

**ASSESSMENT OF EXTREME RAINFALL EVENTS AND HOUSEHOLDS'  
ADAPTATION IN RIVER NAMATALA CATCHMENT, KYOGA BASIN.**

**GESA ISAAC**

**21/U/14154/GMAG/PE.**

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## DECLARATION

I **GESA ISAAC**, declare that this dissertation report titled “***ASSESSMENT OF EXTREME RAINFALL EVENTS AND HOUSEHOLDS’ ADAPTATION IN RIVER NAMATALA CATCHMENT, KYOGA BASIN.***” is my original work and has never been submitted or presented to any university or institution of higher learning for any award.

Signature.....

Date.....

**APPROVAL**

We the undersigned certify that this dissertation entitled “*ASSESSMENT OF EXTREME RAINFALL EVENTS AND HOUSEHOLDS’ ADAPTATION IN RIVER NAMATALA CATCHMENT, KYOGA BASIN.*” has been compiled under our guidance and supervision. It is now ready for submission to the Directorate of Research and Graduate Training with our approval.

.....

Date.....

**DR. FRANCIS WASSWA N. NSUBUGA**

.....

Date.....

**ASSOC. PROF. NABALEGWA MUHAMUD WAMBEDE**

## **DEDICATION**

This dissertation is dedicated to my mother, Naikambo Florence.

## **ACKNOWLEDGEMENT**

I extend my sincere gratitude to my supervisors Dr. Francis Wasswa Nsubuga and Professor Wambede Muhamud for the tireless mentorship they rendered to me during this course. The persistent help from the time of developing the proposal, collecting data, and analysis gave a great opportunity to bring about this work.

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## ABSTRACT.

Extreme rainfall events in river Namatala catchment have increased over the past decades, yet these extremes have persistently caused disasters to the local population. Thus, this study identified extreme rainfall events, analyzed the trends of extreme rainfall events and it examined how households adapt to the extreme rainfall events in the river catchment. The study was conducted in the lower river Namatala catchment covering the districts of Mbale, Budaka and Butaleja. Gridded rainfall data was acquired using <http://hydrology.princeton.edu/data/pgf/0.5deg/> (accessed: 15 March 2024) and the Climate Data Tool (CDT) at. Frequency distribution was used to determine extreme rainfall events River Namatala catchment, Mann-Kendall test and Sens's slope test was used to determine the trend and magnitude of extreme rainfall events experienced in river Namatala catchment. Questionnaires and interview guides were used as data collection tools. The analysis included descriptive analysis computed using in Statistical Package for Social Sciences (SPSS) Version 23 and Microsoft Excel version 2016. The study revealed that May had the highest number of extreme rainfall events and January had the least number of extreme rainfall events. The trend showed an increase in the extreme rainfall events with positive z-scores of 2.164, 2.63 and 0.621 in the districts of Mbale, Butaleja and Budaka respectively. Digging trenches was found to be the most practiced adaptation measure by the households. The study concluded that extreme rainfall events have increased over time in Namatala catchment over time which requires stringent measures to as to mitigate their impacts. In order boost the resilience of the areas that are affected by the effects of the extreme rainfall events, we need to monitor frequently the occurrence of these events in the catchment, taking into account their socioeconomic network towards disaster resilience among the households along the river Namatala catchment.

## CHAPTER ONE: INTRODUCTION

### 1.1 Background to the study

An extreme event is defined as the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable (IPCC, 2012). Extreme events have increased across the globe than they were before the 20<sup>th</sup> century (Brooks & Adger, 2011). These extreme rainfall events for instance floods, are identified as the leading human and environmental crisis of the 21st century (IPCC, 2022) which is ravaging activities that are carried out in the environment (Cecinati, 2013; IFRC, 2021; Marengo et al., 2020). This is as a result of an increase in rainfall which has led to such incidents (Government of Uganda, 2016; Kundzewicz, 2016; Marengo et al., 2020). Extreme rainfall events have become a threat to management of ecosystems in the environment (Di Luca et al., 2020; Hussain et al., 2020)

Extreme rainfall events are affecting most parts of the world (Protocol, 2020) yet their impacts are so devastating to both human activities and nature, they have affected the people of Africa and its food system like production, processing that are already vulnerable (Tadesse & Paper, 2010). The varying conditions of climate and weather from its long-term average conditions which cause extreme rainfall events have been manifested in the environment and this is evident by the effects which have deteriorated human activities for instance agriculture which is victim of disasters caused by the effects of climate extremes (Eni & Mattei, 2013). Severe and prolonged droughts, floods, desertification and soil erosion are reducing agricultural yields, which endanger rural communities and pastoralist populations (Tadesse & Paper, 2010).

In Africa, there are countries, regions and communities experiencing increasing extreme events over time (Mika, 2011; Oriangi et al., 2020). The ability of livelihoods to deal with the devastating consequences of extreme events is an aspect that needs to be investigated, since socioeconomic characteristics are key in choosing practical measures which can help in coping up with extreme events (Keys et al., 2016). Adaptation to extreme rainfall events varies considerably with location, economy and regions and these keep changing over time (Brooks & Adger, n.d.). The most vulnerable communities are those with limited capacity to contain the effects. For example, countries with low economic resources, low levels of technology (IPCC, 2022), will experience a much more impact of the extreme rainfall events. This is true in countries like South Sudan where heavy rains affected the Pibor-Akobo-Sobat catchment which pours its water in the areas of Jonglei and Upper Nile in 2019 (Mostafa et al., 1800). Different catchments for instance River Nile basin have also registered increased rainfall than before leaving vulnerable communities in shambles (Mostafa et al., 2011). There has been an increase in rainfall amounts received during 2002–2010 (Onyutha, 2017), excess rainfall was received in the months of April and June and also from September and November along the Nile, where by rainfall received in the area showed a gradual increase in the basin over a period of eight years.

Uganda, has been experiencing extreme rainfall events for instance floods, prolonged drought over the past decades (Cecinati, 2013; Oriangi et al., 2020). Extreme rainfall which results into extreme rainfall events has been experienced mostly in the regions that are well vegetated and those that have got highlands. Among these areas include the Bugisu sub region which has experienced floods in the past decades leading to destruction of peoples property and lives (Oriangi et al., 2020), around Lake Victoria where water levels have faced

increase leading to destruction roads as well as claiming human lives, and parts of western Uganda (Gopakumar, 2011; Oriangi et al., 2020). In south western Uganda, extreme events mostly flood have impacted housing, agricultural farmland and transport systems in the area (Republic, 2015; IFRC, 2021). River Namatala is one of the areas that has continuously experienced disastrous floods found in the eastern part of Uganda (Government of Uganda, 2016).

## **1.2 Statement of the Research Problem.**

River Namatala catchment has experienced extreme rainfall events in the last many years (UNICEF-UGANDA report, 2022). These extreme rainfall events for instance floods are as a result extreme rainfall experienced in the catchment. Floods had socio-economic consequences on the local population along river Namatala catchment (Namaalwa et al., 2013; CTI et al., 2016; Government of Uganda, 2016; NEMA, 2019; Overview & Needs, 2022). Floods being a proxy of extreme rainfall(Mika, 2011), whose frequency is not yet quantified(Shaffie et al., 2013). Thus, it's important to interrogate rainfall data in order to establish extreme rainfall events and their trend. The interrogation will provide information which is crucial for adaptation purposes in the catchment.

It is against this background that a study was carried out to establish the trend and occurrence of extreme rainfall events that have prevailed in the catchment in time memorial and identify the adaptation mechanisms of how households are reducing the disastrous effects and also help in government planning in regards to disasters.

### **1.3 Objectives of the study.**

#### **1.3.1 General objective.**

To establish the trend of extreme rainfall events in Namatala catchment in an effort to characterize the occurrence so as to devise adaptation mechanisms among the communities and integrate best options for future planning.

#### **1.3.2 Specific Objectives**

- i.** To determine extreme rainfall events experienced in River Namatala Catchment between 1982-2022 period.
- ii.** To investigate the trend of extreme rainfall events in river Namatala catchment from 1982- 2022
- iii.** To examine adaptation measures carried out by households on extreme rainfall events in catchment.

#### **1.4 Research questions**

- i.** What are the temporal and spatial pattern rainfall events found in Namatala catchment between 1982-2022?
- ii.** What is the trend of extreme rainfall events in river Namatala catchment from 1982- 2022?
- iii.** What are the adaptation measures on extreme rainfall events in river Namatala catchment?

### **1.5 Scope of the study**

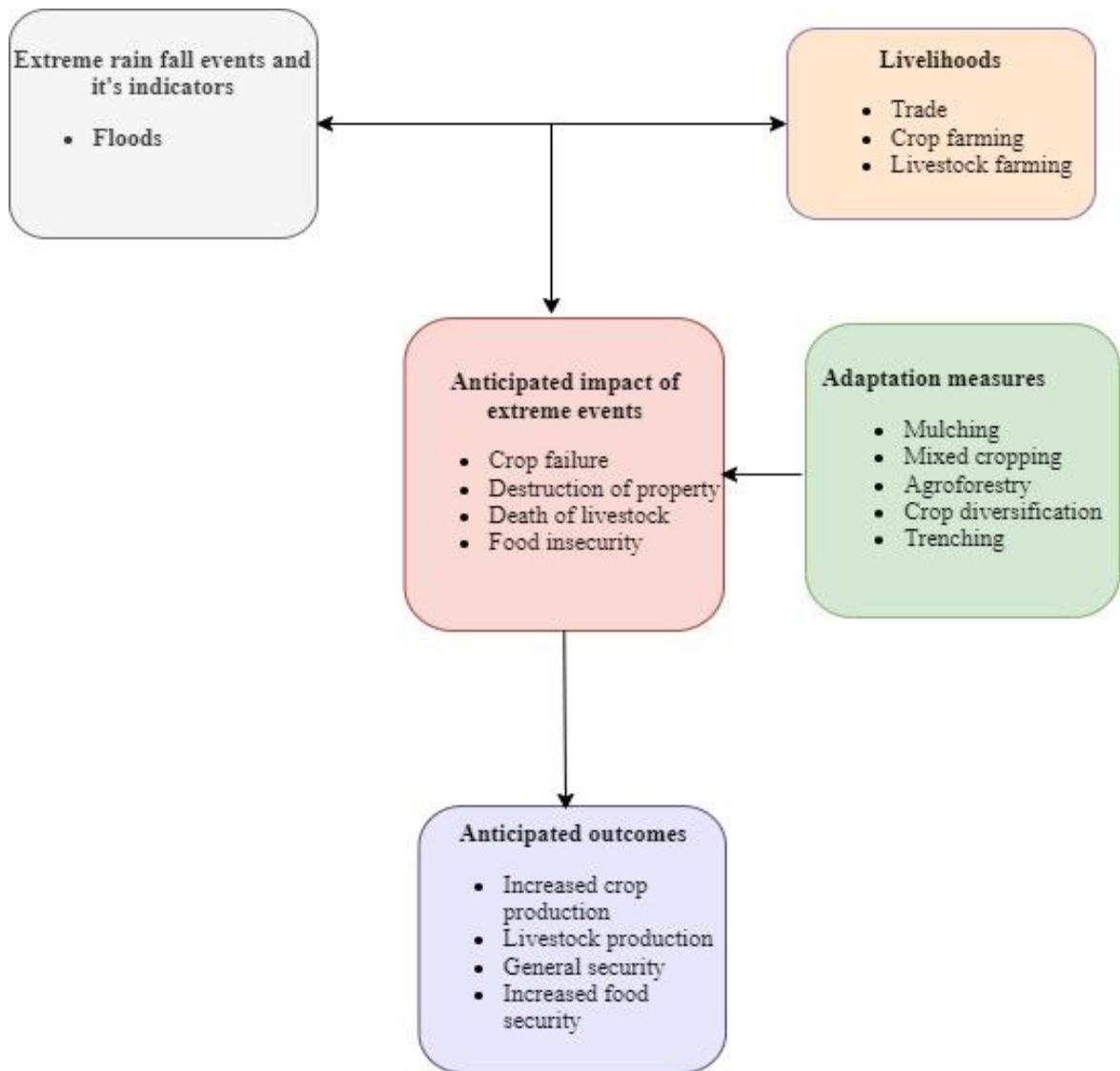
The study was carried out in the lower parts of river Namatala catchment in Kyoga basin system. Extreme rainfall events and their trends for the period between 1982-2022 were investigated. The study was conducted from 1982-2022 because the period has been characterized by immense extreme rainfall events characterized by floods which have persistently affected people's ways of living. The Information on adaptation measures were sourced from the local community.

### **1.6 Significance of the Study**

The current research is a paramount asset to the households in the river Namatala catchment. River Namatala catchment has faced a lot of calamities as a result of extreme rainfall events which have been triggered by the increasing rainfall, as a result many households have been severely affected by the effects of the extreme rainfall events. Thus, this study would help to the households in creating awareness about the time and the velocity of the extreme events so as creating proper adaptation measures. This can be used by government agencies in policy formulation, local government officials in implementation of policies, donors who may intend to uplift the status of the local dwellers. The findings and recommendations will contribute to formulation of policies. These will help to mitigate the effects of the increasing extremes of rainfall events. The study will outline adaptation measures that can be used to deal with the devastating effects caused by extreme rainfall. The findings will add knowledge to the academic body in relation to how to adapt to extreme rainfall events in catchment areas.

## **1.7 Conceptual framework**

The framework below shows how households respond to extreme rainfall events. It was conceptualized that extreme rainfall events through their indicators, for instance floods, have an impact on livelihoods carried out in the catchment. Due to man's interaction within the catchment for instance through activities like crop farming as well as livestock farming, it has led to increase in the vulnerability of households due to extreme rainfall events in the catchment area. Extreme rainfall events like floods have led to damage of buildings, loss of livestock, soil erosion. With increase in the effects, there is need for proper catchment planning and management through a variety of adaptation measures to extreme rainfall events so as households are able to have better livelihoods.



**Figure 1. 1: Conceptual framework showing extreme rainfall events and adaptation measures.**

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 Temporal and spatial extreme rainfall events experienced.

Temporal extreme rainfall events are periods where rainfall intensity surpasses typical levels for a given time frame, such as hours, days, or even longer(WB & ADB, 2020). The intensity of these events often leads to flash flooding, landslides, and significant water runoff. For instance, the 2017 hurricane season in the Atlantic, particularly Hurricane Harvey, saw unprecedented rainfall, with some areas receiving over 60 inches in a matter of days(Manuel-Navarrete et al., 2011). This event set a new record for the most rainfall ever recorded from a single storm in the continental United States, leading to catastrophic flooding in Houston and surrounding areas (Emanuel, 2017; Van Oldenborgh et al., 2017).Spatial Extreme Rainfall Events occur when unusually high levels of rainfall are concentrated in a specific geographic area(Aghakouchak et al., 2020). Such events can be localized, affecting a small region, or more widespread, impacting larger areas. An example is the 2021 European floods, where regions in Germany, Belgium, and the Netherlands experienced extreme rainfall over a short period. This led to severe flooding, with some areas receiving more than double their average monthly rainfall in just a few days (Kreienkamp et al., 2021). The spatial concentration of rainfall overwhelmed local rivers and drainage systems, resulting in widespread devastation (Van Oldenborgh et al., 2023; Tradowsky et al., 2023). In this case an extreme rainfall events are events that occur when rainfall exceeds set threshold of 12mm(0.5inches) in 3 consecutive days.

Both types of extreme rainfall events are influenced by a combination of climatic factors and geographical characteristics. Climate change is a significant driver, as it increases the

atmosphere's capacity to hold moisture, leading to heavier and more intense rainfall events. A warmer atmosphere can hold approximately 7% more moisture per degree Celsius of warming, which can exacerbate both temporal and spatial extreme rainfall events (Trenberth, 2011).

The impact of these extreme events is profound. In urban areas, where impervious surfaces are common, the risk of flooding is particularly high. Infrastructure such as roads, bridges, and buildings can be severely damaged, and there is often a significant loss of life and property. In rural areas, agricultural lands can be flooded, leading to crop loss and soil erosion. For example, the 2010 Pakistan floods, driven by heavy monsoon rains, affected about 20 million people and submerged one-fifth of the country's land area, illustrating the devastating impact of extreme spatial rainfall events on both human populations and agriculture (Pińskwar et al., 2019).

Extreme rainfall events for instance floods pose a significant threat to human settlements, economic development, and agriculture, demanding urgent attention (Haque et al., 2013). Extreme rainfall events impact the environment leading to the destruction of ecosystems and their function (Oriangi et al., 2020). While adaptation measures are devised globally, Africa remains particularly vulnerable to the devastating consequences of extreme rainfall events (Beer, 2018; IPCC, 2022; Kundzewicz & Schellnhuber, 2004; Mika, 2011) due to their levels of income which are low.

Efforts to mitigate the effects of extreme rainfall events include improving weather forecasting and early warning systems, enhancing flood defenses, and implementing sustainable urban drainage systems. These measures are critical in reducing the vulnerability

of populations and infrastructure to these increasingly frequent and severe events (Brakenridge, Anderson, & Nghiem, 2012).

## **2.2 Trend of rainfall extreme events**

The trend of extreme rainfall events has shown a significant increase in both frequency and intensity over recent decades (Westra et al., 2014). This trend is observed globally and is closely linked to climate change, which has altered atmospheric patterns and increased the potential for severe weather events (Biasutti, 2019; Walsh et al., 2020). In Africa, increase in extreme rainfall events has been manifested mostly in the tropical regions where rainfall amounts have increased over time (Mason et al., 1999; Onyutha, 2020; Onyutha et al., 2021; Shaffie et al., 2013). This has made households more vulnerable (Narayanan & Sahu, 2016; Oriangi et al., 2020). In Uganda, extreme rainfall events have experienced an increase due to the increase in the rainfall amounts over time in the region (Bomuhangi et al., 2016; CTI et al., 2016; Project, 2013; UNMA, 2018) which has affected farmlands, trade as well as homes.

This trend is particularly evident in the intensity and duration of these events. A notable example is the increased frequency of extreme rainfall in the eastern United States, where the number of days with heavy rainfall has risen significantly since the mid-20th century (Konrad et al., 2013; USGCRP, 2018; Allen, M. J., & Allen, T.R, 2019). While the global trend shows an increase, the pattern and impact of extreme rainfall events can vary significantly by region (Lehmann et al., 2015; Donat et al., 2016). For example, in South Asia, the Indian monsoon has become more erratic, with instances of both prolonged dry spells and intense rainfall events becoming more common (Sheikh et al, 2015;

Naveendrakumar et al., 2019). Similarly, in Europe, there has been a marked increase in heavy rainfall events, particularly in northern and central parts, contributing to more frequent and severe flooding (Kreienkamp et al., 2021).

The primary driver behind the increasing trend of extreme rainfall events is climate change (Herring et al., 2014). As global temperatures rise, the atmosphere's capacity to hold moisture increases, leading to more intense and frequent rainfall (Gimeno et al., 2016). Specifically, for every 1°C increase in temperature, the water-holding capacity of the atmosphere increases by approximately 7%, intensifying the hydrological cycle and enhancing rainfall extremes (Trenberth, 2014). Changes in atmospheric circulation patterns, such as the jet stream, also play a crucial role in the distribution and intensity of extreme rainfall events (Coumou et al., 2015). The trend of increasing extreme rainfall events has profound implications for both natural and human systems. In urban areas, these events can overwhelm drainage systems, leading to severe flooding, property damage, and loss of life. The 2018 floods in Kerala, India, exemplify this, where extreme monsoon rainfall led to devastating floods affecting millions of people (Khan et al., 2020; Ramesh et al., 2021; Suresh et al., 2024). In rural areas, heavy rainfall can cause soil erosion, landslides, and crop damage, significantly impacting agriculture and food security (Chalise et al. 2019; Jumiyati et al., 2021). Addressing the trend of increasing extreme rainfall events requires comprehensive strategies that include improving climate resilience and adaptive capacity (IPCC, 2012).

### **2.3 Adaptation measures on extreme rainfall events.**

Adapting to extreme rainfall events across the globe involves implementing various measures designed to mitigate their impacts and enhance community resilience. These adaptation measures are critical in reducing the vulnerability of populations and infrastructure to increasingly frequent and severe rainfall events (Pregolato et al., 2016; Salimi et al., 2020). The effectiveness of these measures varies based on implementation, local conditions, and the scale of events. One of the most direct adaptation measures is enhancing the resilience of infrastructure. This includes upgrading storm water drainage systems, constructing flood defenses such as levees and flood walls, and retrofitting buildings to withstand flood conditions (Aerts, J.C. 2018; Karamouzet al 2019). The Netherlands has invested heavily in flood defense systems, including the Delta Works, a series of construction projects designed to protect large areas of land from the sea which significantly reduced flood risk in vulnerable areas (Wesenbeeck et al., 2014).

Further, Sustainable Urban Drainage Systems (SUDS) is a measure which aim to manage rainfall close to where it falls (Srishantha & Rathnayake, 2017). These systems include green roofs, permeable pavements, rain gardens, and retention basins, which help to absorb and slow down runoff, reducing the risk of flooding (La Rosa et al., 2021). Studies have shown that SUDS can effectively reduce peak flow rates and improve water quality (Yu, 2013). For example, the widespread implementation of SUDS in Malmö, Sweden, has successfully mitigated urban flooding and enhanced urban resilience (Sörensen, 2018).

Early warning systems are also crucial for reducing the impact of extreme rainfall events by providing timely information to communities, allowing for the evacuation and protection of

lives and property (Šakić Trogrlić et al., 2022). Effective early warning systems combine meteorological data with communication networks to alert at-risk populations. The use of early warning systems in Bangladesh has significantly reduced casualties from cyclones and associated heavy rains by providing early alerts and facilitating timely evacuations (Paul, 2009). Ecosystem-Based Adaptation Ecosystem-based adaptation (EbA) involves using natural systems to mitigate the impacts of extreme rainfall(Hance et al., 2007). This includes restoring wetlands, reforesting watersheds, and maintaining natural floodplains, which can absorb excess water and reduce flood peaks. Wetlands, for instance, act as natural sponges, absorbing significant amounts of rainfall and releasing it slowly, which helps to mitigate flooding. The restoration of wetlands in the Mississippi River Basin has shown promise in reducing flood risks and enhancing biodiversity (Zedler & Kercher, 2005).

Policy and planning Integration is a key rainfall adaptation policy and planning processes ensure that adaptation measures are systematically implemented. This includes updating building codes, zoning laws, and land-use planning to consider flood risks and climate projections(Marengo et al., 2020). Cities like New York have incorporated climate resilience into their planning processes, requiring new developments to account for future flood risks, which has helped to improve the city's overall resilience to extreme rainfall events (Rosenzweig et al., 2011).

In Uganda various measures like agroforestry has emerged as one of the adaptation measures against the increasing effects of extreme events in Uganda (Thorlakson & Neufeldt, 2012). With rising rainfall amounts and severity, intentional tree planting is perceived as vital in mitigating these effects (Bhatta & Aggarwal, 2016) since they help to control runoff and soil

erosion. Agroforestry is key in erosion mitigation and flood control since agroforestry system slow down heavy rainfall and infiltrate it into the soil (Bahta, 2022; Oskorouchi, 2021). Digging trenches is key since it creates water passage (Jones and Brown 2017) which reduces the risk of floods since the overland flows are reduced (Smith et al. 2013). Modifications to the physical and built environment play a crucial role in mitigating extreme event impacts (Jabeen et al., 2010). Strengthening infrastructure and drainage facilities help reduce displacement risks (Haque et al., 2013). Resilient construction practices are particularly essential for households in regions prone to extreme events like Bugisu and Kigezi in Uganda (Oriangi et al., 2020). Stringent building regulations in countries like the UK and Australia aim to counter extreme rainfall effects (Holm & Stauning, 2011; Hurlimann et al., 2019). Adaptation to extreme rainfall events garners increasing international attention as climate projections gain confidence (Mertz et al., 2009). Flexible livelihoods, incorporating social networks and cultural traditions, enhance resilience against rainfall extremes (Birkmann & Mechler, 2015) since they can adapt to a variety of measures.

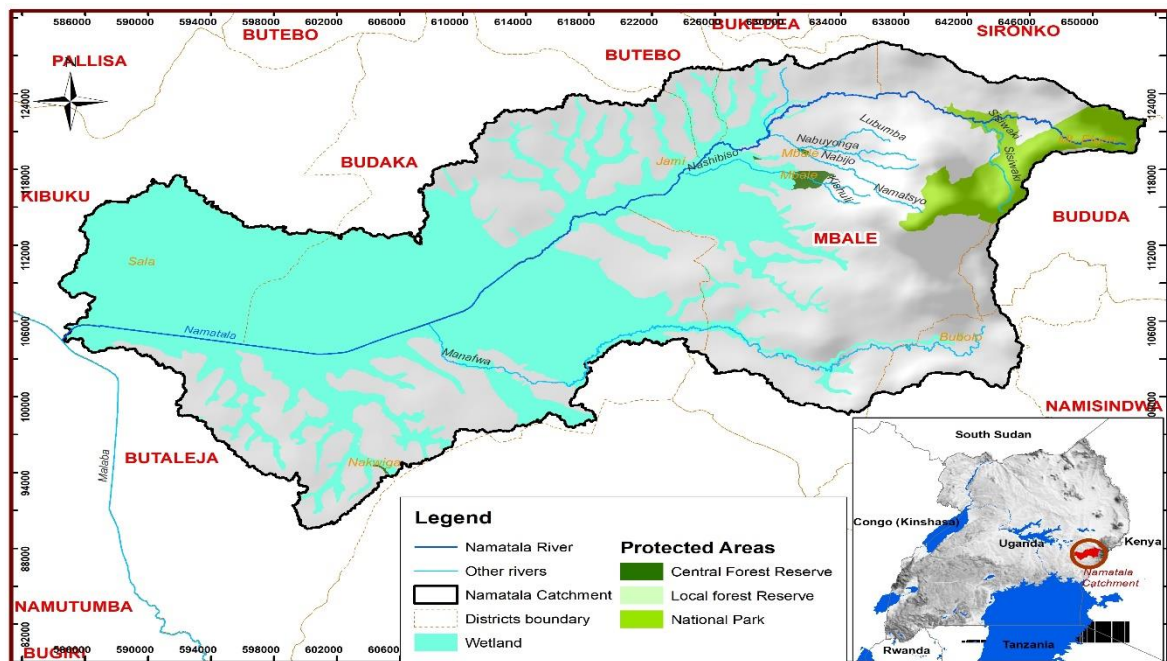
Farmers adapt both physical and non-physical measures to mitigate economic losses caused by extreme events (Huang et al., 2015; Boyd & Ibararán, 2009) which enhances their livelihoods in such conditions. Such measures include crop diversification and diversification of livelihoods (Ecosystems, 2009). In response to the increasing trend of extreme rainfall events, communities seek adaptation options to cope with their severity (Berkhout, 2012). Proper adaptation measures like digging trenches, agroforestry, mixed farming could improve on the livelihoods of households (B. Smit & I. Burton, 2016). Effective adaptation requires a combination of physical infrastructure improvements and socio-economic measures tailored to local contexts could as well improve the standards of

living of households (Thorlakson & Neufeldt, 2012). This may involve community-based early warning systems, land-use planning, and diversification of livelihoods to reduce vulnerability to extreme rainfall events (Ziervogel et al., 2006).

## CHAPTER THREE: METHODOLOGY.

### 3.1 Location

River Namatala is located in Mbale district Budaka and Butaleja, Eastern Uganda. River Namatala has a stretch of about 31km for the upstream to downstream with surface area of 113km<sup>2</sup> and an elevation of 1,150m upstream to 1,060m downstream(Namaalwa et al., 2020). The river discharges its water into the Mpologoma river system and ultimately into Lake Kyoga basin. The catchment also covers the districts of Mbale, Budaka, Butaleja with the catchment covering Pallisa, Sironko (Namaalwa et al., 2013).



**Figure 3. 1: A map showing the districts that are found in River Namatala Catchment (Source: Federation, 2020).**

### **3.2 Relief and Drainage.**

River Namatala in the eastern part of Uganda at 1082 and 1128m altitude flowing from Mount Elgon downwards to the districts of Mbale, Budaka Butaleja(Federation, 2020). The river meanders due to the nature of the geologic system of hard and weak rock along the slopes of mountain Elgon(Oriangi et al., 2019). The river is joined by tributaries like Nashibisho and draining to River Manafwa and later discharging into River Mpologoma River system then later into lake Kyoga (State, 2019).

### **3.3 Climate.**

River Namatala lies in the Mount Elgon which receives montane type of climate along the windward side of the mountain in the districts of Mbale (State, 2019). This area experience modified equatorial climate of above 2000mm per annum (UNMA, 2018). It mostly receives rainfall in the month of May (UNMA, 2018). The region has a high humidity 80% making the area to receive high rainfall amounts with temperatures of above 20.3 °C. (NEMA, 2019; UNMA, 2018)

### **3.4 Socio-economic activities**

River Namatala catchment is dominated by agriculture(Oriangi et al., 2020) as the main economic activity where households grow both food crops and cash crops (mainly subsistence), industrialization has developed with small proximity the river (Mbale industrial park), charcoal burning is also carried out in Doko where the vegetation has been cleared, settlement is dominant in Namabasa, Doko, Kibumbire and Namatala(Republic, 2015).

### 3.5 Research Design

Mixed research design was adopted during the study. Qualitative data was acquired using the CDT software and this data helped in determining extreme rainfall events and their trends. Besides quantitative methods which included questionnaire were used to collect data about the adaptations to extreme rainfall events in the river Namatala catchment. These were uploaded onto SPSS and thus determining the adaptation measures to extreme rainfall events. Thus, the design included acquiring meteorological data from UNMA. After which this data was inspected and quality controlled in order to manage the gaps. Data analysis followed to establish the extreme events in rainfall and the trend of these events. A field study commenced in order to get information on adaptation measures. This information was sorted, coded and analyzed using SPSS software. All in all, Qualitative and Quantitative approaches were used. To acquire data about how people cope with the extreme rainfall events, a survey was required to determine how people deal with occurrences and determine the predominance of occurrences. It could be used to research events that change after a given amount of time because it is appropriate for that purpose.

### 3.6 Study population and size

The targeted population size of this study was 190,108 households in the 3 districts, that is 108,558 households in Mbale, 37,188 households in Budaka and 44,362 households in Butaleja district. Using the Krejcie and Morgan (1970) table of determination of sample size, the sample population considered was 384 households using the formula;

$$S = \frac{x^2(1-P)}{d^2(N-1)+x^2P(1-P)} \dots\dots\dots(I)$$

Where;

$s$  = required sample size.

$\chi^2$  = the table value of chi-square for 1 degree of freedom at the desired confidence

$N$  = the population size

$P$  = the population proportion (assumed to be .50 since this would provide the maximum sample size)

$d$  = the degree of accuracy expressed as a proportion (.05).

Out of the 384 selected households,

Out of the 384 households that were selected, 128 households were selected from each of the 3 districts following the guidelines from UBOS 2014. In Mbale city, concentration was put on Northern division using purposive sampling since it was the one that was near the river where 4 wards were sampled, using simple random sampling with 2 cells from each ward. In Butaleja and Budaka districts, 2 sub counties in each district were selected and 2 parishes in each subcounty and 2 villages in each parish were purposely sampled.

### **3.7 Data and Data sources.**

Data used in the study was both primary and secondary data. Primary socio-economic data was sourced from the field survey. This data included information from respondents about adaptation measures, to extremes of households in river Namatala catchment. Daily rainfall data series in a gridded form of  $(0.25^\circ \times 0.25^\circ)$  covering a period of 1980–2022 (41years)

were acquired from <http://hydrology.princeton.edu/data/pgf/0.5deg/> (accessed: 15 March 2024) and the Climatic Data Tool (CDT). Like other reanalysed climatic products, the dataset possessed a few limitations, such as bias and random errors. Daily observed rainfall data acquired from the Uganda National Meteorological Authority UNMA (Station ID 88340590- Buginyanya) facilitated bias correction of the gridded data.

### **3.8 Data quality control.**

Quality control was applied on daily rainfall records to make it suitable for subsequent analysis. Quality control was carried out by authorities at UNMA which involved station metadata checks for accurate location data and duplicate stations, this was then followed by flagging of suspicious data using a set of time series based on a set of user defined rules (Lewis et al 2019). The raw sets from UNMA are archived daily values using climate-computing format. Data quality checks were conducted to ensure that there are no abnormal values, no missing records and records are valid (UNMA, 2018).

#### **3.8.1 Identifying extreme events.**

***Frequency distribution.***: Extreme rainfall events are determined by the amount of rainfall received in a particular day (Attri and Tyagi 2010, Taylor et al., 2014). In this study, extreme events were construed to mean any high rainfall above 12 millimeters received in 3 consecutive days. In this case, areas that have steep terrains tend to experience flooding due to high speed of running water that is caused by the heavy rainfall (Protocol, 2020; Saharia et al., 2017). Thus in such areas that receive high rainfall amounts with soils that can be easily saturated tend to experience flooding easily (Kundzewicz & Schellnhuber, 2004;

Saharia et al., 2017). Therefore, in such places including R. Namatala catchment rainfall reaches 0.5inches it can easily lead to a flood which is an extreme rainfall(Taylor et al., 2014).

### 3.8.2 Trend of extreme rainfall.

Extreme rainfall events were subjected to the MK-test in order to determine the trend and also the Sens slope test in order to determine the magnitude of trend.

### 3.8.3 Determining trend of extreme rainfall events.

Mann-Kendall test which is a non-parametric test used to test trend in meteorological time series (Cannarozzo et al.,2006; Madarres and Silva 2007; Partal and Kahya 2006; Tabari and Talee,2011). The test is suitable for data that do not follow a normal distribution (Tabari et al; 2011) and allows multiple perception per time series (Kampata et al 2008). The method is the most used method to determine trends in temporal series.

The Mann-Kendall statistics was given by:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sgn}(x_j - x_i) \dots \dots \dots \text{Eqn 1}$$

The application of trend was done to a time series  $x_i$  that is ranked from  $i = 1, 2, \dots \dots n - 1$  and  $x_j$  which was ranked from  $j = i + 1, 2 \dots \dots n$ . each of the data point  $x_i$  was taken as a reference point which was compared with the rest of the data points  $x_j$  so that,

$$\text{Sgn}(x_j - x_i) \begin{cases} +1, & (x_j - x_i) > 0 \\ 0, & (x_j - x_i) = 0 \\ -1, & (x_j - x_i) < 0 \end{cases} \dots \dots \dots \text{Eqn 2}$$

If it has been noted that when  $n \geq 8$ , the statistics  $S$ , was approximately normally distributed with the mean.

$$E(S) = 0 \dots \dots \dots \text{Eqn 3}$$

The variance statistics was given as,

$$\text{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=0}^n t(i)(i-1)(2i+5)}{18} \dots \dots \dots \text{Eqn 4}$$

where  $t_i$  was considered as the number of ties up to a sample  $i$ . The test statistics  $Z_c$  was computed as

$$Z_c = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(s)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(s)}} & S < 0 \end{cases} \dots \dots \dots \text{Eqn 5}$$

$Z_c$  Here follows a standard normal distribution. A positive (negative) value of  $Z$  signifies an upward (downward) trend. A significance level was also utilized for testing either an upward or downward monotone trend (a two-tail test). If  $Z_c$  appears greater than  $Z_{\alpha/2}$  where  $\alpha$  depicts the significance level, then the trend is considered as significant.

$$S = \sum_{j=1}^{n-1} \sum_{i=j+1}^n \text{sign}(x_i - x_j) \dots \dots \dots \text{Eqn 6}$$

Where  $x_i$  was the data value at time  $i$ ,  $n$  is the length of the data set and sign as the sign function which can be computed as:

$$\text{Sign}(x_i - x_j) = \begin{cases} 1 & \text{if } x_i - x_j > 0 \\ 0 & \text{if } x_i - x_j = 0 \\ -1 & \text{if } x_i - x_j < 0 \end{cases} \dots \dots \dots \text{Eqn 7}$$

For  $n > 10$ , the test statistics  $Z$  approximately follows a standard normal distribution

$$Z = \begin{cases} \sqrt{\text{var}(s)}s - 1 & \text{if } s > 0 \\ 0 & \text{if } s = 0 \\ \sqrt{\text{var}(s)}s + 1 & \text{if } s < 0 \end{cases} \dots \text{Eqn 8}$$

In which  $\text{Vars}(s)$  is the variance of statistics  $S$ .

A positive value of  $Z$  shows that there was an increasing trend and a negative value shows a decreasing trend.

If  $|Z| > Z_{1-\alpha/2}$ , the null hypothesis of no auto ordination and trend in data set is rejected in which  $Z_{(1-\alpha/2)}$  is corresponding to the normal distribution with  $\alpha$  being the significance level. If the data has a trend the magnified of trend can be donated by trend slope  $\beta$

$$\beta = \text{median}$$

Where  $t_i$  and  $t_j$  are data values at time  $t_i$  and  $t_j$  ( $i > j$ ) respectively.

This Mann Kendall test for trend was used because of its ability to detect non-linear trends and its robustness to outliers (Mostafa et al., 1800)

### **3.8.4 Adaptation measures to extreme rainfall events.**

Questionnaires were used in the collection of data required for adaptation measures to extreme rainfall events. These were composed of questions which were both open ended and closed ended which required answers from respondents. These questionnaires were distributed among the directly affected persons in the catchment.



## **CHAPTER FOUR: PRESENTATION OF RESULTS.**

### **4.0 Introduction**

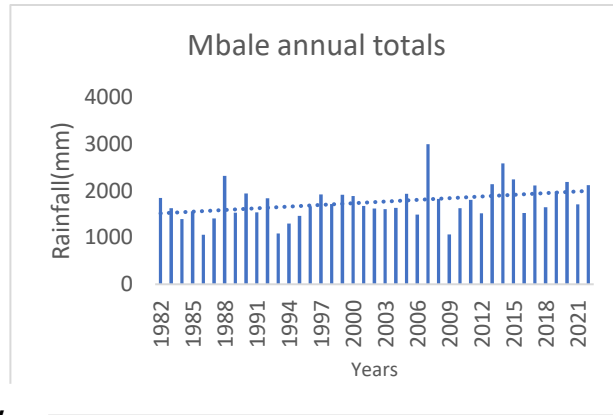
This chapter contains presentation of data collected from the field.

### **4.1 Spatial and temporal extreme rainfall events.**

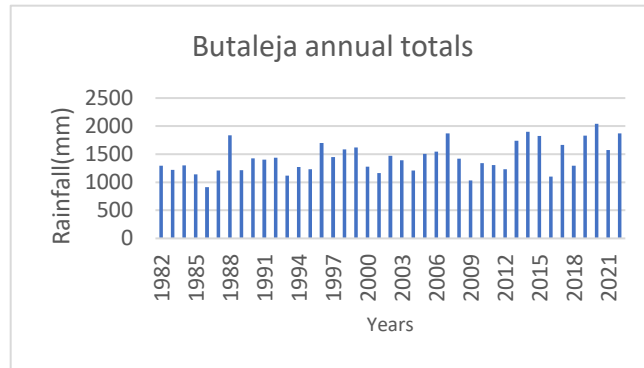
This section presents results of extreme rainfall events that have been experienced in the river Namatala catchment from 1982-2022.

#### **4.1.1 Rainfall distribution.**

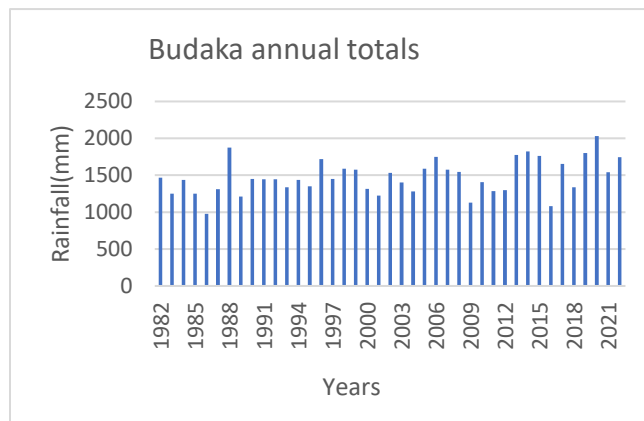
The results reveal that there has been an increase in the rainfall annual amounts throughout the study area. For instance, in the last 10 years that's 2013-2022 and the first 10 years that's 1982-1991, Mbale had rainfall had rainfall totals of 1979.864mm and 16231.6mm respectively, Budaka with totals of 12509.9mm and 12354.4mm respectively as well as Butaleja with a total of 1622.53mm and 12226.2mm respectively. The highest amount of rainfall was received from where rainfall has been notably increasing over time. Total rainfall distribution over the years in Mbale, Butaleja and Budaka are depicted in graphs *a, b, and c*



**a**



**b**

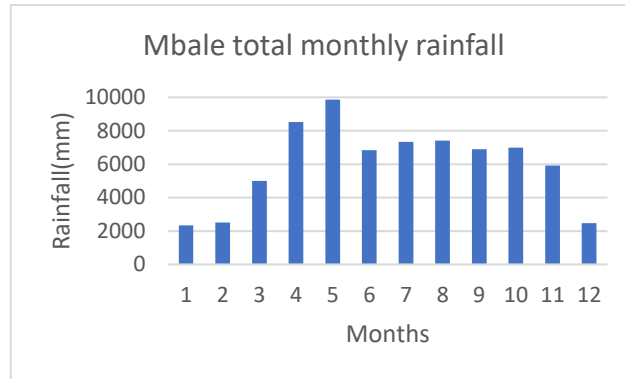


**c)**

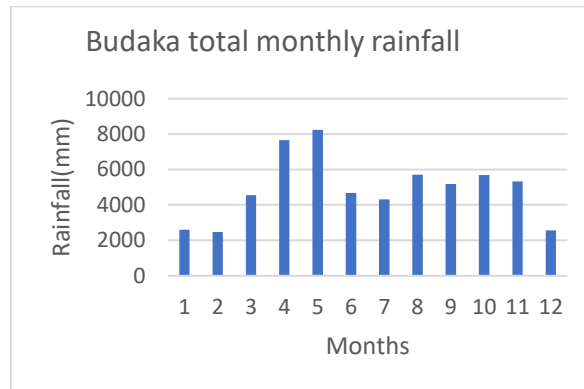
**Figure 4.1: Graphs a, b, and c showing annual rainfall in the districts of Mbale, Butaleja and Budaka over the study area.**

Monthly rainfall distribution indicates that much of the rainfall in the districts was received in the months of April and May having the highest totals and the lowest amount of rainfall

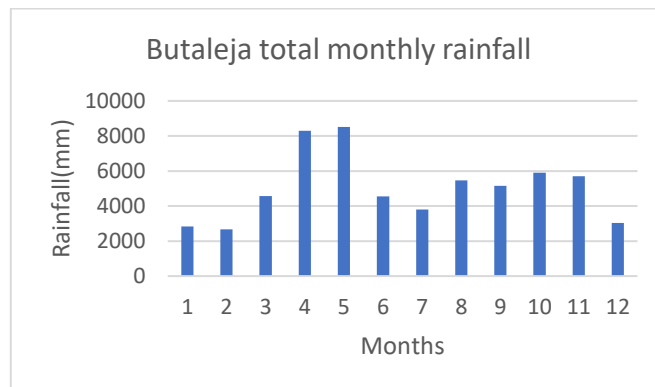
received in the month January throughout the period of 1982-2022 as indicated in the graphs *a*, *b* and *c* in the districts of Mbale, Butaleja and Budaka respectively.



*a)*



*b)*

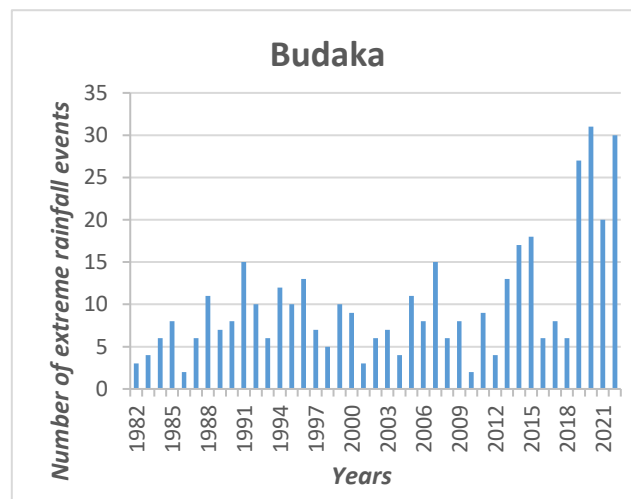
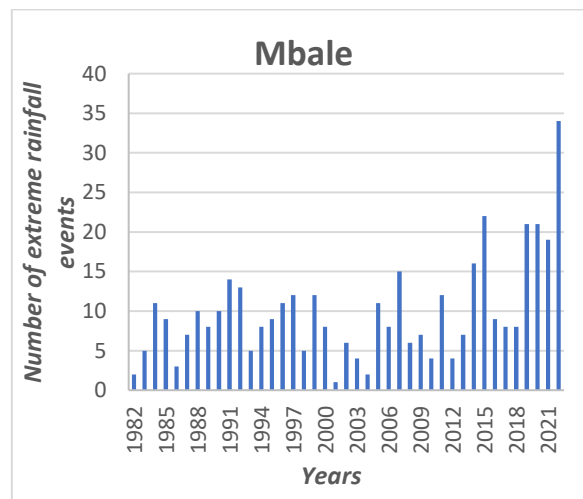


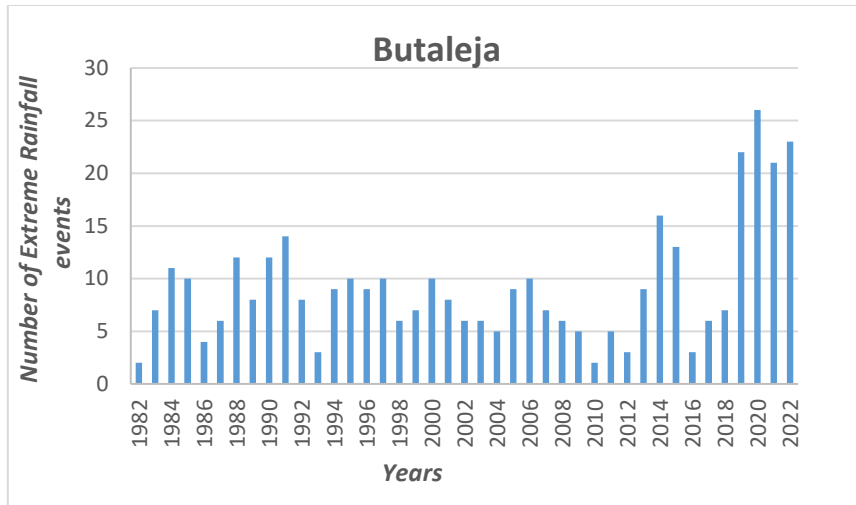
*c)*

**Figure 4.2: Graphs a, b and c showing monthly rainfall distribution in the districts of Mbale, Butaleja and Budaka over the study area**

## 4.2 Extreme rainfall events

In this study, an extreme event is defined as any high rainfall above 12 millimeters received in 3 consecutive days. Rainfall in the catchment was observed that it would rain for 3 consecutive days and if it could surpass the set threshold of 12mm and this was regarded as an extreme rainfall. Rainfall that was received in the three consecutive days but did not exceed the 12mm was not regarded as an extreme event since it is below the considered threshold. The extreme rainfall events count is presented in the graphs for the district of Mbale, Butaleja and Budaka in the study area;





**Figure 4. 3: Bar graphs showing the number of extreme rainfall events.**

### 4.3 Trend of extreme rainfall events in River Namatala catchment

The trend of the extreme rainfall events was determined using the Mann-Kendall statistical analysis technique. This shows the behavior of the extreme rainfall events over time in the study area. These were analyzed according to the districts that were selected in the study area as shown in table 4.4 below;

**Table 4.1: A table showing Mann-Kendall and Sen's slope tests for study districts.**

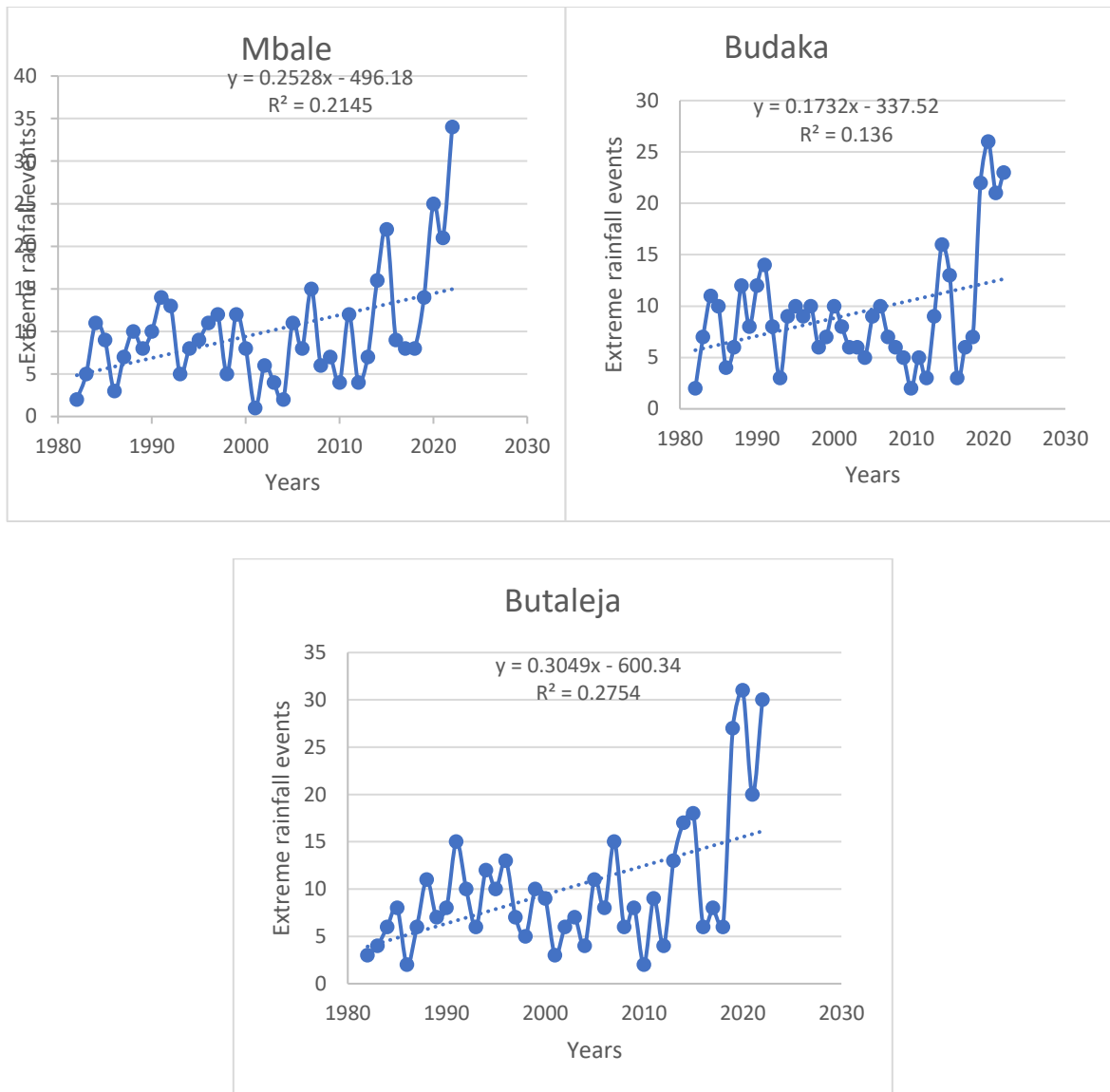
	<b>MBALE</b>	<b>BUTALEJA</b>	<b>BUDAKA</b>
<b><i>N</i></b>	41	41	41
<b><i>Z</i>-score</b>	2.164	2.63	0.621
<b>Sen's</b>	0.174	0.214	0.385

From table 4.4, Mbale has experienced variability in the extreme rainfall events over the years for instance in 1984,1988,1991,2007,2015,2020,2022 and a decrease in 1982, 1986, 1993, 2001, 2010, 2012, 2018. With Mann-Kendall and Sen's test, Mbale experienced an

increase in the extreme rainfall events over time due to the positive Z-value of 2.164 and a magnitude of 0.174. Thus, implying that there is an increasing trend of extreme rainfall events in the district from 1982-2022.

Butaleja experienced an increase in the extreme rainfall events in the years of 1985, 1988, 1991, 1996, 2005, 2007, 2015, and 2020. Whereas there was a decrease in the extreme rainfall events in the years of 1986, 1993, 2001, 2004, 2020, 2016, and 2018 as indicated in the graph below. According to Mann-Kendall, Butaleja had an increasing trend due to a positive Z-value of 2.63 with a magnitude of 0.214. This implies that there is a general increase in the extreme rainfall events in Butaleja district.

Budaka district has experienced an increase in the extreme rainfall events over the years for instance in 1984, 1998, 1991, 2000, 2006, 2014 and 2020 and a decrease in the extreme rainfall events in 1982, 1986, 1993, 1998, 2010, 2012 and 2016. According to Mann-Kendall, the area extreme rainfall events in the years of with a Z-value of 0.62071 and a magnitude of 0.385. Thus, there has been an increase in the extreme rainfall events in river Namatala catchment



**Figure 4.4: Graphs showing the trend of extreme rainfall events in the river Namatala.**

#### **4.4 Adaptation measures to extreme rainfall events and their effectiveness in R. Namatala catchment.**

The data collected from the field showed that there were 384 participants took part in the study. Out of the 384 participants, 74.7% (287) were males while 25.3% (97) were females. Of the 384 persons that were sampled, 81.5% of the participants were engaged in on farm

activities, while 18.5% were engaged in off farm activities. Those who involved themselves in on farm activities were those that were mainly farmers that were found in the area totaling to 313 participants involved in crop growing, livestock and 71 who were carrying out other activities for instance Bodaboda riding, market vending, small retail, construction as presented. The table below shows multiple responses of the adaptation strategies and activities engaged by participants.

**Table 4.2: A table showing the adaptation practices to extreme rainfall events**

	<b>Frequency</b>	<b>Percent</b>
Diversify livelihoods.	343	89.3%
Mixed farming.	343	89.3%
Practicing Agroforestry.	350	91.1%
Crop diversification.	352	91.7%
Digging trenches.	361	94.0%

Most households in the catchment area had adapted to various practices during the extreme rainfall events in the river Namatala catchment. The adaptation measures and their effectiveness were derived from the percentages obtained from the multiple responses from the participants in the area.

Digging trenches was the most dominant strategy used by households in adapting to extreme rainfall events with 94.0%. Most of the participants in Mbale, Budaka and Butaleja were found to be digging trenches in order to create passage in the increased volumes of water in the areas these passages were dug in home compounds, gardens. The participants were asked why they dug trenches and they indicated that 93.3% effects to their activities were results of floods like in Kibumbire zone where gardens were filled with water leading to destruction farmland. They indicated that the yield of beans reduced by 92.2% as a result of much water

in the gardens. They also indicated that 70.5% of agricultural production was reduced as a result of pests and diseases caused by the effects of extreme rainfall events. For instance, in Nyanza A and B where there was a rampant increase in the tsetse flies which affected cattle which forced most of the farmers to locally dig traditional trenches that in the backyards to allow easy flow of water. Digging trenches created a proper flow of water thus reducing on damages which would be caused on farmlands, houses and other infrastructures.



**Figure 4.5: Trench created for water passage in a rice plantation in Namatala village, Kaiti sub-county- Butaleja district.**

Crop diversification is another adaptation practiced by farmers in the river Namatala catchment. it accounted for 92% distributed by Butaleja district with a percentage of 46% (177) participants practicing crop diversification, Budaka with 43% (164) and Mbale with 11% (43). Most people indicated that they carried out crop diversification since it could deal with the changing rainfall patterns which has led to extreme rainfall events, they indicated as well that it could help to reduce soil erosion. In Butaleja, 46% (177) of the participants indicated that they grew potatoes, maize, beans as well as cassava. Those who practiced crop diversification indicated that some crops can die, washed away through erosion and some

can survive. This could help to improve food supply to households as a way of adapting to the effects of extreme rainfall events in the region. Crop diversification was practiced almost all over the catchment and it was considered as to be boosting food security. Thus, it was considered an effective measure since it could lead to stability in food supply for households in the river Namatala catchment.



**Figure 4.6:A photograph showing sugarcane grown alongside Banana plantation in Naboa, subcounty in Budaka district.**

Agroforestry with 91% was practiced as a way of adapting to extreme rainfall events. Households in R. Namatala opted for Agroforestry as a way of dealing with the impacts of extreme rainfall events. Mbale had 52% (198) of the participants carrying out Agro-forestry, Butaleja had 29% (113) participants and Budaka had 19% (73) participants carrying out Agroforestry. When participants were asked why they carried out agro-forestry, they indicated that it was practiced in the order to create food stability in the catchment area, help in reducing the speed of running water at times of an extreme rainfall events which may result into a flood. Trees like eucalyptus that are grown in the catchment can also be sold to

create enhance on the income in case of crop failure. Areas that do not have permanent water supply have grown trees like avocado, jackfruit, mangoes which provide food to the households. However, the 9% (31) participants did not consider agro forestry since they claimed to be having small pieces of land where they resided and thus, they resorted to other activities for instance market vending, Bodaboda riding. Thus, agro-forestry was considered as an effective measure since it has been able to increase on the income of households make them able to mitigate the effects of extreme rainfall events in R. Namatala catchment. as a key practice in adapting to extreme rainfall events.



**Figure 4.7: Agro- forestry where bananas are grown alongside mango trees in Namanyonyi village in Mbale District.**

Mixed farming with 89% (343) was another practice in adapting to extreme rainfall events along the R. Namatala catchment. Households involved themselves in rearing animals and growing crops as a way of improving their standard of living. 82% (313) of the participants involved themselves in on-farm activities as their major source of income where they grew

two or more crops simultaneously on the same piece of land. This was mostly practiced in Budaka district with 51.7% of the households and Butaleja with 38% and Mbale with 10% of the households. Households engaged in mixed farming as a way to increase their income since there were cases of crop destruction during the extreme rains which could leave them with livestock as an income generating venture. However, 11% of the participants did not involve themselves in the practice and considered other measures like crop diversification. Thus, mixed farming has been practiced as a way of mitigating the effects of extreme rainfall events such as floods which affects 93% of agricultural production. Therefore, mixed farming has increased food supply reducing on food insecurity in the catchment hence considered an effective measure in adapting to extreme rainfall events in R. Namatala catchment as shown in the figure below,



**Figure 4.8: A photograph showing Mixed farming where maize is grown alongside cassava in Doko village in Mbale District.**

Diversification of livelihoods with 89% (343) was also a key adaptation strategy practiced by households. 89% (343) households opted for a variety of livelihoods since there was a decrease in the agricultural output due to extreme rainfall events. Participants indicated that agricultural production reduced by 93% due to floods, 92% due to crop failure, 70% due to pests caused by the effects of extreme rainfall events on crops like tomatoes, beans, maize and rice. The effects of low food production have led to food insecurity in the area. Therefore, opting for other livelihoods rather than agriculture could bring in more income which could sustain the household's population.

River Namatala catchment is dominated by mainly agriculture as an activity, the effects of extreme rainfall events lead to low agricultural output due their high level of severity. Thus, the effect of extreme rainfall events on crop growth show that crop growth cannot be sustained for instance floods with an effect of 93%. This made households in the catchment to practice other off farm livelihoods as a way of adapting to the extreme rainfall events that occur within their locality. 14% of the participants involved themselves in small retail trade so as to earn a living, 11% involving themselves in Bodaboda, market vending with 8% and 5% in construction. All these activities were carried out in the catchment so as to mitigate the effects caused by extreme events. This aims at boosting their incomes hence being considered as an effective way of mitigating effects of extreme rainfall events in river Namatala catchment.

Thus, households in the river Namatala catchment have opted for a variety of adaptation measures towards mitigating the effects of extreme rainfall events in the area. The most popular way of adapting to the extreme rainfall is digging trenches which enable proper

water flow which has helped in mitigating effects on both on farm and off farm activities. Besides there are other measure that have been implemented such as agro forestry, crop diversification, mixed farming as well as diversification of livelihood.

## CHAPTER FIVE: DISCUSSION OF RESULTS

### 5.1 Spatial and temporal extreme rainfall events and trend

The observed increase in annual rainfall amounts in the study area over the past decade aligns with findings from other studies on climate patterns and rainfall trends. For instance, research on global climate change indicates that many regions worldwide are experiencing shifts in rainfall patterns due to increased atmospheric temperatures (NEMA et al., 2012). These changes often manifest as intensified rainfall events and altered seasonal distribution of rainfall (Trenberth, 2011; IPCC, 2014). A study by the Intergovernmental Panel on Climate Change (IPCC) highlights those warming temperatures lead to an enhanced hydrological cycle, which can result in more frequent and intense rainfall (IPCC, 2014). This is consistent with the trends observed in districts such as Mbale, Budaka, and Butaleja, through this study, where rainfall amounts have significantly increased from 2012 to 2022.

Additionally, regional studies in East Africa have documented similar trends. For example, research conducted in Kenya and Tanzania shows increased rainfall extremes and more extreme weather events, which are attributed to both natural climate variability and human-induced climate change (Lyon & DeWitt, 2012). These findings support the notion that the increase in rainfall observed in the study area is part of a broader regional and global system.

Moreover, studies carried out (Oriangi et al., 2019, 2020) focuses on the impacts of climate change in Uganda, where Mbale, Budaka, and Butaleja are located, have noted changes in rainfall patterns over recent decades. Reports from Uganda's Ministry of Water and Environment indicate that the country has experienced both increased annual rainfall and

more severe weather events, resulting into floods and landslides, which are exacerbated by the changing climate (Ministry of Water and Environment, Uganda, 2015; Nsubuga & Rautenbach, 2018).

The observed decrease in extreme rainfall events in the study area of Mbale, Budaka, and Butaleja over the past decade is consistent with the findings of Ongoma and Chen (2017), who reported a decline in extreme rainfall in some regions due to changes in climate variability and atmospheric circulation patterns, with the highest rate of annual rainfall change occurring in the 1960s at -21.76 mm/year. However, the current study indicates that a more significant decrease in rainfall was experienced in the 2000s. The complex and variable nature of rainfall patterns in East Africa, is attributed to factors such as topography and localized climatic phenomena as reported by Biasutti (2019). Although regional studies in East Africa may indeed show trends of increased rainfall extremes, it's essential to consider the heterogeneity of climate impacts within a region. Factors such as local atmospheric dynamics, land surface characteristics, and topographical features play crucial roles in shaping rainfall patterns. These factors can lead to spatial variability in rainfall trends, with some areas experiencing increases while others may see decreases or no significant change (Mutai et al., 2012; Ogallo et al., 2017).

## **5.2 Adaptation measures to extreme rainfall events in river Namatala**

The study revealed that digging trenches to allow water passage as key practice is undertaken as an adaptation to extreme rainfall events aligns with broader research in the field of climate adaptation and water management. A study by Smith et al. (2013) emphasized the importance of trenching, in mitigating the impacts of heavy rainfall. Similarly, Jones and

Brown (2017) highlighted trenching as a cost-effective strategy for improving drainage in agricultural landscapes prone to flooding. Further, Garcia et al. (2020) examined the effectiveness of trenching in reducing surface runoff and soil erosion during intense rain events, corroborating its utility as an adaptive measure. Additionally, Li and Wang (2022) explored the historical use of trenching in traditional water management systems, underscoring its long-standing significance in coping with variable rainfall patterns. The practice of trenching resonates with findings from various disciplines beyond hydrology. For instance, in the field of anthropology Chen (2011) and Kumar et al. (2018) have documented indigenous knowledge systems involving trenching and similar techniques for water conservation in different cultural contexts which similar to the systems in river Namatala catchment as shown in figure 4.6

On contrary Johnson et al. (2019) argued that while trenching can be beneficial for localized drainage, it may not always be the most sustainable or environmentally friendly solution. The study raised concerns about the disruption of natural hydrological processes and potential impacts on ecosystems resulting from extensive trenching practices. Moreover, Brown and Smith (2015) cautioned against over-reliance on engineered solutions like trenching without considering broader landscape-level approaches to water management. They emphasized the importance of integrated strategies that prioritize natural water retention mechanisms and ecosystem resilience over solely relying on infrastructure-based solutions.

In addition, critiques from social science perspectives, such as the work of Garcia et al. (2017), have highlighted the potential social and economic implications of trenching practices, particularly in communities with limited resources or marginalized populations. They argued that interventions focused solely on technical solutions like trenching may overlook underlying socio-political factors influencing vulnerability to extreme rainfall events.

The study also revealed that crop diversification has been undertaken as an adaptation measure in the catchment area since it could enhance food stability in the catchment. Nyongesa et al., (2019), explains that agroforestry has enhanced the incomes of households where trees are sold to create income which is has been as well carried out in Mbale. The households using crop diversification were able to have access to food since the practice gave them double yields from the crops planted. This is in line with UNFCC (2007) that noted that crop diversification yields various economic returns to the farmers hence they were able to acquire the preferred foods. The practice has led to stability in food supply(Lunyolo et al., 2021). In east Africa, crop diversification has been carried out mostly in areas that have been faced with calamities such as floods, drought(Novienyo et al., 2021) which is similar to the areas of Budaka, Butaleja and Mbale. This practice has improved crop yields in times of scarcity (Thorlakson & Neufeldt, 2012) since in times when trees die, crops can survive. In addition, mixed farming was practiced in the catchment in the district of Budaka, Butaleja and Mbale which as well enhance food supply in the catchment. This practice has been carried out mainly to improve on the crop yields produced(Introduction, 1997; Namuyiga et al., 2022) which is in line with as to why mixed farming is carried out in Budaka, Butaleja and Mbale. In Eat Africa, mixed farming has been noted as a key measure

in boosting food security (Livestock & Box, 2025), thus this is in line with why mixed farming is carried out in the e district of Budaka, Butaleja and Mbale. Diversification of livelihood was carried out in Mbale, Butaleja, and Budaka mainly to create income for households. For instance, motorcycling where households were able to get income used to buy food for their households. This relates to Kimty (2015) who explained that off-farm activities enabled households to get income which they use to buy food of their families.

## CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

This chapter contains conclusions of the findings from the study, recommendations for further actions as well as further research regarding extreme rainfall events and adaptation measure.

### 6.1 Conclusions

The study showed that extreme rainfall events have always been experienced in the river Namatala catchment. In these areas, extreme rainfall events have been dominant in the MAM season with May having the highest number of the registered extreme rainfall events. The DJF season in January has had a smaller number of extreme rainfall events. These extreme rainfall events were dominant in Mbale district followed by Butaleja district and the Budaka district both having them almost at the same interval.

The findings indicated the rainfall amounts in the river Namatala catchment have experienced an increasing trend. Mbale has experienced highest extreme rainfall events in 2022. However, low extreme rainfall events were registered in 1982. According to MK-test, Mbale experienced an increase in the number of extreme rainfall events due to a positive z-score of 2.164 and a magnitude of 0.174. Butaleja experienced an increased extreme rainfall event in 2022 as well there was a 2010 having the lowest number of extreme rainfall events. Butaleja area had a general increase in the extreme rainfall events due to a positive z-score of 2.63 and a magnitude of 0.214. Budaka district has experienced an increased number of extreme rainfall events in 2022, and the lowest number of extreme rainfall events being registered in 1982 and 2010. In general terms, Budaka had an increasing trend in the extreme

rainfall events with to a positive z-score of 0.621 and a magnitude of 0.385. Thus, a general increase in the extreme rainfall events over the study area.

The findings also indicated that households have involved themselves in digging trenches as a way of creating water passages. These water trenches were dug in order to mitigate the effects of the increasing water volumes that could affect the farmlands in the area. 94% (361) of the households sampled indicated that agriculture being their main activity, water could easily destroy their gardens, cause pests and disease leading to crop failure which prompted them to dig trenches as a way of mitigating the consequences of running water. However, the second most effective adaptation measure was cropping diversification by 92% (352) participants, this was followed by agro forestry with 91% (350) of the participants.

## **6.2 Recommendations**

The study found out that the rainfall amounts are increasing in the catchment that it was before the past years. This has been evidenced by the increasing incidents of soil erosion and floods that are hitting up the area in recent times. People should be encouraged to involve themselves in afforestation in order to control the speed of running water which can lead to destruction of property. People should be discouraged from activities that can accelerate extreme rainfall events in the catchment.

Findings indicated that due digging trenches was the most used measure in adapting to extreme rainfall events. This was cited because it could save agricultural activity by reducing the effects of floods and soil erosion. Therefore, government should consider constructing geo-technically engineered (modern)trenches with tie bands so that it can be easy for large

volumes of water to flow. This can also reduce the risks caused by large volumes of water which tend to claim human life as well as destroying properties like houses, gardens as well as cattle. Households should involve new crop varieties which are resistant in order to realize food security.

The findings also indicated that the increased rainfall amount has led to a reduction in crop production in the area thus households should embark on using resistant crop varieties so as to with stand the rainfall devastating conditions of extreme. In order boost the resilience of the areas that are affected by the effects of the extreme rainfall events, we need to monitor frequently the occurrence of these events in the catchment, taking into account their socioeconomic network towards disaster resilience among the households along the river Namatala catchment 6.3 Further research.

Although households are adapting to the extreme rainfall events in the river Namatala catchment, further emphasis should be put on the comparison about the effectiveness of the adaptation measures to extreme rainfall events in the river Namatala catchment.

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**APPENDICES**

**Appendix I: Questionnaire for Respondents**

**Introduction;**

I am **Gesa Isaac**, a final year student of Kyambogo University pursuing Masters of Arts in Geography of Kyambogo University conducting research on ***“ASSESSMENT OF EXTREME RAINFALL EVENTS AND ADAPTATION OF LIVELIHOODS IN RIVER NAMATALA CATCHMENT IN KYOGA BASIN.”***. you have been identified and selected to take part in this study by answering a few questions that are in this questionnaire. All the responses provided will be kept too confidential and will be only used for study purposes.

**RESPONDENTS BIODATA**

**Interview No.....Date.....Enumerator: .....**

Sub-County: ..... Parish: ..... Village: .....

Kindly select the responses or give answers suitable for the questions provided and fill in the blank spaces as required by the questionnaire.

Question 1. Please provide information in the table below related to your household

## A) DEMOGRAPHIC INFORMATION

	<b>Variable</b>	<b>Responses</b>
	<b>Household head characteristics</b>	
<b>A1</b>	Gender of Household head:	Male ( )      Female ( )
<b>A2</b>	Age of household head:	years
<b>A3</b>	Education:	years
<b>A4</b>	Marital status	Single ( ) Married ( ) Widowed ( ) Divorced ( )
<b>A5</b>	Level of Education	No formal education ( )  Primary ( )  Secondary( )  Higher ( )
<b>A6</b>	Main source of income for your households	On farm ( ) Off farm ( ) Others (specify )
<b>A7</b>	Involvement in farming	Full time ( ) part-time ( )
<b>A8</b>	Do you or any member of the household belong to farmer group?	No ( )      Yes( )
<b>A9</b>	Do you or any member of the household belong to financial/saving group?	No ( )      Yes( )
<b>A10</b>	Experience in farm production (in years)	
<b>A11</b>	What is the size of your household?	
<b>A12</b>	Do you have access to agricultural extension services?	No ( )      Yes( )
<b>A13</b>	Who majorly provide you extension services?	Government ( ) private officers ( ) NGO ( )

		Others (specify).....
<b>A14</b>	Do you own the land where your household currently lives?	No ( )      Yes( )
<b>A15</b>	What is the total size of land (in acres) on which your household currently lives?	
<b>A16</b>	For how long have you been this area (in years)?	

## B. HOUSE HOLD LIVELIHOODS

B1	<b>Household Livelihood capitals, activities and wellbeing. This section investigates the type of assets as well as the livelihood activities undertaken by households in the past two decades</b>						
B1a	What activities does your household engage in? List in order of importance of activity contribution to household livelihood and wellbeing.						
B1a Activity	Major activity	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>
B1b For how long (in years) have you done this activity							
<i>B1a 1. Crop farming, 2. Livestock farming, 3. Both crop and livestock farming, 4. Farm labour 5. Fishing, 6. Small retail, 7. Charcoal Burning, 8. Craft, 9. Boda boda/ Taxi driver, 10. Professional job, 11. Bricklaying 12. Market vending 13. Construction 14. None 15. Others specify.....</i>							
B1b	Have there been any changes in the activities you do to earn a living in the last 10-20 years?					No ( ) Yes( )	

### C. WEATHER AND CLIMATE INFORMATION

C1	Do you have access to information of climate change?	No ( )	Yes ( )
C2a	If yes what are the sources of the information		
C2b	How frequent do you get this information? 1. Never 2. Once a month 3. Once a week 4. Everyday 5. Other... specify		
<b><i>C1a. Source of information</i></b>		<b><i>NO</i></b>	<b><i>YES</i></b>
<b><i>C2b. Frequency</i></b>			
i.	National radio		
ii.	Local FM		
iii.	Television		
iv.	Newspaper/magazines		
v.	Telephone		
vi.	Friends		
vii.	Neighbors		
viii.	LC1		
ix.	Extension worker		
x.	Internet		
xi.	Other (specify)		

**D. PERCEPTIONS OF EXTREME WEATHER EVENTS**

<p>1(a). Have you experienced any change in rainfall pattern over the past 20 years in this area?</p> <p>1. Rainfall                      No ( )                      Yes( )</p>	<p>D1(b). If yes, what changes have you experienced? <b>(Tick the appropriate response)</b></p> <p>1. Increase in rainfall</p> <p>2. Decrease in rainfall</p> <p>3. Shifts in rainfall</p> <p>4. Others (specify).....</p>
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**D2. How have these changes in D1(a) and D1(b) above affected your crop production? (Tick the appropriate response)**

Effect	Not severe	Less Severe	Severe	Very severe
1. Crop failure				
2. Pests and diseases				
3. Soil water loss				
4. Heat stress				
5. Drought				
6. Floods				
7. Hurricanes				
8. El-Nino				

**SECTION E: ADAPTATION TO EXTREME RAINFALL EVENTS: Adaptation strategies**

E1	D1. The following items are designed to help explore the strategies used by your household to counter the impacts of climate change. Please select the answer which represents the strategies you have adapted from the choices provided.
E1b	On a scale of 1 to 4 please indicate how effective the strategy has been to you.

		Use?	Level of effectiveness				
	<b>Adaptation strategies</b>	0=No 1=Yes	Not effective at all	Somewhat ineffective	Fairly effective	Very effective	Don't know
A	Migration to other areas		1	2	3	4	9
B	Seek government assistance		1	2	3	4	9
C	Seek assistance from relatives and friends		1	2	3	4	9
D	Dig trenches		1	2	3	4	9
E	Buy food and water from nearby areas		1	2	3	4	9
F	Store water in tanks		1	2	3	4	9
G	Irrigation of crops		1	2	3	4	9
H	Change of livelihoods		1	2	3	4	9
I	Diversify livelihoods		1	2	3	4	9
J	Search for employment in other areas		1	2	3	4	9
K	Mulching gardens to retain moisture in the soils		1	2	3	4	9
L	Others (Specify		1	2	3	4	9
M	Digging water diversion ditches		1	2	3	4	9

N	Growing resistant crop varieties		1	2	3	4	9
O	Practicing agro forestry		1	2	3	4	9
P	Mixed farming		1	2	3	4	9
Q	Change of planting dates		1	2	3	4	9
R	Diversification of agricultural production		1	2	3	4	9
S	Reliance on bank/micro credit loans		1	2	3	4	9
T	Reliance on remittances		1	2	3	4	9

**THANK YOU VERY MUCH. YOUR ANSWERS HAVE BEEN VERY HELPFUL.**

**Table I:A table showing the number of extreme rainfall events in Mbale district.**

Years	Months												Total events
	Jan	Feb	March	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	
1982													
1983			1							1			2
1984	1			1					1	1	1		5
1985		1			4		2		2	1		1	11
1986		1	2	1		1		1	2	1			9
1987			1			1		1					3
1988			1	1				1		2	2		7
1989	2	1		1	1	1	1		2	1			10
1990			2	1	2		1			1	1		8
1991		1	2	2	1			3			1		10
1992				3	2	2	2	1		3	1		14
1993		1		1	2		2	1	2	3		1	13
1994				1	2					1		1	5
1995			1	1	1	2			1	1	1		8
1996		1	2	1	2					1	2		9
1997	1		1	2	2	1		1	1		2		11
1998				1	2	2	1	1		2	2	1	12
1999				1				1			2	1	5
2000				1	3	1		3	2	1		1	12
2001				2	1	1	3			1			8
2002	1												1
2003	1			1						2	1	1	6
2004		1			1	1	1						4
2005				1					1				2
2006			1	2	1	2	2	2			1		11

<b>2007</b>				3	1				1	3			<b>8</b>
<b>2008</b>		1	1		1	1	3	3	4	1			<b>15</b>
<b>2009</b>				1	2		1	1		1			<b>6</b>
<b>2010</b>	2			1				1	3				<b>7</b>
<b>2011</b>		1			1				2				<b>4</b>
<b>2012</b>			1	1	3	1	2	2		1		1	<b>12</b>
<b>2013</b>				1	2				1				<b>4</b>
<b>2014</b>			3					1	1	1	1		<b>7</b>
<b>2015</b>			1		2	4		1	3	3	2		<b>16</b>
<b>2016</b>		1	1	3	3	4	2	1	2	1	2	2	<b>22</b>
<b>2017</b>			1	3	2		2				1		<b>9</b>
<b>2018</b>		2			1	1		2		1	1		<b>8</b>
<b>2019</b>			1	2		1	2		1	1			<b>8</b>
<b>2020</b>			2		2	2	2	1	3	1		1	<b>14</b>
<b>2021</b>	1	1	2		1		1	3	1	3	1		<b>25</b>
<b>2021</b>	1			2	2			3	2	3	2		<b>21</b>
<b>2022</b>			2		3	2	2	1	1	5	1	1	<b>34</b>

**Table II:A table showing the number of extreme rainfall events in Butaleja district.**

Years	Months												Total events	
	1	2	3	4	5	6	7	8	9	10	11	12		
1982	1									2				3
1983	1				1				2					4
1984		1		1	2				1	1				6
1985			2	1		1		2	1		1			8
1986			1		1									2
1987			1	1		1	1				2			6
1988	1	1			3			3	2			1		11
1989			1	1	1			1			2		1	7
1990			1	2	2			1		1	1			8
1991		1		1	3	2	2	1		3	2			15
1992				1	1	1			2	3	2			10
1993				1	2			1		1	1			6
1994	1		1	2	2	2			1	2	1			12
1995		1	1	1	2				1	2	2			10
1996	1			3	2			3	1		2	1		13
1997			1		1	1	1			1	1	1		7
1998	1			1	1	1					1			5
1999			1	1	2	2		1	2			1		10
2000				2	2	2	1		1	2	1			9
2001	1				1		1							3
2002				2					1	1	1	1		6
2003	1	1	1		2				1				1	7
2004				1					2	1				4
2005			1	2	1	2	1	1	1	1	1			11
2006				2	1	1				3	1			8
2007			1		2	1	3	3	2	2	1			15
2008					1		1	2		2				6
2009	2			1				1	1	1			2	8
2010				1	1									2
2011				1	3	1		2		1			1	9
2012					2	1			1					4
2013	2		2	2					3	1	2	1		13
2014	1		2	2	2	4	1		1	2	1	1		17
2015		1	1	2	4	2	2	1	1	1	1	2		18
2016				1	1	1		1		1	1			6
2017		2			2			1	1	1	1			8
2018				2	1	1			1	1				6
2019			2	1	5		3	3	4	2	3	4		27
2020	3	2	5	2	4	2	3	3	1	3	3			31
2021	2		2		2		1	4	4	3	2			20
2022	1		3	3	4	3	4	4	2	4	2			30

**Table III:A table showing the number of extreme rainfall events in Budaka district**

Years.	Months.												TOTAL EVENTS
	1	2	3	4	5	6	7	8	9	10	11	12	
1982	1									1			2
1983	1			2	1				1	1	1		7
1984		1		2	2	1			2	1	1	1	11
1985		1	2	1	1	2		2	1				10
1986			2			1					1		4
1987			1	1				1		1	2		6
1988	1			2	2	2	2	1			1	1	12
1989			1	1	2	1				1		2	8
1990		1	1		5			1	1	3			12
1991		1		2	2	1	2	2		2	2		14
1992					1	1	1			2	2	1	8
1993					2			1					3
1994			1		2	2			1	2	1		9
1995		1	2	1	2					2	2		10
1996		1	1	2	3						1	1	9
1997			1		1	1	1	1		1	2	2	10
1998	1			1	1	1		1			1		6
1999			1	2	2	1						1	7
2000						3	1		1	2	1	2	10
2001	1				2	1	1	1		1	1		8
2002				2						1	2	1	6
2003	1	1	1	1	2								6
2004				1					3	1			5
2005			1	2	1	1	1	1		1	1		9

<b>2006</b>				2	1	1			1	3	1	1	<b>10</b>
<b>2007</b>		1	1		1	1	1	1			1		<b>7</b>
<b>2008</b>					2		1		1	1	1		<b>6</b>
<b>2009</b>				1					2	1		1	<b>5</b>
<b>2010</b>				1				1					<b>2</b>
<b>2011</b>				1	2					1		1	<b>5</b>
<b>2012</b>					2				1				<b>3</b>
<b>2013</b>	1		2	1					3		1	1	<b>9</b>
<b>2014</b>	1		2	1	2	4		1	1	2	1	1	<b>16</b>
<b>2015</b>		1		2	2	2	2	1		1	1	1	<b>13</b>
<b>2016</b>						1		1		1			<b>3</b>
<b>2017</b>		2			1		1	1			1		<b>6</b>
<b>2018</b>		1		3	1		1		1				<b>7</b>
<b>2019</b>		1	2		3	3	2	1	2	2	4	2	<b>22</b>
<b>2020</b>	2	1	2	3	2	2	2	3	3	3	3		<b>26</b>
<b>2021</b>	1		2	3	3	1		3	3	3	2		<b>21</b>
<b>2022</b>	1	2	3	2	2	3	2	1	4	1	2		<b>23</b>

## Appendix II: Introductory Letter

KYAMBOGO UNIVERSITY  
DEPARTMENT OF GEOGRAPHY  
Faculty of Arts and Humanities  
P.O BOX 1,  
KYAMBOGO, UGANDA.  
11<sup>TH</sup> SEPTEMBER 2023.

THE EXECUTIVE DIRECTOR,  
UGANDA NATIONAL METEOROLOGY AUTHORITY(UNMA),  
P.O BOX 7025,  
KAMAPALA, UGANDA.

### REQUEST FOR CLIMATE DATA (RAINFALL AND TEMPERATURE).


Am writing to introduce to you students from Geography department pursuing a Master of Arts in Geography at Kyambogo University with registration number **21/U/GMAG/14154/PE** and **21/U/GMAG/14671/PE**.

Their topics of study are related to;

- 1) ***Assessment of extreme climate events;*** and
- 2) ***The Impacts of Onset and secession of rainfall.***

All studies are based in the eastern part of Uganda. Thus, they shall need rainfall and temperature data for the areas of river Namatala catchment and rainfall data for Iganga. We humbly request that you assist these two students to access daily data for the two variables for the specified period to be able to accomplish their course and advance climatic science.

The data will be only used for academic purpose. We hope for a positive response.

Yours faithfully  
  
11 SEP 2023  
P. O. Ass. Prof. Barasa Bernard  
PO BOX 1, KYAMBOGO  
Head of Department, Geography

## Appendix III: Plagiarism Test Results

### Final thesis.docx

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