showed that most houses that are highly vulnerable to floods are between a distance of 0.06-0.12km to Lingadzi river in Mtandire ward of LC (Figure 4.20) and 0.198km to 0.317km along the buffer zones of Lufilya river in T/A Kilupula of KD (Figure 4.21).

FLOOD MAP OF MTANDIRE AREA IN LILONGWE CITY

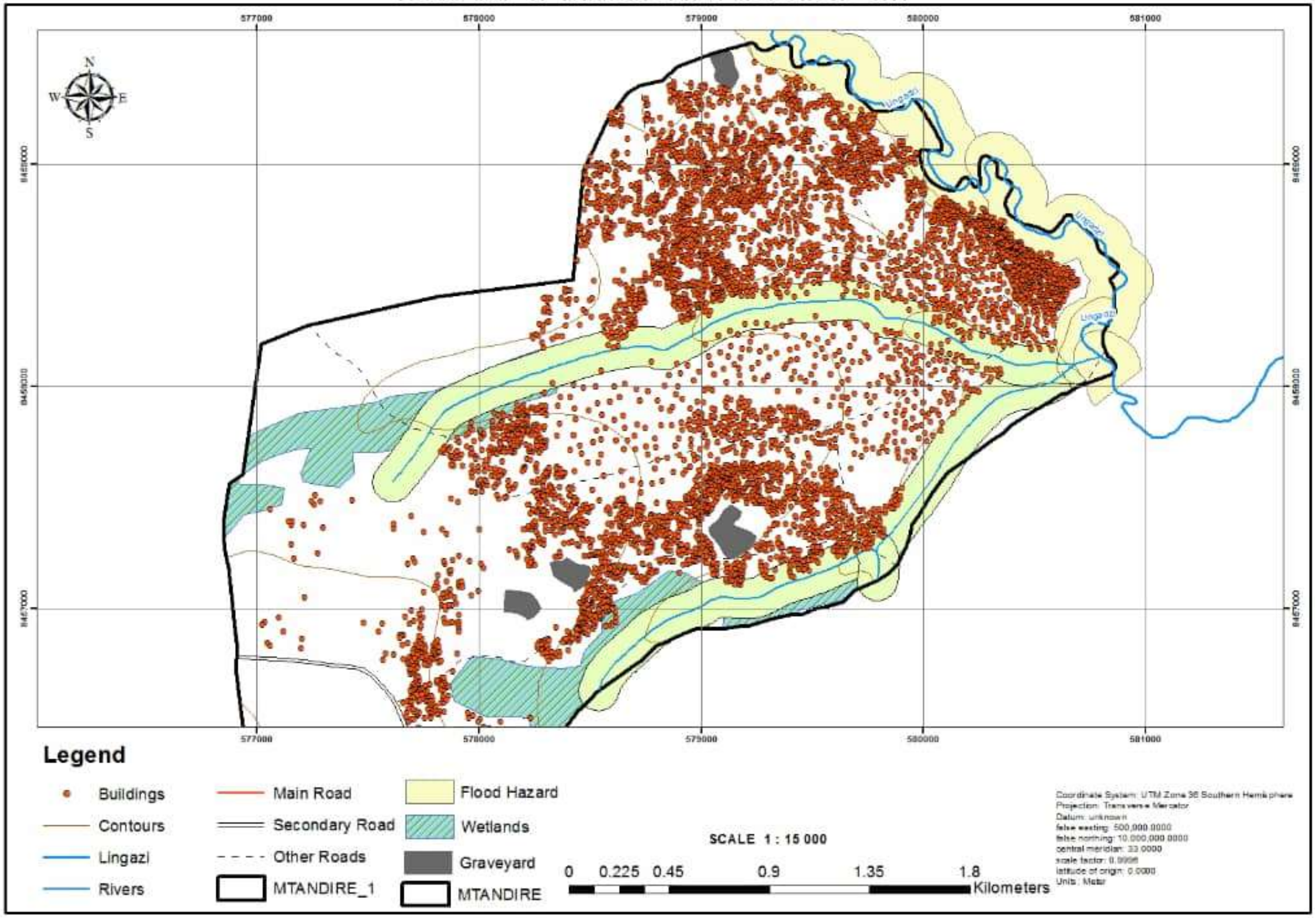


Figure 4.20: Map of Mtandire showing households/buildings in relation to Wetlands and drainage systems

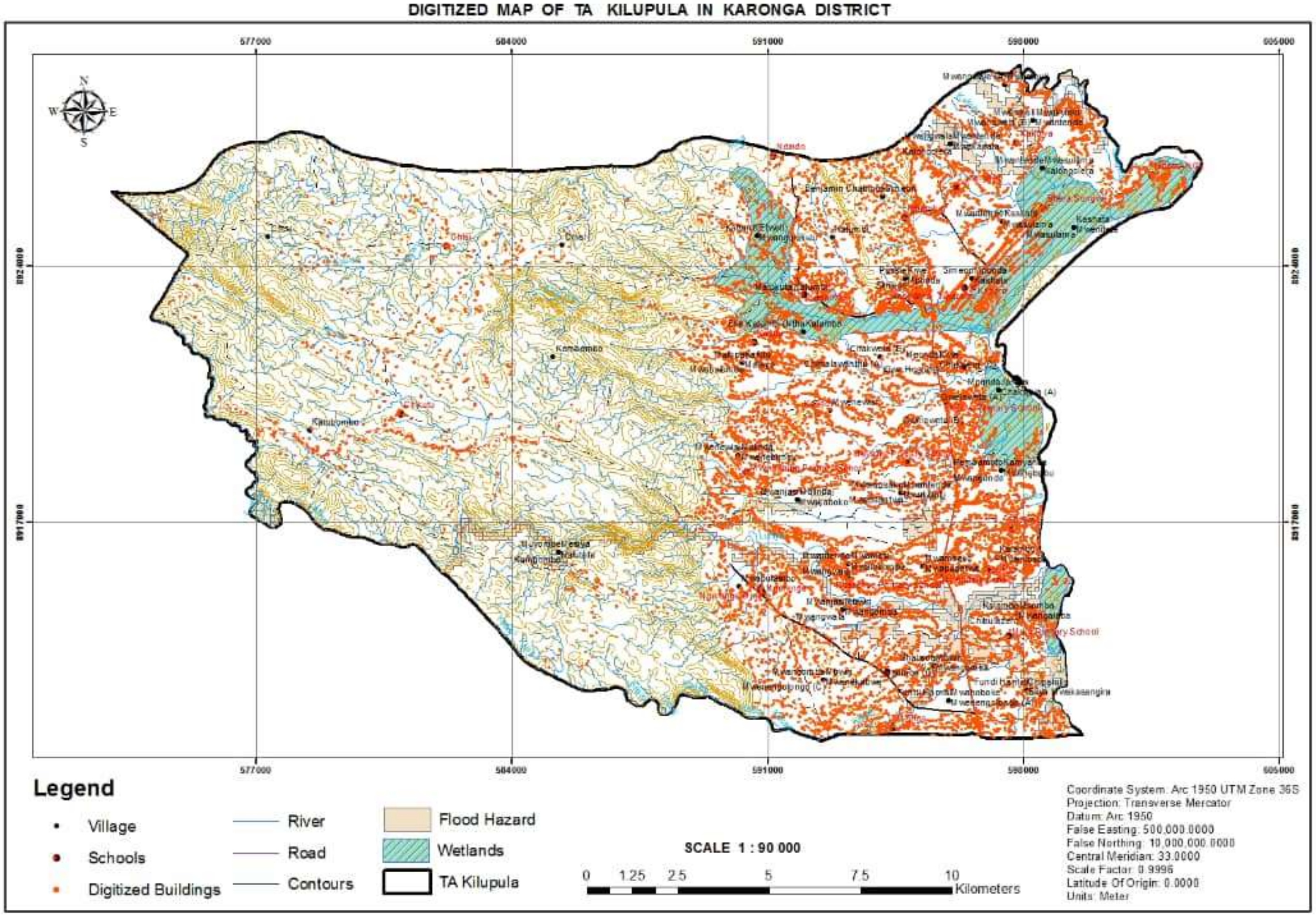


Figure 4.21: Map of T/A Kilupula showing households/buildings in relation to Wetlands and drainage systems

During HVCA, community leaders interviewed for the study expressed that people do not have interest to move to locations farther away from their original homes despite having their households close to the river. It was reported that it would be difficulty for people to vacate flood prone areas because of limited land for expansion lack of access to social services like schools and health services in the new areas. A traditional leader said: "*In 1991 we tried to move to safer places but we did not stay because the conditions were very poo*r" (KII#6: 18 July 2021). The results of the trends of flooding events in Lilongwe revealed that people are building houses closer to the river. The results revealed that some households are as closer as 37.18m from the river. The major outcome of this river trend is that the riverbanks of Lingadzi River are being depleted due to activities such as settlement, farming, sand extraction and brick making.

4.2.4 Land Use Land Cover (LULC) Classification

The analysis of river basins requires land-use and land-cover (LULC) change detection to determine hydrological and ecological conditions for sustainable use of their resources. This study assessed LULC changes over 30 years (1990–2021) in the Lingadzi and Lufilya river basins of LC and KD respectively. Six pairs of images acquired using Landsat 5 TM and 8 OLI sensors in 1990 and 2021, respectively, were mosaicked into a single composite image of the basin. A supervised classification using the Neural Network classifier and training data was used to create LULC maps for 1990-2021. A full methodology has been presented in section 3.4.3.3, complimented by Table 3.16. The results of the supervised classification and land images for LULC in LC and KD are presented in the six figures 4.22-4.27. Furthermore, the results are summarized in figures 4.28 and 4.29, which provide the calculated area statistics for all the land use classes which were analysed.

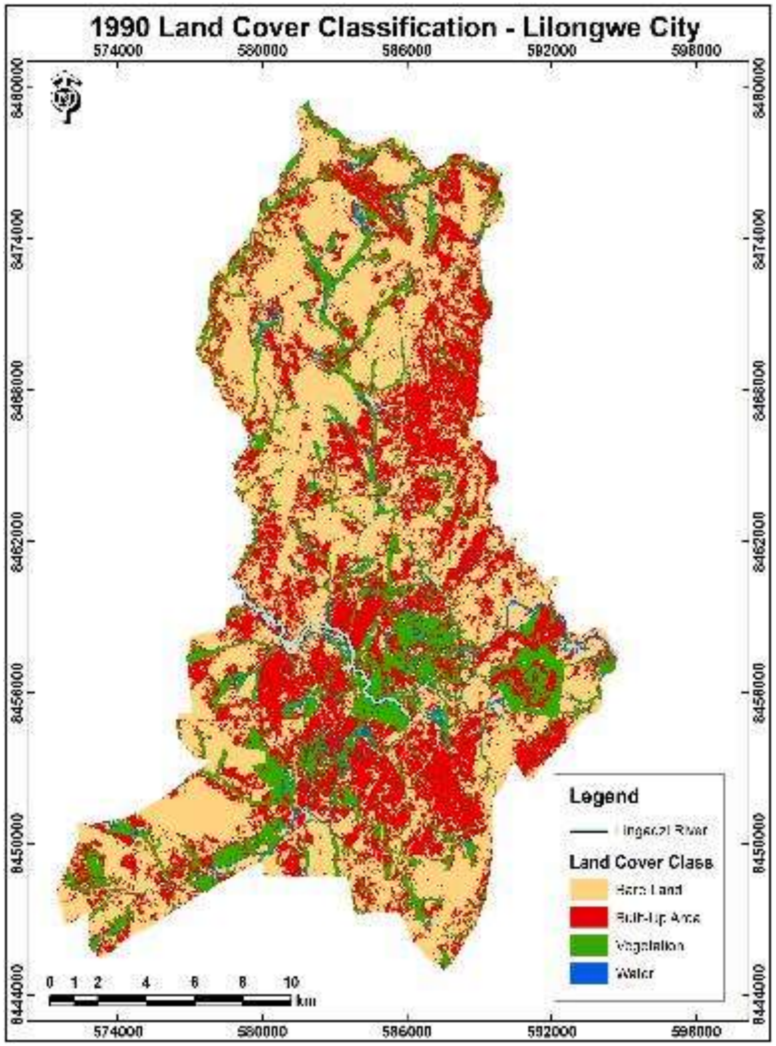


Figure 4.22: Results of Land Cover Classification in Lilongwe for 2006 Image Satellite

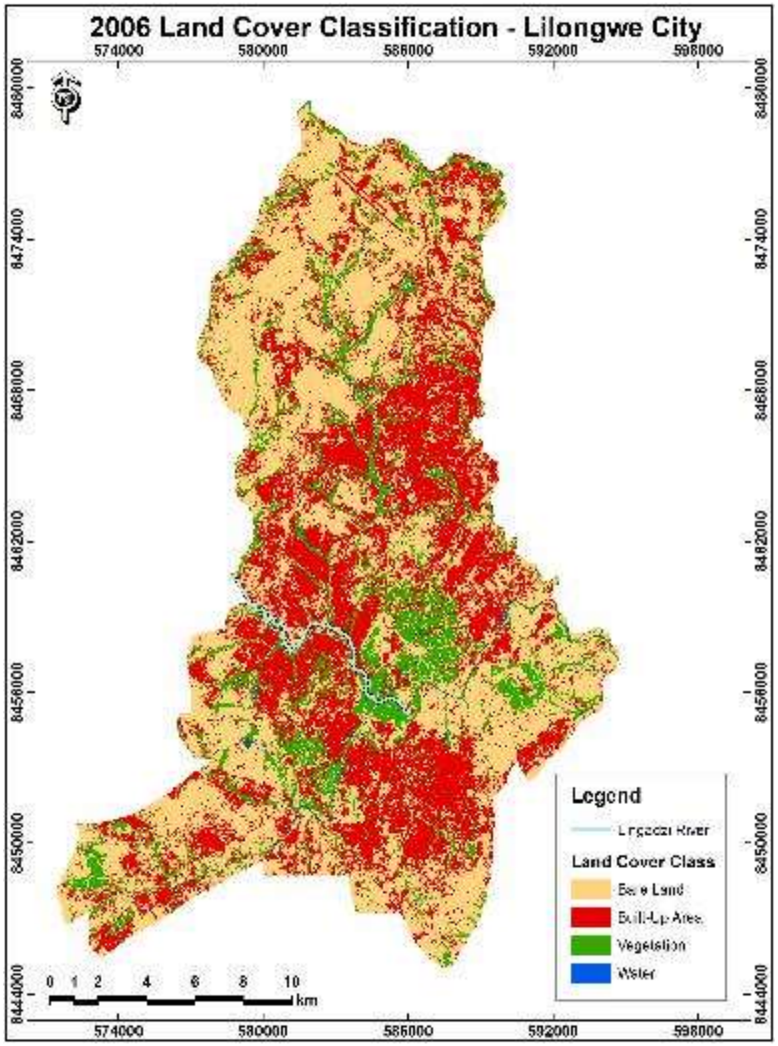


Figure 4.23: Land Cover Classification in Lilongwe city for 1990 Image Satellite

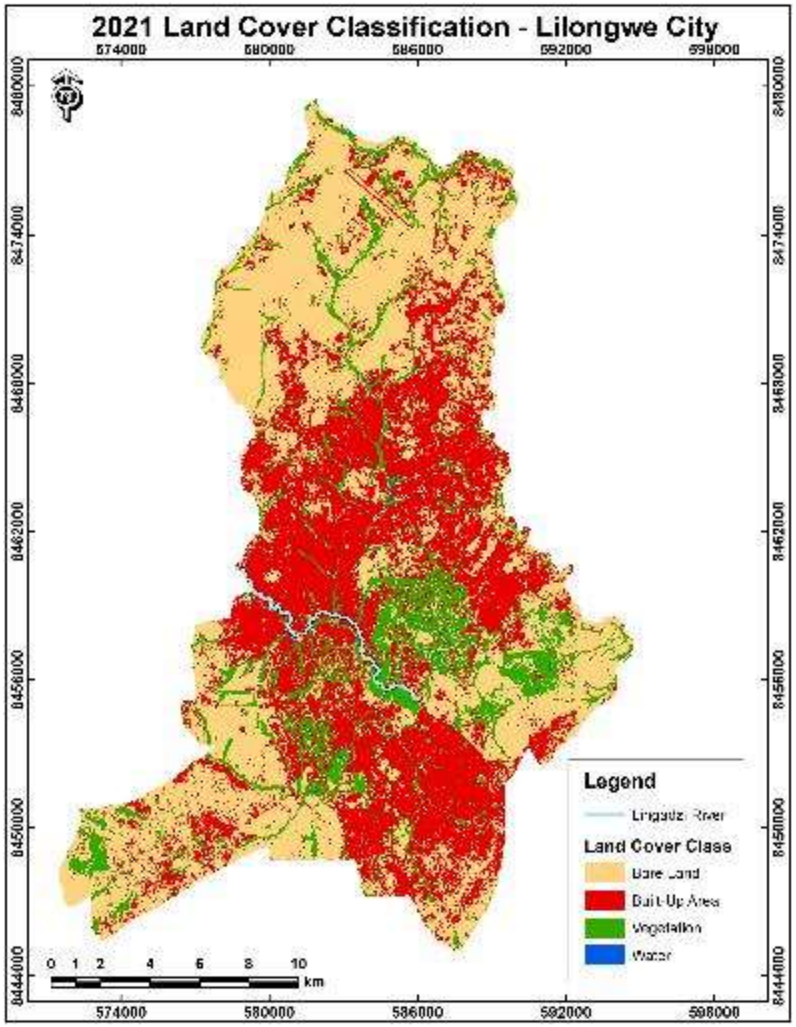


Figure 4.24: Results of Land cover Classification in Lilongwe City for 2021 Image Satellite

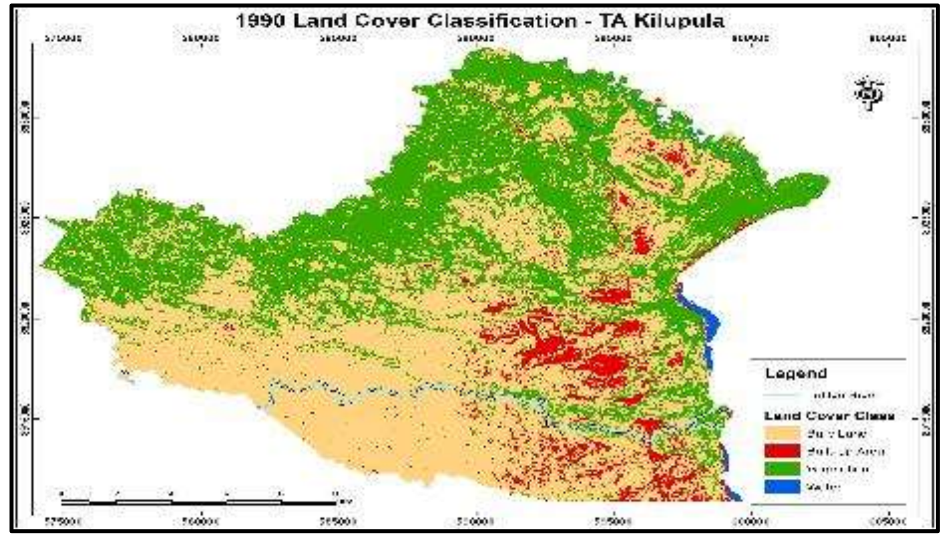


Figure 4.25 Results of Land Cover Classification in Karonga district for 1990 Image Satellite

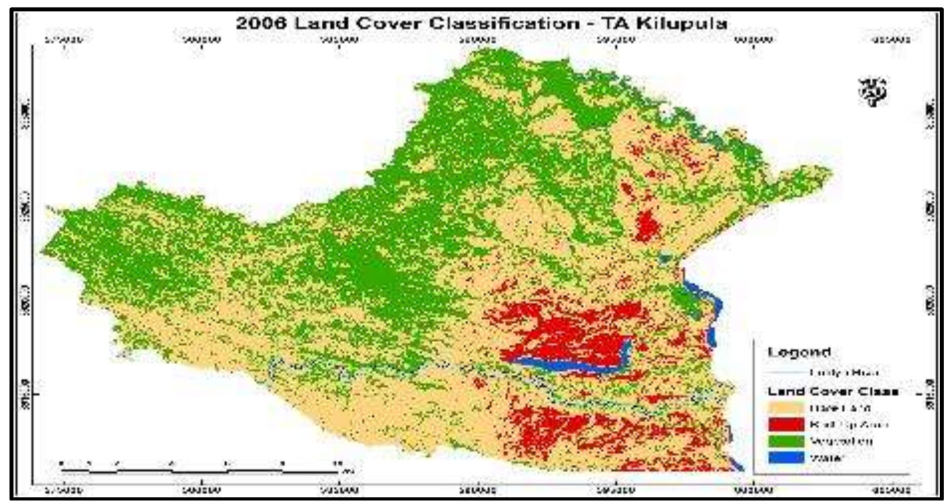


Figure 4.26: Karonga 2006 Image Satellite

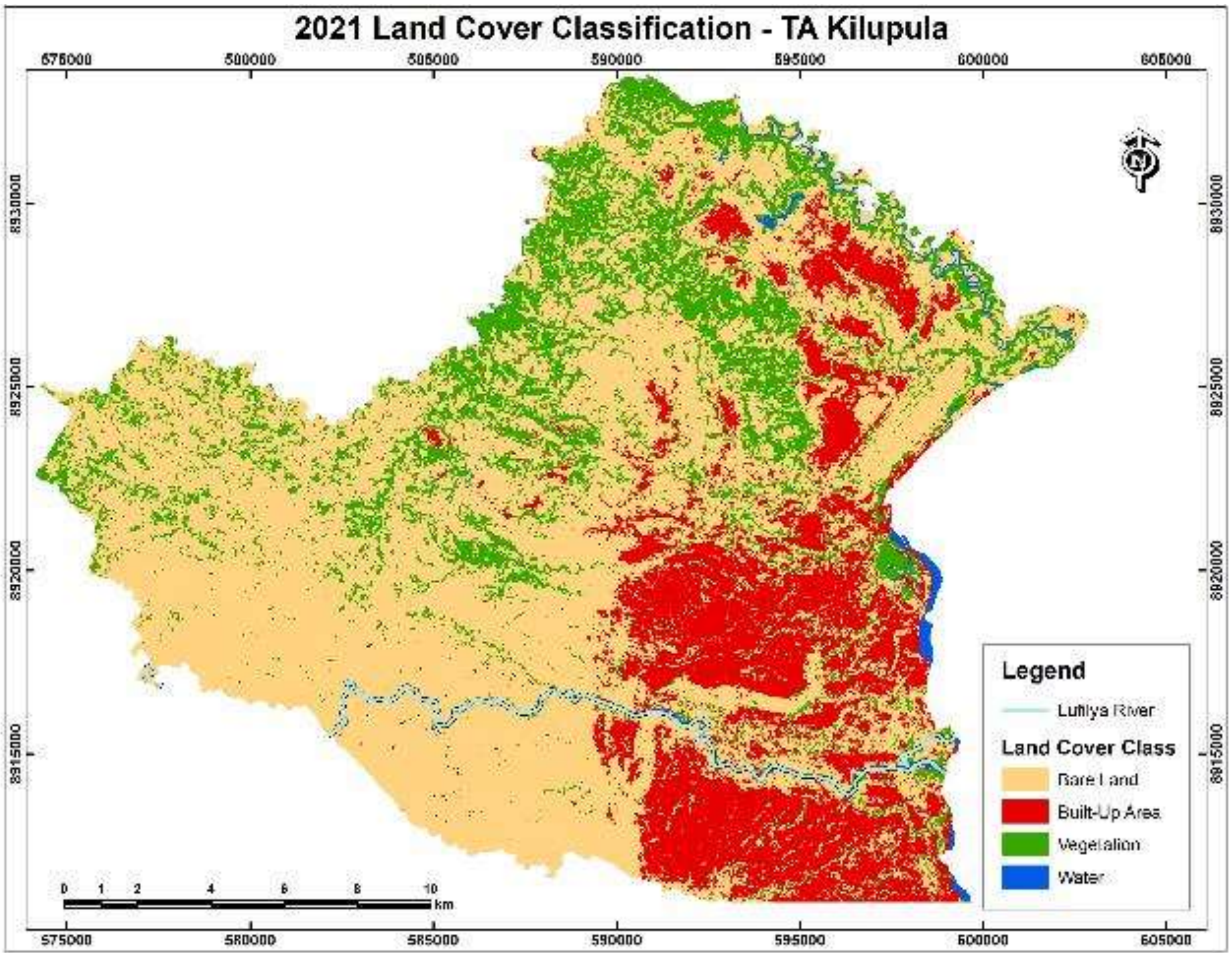


Figure 4.27: Karonga 2021 Image Satellite

4.2.4.1 Land Cover Changes

In Mtandire ward, the results show a total bare land loss of 32km^2 from 1990 to 2021 (representing 16% land loss) and 21km^2 from 1990 to 2006 (representing 11% land loss). The results of this trend indicate that between 2006 and 2021, bare land was lost by 11km^2 representing 5%. The results further show that built up area is gaining area of 21mk^2 in 2021 from 129km^2 in 1990. The results show that the area is losing vegetation by 10km^2 from 1990 to 2021. Finally, the results show water losing an area of land coverage by 10km^2 from 1990 to 2021 (Figure 4:28).

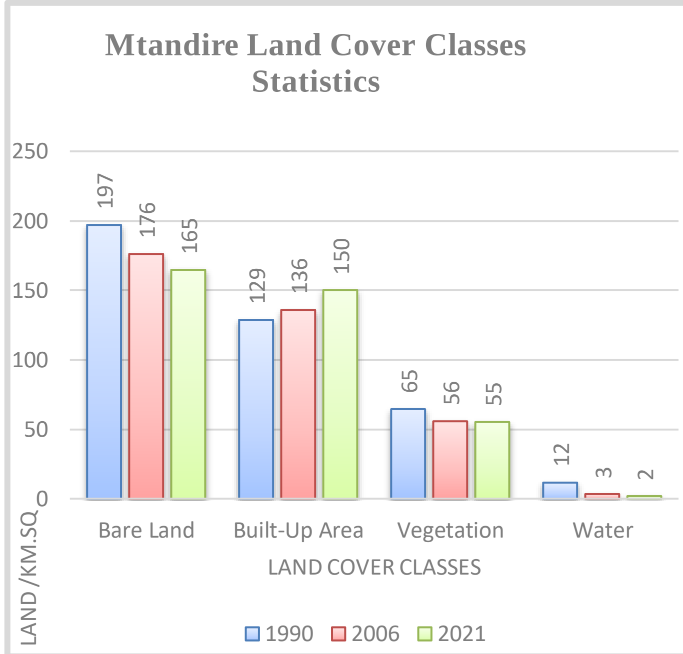


Figure 4.28: Land Cover Statistics in Mtandire wards

While in GVH Mwakasangila in T/A Kilupula, the results show a total bare land loss of 46km^2 from 1990 to 2021 (representing 20% land loss) and 35km^2 from 1990 to 2006 (representing 15% land loss). The results of this trend indicate that between 2006 and 2021, bare land was lost by 11km^2 representing 5%. The results further show that built up area is gaining area of 45mk^2 in 2021 from 24km^2 in 1990. The results show that the area is losing vegetation by 81km^2 from 1990 to 2021. Finally, the results show water gaining an area of land coverage by 2km^2 from 1990 to 2021 (Figure 4:29).

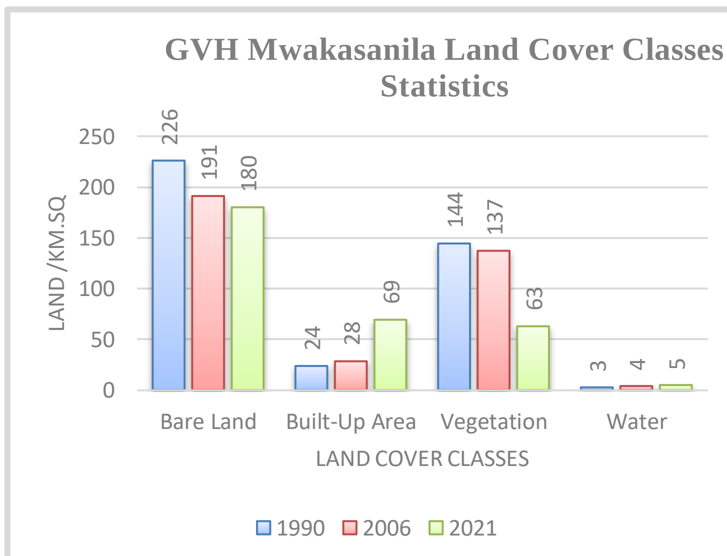


Figure 4.29: Land Cover Statistics in GVH Mwakasangila

4.3 Factors Determining Households' Flood Vulnerability

This study grouped the factors that determine household vulnerability into categories namely (1) underlying vulnerability factors (UVF), (2) vulnerability factors implication and variability on the demographics (3) vulnerability as a component of exposure, susceptibility and resilience, (4) determination of vulnerability (DV) based on flood vulnerability index (FVI) and (5) elements at risk in the vulnerability factors (ERVF) in order to fully examine the factors that determine households' flood vulnerability in Mtandire ward of Lilongwe city and T/A Kilupula of Karonga district. The outcome of the analysis of the results based on the highlighted categories is presented below:

4.3.1 Underlying Vulnerability Factors

The results in a univariate statistical analysis of the UVFs were classified into five sub-themes presented as follows:

4.3.1.1 Underlying Physical Vulnerability Factors (UPVFs)

Table 4.7: Underlying Physical Vulnerability Factors in Lilongwe City and Karonga District

LL: n= 345 & KA: n=200	Underlying physical vulnerability factors							
Measurement scale	Poor construction of infrastructural facilities		Lack of construction materials		Ageing systems		Construction of roads, homes and other structures	
	LC	KD	LC	KD	LC	KD	LC	KD
Less important	11	6	10	10	54	72	8	64
Important	28	26	33	20	34	25	26	27
Very important	**61**	**66**	**57**	**70**	12	3	**66**	**9**
Total Percentage	100	100	100	100	100	100	100	100

The results show that all the physical factors except ageing systems 12% and 3% in Mtandire ward of LC and in T/A Kilupula of KD respectively as well as construction of roads and other structures 9% in T/A Kilupula have low percentage in the category of "very important" underlying factors that determine vulnerability in Mtandire ward of Lilongwe city and T/A Kilupula of Karonga district (Table 4.7).

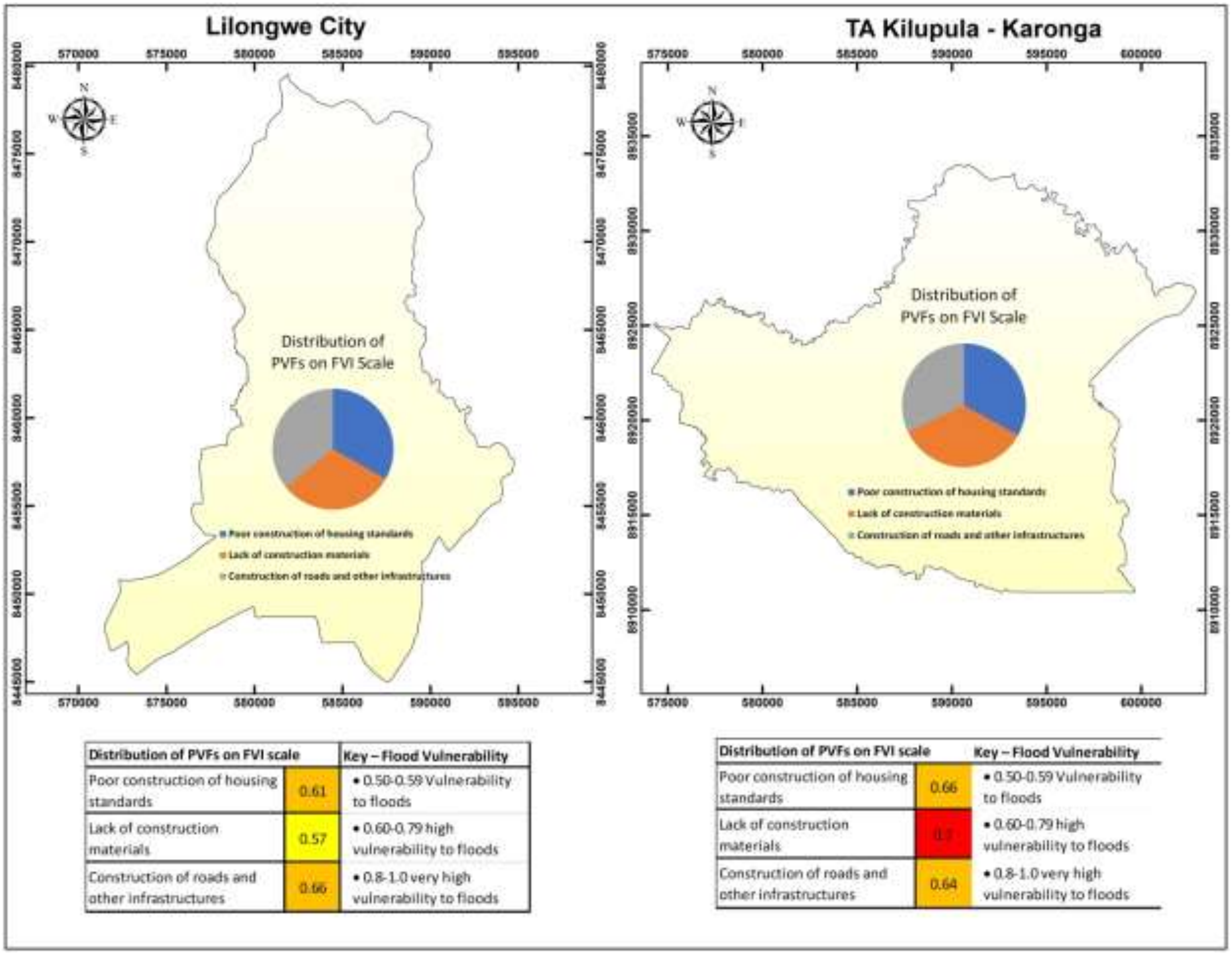


Figure 4.30: Distribution of Physical Vulnerability Factors

The results further revealed that lack of construction of materials is in the index value (IV) of "*high vulnerability"* (0.60-0.75) in T/A Kilupula at 70% while in the IV of "*flood vulnerability"* (0.50-0.59) in Mtandire ward at 59% (Figure 4.30). In terms of poor construction of infrastructural facilities, the results revealed the same IV of "*high vulnerability"* (0.60-0.79) in Mtandire ward of LC and T/A Kilupula of KD at 61% and 66% respectively. On construction of roads and other structures, the results revealed the IV of "high vulnerability" (0.60-0.79) only in Mtandire ward of LC at 66% (Figure 4.30).

4.3.1.2 Underlying Social Vulnerability Factors (USVFs)

Table 4.8: Underlying Social Vulnerability Factors in Lilongwe City and Karonga District

LL: n= 345 & KA: n=200	Underlying Social Vulnerability Factors							
Measurement scale	Lack of capacity to cope		Lack of social security		Lack of human rights		Lack of access to health services	
	LC	KD	LC	KD	LC	KD	LC	KD
Less important	12	64	27	69	17	4	9	1
Important	47	35	40	25	35	30	29	26
Very important	41	1	33	6	48	**66**	**62**	**73**
Total Percentage	100	100	100	100	100	100	100	100

While the results show that lack of human rights (66%) is in the category of ‘very important factor that determine vulnerability in KD, lack of access to health services was revealed to determine household vulnerability in LC (62%) and KD (73%) in the scale category of “very important” (Table 4.8).

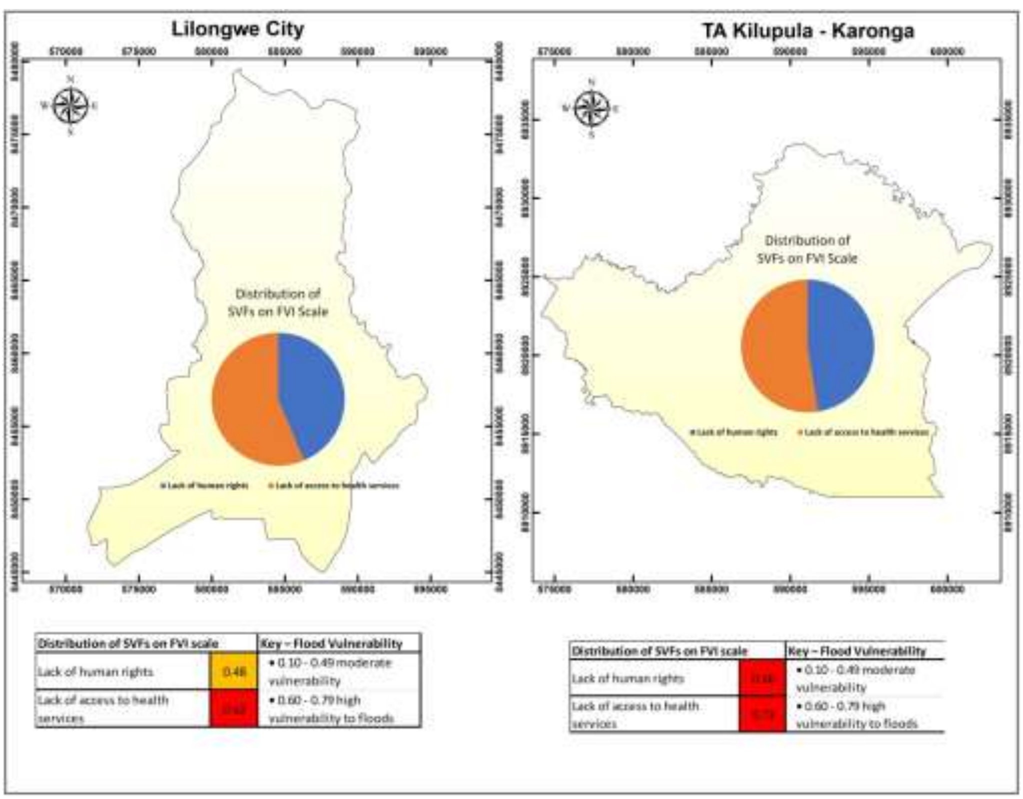


Figure 4.31: Distribution of the Social Vulnerability Factors

The results revealed the IVs of "*small flood vulnerability"* (0.1-0.49) in Mtandire ward of LC for lack of human rights (48%) while of "*high flood vulnerability"* (0.60-0.79) in T/A Kilupula of KD at 66%. In terms of lack of access to health services, the results found the IV of "*high flood vulnerability*" (0.60-0.79) at 62% and 73% in Mtandire ward and T/A Kilupula respectively (Figure 4.31).

4.3.1.3 Underlying Economic Vulnerability Factors (UEVFs)

Table 4.9: Underlying Economic Vulnerability Factors in Lilongwe City and Karonga District

n= 345 LC & 200KD	Outcome % from participants for variables of underlying physical vulnerability factors							
Measurement scale	No credit unions/financial support		Lack of markets and income generating activities		Poverty		Lack of alternative livelihoods	
	LC	KD	LC	KD	LC	KD	LC	KD
Less important	20	**51**	22	34	6	3	10	4
Important	37	32	32	40	21	29	36	25
Very important	43	17	46	26	**73**	**68**	**54**	**71**
Total Percentage	100	100	100	100	100	100	100	100

The results revealed that limited finances (51%) is a "less important" factor generating households' vulnerability in Karonga while it falls in "very important" contributing to vulnerability (43%) in Lilongwe city (Table 4.9), yet its percentage is less than the threshold of 50%.

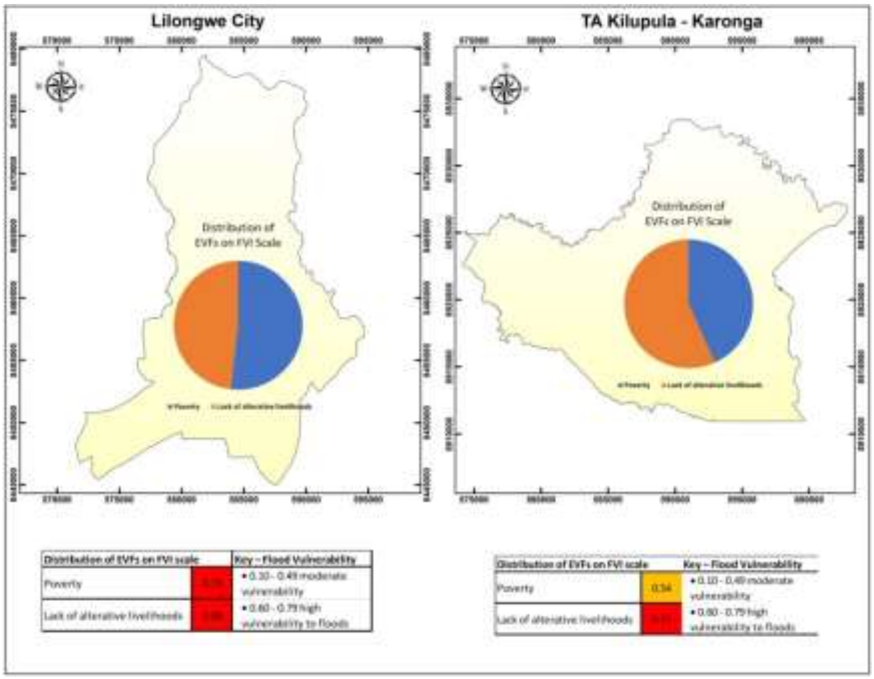


Figure 4.32: Distribution of Economic Vulnerability Factors

The results revealed the IVs of "*high flood vulnerability"* (0.60-0.79) for poverty at 73% and 68% in Lilongwe and Karonga respectively (Figure 4.32). While the results revealed the IV of "*flood vulnerability"* (0.50-0.59) in Lilongwe at 54%, in Karonga (73%) it was categorised in the VI "*high flood vulnerability*" for lack of alternative livelihoods (Figure 4.32).

4.3.1.4 Underlying Environmental Vulnerability Factors (UE_nVFs)

Table 4.10 Underlying Environmental Vulnerability Factors in Lilongwe City

LL: n= 345 & KA: n= 200	Underlying Environmental Vulnerability Factors									
	Pressure on cultivated land		Extensive paving		Environmental mismanagement		Poor land management		In appropriate use of resources	
Measurement scale	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**
Less important	28	12	36	64	11	3	11	4	11	7
Important	34	18	29	32	29	35	28	41	33	28
Very important	38	70	35	4	60	62	61	55	56	64
Total %	100	100	100	100	100	100	100	100	100	100

The results revealed that pressure on cultivated land (70%) contributes to vulnerability in KD district and not in LC. The results further revealed that environmental mismanagement is a factor generating households' vulnerability in LC (60%) and Karonga district (62%); poor land management in LC (61%) and Karonga (55%) and inappropriate use of resources in Lilongwe (56%0 and KD (64%) (Table 4.10).

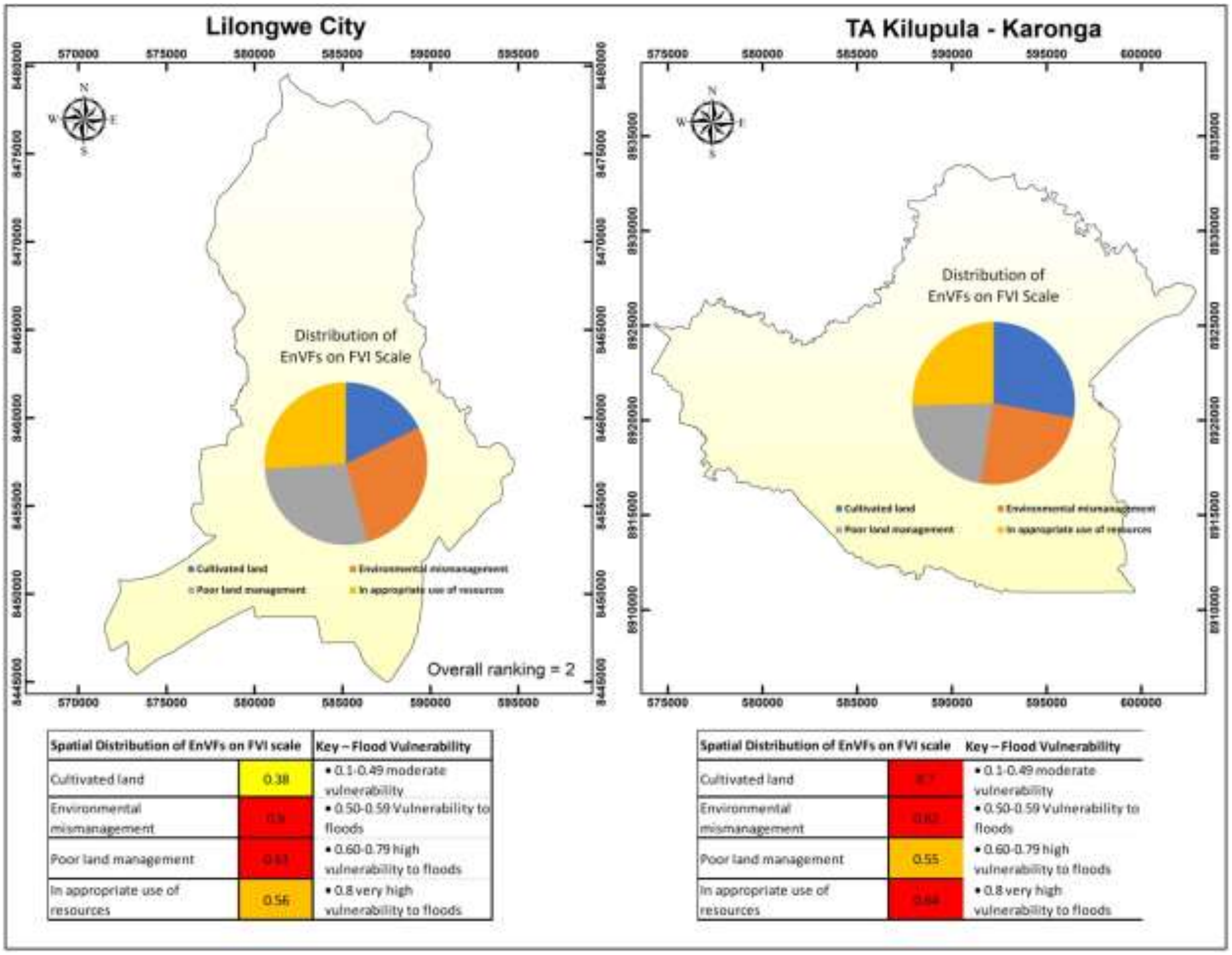


Figure 4.33: Graphs of the Underlying Environmental Vulnerability Factors

The results revealed the IVs of "*small flood vulnerability"* (0.1-0.49) in LC for pressure on cultivated (38%) while of "*high flood vulnerability"* (0.60-0.79) in KD at 70%. In terms of environmental mismanagement, the results found the IV of "*high flood vulnerability*" (0.60-0.79) at 60% and 62% in LC and KD respectively (Figure 4.33). The results further revealed the IVs of "*high flood vulnerability"* in LC for poor land management (61%) while of "*flood vulnerability"* in KD at 55% and vice versa for in appropriate use of resources (Figure 4.33).

4.3.1.5 Underlying Cultural Vulnerability Factors (UCVFs)

Table 4.11: Underlying Cultural Vulnerability Factors in Lilongwe City

LL: n= 345 & KA: n= 200	**Underlying Cultural Vulnerability Factors**									
	Cultural conflicts		**Local behaviour**		**Local norms**		**Defiance of safety precautions and regulations**		**Absence of personal responsibility**	
Measurement scale	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**
Less important	**50**	**42**	23	7	71	**3**	21	27	13	28
Important	31	38	30	20	22	22	49	33	47	44
Very important	19	20	47	73	**7**	75	30	40	40	28
Total %	100	100	100	100	100	100	100	100	100	100

The results revealed that all the cultural vulnerability factors were less important in generating households' vulnerability to floods in Karonga and in Lilongwe city were varying in the scale of "less important" and "important" (Table 4.11).

The results revealed the IVs of "*small flood vulnerability"* (0.1-0.49) for local norms (7%) and local behaviour (23%) in LC while of "*high flood vulnerability"* (0.60-0.79) in KD for local norms and behaviour (75%) (Figure 4.34).

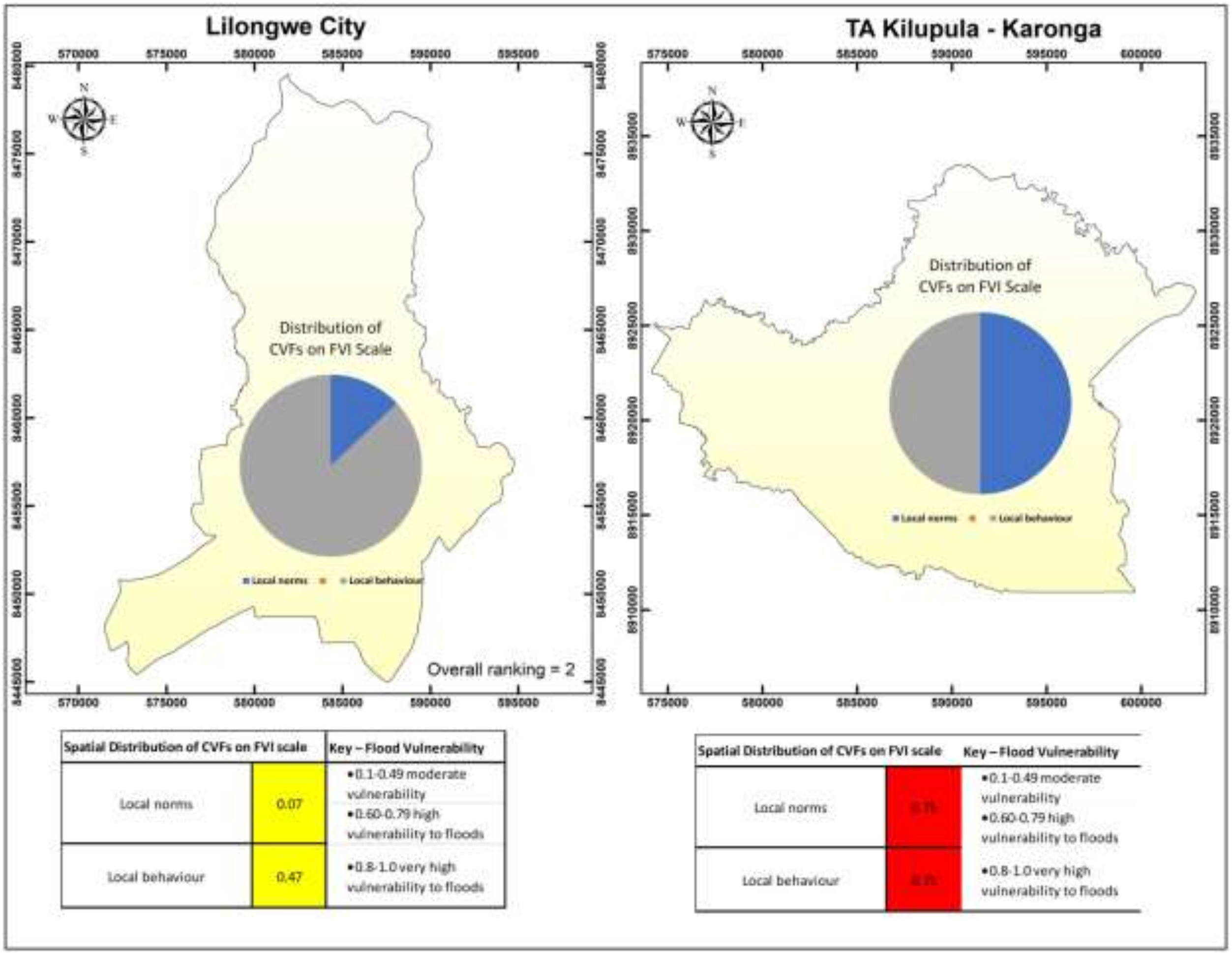


Figure 4.34: Graph of Underlying Cultural Vulnerability Factors

The results of the KIIs also revealed that lack of personal responsibility (76.5%) and defiance of government regulations (76.5%) as key cultural vulnerability determinants (Table 4.12). One key informant said, *"People lack self-responsibility and they defy government orders not vacate and live in prone areas"* (KII# 5, 16 July 2021).

Similarly, a key informant in Lilongwe city indicated that:

> *"Rich people build their mansions without following government regulations and that they are building in risk areas" (KII# 15, 28 July 2021).*

Table 4.12: Results of Key Informants on Underlying Vulnerability Factors

Category	Generated Code on Vulnerability conditions	Count	Cases	% Cases
Vulnerability conditions	**Residing in flood prone areas**	**10**	**10**	**58.8**
	Bad farming practices	6	6	35.3
	Lack of personal responsibility	**21**	**13**	**76.5**
	High illiteracy levels	**12**	**9**	**52.9**
	Defiance of government regulations	**28**	**13**	**76.5**
	Poverty	5	5	29.4
	Flood benefits	**11**	**10**	**58.8**
	Population growth	3	3	17.6
	Diseases	1	1	5.9
	Politicization	3	2	11.8

The results from key informants show that residing in flood prone areas (59%), high illiteracy levels (53%), lack of personal responsibility (77%), defiance of government regulations (77%) and benefit from floods are key causes of vulnerability to floods in both Lilongwe city and Karonga district (Table 4.12) contribute to vulnerability in the studied areas. These results correlate with those that were established from household survey such as inappropriate use of resources, residing close to rivers and low levels of education.

4.3.2 Implications of Underlying Vulnerability Factors on Demographics

The result of a single p-value test in a "combinedPvalue analysis package" for all vulnerability factors against demographic characteristics show that age is not significant with any vulnerability factor in Lilongwe city and Karonga district (Table 4.13).

Table 4.13: Implications of vulnerability factors on demographics (combinedPvalue analysis)

Demographics	CombinedPvalue for vulnerability factors and demographic characteristics									
	Physical		Social		Economic		Environmental		Cultural/human	
	LC	KD	LC	KD	LC	KD	LC	KD	LC	KD
Age	0.25791	0.48852	0.5400	0.1362	0.409	0.758	0.240	0.9950	0.2019	0.1455
Sex	0.08449	**0.03712**	0.12725	**0.05399**	0.2031	**0.0562**	**0.0331**	0.20384	0.9704	**0.0594**
Education	0.23838	0.50214	**0.00100**	0.86669	**0.0235**	**0.0378**	**0.00635**	0.1580	5.5034	0.9308
Marital status	**0.04944**	**0.02652**	0.21879	0.13198	**0.0497**	0.5827	**0.03828**	0.30849	0.4950	**0.0526**
Occupation	0.81009	0.09704	0.43851	0.74881	**0.0106**	0.3154	0.6047	0.5773	0.3604	**0.0075**

In table 4.10**,** the results revealed that sex is significant with social vulnerability factors (0.0539), physical vulnerability factors (0.0371), economic vulnerability factors (0.0562) and cultural vulnerability factors (0.0594) in KD while only environmental factors are significant with sex (0.0331) in LC. The analysis of the key informant interviews also revealed that both female and male are vulnerable to floods due to combination of factors such as lack of resources, cultural issues that impinge on females to use draught animals, and limited access to opportunities. One key informant in Karonga said:

> *Female headed household face difficulties in the event that their houses collapsed because per traditional they cannot neither thatch houses and nor construct houses using locally materials* (10 August 2021).

The result further revealed that marital status is significant with physical vulnerability factors in T/A Kilupula of KD (0.0265), environmental factors (0.0383) and economic factors (0.0497) in Mtandire ward of LC while in T/A Kilupula (0.0526) with cultural factors (Table 4.13). In terms of education, the results established that social factors (0.001), environmental factors (0.0064) and economic factors (0.0235) are significant to education in Mtandire ward of LC while economic factors (0.0378) are significant in T/A Kilupula of KD (Table 4.13).

Finally, the results show that cultural factors (0.0075) and economic factors (0.0106) are significant to occupation in T/A Kilupula and Mtandire ward respectively (Table 4.13). The analysis of the key informant interviews also revealed that both females and males are vulnerable to floods due to combination of factors such as lack of resources, cultural issues that impinge on females to use draught animals and limited access to opportunities. The results of the key informants also revealed that both females and males are vulnerable to floods due to over dependency on subsistence agriculture.

4.3.3 Variability of Vulnerability Factors on Gender

In this category, the study intended to check the variability of males and females in terms of how they are affected by the floods in the study areas. In order to achieve this, the study conducted a hypothesis testing as follows:

H_0: There is difference between the variability of vulnerability factors between male and female.

The result of cross tabulation to obtain adjusted residual (AR) to explain the variability of implications of vulnerability factors based on the constructed hypotheses revealed varied results as follows:

4.3.3.1 Variability of Physical Factors on Gender

Table 4.14: Physical factors on Gender

Sex and scale measurements		Poor construction standards		Lack of construction materials		Construction of roads and infrastructures	
		LC	KD	LC	KD	LC	KD
		AR	AR	AR	AR	AR	AR
Female	**INT**	1.1	1	2.5	2.3	0.7	0.4
	VINT	1.5	0.4	0.4	0	1.2	0.4
Male	**INT**	1.2	-1	2.3	2.5	-0.7	0.3
	VINT	-1.4	-0.4	-0.3	0	-1.1	-0.4

The results show that the AR is above the threshold of 2 (or 1.96) for females and males in the Mtandire ward and T/A Kilupula for lack of construction materials in a scale of "important" (INT). On the one hand, the results revealed a sum of AR of 7.1 in LC and 4.7 in KD. While the sum of AR is above the threshold 1.96 both in LC and KD, but the outcome of these results show a higher AR value in LC. Based on this result, the null hypothesis is rejected; the study concludes that there is no difference between male and female flood vulnerability based on physical causes of vulnerability in both LC and KD.

4.2.3.2 Variability of Social Factors on Gender

Table 4.15: Social Factors on Sex

Sex and scale measurements		Health Services		Human Rights		Social Services		Lack of Capacity	
		LC	KD	LC	KD	LC	KD	LC	KD
		AR	AR	AR	AR	AR	AR	AR	AR
Female	INT	2.0	-1.8	-1.6	1.5	1.9	0.5	2.0	0.3
	VINT	-0.9	2.0	**2.2**	-2.2	-0.7	0.7	0.4	1.4
Male	INT	-1.8	1.8	-2.1	-1.5	-1.8	-0.5	-0.2	-0.7
	VINT	1	-1.9	1.7	2.2	0.8	-0.7	-0.3	-1.4

The results show that the AR is above the threshold of 2 (or 1.96) for females in the LC for health services, social services and lack of capacity to cope on a scale of "important" (INT). On the other hand, the results show that health services and human rights are the social factors that determine flood vulnerability in KD (Table 4.15) and they are above the AR threshold of 1.96. The sum of the AR thresholds was revealed 1.6 and -0.3 in LC and KD respectively, depicting lower than the recommended threshold 1.96 to explain variability of the expected result. Based on this result, the study concludes that there is a difference between male and female on flood vulnerability based on social causes of vulnerability in both LC and KD.

4.2.3.3 Variability of Economic Factors on Gender

Table 4.16: Economic Factors on Gender

Sex and scale measurements		Lack of alternative livelihoods		Poverty		Lack of markets		Lack of credit unions and access to finances	
		LC	KD	LC	KD	LC	KD	LC	KD
		AR	AR	AR	AR	AR	AR	AR	AR
Female	INT	1.6	-0.1	0.6	1.2	0.3	0.6	-2.1	-0.2
	VINT	-1.5	0.1	-0.6	-1.2	0.4	-0.6	2.4	2.6
Male	INT	0	-0.1	1	-0.8	0.2	1.8	2.2	0.2
	VINT	0.1	0.1	-0.8	0.8	-0.1	-1.8	-2.3	-2.6

The results show that the AR is above the threshold of 2 (or 1.96) at $p \leq 0.05$ for females and males in the LC for lack of credit unions and access to finances on a scale of “important” (INT) and “very important” (VINT) respectively. The results show lack of credit unions and access to finances is the only economic factor that contribute to flood vulnerability in Karonga (Table 4.16). Based on this result, the null hypothesis is rejected, the study concludes that there is no difference between male and female flood vulnerability based on economic causes of vulnerability both in LC. However, in KD, the study concludes that there is difference between male and female flood vulnerability based on economic factors.

4.2.3.4 Variability of Environmental Factors on Gender

Table 4.17: Environmental Factors on Gender

Sex and scale measurements		In-appropriate		Poor land management		Environmental mismanagement		Extensive paving	
		LC	KD	LC	KD	LC	KD	LC	KD
		AR	AR	AR	AR	AR	AR	AR	AR
Female	INT	2.1	0	-0.7	1.6	0.4	2	2.4	0.7
	VINT	-0.1	-0.7	2.6	-1	2.1	1.8	-0.5	1.8
Male	INT	-2	0	0.7	-1.6	-0.4	-2	-1	-0.7
	VINT	0.2	0.7	0.2	1	-2	1.8	-1	-1.8

Unlike in KD, the results show that the AR is above the threshold of 2 (or 1.96) for females in LC for in-appropriate use of resources on a scale of “important” (INT), poor land management on a scale of “very important” (VINT), environmental mismanagement on a scale of VINT and extensive paving on the scale of INT (Table 4.17). Based on this result, the study concludes that there is no difference between male and female flood vulnerability based on environmental causes of vulnerability in LC while vice versa for KD.

4.2.3.5 Variability of Cultural Factors on Gender

Table 4.18: Cultural Factors on Gender

Sex and scale measurements		Personal Responsibility		Safety Precautions		Local norms		Local behaviour	
		LC	**KD**	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**
		AR	AR	AR	AR	AR	AR	AR	AR
Female	INT	-0.7	1.4	-0.3	1.9	1	0.7	0.3	0.8
	VINT	0.9	-0.3	-0.2	0.9	0.2	0.8	0.4	-0.7
	INT	0.8	-1.4	-0.3	-1.9	-1	-0.7	-0.2	-0.8
Male	VINT	-0.8	0.3	0.3	-0.9	-0.1	-0.8	-0.3	0.7

The results show that there is no AR above the threshold of 2 (or 1.96) for females and males in the LC and KD. However, the causes that showed closeness to the threshold include local norms in KD, personal responsibility in LC, safety precautions in KD and local behaviour. Based on this result, the null hypothesis is rejected; the study concludes that there is no difference between male and female flood vulnerability based on cultural causes of vulnerability in both LC and KD.

4.2.4 Vulnerability Components

The results in a univariate statistical analysis of the VCs were analysed into three sub-themes namely exposure components, susceptibility components and resilience components presented as follows:

4.2.4.1 Exposure Component (EC)

Table 4.19: Results of Vulnerability as a Component of Exposure

Outcome % from participants on Exposure elements					
Location		House Type		Roofing Material	
Open flat field		Unburnt bricks	Burnt bricks	Iron sheets	
LC	**KD**	**LC**	**KD**	**LC**	**KD**
45	99	58	84	88	54

The results show that most households are located in open flat fields (99%) in T/A Kilupula of KD. In Lilongwe houses are built of unburnt bricks (58%) with many having iron sheets as roofing material yet in T/A Kilupula of Karonga district they are built using burnt bricks with only 54% iron sheets (Table 4.19).

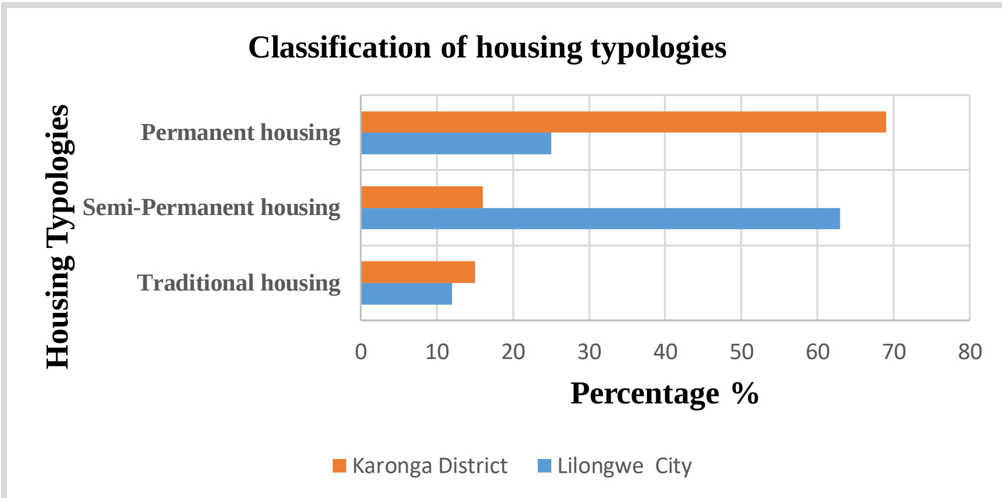


Figure 4.35: Results of Housing Typologies

The results of housing typologies show that in T/A Kilupula of Karonga houses are made up of permanent materials compared to those in Mtandire ward of Lilongwe city (Figure 4.35). The results show that more semi-permanent houses are fully damaged in Mtandire ward of LC (75%) compared to T/A Kilupula of KD (56%) (Figure 4.36).

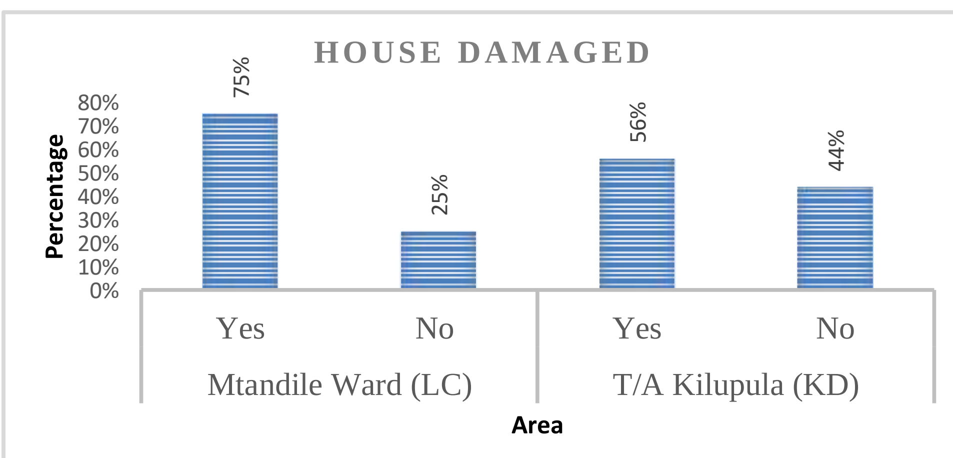


Figure 4.36: Results of Household Damaged During Floods

4.2.3.2 Susceptibility Component (SC)

Table 4.20: Results of Vulnerability Based on Susceptibility Elements

Water sources		Impact on water sources (yes/no)		Toilet facility: Dug out pit (with/out roof)		Impact on toilet facility (yes/no)		Distance from the main house: (0-100 metres)		Access to communication:	
Piped	borehole	Yes	Yes			Yes	Yes			No	Yes
LC	KD	LC	KD	LC	KD	LC	KD	LC	KD	LC	KD
38	76	53	82	61	54	78	87	41	44	69	73

The results show that most households in T/A Kilupula of KD rely on borehole (76%) as source of water while in Mtandire ward of LC the sources of water vary, with 38% households using piped water (Table 4.20 and Appendix 2). In terms of impact on water sources, the results reveal that the flood impact is high in Karonga district (82%) than in LC (53%). The results on toilets show that most households in KD are using pit latrines without roof (54%) while in Lilongwe households use the same type but with roof (61%).

4.2.4.3 Methods of Communication to Floods

In Mtandire ward of LC, household participants indicated that they do not have access to communication before and during floods, (69%) while in T/A Kilupula of KD participants said they have access to communication (73%). In terms of the effectiveness of methods of communication to floods, the results established different outcomes (Table 4.21) in Lilongwe city and Karonga district.

Table 4.21: Results of Effectiveness of Methods of Communication

	Outcome % from participants for variables of underlying environmental vulnerability factors									
	National radio		Television (Zodiak, Times and MBC		Community radio		Print media (Newspaper)		Cell phones	
Measurement scale	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**
Less important	7	8	82	61	6	7	83	73	9	23
Important	6.7	11	3	20	9	30	7	11	7	21
Very important	86	80	15	19	84	63	10	16	84	56
Total %	100	100	100	100	100	100	100	100	100	100

The results show that National radio (MBC), community radio and cell phones are very important methods of communication to floods in both Lilongwe city and Karonga district while television and print media are less important methods of communication during floods in both LC and KD (Table 4.21).

4.2.3.4 Flood Awareness and Trust on local Authority

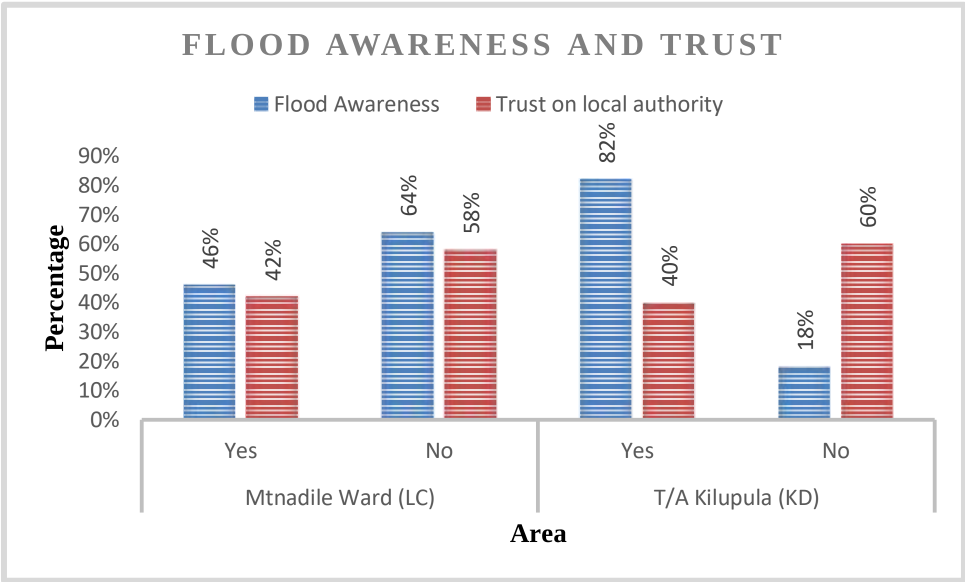


Figure: 4:37: Flood Awareness and Trust

The results show that in T/A Kilupula of KD, 82% household participants interviewed are aware about floods, but they have little trust on local authority dealing with flood management issues in the district (Figure 4.37). On the other hand, in Mtandire 64% of the household participants interviewed have a little awareness on floods.

4.2.4.5 Resilience Component (EC)

Table 4.22: Results of Resilience as Outcome of Income Activity of Household Head

% Participants Responses on Source of Income for Household Head		
Head Income Activity	**LC**	**KD**
Crop production	10	47
Livestock Production	3	2
Fishing	0	7
Agricultural Commodities	6	40
Unskilled labour	71	3
Charcoal burning	3	0
Remittances	0	1
Formal employment	7	0

The results show that while the key source of income for household heads in Lilongwe city is unskilled labour (71%), in KD it is crop production (47%) and agricultural commodities (40%) (Table 4.22).

Table 4.23: Results of Resilience as Outcome of Household Loss from the Farm

	Outcome % from participants					
Indicators	**Crop damage**		**Staple crop**		**Food stock**	
	LC	**KD**	**LC**	**KD**	**LC**	**KD**
YES	86**(25.37)**	112(56.28)	154(45.43)	192(96.48)	165(48.67)	191(95.98)
NO	253(74.63)	87(43.72)	185(54.57)	7(3.52)	174(51.33)	8(4.02)

The results in both Lilongwe city and Karonga district show that households experience loss of crops from the farm during flooding. The loss is huge in food/staple crops (96%) and food stock (95%) for the households of T/A Kilupula in Karonga as well as overall crop damage (74%) in Mtandire Ward of Lilongwe city (Table 4.23).

4.2.4.6 Organisation and Decision Making

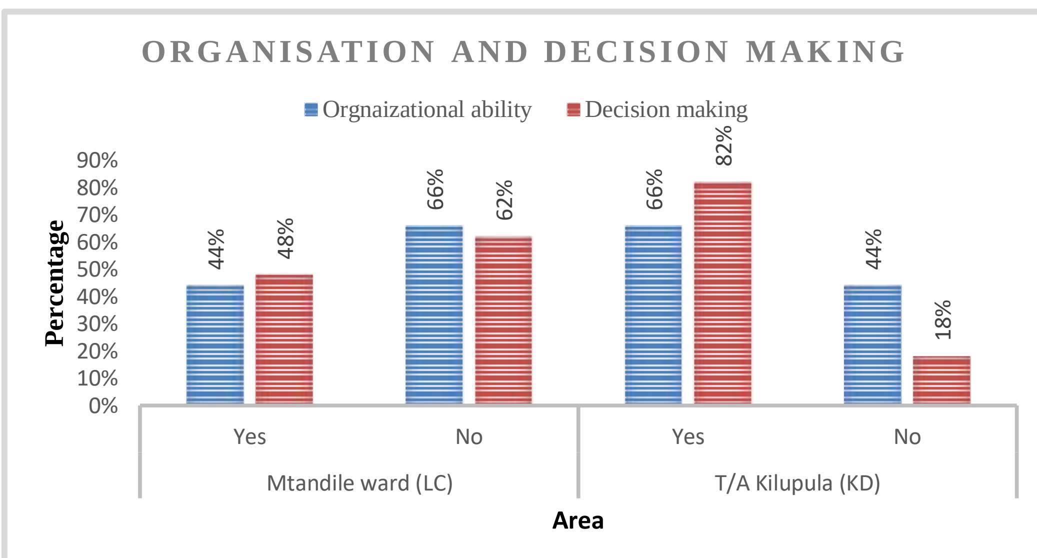


Figure 4.38: Organisation and Decision Making

On the one hand, the results show that in T/A Kilupula of KD, 82% and 66% household participants interviewed are able to make decisions and organise themselves to mitigate floods

(Figure 4.36). On the other hand, in Mtandire 62% and 66% of the household participants interviewed are not able to make decisions to mitigate floods (Figure 4:38)

4.2.5 Relationships between Vulnerability Factors and Components

This section combined underlying vulnerability factors (UVFs) and vulnerability components (VCs) to determine indicators that integrate the two parameters to determine households' vulnerability. The analysis was carried through bivariate statistical test after normalisation of indicators of UVFs and VCs. The results were determined at significant levels p-value 0.05. The significance level of p-values was analysed using combined p-value in r software. The results of the analysis are outlined as follows:

4.2.5.1 Physical Vulnerability Factors versus Exposure

Table 4.24: Results of Combined P-Value of Physical and Exposure Indicators

Exposure Variables	Significance level for combining p-values (LC)	Significance level for combining p-values (KD)
Geography/topography	6.2506	**0.0380**
House type	**0.0001**	0.6118
Roofing material	**0.0072**	**0.0664**

The results between physical factors and exposure variables reveals significant relationships between geography and physical factors (0.0380) in KD, house type (0.0001) in LC and roofing material (0.0072) in Lilongwe and (0.0364) in KD. This result portrays that geography is not significant in LC to generate households' vulnerability, while it is significant in Karonga.

4.2.5.2 Social Vulnerability Factors versus Susceptibility

Table 4.25: Results of Combined P-Value of Social and Susceptibility Indicators

Susceptibility variables	Significance level for combining p-values (LC)	Significance level for combining p-values (KD)
Communication accessibility	**0.0257**	**0.0023**
Access to healthcare	0.0372	0.0010
Access to water and sanitation	**0.0499**	0.0001

The results reveal that all the susceptibility factors are significant to social factors. This result indicates that the susceptibility variables contribute to generate households' vulnerability to floods in Lilongwe city and Karonga district. The results show that communication accessibility, access to healthcare, access to water, and sanitation contribute to vulnerability to floods in Lilongwe city and Karonga district are all significant at P-value 0.05 in both Lilongwe and Karonga (Table 4.25).

4.2.5.3 Economic Vulnerability versus Resilience

Table 4.26: Results of Combined P-Value of Economic and Resilience Indicators

Resilience Variables	Significance level for combining p-values (LC)	Significance level for combining p-values (KD)
Income of household head	**0.0256**	**0.0104**
Crop damage	**0.5985**	**0.0294**
Staple crop affected	0.4532	**0.0017**
Loss of food stocks	0.3541	**0.0183**

The results reveal that all the resilience variables are significant to economic factors in Karonga district while only income of household head is significant in Lilongwe city. This result indicates the resilience variables contribute to generate households' economic vulnerability to floods in Karonga district than in Lilongwe city (Table 4.26).

4.2.5.4 Environmental Vulnerability Factors versus Exposure

Table 4.27: Results of Combined P-Value of Environmental and Exposure Indicators

Exposure Variables	Significance level for combining p-values (LC)	Significance level for combining p-values (KD)
Location	0.8649	0.0084
House type	0.0456	0.2810
Roofing material	0.0253	0.0033

The results reveal that some exposure variables combined with environmental variables contribute to household's flood vulnerability. While geography contributes to very high vulnerability of households to floods in KD (**0. 0084**), the same is not the case in Lilongwe district (0.864). House type contributes to very high vulnerability of households to floods in LC compared to KD while roofing material contributes to generate vulnerability in both LC and KD (Table 4.27).

4.2.5.5 Cultural and human Vulnerability Factors versus Susceptibility

Table 4.28: Results of Combined P-Value of Human and Susceptibility Indicators

Susceptibility variables	Significance level for combining p-values (LC)	Significance level for combining p-values (KD)
Communication accessibility	0.0002	0.0136
Education levels	0.5120	0.0051
Health services	0.9103	0.0525

The combined results of susceptibility variables with human/cultural factors reveal that communication accessibility contributes to flood vulnerability in Lilongwe (0.0002) and not in KD (0.5136). The results further indicate that limited education facilities as well as health facilities contribute to vulnerability in KD and not in LC at p-value 0.05 (Table 4.28).

4.2.5.6 ANN: Multi-Layer Perceptron (MLP)

The results of the ANN in multi-layer perceptron (MLP) to show the relationship of the indicators used in the UVFs and those in the VCs as predicted by the combinedPvalue (Tables 4.21-4.25) are presented in Tables 4.29-4.33.

- **ANN of Exposure Indicators and Physical Factors**

Table 4.29: Combined Exposure and Physical factors in ANN-MLP

VC used	VCs indicator	UVF used	UVFs (indicators	Study area	
				LC	KD
Exposure	House material	Physical	Poor construction standards (PCS)	-9.116	33.321
			Lack of construction materials (LCMs)	1.217	6.928
			Construction of Roads and other infrastructures (CRF)	13.027	3.777

The results of exposure linked with physical factors reveal that there is a strong relationship between house type with PCS in KD, while in LC the relationship is not very strong (-9.116) (Table 4.29). The relationships of house type with CRFs imply that they contribute to household flood vulnerability. Lack of construction materials (PCMs) has strong network value in KD compared to LC with a negative value (Table 4.29). The results revealed that houses made up of bamboo followed by those made up of mudstone are strongly associated with PCS in KD. The results further show that houses made up of unburnt bricks are strongly associated with ageing infrastructure in LC. Lack of construction materials has a strong relationship in KD than LC; CRF and AI have strong relationship with house material type in LC thereby contribute to high household flood vulnerability in LC.

- **ANN of Susceptibility Indicators and Social Factors**

Table 4.30: Combined Susceptibility and Social factors in ANN-MLP

VC used	VCs indicator	UVF used	UVFs (indicators	Study area	
				LC	KD
Susceptibility	Communication accessibility	Social	Lack of capacity to cope (LOC)	-2.125	0.619
			Access to health services (AHS)	16.033	0.2125
			Lack of institutional support (LIS)	6.037	0.9509

The results show positive and negative outcome of LOC in KD and LC respectively (Table 4.30). These results point to the fact that lack of capacity to cope contributes to household vulnerability in KD than LC. The results further show that LAL and LS have positive values both in LC and KD, but with greater contribution to household flood vulnerability in LC. Finally, the results reveal that AHS has positive and negative value in KD and LC. This result indicates that AHS contribute to household flood vulnerability in KD compared to LC.

- **ANN of Resilience Indicators and Economic Factors**

Table 4.31: Combined Resilience and Economic Factors in ANN-MLP

VC used	VCs indicator	UVF used	UVFs (indicators	Study areas	
				LC	**KD**
Resilience	Income of household head	Economic	No credit unions (NCU)	3.297	0.619
			Lack of alternative livelihoods (LAL)	3.839	0.403
			Poverty (PO)	2.829	0.2125
			Lack of income generating activities (LGA)	9.554	0.9509

The results of ANN revealed that all the UVFs for economic factors have positive values in LC and KD, but with higher values in LC. Lack of income generating activities was revealed to be higher both in LC and KD. These results imply that the NCU, LAL, PO and LGA contribute to household flood vulnerability in LC and KD.

- **ANN of Exposure Indicators and Environmental Factors**

Table 4.32: Combined Exposure and Environmental Factors in ANN-MLP

VC used	VCs indicator	UVF used	UVFs (indicators	Study areas	
				LC	KD
Exposure	Geography	Environmental	Cultivated land (CL)	3.297	0.619
			Residing in prone areas (RPA)	3.839	0.403
			Environmental mismanagement (EMS)	2.829	0.2125
			Poor land Management (PLM)	9.554	0.951
			Inappropriate use of resource (IUR)	3.271	0.599

The results of geography linked with environmental factors reveal that there is strong relationship between them, all greater than 0 in LC compared to KD (Table 4.32). The results show that poor land management (PLM) has strong network value (9.554) in LC and (0.951) KD followed by RPA in LC (3.839). These results posit to the fact that the CL, RPA, EMS, PLM and IUR contribute to households flood vulnerability in LC and KD, with higher contribution in LC.

- **ANN of Susceptibility Indicators and Cultural Factors**

Table 4.33: Combined Susceptibility and Cultural factors in ANN-MLP

VC used	VCs indicator	UVF used	UVFs (indicators	Study areas	
				LC	KD
Susceptibility	Communication accessibility	Cultural	Traditional beliefs (TB)	7.872	79.789
			Cultural conflicts (CC)	6.426	11.864
			Lack of adherence to safety measures (LASM)	7.782	-25.912
			Absence of ownership of Resources (AOR)	5.706	0.122

The results of communication linked with cultural factors reveal that there is strong relationship between them, all greater than 0 in LC compared to KD (Table 4.33). The results show that traditional beliefs (TB) have strong network value (79.789) in KD and (7.872) LC followed by 11.864 in KD and 6.426 in LC.

4.2.6 Elements at Risk in Vulnerability Factors

The analysis of the results to understand the extent of the elements at risk to floods in different vulnerability factors, based on Balica et al. (2012) probability scale ranging from "0 to 1" is presented as follows:

4.2.6.1 Elements at Risk for Physical Vulnerability Factors in Lilongwe C and KD

Table 4.34: Elements at Risk for Physical Vulnerability Factors in LC

n=345	Indicators of Elements at Risk for Physical Vulnerability (% participants responses)					
Measurement scale	**Teachers/people's houses**	**People**	**Wells**	**Boreholes**	**Roads**	**Bridges**
Not vulnerable	25	3	22	20	7	5
Slightly Vulnerable	27	35	25	23	21	19
Severely vulnerable	**31**	**59**	**43**	**43**	**59**	**72**
Don't know	17	3	10	15	13	4
Total percentage	100	100	100	100	100	100

Table 4.35: Elements at Risk for Physical Vulnerability Factors in KD

n=200	Indicators of Elements at Risk for Physical Vulnerability (% participants responses)					
Measurement scale	**Teachers/people's houses**	**People**	**Wells**	**Boreholes**	**Roads**	**Bridges**
Not vulnerable	12	35	4	5	6	5
Slightly Vulnerable	47	31	9	15	13	21
Severely vulnerable	38	30	**84**	**66**	**78**	**64**
Don't know	3	5	3	14	3	10
Total percentage	100	100	100	100	100	100

The results show that the physical elements are classified in the "severely vulnerable" in Lilongwe city include people (59%); roads (59%) and bridges (72%) (Table 4.34). Similarly, the results show that wells (84%), boreholes (66%), roads (78%) and bridges (64%) fall in the category of "severely vulnerable" elements in Karonga district (Table 4.35).

4.2.6.2 Elements at Risk in Social Vulnerability Factors in LC and KD

Table 4.36: Elements at Risk for Social Vulnerability Factors in LC

n=345	Indicators of Elements at Risk for Social Vulnerability (% participants responses)					
Measurement scale	**Health clinics**	**Toilets**	**Water supply systems**	**Schools**	**Government warehousing**	**Electricity cables**
Not vulnerable	22	5	18	22	17	22
Slightly Vulnerable	27	23	25	30	16	33
Severely vulnerable	42	68	52	43	17	21
Don't know	9	3	5	5	50	24
Total percentage	100	100	100	100	100	100

Table 4.37: Elements at Risk for Social Vulnerability Factors in KD

n=200	Indicators of Elements at Risk for Social Vulnerability (% participants responses)					
Measurement scale	**Health clinics**	**Toilets**	**Water supply systems**	**Schools**	**Government warehousing**	**Electricity cables**
Not vulnerable	15	7	6	12	30	30
Slightly Vulnerable	34	8	13	40	21	37
Severely vulnerable	32	**84**	**78**	36	8	13
Don't know	19	1	3	12	41	20
Total percentage	100	100	100	100	100	100

The results shows that the social elements are classified in the "severely vulnerable"; they include toilets 68% in Lilongwe city and 78% in Karonga district as well as water supply systems 52% in Lilongwe city and 78% in Karonga district (Tables 4.33 and 4.37).

4.2.6.3 Elements at Risk for Economic Vulnerability Factors in LC and KD

Table 4.38: Elements at Risk for Economic Vulnerability Factors in LC

n=345	**Indicators of Elements at Risk for Economic Vulnerability (% participants responses)**					
Measurement scale	**Staple crops (maize and cassava)**	**Cash crops (rice)**	**Livestock (goats, cattle and sheep etc)**	**Employment**	**Trading**	**Fishing**
Not vulnerable	13	22	24	11	31	24
Slightly Vulnerable	21	13	17	28	34	11
Severely vulnerable	42	29	34	**56**	22	14
Don't know	24	36	25	5	13	51
Total percentage	100	100	100	100	100	100

Table 4.39: Elements at Risk for Economic Vulnerability Factors in KD

n=200	**Indicators of Elements at Risk for Economic Vulnerability (% participants responses)**					
Measurement scale	**Staple crops (maize and cassava)**	**Cash crops (rice)**	**Livestock (goats, cattle and sheep etc)**	**Employment**	**Trading**	**Fishing**
Not vulnerable	2	2	4	59	17	21
Slightly Vulnerable	1	5	26	13	49	23
Severely vulnerable	96	93	68	26	25	44
Don't know	1	0	2	2	9	12
Total percentage	100	100	100	100	100	100

The results show that the economic elements are classified in the "severely vulnerable"; include employment (56%) in LC and staple crops -maize and cassava (96%), cash crops-rice (93%) and Livestock-goats, sheep and cattle (68%) in KD (Tables 4.38 and 4.39).

4.2.6.4 Elements at Risk for Environmental Vulnerability Factors in LC and KD

Table 4.40: Elements at Risk for Environmental Vulnerability Factors in Lilongwe City

n=345	**Indicators of Elements at Risk for Environmental Vulnerability (% participants responses)**				
Measurement scale	**Forest cover**	**Quality of land and soil**	**Trees**	**Natural pasture**	**Rivers**
Not vulnerable	20	8	12	12	12
Slightly Vulnerable	35	21	48	22	24
Severely vulnerable	24	**61**	30	**52**	40
Don't know	21	10	10	14	24
Total percentage	100	100	100	100	100

Table 4.41: Elements at Risk for Environmental Vulnerability Factors in KD

n=200	Indicators of Elements at Risk for Environmental Vulnerability (% participants responses)				
Measurement scale	**Forest cover**	**Quality of land and soil**	**Trees**	**Natural pasture**	**Rivers**
Not vulnerable	12	8	9	6	4
Slightly Vulnerable	49	63	64	48	28
Severely vulnerable	**24**	**28**	**20**	**41**	**64**
Don't know	15	1	5	5	4
Total percentage	100	100	100	100	100

The results show that the environmental elements classified in the "severely vulnerable" include quality of land and soil (61%) and natural pasture (5%) in LC and only rivers (64%) in KD (Tables 4.40 and 4.41).

4.2.6.5 Elements at Risk for Cultural Vulnerability Factors in LC and KD

Table 4.42: Elements at Risk for Cultural Vulnerability Factors in Lilongwe City

n=345	Indicators of Elements at Risk for Cultural Vulnerability (% participants responses)		
Measurement scale	**Cultural heritage**	**Traditional places**	**Traditional beliefs**
Not vulnerable	42	47	34
Slightly Vulnerable	26	19	24
Severely vulnerable	19	**24**	22
Don't know	13	10	22
Total percentage	100	100	100

Table 4.43: Elements at Risk for Cultural Vulnerability Factors in Karonga District

n=200	Indicators of Elements at Risk for Cultural Vulnerability (% participants responses)		
Measurement scale	**Cultural heritage**	**Traditional places**	**Traditional beliefs**
Not vulnerable	42	47	34
Slightly Vulnerable	26	19	24
Severely vulnerable	19	**24**	22
Don't know	13	10	22
Total percentage	100	100	100

The results revealed that no any cultural element in Lilongwe city and Karonga meet the minimum category of 50% and above to be categorised into the category of severely vulnerable (Tables 4.42 and 4.43).

4.2.7 Derived Vulnerability Curves for the Elements at Risk

Vulnerability curves for the two-measurement scale (slightly and severely vulnerable) of the elements at risk have been developed based on the outcome presented in Tables 4.31-4.40.

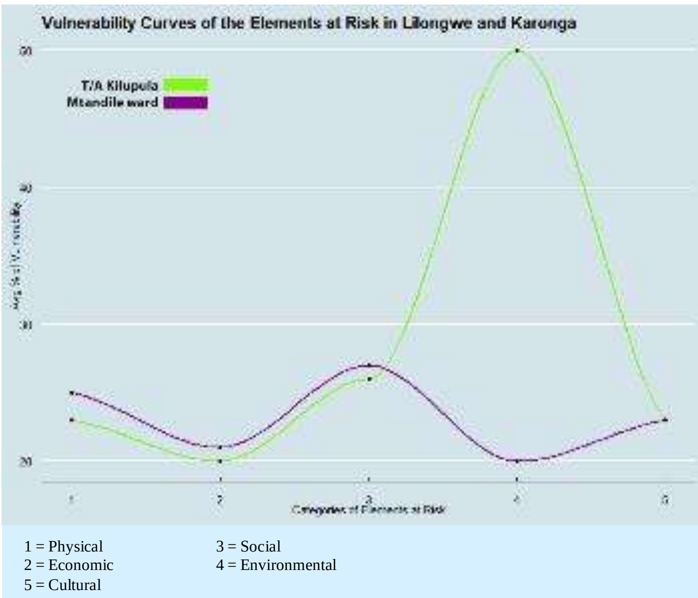


Figure 4.39: Vulnerability Level (a)

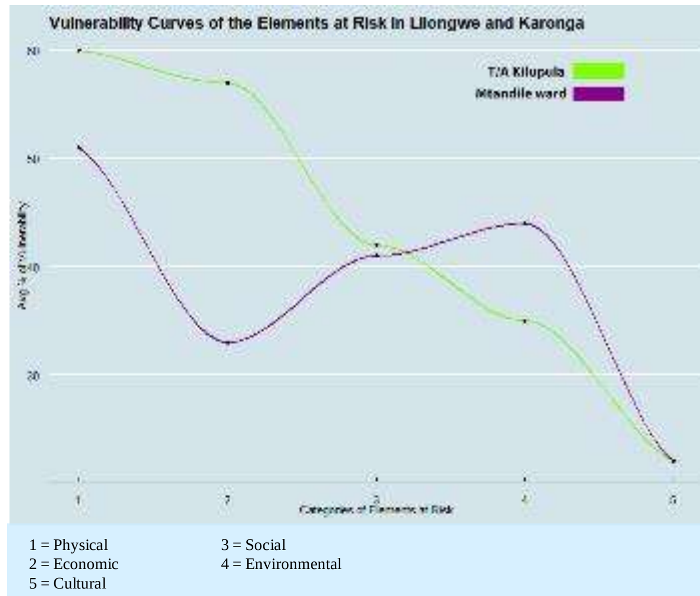


Figure 4.40: Vulnerability Level (b)

The results show that environmental elements at risk are more vulnerable in T/A Kilupula of Karonga on a scale of "slightly vulnerable" (Figure 4.39) compared to Mtandire ward of Lilongwe. The results further show that physical elements at risk on the scale of "severe vulnerable" have the vulnerability thresholds of 0.5 and 0.6 in Mtandire ward and T/A Kilupula respectively (Figure 4.40). The results also show that the economic elements at risk have a higher vulnerability value in T/A Kilupula (0.55) compared to Mtandire ward (0.33) on the scale of severe vulnerable (Figure 4.40).

The results of the HVCA show that people lost a variety of subsistence assets. The results revealed that the elements at risk to floods include infrastructure like houses, water supply systems, roads, bridges and wells; household equipment such as pots, pans, plates, spoons, water containers and livestock such as cattle, goat, sheep and chickens (Table 4.44).

Table 4.44: Key Informants Results on Elements at Risk

Category	Code	Count	Cases	% Cases
Elements at risk	Crops	16	16	94.1
	People	0	0	0
	Livestock	16	16	94.1
	Infrastructure loss	35	17	100
	Household equipment	31	17	100
	Crop fields	16	16	94.1
	Schools	7	3	17.6

One key informant during the interviews said:

> "*Floods affect us by washing away all our household equipment like plates, ploughs, food stuff and blankets" (KII# 4, 12 August 2021)*

The results of key informants further revealed that the relationship between elements at risk and demographic characteristics (such as age and district) relates to agricultural items (like maize, cassava, chickens) and infrastructures (houses, toilets) in KD and LC respectively. One key informant in KD highlighted that:

> "*During flooding, we face a lot loss in terms of field crops like maize and cassava since they are prone to be affected by high amount of water* (*KII#3, 12 August 2021*)

4.2.7 Prediction of Factors Determine Flood Vulnerability

The analysis in this category classified the results into two sections. Section one is about variability of UVFs based on MCA in a multivariate Minitab statistical test. The second section is about the normalised indicators that were generated in the binomial multiple logit regression model in order to predict the factors that determine households' vulnerability to floods.

4.2.7.1 Variability of Underlying Vulnerability Factors

This study analysed the variability that exist among the variables of underlying vulnerability factors in order to determine their contributions to household vulnerability in the study areas. The results of the contribution column in a Multiple Correspondence Analysis (MCA) output have been outlined in Tables 4:45- 4.49.

Table 4.45: Variability of Underlying Physical Vulnerability Variables

Variable	Qual.		Inert		Corr.		Contr.	
	LC:	KD	LC	KD	LC	KD	LC	KD
	INT/VINT		INT/VINT		INT/VINT		INT/VINT	
Poor construction of housing standards	0.6579	0.3074	0.0935	0.0891	0.5352	0.5449	0.2014	0.3130
	0.7199	0.5507	0.0457	0.0429	0.6992	0.6743	0.1286	0.0219
Lack of construction materials	0.6172	0.3017	0.0872	0.0994	0.4398	0.0240	0.1544	0.0113
	0.6167	0.7075	0.0533	0.0391	0.6071	0.1235	0.1301	0.0230
Construction of roads & other infrastructures	0.5689	0.3732	0.0906	0.0904	0.3371	0.1722	0.2341	0.1229
	0.4425	0.0705	0.0470	0.1147	0.4153	0.0428	0.0785	0.0233

Scale Key: INT = Important; VINT = Very Important: LC Lilongwe city; KD: Karonga District

The results in Table 4.45 show that except for construction of roads (0.443) in the scale of “INT” and “VINT”, all the physical indicator variables have larger quality values in LC. But the results in KD show the greater quality value in the scale of “VINT” for indicator values of poor construction of housing standards (0.551) and lack of construction materials (0.708). Furthermore, the results for inert value of ageing of sewer systems deviate most from all the indicator variables in the scale of “VINT” for both LC (0.108) and KD (Table 4.45). The results also indicate higher correlation (corr.) for poor construction of housing standards in the scale value of “INT” and ‘VINT, accounting for higher amount of inertia. Ageing of sewer systems (0.300) and construction of roads and other infrastructures (0.234) account for high contribution to the inertia in LC while poor construction of housing standards account for higher inertia value (0.201) in LC and (0.313) in KD (Table 4.45).

Table 4.46: Variability of Underlying Social Vulnerability Variables

Variable	Qual.		Inert		Corr.		Contr.	
	LC:	KD	LC	KD	LC	KD	LC	KD
	INT/VINT		INT/VINT		INT/VINT		INT/VINT	
Lack of capacity to cope	0.4100	0.8208	0.0782	0.0812	0.3976	0.7904	0.1205	0.2613
	0.2788	0.3516	0.0653	0.1237	0.1914	0.0323	0.0484	0.0163
Social security	0.5055	0.7275	0.0743	0.0939	0.5044	0.5601	0.1453	0.2141
	0.4976	0.5792	0.0773	0.1168	0.1637	0.1724	0.0491	0.0819
Human rights	0.1454	0.6589	0.0769	0.0869	0.6484	0.0826	0.1932	0.0292
	0.1364	0.5243	0.0726	0.0425	0.2865	0.1349	0.0806	0.0233
Heath services inavailability	0.5133	0.1515	0.0885	0.0926	0.5060	0.0974	0.1735	0.0367
	0.4691	0.1606	0.0494	0.0330	0.3037	0.1082	0.0581	0.0145

Scale Key: INT = Important; VINT = Very Important: LC Lilongwe city; KD: Karonga District

The results of MCA show significant contribution of vulnerability with a quality values in the category of social security the scale of INT (0.506) and VINT (0.500). The results further show significant contribution of vulnerability in the category of inavailability of health services (0.513) in the scale of INT in LC. In KD, the results show significant quality values on lack of capacity to cope (0.821) in the scale of INT, social security and human rights in the scale of INT and VINT (Table 4.46). While the results of the inert values in LC do not deviate much from the expected, in KD the inert value of lack of capacity to cope (0.124) in scale of INT and social security (0.117) in scale of VINT deviate from the expected value. The results also indicate higher correlation (corr.) social security (0.504) and human rights (0.648) and inavailability of health services (0.506) in LC while lack of capacity to cope (0.790) and social security (0.560) have higher Corr in KD accounting higher amount of inertia to contribute to vulnerability. The results further show all the indicator variables in the scale of "INT) contribute higher to the inertia in LC while only lack of capacity to cope (0.2613) and social security (0.2141) contribute higher to the same in KD (Table 4.46).

Table 4.47: Variability of Underlying Economic Vulnerability Variables

Variable	Qual.		Inert		Corr.		Contr.	
	LC:	KD	LC	KD	LC	KD	LC	KD
	INT/VINT		INT/VINT		INT/VINT		INT/VINT	
No credit unions	0.4148	0.6079	0.0820	0.0861	0.0452	0.1894	0.0155	0.0728
	0.3988	0.5259	0.0698	0.1027	0.1141	0.3137	0.0333	0.1439
Lack of markets	0.5743	0.5785	0.0832	0.0080	0.0013	0.0080	0.0005	0.0027
	0.4429	0.6138	0.0710	0.4989	0.1870	0.4989	0.0556	0.2060
Poverty	0.5125	0.2470	0.0982	0.1234	0.0131	0.1234	0.0054	0.0485
	0.4966	0.3697	0.0351	0.2031	0.0874	0.2031	0.0129	0.0376
Lack of alternative	0.3736	0.0918	0.0789	0.0888	0.0188	0.0888	0.0062	0.0366
livelihoods	0.4475	0.0962	0.0603	0.0714	0.1333	0.0714	0.0337	0.0120

Scale Key: INT = Important; VINT = Very Important; LC: Lilongwe city; KD: Karonga District

The results in Table 4.47 show that lack of markets (0.574) and poverty (0.513) in the scale of "INT" have higher quality value in LC while lack of credit unions and lack of markets showed higher quality value in KD. These results suggest that they contribute more to household flood vulnerability. The results further show that all the indicator variables in LC have a inertia value at the expected rate of less than 10% while in KD lack of credit unions (0.103), lack of markets (0.499) poverty (0.123) and (0.203); display values that deviate from the expected. Similarly, the results show weak correlation (less than 1) for all the economic indicator variables in LC and only lack of markets (0.499) is close to 1 in KD thereby contribute highly to the inertia. Lack of credit unions and lack of markets account for high contribution to the inertia, thereby suggesting a high contribution to vulnerability.

Table 4.48: Variability of Underlying Environmental Vulnerability Variables

Variable	Qual.		Inert		Corr.		Contr.	
	LC:	KD	LC	KD	LC	KD	LC	KD
	INT/VINT		INT/VINT		INT/VINT		INT/VINT	
Cultivated land	0.2605	0.0603	0.0635	0.0812	0.2419	0.0371	0.0711	0.0115
	0.0422	0.0269	0.0693	0.0310	0.0017	0.0218	0.0005	0.0026
Extensive paving	0.2251	0.4159	0.0652	0.6070	0.0928	0.6737	0.0280	0.1721
	0.0334	0.0386	0.0614	0.0964	0.0330	0.0066	0.0094	0.0024
Environmental	0.5295	0.6330	0.0696	0.0645	0.5241	0.5568	0.1690	0.1369
mismanagement	0.6202	0.6778	0.0433	0.0391	0.4251	0.6770	0.0853	0.1009
Poor land management	0.6320	0.3530	0.0693	0.0584	0.6307	0.2967	0.2024	0.0660
	0.7460	0.4526	0.0433	0.0457	0.5186	0.4524	0.1041	0.0788
In appropriate use of	0.5249	0.6992	0.0631	0.0716	0.5179	0.3195	0.1515	0.0872
resources	0.6015	0.7064	0.0491	0.0360	0.4618	0.0360	0.1051	0.0942

The results in Table 4.48 show that except for poor land management in KD for scales of INT and VINT, environmental mismanagement, poor land management and inappropriate use of resources have larger quality values in LC and KD (Figure 4.36). No indicator variable depicted the unexpected inertia value in LC and KD. In LC, the results further revealed that correlation is higher for environmental mismanagement (0.524) in the scale of INT, poor land management is also higher in both scales and in appropriate use of resources (0.518) in the scale of INT. However, extensive paving (0.674), environmental mismanagement (0.557) and poor land management (0.677) have higher correlation values close to one. Environmental mismanagement (0.169), poor land management (0.202; 0.104) and inappropriate use of resources (0.152; 0.105) account for high contribution to the inertia in LC while extensive paving (0.1721) and environmental mismanagement (0.137; 0.101) account for higher contributions in KD (Table 4.48).

Table 4.49: Variability of Underlying Cultural Vulnerability Variables

Variable	Qual.		Inert		Corr.		Contr.	
	LC:	KD	LC	KD	LC	KD	LC	KD
	INT/VINT		INT/VINT		INT/VINT		INT/VINT	
Traditional beliefs and	0.1604	0.5083	0.0549	0.0709	0.1576	0.5060	0.0470	0.1868
myths	0.0738	0.0045	0.0534	0.0466	0.0410	0.0033	0.0119	0.0008
Cultural conflicts	0.4318	0.1098	0.0560	0.0509	0.1617	0.0947	0.0493	0.0251
	0.3171	0.3996	0.0673	0.0667	0.1032	0.0389	0.0378	0.0135
Informal settlement	0.4043	0.5788	0.0558	0.0662	0.0111	0.5764	0.0034	0.1987
	0.4103	0.1096	0.0388	0.0774	0.0988	0.0088	0.0209	0.0036
Language of	0.3861	0.4390	0.0682	0.0679	0.0500	0.4316	0.0185	0.1526
communication	0.3843	0.2064	0.0178	0.0748	0.0665	0.1835	0.0064	0.0714
Lack of Safety	0.3341	0.0770	0.0489	0.0560	0.0423	0.0102	0.0113	0.0030
precautions	0.5506	0.5962	0.0555	0.0500	0.2085	0.0013	0.0629	0.0003
Lack of personal	0.4791	0.1710	0.0504	0.0474	0.0034	0.1056	0.0009	0.0261
responsibility	0.6316	0.6361	0.0474	0.0598	0.1699	0.0145	0.0438	0.0045

Scale Key: INT = Important; VINT = Very Important: LC Lilongwe city; KD: Karonga District

The results in LC showed that lack of safety measures (0.551) and lack of personal responsibility (0.632) have high quality values above the cut-off of 50% while in KD traditional beliefs (0.508), informal settlements (0.579), lack of safety measures (0.596) and lack of personal responsibility (0.636) have high quality values. No indicator variable depicted the unexpected inertia value in LC and KD. The results further revealed no strong correlation (close to 1) in LC to contribute to inertial variability. Nevertheless, in KD, the results showed strong correlation for traditional beliefs (0.506) and informal settlement (0.576). While results show no higher value for contribution (Contr) in LC, traditional beliefs (0.187), informal settlement (0.199) and language of communication (0.1526) account for high contribution to the inertia in KD (Table 4.49).

4.2.7.1 Flood Vulnerability Prediction

The binomial logit multiple regression (Equ.12) using the generated relationships equations 13-17 as presented in section 3.4.2 (Table 3.13) produced the following computed scores:

- **Computation of Socio-susceptibility Score**

The underlying social vulnerability factors (SVFs) linked with communication accessibility (ca) in the susceptibility indicators generated the output of socio-susceptibility score (Eq.18).

$$S_{ca} = 1.7 - 0.64HR_{int} + 0.37HR_{vint} - 0.3HS_{int} + 0.11HS_{vint} \qquad \textbf{(Eq.18)}$$

Where S= Susceptibility, ca=communication accessibility, HR=human rights, HS=health services sint= scale of less important, svint =scale of very important.

The above output (equ 18) linked the susceptibility indicators (communication accessibility) with social variables. Therefore, to compute the scores in Lilongwe city (Mtandire Ward) and Karonga district (T/A Kilupula), the percentage values generated using descriptive statistics from the scale of "important" and "very important" were separately inputted in the equation (Equ.18).

- **Computation of Physio-exposure Score**

The underlying physical vulnerability factors (PVFs) linked with housing material types (hmt) in the exposure indicators generated the output of physio-exposure score (Eq.19).

$$E_{hmt} = 3.09 - 0.76PC_{sint} - 0.07PC_{svint} - 0.01CM_{sint} - 0.51CM_{svint} - 0.04CR_{sint} + 1.39CR_{svint} \quad \textbf{\textit{(Eq.19)}}$$

Where E= Exposure, hmt=housing material type, PC=Poor construction, CM=Construction materials, CR=Construction of roads, sint= scale of less important, svint =scale of very important.

The output (Equ.19) linked the exposure indicators (housing material type) with physical variables. Therefore, to compute the scores in Lilongwe city (Mtandire Ward) and Karonga district (T/A Kilupula), the percentage values generated using descriptive statistics from the scale of "important" and "very important" were separately inputted in the equation (Equ.19).

- **Computation of Eco-resilience Score**

The underlying economic vulnerability factors (EVFs) linked with income of household head (ihh) in the resilience indicators generated the output of eco-resilience score (Eq.20).

$$R_{ihh} = 1.19 - 0.74PV_{svint} - 0.29PV_{svint} + 1.09AL_{svint} + 0.21AL_{svint} \quad \textbf{\textit{(Eq. 20)}}$$

Where R= Resilience, ihh=income of household head, PV=Poverty, AL=Alternative livelihoods, sint= scale of less important, svint =scale of very important.

The output (Equ.20) linked the resilience indicators (income of household head) with economic variables. Therefore, to compute the scores in Lilongwe city (Mtandire Ward) and Karonga district (T/A Kilupula), the percentage values generated using descriptive statistics from the scale of "important" and "very important" were separately inputted in the equation (Equ.20).

- **Computation of Enviro-exposure Score**

The underlying environmental vulnerability factors (EVFs) linked with geography (ge) in the exposure indicators generated the output of enviro-exposure score (Eq.21).

$$E_{ge} = 3.49 + 18\, CL_{sint} + 1.59 CL_{svint} - 0.98 EM_{sint} + 1.18 EM_{svint} - 1.65 PLM_{sint} + 0.55 PLM_{svint} + 0.93 AUR_{sint} - 1.3 AUR_{Svint} \qquad \textbf{(Eq.21)}$$

Where E= Exposure, Ge=Geography, CL=Cultivated land, EM=Environmental mismanagement, PLM=Poor land management, AUR= Inappropriate use of resources, sint= scale of less important, svint =scale of very important.

The output (equ.21) linked the exposure indicators (geography) with environmental variables. Therefore, to compute the scores in Lilongwe city (Mtandire Ward) and Karonga district (T/A Kilupula), the percentage values generated using descriptive statistics from the scale of "important" and "very important" were separately inputted in the equation (Equ.21).

- **Computation of Cultural-susceptibility Score**

The underlying cultural vulnerability factors (CVFs) linked with inaccessibility of communication (ic) in the susceptibility indicators generated the output of cultural-susceptibility score (Eq.22).

$$S_{ic} = -0.23 CB - 0.18 LN_{sint} + 0.57 LN_{svint} \qquad \textbf{(Eq.22)}$$

Where S= Susceptibility, cb=cultural behaviour, LN=local norms, sint= scale of less important, svint =scale of very important.

The score measure of UVF (physical, social, economic, environmental and cultural) against VCs (exposure, susceptibility and resilience) generated a single value according to the association which was as follows: physical with exposure factors (PEFs), social with susceptibility factors (SSFs), economic with resilience factors (ERFs), environmental with exposure factors (EEFs) and cultural with susceptibility factors (CSFs). This association further generated value that was divided by the total sample size 345 and 200 household participants in Lilongwe city and

Karonga district and multiplied by the 100 percent to obtain a percentage value of each category in the calibrated formula, for example:

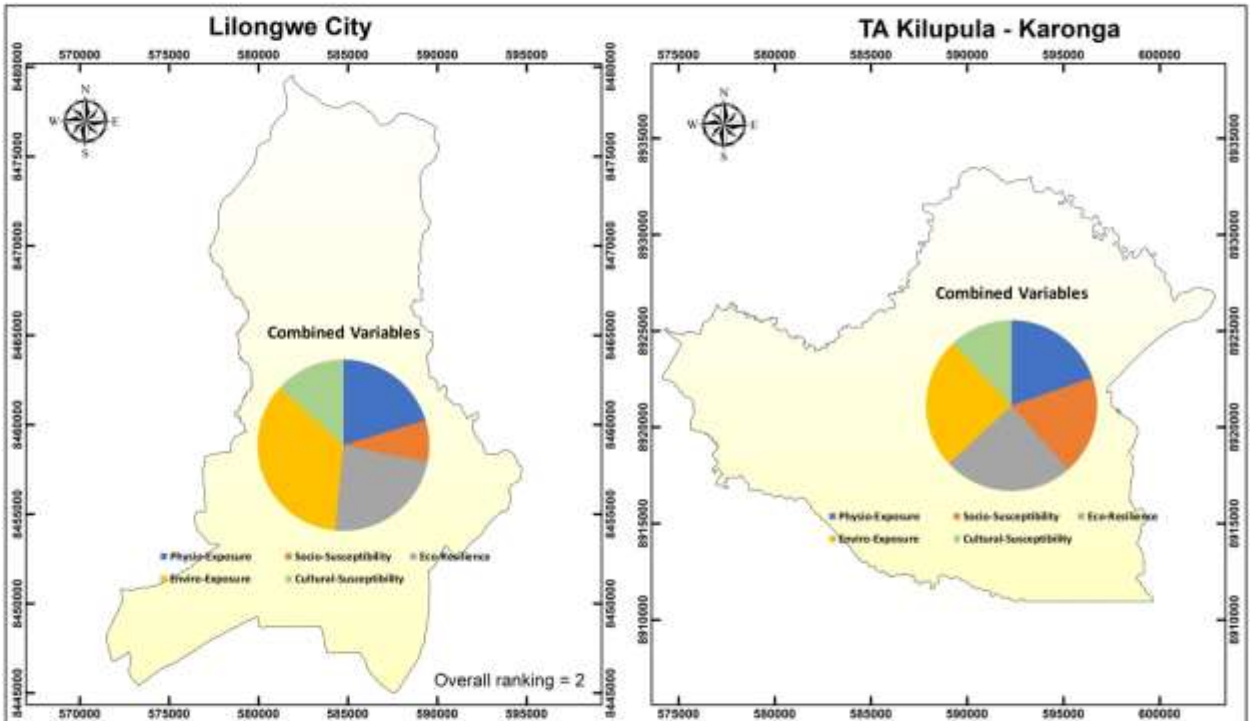
$$Physical\ (P)\ = \frac{PEFs\ value * 100\%}{Sample_{\ Lilongwe\ city\ or\ Karonga\ district}} \qquad \textbf{(Eq. 23)}$$

Then the percentage result obtained in equation (Eq. 17) for each factor was further divided by 100% to generate the vulnerability level (extent of vulnerability) of each factor (i.e., V_LPEFs). This computed arbitrary value was compared to the FVI to predict the extent of vulnerability per factor, for example:

$$V_L PEFs = \frac{\text{PEFs\%}}{100\%} \qquad \textbf{(Eq. 24)}$$

Where V_LPEFs means vulnerability level on Physio-Exposure factors. This formula was applied to all the combined categories (i.e., SSFs, ERFs, EEFs and CSFs) by substituting the category that was required to be worked out in the equation to obtain the value that was used to determine vulnerability.

Finally, the relationship (using equation 24) generated results in the category of the physio-exposure factors (PEFs), social susceptibility factors (SSFs), eco-resilience factors (ERFs), enviro-exposure factors (EEFs) and cultural-susceptibility factors (CSFs) (Figure 4.41).



Combined Variables	In FVI scale
Physio-Exposure	0.52
Socio-Susceptibility	0.2
Eco-Resilience	0.6
Enviro-Exposure	0.9
Cultural-Susceptibility	0.34

Combined Variables	In FVI scale
Physio-Exposure	0.64
Socio-Susceptibility	0.61
Eco-Resilience	0.8
Enviro-Exposure	0.81
Cultural-Susceptibility	0.39

Figure 4.41: Distribution of Flood Vulnerability in LC and KD for Combined UVFs and VCs

The results of PEFs falls in scale range of "vulnerability" in Mtandire ward of LC (0.52) compared to "high vulnerability" in T/A Kilupula of KD (0.64). The SFFs generated a vulnerability value (0.61) of people living in TA Kilupula of KD compared to a low vulnerability value (0.2) of people living in Mtandire ward of LC. The ERFs contribute to "very high vulnerability" in T/A Kilupula of KD (0.8) and "high vulnerability" in T/A Kilupula of LC (0.6). The EEFs revealed "very high vulnerability" in both LC (0.8) and KD (0.9). Finally, the CSFs revealed a low vulnerability in both LC (0.34) and KD (0.39) (Figure 4.41). In the FVI scale, the SSFs and CSFs contribute to low vulnerability in LC while only the CSFs contribute to low vulnerability in KD (Figure 4.41).

4.3 Households Perception on Flooding Occurrence

The analysis of this objective was classified into four sections to determine perception of households on flood vulnerability in urban and rural areas. The key variables which were assessed include location (as defined by urban and rural), time (based historical occurrence of floods) demographics and flood impacts.

4.3.1Perception of Households on Flood vulnerability based on Location

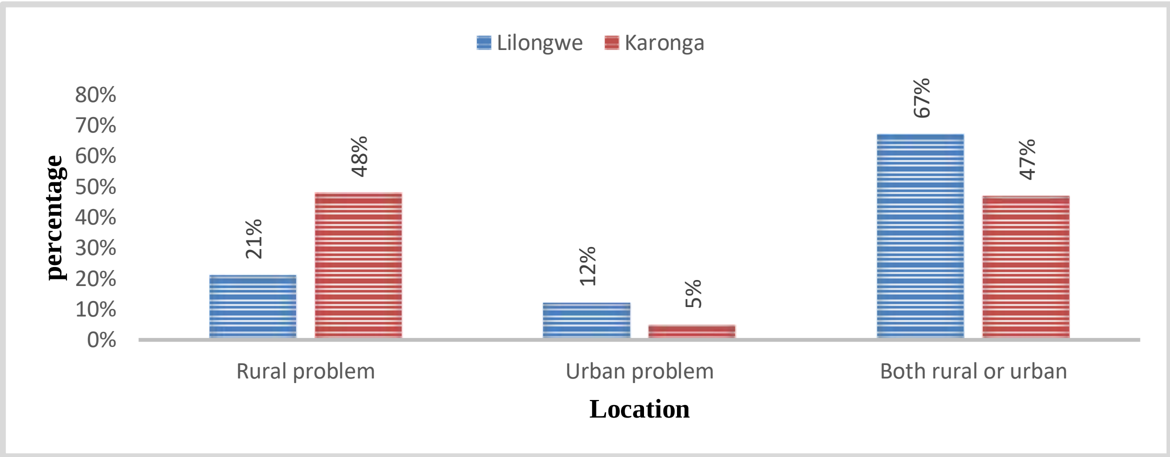


Figure 4.42: Grap of Households Rural-Urban Perception on Floods

The results on flooding perception of the interviewed household participants on whether floods are a rural or urban problem showed that 67% participants perceive floods as both a rural and urban problem in LC. In Karonga, 48% of the interviewed participants indicated that floods are a rural problem only while 47% indicated that floods are both a rural and urban problem (Figure 4.42). The results in Karonga revealed significant barrier of rural people to comprehend floods as a problem of rural and urban. The results obtained from HVCA revealed multiple barriers contributing to influence perceptions on floods. An informant from a local organisation indicated that, *"Due to their cultural beliefs, poverty and illiteracy make people to view floods as something that affect them only*" (KII 17, 20 July).

The findings from another community leader and key informants showed that people perceived floods as a known issue and it has become part of them. A narration from one notable key informant was captured as follows:

Floods are a known issue to many people in this area but past floods were not dangerous than the recent ones. Rivers were very deep and we were able to have water flowing in Lufilya River even in dry season. Recent floods are very devastating because water can flow all over. I believe the problem is due to population growth, overgrazing, building close to rivers and high siltation of Lufilya river" (KII#4: 19 July 2021).

"*We are experiencing these floods because of some influential people who offered land to people to build in the area of 49. We have had no floods in this area"….how land was acquired in area 49 Guliver…the way they are building their fences...Makes us to safer" (KII 14: 28 July 2021).*

The observation also revealed that floods in Mtandire ward of LC are based on reactive approaches. It has not shifted to non-structural solutions like increasing awareness, promoting land planning, early warning systems, and communication to ensure that floods are controlled.

4.3.2 Perception of Households on Flood Vulnerability Based on Demographics

Table 4.50: Households Demographic Implications on Flood Occurrence

Demographics	**Age**	**Gender**	**Education**	**Marital status**	**Occupation**
LC (Mtandire)	0.007	0.103	0.005	0.009	0.987
KD (Kilupula)	0.362	0.462	0.697	0.024	0.030

The results of flood perception based on demographics implications revealed a significant implication of age (0.0065), education (0.0045) and marital status (0.0085) on household flood perception in LC. The results revealed no significant implication of occupation (0.987) on household perception in LC. The results further show no significant relationship between age, sex, education and marital status in KD. Finally, the results established significant implication of occupation and household vulnerability in KD (Table 4.50).

The results of the community leaders, members of the VCPC and ACPC during HVCA, revealed that demographics influence households flood perceptions. Key informants expressed that most indigenous people complain about loss of arable land due to floods. It was also revealed that economically active people have no access to safe land, as such, they perceive floods as a problem because they become displaced. Key informants expressed that due to lack of land, chiefs allocate land to some economically active people (youth-ages 18-30years) to establish new settlements called "majengo" in the local language (Ngonde). It was revealed that these new settlement (Majengo) tend to be established in areas close to rivers. These areas were used by the indigenous people for farming, cultivation and grazing. At the same time they were acting as buffer zones of some rivers and streams. One informant also said:

> "*People in this area….Shalisoni perceive floods based on availability of land. Those that are indigenous look at flood as something that destroy their available lands used for cultivation. Those without enough land consider floods as threat to their lives because they at times build houses in risky areas"* (KII 10: 17 July 2021).

4.3.3 Perception of Households Floods on Education Impacts

- **Flood Impacts on Education**

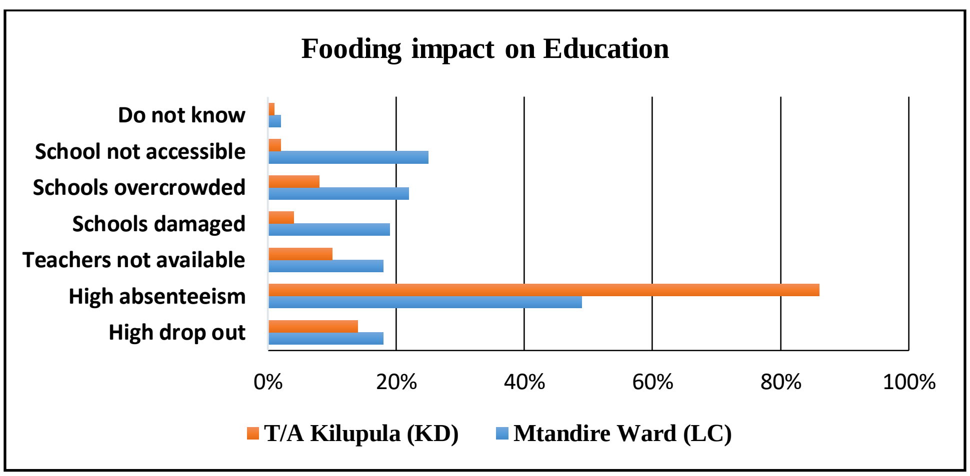


Figure 4.43: Impacts of Flooding on Education System MtandireWard of Lilongwe City

The results show variability of households flood perception based on impacts. The results of the interviewed households participants in LC show school not accessible, schools overcrowded, schools damaged, teachers not available, high absenteeism and high drop out with a high percentage on absenteeism (49%) (Figure 4.43) as key impacts on floods. While the same impacts were revealed in KD, the results show that 86% of the interviewed participants perceived floods to have a larger impact on learner absenteeism (Figure 4.43).

The findings from key informants in participatory HVCA process, revealed that floods affect the education system in different ways. Teachers interviewed highlighted impacts such as students missing morning lessons, low turn up of learners in classrooms, high drop out and scarcity of teaching and learning materials. One key informant in Karonga said:

> "*Parents take advantage of floods for the cultivation of rice. This contributes to high absenteeism because school children are taken as child seaters during cultivation of rice hence absenteeism increases during flooding*" (KII#3 12 July 2021).

4.3.4 Perception of Households Flood Vulnerability Based on Time Period

Table 4.51: Key Informants Responses on Period of Flood Occurrence

Category	Code	Count	Cases	% Cases
Period started	Before 1990's	20	11	64.7
	Early 1990's	3	3	17.6
	Late 1990	1	1	5.9
	Early 2000's	2	2	11.8

Furthermore, the results of key informants in QDA miner level 6.0 linked the occurrence of floods around the years of 1990's to both LC and KD (Table 4.51e). The results show that 64.7% of the key informants expressed that floods have occurred in their areas before 1990s. However, the results of the key informant during HVCA discussion revealed that the impacts of floods of 1990s was not huge compared to the impacts of floods around the 2000's. One key informant in Mtandire ward of Lilongwe city highlighted that:

> "*Floods in Mtandire area man-made, yes; they have been here before but not to this extent like the current trend, 2017, 2019 etc- all this is because of the building that are located in area 49 new Gulliver.*"*(KII#13, 24th July 2022).*

The output of the link analysis in QDA miner summarised the most important issues that were raised by key informants during participatory HVCA process. Most of these issues were linked to the floods of 2000's. Key intersecting issues revealed during the analysis include high literacy levels, defiance of government regulations, flood prone areas, lack of personal responsibility, lack of support, poor social organisation, as key issues raised to contribute to high vulnerability in relation to the 2000's floods.

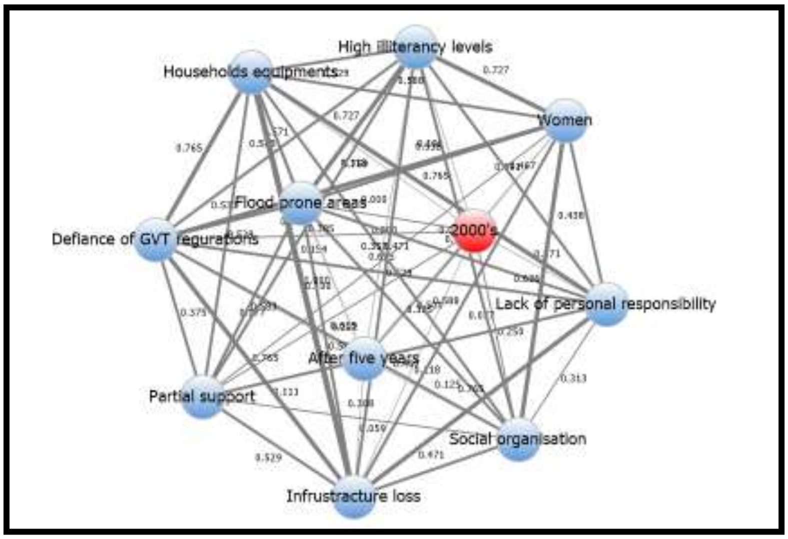


Figure 4.44: Link Analysis of Flood Occurrence

During field survey and interviews with key informants, it was further observed that most huge roofed houses including strong and big fences along Lingadzi catchment contribute to vulnerability of residents in Mtandire ward. The results of the observations revealed that water accumulated from the roofs of the masonry houses have reduced lag time for the Lingadzi River, has increased the volume of water and diverted the river to Mtandire area. The major findings of the observed result are that rich people reclaimed the land which was made up-of marshes and swamps to construct their houses (Figure 4.44). A key informant expressed that

'Indeed, in the past floods have been happening but not to these current magnitudes. Mtandire started experiencing high magnitude of floods around 2017, 2018 and 2019 soon after the construction of structures in area 49 (New Gulliver) along Lingadzi river. To us, these are just human-made floods. Rich people occupied in risky areas. They have constructed fences, which obstruct through-flow of water in the original waterways and eventually causing problems to our area. Government must take action to evict those people if this problem is to be solved".

In the analysis of the data obtained during HVCA, with key informants and members of the WCPC, the results revealed that several human activities are happening in the Lingadzi catchment area, which make the river to change its course and eventually flooding during heavy rainfall. Key among the activities that were observed include sand extraction and brick making**.**

Figure 4.45: Human Settlement along Lingadzi Catchment in Lilongwe city

4.4 Households Adaptive Capacity to Respond to Floods

This objective presents the results obtained using structured questionnaire survey and HVCA assessment tools. The results have been classified into three sections namely (1) household-physical/infrastructural-based strategies (2) economic livelihood strategies (3) and social organisation strategies.

4.4.1 Household Physical/Infrastructural-Based Strategies

The results of this sub-section present the adaptive capacities of households' ability to undertake some form of physical/infrastructural activities to support themselves to respond to floods. The results of the physical/infrastructural capacities which households undertake to respond to floods have been presented in the Figure 4.46.

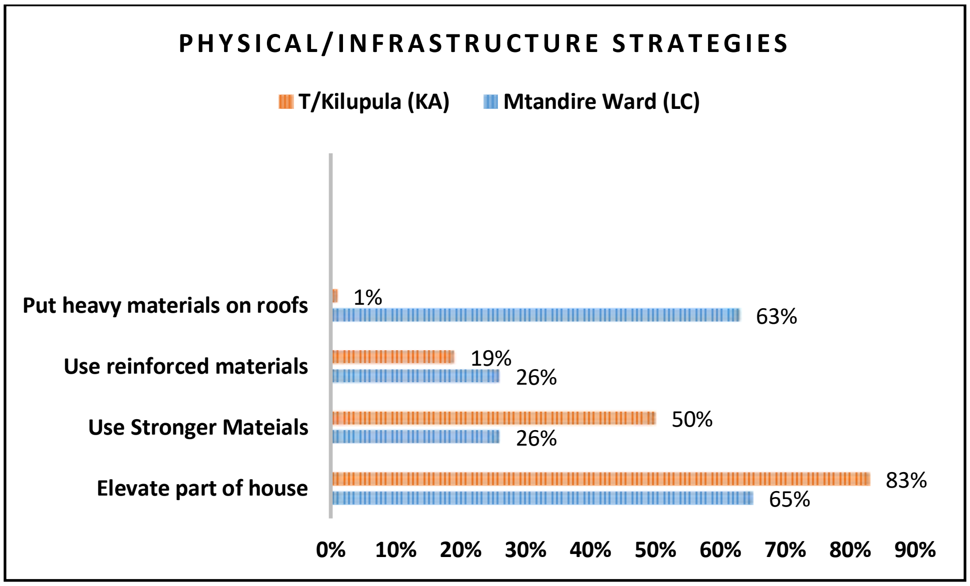


Figure 4.46: Physical/infrastructural Strategies

The results show that 83% and 50% of the interviewed households' participants elevate and build their houses with strong materials to respond to floods in T/A Kilupula and Mtandire respectively. On the other hand, 63% and 65% of the interviewed households were found that they use heavy materials and elevate part of their houses to prepare for floods in Mtandire ward. The results further show that no household tie with wire and put stones on the roof of the house in T/A Kilupula.

In a participatory HVCA process, key informants revealed that households in T/A Kilupula cope with floods by engaging in different activities that reduce their pressures. Community leaders and key informants indicated that most households employ key strategies such as raising households' foundations, elevating part of their houses, planting trees and bananas along some rivers. One local leader in Shalisoni Village indicated that:

> "*Mpherere River was causing a lot of floods. Flooded water from Mphere-Kasisi stream was mixing with flooded water from Lufilya River and could cause a lot of problems. However, with the planting of trees along Mphere-Kasisi stream, floods have been reduced tremendously (K#10: 18 July 2021)*.

4.5.2 Economic Livelihood Strategies (ELC)

The results of this sub-section analysed the capacities of households' ability to undertake some form of economic livelihood activities to support themselves to respond to floods.

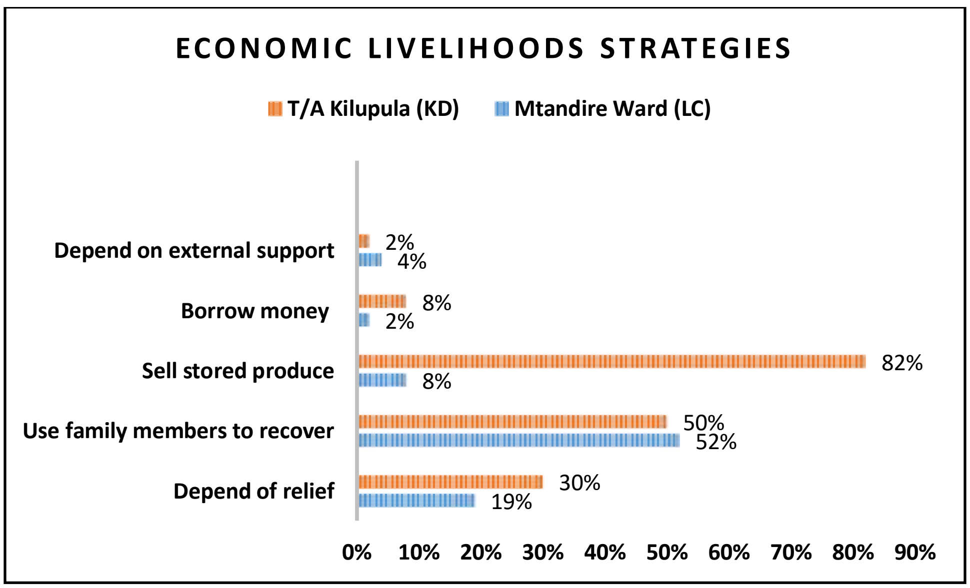


Figure 4.47: Economic Livelihood Strategies

The results show that 82% of the interviewed households in T/A Kilupula sell their stored produce to respond to floods. The results further show that as an immediate response to floods, 50% and 52% of the households interviewed use family members to respond to floods in KD and LC respectively. The results also show that 30% and 19% of the interviewed households indicated that they rely on relief support to recover from floods in KD and LC respectively.

The results of key informants during HVCA, revealed that the economic benefits from the cultivation of rice farms enable people to find some adaptive capacities. Most households indicated that rice is the only crop that does not disappoint them in terms of prices. They indicated that it is easier to sell rice because markets are readily available. Head teachers and teachers who participated in the HVCA, showed some different face on this matter. They maintained that the growing of rice is not homogenous because of the variability of rainfall in the area. One teacher mentioned that most parents take advantage of flooded water to plant rice in their farm lands. Another teacher said:

> *"People are very reluctant to relocate in these areas because they take floods as source of their livelihoods and young people consider school insignificant because they tend to get money from rice farms."*

Another key informant of Gweleweta Village in T/A Kilupula reported that while some households find rice cultivation a key source of livelihood, most of them end up borrowing money from money lenders (locally called Katapila) to buy rice seedlings to replant their farm lands if they are washed away by floods. The key informant reported that most households have pressures to repay the debt and they become more vulnerable to floods.

4.5.3 Social Organisation

The results of this sub-section analysed the capacities of households' ability to undertake some form of social/organisation strategies used to respond to floods. Table 4.52 presents the results of the interviewed participants.

Table 4.52: Results of Relationship between Adaptive Capacity and Resilience Measures

	Outcome % from participants resilience measures							
	Ability to organise		**Decision making**		**No access to Warning to impeding floods**		**Trust on warning systems**	
Measurement scale	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**	**LC**	**KD**
Yes	47	68	51	84	23	5	42	8
No	51	32	45	15	70	94	42	92
Not sure	2	0	4	1	7	1	16	0

The results show that households' knowledge on accees to warning systems to impeding floods is very low. The results show that 70% and 94% of the interviewed participants said they have no access to early warning systems in LC and KD respectively. The results further show that 68% and 51% of household participants indicated that they have the ability to organise themselves during floods in KD and LC respectively. The results further show that 84% of household participants indicated that they make decision in relation to flood problems in KD, with a 51% on the same in LC. While the results further revealed that participants in LC indicated similar response (42%) on trusting to early warning system, those in Karonga district (9%) completely indicated that they do not have trust in the early warning system (Table 4.52).

The results of the key informant in a participatory HVCA process, warnings are provided especially by NGOS and some rain and river gauges are installed in rivers and schools respectively. The results further revealed that people have little interest to follow the warnings installed in river systems. One local leader indicated that: *"In the past, households have had their own systems like local inventions, ants pilling, and amount of rainwater"*. One key informant in the HVCA, indicated that the reluctance is due to discrepancies of the provided systems and those which were already perceived by the communities before the information from Department of Climate Change and Meteorological Services through Relief and Rehabilitation Officer via ACPC and VCPC chairs. It was also observed that illiteracy levels and poor strategies used to train the communities on how to use these gauges affected communities from adopting the EWS.

- **Perception/ motivation**

The results of the key informants revealed that households engage in activities of community-based mechanisms (CB-Ms) by helping each other through cooperation, in developing flood preparedness activities, planting vetiver grass along the rivers, planting bananas along the river, evacuation to safe places. During HVCA, it was revealed that people in T/A Kilupula are aware of floods and the causes such as deforestation, changes in climate patters. One informant indicated there is need to formulate by-laws to control deforestation and encourage one another to build houses with burnt bricks and seek support from other institutions. Some informants expressed dissatisfaction with external assistance. It was revealed that the support tends to be very low and quick; only comes during critical times. It was revealed that even the items that officials bring to support the victims are more temporary and do not reach the actual beneficiaries. One informant said:

> *"The support we get from other institutions is not enough. NGOs bring materials like buckets, plastic bags that do not really assist and meet our needs. I feel what is needed should be tangible solutions like civic education, conducting river conveyance, provision of cement for construction of strong house, improvement on communication so that people stop rely much on human mechanisms like drumming and ululating to communicate about floods. I feel also that dissemination of should be user friendly. (Attached to benefits), the city council rush to say the area belongs to them."*

In the same vein, the key informants in Lilongwe maintained that little support is received from some institutions. Lack of support in LC is attributed to boundary demarcation and power relations between Lilongwe city council (LCC) and Lilongwe district council (LDC). Key informants reported that:

> *"Mtandire is always under power conflict between Lilongwe city council (LCC) and Lilongwe District Council (LDC). Administratively, the area belongs to LCC but when it comes to problems that need attention, the city council push that the area belongs to district council. While when it comes to good things, we depend on ourselves to respond to floods... I feel this is one of reasons that is causing a lot of mess in Mtandire to the extent that the area does not receive support it deserves. LCC and LDC need to come clearly on this in order to ensure development of the area."*

4.5.4 Overall Ranking of Adaptive Capacity

The results of the overall ranking for adaptive capacity in LC and KD using a % scale of low, medium and high from the interviewed households participants have been presented in Table 4.45.

Table 4.53: Overall Adaptive Capacity Ranking

	% Low		% Medium		% High		Overall rank
	LC	KD	LC	KD	LC	KD	
Physical/infistractural	10	5	18	10	72	75	3
Social organisation	25	30	28	32	45	48	2
Economic livelihood	67	58	22	25	11	17	1

4.5.4.1 Distribution of Adaptive Capacity

The results which show the distribution of adaptive capacity ranking reveal a high rank on physical/infrastructural social organisation and economic livelihood in both KD and LC.

- **Physical/infrastructural Measures**

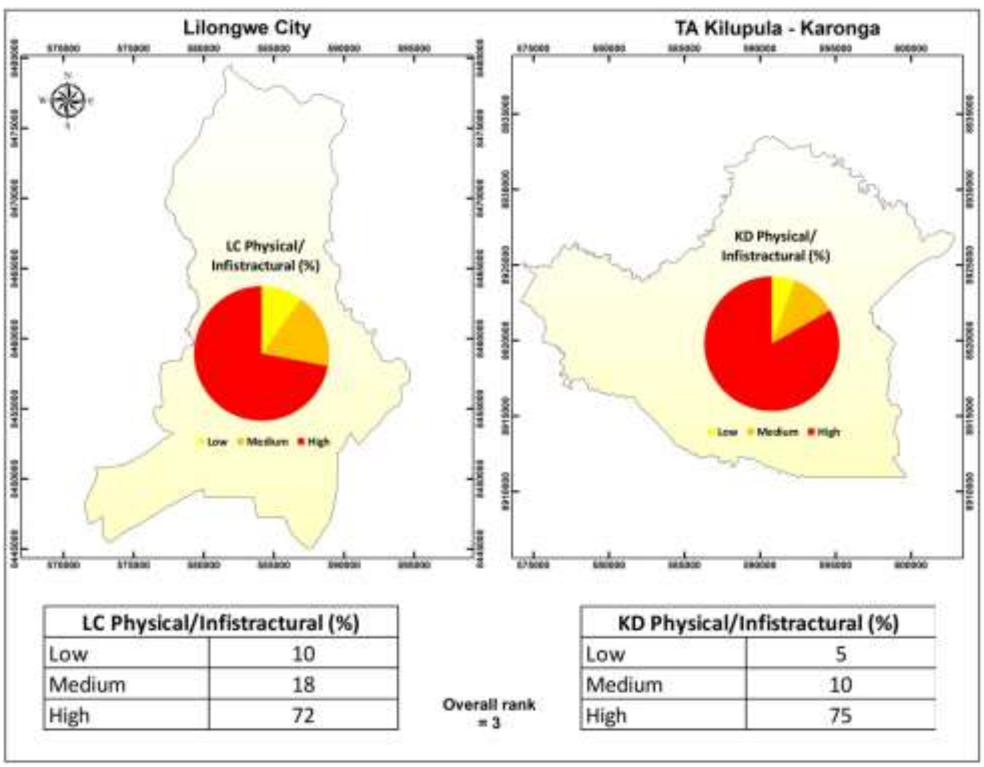
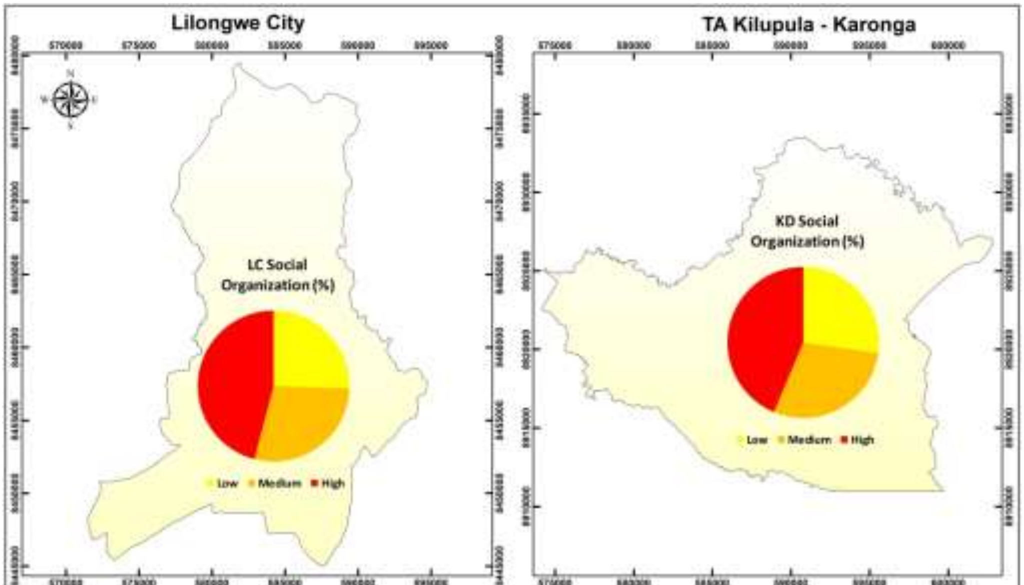


Figure 4.48: Distribution of Physical/Infrastructural Measures

The results of the participants interviewed revealed greater physical/infrastructural measures on the category of high (72%) in LC and (75%) in KD (Figure 4.48). Key measures which fall in this category include enforcing building codes, elevating part of household location, constructing dykes, planting vetiver grass among others.

- **Social Organisation Measures**



LC Social Organization (%)	
Low	25
Medium	28
High	45

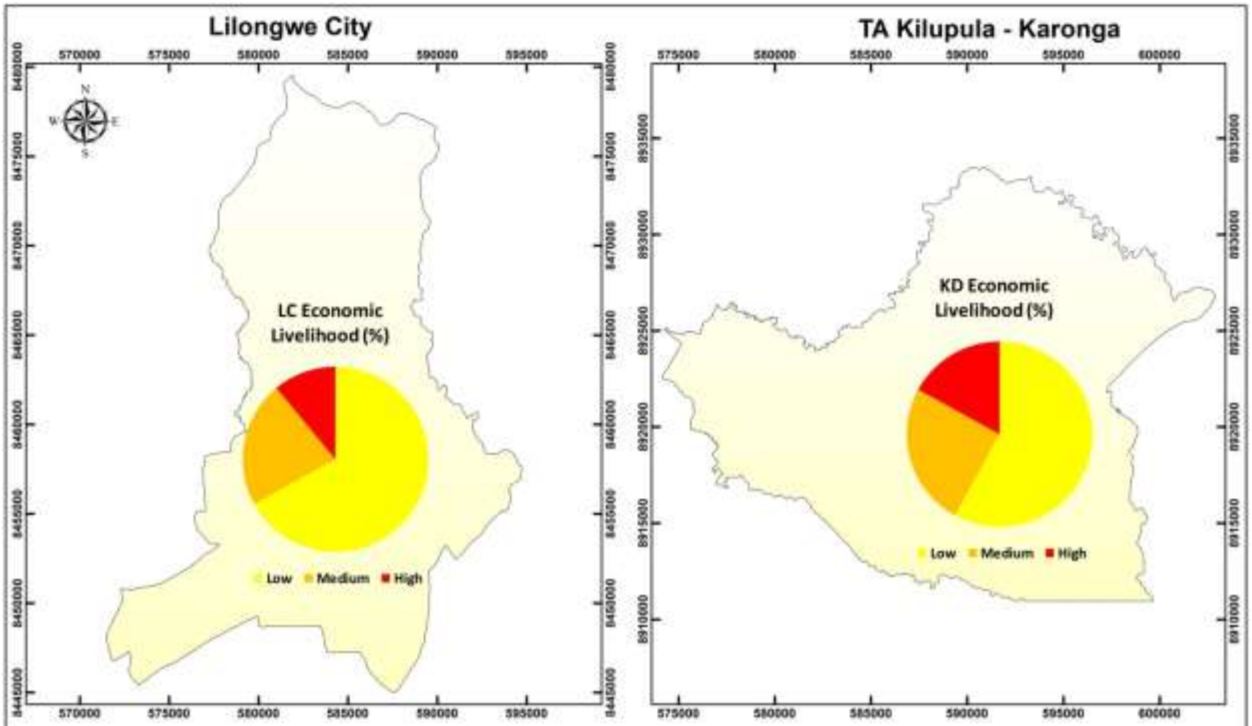
Overall rank = 2

KD Social Organization (%)	
Low	30
Medium	32
High	48

Figure 4.49: Distribution of Social Organisation Measures

The results of the participants interviewed revealed greater social organisation measures on the category of high (45%) in LC and (48%) in KD (Figure 4.49). Based on the results, the measures on the high category were below the threshold of 50% which was the benchmark of this study. Key measures which fall in this category include ability to make decisions, organisation and coordination, awareness, and communal use of strategic grains among others. These results reveal that most households take social organisation measures as adaptive capacity to respond to floods.

- **Economic Livelihood Measures**



LC Economic Livelihood (%)	
Low	67
Medium	22
High	11

Overall rank = 1

KD Economic Livelihood (%)	
Low	58
Medium	25
High	17

Figure 4.50: Distribution of Economic Livelihoods Measures

The results show that very few households have or take economic livelihoods measures as adaptive capacity. The results revealed low (67%) and (58%) in LC and KD respectively (Figure 4.50). Key measures which fall in this category include saving agriculture crops, strengthening diversification and strengthening livelihood opportunities. In HVCA, it was also revealed that people find it very difficult to take some economic measures because most of them are poor. One informant said*: "It becomes very difficult for them to have money to access their basic needs to respond to floods and can't even take some economic measures."* (KII# 17: 27th July 2021).

CHAPTER 5: DISCUSSION

5.1 Introduction

This chapter provides a discussion of the results. It highlights the implications of the major findings of the study. It is divided into four sections. Section one is the discussion of the results of the spatio-temporal flood vulnerability trends in the study areas. Section two discusses factors that determine households' vulnerability to floods. Section three discusses the findings on perceptions of households on floods occurrence in rural and urban areas. The last section is a discussion about households' adaptive capacity to respond to floods.

5.2 Spatial-temporal Flood Vulnerability Trends (STFVT)

The use of spatial-temporal data to understand floods trends provides an important element in understanding households' vulnerability to a particular hazard (Machado et al. 2015). It helps to identify best disaster risk reduction initiatives aimed at reducing human vulnerability (Jian et al., 2014). The process helps to establish technocentric solutions of flooding in river catchments, and thereby bringing innovations in flood catchment management (Grek, 2020). It further helps practitioners to identify best policies that can be employed to reduce household vulnerability to flood risks (Jian et al., 2014). This process can further assist communities to understand their own risks by providing visual representations of the changes that occur in their area due to flooding events. In so doing, decision makers and relevant stakeholders can utilise spatial-temporal data to identify and prioritize certain vulnerable areas and measures to mitigate existing vulnerabilities while preparing for future flood risk mitigation. The results of the STFVT have been discussed in sections 5.1.1 to 5.1.3.

5.2.1 Hydrological Assessment

On one hand, the results of this study revealed that Lufilya river catchment in KD has heterogeneous profiles which make households more vulnerable to floods as the flooding occurs in any direction. On the other hand, the results showed that Lingadzi river catchment in LC has a homogenous profile, but it is affected by human activities such as sand extraction and brick making. The results further revealed that there is high flood occurrence at shorter return period (2years) and vice versa in both catchments. The results also revealed that Lingadzi river catchment has high expected floods compared to Lufilya river catchment at different return periods while flood risk ranking is high in KD and low in LC. Households' flood vulnerability in KD could be attributed to building close to the river due to changes of Lufilya river morphology. This finding concurs with Ludin et al. (2018) in which it was established that residents living close to the river were more vulnerable compared to those that live away from the river. On the other hand, the high-expected flood from Lingadzi basin at different return periods is an indication of the high likelihood for the floods to occur. This study attributes the high-expected floods in LC to, among other factors, rapid population growth caused by increased urbanization, sand extraction, brick making and poor urban planning and development. These factors were also revealed by Ngongondo et al. (2020) who established that flow regime of Wamkulumadzi river basin in Malawi is affected by the rapid population growth and various land use changes in the catchment. However, the results of Ngongondo et al., (2020) did not find issues of river morphology. The difference could be due to the fact that this study profiled the river using field data (coordinates) to determine the changes in time and space, while the previous study used secondary data (Ngongondo et al., 2020). The high floods peak in both catchments indicate that the flow rate of the rivers have higher discharge (R^2=0.994). In Lingadzi River, the high discharge can be attributed to increased human settlements along the catchment, which further contribute to short lag time thereby making the river to flood. On the other hand, in Karonga (R^2=0.9962), this could be attributed to poor agricultural practices, deforestation and siltation of the catchment. These results are also consistent with the findings of Silva et al. (2012) in which they posit that urban drainage systems and poor zoning of urban settlements contribute to flood vulnerability. Furthermore, poor land management practices, buffer zones degradation, deforestation and depletion of marginal land are key to contributing to vulnerability in rural areas (Silva et al., 2012) where the majority of the people depend on agriculture. Villordon et al. (2014) confirms that living in or close to river increases households vulnerability to floods. Ludin et al. (2018) argue that the larger value of R^2 indicates that the parameter under study is significant in explaining the variation of flood vulnerability. However, despite the huge similarities of these findings, still, this study argues that issues of river morphology in relation to conditions of heterogeneous, homogeneous, lag time (short/long) and river profiling combined with existing household vulnerabilities have not been fully analysed and linked in the understanding of households flood vulnerability in Malawi. Therefore, this gap has been filled in this study. As such, the study maintains that the use of real field data can provide a proactive and a clear understanding of spatial and temporal flood characteristics in various river regimes and could be key for programming current and future flood risk reduction measures with a clear informed knowledge.

5.2.2 Land Use and Land Cover Reduction

The results revealed that there is gaining and losing of land in the studied areas. While the results showed that bare land, built up areas, area covered by water and vegetation are being lost (decreasing) in LC, only area covered by water in KD are gained (increasing), but the rest are decreasing. Significantly, the changes in the catchment of Lufilya River in KD have resulted in loss of households land. The total land area that was available to the households before the river changed its course was 0.920970km^2 (about 920,970.180m^2). The morphological changes of the river into different profiles covering a land area of 0.534148km^2 have resulted in a land reduction of about 0.386822km^2. This land was largely used for agriculture and partly for human settlement. The loss of this land means that people in the area are seriously affected in terms of food production and income levels since most of them depend on agriculture as a source of food and income. This loss has an impact on the country's Gross Domestic Product (GDP) and Gross Nation Product (GNP) since agriculture is the main source of Malawi's economy (Lundin et al., 2018; Wright et al. 2017). The findings of this study concur with findings of Nazeer et al. (2020) which revealed that changes of river morphology strongly pose a disadvantage on conditions for people who rely on agriculture.

The above result further provides an assumption as to why relocation is a problematic in T/A Kilupula and Malawi in general. For instance, many policy and decision makers including stakeholders as well as NGOs maintain that people in prone areas must relocate to safer places (Chawawa, 2018). The question is that is it possible to relocate? Practically, not easy to yield tangible results. Despite the merit of relocation is that there is less upheaval in terms of activities and social relations (Jain et al., 2016), but, its setback is that there is no systematic movement of people. The movement is a centric of the people themselves, government and authorities' desistance in the equation of the movement (Chawawa, 2018). Kita (2017) also found that relocation/resettlement in Malawi is obscuring the key drivers of vulnerability while simultaneously exposing those left behind to further risks. . Therefore, this study maintain that relocation would be difficult in the event of not knowing the amount of land which is available for the households where they are told to relocate and the amount of land where they are supposed to relocate. Kita (2017) found that planning and execution of relocation is fraught with multiple challenges emanating from haphazard planning and lack of community participation. Relatedly, Chawawa (2018) also found that smallholder farmers in Chikwawa and Blantyre districts in Malawi are not willing to relocate due to reasons such as land availability in the area they intend to settle. People are just told to relocate without necessarily identifying land where they need to relocate. In a few instances, where land is identified, the size of land and other social services are not considered as priority by government and stakeholders initiating the relocation process. Furthermore, there is an oversight to know the productivity of the land the people had before, which would (would not) attract them to settle in the new areas. Therefore, the dynamic of land issues require top prioritization in policy and decision making process to build on current and future flood risk reduction and mitigation strategies as well as responding to the requirements of the SFDRR (2015-2030). Chawawa (2018) also established that relocation is practically not possible in Malawi due to issues of land ownership because people are not ready to lose their land. Similarly, various studies articulate that relocation is practically impossible due to lack of willingness to settle, level of participation to settle by those being resettled and size of land offered to households (Chen et al., 2017; Kita, 2017; Carmona et al., 2011). In this case, this study highlights the significant need to undertake an evaluation of land dynamics and patterns as critical component of providing insights to decision makers and authorities on how the future programming of flood risk management strategies must be shaped and implemented.

The cause of household's vulnerability to floods in T/A Kilupula of KD is further heightened by community myths and cultural beliefs. The results show that people hold the views that the morphological changes of Lufilya River are due to witchcraft. Indeed, change is gradual, but it can be controlled if appropriate and proper strategies are employed. However, due to cultural beliefs of witchcraft and myths, people have allowed Lufilya River in Karonga district to widen and change its channel and direction respectively now and again. In 2017-2018 season, the whole village turned against three males, "accusing" them of having bought traditional medicines locally called "nyanga" to widen the river course and change its directions. These three males were accused to have bought the traditional medicines to displace other people in the communities who lived along the river catchment. This situation became tense to the point that the Village Headman (VH) called for a community gathering to discuss the way forward on this matter. Then, a resolution at the chief council was made to identify and invite the "traditional doctor" to come and impound the said "nyanga" in the river at a cost of K200, 000 (equivalent to two cattle**).** Despite this effort, the river continued to increase in its channel and in 2018-2019, flooding from the said river rendered 250 households vulnerable and permanently displaced 40 households. This is a clear indication that decision-making of leaders in communities is often made under condition of limited information to hazardous events. As such these leaders must be strongly trained and engaged as key participants enterprises (actors) in the programming of current and future flood vulnerability mitigation and preparedness measures.

This is another clear indication that awareness on these flood events needs to be intensified. Nazeer et al. (2020) established that communities lack of awareness on flooding issues contribute to vulnerability because community tend to have limited strategies to deal with flood events. Rana (2018) argues that lack of awareness, weak institutions, and poor infrastructure contribute to vulnerability because they make people have low information, low support and stay in substandard houses. In KD, the witchcraft behaviour is a clear indication that people lack awareness on floods and still look at hazards (like floods) as pure acts of nature. This could be due to lack of strong institutional support to promote awareness and sensitization on the understanding of hazards and disasters (Wright et al., 2017). Other observed challenges impinging on the promotion of awareness could be limited staff in councils to undertake the awareness and sensitization exercises, lack of funding and negligence because of a culture of business-as-usual attitude. Unless, government take a full commitment to promote reasonable measures to guide disaster risk reduction (DRR) and encourage participation of different enterprises in preparedness, mitigation and advocacy, then a full vulnerability reduction would be realised. Furthermore, this study has shown that the dynamics of beliefs and myths embedded in people's culture contribute to increase vulnerability and therefore, these must be incorporated in the current and future flood risk awareness and communication strategies at all levels to minimise peoples' vulnerabilities, especially those who lack knowledge on the occurrence and nature of flood hazards.

5.2.3 Human Occupancy and Land Use Planning

The results revealed that the risk of flood is accelerating due to human occupancy and land use planning. Particularly, the results showed that households' vulnerability to floods in Mtandire ward of LC is due to construction of settlements along the Lingadzi catchment and land use activities such as sand extraction and brick making. These results are similar to the findings of Amrani et al. (2018) in Nador territory, Morocco in which the increased household's vulnerability to flood risks was attributed to the development of human settlement in marshy and floodable zones. The findings further agree with the study of Kita (2017), in which building of settlements in high flood risk areas and poor construction practices are the cause of vulnerability experienced by the residents of Mzuzu city in Malawi. Significantly, it was revealed that people especially those located in area 49 (New Gulliver) have constructed their houses and fences along the catchment areas of Lingadzi river. This condition has made the river to lose its marshes and swamps, which could control water flow. Furthermore, the activity has increase run-off due to the increase in concrete structures that reduce infiltration of water. Therefore, due to low infiltration and that the houses are close to the river, it means that there is a shorter lag time. This short lag time implies that water from the building structures is flowing a short distance and increasing the volume of water in the Lingadzi River, thereby becoming more prone to flooding. This means that the river fails to contain the amount of water that enters into the catchment and thereby causing floods to Mtandire area. It was observed during the interviews that people occupied land in area 49 which was allocated by the City Council (CC) through the Department of Lands (DL). What is worrisome in this is: what criteria did the CC use to distribute land to the inhabitants in the area? This question is not straightforward to be answered, because of land power dynamics. Among other key factors that bring land governance problems include : lack of full control over land by city councils, social political issues, local actors find it difficult to manage land, availability of local leaders in cities and democracy in terms of land use choices (Kita, 2017; Liu et al., 2022). Therefore, this study portrays that land governance issues are fundamental factors influencing household flood vulnerability and are crucial for programming flood risk management strategies. This study further show that in the process of programming the flood risk reduction measures, officials must not make decisions and actions that violate the law, let alone increasing vulnerabilities of poor households.

5.3 Predictive Factors that Determine Households Vulnerability to Floods

This section provides the discussion of the results based on five combined attributes of Physio Exposure Factors (PEFs), Socio-Susceptibility Factors (SSFs), Eco-Resilience Factors (ERFs), Enviroexposure Factors (EEFs) and Cultural-Susceptibility Factors (CSFs). These combinations were generated from the results of UVFs and VCs during the determination of vulnerability using the Balica et al. (2012) modified probability scale range. The modified probability scale 0-1 is interpreted as follows: 0.32-0.40 very low vulnerability, 0.41-0.49 low vulnerability, 0.50-0.59 moderate vulnerability, 0.60-0.79 high vulnerability and 0.8-1.00 very high vulnerability. The cut off for the determination of a factor contributing to vulnerability was 0.5 (50%) for the factors that were analysed based on scale of “less important”, “important” and “very important”. This means that only causes in each factor that were found with 50% above in the measurement scale of “very important” were considered as the causes of vulnerability in the UVFs. On the group of vulnerability components, the study determined the P-values based on a “combinedPvalue package” in the “r” environment by combining UVFs and VCs. ANN was used to predict the main causes of flood vulnerability from those groups of variables which were statistically significant. The MCA in Minitab statistical test helped to select variables that determine vulnerability to floods based on contribution to the inertia. The combination of these revealed five underlying factors that predict households’ vulnerability to floods both in Mtandire-urban informal settlement of Lilongwe city and in T/A Kilupula-rural area of Karonga district as discussed in sections 5.3.1 to 5.3.5.

5.3.1 Physio-Exposure Factors (PEFs)

The predicted binomial logit regression value of the PEFs falls in scale range of “vulnerability” in Mtandire ward of Lilongwe city (0.52) compared to “high vulnerability” in T/A Kilupula of Karonga district (0.64). However, for specific cause, such as lack of construction materials, the findings indicate a threshold scale of “flood vulnerability” to floods (0.50-0.59) in Mtandire ward, while in T/A Kilupula; it falls in the scale of “high vulnerability” to floods (0.60-0.75). This means that while it contributes to vulnerability in both areas, it is much higher in studied areas of T/A Kilupula of KD compared to Mtandire ward of LC. This implies that people in rural areas have high vulnerability based on lack of building materials. Similar, to this finding Alam et al., (2022) also found a high vulnerability value of 0.7015 for rural people living in the Dammar

Char in Southeastern Bangladesh compared to urban areas. While, Alarm et al. (2022), did not specify the causes of such as high vulnerability, this study attribute the high vulnerability to the aspect of lack of construction materials, distance to markets and transport cost that people have to incur in order to access construction materials in rural areas. These causes agree to the findings of Qasim et al. (2016) in which vulnerability to flooding was attributed to poor/lack of materials used to construct houses.

The results also revealed that poor construction of infrastructural facilities fall in the scale of "high flood vulnerability" (0.6-0.75) in both LC and KD. This implies that substandard construction of infrastructure such as houses contribute to vulnerability. This finding is supported in literature that substandard infrastructures contribute to flood vulnerability (Salami et al. 2017). Furthermore, the ANN results in MLP revealed a strong association of physical vulnerability factors (lack of construction materials, construction of infrastructures, and ageing infrastructures) with housing type. This implies that they contribute in generating vulnerability because people live in substandard houses. This finding confirms the result finding of Movahad et al. (2020) and Aliyu Baba Nabegu (2018) who indicated that people are vulnerable to floods because they usually live in substandard housing conditions which become prone to floods.

The value of topography (geography or simply location) was found to be the only PEFs contributing to increasing household vulnerability to floods in T/A Kilupula compared to Mtandire ward. This means that households in T/A Kilupula are more prone to flooding because of their geographical position of the area than in Mtandire ward of Lilongwe city. This confirms the findings of Nazeer et al. (2020) who indicates that jurisdiction/location is a cause of vulnerability for communities located in Charsada district compared to those in Nowshera district in Pakistan. In addition, Alam et al. (2022) established similar findings that natural vulnerability is higher due to the location among the people of Dammar Char in Southeastern Bangladesh. However, in Mtandire ward both parameters of housing like house type (0.0001) and roofing materials (0.0072) were significant while in T/A Kilupula only roofing materials (0.036) was significant. As confirmed by Movahad et al. (2020), this finding heightened the fact that geography exposes people's houses to be vulnerable to floods. It was further noted that among the key factors to vulnerability, include limited knowledge of building codes, using the same weak building materials in the same locality. Balica et al. (2012) also found that building standards and materials making up the building contribute to vulnerability.

The above-established findings further concur with the findings of the GFDRR (2019), which indicate that most people in Malawi live in dilapidated houses, and depend on very limited resources such that they cannot afford to find durable materials for construction of their homes. Most infrastructures such as houses are traditional and substandard, predominantly built of grass thatch and mud floors (Wright et al., 2018), prone to leaking and thereby becoming weak. In the case of a flooding event, such houses become more vulnerable to floods and get damaged easily (Lindstrom et al. 2014). This is also supported by the results of housing typologies (Figure 4.33), which established that over 60% of the households live in semi-permanent houses. Even though some households were found to reside in houses built of iron sheets, the standards of the iron sheets were prone to leaking, making household members exposed to rainwater. Specifically, the roofing of houses in Lilongwe city is dilapidated and very leaky. This causes floods to have huge impacts on facilities like toilets and houses. The relationship of physio-exposure factors further revealed that house type and roofing material are significant in both Lilongwe and Karonga, implying that they increase vulnerability of people to floods because the houses become too weak to withstand the flooded water. Aliyu Baba Nabegu (2018) also found that 82% of the houses built of mud were destroyed compared to those built by concrete (12%).

The findings from unstructured interviews with key informants reported that people do not have accessibility to strong build structures that can withstand floods. It was further reported by the key informants that several households during the 2019 floods lost their houses completely. In both Lilongwe city and Karonga, it was also noted that most people have substandard houses due to limited income generating activities which could provide them with good materials for their households. With this low level of income, it is very difficult for them to build strong houses that can withstand flooding impacts. This outcome provides a clear justification for the need of strengthening household domestication of agricultural produce in the National Resilience Policy (NRP). This can help households to have access to different sources of income which can enable them procure some housing materials. Otherwise, if the policy focused on issues of food security by depending on subsistence farming, breaking from poverty reduction would be a myth and consequently more vulnerability to natural shocks like floods will increase.

The implications of physical factors (PFs) on demographic characteristics at P-value (<0.05) revealed the significance level of PFs with sex and marital status. While only marital status (0.0490) was significant with PFs in Mtandire ward of LC, sex (0.0371) and marital status (0.0265) were significant with PFs in T/A Kilupula of KD. This finding confirms that physical vulnerability level differs based on sex (either being male or female) and marital status. For instance, a study of Aliyu Baba Nabegu (2018) in Nigeria also found that sex was a demographic variable for vulnerability variation as more females 72% died compared to 28% male death. In Karonga, females are more vulnerable due to the patriarchal system. It was established that female-headed households, widowed and divorced females without male children are more vulnerable to floods than those male-headed households. It was noted that they have poor houses made of mud floors and thatched with grass because the culture does not allow them to perform other duties like thatching houses (Mwalwimba, 2020). They also find it difficult to rebuild their homes once their houses are damaged by floods. It was further established that when resources are being allocated, leaders give priority to influential families who have power to voice out their concerns than the widowed and divorced females. In Mtandire ward, it was observed that most unmarried, widowed and divorced females in Mtandire area find it difficult to have strong houses because they have fewer resources. Most of them live in very weak buildings prone to flooding. This observation relates to the study of Tembo (2013) who found different ideas between men and women in Uganda in terms of adaptivity to climate change. These circumstances illustrate vulnerability determinants of female due to limited power over decision making. Alam et al. (2022) found that females experienced more vulnerability than their adult male counterparts in Dammar Cha area of Bangladesh due to limited power and control of resources created by the society differentiations. Similarly, Chawawa (2018) established that females suffered most during the 2015 floods in Nsanje district compared to males. Key among the factors stipulated by the author include lack of support due to the patrilineal system, emotions due to death of family members, trauma, among others.

The above findings indicate that key factors for households flood vulnerability are associated with knowledge on building codes and standards. This means that the culture of shelter safety is lacking and that there is lack of knowledge of the type of houses that they can build to resist floods and any other type of natural hazards. These could be attributed to be dynamic pressures influencing households' vulnerability to floods. That's to say, people do have enough resources, decision making, and societal skills to access housing materials that can help them to build strong houses. In this situation, the programming of flood risk management and in general DRM mitigation, preparedness and recovery measures should focus on reducing the pressures through strengthening households' knowledge and building standards. This can be achieved through designing mitigation measures that address the root causes that contribute to increase vulnerabilities in the pre-floods and post floods phases rather focusing too much on the trans-flooding phase.

5.3.2 Socio-Susceptibility Factors (SSFs)

The results found that the SSFs factors that contribute to generating vulnerability both in Mtandire ward and T/A Kilupula are lack of access to health services, human rights, limited institutional capacities and lack of awareness. However, the binomial logistical regression of the SFFs generated a vulnerability value (0.61) of people living in the studied area of Karonga district compared to a low vulnerability value (0.2) of people living the studied area of Lilongwe city. This finding differs from the findings of Munyai et al. (2019) in Muungamunwe Village in South Africa, which found that the value of FVI social was 0.80 higher than all the factors assessed. However, it is noted that the later study did not comprehensively link various factors between UVFs and VCs to determine the degree of contribution to vulnerability. The results further imply that the socio-susceptibility factors contribute to high vulnerability in rural areas than in urban areas. This finding is supported by the study of Mwale (2014) in which social susceptibility was categorised from "high to very high vulnerability" among the communities in rural Lowershire of Chikwawa and Nsanje Districts of Malawi.

Contrary to other studies (Munyani et al., 2019; Nazeer et al., 2020), this study has shown how each individual variable contributes to vulnerability. For example, lack of access to health services was found to have a differing degree of vulnerability on probability scale range in the sense that Mtandire ward in Lilongwe city falls under " vulnerability" (0.62) to floods while T/A Kilupula falls in a "high vulnerability" (0.73) to floods. On the other hand, lack of human rights (0.7) is a cause of vulnerability in T/A Kilupula of Karonga district and is classified in a scale of high vulnerability to floods. While other indicators such as lack of capacity to cope and social security did not qualify the threshold of 50% in the probability scale range of vulnerability to floods, as such they were classified as SSFs that lead to "low vulnerability" to floods. However, in the studied area of Lilongwe city they showed some likelihood of "vulnerability" to floods compared to the studied area in Karonga district. This result concurs with the findings of Wisner et al. (2004) in literature, which attributes that poor access to social services such as health; water and sanitation contribute to increasing vulnerability of people to hazards. The only hindrance is that Wesner et al. (2004) did not quantify these parameters as the case in this current study. While looking at these parameters from the qualitative view to understand vulnerability is justified, a quantification of these parameters gives a much better empirical evidence for decision making and policy interventions because stakeholders can utilise indicators for designing mitigation and preparedness strategies. Furthermore, the results of this study have shown various SFFs are limited in the studied areas thereby increasing vulnerability of households to floods and therefore, future and current flood risk management should build on these results for programming flood mitigation measures in all phases of pre-floods, trans-floods and post floods.

Similarly, based on the findings of the SSFs, it is imperative to hold the tenet that vulnerability is amplified by lack of access to knowledge and information on disaster risk reduction and management measures among the people in the studied areas of Lilongwe city and Karonga district. Most key informants indicated that issues such as lack of preparedness plans, limited early warning systems, lack of knowledge and skills to cope with urgent needs, and lack of local support institutions, contribute to vulnerability. Quantitatively, the findings also revealed that communication accessibility was significant (0.0086) in Lilongwe and (0.0060) in Karonga at P-values <0.05 with social factors. This implies that people in the studied areas lack knowledge on flood risk reduction measures. This agrees with the results of Munyai et al. (2019) who found that lack of public awareness and early warning systems increased vulnerability of people to floods in Muungamunwe village. Eventually, it is beyond doubt that the said factors make households to be more vulnerable to floods as they cannot anticipate and respond positively to the impending floods.

The discussion above was further heightened during interviews with key informants. One informant indicated that it is very "difficult to provide education and awareness to people on flood preparedness measures such as early warning systems because of their ignorance". This qualitative view, obviously, asserts the fact that low levels of education of people increase vulnerability to floods. The results of household survey also established that the highest level of education one could attain in T/A Kilupula was Primary School Leaving Certificate (PSLC), while in Mtandire it varies with more people without formal education followed by PSLC and JCE and MSCE respectively. With this level of education, it was observed that many people in the studied areas have little knowledge on risk reduction and early warning systems. Supported by key informant views in T/A Kilupula, it was indicated that early warning system such as rain gauges and river gauges have been installed to provide data on rainfall and water levels to predict flooding but due to ignorance, people do not understand them. In Chawawa (2018) findings, it is indicated that lack of participation in utilising the early warning systems could be a result of people assisting each other within the community during floods. In this case, government, local institutions and non-governmental organisations can intervene by strengthening information disclosure that are people centred, taking into consideration people's levels of understanding and their social systems.

The statistical analysis showed significant level between accessibility and healthcare in Lilongwe (0.0347). These findings point to the fact that vulnerability of households is further heightened due to poor communication and limited social services. This result is in support of Birkmann et al., (2013) findings that lack of social services further heighten the vulnerability of communities to disasters. According to the findings of Chawawa (2018), it was revealed that smallholder farmers in Nsanje and Blantyre rural are vulnerable to floods due to social issues that impinge on them to be more resilient. The findings of Manda et al. (2017) showed that residents in Karonga face the risks of water and sanitation, thereby supporting the significant test of accessibility and water and sanitation in this study. Therefore, for proper programming of current and future flood vulnerability reduction measures, participating actors (enterprises) have the responsibility to strength availability of social services to ensure quality of basic life of households and families.

It was also observed that in Mtandire ward these early warning systems are limited because the disaster risk management did not target urban dwellers until recently when some organisations have started creating institutional structures for DRM/DRR. Furthermore, some key informants reported that inability to incorporate disaster risk reduction in development plans in the past years has contributed to increased vulnerability of people. As observed by the study of Mwale et al. (2015), lack of incorporating DRR in development plans may be attributed to high reliance on community based disaster risk reduction (CB- DRR). The CB-DRR encounter various challenges like: lack of finances, inadequate capacity, power relation in communities (Wright et al., 2017). As such, this study argues that to ensure that DRR measures are seriously incorporated for vulnerability reduction, enterprises participating in the disaster management need to be equipped with enough social security that can strengthen social governance, and the most important aspect of which is to optimize the allocation of resources by political means to achieve social security including establishment of DRR funds. Poor designs of other infrastructures such as roads, dams, bridges and culverts contribute to flood vulnerability. For example, a culvert at Kibwe River along the M1 road in T/A Kilupula of Karonga district is too small to allow water to pass through hence in any event of flooding it increases the volume of water to the communities of Chimalabanthu village affecting even Kaporo Police Station. Therefore, current and future programming of vulnerability reduction measures which can strengthen households' safety need to consider infrastructure construction of disaster prevention and control. Furthermore, other informants reported that reliance on relief than in disaster risk reduction has promoted a culture of laziness among the people. Instead of thinking of measures of assisting themselves, they continue to stay in dangerous areas, allowing floods to be part of their lives (Chawawa, 2018).

In support of the heavy focus on managing emergencies (through relief), this study observed that there is a mismatch between what the Malawi's disaster risk management policies report as the cause of vulnerabilities in most areas. The policies include, among others crude causes like urbanization, rapid population growth and fragile economy (NDRMP, 2015). This study also maintains that the dynamic pressures leading to households flood vulnerability on the basis of the following grounds: attractiveness of relief support by all stakeholders (donors, NGOs, survivors, policy makers etc); lack of support (funding) on disaster risk reduction (DRR); neglect of policy makers to intensify DRR programs; the continuum of leaving out certain enterprises, for example, the academia to participate in the disaster risk mitigation, preparedness and recovery process and lack of support to integrate research findings from the academia. This study argues that the implementation of DRR/DRM activities is done on business-as-usual basis. In support of this argument, Mwale (2015) calls for the need to mainstream disaster risk reduction in development programmes in SSA. Wright et al. (2017) highlight that the focus on community-based flood risk management (CB-FRM) needs to emphasise more on risk reduction and preparedness approaches in order to strengthen DRR. Therefore, unless the government develop DRM policies which reflect properly on these, then investment on flood risk reduction and in general disaster prevention could be a reality. Further to the findings of this study, the proactive thing in Malawi could be just attributed as popular discussion stories in DRM policies, platforms, meetings and conferences. Currently, the Disaster Management Law (DRM Law, 2023) which has replaced the Disaster Preparedness and Relief Act (1991) is still emphasising on disaster response than DRR. In the new DRM Law, the aspect of vulnerability assessment has not come fairy clear, yet it is a starting point for any DRR initiative. The Law lacks a procedure of translating DRR into practice because it has not properly addressed the issue of DRR financing. This remaining gap is likely to make DoDMA and other participating enterprises (actors) struggle to get resources and funds for DRR. As such, the actors would be forced to await a declaration of a state of disaster in order to have access to resources and funds for DRR. If this gap is not addressed, it is unlikely that the DRM can be transformed from disaster response to DRR. Worst still, the DPR Act (1991) was described outdated and stakeholders called for a new DRM Law/Act to focus on DRR and resilience building for long time. The development of the new DRM Bill (now Law) which has replaced the DPR Act (1991) remained in draft form for 7 years from the time it was initiated to be reviewed in 2015. Until, March 2023 when the country was hit by TCF, then the DRM Bill was passed in parliament and the president assented it to be DRM Law. This is a sign that the DRM Policy in Malawi is a centric symbol of disaster enterprise. It is also a symbol of lack of strong commitment of decision makers to prioritize measures of dealing with vulnerabilities while preparing for future flood risk mitigations. This is also an indication that Malawi's disaster risk management policies lack immediacy to update important policies and to translate them into programmes and activities that can mitigate current vulnerabilities and prepare future flood risk mitigation and risk reduction measures. Therefore, understanding various causes of vulnerabilities as evidenced in this study should shape how urgency critical policies must be formulated, updated and translated into sound operational activities to reduce vulnerabilities of people.

5.3.3 Eco-Resilience Factors (ERFs)

Overall, the binomial multiple logistical regression showed that the ERFs contribute to "very high vulnerability" in T/A Kilupula (0.8) while "high vulnerability" in Mtandire (0.6). Specifically, poverty and lack of alternative livelihoods were established as the key causes of vulnerability to floods. The high vulnerability is linked to factors such as poverty, lack of alternative livelihoods, and lack of income generating activities. Similar to these results, the study of Mwale (2014) also established a predominantly very high economic susceptibility based on causes such as lack of economic resources, an undiversified economy and lack of employment opportunities among communities in lower shire valley of Malawi. Despite the results revealing the same outcome, the earlier study linked economic with susceptibility measures while this study agglomerated economic with resilience measures. The existing variation placed some causes in different association order. For example, poverty in the study of Mwale (2014) was categorised as social susceptibility indicator, while in this study it was used as eco-resilience measure. The understanding of this study is that poverty is a measure of income of level of a household. That is to say, a household with enough income will be less poor thereby become more resilient and vice versa. Therefore, poverty was classified as cause of "high vulnerability" both in Lilongwe city with a value of 0.73 and T/A Kilupula with a value of 0.68. On the other hand, lack of alternative livelihoods contributes to "vulnerability" in Mtandire ward with a value of 0.54 while 'high vulnerability" in T/A Kilupula with a value of 0.71). These findings point out to the notion that programming current and future flood disaster mitigation plans and vulnerability reduction measures, require formulation of relevant financial and economic measures which may contribute to poverty alleviation in community and society.

The major outcome of the findings above therefore is that poverty generates more vulnerability to floods for urban households than in rural households while limited access to alterative livelihoods generates more vulnerability to rural households than to urban households. This finding, accord to the results of Oyedele & Vyonne (2022) which stipulate that economic conditions affect vulnerability level. However, the variations in vulnerability level in the findings of this study could be attributed to the fact that most urban people depend on buying food for their survival, as such in the event of flooding their poverty increases because they cannot afford to have income to buy food. While the same is not applicable for rural people who, in most of cases, use their own food produced from agricultural produce. In this case, poverty contributes to vulnerability in the sense that it increases an individuals' proneness to hazard and decreases the capacity to cope with the hazardous event. This finding is in support of ISDR (2011) argument that poverty is a cause of economic vulnerability because the poor tend to have lower coping capacities. It makes households to have less financial resources to prepare for and respond to hazardous event. It can further be argued that lack of alternative livelihoods like (other sources of income) make households to have limited reserves to recover from flooding events as well as it complicates their ability to evacuate. It was further reviewed in the unstructured interviews with key informants that the interest that people have on floods such as using flooded water to plant their rice, plant their winter maize and benefit from alluvial soils for bumper rice yields, were among economic factors generating vulnerability in T/A Kilupula. Chawawa (2018) found similar results especially for rural people in Nsanje. The researcher's finding revealed that people are not willing to move permanently to upland areas because of the economic benefits that come with floods.

The above variation of the results (quantitative and qualitative) could be attributed to the limited capacity of the households to support themselves because of low levels of income generating activities. The majority of people are poor and they cannot raise extra-income to establish and support their families as well as to access another land in safer ground for resettlement or relocation. Consequently, they have developed high interest to reside in the flood risk areas, a condition that contributes to generating their vulnerability. Some key informants explained that the district (Karonga) economy is not well developed owing to its narrow resource base. It was further observed that very low income and rampant poverty among the people prevent many people from living a decent life thereby becoming vulnerable to floods. This observation, concurs with Birkmann et al. (2013) that a country's economic stability determines economic vulnerability. It can also be inferred that apart from being poor, insufficient capacity to provide social services (like schools, health posts) reduces the willingness of people to relocate permanently.

The vulnerability curves show a higher vulnerability value (0.57) in T/A Kilupula compared to (0.33) in Mtandire ward on scale of severely vulnerable (Figure 4.8). The results showed that the economic elements in scale of severely vulnerable include employments (56%) in Mtandire ward and in T/A Kilupula include 96% staple crops-maize, 93% cash crops-rice and 68% livestock (Tables 4.29 and 4.30). This means that most economic elements in T/A Kilupula like maize and cassava (92%), rice (95%) and livestock (82%) fall on the probability scale range of very high vulnerability to floods. In Mtandire ward, the findings indicate that employment falls in the probability scale range of vulnerability to floods. The views of participants during unstructured interviews with key informants also revealed huge economic loss from the impact of floods. For example, it was reported that unspecified number of livestock have been reported missing or dead and 653 hectares agricultural crops have been either washed away or silted in T/A Kilupula. The strategic crops, maize and rice, in the field have been flattened with little room for recovery, a situation which further heightened households' vulnerability.

The economic indicators were significant with other demographic characteristics at P-value <0.05. These include sex (0.056), education (0.0378) and occupation (0.0075) in T/A Kilupula while in Mtandire ward they include marital status (0.0497), education (0.00235) and occupation (0.0106). This result suggests that those economic factors contribute to vulnerability due to gender, education, marital status, education and occupation. In both Mtandire ward and T/A Kilupula, occupation is strongly significant compared to other demographics. This could be attributed to the fact that most households depend on limited livelihoods to secure their income to feed households' members. Similarly, the survey established that females are the most economically vulnerable to floods due to their marital status. It was reported during unstructured interviews with key informants that widowed and divorced females fail to plant their crops at the right time especially in T/A Kilupula. This was observed as a condition that gives them limited access to economic resources. It was noted that they become even more vulnerable to future hazards because they reach the other rainy season without food. Moreover, it was observed that female-sex specific roles of not doing land tillage or ploughing and levelling with draught animals, give them limited time to do land preparation and early planting. This renders them vulnerable to floods or drought. In support of the above findings and observations, Birkmann (2011) accords that societal differentiations and injustices make females suffer disproportionally during disasters. All these findings reveal that most rural households are vulnerable to floods because they depend on limited sources of livelihoods, and mostly agriculture being the main source their daily lives. Therefore, these existing economic dynamisms between rural and urban informal settlements must well understood and prioritize for integration on flood mitigation and preparedness activities. Also, the findings reveal mix of eco-resilience causes of households flood vulnerability which could help decision makers, civil society and politicians prioritize certain vulnerable areas and have their open ears to identify measures that might contribute reduce vulnerabilities.

5.3.4 Enviro-Exposure Factors (EEFs)

The findings of the EEFs in a binomial multiple logistical regression model revealed "very high vulnerability" of EEFs (0.8) in Mtandire ward and (0.9) in T/A Kilupula . Except for the pressure on cultivated land in Mtandire ward of Lilongwe city, all underlying environmental vulnerability factors (UEVFs) contribute to vulnerability in both Mtandire ward and T/A Kilupula. This result points out that pressure on land is an environmental indicator that predicts households' vulnerability to floods in T/A Kilupula and not in Mtandire ward. The high vulnerability depicted by the EEFs is a total indication that households are more vulnerable due to the built environment. This could be attributed to the fact that people have allowed development in areas where danger exists due to the lack of policy and legal systems to help and guide government and stakeholders in disaster risk management. This argument is supported in literature that development in dangerous areas increases peoples' exposure to danger (Birkmann, 2013; Nazeer et al., 2020). Barbier et al. (2012) support that environmental damage affects the well-being of the local people since it leads to soil degradation which eventually cause low food production. To this end, laws and policies to regulate development and habitation in risk areas should be seamlessly programmed in the current and future flood mitigation and preparedness plans at all levels.

Similarly, during unstructured interviews with key informants in T/A Kilupula, the findings revealed that the environmental conditions generating vulnerability are: residing in flood prone areas, degradation, deforestation and bad farming practices. The bottom line is that households do not have an option, as their poverty levels are very high. Eventually, as Munyani et al. (2019) indicates, poor people have no option because they lack financial resources for relocation and evacuation to safer places. Furthermore, they do not have finances to access land in safe areas as well as having limited power in the society to lobby for safe areas. Mwale (2015) also found that vulnerability is dominated by a high to a very high susceptibility component because of the high socio-economic and environmental conditions. In Mtandire ward, the findings from key informants revealed that land use and occupancy contribute to flooding. It was observed that in Mtandire ward there is high insufficient land use planning which in turn exposes people to flood risks. Some participants highlighted that high population growth has created pressure on land that has forced people to occupy or reclaim land which is not suitable for habitation rendering them vulnerable to the effects of flooding. However, these occur due to lack of enforcement of laws and regulations (Mwale, 2015). This entails that strict adherence to the laws and regulations aimed at protecting vulnerabilities of people should not be based on leniency and specific operation process of some groups of people with their own interests. The interests should rather follow the process of disaster risk management of a country in general.

The findings also revealed that gender, marital status, education were significant with environmental factors in both Lilongwe and Karonga. This suggests that environmental factors influence vulnerability of households based on gender, marital status and education. The significance level between sex and environmental factors showed that both males and females face numerous challenges during floods. For example, in Karonga, it was revealed that males find it difficult to graze their livestock because all the pasture is submerged in water. Therefore, males are forced to travel long distances to search for pasture for their livestock. Sometimes they are forced to identify other people in the hilly areas to help them keep their livestock until the flooded water subsides. One participant reported that this also increases their vulnerability because their livestock sometimes get lost or die under the control of another person who lacks ownership of the livestock. The findings of this study concur with the findings of Tembo (2013) in a study of a dynamic assessment of adaptive capacity to climate change: a case study of water management in Mokondo in Uganda. Relatively, Tembo (2013) found that; women spent a lot of time queuing for water while men received less water for bath. Conversely, the identification of people to support during time of crisis has been emphasized. For example, while this study revealed that men identify other people to take care of their livestock, Tembo (2013) found that the households in Michunga and Kigunjo in Uganda were able to employ young men to fetch water for them. Interestingly, for men in KD, it was reported that this further increases vulnerability because at times their livestock get lost or die under the custody of the identified care taker. Similarly, Tembo (2013) found that the employed young men in Michunga and Kigunjo caused disagreements such as jumping the queue to collect water, disrespecting the traditional practices and unwillingness to pay for maintenance of shallow wells because they thought that they already paid to them in the form of voting at election time. Therefore, what is significant is to ensure that programming current and future flood disaster risk mitigation strategies, require addressing the power boundaries which make men and women to have overlapping vulnerabilities and consequently hinder the effective implementation of disaster risk reduction mitigation.

On the other hand, it was revealed that females find difficulties to get firewood during floods. It was reported that the majority use stored maize cobs during time of floods and animal dung after floods, for cooking due to lack of firewood. It was further revealed that females walk long distances to fetch water because all the water sources especially shallow wells are contaminated with flooded water. Therefore, the challenges have the likelihood of overlapping with the disaster management initiatives, resulting in the waste of resources and ineffectiveness of flood mitigation measures. The findings of this study are supported by Yoon (2012) which found that geographical positions like open space, buffer zones, and slopes determine community vulnerability.

5.3.5 Cultural-Susceptibility Factors (CSFs)

The findings of the binomial logistical regression of the CSFs small vulnerability to floods show a value of 0.34 in Mtandire ward and 0.39 in T/A Kilupula. This quantitative finding shows that CSFs are not very important in generating vulnerability in Karonga and are a less predictor of household vulnerability to floods. However, only growth of informal settlements as cultural factors (0.75) failing in the probability scale of very high vulnerability to floods in Lilongwe city. The findings revealed a less average percentage on the category of “very important” ranging from 7% to 48% less than the benchmark 50% altogether in the probability scale range in Karonga district. Those that were quantitatively less than 50% include cultural conflicts, growth of informal settlements, defiance of safety precautions and regulations and absence of personal responsibility. However, in the association of CSF, the findings revealed that all (communication accessibility, education facility and health facility) were significant, implying that they contribute to increase vulnerability. Nevertheless, the results of the qualitative analysis revealed that cultural issues such as beliefs in ancestor’s graveyards, lack of personal responsibility, defiance of safety precautions and regulations, cultural conflicts and governance issues are the main factors generating vulnerability of people. For example, in the triangulation of codes generated from key informants, 13 out of 17 informants mentioned lack of personal responsibility and absence of government regulations. Iloka (2017) also found that defiance of safety precautions and regulation and absence of personal responsibility determine vulnerability. Other factors that were established to contribute to household flood vulnerability in T/A Kilupula include cultural beliefs of conserving their ancestors’ graveyards and land ownership issues. In support of this result, Iloka (2017) found that a system of beliefs regarding hazards and disasters contribute to vulnerability. The findings of the author further established that cultural issues do not assist households to be resilient to the floods. In Mtandire Ward of LC, key informants reported that floods are due to land use and human occupancy in risk areas. Furthermore, it was reported that rich people have occupied places which are not habitable thereby changing the course of Lingadzi river. Further to this, youths have resorted to destroying the banks of the river due to lack of personal responsibility. It was noted that people do not fear or abide by city regulations because there is no punishment that they receive from city councils. What was supposed to be done is that all those occupying risky areas must be evicted by the city in order to stop these floods in this area.

The discrepancy of results of quantitative and qualitative analysis is due to people’s mind-set towards cultural beliefs and customs. It was observed that most people in Karonga value their beliefs such that they refuse to relocate their homes in favour of the cultural philosophies of taking care of ancestors’ graveyards. It was found that people would accept to die by floods and be buried together with their parents, grandparents all relatives than to move out of flooded land. It was observed that it could be difficult to convince people to move out of their original places. Unless more advocacy, awareness programmes and other incentives are provided, people may not show interest to vacate. Kushe et al. (2018) and Chawawa (2018) found that people in rural areas have accepted to endure floods as part of their lives. Moreover, it was noted that chiefs are also reluctant to move out with their subjects for fear of losing chieftainship and powers. In support of this result, Chawawa (2018), traditional chiefs are not ready to relocate their land for fear of losing authority. In Lilongwe the problem is that, city council cannot manage to relocate people already settled in area 49 New Gulliver. They have built permanent houses and cannot accept to relocate. The only remedy to control flooding in the area of Mtandire could be that the city council should increase the channel capacity of Lingadzi River through river conveyance systems. Furthermore, the city council should involve engineering solutions like construction of dykes and embankments to control flooding. In support of the observation of Chawawa (2018), limited support of the government to provide these services continues to increase vulnerability of people to floods.

The findings revealed only sex (0.0594) and marital status (0.0526) being significant with cultural factors in T/A Kilupula. This result showed that culture is the most important factor contributing to determining vulnerability to floods based on sex and marital status. In support of this finding, Chawawa (2018) cited an example from a study in Burkina Faso, which found that culture hindered females from actively participating in economic activities that may promote their adaptive capacity. Views of participants during unstructured interviews indicated females and divorced females or widows are more vulnerability to floods. The cause is cultural beliefs that impede females from doing certain activities that may increase their resilience to respond to floods. The outcome of this is that widowed and divorced female face disproportionate burden of the impact of floods. The survey revealed that the Ngonde culture is gendered sex oriented. For example, the involvement of female on the land is tied on planting, weeding, harvesting, transplanting seedlings, and not on the use of draught animals. Consequently, females without husbands or male children are limited to plough their fields because culturally it is uncommon to find female using draught animals. This makes them vulnerable because they always plant late and in the event of floods or drought, their crops are damaged. This situation results in selective treatment between males and females. This selectivity is supported in the results of Chawawa (2018) in which it was revealed that males never listen to the female's view and consequently their views are never considered and the males still do what they have decided.

Moreover, low education influences their vulnerability because uneducated people lack cooperation and they fail to anticipate the challenges that may come out of their behaviour. Some key informants reported that low education of people make them adamant to adopt measures that could control the flood hazards. It was further reported that some people are rude, defiant and arrogant to accept issues of relocation to safe places due to lack of awareness. The main observation made was that most households have beliefs and practices that flooding events are beyond humanity and no person can control them. Some informants indicated that the major cause of increased vulnerability to the floods is rooted in cultural beliefs. People have a cultural belief that crocodiles never stay in upland areas, implying to say that like crocodiles the people in the area are used to staying in water so it could be very difficult for them to move out and relocate to high areas eating "millet Nsima" when rice is in their blood. This is a total rejection of relocation, implying that the calls of Sendai Framework for Disaster Risk Reduction (2015-2030) and its predecessor-Hyogo Framework for Action (2005-2015), which recommend that those living in flood prone areas should be relocated to safer areas, have not and will not be achieved. The observation of this study is that GOM should create incentives for those willing to relocate in order to align to the call of these international blue prints.

In T/A Kilupula, it was noted that land governance and chieftaincy succession disputes contribute to generating vulnerability. Participants argued that in the Ngonde patrilineal culture, abandoning the ancestors land might result in the future generation of the family becoming landless. It was also reported that in case someone decides to evacuate and search for new land, the chief himself automatically pronounces the evacuated home vacant and immediately the chief confiscates the land and distributes it to another person to occupy. The participants acknowledged that when the evacuee, for instance, has not been successful in the new land and eventually requests to return to his ancestor's land, chiefs rebuff the request. Participants indicated that for fear of losing land, people still occupy areas that are not habitable and thereby increasing their vulnerability.

It was further noted that due to frequent chieftainship wrangles in the area, the lives of females, children, and the elderly have been at high risk. Their vulnerability is generated because they become traumatized when houses are burnt due to conflicts. It was observed that the conflicts have made chiefs to lose their powers to maintain peace, unity, law and order to their subjects. The result has been little implementation of development projects in the area. For example, a local NGO commonly known as Foundation for Community Support Services (FOCUS) shifted its maternal mortality project in Traditional Authority Kilupula to Traditional Authority Wasambo due to lack of safety and increased insecurity as a result of Kilupula chieftainship succession disputes.

5.4 Perception of Households on Flood Vulnerability

Perceptions on floods differ in terms of time and space. Therefore, vulnerability also changes with time and space. Perception further differs in terms of conditions that characterise an individual or households to vulnerability such as age, gender, education attainment, income and location just to mention a few. One would not refute the high expectation that people in urban areas may perceive flooding in a different picture than those in rural areas since they are considered knowledgeable and constitute the majority in terms of literacy and awareness. Though literature is not straightforward to identify variables that may define perception on flooding occurrence (Iloka, 2017), this thesis understood perception of floods based on urban-rural continuum, time, demographics and flood impacts as discussed in sections 5.4.1 to 5.4.4

5.4.1 Households Flood Perception based on Urban-Rural Continuum

This study used the urban and rural variables to understand how people perceive flooding events in Lilongwe city and Karonga district. The aim was to analyse the difference between urban and rural people in terms of understanding flooding events to ascertain its policy implications on flood management. The major outcome of the findings revealed that floods are perceived as both an urban and rural problem. This implies that both urban and rural people look at floods as cause of problems in urban and rural areas. Both urban and rural people showed that floods affect them in terms of trading, farming and livestock grazing. These effects could further contribute to high vulnerability of people living in urban and rural areas of Malawi because they are likely to be deprived of the benefits that urban and rural people can enjoy. This signifies that the programming of flood vulnerability reduction measures requires investment in key economic livelihoods that most people in rural and urban informal settlements rely upon. For example, in Tanzania, there is high evidence of numerous urban-rural linkages in the form of marketing access, social services, financial services and employment creation (Birch-thomsen et al., 2015). A study by Kago and Sietchiping (2017) also found that in Kenya, people living in urban areas are consumers of most of the food produced in the rural areas and most traders from rural areas sell their produce to city dwellers to gain income to take care of their households.

The observation and discussion with key informants in Mtandire ward of Lilongwe city, maintained that policies to support flood events in the city have been side-lined for a long period. This, eventually has affected the disaster risk management in general because most activities are done as a post event relief support with little attention on preparedness and prevention. This problem can further be supported by the fact that Lilongwe city had no DRM plan until 2017 when the city council developed a disaster risk management plan. This implies that all along the city has been operating without a disaster risk management plan. This could be attributed to the fact that the process was adhoc and people and other stakeholders were not able to prepare and respond to floods effectively (Wright et al., 2017). Even though, DRR plans exist in urban areas now, the challenge remains the low adoption of the same plans. This was revealed when some key informants expressed ignorance of the existence of the disaster risk management plans and other DRM structures like Ward Civil Protection Committees (WCPC). This was further noted by the absence of non-governmental organisations operating in the areas, households were only able to mention Malawi Red Cross Society (MRCS) as the organisations that implements some activities in the area. In rural areas, there is the existence of local structures such as Village Civil Committees (VCPC), Area Civil Protection Committees (CPC) and District Civil Protection Committee (DCPC). These structures in rural areas exist and function while in cities, the DRM plans stipulate the arrangement of these structures like City Civil Protection Committees (CCPC) Ward Civil Protection Committee (WCPC) and Neighbourhood Civil Protection Committee (NCPC), but the functionality and existence on the ground is not the true reflection of what is on paper, specifically on DRM plans of LLC. The major problem created in the city is that most disaster events are responded to when the calamities have occurred.

5.4.2 Households Flood Perception Based on Time

This study argues that time and space have changed the shape of floods occurrence in both Lilongwe city and Karonga district. The Hazard of Place Framework (Curter, 1996) emphasizes that each hazard occurs based on geographical locations thereby having specific vulnerability (Joakim, 2008). However, the results of this study establish that past and present floods differ in frequency and intensity. This implies that time is also a determinant to explain variations in terms of hazards occurrence in a specific place. Therefore, this study maintains that while geographical location (space) as emphasised in the Hazard of Place Framework, is significant to understand specific vulnerabilities and hazards; time too, must be factored in because it has influence to shape vulnerabilities. It was confirmed that floods occurred in the past, but the present floods have been rated with high frequency and intensity and thereby contributing to high vulnerability. While frequency is a characteristic of any particularly hazard (i.e., flood) which describe how often the hazard take place at specific point, intensity is a characteristic of space (permanent), which describes the potential of destruction of the hazard. The results confirm the fact that floods tend to change with time and space because of circumstances of human behaviour. Key among the causes of this change which were identified include: limited land, weak policy on human occupancy on dangerous land, cultivation in marginal areas and human rights issues which make people use land the way they want. As such, flood disaster risk management policies should also change in the approaches in order to align with these changes. However, demographically, it was mostly, elderly people who were able to explain the change of flooding with changing time.

5.4.3 Households Flood Perception Based on Demographics

Demographic characteristics such as age, gender, marital status and occupation were revealed to affect perception of households to floods. While age (0.0065), sex (0.0154) and marital status (0.0086) were significant in Mtandire ward, occupation (0.0300) was only significant in T/A Kilupula. In terms of age, most households' participants interviewed were in the age category of 21-30 years and 31-40 years. This implies that this age category has a higher understanding of flood issues compared to the old generation. However, the old generation have higher knowledge that relates the past and present floods. They were able to give more explanations in terms of intensity and frequency of flooding in recent and past times. This means that this knowledge should not be taken for granted, rather, policies must tap this knowledge to include in flood risk reduction strategies. On marital status, it was revealed that most female headed families suffer a lot during floods compared to males in T/A Kilupula and Mtandire ward. They have few options to increase their household income such that in the event of floods, it becomes very difficult for them to withstand its impacts. In support of this result outcome, females are attributed to have less power and decision-making and suffer disproportionately compared to their male counter parts (McEntire, 2011).

On gender, it was revealed that more females have better understanding of floods in Mtandire ward. The reason for this was noted to be the migratory pattern of most males. Most males were reported either to have migrated to elsewhere to search for job opportunities or to work as casual labourers. For example, in a household survey, 74% of females were interviewed compared to 26% males, giving a difference of 48% while in T/A Kilupula, this difference is very minimal only 4%. In these findings, it can be concluded that migration of males in cities may contribute to increase vulnerability of females to floods since they cannot manage to have decent houses and other necessities. In the study of Shan (2022), it is indicated that unavailability of males at home is one of the reasons females suffer to obtain support by those in authority since they have no power to voice out their concerns. However, what is noted is that current DRM polices do not clearly link and address properly the implications of migration on flood risk response and disaster response in general.

Occupation revealed to be the demographic factor that influences households' perception of floods occurrence in the sense that most households have limited economic opportunities. For example, in Mtandire ward, unemployment topped by 51% while in T/A Kilupula, farming was rated at 80%. This is an indication that a large population of people in Mtandire ward of Lilongwe city do not have reliable sources of income. This could be the reason that most people especially middle age (youths) resort to sand extraction, and brick making along the Lingadzi River, thereby affecting the banks of the river.

Education influences households' perception of floods in Mtandire area of Lilongwe city. It was observed that most people have low education, as such, it affects their understanding of the occurrence of floods. Furthermore, it was established that age and marital status do influence households' perception on floods. Most middle-aged group (21-35) were seen to be unaware of the relationship between past floods (1990s) and present floods (around 2000s). Those who provided such unique information were the older group above 50 years. This finding entails that older people play a vital role in providing histories of natural hazards, as such they must be included in policy formulation guidelines.

High dependency on farming, especially maize and rice in Karonga negatively affects people's harvests in case of little or no rain. At the same time, floods wash away or burry with sand their agricultural crops leaving farmers with nothing. In T/A Kilupula in Karonga the main occupation is agriculture (crop production) dominated by farmers. Therefore, their perception of flood occurrence is directly related to agricultural loss. Elements at risk to floods in the area include crops such as maize, crops and cassava. In this equation, policy like the National Resilience Strategy should consider the occupation of people to scale up strategies that can help to build rural resilience initiatives.

5.4.4 Households Flood Perception on Floods Impact

The results revealed that most households are aware of the flood impacts. Key among the revealed impacts was on livelihoods, education and settlement. In both Mtandire ward and T/A Kilupula, education was rated high to be affected by floods. Among the key challenges in the education include high absenteeism (49%) in Mtandire ward and (86%) in T/A Kilupula. This outcome implies that education is slowly dwindling in both areas. This is evident even on education attainment in which a good number of people have no formal education in Mtandire ward (35%) and T/A Kilupula (21%) and very few attained MSCE.

5.5 Households' Adaptive Capacity

Adaptive capacity aims to address a comprehensive mix of factors contributing to communities' vulnerabilities. Adaptive capacity is measured based on the resilience of households as well as availability of resources (coping capacity) which households can utilise to respond to floods.

Tembo (2013) indicates that local adaptive capacities can be a platform for creating policy strategies to address vulnerability. A combination of vulnerability and capacity is a cornerstone to analyse how flood hazards may turn into disaster. A flood hazard may lead a society or an individual household to be vulnerable to it, but with enough capacities, the same society or households may reduce the impact of the same hazards thereby lessening its vulnerability. In this case, adaptive capacity is linked with disaster risk reduction and resilience strategies. It is for this fact that this thesis looked at adaptive capacity as an integral component in disaster risk reduction aimed at reducing household vulnerability to floods. This thesis provides a discussion of the results specifically by elaborating the adaptive capacity employed by households as part of disaster risk reduction aimed at enhancing resilience of households to floods. Further, looking at the outcome of the results, several gaps in adaptive capacity for disaster risk reduction have been spotted and discussed at length. They include, but not limited to, policy formulation, communication, relocation strategies, and institutional set up, legislation, knowledge management and vulnerability assessment. The thesis through its findings examined them critically and provides the link on how the gaps implicate the initiatives that aim at building households and individual resilience in different national policies in the country. It begins with discussing the adaptive capacities and then forwards the gaps in the adaptive capacity for resilience building and vulnerability reduction.

5.5.1 Adaptive Capacity, Resilience and Vulnerability Reduction

The survey found that households and local institutions such as NGOs and communities use various adaptive strategies to mitigate floods. Carby (2015) and Shaw (2012) indicate that disaster risk programmes in Malawi are implemented by NGOS through community-based disaster risk reduction (CB-DRR). Mwale (2014) highlights that capacity induce vulnerability of communities to floods. Most of the strategies found in this study seem not mutually exclusive because they are often taken as a combination at the same time. Tembo (2013) further noted the way adaptive actions within rural Africa connect with the ideas of NGOs that they are not always helpful. The discussion of the adaptive capacity strategies which were evaluated in this study are presented in sections 5.5.1.1 to 5.5.1.3.

5.5.1.1 Physical/Infrastructural Adaptive Strategies

The results revealed that 72% and 75% of the households take the physical measures as part of their adaptive capacities. Elevating part of the house was revealed to the key adaptive measure that households use before, during and after the floods in T/A Kilupula of KD. On the other hand, in Mtandire ward of LC, most households put heavy materials on the roofs. While issues of scarcity of land and population growth force households to elevate part of their houses, it can also infer unwillingness to relocate, and cultural behaviours in the area tend to force them to take such measures. Chawawa (2018) and Kushe et al., (2018) also found that people in the rural valley of Chikwawa district show little willingness to relocate from flood prone areas, despite being vulnerable to floods every year. Instead, people find their own locally made engineering solutions to prevent flooding. Tembo (2013) in understanding adaptive capacity to climate change in rural Africa, with evidence from Michunga and Kigunjo in Uganda, found that variation of villages to adopt adaptive capacity is due to cultural barriers. The high number of households using heavy materials on roofs (such as stones, sand bags, tying with wires etc) is a clear indication that their houses are built and roofed with low weak and low quality materials. This result agrees with the observation of Manda (2013) who argued that majority of urban communities in informal or low income areas have settlements with characteristics of low quality materials for building. Kita (2017) also indicated that unsafe construction practices is one of the multiple vulnerability factors faced by urban residents' of Mzuzu city in Malawi.

This study established that there is use of several initiatives of land management practices as adaptive capacities. For example, in Mtandire ward it was found that households manage the surrounding land in a way that slows down rainwater runoff, creating outlets to manage water overflow when it is in excess. In a study of Sibale (2021) in Mzuzu city, adaptive measures such as creation of numerous drain networks and building flood barriers were some of the physical/infrastructural and land management adaptive measures taken by communities in Chibanja and Zolozolo wards. In T/A Kilupula of KD, most households took the initiatives such as planting of trees, grass or sugarcane around their homes, creation of drainage channels to stabilize the riverbanks and practicing conservation agriculture through the help of organisations. In terms of building and construction, households take adaptive measures such as coping planting bananas along the river banks to shield houses from flooded water, elevating part of the house, constructing dykes. Despite these efforts, it was reported that some people destroy the dykes and riverbanks during the night to have access to water for their rice fields in T/A Kilupula of Karonga district. It was observed that this problem is created because of lack of proper governance to manage some of the initiatives in the community. In this case, it may be proper that national policies should create mechanisms to ensure these problems are prevented. Tembo (2013) noted that national policy, though at times can ignore locally defined goals, it can create an enabling environment for building of adaptive capacity. Despite, these community led initiatives, Mwale et al. (2015) observed several challenges that rock the effectiveness of CB-DRR such as inability to incorporate them in policies at local and national levels, underlying root causes of vulnerability are not tackled (e.g. access to land, inequality), lack of resources and political will.

5.4.1.2 Economic/Livelihood Aspect

The principal elements of this strategy were economic diversification, poverty and alternative livelihoods. The frequency distribution of households taking certain form of economic strategy on both housing and livelihoods showed that very few households undertake economic adaptive strategies. In the respective scale of “low”, “medium” and “high”, the results revealed a scale of “low”, 67% in Mtandire ward of LC and 58% in T/A Kilupula of KD. In the respective scale of “high” and “medium”, 11% and 22% of households participants interviewed indicated that they were able to take some form of economic livelihoods in Mtandire ward. In the same respective scale, in T/A Kilupula, 17% and 25% of the household participants were able to take some economic actions. This means that most households both in urban and rural areas have limitations to undertake the economic activities that can promote their adaptive capacities. These limitations could be attributed to a combination of poverty, limited access to resources and dependency of one form of livelihood. Therefore, limitations of economic adaptive measures further amplify vulnerability of households. Mwale (2014) accords that vulnerability is determined by high limitations in economic capacities. Other findings reveal that lack of adequate reserves is a cause of vulnerability because in the event of disaster it makes recovery to be difficult (Maskrey 2011; van Niekerk et al. 2012).

This study observed that due to lack of diverse source of income generating activities, most households purely depend on one type of enterprise. For example, in T/A Kilupula households purely depend on subsistence farming. This observation concurs with the argument of Mwale et al. (2015) who maintained that lack of economic resources, diversification and local economies shape the vulnerability of people to floods. Further to this, community economic system is purely cultural based, to the extent that generation of other sources of income is very difficult. This confirms the argument that where income generation activities of people are limited, floods have long-term consequences for full recovery (Mwale et al., 2015). On a similar note, in Mtandire ward, this could be due to high levels of poverty and lack of job opportunities. Most households' participants have limited income to take economic measures. Tembo (2013) also observed that adaptive capacity strategies require efforts that address multiple limitations because the limitations may be associated with various determinants of adaptive capacity. Other studies have argued that vulnerability is shaped predominantly by socio-economic conditions such as employment opportunities and high levels of poverty (Munthali et al., 2022; Mwale et al., 2015). Lack of economic livelihood could be attributed to high levels of poverty in the studied areas. The results revealed that in both Mtandire and T/A Kilupula, there are high levels of poverty. Rana et al. (2021) concurs that poverty contributes to vulnerability because people tend to have low limited access to economic opportunities.

Furthermore, in T/A Kilupula those using certain form of economic strategies indicated that they borrow money from money lenders on "katapila" arrangement where the borrower is required to pay a double (100%) interest of the borrowed money not in form of cash again but rather the borrower is told to pay specified number of 200 kilograms bags of rice. During HVCA, it was established that some people pay the whole rice crop they harvest to cover the debt of the money they borrowed to rebuild their damaged houses by the floods. This was observed as one of the situations that renders them more vulnerable because those households tend to be forced to enter into serious debts. With such debts, they reach the other rainy season without anything in their households, having paid the debts to the moneylenders at a double interest. It was found that some NGOs assist households with income generating activities (IGA) such as provision of short maturation rice, and cassava and maize seeds for diversification and training community members in village savings and loans (VSL). However, it was observed that not much has been achieved to support people due to lack of funds. This observation concurs with the findings of Wright et al. (2017) in the study of community based-flood risk management experiences and challenges in Malawi. In this study, Wright et al. (2017) found that NGOs are taking a leading role in CB-DRR, but they also face numerous problems such as lack of existing DRR strategies, lack of project ownership, power relations in communities, too much focus on response and recovery and project allocation. It was observed that this condition contributes to high dependency on short-term interventions that give local people limited ability to cope with future shocks. In most cases, loss of crops and livestock results in flood insecurity, hunger and loss of earnings (Wright et al. 2017). This in turn has an implication on the National Resilience Policy (NRP) - a policy that looks at breaking the cycle of food insecurity among people in Malawi. However, challenges aforementioned imply that the causes of households flood vulnerability are not yet addressed. Unless, households are provided with soft loans so that they can be able to do small business to earn their living. In this way, the policy will really address food insecurity in the country.

5.4.1.3 Social/Organisational Strategies

The results revealed that in Mtandire of LC, the social organisational measures are found in the scale of low (28%), medium (28%) and high (45%). Similarly, in T/A Kilupula of KD, low (30%), medium (32%) and high (48%). The principal adaptive capacity elements on this strategy were community partnerships in terms of ability to organise, decision making, warning to the impeding floods and trust on warning systems. These measures were used to evaluate relationships of adaptive capacity and resilience as key elements of assessing social/organisation strategies. The outcome revealed that T/A Kilupula was better off in the aspects of ability to organise (68%) and decision making (84%) while only decision-making (51%) appeared better in Mtandire ward. This frequency distribution shows that most households have limited capacity on social organisation strategy. This limited capacity entails that their resilience is insufficient to withstand and respond to flood risks. This accords to the fact that community led initiatives in Malawi are affected by power relations in the community including operation and monitoring (Wright et al., 2017). Those taking certain forms of social organisation strategies especially in T/A Kilupula indicated that they vacate their houses to seek for refuge at neighbours or relatives to avoid loss of life and property. This vacation is still a temporary measure because people will still need to find permanent space. It was also found that in both Mtandire ward and T/A Kilupula some flood victims stay in camps waiting for relief items from government, whereas others indicated that they repair their houses with members of the family to mitigate labour costs. However, in the studied areas, it was reported that community associations are difficult to be achieved due to poor cooperation among the people. Even in unstructured interviews with key informants, it was expressed that lack of cooperation and commitment of communities contributes to affect the implementation of coping strategies. All these strategies are adhoc and reactive. The central point is that DRM policies should promote strategies that would enhance DRR for proper resilience building. Furthermore, policy encouragement can be the effective driving force to various communities' members to participate on different activities which can promote resilience building. Similarly, Mwale (2014) found that low social capacity is contributing to high vulnerability among communities in lower shire valley of Malawi. These findings are similar to the findings of this study which are lack of substantial public awareness, public participation and existence of disaster mandated local institutions. This also entails current and future flood disaster management should build on utilisation of various social forces such as artistic skills, including involvement of different enterprises to participate in promotion of disaster awareness.

5.5.2 Gaps in Adaptive Capacity in Relation to Disaster Risk Reduction

This study links adaptive capacity with disaster risk reduction initiatives. It argues that policies must include disaster risk reduction programmes as integral component of adaptive capacity. Through a literature review and document analysis, numerous theoretical DRR strategies, tools and methodologies were identified as key instruments of adaptive capacity practice. Among other theoretical strategies are: strengthening early warning systems, relocation of settlements, use of knowledge sharing and training, strengthening preparedness and response through public commitment and community participation. This thesis analysed and compared these strategies with the findings of this study in terms of the way they are being practiced (and must be practiced) to reduce communities' vulnerabilities to flood risks. One major result from this study analysis is the fact that the practice of these theoretical DRR strategies is very limited in Malawi. The fact is that disaster risk management is characterised by post event activities (Kita, 2017; Wright et al., 2017) that are supported by a weak and outdated legal document. In urban areas, the problem is strengthened by the lack of inclusion of disaster risk reduction into different planning strategies. Kita (2017) also found that urban residents of Masasa in Mzuzu city are vulnerable to floods because of the neglect of national disaster reduction policies in urban areas. Therefore, major to minor issues identified as gaps in these theoretical aspects are discussed in subsections 5.5.2.1 to 5.5.2.7

5.5.2.1 Early Warning System (EWS)

EWS is a structure of disaster management system and a communication system for timely dissemination of warning information to the authorities and general public (Wongsuwan, 2015). According to Wongsuwan (2015), the guiding principles for effectiveness of EWS depends on; levels of alerts and early warnings, keeping constant watch and monitoring, early warning notification, emergency warning, preparation of basic survival needs to cope with the effects of disaster and evacuation and emergency response preparedness. In this case EWS must have the ability to forecast when a hazard is going to occur and predict the scale of intensity. This study however, through its findings noted that the early warning systems to meet these guiding principles are limited. For example, this study found that access to communication is a susceptibility factor that contributes to vulnerability in both Mtandire ward and T/A Kilupula district. This study found a significant value of access to communication to a number of social variables such as awareness to floods, ability to cope, and knowledge on DRR among others. The significant level revealed, implies that households in the studied areas have limited access to communication. Though, most DRM documents reveal availability of EWSs through the support of NGOs (DRMP 2015; NRMCS 2017), the operational mode of these still remains a challenge. For instance, households do not really know how to interpret the levels of alerts associated with colours such as red, green and blue which have been highlighted in the National Contingency Plan (NPC). Furthermore, households are unable to utilise the scientific rain gauge systems which have been installed in some rivers to provide rainfall data to predict flooding. This situation is worse in urban areas where these systems have not been installed because most organisations assisting on these scientific technologies are not implementing projects in urban areas. This confirms the notion that DRM in the country focused much on rural areas than urban areas (Kita et al., 2017; Mwale et al., 2015; Mwale, 2014; Wright et al., 2017). Though the study of Sibale (2021) found that communities in Chibanja and Zolozolo areas of Mzuzu city have access to weather forecast information and early weather warning messages inform of: heavy rainfall, river crossing, guardians/parents escorting children to school among others, these lack the basis of defining the effectiveness of the EWSs because they are not explicit enough to meet the conditions of EWS. The problems of such messages is that they have not been verified to the level of the effectiveness to help people in responding to hazards.

Further to this, in rural areas, river gauges are installed in some rivers to provide data on water levels to predict flooding and communities are provided with loudhailers as part of early warning systems. In addition, local initiatives such as drumming and whistles are used with the same purpose as loudhailers. However, few members of the VCPC and ACPC committees are able to understand the applicability of these technologies. In support of the findings, Chawawa (2018) found that early warning systems are not adequately used because of limited involvement of communities during planning. In the same manner, Wright et al. (2017) found that most NGOs are challenged due to the failure of communal projects, lack of inclusion of local knowledge and communication gap between communities and NGOs as well as limited partnerships among all stakeholders. This implies that there is a need to strengthen institutional partnership, approach and capacity in EWSs.

In urban areas where these technologies have not been adopted, there is a need to integrate these initiatives, but with increasing awareness on the utilisation of these technologies in both settings. Though, rural areas appear to have these initiatives, most key informants highlighted that they also use indigenous knowledge systems. However, most policies in the country do not spell clearly how these can be integrated with scientific systems in the specific areas and Malawi in general. The role of indigenous knowledge systems has not been fully analysed and documented (NDRMP, 2015). Therefore, this study argues that there is need to strengthen indigenous knowledge so that people must be trained and encouraged to use them together with scientific systems.

5.5.2.2 Relocation

Relocation is a key component of DRR. Sendai Framework for Disaster Risk Reduction (2015-2030) and its predecessor-Hyogo Framework for Action (2005-2015) as means to promote adaptive capacity for vulnerability reduction recommend it. However, through a critical observation of the findings of this study, it can be argued that relocation is just an attractive "discussion" that either dominates or could dominate policy and decision makers to converge and spend money on conferences, seminars or workshops without yielding tangible results. Key among the reasons that have been revealed in this study and affect the achievement of the same include the high unwillingness of households on settlement relocation due to cultural beliefs, weak enforcement of policies, human rights issues, the political dichotomy and land governance and benefits from agricultural activities. Kita (2017), argues that emphasis on resettlement/relocation is obscuring the key drivers of vulnerability and thereby exposing both the resettled and those left behind to further risks. Chawawa (2018) argues that relocation is not possible in Malawi because of the detachment of Malawi government from the resettlement process. It is pointed out that people have to settle compensations and start new life on their own. However, this study argues that due to high poverty revealed in the results, it would be practically impossible for the people to relocate. Unless other measures like provision of support in the form of access to incomes and livelihoods to those willing to relocate can be made, then relocation can get another direction.

To expand the above reasons, relocation is impeded due to: first, weak enforcement of policies to curb settlement located in marginal and hazardous areas. The second is that there is high over reliance on relief items to support flood victims by government and stakeholders. This has created a mind-set of people to depend on short-term handouts than to relocate. These handouts are unpredictable and give people minimum ability to cope with future flood shocks. Thirdly, the economic status of most people is very low. This economic level restricts them from procuring materials to support their response and recovery. Most of the people 80% depend on subsistence farming in T/A Kilupula. However, some argued that they could not relocate because it could be very difficult for them to live in higher areas since they are used to lowland areas. Fourthly, there is lack of capacity of local authorities to establish evacuation shelters and social services such as schools and health facilities in areas where people are told to relocate. It was reported that some floods victims attempted to relocate to the nearby hilly areas of Mwabulambo in T/A Kilupula, but due to lack of shelters and poor conditions, they returned to their original homelands. Lastly, there is lack of clearly defined policies aimed at addressing issues of the evacuated land. This is because most participants reported that when they attempt to relocate, chiefs threaten to confiscate their land and give it to other persons. This confirms that power relations indeed is a factor contributing to affect implementation of DRR (Wright et al. 2017).

In the same vein, to stop floods in Mtandire ward of Lilongwe city, it implies relocating households of people in area 49 (New Gulliver); however this looks to be practically impossible based on the structures which have been built in the areas. Unless a very serious leadership with good understanding of relocation can strongly enforce the stiff law, those occupying areas designated to be prone to flooding should be evacuated. Apparently, it would be impossible for the government to enforce a policy to relocate those settled in area 49; the only solution is to bring engineering solutions such as construction of dykes on the side of Mtandire and notification of catchment management activities along the river.

5.5.2.3 Stakeholder Participation

The success of DRR activities depends to a larger extent on the participation of various enterprises. However, this study identified some deficiencies in participation process, which to larger extent negatively impact disaster management in general. For, example, some stakeholders do not have the ability to participate in disaster management at all. This presents a challenge to local and city authorities to identify and implement plans and mechanisms to respond effectively during emergencies including early warning messages. The results revealed that households' lack local institutional support and important activities that could strengthen and mitigate flood impacts. Community sensitization activities aimed at empowering local structures are not viable and effective due to lack of funds. People are not consulted about their needs and wishes on the type of relief items that could help them to respond positively to floods. The gaps are an indication that the country lacks sufficient operation system to manage floods and other hazards. Indeed policies and frameworks exist that spell out the way communities need to be engaged in flood management. However, the actual implementation of these policies like the National Contingency Plan (NCP, 2017) is very difficult because in most cases when disasters strike the NCP is not followed at all. At times, lack of finances affect the implementation of activities that are stipulated in the policy like training the committee members to strengthen their participation. This gap makes the committees not to effectively participate in a number of activities that can help to control risks. Wright et al. (2017) found similar challenges to flood risk management strategies through the focus on community-based flood risk management (CB-FRM). This structure requires a number of improvements in terms of financing, participation, governance and project management (Wright et al., 2017). This study further emphasises that the importance of multi-stakeholder partnerships should be repeatedly addressed for implementing DRR in collaborative manner.

5.5.2.4 Education and Advocacy

The ISDR (2013) stressed that knowledge is of utmost important to determine those things that favour or hinder prevention and mitigation. Furthermore, the Sendai Framework stresses on the need to "train the existing workforce and volunteers in disaster response targeting developmental planners, emergency managers, local government officials etc." (SFDRR-2015-2030, p 22). Furthermore, advocacy seeks to ensure that vulnerable people in the society achieve change empowerment and knowledge. However, this study established that training and advocacy are lacking. As such, people lack knowledge in disaster risk reduction. Furthermore, the results revealed that most households participants interviewed have low education, implying that their understanding on disaster risk reduction issues is very low. The results of this study also revealed that there is lack of knowledge and access to information. This is a condition that cannot be negated that it also contributes to increasing households flood vulnerability. Several factors were observed during assessment that contributes limited knowledge in the studied areas. First, limited knowledge of those trusted with responsibility like the VCPCs, ACPCs, and WCPCs because most of them only think that their duties in DRM is to count and report the number of affected households during floods or any type of natural hazards. They do not have a clear understanding that they have the mandate to: strengthen capacities at local level, promote awareness among the community members on hazards, take mitigation based on the phases of disaster risk management (pre-during and post) such as reinforcing river banks, planting vegetation and vetiver grass, including adjusting some community plans. Second, a limited number of staff at the local council with risk reduction knowledge. Third, limited public financial support for the implementation DRR/DRM activities. Fourth, lack of higher learning institutions to partner in tackling issues of hazard and other DRM disciplines in Malawi. Fifth, limited human resource at the district council which (and which is the case for every district in Malawi) has one desk officer employed by DoDMA and is called the Relief and Rehabilitation Officer.

This study observed several problems with the naming of this officer above. Firstly, the name itself suggests that the officer is directly targeted on relief activities and not on DRR programmes. Secondly, the name itself appears to agree with the legal framework -DPR Act 1991 which also focuses on relief rather than disaster risk reduction that is critical to promote adaptive capacity for vulnerability reduction. Thirdly, the officer in question finds it difficult to conduct DRR activities for the whole district. Even, some people who are delegated the responsibility in case the responsible officer is away to discharge other duties, lack risk reduction knowledge.

5.5.2.5 Responsibility and Commitment

Preparing for evacuation is an important part of disaster risk reduction planning, and requires responsibilities and commitments by government, communities, and individual households. Preparation for evacuation includes among other things informing people of evacuation routes, identifying and/or building evacuation centres (Hartog, 2014). However, this study revealed that there is little effort to establish proper evacuation shelters. The results showed that there are no evacuation centres in strategic areas. Though it was found that there is an evacuation centre in Karonga, the same does not apply to Lilongwe city. At the same times, the evacuation shelters in Karonga are not enough to cater for flood victims. Instead, schools and churches are used as evacuation centres. It was observed that it disturbs the operations of schools because at times classes are suspended and/or there is a scramble for social amenities like water and the issue of sanitation is affected as well. The results further revealed that communities and some individual households lack obligation and commitment to manage resources. It was observed that some individuals destroy dykes to have access to flooded water for their rice cultivation in Karonga. In Lilongwe city, it was established that most of these measures are not available because government, for a long period, has neglected cities in disaster plans and guidelines. This study observed that lack of government commitment to enforce policies with strict penalties, coupled with insufficient resources to fully develop the infrastructure to meet the emergency management needs of the public, remains a major challenge to Malawi as a nation and is contributory to vulnerability.

5.5.2.6 Flood Relief and Recovery Schemes

Article eight of the code of conduct of international Red Cross and Red Crescent states that "Relief aid must strive to reduce future vulnerabilities to disasters as well as meeting basic needs". This study identified that recovery schemes are not planned well enough to reduce future vulnerability because it was observed that people still construct their homes using the same building techniques and materials that caused them to collapse. Moreover, the results revealed that people sell off their scarce productive resources such as livestock to meet basic needs and thus become even more vulnerable to future shocks. The study noted that there is a shortcut in the consultative process due to rapid onset of flood hence side-lining decision-making of local communities in development planning and relief distribution. The situation triggers local authorities and stakeholders to provide materials that are not suitable to the local needs and problems to reduce their vulnerabilities.

5.5.2.7 Gender Mainstreaming and Vulnerability

The results of the study revealed that, except for social factors, all other factors are associated with gender. The results revealed that adjusted residual (AR) threshold above 2 (or 1.9) for physical underlying factors and sex. This result implies that both males and females are equally affected by floods based on physical underlying vulnerability factors. The results further showed that the AR above 2 (1.9) for females and less than 2 for males on the association of social underlying vulnerability factors and sex. These results imply that females are more vulnerable to floods based on social factors than males. Specifically, health services revealed a threshold of above 2 on females than males. This implies that females face more problems to access health services during floods than males. On economic underlying factors, the result showed no difference between females and males in Mtandire ward. This implies that they are equally affected by economic factors. However, in T/A Kilupula, the results showed a difference AR threshold. It signifies that females are more affected by floods due to economic factors than males. Similarly, in Mtandire ward environmental factors showed no difference, while in T/A Kilupula they showed different results. In terms of cultural underlying factors, the results showed that females in T/A Kilupula are more vulnerable than males. The cause was observed to be the patriarchal system dominated by the Ngonde culture. There are cultural beliefs that are still prevailing in the communities. Some community members, including some traditional leaders, still harbour the perception that female empowerment and gender equality is alien and a threat to their culture; that always places male as leaders in all spheres of life. In this respect, there are pockets of resistance to accept the fact that females can also contribute to family and community development. For example, it is uncommon to find females using draught animals to farm their land. Therefore, widowed and divorced females without male children face problems to farm their land because of the patriarchal systems that discriminates females and prevents them from becoming active participants in development projects.

5.6 Chapter Summary

The analysis of the results have revealed various causes of households flood vulnerability assessment in the studied areas. It is important to note that these causes overlap in the factors that were combined to assess flood vulnerability. It is on this basis that this study proposed a FVA framework with constituted indicators that overlap in a cyclic set theory approach. The FVA framework intersects the indicators that influence vulnerability to floods in rural and urban informal settlements and vice versa. The framework provides systematic indicators that can be used to assess vulnerability to floods in rural and urban areas in Malawi and beyond. Significantly, the analysis of the results gives emphasis that flood vulnerability should be assessed based on the interaction of UVFs (physical, social, economic, environmental and cultural) with VCs (exposure, susceptibility and resilience) that facilitate generation of vulnerability with limited adaptive capacity. In this case, this study highlights that either household vulnerability to floods would increase or decrease based on availability or unavailability of adaptive capacity to the flooding event. This analysis, directs that the physical causes of vulnerability should be analysed in relation to the exposure factors, to understand how the physical causes of vulnerability could be influenced by the exposure factors. Similarly, the social causes with susceptibility, economic with resilience, environmental with exposure and cultural with susceptibility. The findings of this study were generated based on a comprehensive vulnerability assessment using data that was generated through mixed method approaches (i.e. quantitative and qualitative), hydrological flows, GIS and Remote Sensing. It envisioned that using varied methods, simple and well balanced FVA indicators would be developed. Nazeer et al. (2020) maintains that the use of different methods in flood vulnerability addresses issues of subjectivity in the selection of indicators. Unlike other frameworks in literature: Urban Flood

Vulnerability Assessment (Salami et al., 2017) and MOVE (Birkmann, 2006) which use either quantitative or qualitative assessment, the development of the FVA indicators are comprehensively done through mixed methods. The results of this study provide comprehensive data for multi sector decision making process. For example, the results can be utilised by health sector, engineers, water resources planners, disaster risk management professionals, urban planners and academicians just to mention a few. The fact that indicators generated from the analysis of the results have been used to develop the FVA framework, then it is justified that the framework has multi-sectoral approach.

CHAPTER 6: TOWARDS A FRAMEWORK FOR FLOOD VULNERABILITY ASSESSMENT FOR RURAL AND URBAN INFORMAL SETTLEMENTS IN MALAWI

6.1 Introduction

Flood vulnerability assessment (FVA) is significant for application to address flood risks for both rural and urban settlements in Malawi. Nevertheless, there is lack of FVA framework which can be applied as a three phased (pre, trans and post) flood assessment tool for rural and urban settlements. On one hand, those that exists such as the unified beneficiary register (UBR) and rapid assessment (RA), they both reflect assessment indicators for the aftermath of a disaster. On the other hand, the participatory vulnerability capacity assessment (PVCA), though used as a tool, it cannot be negated that it is an approach rather than a tool because indicators are not systemitise. Informed by this gap, this study assessed households flood vulnerability in Lilongwe city and Karonga district in order to propose FVA framework for rural and urban informal settlements in Malawi which can be applied in all the phases of flood risk reduction and management. Vulnerability was explored through a combination of underlying vulnerability factors (UVFs)-physical-social-economic-environmental and cultural with vulnerability components (VCs)-exposure-susceptibility and resilience. The UVFs and VCs were agglomerated using binomial multiple logit regression model. Variance independent factor (VIF) was used to check multicollinearity of variables in the regression model. FFA was applied to show the evidence and causes of flood trends in the study areas. MCA and ANN were used to analyse the contributions of different variables of UVFs and VCs to flood vulnerability. The results reveals that except cultural-susceptibility factors (CSFs), all the factors contribute to flood vulnerability in Karonga district (KD) and Lilongwe city (LC) as presented and discussed in chapter 4 and 5 respectively. Therefore, this chapter presents the proposed FVA framework. The chapter has been divided into five sections. The first section presents the FVA approach. The second section is about the assumptions of the framework. The third section describes the FVA framework. The fourth section discusses the agglomerated indicators that have been used in the framework. The fifth section discusses the comparability of FVA framework with other contemporary frameworks such as the PAR model (Wisner et al., 2004), hazard of place framework (Cutter et al., 2003) and BBC framework (Birkmann et al. 2004).

6.2 FVA Approach

The FVA framework follows a cyclic set theory approach. A set is a collection of different objects (Pinter, 2014). The collection of objects can take the form of; empty set (no objects), union set (collection of all objects that are in either set), intersection set (collection of objects that are in both sets) and universal set (set of all possible objects). Sets can be shown in a Venn diagram-which depicts the relationship between sets (Pinter, 2014). Each set is shown as a circle and circles overlap if the sets intersect. The intersection point, relates to elements that are common. Therefore, this study applied the intersection set using Veen diagrams. FVA indicators which contribute to vulnerability in both rural and urban informal settlements were placed at the intersection and vice versa. The framework utilised all the indicators that were revealed as significant at p-value 0.05 between UVFs and VCs and those that generated higher inertia in a Minitab-MCA.

6.3 Assumptions of the FVA Framework

Assumptions are key to the realisation of the results. They are critical for achieving the successful implementation of an intervention. In this regard, the fact that FVA framework provides the indicators which can be used to assess flood vulnerability in rural and urban informal settlements, the following twelve assumptions are vital in order to achieve the results:

1. The UFV should be constituted by physical, social, economic, environmental and cultural factors while the VC composed of exposure, susceptibility and resilience in order to determine flood vulnerability. Selection of variables for these key components should consider vulnerability a combination of physical and social sciences.

2. The UVFs and VCs should be linked to generate Physio-Exposure Factors (PEF), Socio-Susceptibility Factors (SSF), Eco-Resilience Factor (ERF), Enviro-Exposure Factors (EEF) and Cultural-Susceptibility Factors (CSF) in order to determine flood vulnerability or any particular hazard.

3. The generated indicators in the PEF, SSF, ERF, EEF and CSF should lead to the production of physio-exposure indicators (PEIs), social susceptibility indicators (SSIs), eco-resilience indicators (ERIs), enviro-exposure indicators (EEIs) and cultural-susceptibility indicators (CSIs), which in turn should capture indicators for FVA framework (Figure 6.1).

4. The breakdown on the elements at risk poses a serious households' flood vulnerability. Therefore, assessing the elements at risks based on the scale of 1-4: 1=severely vulnerable, 2=vulnerable, 3=slightly vulnerable and 4=not vulnerable would help to determine the extent of vulnerability.

5. A comprehensive flood vulnerability assessment framework that can give rise to multi-hazard vulnerability assessment should deviate from the common systematisations of vulnerability from using one set of variables. A combination of UVFs and VCs should be used to generate wide range of issues and variables.

6. The linkage between the factors that amplify vulnerability and those that can enhance vulnerability reduction should be demonstrated through adaptive capacity and disaster risk reduction measures and be incorporated in the framework. Those that cannot be quantified should be supported by qualitative methods.

7. The linkage of the UVFs and VCs as key explanation of the generation of vulnerability should be emphasised and that conceptual framework for FVA should provide clear connectivity of the variables of the UVFs and VCs.

8. The variables for UVFs (physical, social, economic, environmental and cultural) should be measured as absolute proportion value of household participants involved during the survey. The percentage values should be generated using a scale range with operator of "*less important*"; "*important*" and "*very important*" to contribute to flood vulnerability". However, for flood vulnerability determination, a cut-off point should be placed at greater or equal to 0.5 (50%) for each indicator from the operator of the scale range of "important" and "very important". In this case, all the

values generated in the scale of “less important” as responded by the participants should be left out during determination of flood vulnerability.

9. The selected variables UVFs indicators (at 50%) should be tested using the variables of VCs (exposure, susceptibility and resilience) in the order stipulated in 2 and 3 through statistical tests using P-values or correlation (r) or simply any statistical test applicable by the researcher. The values that are significant at certain confidence level (i.e. 0.05 in this study) should be selected to be included in the framework for specific combination like PEFs, SSFs, ERFs, EEFs and CSFs (Figure 6.1). Furthermore, those values significant at an appropriate confidence level should be considered as factors generating flood vulnerability.

10. Households vulnerability to floods should be predicted based on logistical regression test between the UVFs for all the operators of less important, important and very important (appendix 9) and the VCs indicators (in exposure, susceptibility and resilience). The selection of the VCs indicators should be based on those that were significant during statistical test as explained in assumption 9 (Table 3.13). Furthermore, variance independent factor (VIF) should be used to check the multicollinearity of the indicators for computation in the regression model.

11. Demographic characteristics should be statistically tested to determine their significant level of at P-value 0.05 with the underlying vulnerability factors (UVFs) in order to provide explanation of who is vulnerable to what. However, because other explanation might be hidden in a quantitative assessment, a qualitative –in-depth assessment must be done to understand those hidden issues per se. In so doing, the assessment would be informative in identifying the factors that give rise to the pressures that generate vulnerable conditions in the society for different groups.

12. Adaptive capacity should be assessed both quantitatively and qualitatively since it is a component of vulnerability reduction. This entails that if adaptive capacity is

sufficient, it is likely that households response to floods would be high and vulnerability is also likely to reduce and vice versa.

Finally, vulnerability equation would be generated as a sum of UVFs, VCs, hazard (flood) and (-) adaptive capacity. Mathematically the equation is coined as $FV = [(UVFs + VCs) + H] - AC$ where FV is (flood vulnerability), UVFs (Underlying vulnerability factors), VC (Vulnerability components), H (hazard in this case floods) and AC (adaptive capacity). The flexibility of the framework is that it gives room for H (hazard) and F (flood) to change based on the type of hazard the assessor is interested in. Hence, this framework can be utilised in a multi hazard assessment. The equation is interpreted as follows: a positive value denotes vulnerable to floods while a negative value denotes not vulnerable to floods. For example, using this equation, the sum of UVFs and CVs was found to be 3.25 in T/A Kilupula and 2.56 in Mtandire ward on a FVI scale. In terms of hazard (H) represented by floods in this study, was found with a frequency of "3" and "1" in T/A Kilupula and Mtandire ward respectively. Adaptive capacity was found to be "1" for both areas (Table 4.49). Computing these values in the equation, both Karonga and Lilongwe were found with positive value 5.25 and 2.56 respectively. Flood vulnerability of the positive must be differentiated using a scale of 1-10 interpreted as follows: 1-4.0 moderate vulnerability, 4.1-7.0 high vulnerability, 7.1-10 very high vulnerability.

6.4 The FVA Framework

The FVA framework should be implemented as a pre-hazard, trans hazard and post hazard (flood) assessment tool. In the pre-hazard category, all the proposed indicators should be used to determine vulnerable conditions which may (or may not) make some households at risk to flood disaster in an event of a flood occurrence. In the trans-hazard, the FVA indicators should be used to determine vulnerabilities of households in order to identify the households that have been affected by floods as part of disaster response and recovery process. In so doing, the FVA indicators should be used as a means of establishing strategies for disaster response and recovery as part of building back better. As a post-hazard tool, indicators should be used to determine the vulnerabilities that contributed to a disaster situation. Users should prioritize these indicators as a means of building DRR for disaster rehabilitation and reconstruction. In this case, the FVA framework contrasts itself to available tools such as Unified Beneficiary Register (UBR) and Hazard Rapid Assessment (HRA) which largely are implemented only after the hazard in Malawi. Furthermore, it clearly separates indicators that generate vulnerability in subsectors, but most available frameworks do not portray this separation. Therefore, participating enterprises can implement FVA framework based on the need of the assessment. The FVA framework can be implemented through hydrological assessment, flood modelling, quantitative, qualitative, GIS and remote sensing methodologies, giving opportunity to multiple users. The framework puts emphasis on UVFs (physical, social, economic, environmental and cultural) and VCs (exposure, susceptibility and resilience) as intersection construct of flood vulnerability in rural and urban areas of Malawi and other places where it can be applied. It provides very simplified indicators of assessing flood vulnerability at local and national level, deviating from the generalised frameworks that look at wider scale like the PAR model (Wisner et al., 2004). More importantly, the framework provides tailor-made indicators thereby by localizing the assessment of flood vulnerability in Malawi. This framework gives indicators that can be easily measured and evaluated at any level using different tools (Statistical applications, GIS, Remote Sensing and hydrological models) thereby giving empirical scientific data on FVA. The framework is coined strategically for researchers to utilise it in measuring vulnerability of a single underlying factor of interest (i.e., physical vulnerability or social vulnerability etc.). It also gives simplified indicators that can be utilised by policy and decision makers for planning interventions. The framework provides a good alignment of adaptive capacity to underlying vulnerability factors and components. In this case, the framework integrates DRR into vulnerability reduction strategies. Unlike the PAR model (Wisner et al., 2004) which does not explain exactly the measures of vulnerability reduction, this framework, through integration of adaptive capacity, it has filled up this gap. Finally, the framework intersect the significant factors of vulnerability in a set theory analysis giving a new thinking in outlining FVA indicators in Malawi and beyond. The framework goes beyond the Community Based Disaster Risk Index (CBDRI) by Bollin et al. (2003) which does clearly provide proper link of indicators between vulnerability factors and components. For example, the CBDRI considers vulnerability components as structure, population, and economy, environmental and capacity measures (Mwale et al., 2015) yet alone these could be grouped as conditions that generate flood vulnerability as tested in the FVA framework.

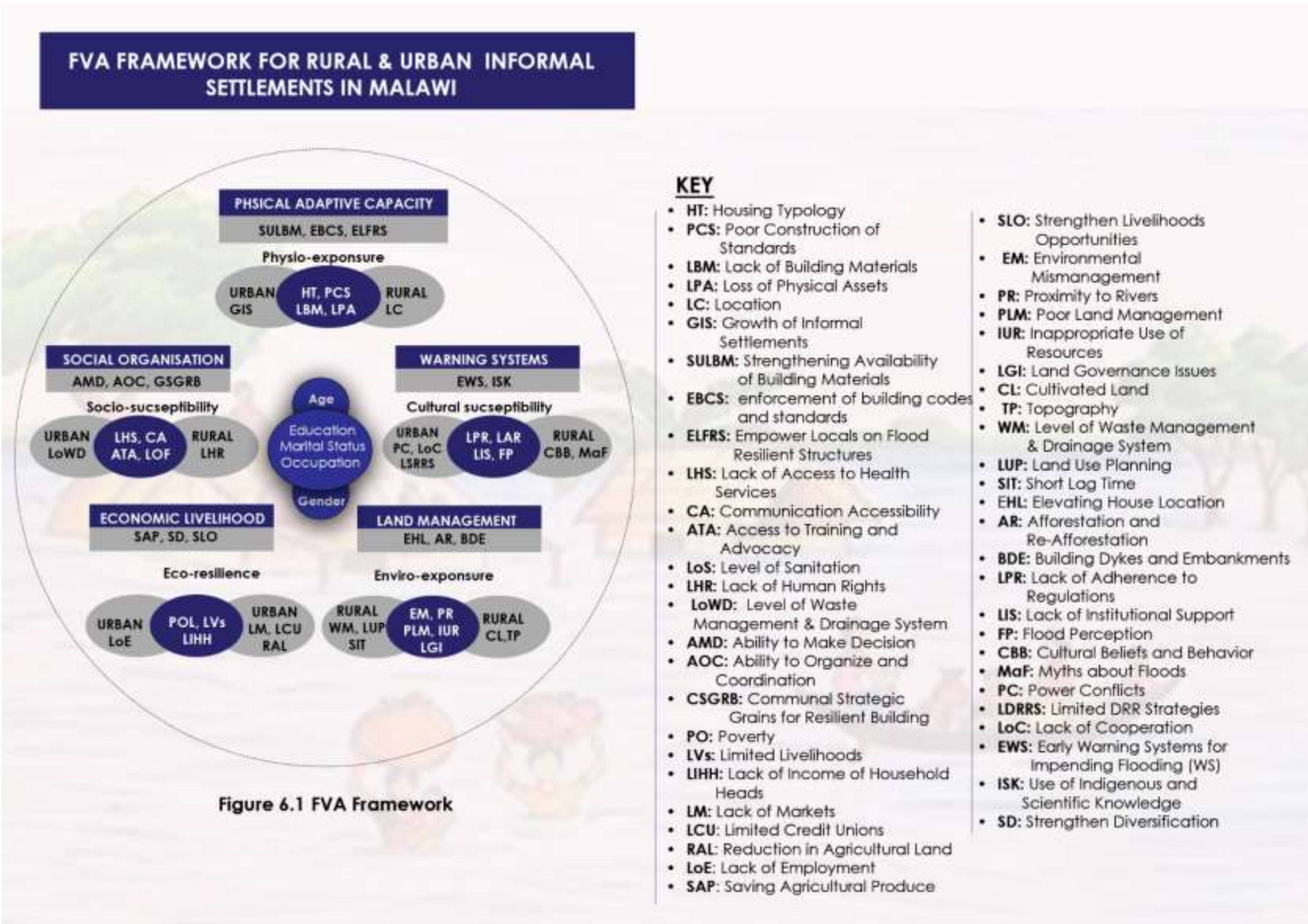


Figure 6.1: FVA Framework

6.4.1 Physio-Exposure Indicators (PEIs)

The PEIs have been generated from the PEFs. Therefore, in the FVA framework, the PEI relates the physical causes to housing and infrastructures. In this case, the PEIs must be evaluated based on exposure with its operator house material and type to understand how they contribute to vulnerability. This is supported in literature that exposure entails the probability of flooding to affect physical objects-buildings and people (Balica & Wright, 2010; Nazeer et al., 2020) due to location. Since location is an exposure variable, defined by geographical position to which assessment was done (Nazeer et al., 2022), this study relates the physical causes to those location/geography to predict household vulnerability and thereby all the indicators that were significant were grouped as physio-exposure factors (PEFs) to give rise to the PEIs. In figure 6.1, those that intersect the Venn diagram (housing typology (HT), poor construction of standards (PCS), lack of building materials (LBM) and loss of physical assets (LPA) and infrastructural standards) are the PEIs for both rural and urban areas. While location (LC) and growth of informal settlement (GIS) are PEIs for rural and urban areas respectively.

6.4.2 Socio-Susceptibility Indicators (SSIs)

This framework further relates that the social causes must be linked to susceptibility with operator access to communication. Susceptibility deals with elements that influence an individual or household to respond to the hazard itself. Birkmann et al. (2013) and Kablan et al. (2017) stated that susceptibility relates to predisposition of the elements at risk in social and ecological spheres. Hence, most of the susceptibility factors relate to social and cultural causes because they are all an integral part of humanity suffering if conditions do not support them to withstand and resist the natural hazard impacts. So, access to communication is susceptibility condition which may result in making households vulnerability to floods because they cannot anticipate the impending flooding. Hence this study related social causes with access to communication to develop a combination of socio-susceptibility factors (SSFs). In figure 6.1, the SSIs, lack of access to health services (LHS), communication accessibility (CA), access to training and advocacy (ATA) and level of sanitation (LS) indicators that intersect the Venn diagram, implying they are applicable both rural and urban informal areas. However, lack of human rights (LHR) and level of waste management and drainage systems (LWDS) are SSIs in rural and urban respectively.

6.4.3 Eco-Resilience Indicators (ERIs)

The framework also put much emphasis on economic causes of vulnerability. Economic indicators such as limited access to alternative livelihoods and poverty contribute to generate vulnerability. These indicators may or may not be affected by the resilience of households to the shock. Qasim et al. (2016) stated that certain beliefs and poverty play a role in the lack of resilience among communities. Birkmann et al. (2013) stipulated that resilience comprise pre-event risk reduction, in time-coping, and post-event response actions. As such, resilience is measured based on the ability of the households to cope with the event. As such, key factors to measure resilience include access to resources, improved livelihoods and access to income among others. The framework therefore strongly overlaps economic causes with resilience factors to assess vulnerability of households to floods. In the Figure 6.1, the combination is referred as ERFs. In figure 6.1, poverty (PO), limited livelihoods (LVs), lack of income of household head (LIHH), loss of economic assets (LEA) intersect the Venn diagram, implying that they are eco-resilience indicators (ERIs) for both rural and urban areas. The ERIs for only rural lack of markets (LM), limited credit unions (LCU) and reduction in agricultural land (RAL) while in urban informal settlements they include lack of employments opportunities (LEO).

6.4.4 Enviro-Exposure Indicators (EEIs)

The FVA framework relates the environmental causes to land use planning and management as such they were predicted based on exposure variables, specifically location. This is supported in literature that exposure is the extent to which an area that is subject to an assessment fall within the geographical range of a hazard event (Balica & Wright, 2010; Nazeer et al., 2020) due to location. Therefore, since location is an exposure variable, defined by geographical position to which assessment was done (Nazeer et al., 2022), then this study related the environmental causes to those location/geography to predict household vulnerability and thereby all the indicators that were significant were grouped as enviro-exposure factors (EEFs) and referred as the EEIs in figure 6.1. In the same figure (6.1), environmental mismanagement (EM), proximity to rivers (PR), poor land management (PLM), inappropriate use of resources (IUR) and siltation of rivers (SR), river catchment morphology (RCM) flooding risk location (FRL) intersect in the Venn diagram, implying that they are the EEIs for both rural and urban informal areas. Those outside the intersection apply specifically as EEIs conforming either in Lilongwe include waste management (WM), land use planning (LUP) or in Karonga (cultivated land: CL and topography TP).

6.4.5 Cultural-Susceptibility Indicators (CSIs)

This framework relates that the cultural causes must be linked to susceptibility with operator access to communication. Susceptibility deals with elements that influence an individual or household to respond to the hazard itself. Birkmann et al. (2013) and Kablan et al. (2017) stated that susceptibility relates to predisposition of the elements at risk in social and ecological spheres. Hence, most of the susceptibility factors relating to cultural causes are all integral part of humanity suffering if conditions do not support them to withstand and resist the natural hazard impacts. So, access to communication is susceptibility condition which may result in making households vulnerability to floods because they cannot anticipate the room danger for immediate response. In figure 6.25, lack of personal responsibility (LPR), lack of adherence to regulations (LAR), lack of institutional support (LIS) and flood perception (FP) intersect the Venn diagram, implying that they are the CSIs for both urban and rural areas. However, cultural beliefs and behaviour (CBB) and myths about floods (MF) should be indicators to be evaluated specifically in rural areas, while power conflicts (PC), limited DRR strategies (LDRRS) and lack of cooperation (LC) should be used to assess vulnerability in urban areas, though they can be applicable to rural areas too.

6.4.6 Adaptive Capacity

The framework further provides key adaptive measures that can be incorporated to deal with vulnerability conditions generated from each intersected category. The adaptive measures relating to housing strategies can be utilised to minimised floods impact on households under the physio-exposure factors in the category of the PEIs are strengthening availability of building materials (SULBM), enforcement of building codes and standards (EBCS) and empower locals on flood resilient structures (ELFRS). Similarly, the social organisational measures can be utilised to minimise socio-susceptibility factors relating to the SSIs. The adaptive capacity that can contribute to reduce vulnerability in the category are: ability to make decisions (AMD), ability to organise and coordination (AOC) and communal strategic grains for resilient buildings (CSGRB). In addition, the economic measures can be utilised to minimise floods impacts relating to eco-resilience factors for the category of ERIs and they include saving agricultural produce (SAP), strengthen diversification (SD) strengthen livelihoods opportunities (SLO) can be used as adaptive capacity under this category. In terms of enviro-exposure, households to adapt to floods impact can use land management measures. These practices include: elevating house location (EHL), afforestation and re-afforestation (AR) and building dykes and embankments (BDE) can be used as adaptive capacity under this category. Finally, households can minimise the cultural-susceptibility factors that generate their vulnerability through the application of warning systems for impending flooding (WS) and use of indigenous and scientific knowledge (ISK) This is contrary to the PAR model (Wisner et al., 2004) and Urban Flood Vulnerability Assessment (Salami et al., 2017), which did not elaborate the adaptive strategies. However, the FVA relates well with the ISDR framework (2004) on adaptive capacity because the ISDR (2004) puts emphasis on the disaster risk reduction through adaptive responses such as awareness knowledge, development public commitment, application of risk reduction measures, early warning and preparedness (Mwale, 2014).

6.4.7 Spatio-Temporal Flooding Trends

The FVA framework considers the spatial-temporal variables as critical to understand the existing conditions that generate households' vulnerability to flooding in the assessed areas. Therefore, the framework selected those variables that intertwine in the physical, environmental and economic causes of vulnerability. For example, in the analysis of the results, it was revealed that environmental vulnerability is high to very high because of drivers such as land cover changes (LCC), loss of forest area (LFA), river morphological changes (RMC) and increased volume of water in the river systems due to short lag time. Therefore, these variables were placed outside the intersection of all the UVFs and VCs on environmental factors. However, due caution should be taken when assessing these factors as they can be context specific. The physical drivers can be attributed to settlement located close to rivers and type of building used to withstand the flooding situations. In terms of economic drivers, the spatio-temporal analysis revealed drivers such as loss in economic activities like agricultural land. Significantly, the key drivers were integrated into the framework (Figure 6.1).

6.5 FVA Benchmarking, Comparability and Knowledge Contribution

This study benchmarked the FVA with various contemporary disaster management frameworks. The aim was to test for its comparability and reliability of indicators. The test was also done to check the variations of the FVA and the contemporary frameworks. This study argues that the ability to identify variations between the earlier and the later imply that a new face in the later phenomenon has been added. Therefore, key contemporary frameworks and models which were used in order to achieve this goal include; PAR Model (Wisner et al., 2004), Hazard of Place Framework (Cutter, 1996), Sustainable Livelihood

Model (2004), Community based Disaster Risk Management Model, Tunner et al. (2003) framework and the International Disaster Risk Reduction Framework. The FVA was further benchmarked with studies carried in Malawi on flood vulnerability assessment (Chawawa et al., 2018; Kita, 2017; Kushe et al., 2018; Munthali et al., 2022; Mwale et al., 2015) to check the relevance of the indicators that have been generated in the intersection parameters of the associated UVFs and VCs.

Therefore, based on the indicators intersected in figure 6.1 (such as housing conditions, access to information, access to resources, poor land use, social networks, location), the FVA framework correlates very well with most of the indicators stipulated in Hazard of place model (Cutter, 1996), PAR model (Winser et al., 2004), Urban Flood Vulnerability Assessment Framework (Salami et al., 2017), ISDR framework (2004). However, the FVA framework has provided simplified indicators of flood vulnerability assessment because the indicators are simple to be used by experts and non-experts. They can be easily understood by ordinary users and policy makers. Furthermore, the indicators can be used for multi-hazards vulnerability assessment, since the H and F in the constituted equation can be changed based on hazard. In this case, the FVA Framework has contributed to widen vulnerability assessment. The FVA, therefore, eliminates the gaps that most studies in literature mainly focus on, single hazards, ignoring the multi-hazard assessment (Kamanga, et al. 2020). The FVA includes variables that can be measurable through quantitative and qualitative thereby expanding the process of vulnerability analysis.

The FVA separated the indicators that generate vulnerability in different subsector of UVFs and VCs. This separation deviates from most of the contemporary frameworks. Joakim (2008) noted that most contemporary frameworks fail to portray the linkages and networks that exist with the layers or sections leading to the vulnerability. For example, the PAR (Wisner et al., 2004) model provides a generalised causation of vulnerability. It portrays the progression of vulnerability from root causes to unsafe condition, but it fails to explicitly acknowledge the linkages that exist within each progression (Joakim, 2008). However, the FVA has provided straightforward linkage of indicators of systemitising and assessing vulnerability in different subsectors. Similarly, the contemporary frameworks such as International Strategy for Disaster Reduction (ISDR) (2004) framework, Hazard of Place Framework (HOP) (Cutter 1996), Borgardi, Birkmann and Cadona (BCC) (2004) and the Turner II et al.’s (2003) framework, they all have methodological difficulty of translation of some concepts into practice (Mwale, 2014). This methodological variation, further makes the contemporary frameworks to be difficult to incorporate different links that exist between vulnerability factors. Mwale (2014) argues that HOP framework does not provide a causal explanation of the vulnerability, instead variables are selected the way they are. Joakim (2008) further noted that the applicability of HOP framework is a Canadian context, giving an impression that some indicators might manifest themselves different in small political, economic and social processes. Though, HOP framework in some instances, relates very well with FVA, particularly the inclusion of perceptions, emphasis on understanding the underlying vulnerability factors, inclusion of mitigation and adaptive capacity in the analysis of vulnerability. It is also purportedly highlighted that the Turner II et al.'s (2003) framework is too theoretical and lacks specificity (Mwale, 2014). In this case, it means that the framework is not simple and easy to use. The ISDR (2004) does not link preparedness response system and thereby not explicit on how vulnerability can be reduced. Also, the use of one dimensional indicators is demonstrated in the Turner II et al.'s (2003) framework which define vulnerability in terms of exposure, susceptibility and responses. On the other hand, the ISDR (2004) defines vulnerability in the realms of social, economic, environmental and physical (Mwale, 2014), missing the aspects of exposure, susceptibility and resilience. Above all, most of these frameworks have neglected to agglomerate the UVFs and VCs in their analysis and development of vulnerability frameworks. These variations are a clear manifestation that the FVA has filled the gaps. Hence, it is justified that the FVA has given vulnerability assessment a new face and thereby contributing to add new knowledge in the sector of vulnerability assessment altogether.

In Malawi and SSA in general, Mwale et al. (2015) in a study of contemporary disaster management framework quantification of flood risk in rural lower shire valley, Malawi found medium, high and very high flood vulnerability in the same construct of indicators of the FVA framework. This implies that the FVA indicators are locally comparable and that can be used for decision making process. The FVA indicators are more practical and can ably enhance communities' resilience. This is because the FVA indicators are comparable, reliable and verifiable for different vulnerability categories. These indicators can be applied in promoting resilience of communities to mitigate flood risks and key component for planning and decision making process.

6.6 Chapter Summary

This chapter has presented the FVA framework. The FVA framework is the first-ever framework which has agglomerated operators in the UVFs and VCs through a multicollinearity analysis in a logit multiple regression to give rise to indicators in the PEIs, SSIs, ERIs, EEIs and CSIs for flood vulnerability assessment. It is a framework that emphasises both on understanding the conditions that generate vulnerability and those that can reduce vulnerability. This FVA framework put emphasis on the importance of conducting an assessment for flood hazards in order to with a view to providing the highest mitigation measures to the most vulnerable areas. It is a framework that provides an integrated approach by including the scope of existing vulnerability criteria such as the RA and PVCA that are current used in Malawi.

CHAPTER 7: CONCLUSION AND RECOMMALEDATIONS

7.1 General Overview of the Study

This study aimed at assessing household flood vulnerability in Lilongwe city and Karonga district in order to propose a FVA framework for rural and urban informal settlements in Malawi. The FVA framework constituted indicators that overlapped in an intersection set theory approach. The assessment was implemented through flood frequency analysis, indicator-based method and HVCA approach. Indicators of vulnerability were framed through a combination of UVFs (physical, social, economic, environmental & cultural) and VCs (exposure, susceptibility and resilience) using a binomial multiple logistical regression model. Variance independent factor (VIF) was used to check the multicollinearity of the indicators in the regression model.

In the process of assessing household flood vulnerability in order to develop FVA framework, this study argues that floods do not automatically lead to disasters. Only when a flooding event interacts with existing vulnerabilities in the community that is unable to cope, then a disaster does occur (Birkmann et al., 2013; Nazeer et al., 2020). The study has demonstrated several vulnerability conditions that make people unable to cope with floods and thereby becoming disasters in the studied areas. The fact is that any policy aimed at promoting flood risk reduction needs to comprehensively understand the causes of vulnerabilities in order to implement proper mitigation and resilience strategies (Munyani et al., 2019).

The idea behind is that floods are natural (Wisner et al. 2004), but that in general disasters caused by them are not and should not be seen as the inevitable outcome of floods' impact only (Birkmann et al., 2013). Explicitly, the social production of vulnerability turns floods to become disaster (Qasim et al., 2015). The degree of societal vulnerability to floods depends on physical, social, economic environmental and cultural characteristics of the society (Mwale, 2014). These characteristics must be analysed based on the ability of the households to anticipate, cope with, resist and recover from the flood event. Furthermore, these characteristics should be estimated based on household's demographics so that a full understanding of characteristics influencing households to respond to floods are known (Nazeer et al., 2020).

The thesis reviewed the contemporary vulnerability frameworks but with more attention to the Pressure and Release-PAR model (Wisner et al., 2004) and Urban Flood Vulnerability framework (Salami et al., 2017) as theoretical frameworks to the understanding of the generation of vulnerability. The frameworks were used to select indicators that formed part of the assessment during the household survey as well as to the development of conceptual framework used in this study. The PAR model was considered critical in the sense that vulnerability is understood as being generated by structures and processes stemmed in the underlying root causes (1), dynamic pressures (2) and unsafe conditions (3), (Figure 2.1). The implication is that the extent of vulnerability depends on how the society deals (or does not deal) with the hazard in terms of addressing structures and processes that generate vulnerability. However, invisibly, PAR emphasises on the adaptive capacity of people in the society to use their skills and resources in order to respond positively to the impacts of hazards. Hence, this study considered the evaluation of households' adaptive capacity to ascertain whether they are significant to minimise their vulnerability levels.

This study sported that the PAR model does not provide a clear explanation on how the generated vulnerability can be reduced or released (Hing et al., 2010). In other words, the model gives much emphasis on the pressures that give rise to the generation of vulnerability rather than on the release section (Mwale, 2014). It is upon this fact that this study developed a release model to provide explanation as to what actions need to be undertaken to release the pressures that generate vulnerability (in this way outlining measures of vulnerability reduction). This study constituted the release model based on underlining root causes addressed, dynamic pressures released and unsafe conditions addressed. Some suggested measures to deal with these stages are presented and outlined appropriately (Figure 2.2). The development of this model inculcated the aspects of adaptive capacities and elements of flood risk reduction such as mitigation, preparedness, early warning systems, communication, institutional capacity and commitment and hazard minimisation. It is significant to note that measures to deal with the three stages of the progression to vulnerability are stemmed in policy and institutional response, while those to deal with the hazard itself (floods in this case) rely more on technocentric solutions. Hence, the scope of this thesis posited two approaches to undertake this study namely the social science approach (from a social perspective) and the techno-engineering approach (focused on engineering solutions).

The study developed a conceptual framework which specified flood vulnerability variables which were assessed in Lilongwe city and Karonga district. The variables that were captured included the UVFs and VCs. The indicators of UVFs included physical-social-economic-environmental and cultural while those of VCs included exposure, susceptibility and resilience. The conceptual framework considered adaptive capacity to mean actions taken by households before, during and after floods that either turn or do not turn floods into disaster. The adaptive measures entail the level of resilience households would be (or would not be) to floods. This study considered it crucial to constitute this conceptual in this manner because it provided a roadmap of identifying the underlying causes of households' vulnerability to floods. Lack of this conceptual framework would have prompted this study to analyse negative impacts triggered by floods in the concerned areas.

In the review of the factors generating vulnerability, several characteristics were found with respect to physical, social, economic, environmental and cultural factors. Similarly, this study revealed the relationship of vulnerability with other important parameters such as development, environmental degradation, poverty, disaster response and early recovery as well as climate change. One main result from this review is the notion that vulnerability needs to be understood in a wide context, which spans many sectors, components and levels (Birkmann et al., 2013). This is a major justification of this study so that it developed a tailor-made framework for flood vulnerability assessment in urban and rural areas of Malawi. Lack of framework implies that there is limited scientific data and indicators that would support policy development and planning (Hossain 2015).

This study also analysed ways of reducing vulnerability through adaptive capacities and disaster risk reduction interventions. From the review, it has been noted that the availability (or unavailability) of these interventions has a bearing in the way people respond to hazards and disasters. Furthermore, the review showed that lack of adaptive capacity impact on community adaptation and resilience to natural shocks. This thesis noted that while adaptive capacity, adaptation and resilience are used differently (Kablan et al., 2017), but they less similar in application and utilisation in order to help communities respond to disasters. Lack of adaptive capacity implies that the society may not able to adapt to changing circumstances caused by the hazardous event and consequently become less resilient to the same event (Hagenlocher et al., 2013). In most cases, resilience and adaptation are used as a measure of adaptive capacity.

This study also reviewed the methodologies of assessing vulnerability. The study established that there are several methods of conducting vulnerability assessment. The diversity of these methods make the process of vulnerability assessment difficult. These methods use indicators which are applied sometimes differently in the analysis. The selection of indicators is hazard and location specific. The review also understood that most countries have implemented vulnerability assessment in order to properly develop appropriate disaster risk reduction measures, but little has been done in Malawi to implement a comprehensive vulnerability assessment. The result is that the methodology is very low, sporadic, isolated and lacks standardised principles. Hence, this study is of significant contribution in flood vulnerability assessment in Malawi.

This study provide a justifiable need to many stakeholders and policy developers to understand the kind of the DRR programmes and initiatives being implemented in Malawi. The underlying principle is that DRR programmes are inefficient and unrealistic in the absence of vulnerability assessment, a key component of risk assessment. The study understood that while some efforts have been made by stakeholders to carryout vulnerability assessment in Malawi, the process lacks standardised framework and is done on a very small scale. More importantly, there has been a neglect of stakeholders to compare rural and urban vulnerability. Therefore, the assessment of household flood vulnerability in order to develop FVA framework was constituted based on four specific objectives from which the following conclusions were made:

7.1.1 Spatio-temporal Vulnerability Trends of floods

The spatial and temporal trends of floods established that households are totally affected by changes happening in the catchment areas of Lingadzi and Lufilya rivers in LC and KD respectively. Key issues that contribute to increase household vulnerability include increased volume of water in the channels due to short time lag resulting from sealing of land surface due to urbanization, loss of agricultural land due to changes in river channels, human occupancy in river channels, popular myths about occurrence of floods and poor catchment management due to agricultural activities and other income generating activities such as sand extraction and brick making in the catchment areas. These vulnerability conditions characterised all the stages of the PAR model (Winser et al., 2004). In summary, the following are some of the key issues that were revealed:

- High expected floods for Lingadzi catchment compared to Lufilya catchment at different return periods i.e. at a return period of 5 years in Lingadzi catchment, the expected floods were revealed to be 296.77cumecs/s compared to 258.64cumecs/s at a return period of 500 years in the Lufilya catchment.
- High flood risk in T/A Kilupula of KD (6) compared to Mtandire ward of LC (2).
- Higher discharge (Q) from the years 1980s to 2006 for both Lingadzi and Lufilya catchments.
- High instability of river morphology for Lufilya catchment compared to Lingadzi catchment. This makes the households to be close to rivers and thereby become vulnerable to floods.
- More probability of flooding occurrence for both catchments from 1980s to 2006.
- Karonga district experienced more flood events in a 10 year interval between 1992-2001 and 2012 -2021 than Lilongwe city.

Therefore, this study has revealed that flood vulnerability trends is high in both LC and KD as demonstrated in high exceedance probability of flooding, high expected floods at shorter return periods and high discharge all defining the higher spatio-temporal characteristics of floods. This information is useful for stakeholders and decision makers to understand the targeted flood risk mitigation and preparedness activities such as installation of river gauging systems for flood monitoring in the catchments and for design any hydraulic structures round the stream catchments. In this way, stakeholders can find these indicators and background information useful for creating a targeted flood mitigation plan to the most vulnerable zones.

7.1.2 Predictive Factors of Households Vulnerability to Floods

The factors that may predispose households' vulnerability were established both in Mtandire ward of Lilongwe city and T/A Kilupula of Karonga district. A combination of several conditions in the underlying vulnerability factors linked to the vulnerability components as well as demographic characteristics were established. Key among these include the PEF (such as substandard infrastructures caused by lack of knowledge in disaster resilient shelters), the SSF (such as attractiveness of relief support, neglect of DRR, limited integration of research findings, weak political commitment, limited institutional capacity, human rights and lack of access to health services), the ERF (such as poverty, lack of alternative livelihoods, low levels of income, and occupation of people), the EEF (such as environmental mismanagement, poor land management, inappropriate use of resources, deforestation, land degradation, land use planning and poor farming practices) and the CSF (such as cultural conflicts, myths about floods, growth of informal settlement, defiance of safety precaution and regulations, lack of enforcement of laws and absence of personal responsibility). This thesis established key demographic characteristics such as gender, marital status, occupation, education and sex explaining variations of the above causes of household vulnerability to floods. These demographic characteristics influence households, male, female, children and elderly to have different access to resources, inhabit in flood prone areas and live in absolute poverty. These conditions fit the root causes, the first stage of the PAR model.

Specifically, the EEFs were found to contribute to very high vulnerability to floods with a value of 0.9 in Mtandire ward and 0.8 in T/A Kilupula. The ERFs followed with the category of "high vulnerability" with a value of 0.6 in Mtandire ward y and in the category of "very high vulnerability" with a value of 0.8 in T/A Kilupula. On the PEFs, Mtandire ward in Lilongwe city generated a value of 0.5 and falls in the category of "vulnerability to floods" while T/A Kilupula in Karonga district falls in the category of 'high vulnerability to floods" with a value of 0.7. While the SSFs had a category of "very low vulnerability in Mtandire ward of Lilongwe city, but in T/A Kilupula it was established in the category of "high vulnerability to floods" with a value of 0.6). Finally, the CSFs fall in the category of "small vulnerability to floods" with value of 0.4 and 0.3 in Lilongwe city and T/A Kilupula respectively.

The above findings characterise the root causes of flood vulnerability in LC and KD. This assessment process provides important information for stakeholders and decision makers to take necessary strategies which can help to deal with a mix of factors that contribute to households' vulnerability. This information would further assist decision makers to strengthen flood risk management measures to be more proactive, including commitment to update and formulate policies aimed at reducing households flood vulnerability.

7.1.3 Households Perception on Flood Occurrence

This study established that households strongly perceive floods as both an urban and a rural problem. However, the study found that there are differentiators defining households' perception on floods between urban and rural people in the study areas. Key among the factors include the demographic characteristics such as education, marital status, sex and occupation. While education, marital status and sex influence floods perception in Mtandire ward, the study found that occupation influences floods perception both in Mtandire ward and T/A Kilupula. The second differentiator is the increased migration of males in the informal settlement of Mtandire area in Lilongwe city. Most females in Lilongwe city were able to give a history of floods compared to males. Thirdly, lack of disaster risk reduction policies in the city could contribute to low awareness of people to understand flood hazards issues. Though it was revealed that DRM structures exist, this study found that the functionality of the urban structures is limited compared to local structures. This eventually affects households to perceive flooding events differently in urban and rural areas. These conditions characterised the unsafe conditions, the third stage of the PAR model (Wisner et al., 2004). These unsafe conditions make households more vulnerable to floods so that they end up into a disaster situation in the event of flooding. As such the FVA framework has systematised these indicators as key issues to be assessed in any VA. Therefore, these must be fully understood and incorporated in the programming of current and future flood risk reduction mitigation and preparedness measures.

7.1.4 Households Adaptive Capacity to Respond to Floods

The study found some adaptive capacity in practice by households in Mtandire ward and T/A Kilupula which were categorised as infrastructural/technological strategies, social organisation strategies and economic strategies. However, it was noted that the implementation of these adaptive strategies was not effective due to poor cooperation of people, unwillingness of people to relocate, lack of resources of some participating agencies such as VCPC, ACPC and WCPC. Other challenges affecting the achievement of these adaptive capacity include: lack of diverse source of income, high levels of poverty, lack of job opportunities, inability of people to organise themselves, lack of early warning systems and lack of innovations and skills on standard of buildings. These gaps basically characterise the dynamic pressures, the second stage of the PAR model. Furthermore, existing gaps between theory and practice in disaster risk reduction and management such as lack of emergencies evacuation shelters, lack of knowledge in disaster risk reduction, weak enforcement of policies, land governance issues, lack of training to strengthen community participation were identified as conditions characterising the unsafe conditions, the third stage of the PAR model (Wisner et al., 2004).

In summary, based on the key findings from the objectives of this study as indicated above, it is highlighted that the extent of vulnerability in the study areas is very high. The analysis predicted that vulnerability of households to floods is very high in both Mtandire ward and T/A Kilupula. Variation of issues influences the vulnerability of male, female, children and the elderly to respond to floods. Some of the remaining gaps and challenges influencing variation of vulnerability include:

- Lack of harmonisation of government institutional systems towards implementation of common goal for flood mitigation and prevention measures.
- Reactiveness of disaster policies which are formulated or updated as a centric symbol of disaster enterprise.
- Lack of disaster risk knowledge among communities and individuals due low education levels, cultural beliefs and limited training.
- The problem of urban intelligence. Urban people think they are more intelligent to fight nature in the sense that they tend to build their dwellings in risk areas.
- Non-functionality of the local structures in urban areas making the DRR activities not being integrated at all levels.
- Lack of integrated standardised operating procedure/protocols to integrate information system to suit local conditions.
- Limited public/private financial support for the implementation of flood risk reduction strategies at all levels.
- Inadequate human resource coupled with lack of funds to support disaster risk reduction activities.

7.2 Recommendations

Overall, FVA is a significant step for flood mitigation projects with a view for providing the greatest concern to the most vulnerable zones. It is the key step in the emergency response to a disaster. It provides indicators and background information to develop a targeted disaster mitigation plan. Therefore, FVA process should be intensified as pre-condition for implementation of disaster risk reduction measures by all stakeholders involved in these projects. The FVA framework can be utilised as a tool to assist in the assessment process and a component of planning and decision making for several enterprises participating in the flood disaster prevention and mitigation. Specifically, the following recommendations were made on the basis of objectives and results:

7.2.1 The spatio-temporal flood vulnerability trends through hydrological assessment, GIS and remote sensing are significant data-driven tools necessary to provide data for the implementation of proper flood risk reduction and mitigation measures aimed at reducing household vulnerability. This study applied these tools only at micro level, using Lufilya catchment in T/A Kilupula of Karonga District and another Lingadzi catchment in Mtandire of Lilongwe City. The findings reveal that the spatio-temporal characteristics in these catchments contribute to increase household flood vulnerability. As such, it is paramount that future research study should undertake a more integrated flood frequency analysis for multiple catchments in both Karonga District and Lilongwe City in order to provide accurate estimation of design floods for current and future programming of flood mitigation measures. This would assist to understand flood vulnerability at macro level.

7.2.2 The predicted factors that determine household flood vulnerability were constructed from the lens of underlying vulnerability factors (UVFs) and vulnerability components (VCs) based on a perspective of one hazard (floods). The fact that Mtandire and T/A Kilupula are prone to other type of hazards, vulnerability data on these hazards is required to inform decision making. Therefore, a more-robust multi-hazard vulnerability assessment (MHVA) should be conducted in the multicollinearity construct of UVFs and VCs to give comprehensive indicators of vulnerability at wider scale for decision making process. More importantly, mapping vulnerability to natural hazards in all urban areas should be enhanced to provide data necessary for developing disaster risk awareness and communication strategies which can assist to strengthen urban risk knowledge to natural hazards.

7.2.3 In terms of perception of flood vulnerability, future studies should go beyond to construct and propose the best methods and frameworks for dealing with challenges that people perceive as contributing factors to flood vulnerability. The studies should show how these methods and frameworks would shape the programming of flood risk reduction and management strategies in the affected communities. Lastly, studies should understand how perception of household flood vulnerability is influenced by factors such as agricultural and economic specialisation, human skills and spatial dimension of social skills.

7.2.4 Assessment of various indicators that define adaptive capacity for both rural and informal urban settlements at macro level should be undertaken for proper mitigation of flood risks. Future study should also pay attention to understand integrated adaptive capacity protocols that best suit local conditions. Furthermore, understanding of institutional harmonization in terms of bottom-up approach especially in Mtandire and other informal settlements should be prioritise in the future research study in order to inform decision-making process for building adaptive capacity.

7.2.5 Participating enterprises should apply the proposed FVA framework as an assessment tool and component of planning process for multi-hazard disaster prevention and mitigation plan. Future researchers should apply and test the FVA framework for assessing single hazard or multiple hazards, including as a benchmark tool for flood modelling and disaster risk management in general.

7.2.6 Overall, this study further suggests that there is a need to compare flood vulnerability in urban between planned settlement and unplanned traditional housing areas (UTHA). Also, a comparison of flood vulnerability using multi-dimensional approach for the typology of rural and urban classes can be helpful for decision-making process.

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APPENDICES

Appendix 1.1: Research and Ethical Approval

MZUZU UNIVERSITY

DIRECTORATE OF RESEARCH

Mzuzu University
Private Bag 201
Luwinga
Mzuzu 2
MALAWI
TEL: 01 320 722
FAX: 01 320 648

Ref No: MZUNIREC/DOR/21/37 **25th June, 2021.**

Mr. Isaac Mwalwimba,
Mzuzu University,
P/Bag201,
Luwinga,
Mzuzu 2.

Email:
isaacmwalwi@gmail.com

Dear Mr. Isaac Mwalwimba,

RESEARCH ETHICS AND REGULATORY APPROVAL AND PERMIT FOR PROTOCOL REF NO: MZUNIREC/DOR/21/37: FLOOD VULNERABILITY ASSESMALET: A COMPARATIVE STUDY OF LILONGWE CITY AND KARONGA DISTRICT IN MALAWI

Having satisfied all the relevant ethical and regulatory requirements, I am pleased to inform you that the above referred research protocol has officially been approved. You are now permitted to proceed with its implementation. Should there be any amendments to the approved protocol in the course of implementing it, you shall be required to seek approval of such amendments before implementation of the same.

This approval is valid for one year from the date of issuance of this approval. If the study goes beyond one year, an annual approval for continuation shall be required to be sought from the Mzuzu University Research Ethics Committee (MZUNIREC) in a format that is available at the Secretariat. Once the study is finalized, you are required to furnish the Committee with a final report of the study. The Committee reserves the right to carry out compliance inspection of this approved protocol at any time as may be deemed by it. As such, you are expected to properly maintain all study documents including consent forms.

Wishing you a successful implementation of your study.

Committee Address:

Secretariat, Mzuzu University Research Ethics Committee, P/Bag 201, Luwinga, Mzuzu 2; Email address: mzunirec@mzuni.ac.mw

Yours Sincerely,

Gift Mbwele

MZUZU UNIVERSITY RESEARCH ETHICS ADMINISTRATOR

For: CHAIRMAN OF MZUNIREC

Appendix 1.2 Letter of Support to Collect Data

MZUZU UNIVERSITY

FACULTY OF ENVIRONMALETAL SCIENCES

Dr. Russel C.G. Chidya (*PhD, MSc*)
Head of Department and Postgraduate Coordinator (PGC)

P/Bag 201,
Mzuzu. Malawi.

Department of Water and Sanitation (DWAS)
Tel (Office): +265 (1) 320-384
Cell: +265 (0) 884-023-509.

E-mail: russelchidya@gmail.com

DATE: 7th July 2021

ATTENTION· ______________________________

____
____
____
____

Dear Sir/Madam,

Re: LETTER OF SUPPORT AND REQUEST FOR PERMISSION TO COLLECT DATA FOR RESEARCH PURPOSES

Refer to the above captioned subject matter.

This letter serves to confirm that **Isaac Mwalwimba** (*name*) with **Reg. No PHD/WRM/02/19**.) is our postgraduate (PG) student here at Mzuzu University pursuing a **Doctoral (PhD)** Degree Study Programme in **Water Resources Management (WRM)**.

As part of the requirements for the award of a ***Doctor of Philosophy (Ph.D) in Water Resources Management,*** the above-mentioned student is supposed to undertake a research study of any subject matter in line with our research themes. The research study is conducted upon approval by the Faculty of Environmental Sciences and Mzuzu

University Research Ethics Committee (MZUNIREC) and that it is of interest in the Water, Sanitation, Health, and Environmental Science fields in Malawi, SADC, and beyond.

We are glad to inform you that our student presented his proposal and got approval/clearance from the faculty and MZUNIREC. Below is a summary of the student's research work:

Research Project Title	Towards a Framework for Flood Vulnerability Assessment for Rural and Urban Informal Settlements in Malawi: A study of Karonga District and Lilongwe City.
Study Areas (site)	Lilongwe Karonga
Supervisors	Professor I. Mtafu Manda Professor Cosmo Ngongondo (PhD)

This being the case, we would be very grateful if you support our student with the relevant data that she/ he may require from you or your organisation to assist the student to accomplish the research work. We declare and confirm that the information or data shared or support rendered by you and or your organisation will be treated as ***"confidential"*** and used for academic and intended purposes only.

Thank you for your cooperation and in anticipation of your assistance. For further inquiries, please contact the undersigned senior lecturer/Postgraduate coordinator and Head of Department at Mzuzu University.

Yours Faithfully,

Dr RUSSEL CHIDYA (Ph.D.)
Head and Postgraduate Coordinator (PGC)
Department of Water and Sanitation (DWAS)
E-mail: russelchidya@gmail.com
Cell: +265 (0) 999 317 176 or 0884 023 509

THE HEAD
DEPARTMENT OF WATER AND SANITATION
JUL 2021
MZUZU UNIVERSITY
P/BAG 201
MZUZU 2 – MALAWI

Appendix 1.3: Informed Consent Form for Participation in the Research

Mzuzu University Research Ethics Committee (MZUNIREC)

Informed Consent Form for Research in
Flood Vulnerability Assessment: A Comparative Study of Lilongwe City and Karonga District, Malawi.

Introduction

I am **Isaac Kadono Mwalwimba, a PhD student at Mzuzu University**. I am conducting a research on **Flood Vulnerability Assessment: A Comparative Study of Lilongwe City and Karonga District in Malawi.** I would like to request your participation in providing data relating to the flooding situation in Mtandire/TA Kilupula which will be used in my dissertation, in partial fulfilment of a **Doctor of Philosophy Degree in Water Resources Management and Development.** This consent form may contain words that you do not understand. Please ask me to stop as we go through the information and I will take time to explain. If you have questions later, you can ask them of me or of another researcher.

Purpose of the research

This research aims to develop Flood Vulnerability Assessment Framework through a comparative study of Lilongwe city and Karonga district.

Type of Research Intervention

This research will involve your participation in a group discussion and/or individual interview.

Participant Selection

You are being invited to take part in this research because **you are one of the key persons who can provide data related to this research study**.

Voluntary Participation

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. If you choose not to participate nothing will change. You may skip any question and move on to the next question.

Duration

The research takes place for a period of **30 minutes**.

Risks

You do not have to answer any question or take part in the discussion/interview/survey if you feel the question(s) are too personal or if talking about them makes you uncomfortable.

Reimbursements

You will not be provided any incentive to take part in the research.

Sharing the Results

The knowledge that we get from this research will be shared with you and your community before it is made widely available to the public. Following, we will publish the results so other interested people may learn from the research.

Who to Contact?

If you have any questions, you can ask them now or later. If you wish to ask questions later, you may contact: **Mr. Isaac Kadono Mwalwimba**, Catholic University of Malawi, P.O. Box 5452, Limbe; Phone 0999342563/0999247037

This proposal has been reviewed and approved by Mzuzu University Research Ethics Committee (MZUNIREC) which is a committee whose task it is to make sure that research participants are protected from harm. If you wish to find out more about the Committee, contact Mr. Gift Mbwele, Mzuzu University Research Ethics (MZUNIREC) Administrator, Mzuzu University, P/Bag 201, Luwinga, Mzuzu 2, Phone: 0999404008/0888641486

Do you have any questions?

Part II: Certificate of Consent
I have been invited to participate in research about:

____

____

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study

Print Name of Participant__________________
Signature of Participant ___________________
Date __________________________
Day/month/year

If illiterate [1]
I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Print name of witness____________

Signature of witness _____________

Date ________________________
Day/month/year

Thumb print of participant

Statement by the researcher/person taking consent

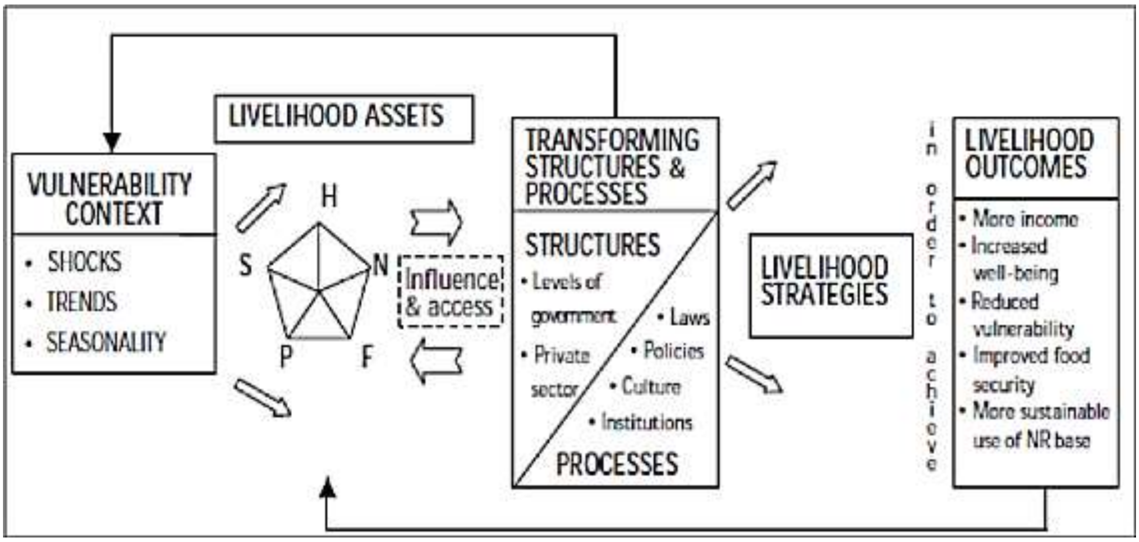
I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands the research project. I confirm the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher /person taking the consent_________________________

Date __________________________
Day/month/ye

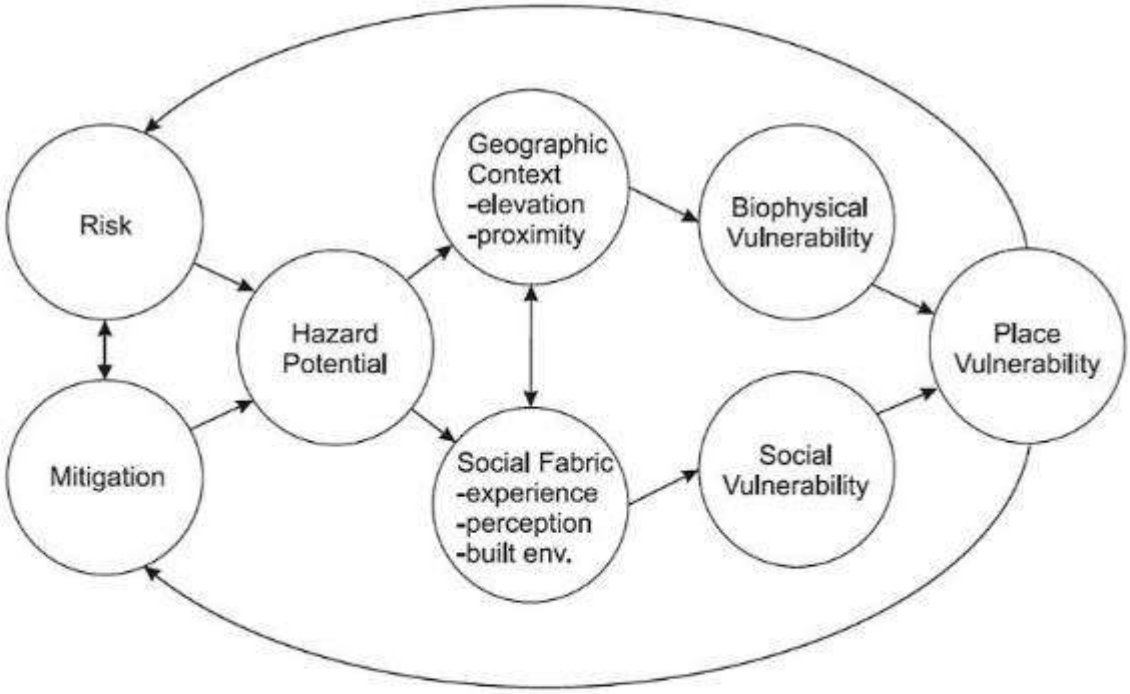
[1] A literate witness must sign (if possible, this person should be selected by the participant and should have no connection to the research team). Participants who are illiterate should include their thumb print as well.

Appendix 2: Contemporary Vulnerability Frameworks
Appendix: 2.1 Sustainable Livelihood Framework



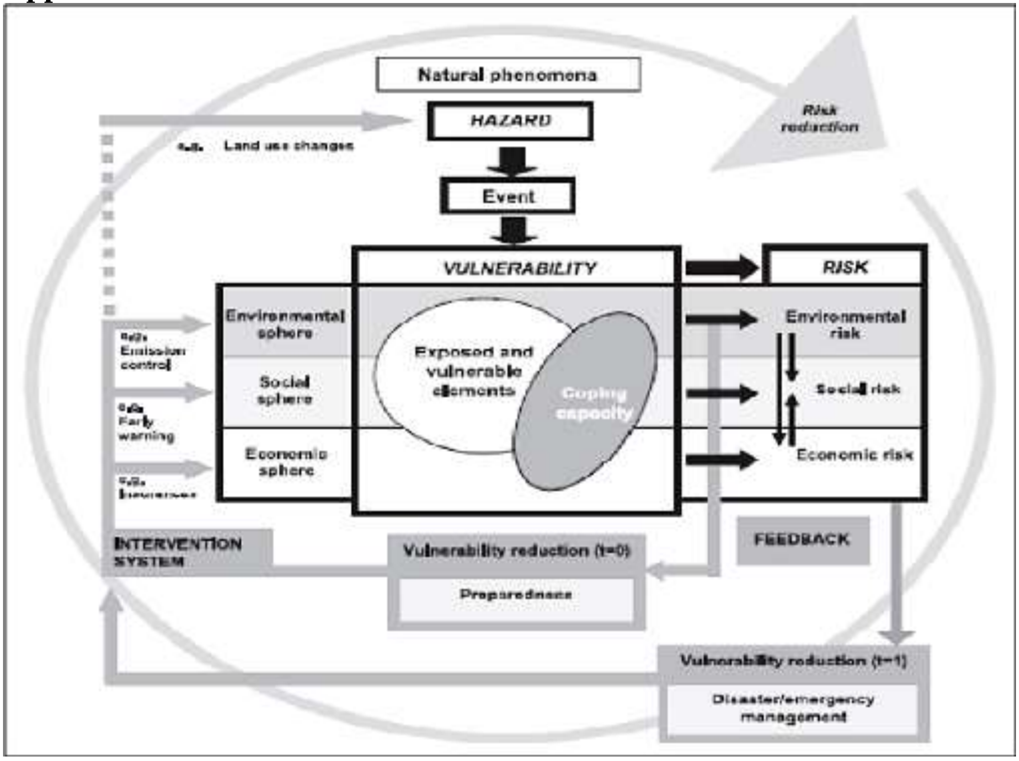
Sustainable Livelihood Framework.
H=human capital, N=natural capital, F=financial capital, P=physical capital, S=social capital. Source: (DFID, 1999)

Appendix 2.2: Hazard of Place Framework



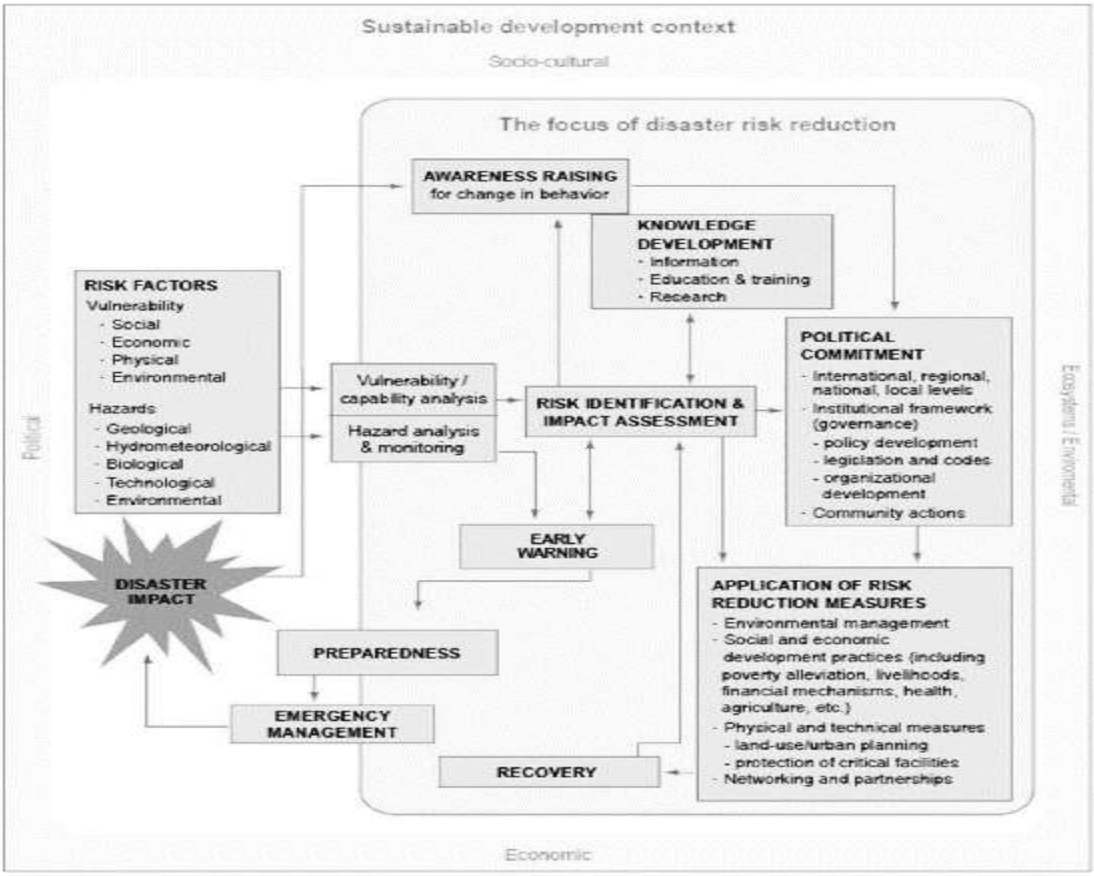
Source: (Cutter et al., 1996)

Appendix 2.3: BBC Model

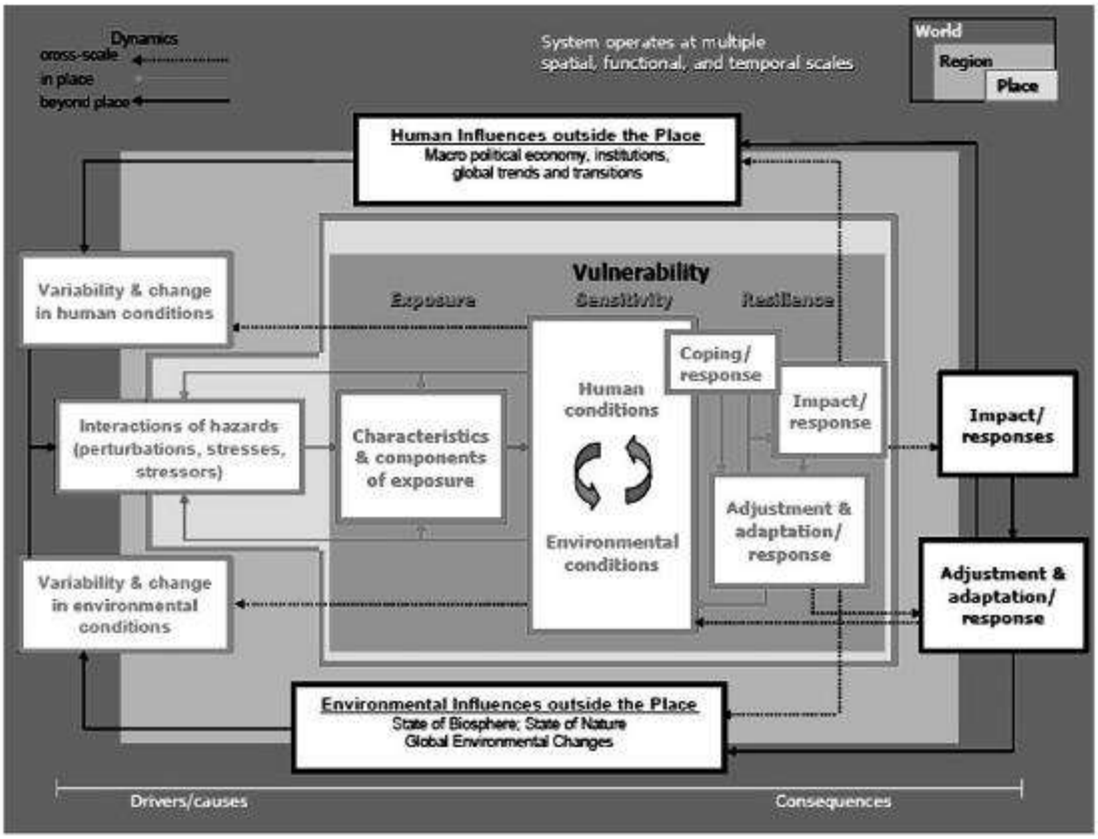


Source: (Birkmann, 2006)

Appendix 2.4: ISDR Framework for Disaster Risk Reduction



Appendix 2.5: Vulnerability Framework



Source: Turner et al. (2003)

Appendix 3.1: Household Questionnaire Survey

TOWARDS A FRAMEWORK FOR FLOOD VULNERABILITY ASSESSMENT FOR RURAL AND URBAN INFORMAL SETTLEMENTS IN MALAWI : A CASE STUDY OF KARONGA DISTRICT AND LILONGWE CITY

HOUSEHOLD QUESTIONNAIRE

My name is Isaac Kadono Mwalwimba, a PhD student at **Mzuzu University**. I would like to request your participation in providing data relating to the flooding situation in Mtandire/TA Kilupula which will be used in my dissertation, in partial fulfilment of a **Doctor of Philosophy Degree in Water Resources Management and Development.** The aim of the dissertation research is to **Assess Households' Flood Vulnerability in order to propose a Flood Vulnerability Framework for rural and informal settlements in Malawi.** Your participation in this questionnaire will contribute vital information required to achieve this objective. Kindly, note that the data provided will be used for academic purposes only and will not be discussed with any third party without prior consent except as part of the dissertation academic requirements.

Participant declaration to take part in the interview	I have read & understood the purpose of the study, I therefore:	
	Accept to be interviewed	
	Decline to be interviewed	

Questionnaire Number	
Name of Interviewer	
Date of Interview	

A. BASIC HOUSEHOLD INFORMATION

Accessibility	Is the household accessible to the main road	? 0=Yes	1= No
GVH and Village/ward/block leaders	Name of Group village headman/ward		
	Name of Village headman/block leader		
GPS Coordinates	Household X-coordinate		
	Household Y-coordinate		

B. HOUSEHOLD DEMOGRAPHICS

Item	**Question**	**Answer categories**
Sex	What is the Sex of the participant?	0=Male 1=Female
Age	What is the age of the participant?	1= 21-30 years 2= 31-40 years 3= 41-50 years 4= 51-60 years 5= + 61 years
Head	Is this participant the head of the household?	0=Yes 1=No

Relationship to household head	How is the participant related to the household head?	1=Son/daughter 2=Spouse (wife or husband) 3=Sister/brother 4=Father/mother 5=Father in law/mother in law 6=Grandson/granddaughter 7=Grandfather/grandmother 8=Brother in law/sister in-law 9=Uncle/aunt 12=Other
Marital status	What is the marital status of the participant?	1= Single 2=Married 3=Divorced 4=Separated 5=Widowed
Literacy	Is the respondent able to read and write?	0=Yes 1=No
Education	What is the highest education qualification that the participant acquired?	1=No formal education 2=PSLC and equivalent 3=JCE and equivalent 4= MSCE and equivalent 6=University diploma 7=University degree 8= Other specify
Occupation	What is the main occupation of the participant?	1= Formally employed 2=Informally employed 3=Unemployed 4= Farming 5=Fishing 6= Business

C. FLOOD HAZARD ASSESSMENT

Item	Question	Answer /categories
Past flood	How have you been affected by flood events in the past	1= Not affected 2=Affected 3= Highly affected

Frequency	How often have the flooding events been happening in this area?	1= Every year 2=After two years 3=After five years 4=Don't know
Year	When did you experience last flood?	1=2020/2021 2=2019/2020 3=2018/2019 4= 2017/2018
Depth	What was the depth of the flood last experienced?	1=Up to ankle joint level (<25cm) 2=Up to Knee joint level (26-55cm) 3=Up to hip joint/widow level (>55 cm)

Time	How much time did the last flood you experienced take? (hour/minute)	1= 30 minutes 2= 2 hours 3= 4 hours 4= 6 hours 5= other	
Intensity	What was the intensity of the recent floods compared to past floods?	1=Not severe, 2 Severe, 3 Very severe	
		Recent floods	
		Past floods	
Causes	What do you think are the causes of floods in the area? (**select more than one if applicable**)	1=Poorly maintained river 2= Heavy rains 3=Deforestation 4=Siltation of river 5= Poor farming technique 6=Deliberate breaking of banks to irrigate of river 7= Climate change 8= poor urban planning	

D. VULNERABILITY ASSESSMENT

D1. Exposures

Item	**Question**	Indicator/drivers	**Answer/categories**
Geography	What is the geographical terrain of the site? **(Select one)**	Physical	1= Hilltop 2= Mild slope 3= Open flat field 4= Steep slope
Material of outer wall	The outer walls of the house are predominantly made of what materials? **Select applicable**	Physical	1= Mudstone 2= Bamboo 4= Burnt bricks 5= Unburnt bricks
Roofing material	The roofing of the house is made predominantly of what materials? **Select applicable**	Physical	1= Iron sheets 2= Thatched grass 3=Clay 4=Tiles 5= Concrete 6= Plastic sheeting 7= Others
Damage	Was your house damaged by the last flooding?	Physical	0=Yes 1=No
Reason damaged	If yes, why was it damaged **Select applicable**	Physical	1= Weak materials (Grass, and bamboo) 2= Leaking 3= Located near river 4= Other specify
Reason not damaged	If no, why was it not damaged? **Select applicable**	Physical	1= Strong materials (concrete, burnt bricks, iron sheets) 2= No leakage
			3= Located at high ground 4=Other

Water source	What is the main source of drinking water for your household during this time of the year?	Physical	1= Piped in dwelling 2= Communal stand pipe 3= Private protected well 4= Private unprotected well 5= Public protected well 6= Public unprotected well 7= Borehole, handpump 8= River/stream 10= Rain water
Water source	What was your main source of drinking water during the last floods	Physical	1= Piped in dwelling 2= Communal stand pipe 3= Private protected well 4= Private unprotected well 5= Public protected well 6= Public unprotected well 7= Borehole, handpump 8= River/stream 9= Lake/dam 10= Rain water
Impact	Was the main source of water affected by the last floods	Physical	0=Yes 1= No
Toilet	What kind of toilet facility does your household have?	Physical	1= Flush toilet 2= VIP latrine 3= Dug out pit (simple) with roof 4= Dug out pit (simple) without roof 5= Flying toilet 6= Bucket toilet 7= Open defecation
Toilet	Was your toilet facility affected by the last flood	Physical	0= Yes 1= No
Distance	What is the distance between the toilet facility/open defecation and the main water sources	Physical	1= 0-50 metres 2= 51-100 metres 3= 101-150 metres 4= >151 metres

D2. Susceptibility

Item	**Question**	Indicator/drivers	**Answer/categories**
Communication accessibility	Did you have access to communication before the last flooding?	Social	0=Yes 1= No
Mode	If yes, what were the mode of communication? Order them according to importance **(1 not important, 2 important, 3 very important)**	Social	1= National radio station 2= Community radio station 3= Television 4= Print media 5= Cellphone 6= Do not know
Education facilities	Are there any education facilities in your area? **(Select one)**	Social	0= Yes 1= No
Results	How does flooding affect education system in your area (**select by encircling more than one)**	Social	1= High drop out 2= High absenteeism 3= Teachers not available 4= Schools damaged 5= Schools overcrowded 6= School not accessible 7= Do not know
Health facilities	Are there any facilities in your area?	Social	0=Yes 1= No
Access to healthcare	During the last flooding, did any of the household members get sick?	Social	0= Yes 1= No
Diseases	Which disease was experienced by the household member who got sick?	Social	1= Diarrhea 2= Malaria 3= Cholera 4= Measles 5= Cough 6= Others

D3 Resilience indicators

Item	**Question**	Indicator/drivers	**Answer/categories**
Income of head	What are the main sources of income of the head of the household	Economic	1= Crop production 2= Livestock and poultry 3= Fishing 4= Agriculture commodities trade 5= Unskilled wage labour 6= Charcoal burning 7= Remittances 8= Other specify
Crop damage	Did the household experienced crop damaged during the floods	Economic	0= Yes 1= No

Staple crop	Was the main staple crop the one which was damaged?	Economic	0= Yes 1= No
Food stocks	Did the household experience any loss of food stocks during the floods	Economic	0= Yes 1= No

D4. Extent of vulnerability;

Question	**indicators**	**Existing vulnerabilities**	**rate**
What factors determine the trends and magnitudes? of vulnerability to flooding in the area? **Use a rating scale of 1-3; (1) less important, (2) important, and (3) very important)**	Physical	• Lack of water sources (borehole, wells & piped water) • Poor construction of infrastructural facilities • lack of construction materials • residing in flood prone areas	
	Social	• lack of knowledge on the prevailing situation • lack of skills to cope with Urgent needs • spread of HIV/AIDS	
	Economic	• no credit unions/financial institution • lack of markets and income generation activity • poverty • lack of alternative livelihoods	
	environmental	• pressure on cultivated land • energy scarcity • water scarcity	
	Human	• traditional beliefs (myths about floods) • cultural conflicts • defiance of safety precautions and regulations • absence of personal responsibility	

Question	Indicator	Elements at risk	Ranking
How vulnerable were these elements to the last flooding? % of vulnerability 1=76-100 3=51-75	Physical	Village houses	
		Teacher's houses	
		Life/people death	
		Wells	
		Boreholes	
		Roads	
		Toilets	
		Bridges	
	Social	Health clinics	
		Schools	
5= 26-50 7= 0-25 **Rank 1=not vulnerable, 3= severely vulnerable, and 5= slightly vulnerable 7= do not know**		Government warehousing	
		Electricity cables	
	Economic	Staple crops (maize &cassava)	
		Cash crops (rice)	
		Livestock (goats, cattle sheep etc.)	
		Trading	
		Fishing	
	Environmental	Forest cover	
		Quality of land & soil	
		Trees	
		Natural pasture	
		River channels	

THANK YOU VERY MUCH FOR YOUR PARTICIPATION

Appendix 3.2: HVCA Interview Guide (Key Informants)

A. **Hazards Assessment**

1. Explain if the community/location has been flooded in the past?
2. Can you briefly state when did you record the recent flood in the community/location?
3. Explain how severe was the recent flood in comparison to other past floods?
4. Give reason(s) for your choice in 3 above (be as detailed as possible)?
5. Why the community/location is vulnerable to floods? Describe to me by explaining the nature of soil characteristics, water resources and trends in precipitation of the area.

B. **Vulnerability Assessment**

1. Can you briefly explain to me who are the most vulnerable groups?
2. What are the elements at risk (items) which are more vulnerable to floods (list all you know)?
3. Explain why do you think these elements at risk are vulnerable?
4. Who do you think is responsible for creating vulnerable conditions in the area?
5. Explain what you think are the impacts of flood to the people in this community/location (educational, health, water, sanitation and hygiene, housing, transport and communication & other related impacts)?
6. Explain the major factors that determine the trends and magnitudes (amount/strength) of people's vulnerability to floods in the area?

C. **Capacity Assessment**

1. What activities do households in flood prone areas undertake to mitigate flood impacts to build local resilience?
2. In what ways do you think households' adaptive capacities can be supported to become more effective in building local resilience?
3. What support do you provide from your institution/organisation to assist people in flood prone areas to reduce their vulnerability and increase community resilience to the impact of floods?
4. What mitigation measures are used to prevent flood impact in the area?
5. What mechanisms are put in place to inform the population on what to do in case of a flood?
6. What emergency equipment do you provide to households exposed to floods?
7. Explain how stakeholders (Government/ NGOs) who help communities to prepare for and respond to floods work together.

Appendix 3.3: Approved Presentation

southern africa society for disaster reduction

NWU ACDS

MUST

SDI Sustainable Development Initiative

Sustainable Development Initiative (SDI)
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09th September, 2022

Dear Author,

Re: ABSTRACT SUBMISSION APPROVED

We are pleased to inform you that your abstract titled *"Measuring Vulnerability to Assess Households Resilience to Floods Risk in Karonga District, Malawi "* has been accepted.

The conference takes place on 26th-28th October at Amaryllis Hotel, Blantyre, Malawi. Please confirm your availability to present the paper by 23rd September, 2022.

Should you require more information about the conference inclusion Visa Application and COVID-19 requirements, please visit our conference website at http://sasdir.org . You may also contact me at +265888749928 or menzonyirenda@yahoo.com

Thank you, and we look forward to seeing you at the conference.

Yours faithfully,

MAYNARD NYIRENDA
Team Leader- 5TH Biennial SASDiR Conference
Founder & Executive Director- Sustainable Development Initiative (SDI)-Malawi
Founding member of SASDiR

SASDiR is a community of practice for disaster risk reduction within the regional context of the Southern Africa Development Community (SADC)