EFFECTIVENESS OF ECOSYSTEM-BASED ADAPTATION STRATEGIES FOR FLOOD MITIGATION IN LAKE NAIVASHA CATCHMENT, KENYA

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A Thesis Submitted in Partial Fulfillment of the Requirements for the award of a Master of Science degree in Climate Change Adaptation and Sustainable Development of Masinde Muliro University of Science and Technology

March 2025

DECLARATION AND CERTIFICATION

Declaration by the Candidate

This is to declare that this is my original work that has never been presented in any institution of higher learning for examination.

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The undersigned certify that they have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology thesis entitled **''Effectiveness of Ecosystem-Based Adaptation Strategies for Flood Mitigation in Lake Naivasha Catchment, Kenya"**

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DEDICATION

This achievement is a special dedication the Almighty GOD, my late Grandmother Mrs. Rosa Muhanda Isindu and my late mother Ms. Agripinah Kuvochi Isindu (may they rest in eternal peace).

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ABSTRACT

Several factors are affecting the hydrological cycles but human activities have played a major role in the experienced hydrological changes. Some human activities such as agriculture and industrialization have contributed to the change in the water balance through the extraction of water, construction of impoundments and climate change factors. Some of the methods used to mitigate floods in Kenya include the; establishment of early warning systems, establishment and improvement of infrastructure such as flood-resistant roads and bridges in affected areas, and community-driven initiatives such as the participatory mapping of flood-prone areas. Therefore, the main objective was to determine the effectiveness of ecosystem-based adaptation strategies for flood mitigation in Lake Naivasha catchment, Kenya. Based on the Socio-Ecological Systems (SES) Theory, this study has incorporated a multi-faceted design of field surveys, observations, and stakeholder interviews to meet the following specific objectives; to assess the severity of flood occurrence, to determine ecosystem-based adaptation strategies, and to examine the effectiveness of existing ecosystem-based adaptation strategies for flood mitigation in the lake Naivasha catchment. With a target population of 29,190, a sample size of n=395 comprising of stakeholders in different areas including fishermen, farmers, tour guides, and tourists and other residents was identified randomly and helped to collect data to determine the existing Ecosystem-based adaptation (EBA) strategies for mitigating floods in the catchment. The study employed a descriptive correlational method comprising of combined quantitative and qualitative approaches to comprehensively assess severity of floods in the Lake Naivasha catchment, identify the existing EBA strategies in the catchment and understand their effectiveness in mitigating floods in the catchment. Primary data was collected through structured questionnaires, key informant interviews, and focus group discussions. Descriptive analysis was used and this included a chi-square test used to analyze categorical variables to examine any significant differences between occupation and awareness of ecosystem-based strategies among participants. The findings of this study indicated that EBA strategies such as agroforestry and afforestation were the highly adopted non-structural strategies while soil conservation terraces and rain-water harvesting techniques were the highly adopted structural strategies and were highly effective in mitigating the floods hence combating the impacts of climate change (Sustainable Development Goal 13) such as flood risks, improving water quality and enhancing community resilience in Lake Naivasha catchment. From the study, 77.75% of the participants reported that they had experienced observable positive changes in flood occurrence with most of the residents (81.87%) who use afforestation and agroforestry claiming to have observed a reduction in floods occurrence in the catchment. The study revealed that afforestation and agroforestry were the most widely adopted non-structural EBA strategies, driven by their co-benefits and government support, while mulching and cover cropping were the least adopted due to a lack of knowledge about their application methods. The study recommends that more research should be done to understand other flood mitigation measures to help reduce the impacts of severe floods in the catchment, awareness creation among more community members regarding EBA strategies, their effectiveness in flood mitigation and how the community members can participate at the individual and community levels in adopting these strategies.

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LIST OF ABBREVIATIONS AND ACRONYMS

ABMs	Agent-based models
EBAs	Ecosystem-based adaptation strategies
ECOWAS	Economic Community of West African States
FAO	Food and Agricultural Organization
FDC	Flow Duration Curve
FGD	Focus Group Discussions
KII	Key Informant Interviews
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
LULC	Land Use Land Cover
NEMA	National Environment Management Authority
NACOSTI	National Commission for Science, Technology and Innovation
SDGs	Sustainable Development Goals
UN	United Nations
UNDP	United Nations Development Program
WCDRR	World Conference on Disaster Risk Reduction
WRA	Water Resources Authority
WWF	World Wide Fund for Nature

OPERATION DEFINITION OF TERMS AND CONCEPTS

Catchment - An area of land where water collects when it rains, often bounded by hills

Basin - An area of land where all flowing surface water converges to a single point, such as a river mouth, or flows into another body of water, such as a lake or ocean

Ecosystem - Biological existence of a community comprising of interacting organisms of both plants and animals and their physical surrounding

EBA - Ecosystem-based adaptation strategies are approaches that focus on the restoration of the ecosystem and enhancement of its services to protect the society from the negative impacts of climate change

Effectiveness- The degree of successfulness of a strategy or method in producing desired results

Flood mitigation - Methods used to reduce or prevent the detrimental effects of flood waters

Flood risks - The product of the vulnerability to flooding multiplied by the total value of the assets at risk to flooding

Flood impacts - Are all outcomes of floods that threaten lives, inundate properties and businesses, destroy belongings, damage vital infrastructure and prevent access to essential public services

Flood occurrence - Impacts of heavy precipitation that occur when an overflow of water submerges land that is usually dry

Conservation Agriculture - Is a farming system that ensures minimum soil disturbance, diversification of plant species, and maintenance of permanent soil cover.

Soil and water conservation measures - All techniques applied to protect the soil and water from degradation and pollution respectively

Flood severity- the degree of occurrence of floods which could be minor, moderate, or major in other terms could be termed as extremely severe, moderately severe, or not severe

CHAPTER ONE

INTRODUCTION

1.0 Introduction

This chapter provides an illustration and understanding of the background information of the research topic, statement of the problem, research objectives, hypothesis, justification of the study, scope and limitation of the study.

1.1 Background of the study

The world responses to disasters and calamities have been highly advocated for with the rise in different disasters, calamities and pandemics such as floods and the most recent being Covid 19. The major types of floods are interlinked since the hydrological system is interconnected. For instance, fluvial floods negatively impact the surrounding where the river flows as it drains its water into larger water bodies. Pluvial floods on the other hand are highly experienced in urbanized areas and other areas independent of their proximity to water bodies (Muia *et al.*, 2021). Coastal floods which may also be referred to as 'storm surge' affect large water bodies such as lakes, oceans and seas. All these types of floods have different impacts and therefore their mitigation and management strategies are different. The impacts of floods have been felt globally with the worst being deaths of people humans and animals and the destruction of property. The negative impacts of disasters on the livelihoods of individuals are more adverse compared to the positive ones (Rahman, 2014).

There exist positive impacts of floods especially to the health of the vegetation on the floodplains. When there are floods, some species of animals are able to secure new breeding grounds while the rise in water levels enable the germination of different plants and also provide irrigation waters for agriculture. Despite the flood benefits, the negative impacts of floods are extreme which call for immediate mitigation (Jonkman, 2005). Globally, floods account for approximately 47% of the disaster risks recorded in the past 20 years (Suhr & Steinert, 2022). The impacts of floods have affected about 2.3 billion people globally and recording about 43.5% death in 2019 (Suhr & Steinert, 2022). Floods contribute to the economic losses as it affects economic activities such as tourism, agriculture and fishing. The migration of wildlife from their natural habitats to human environment results in the increase in human-wildlife conflicts. There is displacement of people from the flooded settlements as well as the rise in the prevalence of water borne diseases (Muia *et al*., 2021). The rehabilitation of property and infrastructure destroyed by floods is costly, especially in the third world countries that depend on grant relief help.

Information obtained from different research findings has different anthropogenic, geological, and hydro-climatic explanation attributed to the causes of the rising water levels causing floods in different water bodies and urban areas. Some of the findings base their argument on tectonic plate movements, climate changes aspects such as increase precipitation in the areas, human activities such as over cropping, change in land use land cover (LULC), urbanization, settlement, and industrialization that has resulted in erosion causing siltation of the lake basins hence increasing the water levels among other theories (Herrnegger, Stecher, Schwatke, & Olang, 2021). There is no specific theory that has been proven to be the actual cause of the increased water level in the rift valley lakes. However, there is an evident persistent rise in the water levels for the past decade (Muia *et al.*, 2021).

This has therefore called for the intervention of the government and other organizations to help the residents adapt to the new changes since there is little information on whether or not the water levels will keep rising.

In areas like Baringo and Bogoria, schools, hospitals, and other social facilities have been submerged by water hindering the day-to-day activities and forcing the surrounding communities to vacate the area (Muia *et al*., 2021). The displacement of people results in population pressure in the new settlements which equally result in social issues and conflicts. The government, nongovernmental organizations and other concern stakeholders like Kenya Red-Cross in different institutions play a major role in offering relief services, early warning systems and also help in settling the affected communities, construction of human engineer barriers as well as flood resistant infrastructure such as roads and bridges, zoning of flood prawn areas, channelization among other measures (Nashipay, Mabwoga, & Konana, 2022; Nguma & Kiluva, 2022). However, such help solves the problem temporarily and with consistency of the flood risks, Ecosystem-based approaches (EBA) becomes the only measure in mitigating the impacts and creating adaptation strategies to the affected communities. Use of EBA strategies involves the incorporation of biodiversity together with the ecosystem to adapt to the occurrences that are linked to climate change.

EBA strategies include the protection of kelp beds and wetlands, agroforestry, afforestation, restoration of coastal areas including mangroves and river banks (Nashipay et al., 2022). The use of EBA strategies to manage floods have been assessed in some areas such as the Upper Suswa in Magadi catchment and have proved to be economically efficient and more flexible to implement compared to the conventional strategies. EBA strategies are multidimensionally and multifunctionally efficient in adopting both ecosystem service and biodiversity in mitigating flood risks (Nashipay *et al*., 2022). This study has assessed the effectiveness of using ecosystem-based, structural, and non-structural strategies to mitigate flood risks on lake Naivasha catchment.

1.2 Statement of the Problem

The flood situation in the Lake Naivasha catchment has attracted significant attention in recent literature due to its ecological and socio-economic implications. The main driver of flooding in the Lake Naivasha Basin is intense rainfall, exacerbated by climate change. Studies by Mulatu *et al.* (2015) and Opere (2013) emphasize that changing weather patterns have led to increased precipitation and prolonged wet seasons, contributing to elevated water levels in the lake and its tributaries. Human activities such as unplanned urbanization and agricultural expansion disrupt natural drainage systems and increase surface runoff, leading to enhanced flood risks and additionally, the alteration of catchment areas through deforestation and land degradation affects the basin's water regulation capacity, intensifying flooding (Imarisha Naivasha Board, 2012). The flood impacts within the Lake Naivasha catchment encompass ecological, agricultural, and socioeconomic dimensions while ecologically, flooding affects the fragile wetland ecosystems surrounding the lake. Increased water levels result in habitat loss and disturbances to bird and aquatic life, affecting biodiversity (WWF, 2015). Agriculture, a significant economic activity in the basin, is severely impacted as flooding damages crops and disrupts farming activities, thus, the flower industry, which relies heavily on water availability and stable weather conditions, is particularly susceptible to flooding-related disruptions (Opere, 2013).

The negative impacts of floods caused by climate change are bound to be felt for a long period and therefore different nations have to adopt adaptation strategies that can trickle down to local communities to mitigate floods (Mugagga, Kakembo, & Buyinza, 2012). Most of the affected communities face similar impacts and therefore a strategy that has been proven workable for one locality can be adopted by others. Effective flood management strategies, combined with conservation efforts in the catchment area, are essential to mitigate the impacts of floods on the environment and the livelihoods of local communities in the region. Most mitigation measures are applied at the coastal areas when it comes to the lakes while forgoing the entire catchment (Zari *et al.,* 2017).

This research explores the effectiveness of EBA strategies that can be used to mitigate floods along all rift valley lakes and others catchments. Ecosystem-based adaptation strategies are approaches that focus on the restoration of the ecosystem and enhancement of its services to protect the society form the negative impacts of climate change. Mitigation measures have been established but they have not met the objective of flood mitigation, however the assessment of using EBA strategies along the lake Naivasha catchment has not been explored to establish if they can help in mitigating the severity and risks of floods in the catchment. Flooding of a given catchment is first determined at the upper part of the catchment where runoff is felt as it flows to the middle catchment where a lot of activities such as urbanization, agriculture and settlement is done as it continues to the lakes or the basins where the run off settles. Mitigation measures such as agroforestry and soil and water conservation strategies have not been applied following the similar sequence so as to ensure little or less runoff that is likely to cause flooding reaches the basins (Ma & Jiang, 2023). Mitigation strategies would also help reduce both economic and social impacts of floods especially in the rift valley lakes which are inhabited by different communities as well as different species of animals and birds.

1.3 Study Objectives

1.3.1 General objective

The overall objective was to determine the effectiveness of ecosystem-based adaptation strategies for flood mitigation in Lake Naivasha catchment, Kenya

1.3.2 Specific Objectives

The study was be guided by the following specific objectives, To;

i. assess the severity of flood occurrence in Lake Naivasha catchment
ii. determine ecosystem-based adaptation strategies for flood mitigation in lake Naivasha catchment.
iii. examine the effectiveness of existing ecosystem-based adaptation strategies for flood mitigation in the lake Naivasha catchment.

1.4 Research Questions

i. How severe is flood occurrence in Lake Naivasha catchment?
ii. What are some of the ecosystem-based adaptation strategies existing in lake Naivasha catchment?
iii. What is the effectiveness of the existing ecosystem-based adaptation strategies on flood mitigation in the lake Naivasha catchment?

1.5 Justification of the Study

This study aimed at meeting the sustainable development goals (SDGs) number 11, 13 and 15. It also focused on achieving the 2030 agenda agreements which include the 2015

Sendai Framework, and UN World Conference on Disaster Risk Reduction (WCDRR) and the Paris agreement on Climate Change. If adopted the findings of this study would inform right recommendations for mitigating the impacts of floods which plays a major role in combating the impacts of climate change (SDG 13). The use of EBA strategies equally helps in protecting, restoring, and promoting sustainable use of terrestrial ecosystems, shows sustainability in forest management, helps in combating desertification in the upper catchment of the Lake Naivasha catchment, and equally halting and reversing land degradation as well biodiversity loss (SDG15). Flood mitigation in the middle catchment which comprises of settlements and cities will enable in ensuring the cities and human settlements are inclusive, safe, resilient and sustainable as required in SDG 13.

This study is equally relevant and significant for communities, decision-makers, and academia. Floods constitute a persistent and deadly danger to people in the Lake Naivasha catchment area's ability to support themselves. Understanding and putting into practice ecosystem-based adaption strategies can provide long-term fixes that not only safeguard people and property but also improve the general well-being of these communities. If adopted by the government and other disaster management authorities, the study can be used to educate locals about efficient flood mitigation strategies that harness the resilience of the environment by concentrating on natural systems like wetlands and forests, thereby reducing vulnerability and enhancing their quality of life.

The study offers crucial insights into evidence-based decision-making for policymakers. The research findings can help shape laws and policies that support ecosystem restoration and preservation as key elements of flood mitigation plans. Ecosystem-based strategies provide affordable alternatives, possibly saving public resources and obviating the requirement for pricey infrastructure. Academically, this research adds to the expanding fields of climate change mitigation, and environmental management. It expands our understanding of ecosystem-based adaptability, particularly in relation to tropical climatic environment. The empirical data and methodology used in this work can help academics and scholars and researchers gain a greater grasp of the complex connection between ecosystems and flood control. Therefore, this research is essential as it addresses a pressing issue with far-reaching implications for communities, policy formulation, and academic pursuits, making it a valuable and timely undertaking.

1.6 Scope and limitations of the study

The study was done in the lake Naivasha catchment in three sections whereby the catchment was divided into; the upper, middle and lower catchments. The study aimed at assessing the severity of floods, identifying the EBA strategies for flood mitigation, and their effectiveness in mitigating the flood risks in Lake Naivasha catchment over the past 30 years from 1993-2023. The upper catchment included the higher altitude areas of the catchment which drain their runoff into the middle catchment that comprises of settlements and urban areas in the catchment. Floods in the middle catchment also influence the lower basin and therefore have to be managed before runoff flows to the lower catchment which holds the lake waters. Floods mitigated in the three stages will help reduce the flow and velocity of runoff flowing into the lake and the amount of silt deposited in the lake basin.

The study was limited to conservation agriculture strategies as well as structural EBA strategies in flood mitigation in the lake Naivasha catchment.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter section provides a critical understanding, discussion, and analysis of the past and current literature in regards to the research topic; *effectiveness of ecosystem-Based Adaptation Strategies in Flood Mitigation along Lake Naivasha Catchment, Kenya*. Therefore, this chapter discusses and analyzes the severity of global, regional, and flood risks in Kenya. It also highlights flood mitigation measures; convention methods of flood mitigation and their shortcomings, Ecosystem-based adaptation strategies, their strengths and shortcomings in flood mitigation.

2.1 Empirical Review

Empirical studies point to the utilization of ecosystem-based adaptation (EBA) strategies for flood-risk mitigation with co-benefits such as better water quality and biodiversity conservation. For instance, in Upper Suswa-Magadi catchment in Kenya, it can be observed that EBA, including agroforestry and afforestation, are cost-effective and flexible alternatives to conventional structural measures (Nashipay et al., 2022). Similarly, South Africa has illustrated that rainwater harvesting hugely contributes to the reduction of urban flooding while providing water resources during dry periods (Busayo et al., 2022). The Lake Naivasha catchment study placed high adoption rates on EBA strategies, such as agroforestry and afforestation, as a means of realizing the dual benefits of flood mitigation and carbon sequestration. Policy support from the Kenyan government, such as the Agroforestry Strategy 2020-2030, has further encouraged the implementation of such strategies; however, studies highlighted mulching and cover cropping as less adapted because of knowledge gaps and supply chain limitations in horticulture, which dominantly practices in the area. Other structural measures like rainwater harvesting systems and soil conservation terraces proved successful to mitigate floods, resembling a similar trend observed in the Atlas Mountains of Morocco, where agricultural terraces reduced the runoff and soil erosion which contributed to flood control (Meliho *et al.,* 2021).

However, other echoing challenges faced by the whole region include, among others, high costs and maintenance measures to be put in place for detention and retention basins in Lake Naivasha. According to empirical evidence, a lot of community awareness and government intervention are required to scale up the adoption of EBA strategies. Indeed, with the sheltering of floods through declining severity-their strengths-must be weighed against a cost-effect technical know-how on such systems, other land uses opposing this type of practice, and the wide-scale field implementation programs for better promotion

2.2 Severity of flood occurrence on a global, regional, and local scale

2.2.1The status of global flood risks

Generally speaking, floods, as natural disasters, have a profound impact on societies worldwide, causing extensive damage to infrastructure, displacing communities, and disrupting daily life according to (Adedeji, Odufuwa, & AdEBAyo, 2012). A study by Geneletti and Zardo (2016) have posited that the increasing frequency and intensity of extreme weather events, attributed to climate change, have elevated global flood risks to critical levels. The causes of global flood risks are intricate, resulting from a convergence of climatic, hydrological, geomorphological, and human-induced factors (Loboguerrero Rodriguez *et al.,* 2018). Climate change significantly amplifies these risks by altering precipitation patterns and elevating the likelihood of intense storms, leading to increased instances of heavy rainfall. This heightened rainfall, combined with the loss of natural water storage due to deforestation and urbanization, leads to rapid runoff and elevated flood hazards.

The rising sea levels and glacial melt further contribute to the vulnerability of coastal and riverine regions, underscoring the multifaceted nature of global flood risks (Zölch, Wamsler, & Pauleit, 2018). Jeb and Aggarwal (2008) have pointed out that the impacts of floods extend beyond the immediate destruction of property and infrastructure while (McGree, Yeo, & Devi, 2010) claimed that communities face the upheaval of daily life, with families being displaced, transportation networks disrupted, and vital services, including water supplies, contaminated. In addition, lives are tragically lost, and social vulnerabilities are exacerbated, disproportionately impacting disadvantaged populations. Additionally, ecosystems bear the brunt of these disasters, suffering from soil erosion, habitat degradation, and ecological disruption. The financial toll is staggering, with flood-related damages incurring substantial economic losses and straining emergency response systems (Merz, Kreibich, Schwarze, & Thieken, 2010).

According to a survey by Garschagen and Romero-Lankao (2015), the increasing frequency and severity of extreme weather events linked to climate change have elevated global flood risks to a critical level and the study further claims that these risks arise from a complex interplay of factors, including changing precipitation patterns, rising sea levels, urbanization, and inadequate land management. Climate change intensifies rainfall patterns, increasing the likelihood of heavy downpours that can overwhelm drainage systems and cause flooding especially in coastal areas that can face additional challenge of sea-level rise, resulting in heightened susceptibility to storm surges and inundation as has been witnessed in Fije (Hills, Carruthers, Chape, & Donohoe, 2013).

Urbanization leads to the creation of impermeable surfaces, reducing natural water absorption and exacerbating runoff and the scale and scope of global flood risks necessitate comprehensive strategies for adaptation and mitigation. Using a critical and comparative understanding of flood risk on a global perspective, some studies have shown that Asia is particularly vulnerable to floods due to its dense population, extensive river systems, and varied climatic conditions (Zölch, Henze, Keilholz, & Pauleit, 2017).

Jayasooriya and Ng (2014) have posited that monsoon seasons bring intense rainfall, leading to widespread flooding across the region and simultaneously, rapid urbanization and deforestation compound the risks, as exemplified in the 2015 Chennai floods in India The urban landscape, insufficient drainage infrastructure, and improper land use exacerbated the disaster, highlighting the need for improved urban planning and climate-resilient infrastructure. Additionally, riverine floods, such as those along the Yangtze River in China, pose significant threats to agriculture, livelihoods, and infrastructure and this challenge in Asia lies not only in addressing immediate flood risks but also in managing the long-term effects of climate change on water resources (Griffiths, Chan, Shao, Zhu, & Higgitt, 2020; Hamel & Tan, 2022).

On the other hand, in the United States, some literatures have claimed that flood risks vary across regions due to diverse geographies, land use practices, and climate conditions (Shames & Scherr, 2019) while the coastal areas along the Gulf of Mexico and the Atlantic Ocean are susceptible to hurricanes and storm surges, as evidenced by Hurricane Katrina's devastation in 2005 (BenDor, Shandas, Miles, Belt, & Olander, 2018). Furthermore, Shames and Sara (2019) claimed that the catastrophic flooding of New Orleans underscored the interconnectedness of natural processes and human interventions. In contrast, riverine floods, such as those along the Mississippi River, result from a combination of heavy rainfall and snowmelt. The historic 1993 flood highlighted the challenges of managing floodplains, as the region grappled with the balance between agricultural practices and flood protection (Adeaga, 2008). The diversity of flood risks in the US underscores the importance of region-specific mitigation strategies that consider both natural and anthropogenic factors.

Lastly, the United Kingdom faces a different set of challenges in managing flood risks. Like in Asia and the US, urbanization, river management, and coastal erosion play crucial roles in flood susceptibility (Naumann *et al.,* 2011). Existing literature has shown that the 2014 winter storms caused extensive flooding, particularly in urban areas like Somerset and as a result to this, various drainage systems were overwhelmed, exposing the tension between urban development and the need for effective water management (Geneletti & Zardo, 2016). The Flood and Water Management Act of 2010 aimed to enhance flood resilience, emphasizing collaborative approaches and community engagement, however, flood risks remain a complex issue, with coastal erosion and rising sea levels threatening both urban and rural areas. The UK's case demonstrates the significance of integrated policies that consider the multifaceted nature of flood risks (BenDor *et al.,* 2018; Naumann *et al.,* 2011)

2.2.2 Regional analysis of floods in Africa

According to existing studies, findings have shown that floods are recurrent natural disasters with severe socioeconomic and environmental implications, affecting regions worldwide, including Africa (Nashipay *et al.,* 2022; Opere, 2013). Based on existing study, urban areas in Africa are rapidly growing exponentially, and this urbanization poses challenges as far as flood management and mitigation is concerned and analysis has shown that poor urban planning, inadequate infrastructure, and informal settlements exacerbate the vulnerability of cities to floods in Africa (Aderogba, 2012). For instance, some studies have posited that rapid urbanization often leads to land encroachment in flood-prone areas, disruption of natural drainage systems and increasing runoff and Lagos, Nigeria, faces recurrent flooding due to a lack of proper drainage systems and uncontrolled construction in low-lying areas (Adedeji *et al.,* 2012; Aderogba, 2012). Moreover, some studies have also shown that climate change has greatly and significantly intensified the urban flood problem in most of the African countries (Adedeji *et al.,* 2012; Ogundele & Ubaekwe, 2019). At the same time, research has shown that increased rainfall variability and extreme weather events have significantly amplify flood risks in Africa and for instance, the 2019 floods in Nairobi, Kenya, were triggered by unusually heavy rainfall, causing destruction in a city ill-equipped to handle such deluges and this was linked to the impacts of climate change (Opere, 2013).

In Africa, researchers have found that river basins are one of the crucial sources of water for agriculture, domestic use, and energy generation, however, literature and situational analysis of floods in Africa have shown that the same rivers can turn into destructive forces during floods as far as climate change and vulnerability is concerned (Winter, Bijker, & Carson, 2017). Existing studies have posited that the Nile River which is the longest river in Africa has witnessed both historic benefits and catastrophic floods over the past years and this has been greatly linked to changes in land cover land use, and climate change and despite the fact that the Nile supports livelihoods and sustains agriculture in Egypt and Sudan, occasional floods jeopardize the beneficial aspects of the river in the areas it passes through (Distefano, 2012). At the same time, some studies have claimed that unplanned land use changes in river catchments in most countries in Africa, including deforestation and wetland drainage, have significantly impacted river flow patterns and in doing so, such alterations exacerbate downstream flooding (Munang *et al.,* 2013). For instance, available literature has documented that the 2020 floods in Sudan that was caused by heavy rainfall and changes in the Blue Nile basin's land use led to unprecedented and unforeseen impact such as human population displacement and interference of agricultural lands (Distefano, 2012).

Simultaneously, Africa’s great lakes such as Lake Victoria, Lake Tanganyika, and Lake Nyasa, have played a vital and significant role in regional economies over the past years as far as available literature is concerned and in addition, these lakes, however, have also presented unforeseen, and unprecedented flood risks that have greatly changed the human lifestyle as far as agricultural activities are concerned (Meijer, 2018). Most importantly, existing studies have shown that variability in lake water levels as a result to climate change and human interventions, like dam construction, have significantly affected communities around the lakeshores as far as their livelihoods are concerned. Lake Victoria in East Africa for instance, has experienced fluctuations in water levels, causing shoreline erosion and flooding in lakeside towns (Kyeyune, 2015). At the same time, available literature has shown that the 2021 floods in Bukoba, Tanzania, were highly linked to rising lake levels due to climate change and the floods greatly disrupted fishing activities, damaged infrastructure, and even spread waterborne diseases in lakeside settlements (Meijer, 2018). As far as the flood challenges are concerned in Africa, various strategies have been proposed by various researchers as far as mitigation measures are concerned and according to (Mugagga *et al.,* 2012), addressing floods issues in Africa requires a multi-pronged approach involving governments, local communities, and international organizations.

Researchers have claimed that urban flood management demands improved urban planning, investment in drainage systems, and sustainable construction practices as is evident in west Africa where the Lagos State Government's "Clean and Green" initiative exemplifies efforts to mitigate urban floods by enhancing waste management and restoring waterways (Aderogba, 2012). At the same time, effective river basin management involves upstream-downstream coordination as well as the fact that sustainable land use practices, reforestation, and the preservation of wetlands can mitigate flood impacts and this is because available literature has also shown that initiatives such as the Nile Basin Initiative seek collaborative strategies among riparian states to ensure sustainable river basin development and management as far as human and ecosystem sustainability is concerned and this is based on the fact that lake basin flood management necessitates adaptive strategies (Nashipay *et al.,* 2022). Early warning systems, community-based disaster preparedness, and shoreline erosion control are essential (Ogundele & Ubaekwe, 2019) and Uganda's approach to managing Lake Albert's rising water levels through community involvement showcases the significance of localized solutions (Masiga 2012; Kyeyune, 2015).

2.2.3 Floods occurrence in Kenya

According to existing studies, the flood situation in Kenya has garnered increasing attention from researchers and policymakers due to its recurring and adverse effects on both urban and rural areas. One prominent cause of flooding in Kenya is intense and erratic rainfall patterns resulting from climate change. Studies such as Shames & Heiner (2014) and Mulatu, van Oel, and van der Veen (2015) highlight that increased rainfall variability and prolonged heavy downpours have contributed to flash floods in urban and rural settings and at the same time urbanization and poor land-use planning further exacerbate the issue.

World Wide Fund for Nature (WWF) (2015) emphasize that unplanned construction and encroachment on floodplains disrupt natural drainage systems, impeding water flow and causing urban floods and furthermore, the geographical location of Kenya, with its topographical variations, makes it susceptible to both river and flash floods during the rainy seasons (Imarisha Naivasha Board, 2012). Based on existing studies, several researchers have claimed that the impacts of flooding in Kenya are wide-ranging and multifaceted that requires various stakeholder approaches and research Mulatu *et al*. (2015) has underlined that floods disproportionately affect vulnerable populations, including low-income urban dwellers and rural communities on far wider scale. At the same time, it has led to destruction of homes, displacement of residents, and loss of livelihoods not only in the urban areas but also in the rural setup agricultural activities are also severely hampered, resulting in food shortages and increased food prices (Mulatu *et al.,* 2015).

There are several factors that are affecting the hydrological cycles and human activities have played a major role in the experienced hydrological changes. Some human activities such as agriculture and industrialization have contributed to the change in the water balance through the extraction of water, construction of impoundments and climate change factors. Studies have established that climate change has contributed to the prevalence of disasters such as drought in some place and floods in others (Aura *et al.,* 2023; Merz *et al.,* 2014). The change fluctuations in the water levels have effects on the ecosystem, as it interrupts the natural and breeding habitats of some animals such as the fish and other wildlife and the germination of coastal plants. In the recent past, the Kenyan Rift Valley lakes such as lake Baringo, Bogoria, Nakuru, Naivasha, Elementaita, Turkana, and Solai, have had their water levels rising and negatively impacting the communities occupying these areas (Nashipay *et al.,* 2022).

For, instance the waters in lake Naivasha have risen submerging the surrounding vegetation and islands hence effecting economic activities like fishing, tourism, and agriculture (Muia *et al.,* 2021). The different catchments in the Kenyan rift valley have shown consistency in the rise of water levels since 2010 with a significant rise evident in 2020 (Aura *et al.,* 2023). In other catchments, floods have destroyed infrastructure like schools, hospitals, roads and even markets in the urban and local settlements. The destruction of property results in the displacement of the people and in return causing population pressure and other social issues in their new settlements. There has been a notable rise in water borne diseases such as malaria in some areas especially the western part of Kenya. Floods are natural phenomena which are caused by increase precipitation caused by climate change globally. However, human activities such as industrialization, deforestation, agriculture among others have contributed to the increase of floods through soil erosion that results siltation. Change in land use land cover leaves the land bare in most causes hence making it vulnerable to erosion.

2.2.4 Flood analysis and occurrence: A case of Lake Naivasha catchment

Lake Naivasha and its surrounding catchment have been historically susceptible to flooding events, with these occurrences often having significant implications for both the environment and local communities. The basin's vulnerability to floods can be attributed to several factors, including its unique geographical setting and land-use practices (Karanja, 2022). One key factor contributing to flooding in the Lake Naivasha basin is the region's irregular rainfall patterns. The basin experiences two distinct rainy seasons, the long rains from March to June and the short rains from October to December (Nyokabi, Wambua, & Okwany, 2021). Intense and prolonged rainfall during these periods can lead to rising water levels in the lake and the saturation of the surrounding catchment area.

To estimate the impact of rainfall on runoff and flooding, the Rational Formula is commonly applied in hydrological studies. This formula, expressed as;

$$Q = CIA,$$

calculates the peak runoff rate (Q) as a function of the runoff coefficient (C), rainfall intensity (I), and catchment area (A). It has proven particularly useful in small watersheds for quantifying surface runoff during intense rainfall events. In the context of Lake Naivasha, this formula can help estimate the contribution of rainfall to peak flows in tributaries and assess the potential for flooding in low-lying areas. The runoff coefficient (C) varies based on land-use practices, such as deforestation and urbanization, which are known to increase surface runoff and exacerbate flood risks in the basin (Karanja, 2022).

The Rational Formula is widely used for estimating peak runoff due to its simplicity, ease of application, and minimal data requirements. It is particularly effective for small catchments with uniform land use and short rainfall durations, making it a practical tool in regions like the Lake Naivasha catchment, where data availability may be limited. However, its limitations include the assumption of constant rainfall intensity, uniform watershed characteristics, and neglect of infiltration and storage effects, which can reduce accuracy in complex or large catchments (Hua, Liang, and Yu, 2003). Despite these drawbacks, the formula remains valuable in flood studies due to its ability to provide quick, first-order runoff estimates, especially when used in conjunction with other hydrological models or field data for validation. Its efficiency and adaptability make it a useful starting point for flood risk assessments in data-scarce regions.

The flood analysis also uses the Weibull formula. The Weibull formula is a widely applied statistical tool in hydrology and flood frequency analysis for estimating the probability of exceedance of specific hydrological events, such as peak flows or rainfall intensities. The formula,

$$P = 100 \times \frac{m}{(n+1)}$$

, where P represents the probability of exceedance, m is the rank of the event in a descending order of magnitude, and n is the total number of observations, provides a straightforward method to predict the likelihood of an event being equaled or exceeded. This method assumes that events are independent and follow a stationary distribution, making it particularly useful in assessing extreme hydrological events for infrastructure design and flood risk management ((Sugiyama, Vudhivanich, Whitaker, & Lorsirirat, 2003)). Despite its simplicity and practicality, the Weibull formula has limitations, such as its reliance on historical data, which may not fully account for the variability introduced by climate change ((Sugiyama et al., 2003)). Nevertheless, it remains a valuable tool due to its ease of application and ability to provide critical insights for flood frequency analysis and risk assessment. Human activities in the basin also play a significant role in exacerbating flood risks. Deforestation, urbanization, and agricultural expansion have led to increased surface runoff and reduced natural flood mitigation capabilities. The removal of vegetation and wetlands that once absorbed excess water has left the basin more susceptible to inundation during heavy rains (Karanja, 2022).

Furthermore, the absence of well-defined outlets for Lake Naivasha means that excess water cannot easily drain away, making the lake particularly sensitive to fluctuating water levels. In the past, uncontrolled water levels have caused flooding, displacing communities, damaging infrastructure, and affecting agriculture. Efforts to address flood risks in the Lake

Naivasha basin have included the implementation of flood early warning systems and land-use planning initiatives (Misongo, 2020). However, the challenges posed by climate change and the ongoing need for sustainable development continue to pose significant challenges. Therefore, flood occurrences in the Lake Naivasha basin are influenced by a complex interplay of factors, including rainfall patterns, land-use changes, and the lake's unique hydrological characteristics (Misongo, 2020). Effective flood management strategies, combined with conservation efforts in the catchment area, are essential to mitigate the impacts of floods on the environment and the livelihoods of local communities in the region.

To ensure the collection of representative data on the socio-environmental dynamics within the catchment, the Yamane formula (1973) was adopted to determine the sample size for this study.

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

This statistical formula, widely recognized for its simplicity and efficiency, calculates the required sample size for a finite population while accounting for an acceptable margin of error (Kuswanto, Pratama, & Ahmad, 2020). This formula is advantageous for its simplicity and ease of use, particularly in cases where the population size is known. The main strength lies in its ability to provide a reliable sample size without the need for complex statistical software. However, its limitation lies in the assumption of a simple random sample and the need for an assumed margin of error, which may not always reflect the variability in more heterogeneous populations. Despite these limitations, the Yamane formula was chosen for this study due to its practicality and ability to efficiently determine a sample size that would provide valid insights into the perceptions and awareness of flood mitigation strategies among the local population. It ensures that the findings are generalizable to the larger community while maintaining manageable survey efforts.

By applying the formula, the study ensured that the selected sample accurately represented the population of the Lake Naivasha basin, facilitating a comprehensive analysis of participants' perceptions and knowledge. The use of such an approach underscores the importance of precise and reliable sampling methods in addressing complex challenges such as flood risk and management.

2.3 Ecosystem-based adaptation strategies for flood mitigation

Numerous scholars have shown that communities all over the world have turned to conventional flood mitigation techniques in order to deal with the enduring threat of floods (Pedersen Zari *et al.,* 2017; Njeru, Mabwoga & Konana, 2022). These tried-and-true methods seek to reduce the devastation caused by flooding through a variety of structural improvements, however, a closer examination of these techniques exposes fundamental flaws that raise concerns about their durability and long-term usefulness (CTCN, 2017). Studies already done show that levees and embankments are two of the most traditional yet common flood prevention techniques. Communities and infrastructure are protected by these human-engineered barriers, which act as bulwarks against advancing floodwaters. But these frameworks have significant built-in constraints. The presence of them tends to encourage habitation of high-risk floodplain areas, despite the fact that they might provide a sense of protection (ECOWAS, 2017). These barriers are prone to erosion and slow disintegration over time, yet complacency frequently ignores this fact. Moreover, embankments and levees have a tendency to break catastrophically if they are breached, causing an uncontrollable and rapid deluge. This is where the potential danger resides (FAO, 2005).

The channelization and dredging of natural watercourses constitute another traditional strategy and the purpose of changing river channels artificially is to increase water flow and reduce flood hazards. This strategy does not, however, come without consequences. The delicate balance of the aquatic ecology and river dynamics is regularly upset by the changes. Channelization can accelerate water flow, resulting in increased erosion downstream, worsening the erosion of riverbanks and changing sediment transport patterns (Njeru, Mabwoga & Konana, 2022). Dredging may unintentionally disrupt aquatic life and ecosystems while seeking to improve water transportation, leading to unforeseen ecological effects. Given their propensity to exacerbate environmental imbalances, these measures' viability is debatable.

Additionally popular as traditional flood mitigation strategies are the construction of reservoirs and the use of floodplain zoning. Reservoirs serve as storage facilities, collecting extra water during periods of high rainfall and releasing it gradually to prevent floods downstream (Adedeji *et al.,* 2012). However, this method faces difficulties when rainfall exceeds the reservoir's storage capacity, resulting in regulated or uncontrolled releases that may still cause flooding of the downstream area. In contrast, floodplain zoning aims to limit exposure by limiting development in flood-prone areas. However, in urban areas where land is in high demand, responsibilities like enforcing zoning laws and defining floodplains frequently prove to be challenging. A false sense of security can be created by improperly applied zoning, which leaves built environments ill-prepared for unforeseen flood disasters (Garschagen & Romero-Lankao, 2015).

The tendency of traditional flood mitigation techniques to maintain structural rigidity while compromising the innate resilience of natural systems is a prevalent theme underlying their failures. These techniques disregard the complex relationships among ecosystems and the larger hydrological cycle by concentrating on single solutions that control the physical enviroment (Geneletti & Zardo, 2016). Flood risks may ultimately increase rather than decrease due to unexpected consequences of changing natural processes and disregarding the intricate connection of rivers, floodplains, and wetlands. A paradigm shift in flood mitigation measures is important in light of these critical assessments and a comprehensive and integrated approach is necessary rather than merely relying on conventional approaches. In order to maintain the integrity of natural systems and take into account the possibility of adaptation and development, this strategy should combine structural interventions and nature-based solutions (Munang *et al.,* 2013; Geneletti & Zardo, 2016).

Green infrastructure can be integrated to absorb surplus water, improve water quality, and reduce flood hazards. Examples of this include wetland restoration and afforestation. Incorporating traditional knowledge, promoting community involvement, and increasing public awareness can also help us gain a more thorough understanding of local flood dynamics (Pedersen *et al.,* 2017). Kenya has implemented various flood mitigation and adaptation strategies to address the challenges posed by recurrent floods. One notable approach is the establishment of early warning systems. Musau *et al.* (2020) highlight the effectiveness of community-based early warning systems in informing residents of impending floods, allowing for timely evacuation and preparation. Additionally, the Kenyan government, in collaboration with international organizations, has invested in improving infrastructure, such as constructing flood-resistant roads and bridges (Opere, 2013). Furthermore, community-driven initiatives, such as the participatory mapping of flood-prone areas, have been successful in enhancing local resilience (Mulatu *et al.,* 2015). Despite these efforts, challenges remain in effectively addressing the flood situation in Kenya.

Limited financial resources hinder comprehensive flood management programs, particularly in rural areas and lack of coordinated efforts between national and local authorities, resulting in fragmented flood management strategies (Mulatu *et al.,* 2015; Opere, 2013). Additionally, while various studies have focused on the impacts of floods, there is a dearth of research exploring the long-term psychological effects of flooding on affected communities. Several studies have showed that efforts to mitigate global flood risks encompass a spectrum of EBA strategies that seek to minimize the frequency, intensity, and repercussions of flooding and these strategies encompass both structural and non-structural measures that play a significant role alleviating the impacts of floods (Shames & Scherr, 2019; UNDP, 2015a).

2.3.1 Structural flood mitigation strategies

Structural measures involve the construction of physical infrastructure designed to manage floodwaters and in most cases dams, levees, and floodwalls offer direct protection against inundation, although their design must carefully consider downstream impacts and evolving flood patterns (Mugagga, Kakembo & Buyinza, 2016). A study by Masiga (2012) claimed that reservoirs and retention basins serve as temporary water storage facilities during heavy rainfall, gradually releasing water to reduce downstream flooding while Pour *et al.* (2020) claimed that channelization modifies river pathways to optimize water flow and prevent overbank flooding, although ecological considerations are vital. Research by Winter *et al*. (2017) underscores the importance of enhancing the basin's water storage capacity through the construction of reservoirs and improved water management techniques and watershed management programs, such as reforestation and soil conservation, are vital for reducing surface runoff and erosion (WWF, 2015).

In other studies, retention ponds and detention basins have equally played a role in flood reduction. For instance, study done in Mesquita city in Brazil for a rainfall event with return period of 50 years shows the effectiveness of using detention basins and retention ponds to mitigate floods in the city (Jacob *et al.,* 2019). The water is collected in the detention ponds and used for other purposes like irrigation and domestic uses while excess is released slowly hence reducing the floods. In Northern Tehran in ran, storm water is also managed in retention ponds to mitigate the effects of floods and help in soil conservation (Ahmadisharaf, Alamdari, Tajrishy, & Ghanbari, 2021). Soil conservation terraces have equally helped mitigating floods especially on the hilly slopes and high-altitude areas. For example, with increased population, people have resolved into settling on the slopes of hills, escarpments and mountains, as they settle, there is experienced changes in land use land cover which in most cases result in high risks if soil erosion (Masiga, 2012). Soil conservation terraces come in handy in controlling erosion and flooding such areas. In Morocco, a study done on the Ourika watershed to control floods on the slopes of the Atlas Mountains indicated a positive outcome from the use of soil conservation terraces (Meliho, Khattabi, Nouira, & Orlando, 2021). Applying similar approaches on the different parts of the lake Naivasha catchment, a positive outcome can be attained on mitigating floods on the catchment and other catchments with similar characteristics.

2.3.2 Non-structural flood mitigation strategies

Non-structural measures focus on enhancing resilience through planning, awareness, and sustainable practices (Kaspersen *et al.,* 2017) and on the other hand Ogundele & Ubaekwe (2019) claimed that early warning systems provide timely information about impending floods, enabling communities to evacuate and take precautions, thereby reducing loss of life and property. Land use planning, encompassing zoning regulations and sustainable urban development, helps prevent construction in flood-prone areas and promotes the use of permeable surfaces that aid in water absorption as opined by Hamel & Tan (2022). According to Griffiths, Chan, Shao, Zhu & Higgitt (2020), embracing ecosystem-based approaches involves the restoration and preservation of natural habitats such as wetlands, mangroves, and forests, which contribute to flood resilience by absorbing excess water and minimizing runoff (Barnes, Bathurst, Lewis, & Quinn, 2023). Agroforestry and afforestation measures have been used to increase forest cover in different parts of the world to help curb the harsh impacts of climate change such as drought and floods in south central Chile (Bathurst *et al.,* 2022). Conservation agriculture practices such as minimum tillage, planting of cover crops, intercropping, and mixed farming have also proven to be effective in soil and water management hence reducing flood risks (Abdallah *et al.,* 2021).

While community engagement and preparedness play pivotal roles in flood risk reduction, educating and raising awareness among the public about flood risks and preparedness measures are essential for fostering an effective response and evacuation during flood events (BenDor, Shandas, Miles, Belt & Olander, 2018). Furthermore, a study conducted in Indonesia by Afriyanie *et al.* (2020) showed that community-based adaptation capitalizes on local knowledge and practices to inform mitigation efforts, acknowledging that indigenous communities often possess invaluable insights into flood patterns and adaptation strategies while strengthening the capacity of local authorities and disaster response teams through capacity building is essential for efficient emergency management during floods (Yongchi & Yong, 2023).

Urban green spaces have played a major role in mitigating floods and enhancing and ecosystem balance through environmental management and cultural benefits. Examples of urban green spaces include engineered green roofs, grassy lawns, and residential parks. Urban green spaces have provided land cover in spaces that were initially bare hence reducing the floor of runoff and protecting the urban centers from erosion. They also help in increasing the rate of infiltration thereby lesser runoff is released to the basin. Research done in Luohe City in central China where floods were dominant indicated that the presence of urban green spaces reduced the flood risks and enhanced land cover in the city (Bai, Mayer, Shuster, & Tian, 2018). Rainwater harvesting is also another structural measure for flood mitigation where rainwater in collected in structures such as water pans, dams and weirs and released slowly (Akter, Tanim, & Islam, 2020). Roof catchment also helps in mitigating floods as the rainwater is collected and used for various purpose rather than draining freely into the basin and resulting into floods (Palla & Gnecco, 2022)

2.3.3 Flood Mitigation Measures in Kenya

In Kenya, flooding is a recurrent predicament with major environmental, social and economic consequences. As flooding is becoming more prevalent, the country has been able to put in place non-structural and structural measures aimed at reducing the flooding risks. Such measures are aimed at reducing the impacts of the flooding on society, the economy, the built environment and the environment. A detailed and comprehensive flood mitigation strategies for Kenya in general and for the Lake Naivasha basin in particular demonstrates the need for ecosystem and integrated approaches to solving this problem (Herrnegger *et al.,* 2012). At the same time, the principal use of structural measures such as levees, dams, and embankments are to restrain and redirect floodwater. An example includes the Masinga dam that is located in the seven fork's hydropower scheme that operates for the generation of electricity, but functions as a flood controlling dam as well. Also, for instance, levees and drainage systems have been built in the Nyando Basin and other flood prone areas to keep the farmlands and settlements dry from inundation. The efficiency of such measures is often constrained due to failure to maintain them, siltation and wide variations in climatic conditions worsening extreme climatic events (Karanja, 2022).

Other non-structural measures have equally gained momentum in Kenya because they are cost-effective and sustainable. These include flood forecasting and early warning systems, community-based disaster preparedness programs, and land-use planning. The Kenya

Meteorological Department, in collaboration with regional and international partners, has developed advanced forecasting tools to predict extreme rainfall events and issue timely alerts (Kyambia & Mutua, 2015). In addition, the community-based initiatives include emergency response training and the formation of disaster management committees to empower the local people in the management of flood risks. Land-use policies have included zoning regulations, with the enforcement of riparian buffer zones, so as to minimize exposure to flooding by discouraging settlements and agriculture in high-risk areas. Ecosystem-based adaptation is an emerging key component of flood mitigation strategies in Kenya (Mulatu *et al.,* 2015). EbA focuses on restoration and sustainable management of ecosystems to enhance their natural capacity for water flow regulation and reduction of flood risks. Examples include reforestation programs in water catchment areas, such as the Mau Forest Complex, contributing to increased water retention and reduced surface runoff. Wetland conservation initiatives, including the restoration of degraded wetlands in the Lake Victoria Basin, have also demonstrated significant potential in mitigating flood risks by acting as natural sponges that absorb excess water during heavy rains (Mumina & Bourne, 2020).

The Lake Naivasha catchment is a critical economic and ecological hotspot that, over time, has been predisposed to flooding through a mix of natural factors and human activities. Dominated by intense land-use changes like deforestation, expansion of agriculture, and urbanization, the hydrological regime of this catchment area has shifted and increased vulnerability toward flood occurrences. Subsequently, many different measures related to flood mitigation have been pursued to address these issues and protect both the ecological integrity and economic activities in the catchment (Herrnegger *et al.,* 2012).

In the Lake Naivasha catchment, for example, one of the main measures put in place has been establishing riparian buffer zones for protection to the lake and its feeding streams from encroachment and pollution. These will reduce surface runoff and sedimentation that enhance flooding. Reforestation and afforestation programs in the upper catchment areas done by government agencies and non-governmental organizations restore degraded landscapes and increase water infiltration. These efforts help not only in mitigating flooding but also contribute to biodiversity conservation and carbon sequestration (Herrnegger *et al.,* 2012). There is also emphasis on wetland restoration for flood mitigation in the Lake Naivasha catchment. Wetlands like KWS Hippo Point wetland and Malewa Delta play an important role in the regulation of water flow and flood control. Restoration has included removal of invasive species, replanting native species, and sensitization of the community on wetland conservation. These initiatives have enhanced wetland capacity in floodwater absorption and supported livelihood activities among the locals through fishing and ecotourism (Muthuwatta, 2004).

Community-based approaches have also enhanced flood resilience in the Lake Naivasha catchment. Local communities have actively participated in disaster preparedness and response activities, which include early warning systems and evacuation plans. Public awareness campaigns and capacity-building programs have equipped residents with knowledge and skills to adapt to flood risks. Moreover, stakeholder collaboration among government agencies, private sector players, and civil society organizations has promoted integrated and participatory approaches to flood management (Nyokabi *et al.,* 2021). Notwithstanding these few initiatives, the challenges in flood mitigation in the Lake Naivasha catchment are still evident. Small budgets, poor enforcement of environmental regulations, and climate change continue to reduce the effectiveness of existing measures. These challenges require a multi-faceted approach that incorporates traditional engineering solutions with innovative and sustainable strategies, such as ecosystem-based adaptation. The institutional strengthening will be needed regarding capacities, stakeholder coordination, and leveraging scientific research and technology in building flood resilience in the catchment and beyond (Odongo *et al.,* 2015). The mitigation of floods in Kenya, therefore, involves a series of structural, non-structural, and ecosystem-based strategies that have been put in place to reduce the adverse impacts of flooding. The Lake Naivasha catchment exemplifies how integrated and participatory approaches can be used to enhance flood resilience while promoting sustainable development. Kenya will be further capable of managing floods and protecting its people and ecosystems by addressing the existing challenges and scaling up the successful initiatives (Opilo & Mugalavai, 2023).

2.4 Effectiveness of existing ecosystem-based adaptation strategies for flood mitigation

Efforts to address the flood situation in the Lake Naivasha catchment encompass a mix of structural and non-structural measures. Integrated land-use planning is crucial to curb urban sprawl and encroachment on floodplains, thereby minimizing flood risks as well as community-based approaches that involve local residents in flood forecasting and response have proven effective in enhancing adaptive capacity (Shames & Heiner, 2014).

Compositing and boma manuring strategy were used in Tanzania to mitigate floods in the semiarid area occupied by the Maasai pastoralists and the cultivation of *Cenchrus ciliaris* L. (Buffel grass) helped in flood reduction in the area (Ngenzi, Ruvuga, Msalya, & Maleko, 2024). Despite these strategies, challenges remain in managing the flood situation in the Lake Naivasha Basin. Inadequate coordination among stakeholders, including local communities, government agencies, and industries, hampers the implementation of comprehensive flood management plans (Opere, 2013).

A promising strategy for reducing the effects of climate change is ecosystem-based adaptation (EBA), which makes use of the innate resilience of natural systems (Njeru *et al.,* 2022). Utilizing ecosystems' natural capacities, ecosystem-based adaptation increases resilience and reduces vulnerabilities. EBA tactics have a number of distinguishable advantages. By preserving ecological processes and services that act as a buffer against risks brought on by the climate, they firstly promote natural resilience. This is demonstrated in coastal regions where mangrove regeneration reduces erosion and storm surges (Naumann *et al.,* 2011). Secondly, EBA plans frequently coincide with objectives for biodiversity conservation, protecting the species and habitats that support ecological stability (Rao *et al.,* 2013). For example, maintaining forests preserves vital ecosystems for both plant and animals in addition to sequestering carbon. Thirdly, EBA combines traditional and local knowledge, boosting community empowerment and engagement. As stewards of their habitats, indigenous cultures have important knowledge about the dynamics of ecosystems and adaptation strategies (Geneletti & Zardo, 2016).

Simultaneously, EBA holds promise, but it also faces difficulties that should be carefully taken into account. The prediction of adaption effects may be hampered by complex ecological processes. For instance, according to Munang *et al*. (2013), restoring coral reefs for storm protection depends on a variety of variables, including coral species and oceanographic circumstances. Furthermore, due to different ecosystem characteristics and local contexts, scaling up EBA techniques to regional levels is difficult (Pedersen *et al.,* 2017). It is crucial to make sure that the spatial distribution of vulnerable communities corresponds with suitable environments.

Another challenge is policy integration, as EBA is frequently neglected in favour of engineered solutions in adaptation planning (Zölch, Wamsler & Pauleit, 2018). The policy narratives must change to emphasize the inherent worth of ecosystems in order for mainstreaming to be effective. A multifaceted strategy is needed to overcome these obstacles. EBA can be implemented more successfully if it is incorporated into larger climate and development programmes (Pedersen *et al.,* 2017). EBA will become the cornerstone of adaptive governance due to policy consistency rather than remaining an afterthought. The holistic aspect of EBA can be improved by cross sector cooperation (Yongchi & Yong, 2023). Urban planning can be integrated, for example, to support green infrastructure and increase urban resilience (Yongchi & Yong, 2023). Strong scientific research is also necessary for comprehending ecosystem dynamics, forecasting adaption results, and choosing appropriate treatments (Ogundele & Ubaekwe, 2019). Simulating ecosystem reactions to various climate scenarios is made easier by the expanding discipline of ecological modelling (Ma & Jiang, 2023). According to Ogundele & Ubaekwe (2019), an emphasis should be placed on the social aspects of EBA and understanding the needs and vulnerabilities of the community is crucial for ensuring equitable outcomes. To co-design adaptation solutions that respect local communities' rights and traditions, there must be meaningful engagement with them. In addition, gender dynamics are acknowledged, and women are included in decision-making processes, which increases the resilience of both ecosystems and society (UNDP, 2015a).

Successive case studies highlight their benefits in boosting ecological resilience, biodiversity conservation, and the incorporation of local knowledge. For instance, use of mulching techniques to reduce the rate of evapotranspiration and minimize flooding agricultural lands and settlements has proven effective in rice growing areas (El-Beltagi *et al*., 2022). But its drawbacks, such as the complexity of ecosystem dynamics, difficulties with scaling up, integration of policy, and social justice issues, call for careful planning and policy consideration (Ogundele & Ubaekwe, 2019). An integrated strategy encompassing policy, science, and community involvement is required to address these difficulties. The potential of EBA solutions may be fully tapped to build a resilient future in the face of climate change by mainstreaming EBA into climate policies, encouraging collaboration across sectors, performing rigorous scientific research, and giving social equality priority (Zölch *et al.,* 2018).

Additionally, gaps exist in understanding the long-term impacts of flooding on the mental and psychological well-being of affected communities, an area that requires further exploration in research. When structural interventions are separated from a larger ecological viewpoint, they run the risk of unintentionally exacerbating the problems they are meant to address (Zölch, Wamsler & Pauleit, 2018). A well-balanced mix of structural engineering and ecological harmony is necessary to pave the way for more efficient flood control. Societies may go beyond the bounds of convention and forge a resilient future in the face of rising flood threats if they acknowledge the complex interplay of natural processes, welcome innovation, and place a high priority on maintaining ecosystem services (Zölch, Henze, Keilholz & Pauleit, 2017). Reiterating earlier literature analysis and discussion, investigations have revealed that, despite offering temporary relief, the conventional flood mitigation strategies have serious flaws that call into question their sustainability and long-term efficacy.

2.5 Theoretical Review

The theoretical literature review grounds this research in the broader framework of ecosystem-based adaptation (EBA) approaches to flood risk reduction. Environmental flow strategies are often based on climate adaptation, ecosystem management, and sustainability concepts. These approaches fit within theories, such as the socio-ecological systems (SES) theory that focuses on the interconnectedness of human and ecological systems. The link between environmental, and human resilience can be made through SES theory. It claims that ecosystems, provided they are sustainably managed, can provide critical services such as flood mitigation, biodiversity conservation, and climate regulation (Mugagga *et al.*, 2021). Alternatively, you can try a different theoretical framework and the idea behind it, like adaptive management theory and the learning-action approach- an iterative process of learning through action and adapting to changing conditions. This is particularly true for flood-prone areas, where climatic and anthropogenic drivers resulted in highly dynamic hydrological systems. Adaptive management, characterized by flexibility and learning by doing, can motivate communities and stakeholders to increasingly improve various EBA strategies (e.g., afforestation and agroforestry) to prevent flooding (Shah *et al.,* 2019).

Furthermore, EBA techniques are related to the resilience theory of ecology, which emphasizes the ability of ecosystems to withstand disturbances and remain functional. Focusing on wetland restoration or building soil conservation terraces, the communities strengthen the resilience of the ecosystem and lessen the exposure to flooding impacts. The theoretical concepts discussed above all derive the justification for the use of EBA approaches in the Lake Naivasha catchment area. At the same time, they highlight the importance of a multidisciplinary approach that integrates ecological health, community participation, and policy support to create sustainable and adaptive flood mitigation measures (Pedersen Zari *et al.,* 2017). This review provides the basis for examining the empirical evidence of EBA effectiveness in the subsequent section.

2.5.1 Socio-Ecological Systems (SES) Theory

The Socio Ecological Systems (SES) Theory focuses on the interactions between human societies and ecological systems through a dimensional approach. According to this theory, healthy ecosystems are crucial for human beings, and the management of ecosystems is essential to address environmental issues such as floods. Under the SES theory, both ecological and social systems are viewed as one unit and as responsive systems that can change structure and functioning in reaction to external or internal perturbations. This theory further stresses on the need of ensuring the ecosystem resilience, which is the capacity to withstand disturbances, change and still provide a range of functions (Cote &

Nightingale, 2012). Floods for instance are mitigated by absorbing upland water, stabilizing soil and regulating hydrological cycles, which wetlands and forests ecosystems do best. In connection with areas of Lake Naivasha drainage basin, which are prone to flooding, SES theory emphasizes the need for holistic strategies that incorporate ecological as well as social aspects.

For instance, afforestation, agroforestry and wetland restoration activities can be referred to as EBA strategies that satisfy the SES principles by improving environmental conditions and increasing the capacity of the communities to cope with floods. SES theory also highlights the role of individual stakeholders in the management of ecosystem (Virapongse *et al*., 2026). It accepts that the communities, agencies, and others have to work together in the formulation of active management measures that would be effective considering the climatic and social changes. The possibilities of the socio-ecological systems to adapt, as the theory postulates, are improved through being actively engaged, through learning through doing, and through combining local and scientific knowledge. Using this theory, the study places ecosystem-based flood mitigation strategies within a broader context concerning the prevention of environmental degradation, the improvement of the community, and the adaptability of the climate (Hertz & Schlüter, 2015). That is how this theoretical perspective fulfills its functions in the evaluation of the environmental benefits of EBA strategies in Lake Naivasha and places that target the same objectives.

2.6 Conceptual framework

The relationship between environmental variables, conservation agriculture practices, infrastructural variables, and the occurrence of floods is a complex and interconnected web that underscores the critical role of government policies and regulations as intervening variables in mitigating or exacerbating flood risks. Environmental variables such as climate change and deforestation significantly influence flood patterns. Climate change leads to more frequent and severe weather events, including heavy rainfall, while deforestation reduces natural flood buffers like forests (Shames & Scherr, 2019). Conservation agriculture, on the other hand, involves sustainable farming practices that minimize soil erosion and increase water infiltration, potentially reducing flood risk. The choice to implement such practices becomes crucial in areas prone to flooding. Infrastructural variables encompass the built environment, including levees, dams, and drainage systems. These structures can either protect or exacerbate flood risks. Well-maintained and strategically designed infrastructure can mitigate flood damage, whereas inadequate or poorly designed systems can amplify the destructive potential of floods (Shames & Scherr, 2019).

However, the effectiveness of environmental and infrastructural variables is heavily influenced by government policies and regulations. These interventions can dictate land-use planning, environmental protections, and infrastructure development standards (Rao *et al.,* 2013). Robust policies that promote sustainable land management, responsible infrastructure development, and disaster preparedness can enhance a region's resilience to floods. Conversely, lax or outdated regulations can expose communities to greater flood risks. To summarize, the relationship between environmental variables, conservation agriculture, infrastructural variables, and floods is intertwined, with government policies and regulations acting as crucial intervening variables as represented in Figure 2.1.

Effective policies can promote sustainable practices and infrastructure development that mitigate flood risks, while inadequate regulations can leave communities vulnerable to devastating floods. Recognizing and addressing this complex web of interactions is essential for reducing the impacts of floods and building more resilient societies.

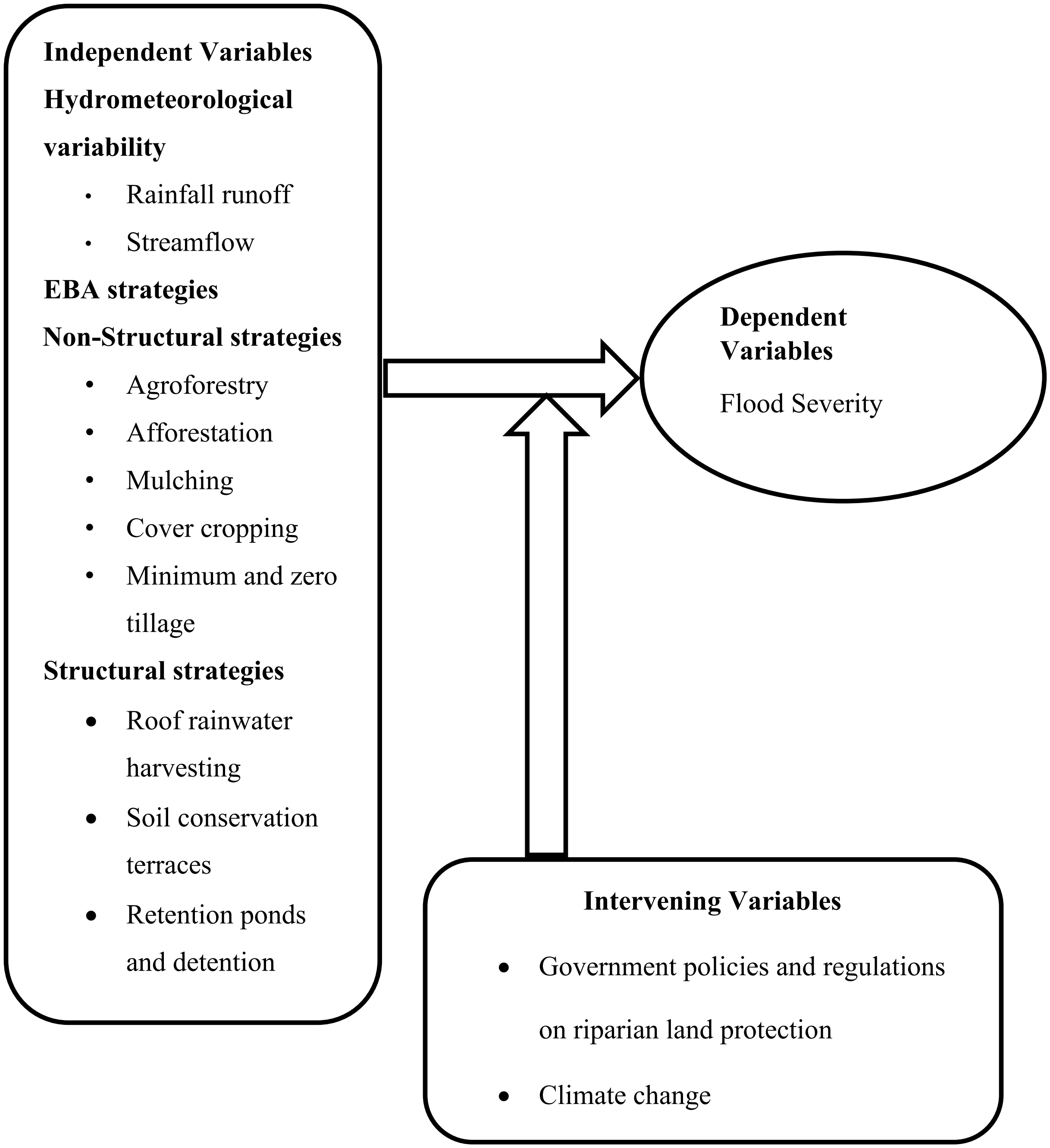

Figure 0.1Conceptual Framework

Source: Researcher, 2024

2.7 Literature Gap

From the literature review, a number of key gaps in understanding the application and effectiveness of EBA strategies for flood mitigation have been identified, especially in the Lake Naivasha catchment. While the previous studies indicated benefits from some EBA strategies, such as agroforestry and afforestation, in terms of runoff reduction and biodiversity enhancement, detailed analyses concerning scalability and long-term effectiveness within different socio-ecological settings were scant. Thirdly, few studies were focused on the integration of structural and non-structural measures or a community involvement in the development of flood resilience. Another gap involved data related to local perceptions on the effectiveness of EBA measures and those factors that influence occupation, awareness, and socio-economic status to adopt the strategy. Moreover, much of the previous research badly assessed the wide co-benefits-from an EBA strategy like improved water quality-and their relationships with the Sustainable Development Goals.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Introduction

This chapter outlines the research methodology used in the study. It includes the research design, sampling procedures, data collection methods, and the ethical considerations taken into account. The methodological approach adopted aligns with the aim of the research which is to determine the effects of ecosystem-based adaptation strategies in flood mitigation along Lake Naivasha catchment to provide a comprehensive understanding of the role of ecosystem-based adaptations (EBAs) in flood mitigation within the Lake Naivasha catchment area.

3.1. Description of the Study area

Lake Naivasha is located on the floor of Africa's Eastern Rift Valley and lies within an area of approximately 139 km^2 during the wet season (Owiti & Oswe, 2007) and the lake Naivasha catchment covers approximate 3400 m^2. It is located at Latitudes 0^0 41' 0" S and 0^0 50' 0" S and Longitudes 36^0 17' 0" E and 36^0 26' 0" E. Lake Naivasha catchment geographical location is mainly distinguished by Kinangop Plateau and Eburru Hills as it lies between these physical features. At roughly 1,890 metres (6,200 feet) above sea level, it is situated in a distinctive area of the Rift Valley system. In Fig 3.1 a map of lake Naivasha Basin and its catchment. The catchment experiences an equatorial type of climate comprised of two rainy seasons and a dry season. The rainy seasons are experienced between April and May, then September and October while the dry season sin in December, January and February.

The catchment area of the lake, which comprises a number of tiny streams and rivers flowing from the nearby Aberdare Mountains and the Mau Escarpment, serves as the primary source of the lake's drainage pattern. The Malewa River is the main source of water into Lake Naivasha. Due to the lake's unusually high altitude and lack of a visible outflow, its waters are mostly lost through evaporation, which is particularly significant. A moderate, subtropical highland climate best describes the climate in the area surrounding Lake Naivasha. The long rains, which occur from March to June, and the short rains, which come from October to December, are distinct wet and dry seasons in this region. A popular location for both tourists and agriculture, the region around Lake Naivasha boasts consistent, mild temperatures all year long.

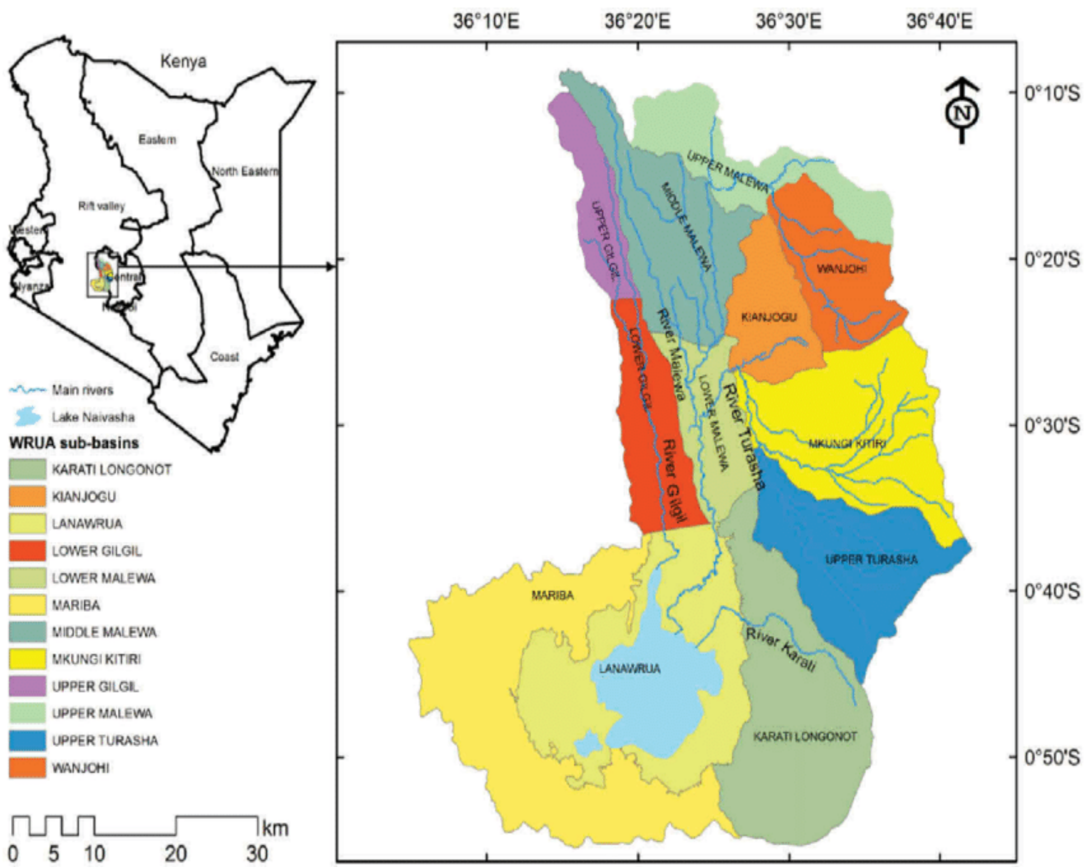

Figure 0.1Map of Lake Naivasha Catchment

Source:(Ogada, Krhoda, Van Der Veen, Marani, & van Oel, 2017)

3.2 Research Design

The study employed a mixed methods combined quantitative and qualitative approaches to comprehensively assess severity of floods in Lake Naivasha catchment, identify the existing EBA strategies in the catchment and understand their effectiveness in mitigating floods in the catchment. This approach was selected due to the complexity of the research problem. As such, the mixed methods research approach allowed for a comprehensive understanding of the relationship between EBAs and flood mitigation which is the primary problem affecting Lake Naivasha and other Rift Valley lakes.

Table 0.1Summarized matrix for the study objectives

SN	Research objective	Data variables	Data sources	Data collection method	Data analysis method
1	Assess the severity of flood occurrence on Lake Naivasha catchment	Flood intensity reduction Rainfall intensity Catchment characteristics	FGD KII KMD WRA	Questionnaires Kenya Meteorological Department (KMD)data	Descriptive Analysis (Excel and Mann-Kendall trend test) Rational formula
2	Determine ecosystem-based adaptation strategies for flood mitigation in lake Naivasha catchment.	Afforestation Agroforestry Wetland Restoration Minimum and Zero Tillage Cover Cropping Mulching Rainwater Harvesting Soil Conservation Terraces Detention Basins Retention Ponds	FGD KII	Interviews Questionnaires	Descriptive Analysis (Excel, mean and standard deviation)

3	Examine the effects of ecosystem- based adaptation strategies for flood mitigation in the lake Naivasha catchment.	Reduced Flood Risk Improved Community Resilience Improved Soil Stability and Prevention of Soil Erosion Improved Biodiversity and Conservation Economic Benefits Improved Water Quality	KII Surveys	Questionnaires	Descriptive Analysis (Excel, mean and standard deviation)

Source; Researcher, 2024

The quantitative methods involved the collection and analysis of primary numerical data obtained from Kenya Meteorological Department (KMD), and Water Resources Authority (WRA) to identify trends and patterns in hydrological variabilities to assess the severity of floods in the catchment, while the qualitative methods focused on gathering and interpreting non-numerical data through household interviews, Key Informant Interviews (KII), and Focus Group Discussion(FGD) interviews to explore the underlying reasons and perceptions of the residents on EBA strategies and flood severity in the catchment hence identifying the EBA strategies and examining their effectiveness in mitigating floods in the catchment. Therefore, the mixed methods approach utilized in the study aimed at providing a better understanding of the effectiveness of EBAs for flood mitigation in the catchment.

The research design was classified as primarily descriptive and correlational since the study aimed to describe the existing ecosystem-based adaptation strategies, their perceived effects on flood mitigation, and the severity of flood occurrences as perceived by different stakeholder groups. Additionally, the research design allowed for the exploration of the relationships between variables such as occupation, residency duration, and awareness or perception of flood severity and EBA effectiveness.

3.2.1 Severity of flood occurrence on Lake Naivasha catchment

The study adopted a descriptive research design to address the first specific objective. This design was selected to provide a systematic description of the severity of flood occurrences within the catchment area, based on both primary and secondary data.

Primary Data Collection:

A survey questionnaire was administered to residents of Lake Naivasha catchment to gather subjective perceptions of flood severity. The questionnaire included questions about the frequency and intensity of flood events experienced by participants, as well as the impacts of floods on livelihoods and the environment.

Participants rated flood severity on a Likert Scale of 1 to 5, where:

1 = Not severe

2 = Moderately severe

3 = Severe

4 = Very severe, and

5 = Extremely severe

Secondary Data Collection:

Rainfall secondary data between 1993-2023 was obtained from the Kenya Meteorological Department and the Water Resources Authority and was used to compute the Runoff using the rational formula (Equation 1)

$$Q = 0.0027CIA \qquad (1)$$

Where;

Q: Runoff peak rate (cubic meters per second)

C: Runoff coefficient (average of surface-specific coefficients) =8.5%(Muthuwatta, 2004)

I: Rainfall intensity (mm/hr)

A: Area of the watershed (44239.9 hectares, calculated using Google Earth Engine ((Aja, Elias, & Obiahu, 2020).

Runoff coefficients for various land uses were applied, as shown in table 3.2

Table 0.2:Run-off coefficients of different surfaces.

Ground cover	**Runoff Coefficient, c**
Pasture	0.12-0.62
Meadow	0.1-0.5
Cultivated land	0.08-0.41
Forest	0.05-0.25
Parks, Cemeteries	0.1-0.25
Unimproved areas	0.1-0.3
Lawns	0.12-0.62
Residential areas	0.3-0.75
Business areas	0.5-0.95
Industrial areas	0.5-0.9
Asphalt Streets	0.7-0.95
Brick streets	0.7-0.85
Roofs	0.75-0.95
Concrete streets	0.7-0.95

Source, (Herrnegger et al., 2021)

The rainfall intensity was also computed from the rainfall data using the formula; Rainfall intensity = total rainfall amount/the duration (mm/hr), (Martel, Brissette, Lucas-Picher, Troin, & Arsenault, 2021). The Mann-Kendall trend test was applied to detect trends in rainfall and streamflow, while flood frequency analysis was conducted using the Weibull distribution method to predict return periods and exceedance probabilities (Nyokabi, Wambua, & Okwany, 2021; Sugiyama *et al*., 2003)).

The probability of exceedance is a statistical measure used to estimate the likelihood that a particular event (such as a flood) will exceed a specified threshold within a given period. This concept is often used in flood frequency analysis to determine the likelihood of a given streamflow or rainfall value being exceeded in a specific time frame ((Sugiyama et al., 2003)). The probability of exceedance was calculated as in equation 2

$$P = 100 \times \frac{m}{(n+1)} \qquad (2)$$

Where

P - Probability of exceedance (%)

m - Rank of the daily mean flows

n - Total number of observations

The formula calculates the probability that a given daily flow (or rainfall) value will be exceeded, based on the rank of that value in a sorted list of all observations. A higher rank value (m) leads to a higher probability of exceedance. Essentially, the higher the rank, the more likely it is that the value will be exceeded in future observations. Flood prediction was essential as it estimates the return periods giving the magnitude and periods43 that are necessary for early warning systems. Streamflow and exceedance probability graphs were plotted to illustrate the magnitude and return periods of flood events, providing essential insights for early warning systems and flood management strategies.

3.2.2 EBA strategies for flood mitigation in the Lake Naivasha catchment

The study employed a descriptive research design to identify and document ecosystem-based adaptation (EBA) strategies applicable for flood mitigation in the Lake Naivasha catchment. This design was selected to document the EBA strategies based on participants' knowledge and awareness.

Primary Data Collection:

Data for this objective were collected using a structured survey questionnaire specifically designed to explore participants' knowledge and awareness of EBA strategies in the catchment. The questionnaire included closed-ended questions asking participants to identify specific EBA strategies they were aware of, such as afforestation, reforestation, wetland restoration, among others. It also included open-ended questions inviting participants to suggest additional strategies they believed could be implemented for effective flood mitigation.

The EBA strategies mentioned formed categorical independent variables, representing the various techniques identified by respondents. The data collected through these questionnaires were used to identify existing EBA strategies and provide insights into the knowledge and perceptions of local stakeholders regarding their potential for effective flood mitigation. The findings informed the evaluation of EBA strategies and helped to document the range of practices that could be applied in the catchment.

3:2.3 Effectiveness of existing EBA strategies in mitigating floods on the Lake Naivasha catchment

The study adopted a descriptive and correlational research design to evaluate the perceived effectiveness of existing ecosystem-based adaptation (EBA) strategies in mitigating floods in the Lake Naivasha catchment. This design was selected to describe the perceived impacts of existing EBA strategies and explore relationships between participant characteristics and their perceptions of the effectiveness of EBA strategies in flood mitigation.

Primary Data Collection

The data was collected using a survey questionnaire, which includes closed-ended questions on participants' observations of changes in flood occurrences (categorized as decreased, increased, or no change) since the implementation of EBA strategies. The questionnaire also included likert scale-based questions (ranging from 1 to 5) to assess participants' subjective perceptions of the effectiveness of specific EBAs in reducing flood severity. Additionally, the questionnaire included open-ended questions inviting participants to share insights on the benefits and drawbacks of EBA implementation in the catchment.

Additional questions in the questionnaire captured the demographic information, including: Occupation (categorical variable): Used to analyze differences in EBA awareness and perceived effectiveness based on respondents' primary livelihoods, residency duration (continuous variable): Used to examine its relationship with participants' awareness and perceptions of EBA strategies and their effectiveness.

3.3 Target population

This study targeted the households in the Lake Naivasha Catchment which included households in the upper, middle and lower parts of the catchment. This included parts of Karati, Lake View, lake Naivasha, Malewa, and Sokoni areas. These areas are characterized by different population as shown in table 3.2 based on the 2019 Kenya Bureau of Statics (KNBS) Census conducted in 2019. The total number of households in the stud area was approximated to be 29,190.

Table 0.3: Population of the study area

Area	Sex			Households		
	Male	Female	Total	Conventional	Group Quarters	Total
Karati	5,789	5,574	11,363	3,303	218	3,521
Lakeview	19,157	20,115	39,286	13,640	48	13,688
Malewa	5,853	5,442	11,296	3,993	-	3,993
Lake Naivasha	15	6	21	*9*	-	*9*
Sokoni	10,486	11,074	21,562	7,979	-	7,979
Total	41300	42211	83528	28924	266	29,190

Source: KNBS 2019

3.4 Sampling Procedures and sample size

The study population comprised residents of the Lake Naivasha catchment, including farmers, fishermen, tour guides, and other individuals directly or indirectly affected by flooding. the respondents to household questionnaires were selected randomly from a random frame list of about 29190 households of residents in the catchment.

3.4.1 Sample size

The sample size was calculated using the Yamane formula, (1973) (Kuswanto, Pratama, & Ahmad, 2020) for finite population formula shown in Equation 3;

$$n = \frac{N}{1+N.e^2)} \qquad (3)$$

where;

n= sample size

N= population size (29,190 for Lake Naivasha catchment)

e = margin error (0.05).

$$n = \frac{29190}{1+29190\times0.05^2)}$$

n= 395

Assumptions of the Yamane Formula:

1 Normal Distribution: The formula assumes that the population is normally distributed, or that the sample size is large enough for the Central Limit Theorem to apply. This is a typical assumption when working with a finite population, and it ensures that the sample will be representative of the entire population.

2 Continuous Variable: The formula also assumes that the population being studied involves a continuous variable. In this case, the population (the number of people in the Lake Naivasha catchment) is treated as a continuous variable for the purposes of sample size determination, even though it is discrete in nature.

3 Random Sampling: The formula assumes that the sample is selected randomly, ensuring that each individual has an equal chance of being included in the study.

The house-hold sample size was computed as a proportion of the sample size was calculated as in equation 4

$$x = n \times \frac{Q}{P} \qquad (4)$$

Where

x= proportion

n= sample size

Q= area population

P= total population

Table 0.4:Sample size per area

SN	STUDY AREA	HOUSE HOLD	SAMPLE SIZE
1	Karati	3,521	47
2	Lake view	13,688	185
3	Malewa	3,993	54
4	Lake Naivasha	9	2
5	Sokoni	7,979	107
6	Key stakeholders from different organizations such as administration, WRA, KMD, county Agriculture officers, NEMA, and Kenya Redcross - 6		
	TOTAL	**29190**	**395**

Source, Researcher, 2024

3.5 Data collection

The data collection methods included the use of questionnaires to collect qualitative data on respondents' awareness of EBA strategies, perceived changes in flood occurrences, and perceived flood severity. Interviews with key stakeholders were used to gather qualitative insights into the effects of EBA strategies, challenges faced, and additional mitigation measures. Finally, the rational formula was used to calculate the streamflow and runoff which was vital in the visualization of the distribution of flood-prone areas, the flood severity, flood patterns, and the effectiveness of implementing EBA strategies within the catchment. Rainfall secondary data was also obtained from the Kenya Meteorological Department and the Water Resources Authority from different gauging stations as in figure 3.2;

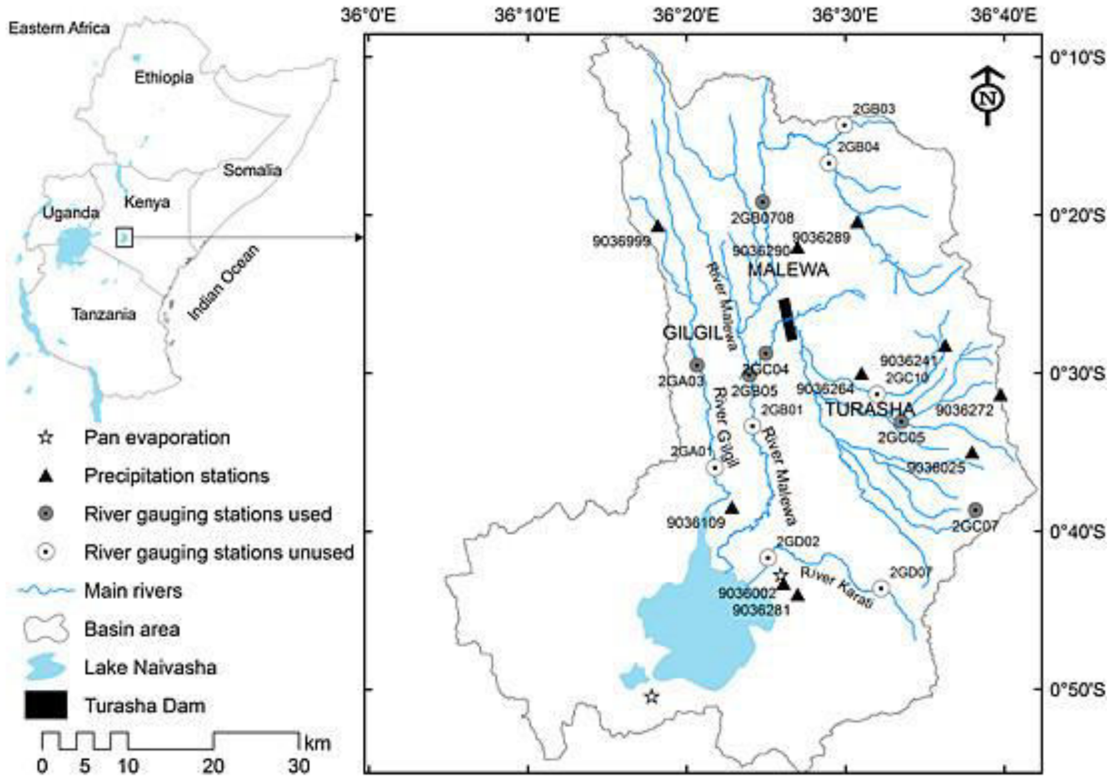

Figure 0.2 Gauging stations in lake Naivasha catchment

Source: (Odongo et al., 2015).

The secondary data on rainfall and streamflow were obtained from the different stations in the catchment as shown in table 3.4 and 3.5 respectively. The reliability of each data per station was detected using the mass curve and double mass curve. The mean monthly rainfall for all the stations was calculated using the Theissen polygon method because the stations are not uniformly distributed in the catchment and they also have varying measurements.

Table 0.5: Rainfall Gauging stations

S/NO	STATION	LONGITUDE	LATITUDE	ALTITUDE	RECORDS(YEARS)
1	9036025	-0.58333	36.6333	2635	64
2	9036002	-0.71667	36.4333	1907	86
3	9036241	-0.46667	36.61667	2605	60
4	9036264	-0.5	36.51667	2418	53
5	9036290	-0.3667	36.45	2315	46
6	9036294	-0.45	36.667	2175	32
7	9036336	-0.2667	36.28333	2510	40

Table 0.6:Stream gauging stations along Malewa river

S/NO	STATION	River	Y-UTM	X-UTM	RECORDS(YEARS)
1	2GB1	Malewa	9937654	0210988	77
2	2GB5	Malewa	9945348	0210217	53
3	2GB4	Malewa	9969390	02109913	44

3.6 Validity and reliability of the data instruments

3.6.1 Pilot Study

The questionnaires were administered to 13 respondents. The 13 respondents represented more than 10% of the total sample based on (Connelly, 2008) recommendations. Similar questionnaires were also administered to the same respondents after some time and the answers were compared for both tests to assess the consistency.

3.6.2 Instrument Validity

The validity of the instrument is the ability of an instrument to meet its desired purpose by measuring and performing and it is designed to perform (Taherdoost, 2016). Instrument validity was achieved through the study used 13 respondents in a pilot study to assess their understanding EBA strategies and could comprehend the questions, easily, clearly, and logically and to gauge the approximate time needed for one to complete a given questionnaire and assess its length.

3.6.3 Instrument Reliability

The reliability of an instrument refers to its ability yield similar results consistently over several attempts (Taherdoost, 2016). In this study, the instrument reliability was tested using the test-retest technique through pilot study. The questionnaires reliability was measured using the Cronbach's alpha computed using the formula in equation 5 below (Alinaitwe, Apolot, & Tindiwensi, 2013)

$$Alpha = \frac{NC}{v+(N-1)C} \qquad (5)$$

Where

N = the number of items,

v = the average variance

C = the average inter-item covariance.

From the computations, the Cronbach's alpha coefficient value was above 0.7 and was consistent for all the questions in the different categories of the questionnaire hence the instrument was adopted for the research.

Table 0.7 Reliability statistics table

	Cronbach's Alpha	Cronbach's Alpha Based on Standardized questions	No of Items
Climatic variables	.755	.760	10
EBA strategies	.756	.759	10
Flood risks and impacts	.772	.773	8
Flood mitigation factors	.717	.701	7
Flood risk reduction	.803	.807	9

Source; Researcher, 2024

3.7 Estimation of missing data

This study applied the arithmetic mean method to estimate precipitation data that was missing from the secondary data provided by KMD and WRA. According to research done by (Sattari, Rezazadeh-Joudi, & Kusiak, 2017) the computational results computed using adaptive-additive algorithm (AA-algorithm) performed were the best compared to other classical statistical methods hence its use in this study to estimate the missing data

The missing rainfall 'Px' (Sattari et al., 2017) given as in Equation 6:

$$P_x = \frac{1}{n}\sum_{i=1}^{n} Q\, P_i \qquad (6)$$

‘Q’ = number of nearby stations

'Pi' = precipitation at the interpolating station

'Px' = missing precipitation.

3.8 Data analysis

Based on the type of data collected, descriptive statistics summarized and described the key variables and their distributions, while a correlation analysis examined the relationships between variables, such as occupation and awareness of EBA strategies, or residency duration and perceived flood severity. Chi-Squared test was used to examine the statistical significance of differences in occupation and awareness of EBA strategies. The qualitative data made use of thematic and content analysis to identify key themes, patterns, and insights related to EBA strategies and flood mitigation. Therefore, the interview transcripts needed careful review, and organization of field notes before data coding and final categorization to identify emerging themes and patterns. The trends in rainfall and streamflow were estimated using the Mann-Kendall trend test as used in other studies in the area by (Nyokabi *et al*., 2021; Odongo et al., 2015).

The Mann-Kendall test is a non-parametric test commonly used to detect monotonic trends (increasing or decreasing) in time-series data, such as rainfall. The Mann-Kendall test does not assume a specific distribution of the data, making it ideal for environmental data like rainfall, which can often exhibit non-linear patterns. The test works by comparing each value in the time series with the following values to assess whether the data points tend to increase or decrease over time. The result of the test provides a statistic, usually denoted as S, and the significance level is assessed to determine whether the trend is statistically significant. A positive value of S suggests an increasing trend, while a negative value suggests a decreasing trend. The p-value associated with the test helps to determine whether the observed trend is statistically significant.

As such, the mixed methods approach combined descriptive, correlational, and inferential analyses to provide a robust framework for addressing the research objectives and answering the research questions posed in the study. Table 3.6 provides a summarized matrix of the study objectives.

3.9 Ethical considerations

The study received ethical approval from Masinde Muliro University of Science and Technology and a research permit from the National Council of Science, Technology, and Innovation (NACOSTI). The researcher further sought permission from the respective County Commissioners and County directors of education, fisheries, agriculture, and environment before carrying out the study. Participants were informed about the study's purpose and their voluntary participation. Confidentiality and anonymity were ensured through the use of coded identifiers and the secure storage of data.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the findings derived from the analysis of data collected during the study. The analysis specifically focused on addressing the three research objectives: (1) assessing the severity of flood occurrences in the Lake Naivasha catchment, (2) identifying ecosystem-based adaptation strategies for flood mitigation in the Lake Naivasha catchment, (3) determining the effectiveness of existing ecosystem-based adaptation strategies in the catchment. The subsequent sections detail the results obtained for each objective, offering insights into the effectiveness of ecosystem-based adaptation strategies in mitigating flood risks within the Lake Naivasha catchment.

4.1 Severity of flood occurrence in the Lake Naivasha catchment area

The study computed the trends in rainfall, runoff, and streamflow of the catchment to assess the flood severity and percentage exceedance. The interview questions also sort to assess the participants' perception on the severity of floods in the catchment and the effectiveness of EBA strategies in mitigating the floods.

4.1.1 Rainfall trends

From the secondary data obtained from the Kenya Meteorological Department and Water Resources Authority an analysis of the average mean annual rainfall between 1993-2023 was drawn as shown in Figure 4.1 Understanding the rainfall patterns in the catchment was essential as it informed the streamflow, and runoff's, frequency and volume in the catchment.

4.1.1.1 Temporal analysis

The mean annual rainfall for the catchment was computed as shown in Figure 4.1. From the analysis, the amount of rainfall received in the catchment shows an increasing trend except from 1998-2004 where the amount of rainfall received was lesser compared to the other years. The highest amount of rainfall recorded was in 2023 and the least was in 1998. The rainfall amount received has been showing a consistent increasing trend from 2019-2013 and this explains the increase in floods experienced in the catchment during this period which is consistent with the findings of (Karanja, 2022; Nyokabi et al., 2021).

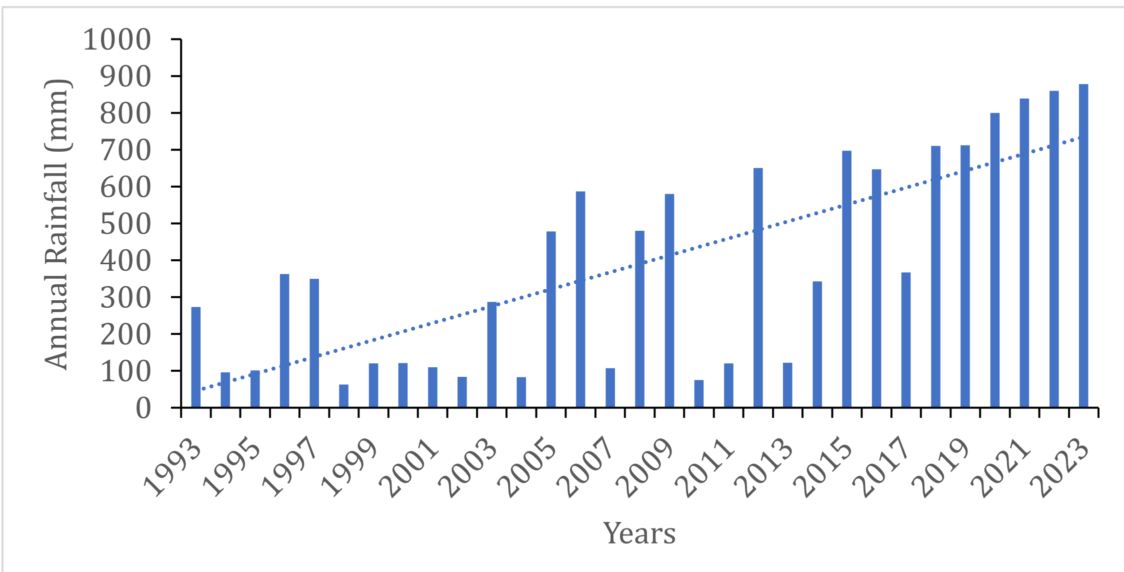

Figure 0.1Mean Annual Rainfall (mm) received in Lake Naivasha catchment (1993-2023)

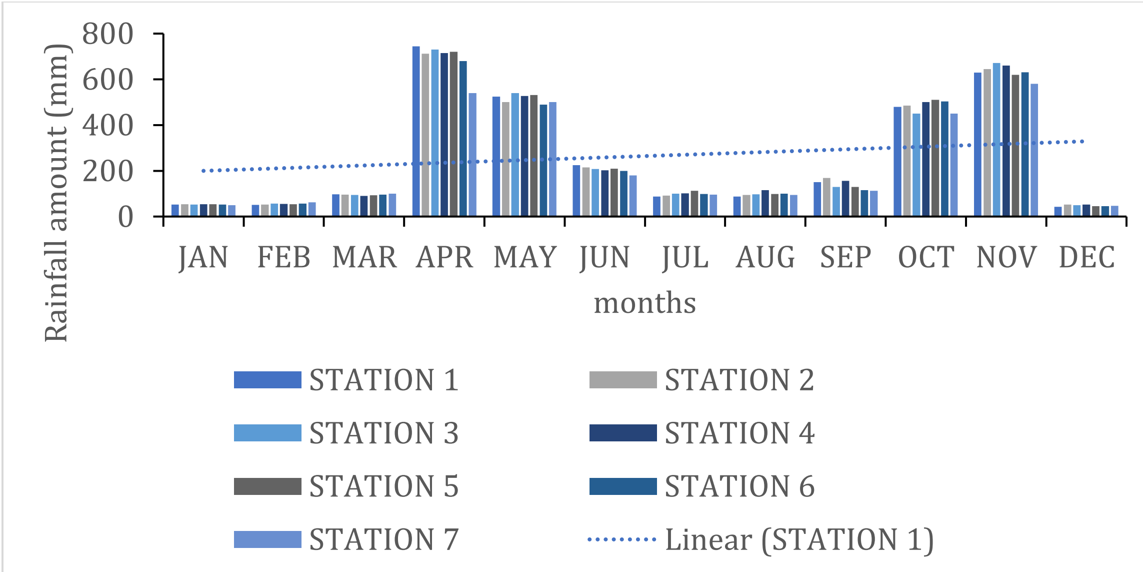

Figure 0.2:Mean monthly rainfall in the stations

Rainfall trends in the different stations were computed as in Figure 4.2 and from the analysis, the different areas in the catchment experience similar rainfall patterns. ANOVA results indicated that there was no significant difference ($p > 0.05$) in the rainfall from the different stations.

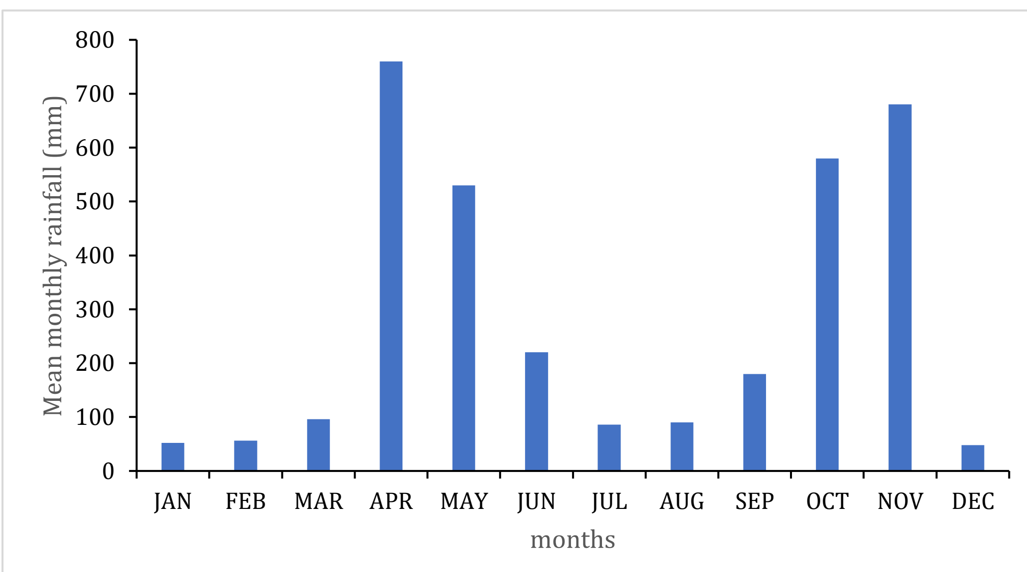

Figure 0.3:Mean Monthly Rainfall for the study period (1993-2023)

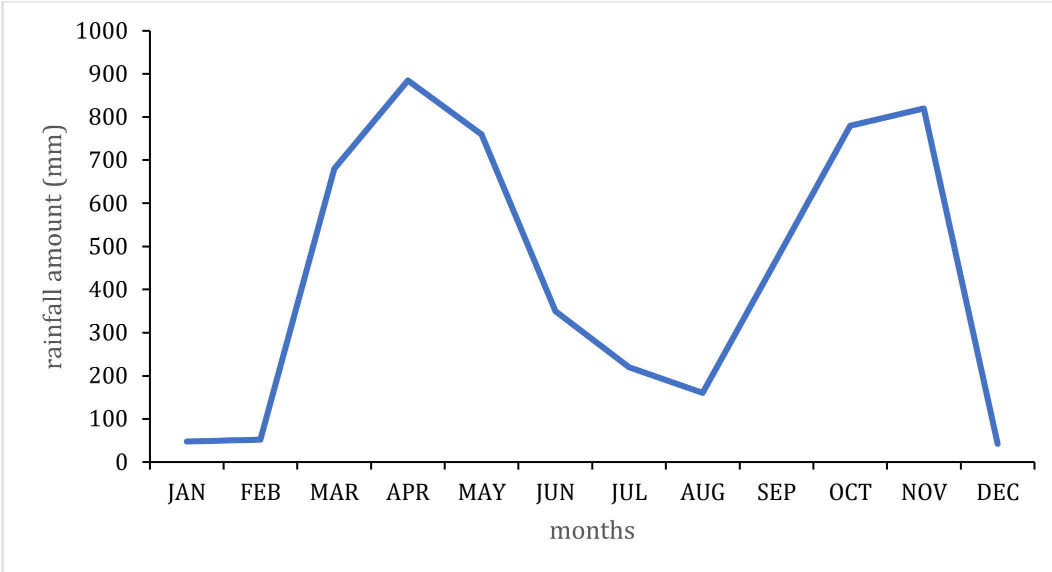

Figure 0.4: Trends in mean Monthly Rainfall for the study period (1993-2023*)*

Figures 4.3 and 4.4 show the trends in the mean monthly rainfall in the catchment over the study period. The analysis indicated that the catchment experiences bi-modal patterns of rainfall with two rainy seasons as shown in Figures 4.3 and 4.4. From the Figures, the highest amount of rainfall is experienced between April and June (long rain season) with the wettest month being April which has an average of 760mm of rainfall. The second season is between September and November (short rain season) with November recording the highest rainfall of about 680mm. The two dry seasons are experienced from July to September and December to February with a mean rainfall of less than 40mm. Research done by (Muthuwatta, 2004; Nyokabi et al., 2021) on the modeling of rainfall and runoff in the catchment also indicated a similar trend. Whenever there is an increase in rainfall, the catchment experiences a rise in extremely severe floods. One of the tour guides from the tour-guides' association started,

> "This region has flooding issues whenever it rains. Initially, our lake was smaller with a lot of fishing activities and tourism that was attracted by the wildlife that live here. However, over time, the water levels have been rising submerging trees. As you can see, several trees have been dried up and the birds around the lake have migrated. The residential areas around the lake have also flooded making the affected families relocate to other areas. Our roads and streets have been submerged by water even the police station and the nearby schools."

The catchment experiences floods during the two rainy seasons which affects a lot of activities in the catchment such tourism, schooling, business, farming, administrative activities, fishing, among others. The government through institutions such as NEMA, environmental department in the county government of Nakuru, and other stakeholders provide early warning systems through media announcements as well as unblocking drainage systems before the rains to provide for easy drainage of runoff. Evacuation of affected families residing in the lower catchment and those occupying riparian lands are also done.

4.1.1.2 Runoff analysis

The study analyzed the duration of rainfall and rainfall intensity which are the major factors that influence the amount of runoff experienced in the catchment as stated in the rational formula.

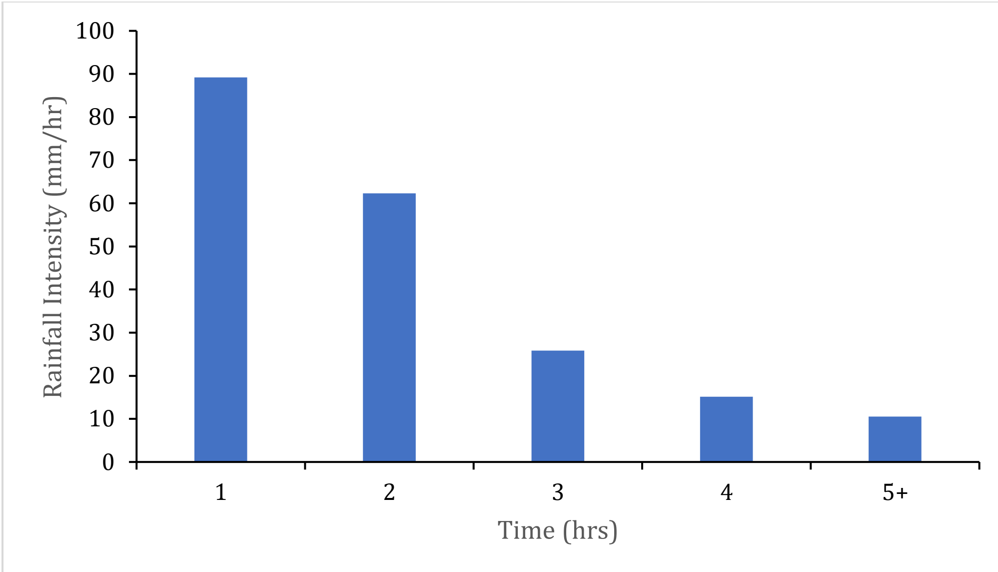

Figure 0.5: Rainfall duration of the catchment from 1993-2023

Secondary rainfall data from KMD indicated the cumulative rainfall amount received daily. The hourly results calculated in the catchment depicted that the highest rainfall intensity recorded was between 60-90mm/hr and it lasted for 1 hour followed by 30-60mm/hr that lasted for 2 hours, 15-30mm/hr for 3 hours and drizzles experienced could last between 4-8 hours as shown in Figure 4.5.

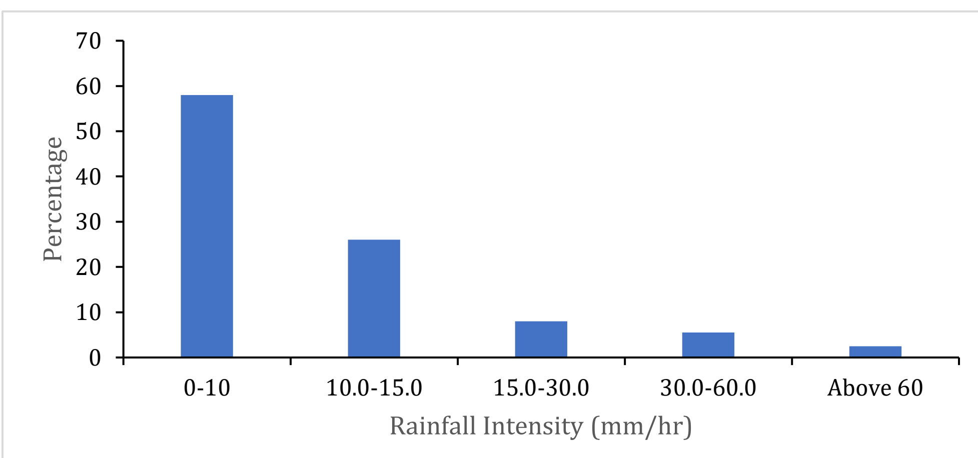

Figure 0.6: Mean rainfall intensity for Lake Naivasha catchment from 1993-2023

The analysis in Figure 4.6 indicated that drizzles with an intensity between 0-10 mm/hr were common with the highest percentage of 58% followed by light rains between 10-15mm/hr with 26%. Moderate rains with an intensity of 30-60mm/hr and 15-30mm/hr were about 26% and 8% respectively. Heavy rains received in the catchment had a higher intensity (above 60mm/hr) with 2.5% of the total number of events.

Figure 0.7: Runoff trend between 1993-2023

From the obtained data, the trend in rainfall runoff from 1993-2023 was computed using the Mann-Kendall trend test as shown in Figure 4.7. The Z-values indicated decreasing trends observed between 1993-2010 and increasing trends from 2011-2023. Statistically, the trends indicated no significant change except for the three years (1998,1999 and 2010) that had a decreasing trend in the P-values which is consistent with (Muthuwatta, 2004; Nyokabi et al., 2021; Odongo *et al.*, 2015). The analysis indicated that while rainfall intensity remained fairly uniform over the years, the surface runoff varied, particularly from 2012 to 2020, when the region experienced a notable increase in surface runoff. In 2012 there was a significant reduction in rainfall while in 2020 the rainfall received in the catchment was higher and kept increasing hence the increase in the runoff as also seen i (Karanja, 2022; Nyokabi *et al.*, 2021).

The increase in rainfall-induced runoff was directly proportional to the increase in rainfall intensity and duration. The increase in runoff could also have been resulting from the change in LULC among other factors such as poor farming methods. Naivasha is well known for its growth through industrialization and horticultural production of flowers. Change in LULC has resulted in increased population, erosion, drainage issues, increase in the area of bare land and other factors that affect the rate of infiltration resulting in increased runoff. The trend in rainfall indicated an continuous increase in the amount of rainfall from 2020-2023 which explains the rising water levels in the lake basin of the catchment in the same years (Karanja, 2022). According to (Karanja, 2022) the water levels of the rift valley lakes have been increased since 2020 due to the heavy rainfall received in the region over this period.

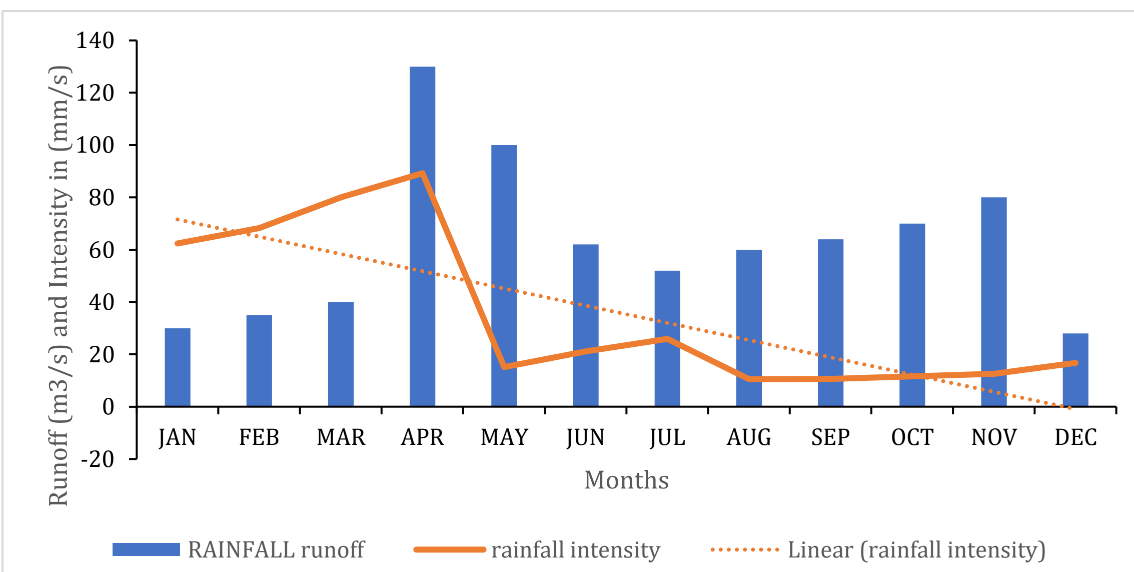

Figure 0.8: Mean monthly Rainfall Intensity and Runoff (1993-2023)

The mean monthly runoff was computed using the rational formula and the trend shown in Figure 4.8. From the calculations, the rainfall intensity was found to be 89.24mm/hr which is in accordance with the peak rainfall received during the study period. The analysis indicated that the catchment had more runoff in the months of April and November where the runoff was estimated to be 199m^3/s and 83m^3/s respectively. These were the same months in which the catchment received the highest amount of rainfall and therefore the high amount of runoff recorded. A similar study done by (Karanja, 2022; Nyokabi *et al.*, 2021) indicated a similar trend however the runoff has been increasing since 2020 and the runoff values were extremely high due to the rational formula used to estimate the peak runoff. The over-estimated values could be because the rational formula has several runoff coefficients values that allow room for prediction and estimation. This does not put into consideration the time of concentration which would give a large discrepancy which makes the rational formula not suitable for runoff estimation.

4.1.2 Streamflow trends of river Malewa

This study also sought to analyze the trends in streamflow of Malewa River which is the largest river in the catchment that drains into Lake Naivasha. The mean discharge from the different stations was computed and presented as shown in Figure 4.9. ANOVA results indicated that there was no significant difference ($p > 0.05$) in the streamflow from the different stations.

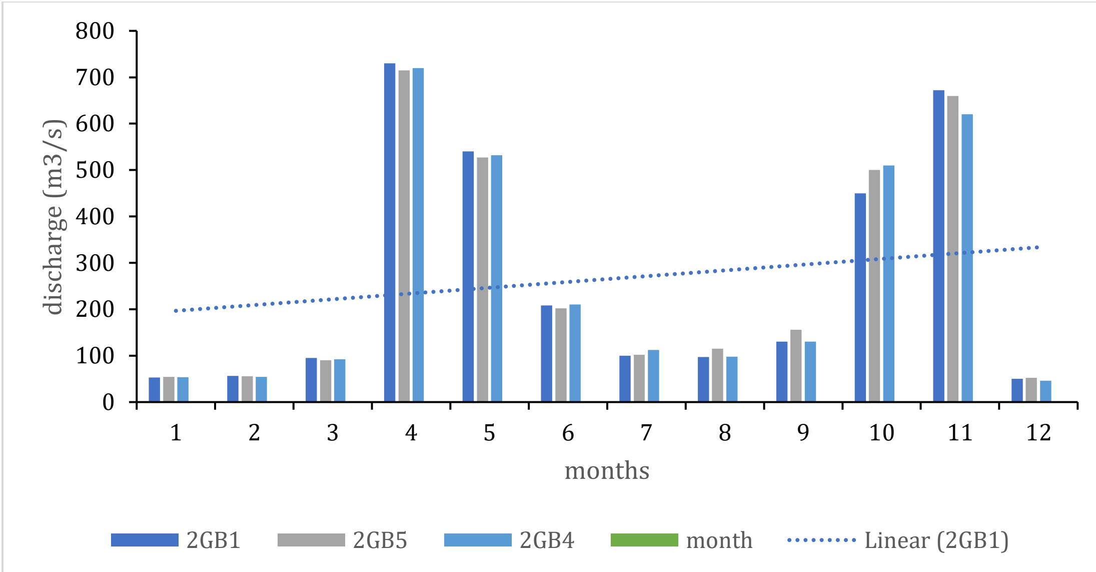

Figure 0.9: Mean monthly Discharge (1993-2023)

The mean monthly trends in streamflow were also computed as shown in Figure 4.10 and the findings showed an increasing trend from March to May in the first rainy season and October to November in the second season. The was no significant change in the P-values hence the study findings were consistent with (Nyokabi *et al*., 2021). The increased stream flow explained the floods experienced along river Malewa hence the rise in the water levels of the lake basin.

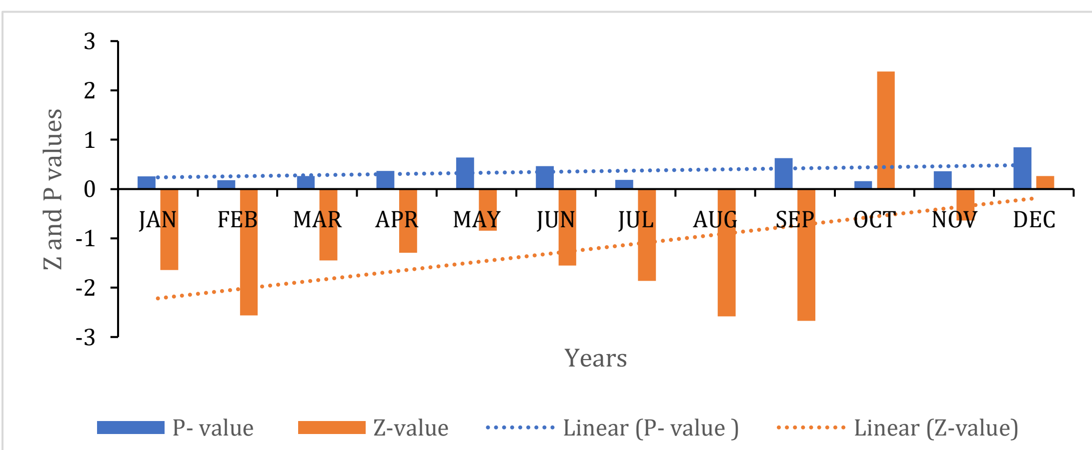

Figure 0.10: Mean monthly streamflow trends of Malewa River

The annual streamflow data was computed using the Mann Kendall Test as shown in Figure 4.11. The results indicated no significant trends in the streamflow discharge computed annually. The changes in the P-values had no significant change while the Z-values had an increasing trend over the years. For instance, the Z-values were lowest in 1993 and 2013 but showed a continuous increasing trend from 2019-2023 and this trend was similar to the findings of (Nyokabi *et al*., 2021). This explains why the areas along the Malewa River flooded and the increase in the water levels of the lake basin where the river drains its water.

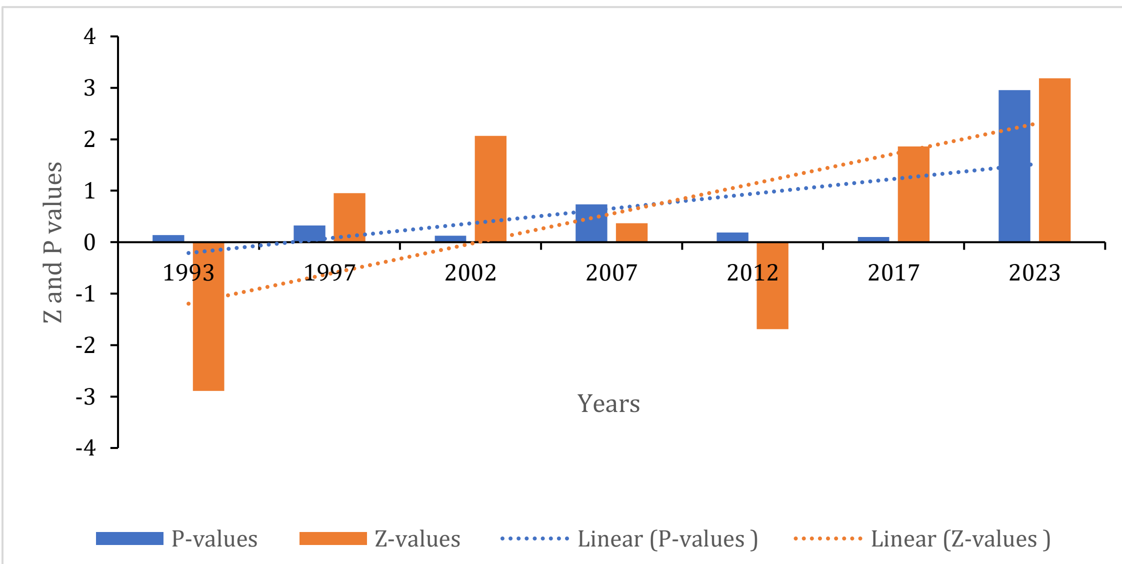

Figure 0.11: Trends in streamflow of river Malewa in the catchment

The relationship between mean monthly streamflow and mean monthly rainfall from 1993-2023 was strong ($R^2 = 0.89$) as illustrated in Figure 4.12. This indicates that an increase in streamflow of River Malewa is strongly associated with an increase in rainfall in the catchment which leads to rainfall-induced runoff. Therefore, flood mitigation involves adoption of strategies that aim to reduce runoff.

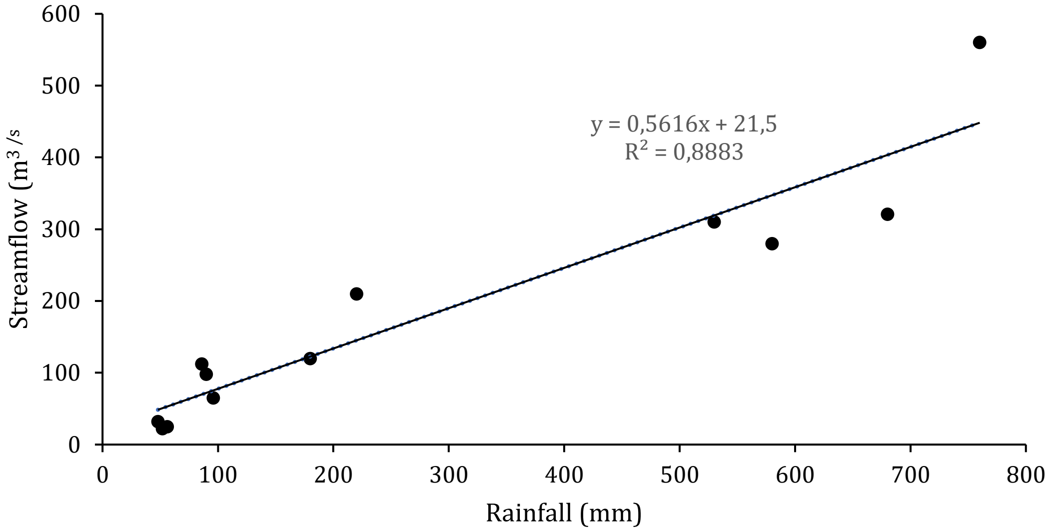

Figure 0.12: Relationship between mean monthly stream flow and mean monthly rainfall for river Malewa

4.1.3 Flood prediction

The average duration of flow was computed from the discharge values of Malewa River. During computation, flow rates ranging from Q5 - Q10 were termed as high flow rates hence the presence of floods which resulted from extreme precipitation and high runoffs. Flow rates between Q20-Q70 on the other end were median flow, while those between Q80-Q99 were low flows hence less or no floods in the catchment.

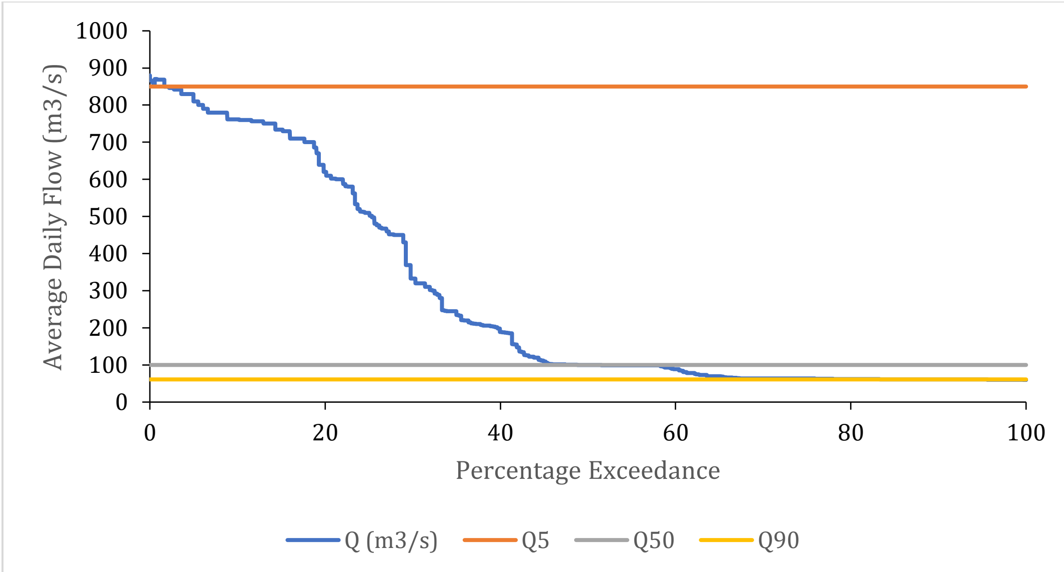

Figure 0.13: Streamflow, duration curve, and percentile flows for Malewa river

From the graph, the curve indicates a gentle slope from the highest discharge while on the extreme lower part it appears almost parallel to the X-axis which is due to reduced streamflow causing a recession on the base flow as a result of several factors such as evaporation and soil infiltration or absorption. From the plotted graph in Figure 16, the Malewa River discharge was over 97% of the period. In this case, the highest flow will be Q5 as shown in Figure 16 with a discharge of 850m^3/s, the median flow was Q50 with 100 m^3/s, and the least flow was Q99 with a discharge of 60.98m^3/s. This indicated that the floods were extremely severe with the discharge Q5- 850 m^3/s between 2018 and 2021 and had a return period of 20 years.

4.1.4 Participants perception of flood severity

The interviews indicated that flooding caused damage to infrastructure, loss of lives and livelihoods, and negative effects on agriculture and the environment. Focus group one stated "Loss of lives and properties" and "destruction of infrastructure" as some of the impacts of flood occurrence. The analysis shows that most respondents perceive a decrease in flood incidents in the Lake Naivasha catchment area over the years. The perceived severity of these floods is significantly influenced by the duration of residency, with longer-term residents reporting higher severity levels than shorter-term residents. The severity levels were assessed on a scale of 1(Not Severe at All) to 5 (Extremely Severe) as shown in table 4.1.

Table 0.1Percentage of severity levels

Scale	Value description	n	Frequency	Percent
5	Extremely severe	395	205	52
4	Very severe	395	110	28
3	Severe	395	40	10
2	Moderately severe	395	35	8.74
1	Not severe	395	5	1.26

Source, Isindu 2024

According to the study, 52% of the participants reported extreme severity in flood occurrence in the Lake Naivasha catchment area. Previous results done in the catchment revealed that there has been a consistent rise in rainfall and an increase in water levels in the lake basin over the years resulting in severe flooding scenarios (Karanja, 2022; Kyambia & Mutua, 2015; Nyokabi *et al.*, 2021) Which is also consistent with the hydrological analysis done in this study. Respondents generally asserted that the severity of flood occurrences in the catchment is extreme, leading to loss of lives, property damage, and infrastructure destruction. They also revealed the significant impact of flooding, including damage to infrastructure, loss of lives and livelihoods, and negative effects on agriculture and the environment. While most focus groups mentioned increased severity, they did not give specific impacts. However, individual interviews did specify some of these impacts. One respondent from the focus discussion groups affirmed,

> "Farming around Lake Naivasha basin and settling around Lake Naivasha riparian region leads to the Lake expansion as the riparian lands move outwards due to lack of strong waterbucks. There are no clear guidelines on how to avoid invading the riparian lands. Further, overfishing is rampant. Tourist farming camping sites end up destroying the riparian lands."

From the study, the increase in rainfall amounts received in the area from 2019 to 2023 had continuously increased due to the change in LULC which resulted in the increase in the runoff and streamflow hence the increase in the flood occurrences to extreme events. It was also noted that the levels of adoption of EBA strategies and other mitigation measures were low hence the severe floods

4.1.5 Summary of objective one

Lake Naivasha catchment has two rainfall seasons with the wettest months being April and November and the dry months are January, February, June, July, and December. The runoff and streamflow have an increasing trend from 2019- 2023 and this explains the flooding incidences in the catchment and the continuous rising of water levels in the lake basin. The floods experienced in the catchment are extremely severe with Q5 of $850m^3/s$ and a return period of 20 years. The respondents also confirmed extremely severe floods that have caused destruction of property, death, displacement of people and wildlife among other economic losses.

4.2 Ecosystem-based adaptation strategies for flood mitigation in the Lake Naivasha catchment area

The study sort to identify the structural, nonstructural, and any other existing EBA structures for flood mitigation in the Lake Naivasha catchment.

4.2.1 The demographics in percentages

The study sort to understand the demographics of the respondents in terms of age and gender in the catchment.

Table 0.2Respondents' demographics in percentages

	n	**Gender**		
Age Bracket		**Male**	**Female**	**Percentage**
18-30 Years	395	39.12	12.5	51.62
31-40 Years	395	19.18	12.63	31.81
41- 50 Years	395	6.593	3.846	10.44
Above 50 Years	395	3.846	2.747	6.05
Grand Total	**395**	**68.74**	**31.72**	**100**

Source, Isindu 2024

From Table 4.2, a majority of the respondents were male aged 18-30 years with the least number of participants being female aged above 50 years. Comparing the numbers, the male were the majority with 69.23% of respondents compared to female who had a 30.77% representation in the surveys. Most of the young people were willing to take part in the research as the people aged between 18-30 years were more by 51.62% while those above 50 years were the minority with 6.05% representation.

4.2.2 Structural and Nonstructural EBA Strategies

These EBA strategies in the catchment were categorized into two i.e., structural and non-structural. The non-structural strategies identified in the study included wetland restoration, afforestation, agroforestry, mulching, cover cropping, and minimum and zero tillage. On the other hand, the structural measures identified were rainwater harvesting, retention ponds, detention basins, and soil conservation terraces (Table 4.3).

Table 0.3Frequency of EBA strategies among study participants

Type of Strategy	Strategy	n	Mean	Std. dev
Non-Structural Adaptation Strategies	Afforestation	395	0.66462	0.02619
	Agroforestry	395	0.53846	0.02765
	Wetland Restoration	395	0.52000	0.02771
	Minimum and Zero Tillage	395	0.32000	0.02588
	Cover Cropping	395	0.24308	0.02379
	Mulching	395	0.23077	0.02337
Structural Adaptation Strategies	Rainwater Harvesting	395	0.76923	0.02337
	Soil Conservation Terraces	395	0.52308	0.02771
	Detention Basins	395	0.15385	0.02001
	Retention Ponds	395	0.11077	0.01741

Source, Isindu 2024

Based on the study findings in Table 4.3, the following are the common non-structural EBA strategies used in the Lake Naivasha catchment area; afforestation (M = 0.6642, SD = 0.0262), agroforestry (M = 0.5385, SD = 0.0277) where M is the mean and SD is the standard deviation. According to studies done by (Akamani & Holzmueller, 2017; Matocha, Schroth, Hills, & Hole, 2012; Shah, Zhou, & Shah, 2019) incorporating agroforestry and afforestation in mitigating the effects of climate change is easily adopted because the trees have several co-benefits including but not limited to carbon sequestration, economic benefits together with aesthetic and environmental management approaches. The Kenya government has equally supported agroforestry and agroforestry through its provision of favorable agroforestry policies and formulation of the agroforestry strategy 2020-2020 (Mumina & Bourne, 2020). The Kenyan President has severally declared and gazette public holidays for tree planting to help mitigate the negative impacts of climate change such as floods. The recent public holiday was on May 10th, 2024 (Ministry of Interior and National Administration, 2024). These holidays have had different organizations, institutions, and individuals participate in national tree planting hence increasing the adoption rates of the strategies.

According to one respondent, it is easier for everyone to practice afforestation and agroforestry because of the government policies that support the activities. They stated that the government supports growing trees and each person was willingly growing trees on their farms and homesteads. One respondent from the FGDs stated;

> "Every person grows trees in their homesteads willingly and even our president has gone further holding public holidays just for planting trees. You will not fail to get a homestead with no trees and also trees have economic impact, environmental conservation benefits among others. These are the reasons why we are growing more trees."

While agroforestry and afforestation are gaining a lot of relevance as EBA strategies in flood mitigation in the catchment, the use of mulching and cover cropping as EBA strategies were least adopted in the catchment with cover cropping having (Mean = 0.2431, SD = 0.0238) and mulching (M = 0.2308, SD = 0.0234) respectively. Research done by (Srivastava, Basche, Traylor, & Roy, 2023) indicated that mulching and cover cropping are conservation practices that have played a major role in flood reduction and improvement in water quality. The conservation practices reduce the amount of runoff causing erosion and allowing much time for infiltration. The practices also conserve the amount of moisture in the soil which is essential for crop production. Adoption of this practices is however limited to the type of crops being produced and the amount of mulch to apply which is linked to the knowledge of the application process (Srivastava et al., 2023).

Most of the respondents agreed to not having enough knowledge in mulching and cover cropping. To others, mulching and cover-cropping are primarily used as soil moisture conservation measures. According to one farmer in the FGDs, horticultural farming does not involve much use of cover crops and mulches;

> "In Naivasha most of the agricultural practices are horticultural and therefore done in greenhouses. We only follow instructions given for crop management while serving in the greenhouses and very little is being done with regards to mulching and cover cropping."

According to this study, there was existence of structural EBA strategies with rainwater harvesting (M = 0.7692, SD = 0.0234), soil conservation terraces (M = 0.5231, SD = 0.0278) being the highly adopted measures. Research done in South Africa indicated that the use of rainwater practices helped in mitigating floods that had severe impacts between 1959-2019 (Busayo et al., 2022). Rainwater harvesting has helped in managing urban floods where water harvesting tanks are distributed to help reduce the impacts of small to medium flooding events (Jamali, Bach, & Deletic, 2020). The Kenyan government in collaboration with other stakeholders including donor funding and non-governmental organizations among others, have also invested a lot in rainwater harvesting structures such as water pans, earth dams, and rainwater storage as evident in the National Water Harvesting and Storage Strategy 2020-2025 (FAO, 2021).

Soil conservation terraces were also well adopted since most of the farmers use the same practice as a form of conservation agriculture strategy in soil and water conservation. According to the research done in the Atlas Mountains in Morrocco, it was easier to use agricultural terraces in mitigating floods since majority of the farmers had the knowledge and the structures in place this contributed to the reduction of flood occurrence (Meliho, Khattabi, Nouira, & Orlando, 2021). A farmer from the FGDs highlighted that it was easier for most farmers to use soil conservation terraces in flood mitigation and they have seen their significance in managing soil erosion hence flood mitigation becomes a co-benefit.

> "In my farming practices, I have used soil conservation terraces to manage soil erosion on my farm. These terraces have significant importance such as temporal water storage structures, soil erosion control measures and now flood mitigation measures."

The use of detention basins (M = 0.1239, SD = 0.0200), and retention ponds (M = 0.1108, SD = 0.0174) were the least adopted structural measures in this study. Retention ponds and detention basins are water-filled pools used to regulate the flow of runoff by retaining runoff water and releasing it slowly to reduce the occurrence of floods. A study done in central Belgium to investigate the spatial-variation of flood occurrence and muddy floods in rural areas indicated that the retention ponds and detention basin helped in controlling floods (Verstraeten & Poesen, 1999). The study indicated that the major challenge hindering the adoption of retention ponds and detention ponds was the cost of construction, dredging, and general maintenance of the structure.

Most farmers in the Lake Naivasha catchment did not know the retention ponds and detention basins and their existence in the catchment. Those who had the idea of their existence complained of the high cost of construction, maintenance costs, and also stated that the structure occupied land that could be used for other purposes. One farmer from the flower farm FGDs highlighted that the ponds contributed to malaria and other water-borne diseases.

> "The ponds are great structures when mitigating floods but require land space which we can be used to produce crops or other purposes. The cost of construction and maintenance is high and we would wish the government to intervene."

Out of 325 responses, 286 participants were not aware of other adaptation strategies, while 39 identified additional strategies implemented at the catchment as follows; Building gabions, Construction drainage systems, development of terraces along the riverbanks, and establishment of city green spaces (Structural). The other proposed nonstructural structures included; relocation of wildlife, clearing drainage systems, establishment of tree nurseries, sewage treatment, and conservation and reclamation of the water resources and wildlife reserves.

4.2.3 Occupation and awareness of EBA strategies in the catchment

The study also aimed to examine the relation between the participants' occupation and its relationship to the awareness of EBA strategies. Participants in different occupations had different perceptions of EBA strategies while others had little knowledge about EBA strategies. Table 4.4 shows the percentage representation of the respondents' awareness of the different EBA strategies.

Table 0.4Occupation and level of perception in percentages

Strategy	Occupation and level of perception in percentages					
	Farmer	Environmentalists	Fishermen	Business people	Employees	Others
Afforestation	46.59	57.81	10.22	40.44	16.8	12.44
Agroforestry	57.79	57.81	10.05	42.51	22.43	16.55
Wetland Restoration	22.32	30.18	46.44	6.46	0.58	0.52
Minimum and Zero Tillage	42.34	45	8.44	4.01	6.43	0
Cover Cropping	10.12	15	5.32	2.02	4.66	0.39
Mulching	10.34	12.01	6.48	2.11	4.31	0.27
Rainwater Harvesting	58.24	56.44	28.97	58.24	22.03	16.97
Soil Conservation Terraces	48.88	44.06	14.56	32	10.55	6.22
Detention Basins	2.02	8.32	0.57	0.29	0.88	0
Retention Ponds	2.38	10.56	0.36	1.08	0.59	0

Source, Isindu 2024

The analysis also included a chi-square test used to analyze categorical variables to examine any significant differences between occupation and awareness of ecosystem-based strategies among participants. There was a significant difference in awareness of two strategies by occupation: wetland restoration (p-value = 0.00164) and soil conservation terraces (p-value = 0.00133). There is no significant difference between occupation and awareness of ecosystem-based strategies for the other strategies in the study at the 95% confidence level.

The occupation groups with the highest number of individuals aware of these two strategies were environmentalists who had 30.18% of respondents aware of wetland restoration, and farmers who had 48.88% of respondents aware of soil conservation terraces. Further, 57.81% of respondents were aware of afforestation and agroforestry (environmentalist), and 58.24% of respondents aware of rainwater harvesting were farmers and business owners. These three groups potentially had higher education levels and specific experience than the other groups in the sample which included farmers, business people, fishermen, tour guides, and those in other informal occupations). Consequently, their education levels and business affiliations potentially exposed them to these strategies, resulting in higher awareness levels. Farmers and environmentalists had a lot of knowledge of EBA strategies due to their day-to-day interactions with the strategies as they directly benefit from the co-benefits that come with their uses. For instance, the use of agroforestry, afforestation, soil conservation terraces to manage soil erosion also helps in mitigating flood risks and general environmental management.

4.2.4 Summary of objective two

From the study, the highly adopted nonstructural EBA strategies were afforestation and agroforestry due to their co-benefits and government support while the least were mulching and cover cropping due to insufficient knowledge on the application methods. On the other hand, the highly adopted structural EBA strategies were soil and water conservation terraces and rainwater harvesting structures due to their co-benefits and government interventions while the least adopted were retention ponds and detention basins due to the high cost of installation and maintenance. Most of the Environmentalists and the agriculturalists had better knowledge of EBA strategies compared to other respondents from other professional fields.

4.3 Effectiveness of EBA strategies for flood mitigation in the Lake Naivasha catchment area

The study sought to identify the general impacts of EBA strategies in Lake Naivasha catchment and the perceived effectiveness in flood mitigation.

4.3.1 Impacts of EBA strategies in the catchment

The study sought to examine participants' perceptions of the effects of EBA strategies on flood mitigation in the study area. The data analysis revealed that participants perceived changes in the frequency of flood occurrence following the adoption of EBA strategies in the Lake Naivasha catchment area. From the study, 77.75% of the participants reported that they had experienced observable positive changes in flood occurrence. Table 4.5 illustrates participants' observed changes following the adoption of EBA strategies:

Table 0.5Effectiveness of EBA strategies for flood mitigation in the Lake Naivasha catchment area

Impact	n	Frequency	Percent
Reduced Flood Risk	395	226	57.24
Improved Community Resilience	395	146	37.02
Improved Soil Stability and Prevention of Soil Erosion	395	145	36.75
Improved Water Quality	395	135	34.28
Economic Benefits	395	120	30.39
Improved Biodiversity and Conservation	395	73	18.37

Source, Isindu 2024

Table 4.5 shows that the study participants were aware of the various effects of EBA strategies in the study area. The majority of participants 57.24% identified reduced flood risk as the most common effect of the adoption of EBA strategies, followed by improved community resilience at 36.04%. This outcome is equally evident in studies done in European countries, Sri Lanka, and South Africa where the use of EBA strategies in mitigation floods have contributed to reduced flood risks as they are less costly to install and equally offer other co-benefits making it easy for the affected communities to adopt them (Busayo *et al*., 2022; Doswald & Osti, 2011; Khaniya, Gunathilake, & Rathnayake, 2021; McVittie, Cole, Wreford, Sgobbi, & Yordi, 2018). Research done in western Kenya by (Opilo & Mugalavai, 2023) shows the effectiveness of EBA strategies in mitigating floods in the region. EBA strategies have also mitigated drought and flood impacts in the rural and urban parts of East Africa(Kalantari, Ferreira, Keesstra, & Destouni, 2018) and in Masai land (Osano et al., 2013) respectively.

The effectiveness of using EBA strategies in improving Improved Biodiversity and Conservation was the least identified with 18.37%. The occurrence of floods in the region has affected the quality as floods resulted in contamination of water sources and pollution of water. Naivasha catchment is known for horticultural farming, tourist activities, and fishing which depend on water. Most farmers complained of contaminated water attributed to flood occurrence as floods cause stagnation of water resulting in other issues like water-borne diseases and pollution of clean water sources. One informant from NEMA expounded on how water sources get polluted from farming activities, erosion, and incidences of floods;

> "Until the issue of floods is completely addressed in Naivasha, residents of the catchment will experience water pollution right from erosion, poor farming practices, and floods. Most of the residents are ever hospitalized with water pollution-related ailments. A solution for floods will help improve water quality."

Research in Sir Lanka highlights the effectiveness of using EBA strategies in water quality and water supply regulation(Khaniya *et al*., 2021). This clearly indicates that well-adopted EBA strategies can be the solution to water quality in the Lake Naivasha catchment as they are eco-friendly, less costly, and have a wide range of benefits that are also long-term.

4.3.2. Participants' Perceived Effectiveness of Existing EBA Strategies in flood mitigation

The study also intended to examine participants' perceptions of the effectiveness of existing EBA strategies. Participants' perceived effectiveness of existing EBA strategies was varied but generally positive. The study used a Likert scale with values of highly effective, moderately effective, effective, ineffective, and not sure to evaluate participants' subjective perceptions of the effectiveness of existing EBA strategies as shown in table 4.6.

Table 0.6Participants' subjective perceptions of the effectiveness of existing EBA strategies

Scale	Value description	n	Frequency	Percent
5	Highly effective	395	204	51.5
4	Moderately effective	395	118	30.04
3	Effective	395	47	12
2	Ineffective	395	18	4.62
1	Not sure	395	8	1.84

Source, Isindu 2024

From the study, 51.5% of respondents considered the adopted EBA strategies highly effective in mitigating floods. Most of the residents were comparing the flood occurrence and intensity over the period they had resided in the catchment. For instance, they compared the urban floods experienced in Naivasha town during industrialization and urbanization and the current experience after conservation measures have been put in place. One respondent in the horticultural farmers' group stated that;

> "In the recent past, the Naivasha catchment experienced both very dry and very wet seasons. The area would go for months without rainfall and when it pours, the lower and middle parts of the catchment would flood. The town flooded because of drainage issues while the flower catchment was majorly due to erosion and other human activities like poor agricultural practices."

Respondents were also asked whether they believed incidences of flooding had reduced, increased, or remained the same in the Lake Naivasha catchment area. The analysis revealed that most respondents (81.87%) perceived a relative decrease in flood occurrence and period in the region. Similar research done in Kenya indicated that the use of EBA strategies in flood mitigation was highly effective and recommended that they should be adopted (Agol, Reid, Crick, & Wendo, 2021; OMWENGA, 2019; Osano *et al*., 2013). For instance, the study done along the Lake Victoria basin recommended the use of EBA measures such as restoration of wetlands and afforestation to mitigate the negative impacts of climate change and also recommended the identification of EBA synergies and trade-offs and their distribution to enhance planning and climate change mitigation(Agol *et al*., 2021).

In this study, 4.62% of respondents perceived the existing strategies ineffective in mitigating floods while 1.84% were not sure. According to some respondents, it was not easy for them to tell the effectiveness of agroforestry and afforestation in mitigating floods as trees took too long to grow and with the changes in seasons, they could not track any progress or effect. Research done in Samoa and Cambondia revealed how legal barriers affected the operationalization of EBA strategies (Lukasiewicz, Pittock, & Finlayson, 2016) while the institutional analysis done in Murray-Darling Basin, Australia, indicated that institutional issues like narrow funding, multi-agency management, privatization of property, under-development institutions, and legal interferences were among the major issues that affected the adoption of EBA strategies (Lukasiewicz *et al*., 2016). These issues were also similar in Kenya among others like the need for attitude change of the people as well as knowledge dissemination on EBA strategies and their relevance.

Participants also identified challenges associated with the adoption of EBA strategies. Some challenges identified include; the lack of economic benefits of EBA, EBA strategies require a lot of time to be established and especially the non-structural ones, the structural ones are too costly especially during initial installation and maintenance, overpopulation resulting in riparian encroachment by the communities, human-wildlife conflict, water pollution, and limited awareness and understanding of EBA among communities. For example, the focus group interview with group six identified "Construction of huge accommodation hotels around the catchment area" as one of the challenges.

4.3.3 Summary of objective three

From the study, EBA strategies were highly effective in reducing flood risk and enhancing community resilience. However, their effects in improving water quality were least felt by the residents of the catchment. The few adopted strategies have shown a significant impact in flood mitigation and the residents believe the impact would have been higher if the adopted measures did not depend on the longtime of implementation for example, the time taken for growing of trees to maturity.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter presents the summary of the study findings, conclusions, and recommendations from the findings and further study.

5.1 Summary of the findings

This section summarizes the findings of the study based on each specific objective.

5.1.1 Assessing flood Severity in lake Naivasha Catchment

The floods in Lake Naivasha are extremely severe based on the research findings with extreme events being experienced from 2020 to 2023 as observed with the increase in the stream flow and runoff of the same years which could be due to the less adoption of EBA strategies. The floods were extremely severe with a discharge of Q5 – 850m^3/s with a return period of 20 years. The moderately severe floods were experienced at a median flow of Q50-100 m^3/s and the least flow was at Q99- 60.98m^3/s. The continuous increase in the streamflow and runoff amounts has contributed to the flooding of River Malewa and its environment. The respondents confirmed severe floods experienced in the catchment with 52% recording an extremely severe event while 1.26% stated that the floods experienced were not severe.

5.1.2 Identifying the EBA strategies in Lake Naivasha catchment

From the study, the most adopted nonstructural EBA strategies were afforestation and agroforestry with means and standard deviations of 0.6642, 0.02619, and 0.53846,0.02765 respectively while the least adopted were mulching and cover cropping with 0.23077, 0.02337 and 0.024308, 0.02379 respectively. Afforestation and agroforestry were highly adopted due to their associated co-benefits and favorable government policies while mulching and cover cropping were least adopted due to limited knowledge in the application methods. On the other hand, the most adopted structural EBA strategies were rain-water harvesting and soil and water conservation terraces with means and standard deviations of 0.76923, 0.02377, and 0.53208, 0.02771 respectively. Their high adoption rate was linked to their co-benefits such as erosion control while the least adopted were the use of detention basins and retention ponds with means and standard deviations of 0.15385, 0.02001, and 0.11077, 0.1741 respectively. Their slow rate of adoption was due to the initial high-cost of installation and maintenance. The occupation groups with the highest number of individuals aware of these EBA strategies were environmentalists who had 30.18% of respondents aware of wetland restoration, and farmers who had 48.88% of respondents aware of soil conservation terraces. Further, 57.81% of respondents were aware of afforestation and agroforestry (environmentalist), and 58.24% of respondents aware of rainwater harvesting were farmers and business owners. According to the respondents, most of the EBA strategies were primarily known for conservation agriculture and not flood mitigation.

5.1.3 Examining the effectiveness of EBA strategies for flood mitigation in Lake Naivasha catchment.

On the effectiveness of EBA strategies in flood mitigation, 77.75% of the respondents recorded a notable reduction of flood risk in the catchment which was linked to EBA strategies. Apart from flood mitigation, the respondents stated that EBA strategies had other co-benefits such as improved soil stability and reduced soil erosion 36.75%, enhanced community resilience with 37.02%, economic benefits with 30.39%, and improved water quality with 34.28% among other benefits. EBA strategies were less effective in improving and conserving biodiversity. On the assessment of the respondent's perception of the effectiveness of EBA strategies in flood mitigation, 51.5% recorded that EBA strategies were highly effective, 30.04% stated that they were moderately effective while 1.84% were not sure.

5.2 Conclusions

5.2.1 Assessing flood Severity in lake Naivasha Catchment

Lake Naivasha catchment has two rainfall seasons with the wettest months being April and November and the dry months are January, February, June, July, and December. The runoff and streamflow have an increasing trend from 2019- 2023 and this explains the flooding incidences in the catchment and the continuous rising of water levels in the lake basin. The floods experienced in the catchment are extremely severe with Q5 of $850m^3/s$ and a return period of 20 years. The respondents also confirmed extremely severe floods which caused displacement of people, loss of lives and property, and interference with other economic activities like tourism, fishing, running of businesses, and even closing of institutions like schools.

5.2.2 Identifying the EBA strategies in Lake Naivasha catchment

From the study, the highly adopted nonstructural EBA strategies were afforestation and agroforestry due to their co-benefits and government support while the least were mulching and cover cropping due to insufficient knowledge on the application methods. On the other hand, the highly adopted structural EBA strategies were soil and water conservation terraces and rainwater harvesting structures due to their co-benefits and government interventions while the least adopted were retention ponds and detention basins due to the high cost of installation and maintenance. Most of the Environmentalists and the agriculturalists had better knowledge of EBA strategies compared to other respondents from other professional fields.

5.2.3 Examining the effectiveness of EBA strategies for flood mitigation in Lake Naivasha catchment.

From the study, EBA strategies were highly effective in reducing flood risk and enhancing community resilience. However, their effects in improving and conserving biodiversity were least felt by the residents of the catchment. The few adopted strategies have shown a significant impact in flood mitigation and the residents believe the impact would have been higher if the adopted measures did not depend on the longtime of implementation for example, the time taken for growing of trees to maturity. The catchment however still experiences floods due to low adoption rate of the EBA strategies which is linked to the limited community knowledge in EBA strategies and unfavorable government policies in favor of EBA strategy adoption in the area. Structural EBA strategies are expensive to install while the nonstructural strategies take a longer period to establish. While a good number of the respondents had little knowledge of EBA strategies. The study was also able to validate the findings from the hydrometeorological analysis with the social data from the household data and key stakeholders in the catchment which were also consistent with existing literature.

5.3 Recommendation from the findings and for further research

5.3.1 The recommendations from the study

The recommendations made from the findings of the study include:

a) More research should be done to understand other flood mitigation measures to help reduce the impacts of severe floods in the catchment.

b) Awareness creation among more community members regarding EBA strategies, their effectiveness in flood mitigation and how the community members can participate at the individual and community levels in adopting these strategies. Equally, active governmental involvement in flood mitigation may be beneficial in promoting the implementation of EBA strategies on a larger scale.

c) The observed positive changes and perceived effectiveness suggest that EBA strategies can be a valuable tool for flood mitigation in this region. However, addressing the identified challenges is essential for maximizing the potential of these strategies and ensuring their long-term success.

5.3.2 Recommendations for Further Research

a) Future research could also expand the geographical scope to include other flood-prone regions in Kenya or other countries with similar ecological and socioeconomic contexts. This would allow for a comparative analysis of EBA effectiveness and community perceptions across different settings. More research should also be done to understand the causation of continuous floods in the Lake Naivasha catchment since 2020-2023 and more measures to be put in place to mitigate the flood risks.

b) Longitudinal studies could be conducted to assess the long-term impacts and sustainability of EBA strategies in the Lake Naivasha catchment. This would provide valuable insights into the adaptive capacity of ecosystems and communities over time.

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APPENDICES

Appendix I: Household Interview Schedule/s

Dear Respondent,

I am Nelly Shitakwa Isindu a student from Masinde Muliro university of Science and Technology taking a master's degree in Climate Change Adaptation and Sustainable Development. I am conducting academic research on ***"Effects of Ecosystem-Based Adaptation Strategies in Flood Mitigation Along Lake Naivasha Catchment, Kenya"*** for the qualification of the award. The information that you will provide during this study will be confidential and entirely used for the purpose of this research. I will appreciate if you help me in answering the questions contained in the questionnaire.

Section A: Demographic Information

1. What is your gender please tick in the box?

Male ☐ Female ☐

2. Which is your age bracket?

18-30 Years ☐ 31-40 Years ☐ 41- 50 Years ☐ Above 50 Years ☐

3. What is your occupation?

Farmer ☐ Fisherman/Fisherwoman ☐ Business owner ☐

Employee ☐ Tour guide ☐ Other (please sp ☐

4. How long have you lived within Lake Naivasha catchment area?

Less than 5 years ☐ 5-10 years ☐ Over 10 years ☐

Section B: Ecosystem-Based Adaptation Strategies applicable for flood mitigation in lake Naivasha catchment

5. Are you aware of any ecosystem-based adaptation strategies implemented in the Lake Naivasha catchment area for flood mitigation?

Yes ☐ No ☐ Not sure ☐

6. If yes, please tick besides the ecosystem-based adaptation strategies you are aware of

SN	TYPE	EXAMPLE	Tick (√)
1	Non-structural	Wetland restoration	
		Afforestation	
		Agroforestry	
		Mulching	
		Cover cropping	
		Minimum and zero tillage	
2	Structural	Rainwater harvesting	
		Retention ponds	
		Detention basins	
		Soil conservation terraces	
3.	Others (specify)		

7. **Who/which organization is involved in the** ecosystem-based adaptation strategies implemented in the Lake Naivasha catchment area for flood mitigation?

Individual household members ☐ ganized Community groups ☐ vernment

Agencies ☐ Non-State Actors ☐ Other (specify)……………………………….

8. **Are you aware of any existing policies and governance structures in supporting ecosystem-based adaptation strategies for flood mitigation in the Lake Naivasha catchment area?**

Yes ☐ No ☐ Not sure ☐

9. **If yes in 8 above, how do you perceive the effectiveness of existing policies and governance structures in supporting ecosystem-based adaptation strategies for flood mitigation in the Lake Naivasha catchment area?**

Highly effective ☐ **Moderately effective** ☐ **Ineffective** ☐ **Not sure** ☐

Section C: Effects of Ecosystem-Based Adaptation Strategies

10. Have you observed any changes in flood occurrences since the implementation of ecosystem-based adaptation strategies in the Lake Naivasha catchment area?

Yes ☐ No ☐ Not sure ☐

11. If yes, please tick the observed changes:

a.	**Reduced Flood Risk**	
b.	**Community Resilience**	
c.	**Improved soil stability and prevented soil erosion**	
d.	**Biodiversity Conservation**	
e.	**Economic Benefits**	
f.	**Improved water Quality**	

12. **How do you perceive the effectiveness of the existing ecosystem-based adaptation strategies for flood mitigation in the Lake Naivasha catchment area?**

Highly effective ☐ **Moderately effective** ☐ **Ineffective** ☐ **Not sure** ☐

13. What additional ecosystem-based adaptation strategies do you think could be implemented for better flood mitigation in the Lake Naivasha catchment area?

……………………………………………………………………………………………
……………………………………………………………………………………………
…………

Section D: Severity of Flood Occurrence

14. In your opinion, have incidences of flood reduced or increased in the Lake Naivasha catchment area?

Reduced ☐ Increased ☐ No difference ☐

15. On a scale of 1 to 5, how severe do you perceive the flood occurrences in the Lake Naivasha catchment area?

- ☐ 1 (Not severe at all)
- ☐ 2 (Slightly severe)
- ☐ 3 (Moderately severe)
- ☐ 4 (Severe)
- ☐ 5 (Extremely severe)

Section E: Suggestions and Feedback

Please make any general comments

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……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
………………………………

Thank you for your participation! Your input is valuable for our study on flood mitigation in the Lake Naivasha catchment area.

APPENDIX II; FOCUS GROUP DISCUSSION GUIDE

1. How well are you versed with Ecosystem based adaptation strategies?
2. Which EBA strategies do you know of?
3. What could be possible effects of EBA strategies on Flood risk?
4. What are possible causes of floods in the catchment?
5. What is the severity of flood occurrences in the catchment?
6. Can you share any personal experiences or anecdotes related to flooding events or ecosystem-based adaptation strategies in the Lake Naivasha catchment area?
7. In your opinion, what are the social, economic, or cultural factors that influence community resilience to flooding in the Lake Naivasha catchment area?
8. How can these factors be addressed or leveraged to enhance resilience?
9. Can you identify any potential trade-offs or conflicts between ecosystem-based adaptation strategies and other development priorities or land use interests in the Lake Naivasha catchment area?
10. How can these conflicts be managed or mitigated?

APPENDIX III; INTERVIEW QUESTIONS FOR POLICYMAKERS IN THE COUNTY.

1. What are the current policies and initiatives aimed at flood mitigation in the Lake Naivasha catchment area?

2. How are ecosystem-based adaptation strategies integrated into the broader framework of flood management and environmental conservation?

3. What are some of the key challenges encountered in implementing ecosystem-based adaptation strategies for flood mitigation in the Lake Naivasha catchment area?

4. In your opinion, what are some of the major causes of floods within the urban, rural and the lake Naivasha basin and how have they impacted the area?

5. Do you think the methods used to mitigate floods have generated any results? If yes, are the results positive or negative?

6. What do you think can be done to mitigate floods and reduce on its impacts on the lake Naivasha catchment.

7. Are there any specific policy gaps or areas that require further attention in order to enhance flood resilience and ecosystem sustainability?

8. How are the local communities involved in the development and implementation of ecosystem-based adaptation strategies?

9. Comment briefly on the level of awareness of ecosystem-based mitigation strategies in mitigating floods and helping in mitigating climate change among the communities occupying the Lake Naivasha catchment.

10. In your opinion, what are the priority areas or actions needed to further strengthen flood resilience and ecosystem sustainability in the Lake Naivasha catchment area?

Appendix IV: Plates 1

Residents of Karati area navigating through floods

Residents of Lake View area affected by floods

Residents of Karati area evacuating families affected by floods

APPENDIX V; NACOSTI RESEARCH PERMIT

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **734662**

Date of Issue: **06/May/2024**

RESEARCH LICENSE

This is to Certify that Ms.. NELLY ISINDU SHITAKWA of Masinde Muliro University of Science and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nakuru on the topic: EFFECTS OF ECOSYSTEM-BASEDADAPTATION STRATEGIES IN FLOOD MITIGATION ALONG LAKE NAIVASHA CATCHMENT, KENYA for the period ending : 06/May/2025.

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