BUSITEMA UNIVERSITY

FACULTY OF NATURAL RESOURCES AND ENVIRONMENTAL SCIENCES

DEPARTMENT OF ENVIRONMENTAL PLANNING AND MANAGEMENT

IMPACT OF CLIMATE VARIABILITY ON MILLET PRODUCTION IN PALLISA DISTRICT, EASTERN UGANDA

BY

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A DISSERTATION SUBMITTED TO THE DIRECTORATE OF GRADUATE STUDIES, RESEARCH AND INNOVATION IN **PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE IN CLIMATE CHANGE AND DISASTER MANAGEMENT DEGREE OF BUSITEMA UNIVERSITY**

AUGUST, 2025

DECLARATION

I, **Oriada Oseku Mathias,** declares that this Dissertation entitled ***"Impact of Climate Variability on Millet Production in Pallisa District, Eastern Uganda"***, is original, it has never been presented anywhere in any institution of higher learning by any individual for any academic award.

Signature:..................................... Date: 2/08/2025.......

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APPROVAL FORM

This is to certify that this Dissertation entitled *""Impact of Climate Variability on Millet Production in Pallisa District, Eastern Uganda"*, has been written under our supervision. It is now ready for submission as for examination with our approval.

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DEDICATION

I dedicate this work to Mrs. Kabarangira Christine Oseku, my dear wife whose tireless efforts gave a firm background to my academic path up to this level, my family who withstood hard times because of my decision to pursue further studies and finally my late mother Dera Kasakamu Oseku for shaping my destiny!

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LIST OF ABBREVIATIONS/ ACRONYMS

CDO	:	Community Development Officer
DAO	:	District Agricultural Officer
DPO	:	District Production Officer
DRC	:	Democratic Republic of Congo
FAO	:	Food and Agriculture Organization
GHG	:	Green House Gases
IPCC	:	Inter-governmental Panel on Climate Change
KIIS	:	Key informant interviews
LC1	:	Local Council One
MWE	:	Ministry of Water and Environment
NEMA	:	National Environmental Authority
OPM	:	Office of the prime minister
UNFCCC	:	United Nations Framework Convention on Climate Change
UNICEF	:	United Nations Children’s Emergency Fund
UNMA	:	Uganda National Meteorological Authority

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ABSTRACT

Climate variability has posed serious threats to millet production in Pallisa district, yet the crop is vital in contributing to household income and food security. The study examined the impact of climate variability on millet production in Pallisa District. Specifically, the study: analyzed rainfall, temperature and millet production trends; assessed the effect of climatic factors on millet production; and examined the adaptation measures taken by millet farmers. The study used a descriptive research design. Secondary and primary data were used, in that secondary data informed primary data collection. Data on 30 years' trend in rainfall and temperature were obtained from Uganda National Meteorological Authority (UNMA), while data on the 10 years' trend in millet production from Census data and Annual Agricultural Survey (AAS). Simple random sampling was used to collect primary data from 365 households using a structured questionnaire. Analysis was done in SPSS version 20. Findings indicate that in the period 1991 to 2021, low rainfall was received while the years; 1993, 2000, 2016, with 2000 experienced the least rainfall. In contrast, the year 1996 there was a lot of rain experienced. Maximum temperatures were experienced in 2000 and 2016. Furthermore, during this period the first season yields were higher than those of the second seasons. Climate variability had resulted in premature drying of crops, reduction in yield per acre, shift in planting and harvesting time, losses due to hailstorms, and increased pests. All the interviewed farmers were adapting to climate variability by utilising native species perceived to be resistant varieties, adjusting the sowing dates, diversification, and intercropping. Government and other stakeholders should consider investing in research and development to come up with highly yielding and resistant varieties, encouraging diversification, and development of irrigation schemes for sustained production and livelihood.

CHAPTER ONE: INTRODUCTION

1.1 Background

Globally, climate variability accounts for approximately one-third of observed crop yield variability (Ray et al., 2015). It is projected to significantly affect agricultural productivity in developing nations like Uganda, where the majority of farming households depend on rain-fed agriculture (Kontgis et al., 2019). Due to low soil fertility, utilizing drylands to produce sufficient and quality grain remains a significant challenge (Kumar et al., 2018).

Uganda's climate is undergoing notable changes, including rising temperatures and altered precipitation patterns, which have led to extreme meteorological conditions (Mwaura & Okoboi, 2014). Specifically, projected annual rainfall amounts are expected to decrease significantly during the period 2013–2033 (Oriangi et al., 2024), with Pallisa District not exempt. These projected changes in climate pose a serious threat to agricultural production, especially considering the country's reliance on rain-fed crop systems (MacCarthy et al., 2021).

Finger millet is recognized as a climate-resilient crop that provides food and nutritional security as well as income for households (Hamba et al., 2024). It is widely grown in Eastern and Southern Africa, particularly in the sub-humid uplands of Uganda, Kenya, Tanzania, Malawi, DRC, Zambia, and Zimbabwe. In Uganda, the crop serves as a staple food for more than 75% of rural households (Rajpal et al., 2016), especially in regions such as West Nile, Teso, and Acholi. However, over the last three decades, millet production has declined significantly due to persistent climatic changes, placing many households at risk (Vink et al., 2016).

Approximately more than 68% of Ugandans rely on rain-fed agriculture, which is highly vulnerable to climate variability (Babyenda, 2023). Consequently, variations in climate have had a tangible and adverse impact on food production, including millet (Mitchell & Tanner, 2006). In Sub-Saharan Africa, climate change has notably reduced agricultural productivity through extreme weather events such as recurrent droughts and floods (Deressa et al., 2018).

Pallisa District is among the regions in Uganda most affected by climate variability, resulting in acute food shortages including millet in some communities (OPM, 2015). The district experiences extreme climate events, such as prolonged droughts and unpredictable rainfall patterns, often leading to famine and related humanitarian crises. While most climate change research in Uganda has traditionally focused on arid and semi-arid lands (ASALs), where rainfall consistently constrains productivity (Notter et al., 2017), this study shifts focus to high-potential agro-ecological zones intended to support the majority of the population in food production.

Given the existing variability and uncertainty in Uganda's crop production systems, there is a critical need to deepen our understanding of how long-term trends in climate variability are experienced and interpreted at the local level (Roncoli, 2016). The scarcity of data on these localized perceptions and impacts provided the foundation for this study, which specifically investigates the effects of climate variability on millet production in Pallisa District.

1.2. Problem Statement

In Uganda, the agricultural sector remains highly vulnerable to climate shocks, including prolonged droughts, high temperatures, and increasingly unreliable rainfall patterns (Mwaura & Okoboi, 2014; Abidoye et al., 2017a). This vulnerability is further compounded by the lack of timely and reliable climate forecast information accessible to subsistence farming households. Many of these farmers also lack the skills, technologies, and financial resources necessary to effectively adapt to climate variability (Guloba, 2014). These challenges directly threaten progress toward Sustainable Development Goal (SDG) 2 - Zero Hunger, which aims to end hunger, achieve food security, and promote sustainable agriculture.

The Eastern Region of Uganda, where Pallisa District is located, is projected to experience more extreme variability in temperature and rainfall beyond average climatic shifts in both intensity and frequency of extreme weather events (Solomon et al., 2017). Pallisa District is one of the areas most affected by climate variability, resulting in periodic food shortages, particularly of millet, in some communities (OPM, 2015). However, the majority of climate change research in Uganda has focused on arid and semi-arid lands (ASALs), where rainfall has consistently been a constraint to agricultural productivity (Notter et al., 2017), leaving high potential zones like Pallisa understudied. This underscores the importance of addressing SDG 13-Climate Action, which calls for urgent action to combat climate change and its impacts.

Millet production is a primary source of livelihood for smallholder farmers in Pallisa District. However, changing rainfall patterns, prolonged droughts, floods, hailstorms, and the emergence of new pests and climate-related diseases have severely affected millet output. The annual growth rate of millet production has remained marginal at about 2%, which is significantly lower than the national average population growth rate of 3.5% (Tibaingana et al., 2020). Historical drought events in 1994, 2000, and 2016 serve as clear examples of how climate extremes have disrupted millet production in the district. These adverse impacts undermine efforts toward achieving SDG 1-No Poverty, which seeks to build resilience among the poor and reduce their vulnerability to climate-related shocks.

Although government interventions have been made to support farmers and improve agricultural productivity, there is limited empirical evidence to confirm the effectiveness of these measures in mitigating the impact of climate variability on millet production. Moreover, projections show that Eastern Uganda will continue to face intensified climate variability, posing even greater risks to crop yields (Solomon et al., 2017). These fluctuations are expected to have more detrimental effects on millet yields than shifts in average climate conditions alone (Tubiello et al., 2017).

In response to these challenges, this study examined the impact of climate variability on millet production in Pallisa District, with the aim of understanding the extent of its effects and the capacity of local farmers to adapt. The study aligns with SDG 2, SDG 13, and SDG 1 by contributing to knowledge that can inform sustainable agricultural strategies and enhance food and livelihood security in vulnerable regions.

1.3 Main Objective

The main objective of the study was to examine the effect of climate variability on millet production and adaptation measures in Pallisa District.

1.3.1. Specific objectives

The study was informed by the following specific objectives.

i. To analyze rainfall, temperature and millet production trends in Pallisa District

ii. To assess the effect of climatic factors on millet production.

iii. To examine the adaptation measures taken by millet farmers in the study area.

1.3.2. Research questions

The research questions of the study included the following.

a) What are the trends of rainfall, temperature and millet production in Pallisa District?

b) What climatic factors affect millet production in Pallisa District?

c) How do millet farmers adapt to climate variability?

1.4. Scope of the study

The study was carried out in Pallisa District, Bukedi sub-region, Eastern region, Uganda (as seen in Figure 2). The study was limited to the impact of climate variability on millet production in Pallisa District. The study covered a period of 5 years, i.e., 2019-2023 in order to obtain the most current information. However, secondary data covered a period of 30 years that was, from 1992-2022 in order to obtain the information on rainfall and temperature variations and compare the changes in seasons.

1.5 Significance of the study

The study provides information will benefit policy makers, agricultural extension staff, and Ministry of Agriculture technocrats, Climate change department, Households/local farmers, as well as the researcher. This is because the survey findings provide an understanding of the past, present and future trends of rainfall and temperature in the study area. The water availability and household knowledge regarding the effects of climate change on millet production helps in developing and promoting climate smart agricultural practices. The information also helps in developing the resilience of the local community to climate variability.

1.6 Conceptual Framework

The conceptual framework depicts a summary of the independent variables, intervening variables and the dependent variable as supported by (Helfert & Bell, 2010), who argued that in investigative research, the topic of focus must clearly bring out the independent, dependent and intervening variables.

In the study, our independent variables included temperature, changing seasons, floods, variable rainfall, drought and heat stress. These are variable that stand alone and can't be changed by the others being measured.

The dependent variable in this study was millet production and this changes as a result of the independent variable manipulation. It was the outcome we were interested in measuring and also depends on our independent variables stated above. In statics, dependent variables are also called response variables as they respond to change in others variables. While on the other hand our intervening variable in the study included; phenotypic, management and household based factors in millet production. These are variable that handle the change in the dependent variable due to the change in the independent variable. In other words, the outcome of the dependent variable is decided through the intervening variables which themselves get influenced by the independent variables as indicated in Figure 1 below

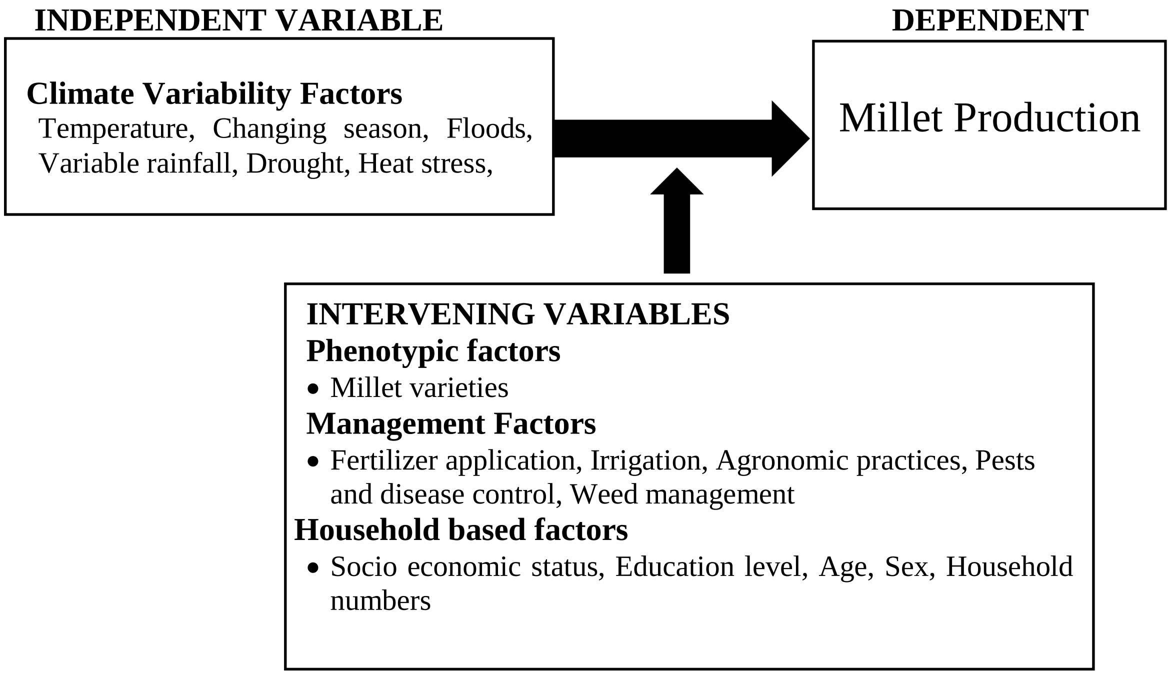


Figure 1. Above a conceptual frame work showing Independent, Dependent and Intervening Variables of the study

CHAPTER TWO: LITERATURE REVIEW

2.1 Climate variability and Millet Production

2.1.1 Rainfall trends

Globally, long-term precipitation records reveal that the annual maximum daily rainfall has risen slightly about 5.7 mm over the past century (Asadieh & Krakauer, 2015). Across Africa, rainfall patterns differ by climate zone, with noticeable increases in arid areas and declines around the equatorial belt (Nguyen et al., 2018). The study by Alahacoon et al. (2022) finds that the highest annual rainfall trends were recorded in Rwanda (11.97 mm/year), the Gulf of Guinea (river basin 8.71 mm/year), the tropical rainforest climate zone (8.21 mm/year), and the Central African region (6.84 mm/year), while Mozambique (0.437 mm/year), the subtropical northern desert (0.80 mm/year), the west coast river basin of South Africa (0.360 mm/year), and the Northern Africa region (1.07 mm/year) showed the lowest annual rainfall trends.

There is a statistically significant increase in the rainfall in the countries of Africa's Northern and Central regions, while there is no statistically significant change in the countries of the Southern and Eastern regions. In East Africa, long-term analyses indicate mixed rainfall patterns — modest declines in parts of Ethiopia and Kenya, and in much of Tanzania during the main rainy season (Gebrechorkos et al., 2019).

Rainfall patterns in Uganda fluctuate considerably across regions, creating uncertainty for farmers when planning planting periods. For example, the March–June period over 1981 to 2015 experienced reduction in rainfall amounts for the greater part of Central and Northern Uganda while part of Eastern and Southwest had some incremental rains (ICPAC & WFP Atlas, 2018). In 2022,

Uganda's seasonal rains were characterized by a delayed onset and below-average amounts, especially over Northern areas, negatively impacting yields. The first season harvest started in early June, 30 to 50 days later than normal and production was expected at a below-average level.

Similarly, in the unimodal rainfall Karamoja Region, the ongoing rainy season has been characterized by a delayed onset and prolonged dry spells with the harvest forecast expected below-average and delayed by one to two months into September/October (FAO, 2022).

Overall, Future projections indicate a likely decline in Uganda's annual rainfall from roughly 1,160 mm to about 1,090 mm a 6 percent reduction overall (Hunter et al., 2020). Furthermore, all regions are predicted to experience an overall decrease in annual and seasonal precipitation between the present day and the 'Mid-Century' future (defined by the period 2040–2069) (Hunter, et al., 2020).

Observed seasonal rainfall totals for Uganda are characterized by a bimodal cycle (two rainy seasons) in the South with higher rainfall during the rainy seasons MAM (March-April-May) and SON (September October-November). In the North, a unimodal cycle (one rainy season) becomes more obvious with a longer single rainy season that extends across the seasons MAM, JJA (June-July-August) and SON, while the DJF (December-January-February) season is drier.

The far North-East of Uganda receives little rain during all months of the year (CDKN, 2015). For Pallisa district, it normally experiences two rainfall regimes with the main peak spanning from March to June and the second one from August to November. However, in some instances the rainfall pattern described is irregular causing farmer's failure to plan accordingly (Pallisa district statistical Abstract, 2019).

2.1.2 Temperature trends

The Intergovernmental Panel on Climate Change (IPCC, 2001) predicts that global average temperatures may rise by between 1.4 °C and 5.8 °C by the end of this century, with African land areas especially the drier zones warming at a slightly faster rate (Niang et al., 2014). Model-based predictions of future greenhouse gas induced climate change for the continent clearly suggest that this warming will continue to accelerate so that the continent on average could be between 2 and 6°C warmer in 100-year time (Hulme, et al., 2001).

East Africa is one of the regions that is severely experiencing the adverse impacts of everchanging climate due to its dependence on rain-fed agriculture and tourism as the backbone of its economies, sectors that are highly vulnerable to extreme climatic variations (Apollo & Mbah, 2021). Estimates suggest that mean temperatures across East Africa could rise by roughly 1–2 °C by mid-century (Jones et al., 2009). With regard to annual trends, results largely confirm seasonal analyses: only a few significant trends in rainfall, but significant increasing trends in T-max (up to 1.9 °C) and T-min (up to 1.2 °C) for virtually the whole region (Gebrechorkos et al., 2019).

According to UNICEF (2017), Uganda has one of the fastest changing climates, with temperatures predicted to rise by an unprecedented 1.5ºC in the next 20 years and by up to

4.3ºC by the 2080s. Observed averages in annual near-surface temperatures for Uganda are around 21°C. Monthly temperatures range from a minimum of 15°C in July, to a maximum of 30°C in February. The highest temperatures are observed in the north, especially in the northeast, while lower temperatures occur in the south. The JJA season is the coolest, while DJF and MAM are the warmest (CDKN, 2015). The predicted changes in Mean Monthly Temperature (TMean) from the historical baseline to the mid-century (2050) future indicate that climate change will result in consistent increases in T Mean across regions and months. The hottest months of January, February and March are predicted to increase by 1.7 °C, relative to a Historical average of 24.4–25.2 °C. Similar increases of 1.6–2.1 °C are predicted for all other months of the year.

The predicted changes in Minimum Monthly Temperature (Tmin) are similar, indicating consistent increases in temperature minimums of at least 1.6°C, and up to 1.9–2.1°C during the rainy season months of March-May and August-October (Hunter, et al., 2020). Mean annual temperature has increased by 1.3˚C since 1960, an average rate of 0.28˚C per decade. This increase in temperature has been most rapid in JF at a rate of 0.37˚C per decade. Annual rainfall has decreased at an average rate of 3.4mm per month (3.5%) per decade, but this trend is strongly influenced by particularly high rainfall totals in 1960- 61. MAM rainfalls have decreased by 6.0mm per month per decade (4.7%) (McSeeney, et al., 2010). The entire country is predicted to experience increased temperatures throughout the year.

2.1.3 Millet Production trends

Worldwide, the area sown to millet has remained relatively stable at around 38 million hectares for the past two decades. Both production and yield increased by a little over 10 percent through the 1980s, but have remained unchanged since then. Current global production is about 28 million tons, and average yields are 0.75 t/ha (Duressa and Bonso , 2022). Global production of coarse grains – sorghum, barley, millets, rye, and oats – is projected to reach 335 Mt by 2031, up 28 Mt from the base period. African countries will contribute the most (16 Mt) (FAO, 2022).

Of the 33 million ha planted to millets worldwide in 2010-2012, 19 million ha (60%) are grown in Africa, compared to 38% in Asia. Within Eastern and Southern Africa, millets are the least widely grown cereal crop, planted on only 2% of the area planted to cereals. In East and Southern Africa, 85% of the area planted to millets lies in eastern Africa and only 15% in southern Africa (Orr, et al., 2016). Nine species are common in Sub-Saharan Africa, but only four are grown on a significant scale: Pearl or candle millet (Pennisetum glaucum), Finger millet (Eleusine coracana), Teff (Sragrostis teff) and Fonio (Digitaria exilis and Digitaria iburua).

Among millet species, pearl millet covers the largest cultivated area, primarily because of its strong tolerance to drought and high temperatures. Finger millet predominates in Eastern and Southern Africa, while Fonio is mainly a West African crop. In Ethiopia's mid-highlands, Teff contributes about a quarter of the national cereal output (African Organic Agriculture Training Manual, 2013). The most recent estimate suggests that about 50% of global millet grain production is pearl millet, with about 10% for finger millet (Mitaru, 2012).

Between 1981 and 2012, trends in the Southern and Eastern Africa, production and yield of millets over the same period showed weak but positive growth. Four countries – Ethiopia, Zimbabwe, Tanzania and Uganda – accounted for the bulk of production. During the period, strong production growth in Ethiopia was offset by negative growth in Uganda due to civil unrest (Orr, et al., 2016). Within Eastern and Southern Africa, millets are the least widely grown cereal crop, planted on only 2% of the area planted to cereals. In East and Southern Africa, 85% of the area planted to millets lies in eastern Africa and only 15% in southern Africa (Orr, et al., 2016).

Pearl millet is an important cereal grown by farmers in environmentally marginalized areas. In Uganda it is mainly grown in northern (Acholi), northeastern (Karamoja) and eastern (Teso) regions (Lubadde, et al., 2015). Millet is the main staple food in Acholi, Lango, and Teso, and supplements other staples such as plantain, sweet potato, and cassava in Bugisu, Busoga, Bukedi, West Nile, Ankole, and Kigezi (Vogel & Graham, 1979). Millet yields in Eastern Africa were the highest in the continent, averaging 1,001 kg/ha in 2010-12, compared to just 652 kg/ha in western Africa and a mere 217 kg/ha in southern Africa Orr et al. (2016).

The total number of plots under Finger Millet was estimated to be 936,000 with 459,000 (49.0%) under pure stand while the national MPS was estimated to be 0.27 Ha (UBOS, 2010).The national yield of Finger Millet was estimated to be 1.1 Mt/Ha. In the second season of the 2008 the total production of millet was 879 mt while for the first season of 2009, it was 9,013 Mt. It is worth noting that much as there was an increase in area under the crop from 116,000 Ha to 134,000 Ha (16%) between the Second Season 2008 and the First Season of 2009, there was a decrease in production from 163,000 Mt to 114,000 Mt (UBOS, 2010) .

According to UCA, in second season of 2008, total millet production in Pallisa district was 879mt while in the first season of 2009, production was 9,013mt.

2.2 Effect of climate variability on millet production

By the 2050s, national yields of major staples including cassava, maize, millet, and groundnuts are projected to decline due to changing climatic conditions (Climate Risk Profile, Uganda, 2021). Eastern Africa tends to experience drier-than-normal conditions, affecting the second agricultural season of the region from November to March (WMO, 2020). The study by Ekiyar (2012) reveals that an increase in rainfall due to climate change and variability led to loss in cereal (millet) output by 2.8% in Teso sub-region of eastern Uganda.

Sserwada, et al., (2015), in his study in Bugisu, Teso and Karamoja Sub-Regions, found out that the number of storms had increased over time, resulting in flash floods that wash away their crops; short rains turn into hailstorms that come with strong winds and destroy our crops, including millet. The study by (Bhandari, 2013) on the effect of precipitation and temperature variation on the yield of major cereals in Dadeldhura district of far western development region found out that Rainfall was insignificant in influencing yield for rice, wheat and millet. (Blanc, 2011) and (Eregha, 2014) found out that CO2 concentration had a significant effect on millet. As climate varies, areas of cultivatable land are projected to decrease (Solh & Saxena, 2011), with adverse effects on food production.

Mahrous (2019) notices that rainfall has a positive effect; food security may go up by 0.32 per cent due to 1 per cent increase in annual precipitation. More frequent extreme weather episodes have contributed to soil erosion and degradation, reducing the amount of cultivable land (Ajilogba & Walker, 2021). Climate fluctuations influence rainfall, evaporation, and soil moisture balance, limiting the capacity of soils to sustain diverse crops and often compelling farmers to adopt different varieties.

Sawe et al. (2018) notices that climate change and variability have impacted crop farming system in different ways such as, damaging of crops and persistent low yields, reduction of crop varieties and species, decreasing soil fertility, increasing crop pests and diseases and drying of water sources. (Zinyengere, 2016) foresee that climate variations could see a reduction in the national production of food crops such as cassava, maize, millet and groundnuts by 2050, yet these are some of the crops grown by the community of Pallisa district.

2.3 Adaptation measures undertaken by millet farmers

The study by (Haussmann, 2012) in West Africa indicates that developing variety types with high degrees of heterozygosity and genetic heterogeneity for adaptation traits helps achieving better individual and population buffering capacity. Certain crop traits such as flexible flowering periods, capacity for tillering, tolerance to flooding or heat at seedling stages, and efficient phosphorus use can improve plant adaptation and yield stability under changing climates. Findings by (Bouba, 2014) in Gambia show that drought tolerant, short maturing crop varieties and appropriate planting dates were the commonly preferred adaptation strategies to deal with climate variability.

Ugandan millet farmers have adopted various coping approaches such as seeking non-farm employment, altering planting schedules, diversifying crops, and practicing intercropping (Oriangi, 2013). Ekiyar, V. et al. (2012) suggest that the policies that promote millet farmer's climate change adaptation should aim at creating credit institutions to support farmers, developing irrigation infrastructure and provision of both climate and agricultural information on better technologies for farmers in Teso and Uganda as a whole.

2.4 Research gaps

There is now no doubt that the climate is changing with significant impacts of a diversity of crops (millet inclusive)., on which various households depend for their livelihood. Review of prior studies shows notable uncertainty surrounding climate elements such as rainfall and temperature, yet limited research has examined their specific impacts on individual crops.

Africa has been identified as one of the continents with high vulnerability to climate change due to over depending on rain fed agricultural activities. It has been estimated that from 1961 to 2018 around 25.71% area under millets cultivation has been declined across the continents (R. P. Meena et al. 2021). Additionally, there is an anticipated 17% decrease in pearl millet production in Sub-Saharan Africa by 2050 under future climate change projections (Abubakar et al, 2023). These could further exacerbate food insecurity and poverty.

In Uganda, however, crop specific studies are still in their infancy and scarce, yet agriculture accounts for over 70% of the working labour force and is the backbone of the economy. The regional and crop-specific analysis show that, relative to other regions of the country, Eastern Uganda is likely to be the region affected the most (Babyenda et al., 2023). The information on climatic variability with its impacts on crop yields are needed more than ever especially on grains that serve as staple food in most part of the world (Ojo et al, 2020). Thus, it is upon this brief that the study sought to close the information gap.

CHAPTER THREE: METHODOLOGY

3.1 Research design

The descriptive research design was used to obtain information concerning the status of climate variation and also describe what exists with respect to the situations on the ground concerning the production of millet. A descriptive approach was appropriate because it focuses on describing patterns answering questions such as what, when, where, and how without necessarily testing causal hypotheses.

3.2 Study Area

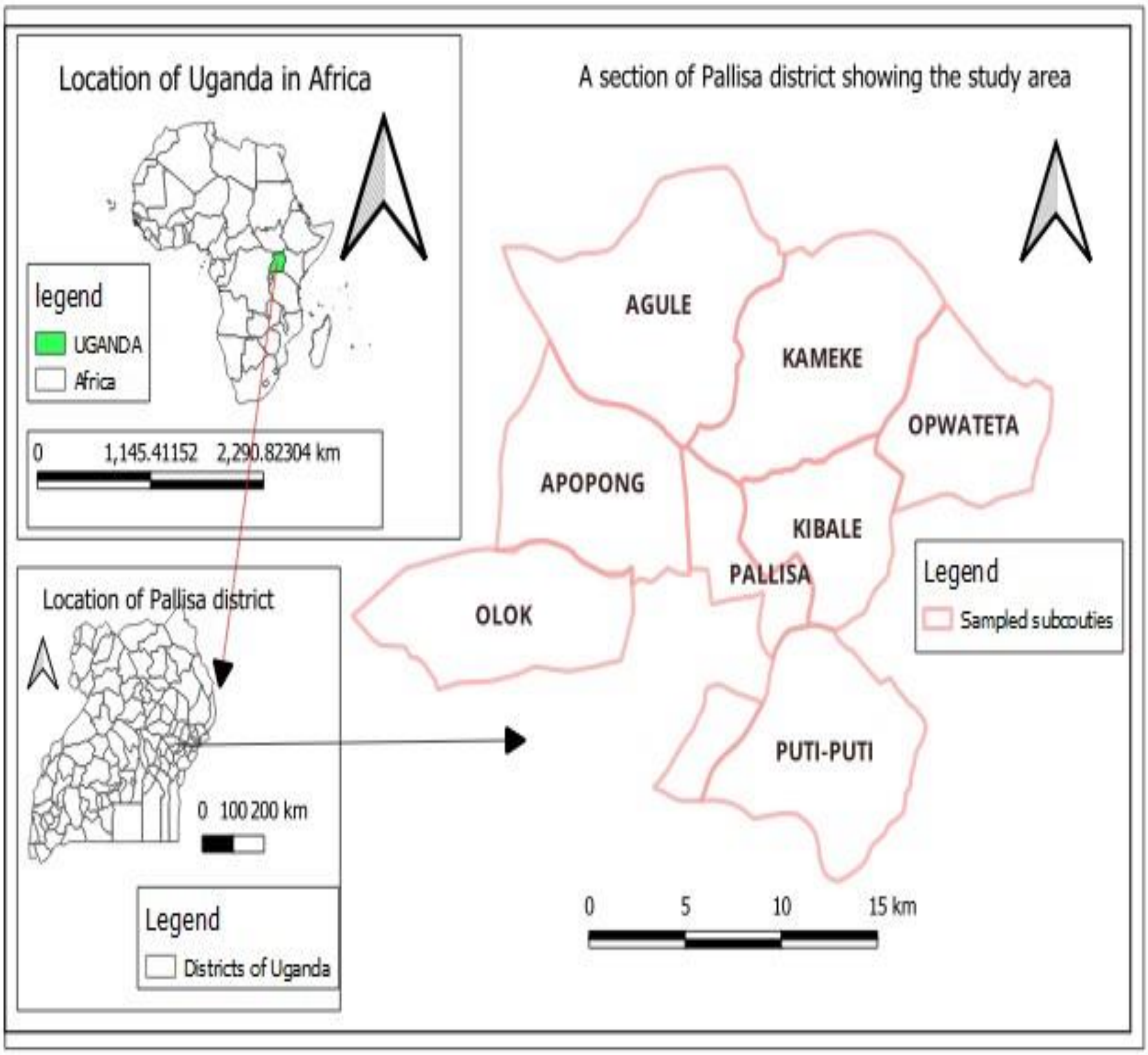


Figure 2: A section of the Map of Pallisa District showing the Location of the Study area

Pallisa District lies in Eastern Uganda, bordered by Kumi, Ngora, Serere, and Bukedea to the north; Kibuku and Budaka to the south; Mbale to the east; and Kaliro and Buyende to the west as shown in Figure 2 above. The district has a population of 386,889 people (UBOS, 2010), with 14 sub counties, 68 parishes and 583 villages. Physically the district lies between: Latitudes 0˚ 45’ N and 1˚ 05 ‘N and longitudes 33˚47’E and 34˚05‘E (Uganda, 2016).

The inhabitants of the area are Itesots and Bagwere. Agriculture is the main activity, with millet, maize, sorghum, potatoes and cassava being the major crops grown. The district has a variety of soils – clay soils along swamps and lakes, clay loams covering west and central, sandy loams covering mainly the south and south east and black loams to the north. Pallisa has had frequent and severe hailstorms, soil erosion, crop pest’s/animal parasites and diseases, flash floods, drought, invasive species and strong winds (Uganda, 2016).

The district has been experiencing occasional rains punctuated by dry conditions in many parts since January 2021 (UNMA, 2021). Onset of the seasonal rains is expected around mid to Late March while the peak rains are expected around late April to Early-May with cessation expected around late May to early June (UNMA, 2021). The coldest month of the year in Pallisa is August, with an average low of 62°F and high of 83°F. Over the course of the year, the temperature typically varies from 62°F to 93°F and is rarely below 60°F or above 99°F. Normally, the hot season lasts for 2.4 months, from January 3 to March 16, with an average daily high temperature above 91°F.

The soil type in Pallisa consist of both black- and red-loams (Orr, et al, 2003). The soil type is always key in determining the water retention capacity of the soil, type of crop grown, as well as fertility of the soil. However, the varying climate could have a big impact on the soil productivity, with profound effects on millet production, food security and wellbeing. In Pallisa district, farmers plant millet in February and harvest in July (Orr et al. 2003). Pallisa lies in the Teso farming system where farmers grow cotton-millet in rotation, along with a wide range of other crops. Traditionally, farmers opened land by ox-ploughs and cotton was weeded four or five times to help prepare a good seedbed for millet, the staple food crop (Orr, et al., 2003).

3.3 Sample size determination and procedure

3.3.1 Sampling procedure

The study purposely selected Pallisa District because millet is widely cultivated there and the area frequently experiences droughts that affect production.

Sub-counties and parishes were also purposively selected based on the concentration and distribution of millet farmers.

From the 21 sub-counties in Pallisa District, eight (8) were selected. In each sub-county, two (2) parishes were chosen, giving a total of 16 parishes (as detailed in Table 1). A sample of 365 smallholder millet-farming households was drawn using systematic random sampling. Based on an estimated population of 3,650 eligible households in the selected parishes, a sampling interval of ten (10) was calculated. Using a lottery system, a random number between 1 and 10 was chosen to mark the starting point, after which each tenth household was included in the sample.

This approach was chosen due to the relative homogeneity of smallholder millet farmers in the area, and to ensure equal selection probability and geographic spread. The final sample size of 365 households was deemed adequate to account for potential non-response while still allowing for representativeness and generalization of the findings. This aligns with Amin's (2005) guidance that systematic random sampling ensures a fair representation of the target population in survey-based research.

3.3.2 Sample size calculation

The sample size for respondents was calculated using the formula as shown below: (Yamane, 1967).

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

Where;

n = sample size

N = the population

e = the level of precision of 0.05 used

A 95% (1.96) confidence level was assumed in the equation.

$$n = \frac{4,134}{1 + 4,134\,(0.05)^2} = 365 \text{ households.}$$

The sample was collected from eight sub counties as indicated in Table 1.

Table 3.1: Distribution of the sample across the study area

Sub county	Frequency
Opwateta	51
Kibale	45
Putiputi	44
Apopong	46
Kameke	45
Pallisa	46
Olok	43
Agule	45

During the study, five (5) millet farmers were sampled from each of the sampled sub counties indicated in table one above to help in identifying the adaptation strategies used by millet farmers in the area.

3.4 Data collection methods and tools

3.4.1 Data types and sources

Data were obtained from both primary and secondary sources. Household surveys provided the primary data, while long-term climatic records were sourced from UNMA and relevant online databases

3.4.2 Data collection methods

Data for objective one was collected using a datasheet designed to collect secondary data on climatic factors like rainfall, temperature, as well as the trend in production of millet. A semi structured questionnaire was also used to collect the farmers' perception on the trend in millet production.

For the second objective, data was collected using a semi- structured questionnaire and KIIs guide. The questionnaire contained precise questions on demographics, knowledge on climate variability, perception of millet farmers on how the various climatic factors influence harvest, planting season, harvesting, drying, among other aspects. Data on farming methods, pests and diseases, poverty, weed invasions was also sought.

Data for the third objective, was collected using semi-structured questionnaire, KIIs (with

Community Development Officer (CDO), Assistant Agricultural Officers (AAO's), Agricultural Officers (AOs), Pallisa District Environmental Office, District Agricultural Officer (DAO), District Production Officer (DPO) and in-depth interviews with some millet farmers. Only farmers with an experience of over 30 years in cultivating millet were involved in the in-depth interviews across all the sampled sub counties. Perception on soil management, water management, varieties grown and their productivity, among other aspects were sought.

Data were collected in two stages: first, a qualitative instrument was designed and applied to five experienced millet farmers in each sampled sub-county. The selection of responds was based on the experience in growing millet (30 years and above) and was guided by the chairperson LC1. The questions of interest were on the adaptation strategies and seeking their perception on climate variability in their areas.

This was followed by summarizing the adaptation measures and incorporating them in the semi-structured questionnaire for the household survey. The section in the tool was intended to capture the various climate variability adaptation strategies used by the farmers. Other responses after transcription of the audios were maintained as narratives.

3.5 Data analysis

Qualitative data in form of audios recorded from the interviews were transcribed and coded basing on the themes in the checklist or the most recurring responses. Quantitative responses were coded and analyzed with the aid of the Statistical Package for Social Sciences (SPSS), version 20

3.5.1 Objective One

Trend analysis (a statistical and analytical technique used to evaluate and identify patterns, trends, or changes in data over time) was used on rainfall, temperature, millet yield and monthly area specific precipitation data of 30 years. Line graphs were used to depict the trend in Millet production, rainfall pattern and temperature over the past 10 years. A non-parametric technique (Mann Kendall and Sens slope) were also used to depict the trend in rainfall, temperature and millet yield. Mann Kendall trend analysis was used to establish the significance of the trend while Sen's slope was used to depict whether there was a decreasing or increasing trend.

3.5.2 Objective Two

Data for the second objective was analyzed using correlations and linear regression. Linear regression was used to predict the impact of climatic factors like rainfall and temperature on millet yield for 10 years (2011-2020). Chi-square was used as a way of assessing the relationship between climatic factors and millet production. Pearson Chi-square was used to establish the relationship between quantitative and the qualitative variables. Some of the numeric variables included factors like acreage, yield, household size, millet farming experience, mean temperature and rainfall, income level, among others while the qualitative variables included education level, method of farming, knowledge on climate variability, adaptation strategies used by millet farmers.

The demographics e.g., gender, education level, household size, farming methods used, labour sources of the millet farmers were cross tabulated with variables like knowledge/perception on climate variability, as well as the various perceptions on the climatic variables and millet production. Content analysis was used to capture the views collected through KIIs in the report. KII notes were compared for the various interviews with reference to the themes in the questionnaire and the most occurring responses. This was also used to summarize the strategies farmers use to adapt to climate variability for enhanced millet production. To establish the contribution of Climate Variability and other factors to millet production in Pallisa district, Pearson Chi-square was used to depict the relationship between climate variables as well as other factors and millet production, while Correlation analysis was used to depict the strength and direction of the relationship. A significant relationship existed whenever the p-value was ≤ 0.05.

3.5.3 Objective Three

Primary qualitative data collected during the in-depth interviews with farmers. The audios were transcribed in word document and then analyzed using content analysis and narrative analysis.

This focused on identifying and analyzing farmers' responses in form of themes related to adaptation measures to climate variability. Responses were categorized and analyzed using SPSS, and results were presented inform of tables.

3.6 Ethical consideration

First, permission was obtained from the Course coordinator, Busitema University, with the acquisition of an introduction letter. Protection of the rights of the study participants was ensured by giving them due freedom to participate in the study or not to participate. Privacy and confidentiality were maintained. Names of respondents didn't appear on data collection tools (anonymous).

Consent was sought from the respondents during the research with assurance of the study being purely for academic purposes. At each of the selected study sites, the focal persons were contacted for permission and necessary information before the commencement of the study. The purpose, general content and nature of the investigation were explained to each respondent to obtain a verbal and written consent before inclusion into the study.

3.7 Limitations and delimitations of the study

The first limitation of the study was the small sample size which made estimates unstable and associations between dependent and independent variables undetectable. Weather changes particularly rain disrupted the movements of the researcher and his research assistants, which ended up even making the materials wet, in cases where there is no shelter nearby. However, the researcher secured umbrellas, which helped to shield the researcher and his research assistants from rain. Time constraints, time allocated to the researcher was limited hence the scope of the study became limited.

The researcher overcame this challenge by talking to the university registrar and the study supervisor to extend more time to allow the researcher to be in position to complete the research. For secondary data, some documents were presumed to have been destroyed or lost through the force or vandalism and the researcher had to rely on long-serving employees. However, this was solved by the researcher visiting the internet to access the required information to accomplish the study. Some parts of the district were hard to reach and mountainous, this also affected the researcher and his assistants' movements. However, the researcher made use of motorcycles to easily reach areas where vehicles cannot reach.

CHAPTER 4: RESULTS AND DISSCUSION

4.0 Introduction

This chapter presents the demographic characteristics and economic activities of the respondent farmer households, and infrastructure provisions in the study area are highlighted in the context of climate variability. The household variables analyzed include age, sex, education, family size, marital status and education, experience in millet farming, land size, millet varieties cultivated, weeding, labour availability, etc. These variables have implications on millet production and they are used as background information for the succeeding chapters.

4.1 Demographic characteristics of the millet farmers

Majority of the millet farmers encountered were 51 years and above of age (35.1%) while very few farmers belonging to the 21-30 years' age bracket were encountered (10.4%) as seen in table 2 below. Most of the farmers were male (51.8%). The highest percentage of millet farmers had primary level of education (50.5%) while 20.8% had no formal education.

Table 4.2: Demographic characteristics of millet farmers, May 2023

		Percentage (%)
What age range are you in?	21-30 years	10.4
	31-40 years	22.2
	41-50 years	32.3
	51 yrs. and above	35.1
Sex	Male	51.8
	Female	48.2
Highest Education level	Primary	50.5
	Secondary	17.5
	Certificate	5.5
	Diploma	3.8
	Degree	1.9
	Masters	0.0
	PhD	0.0
	No formal education	20.8

	Less than a year	0.2
	1- 2 years	5.5
Experience in cultivating millet	3-4 years	12.1
	5-6 years	14.0
	Above six years	68.2
	Hand hoe Oxen	56.7
Major method of tilling used		43.3
	Tractor	0.0

4.2 Methods of millet production

4.2.1 Methods of Tilling

Generally, most of the millet farmers used hand hoes to till the land (56.7%). However, there were some millet farmers (43.3%) who could afford to hire people with oxen to plough for them. With respect to the sub counties, the use of oxen to till the land was very high in Opwateta (96.1%) and Kameke (82.2%) sub counties, these sub-counties were followed by Apopong with 56.5%, Putiputi 50.0%, Olok 37.2%, Agule 8.9%, Kibale 6.7%, while Pallisa had the least percentage of 2.2%.

In Table 3 below the majority of the farmers in Pallisa sub-county (97.8%) used hand hoe, followed by Kibale sub-county 93.3%, then Agule with 91.1%, then Olok followed with 62.8%, in Putiputi and Apopong 43.5%, Kameke 17.8% used hand hoe while only 3.9% used hand hoes in Opwateta. Findings from all the farmers interviewed, across all the sub counties showed that none used a tractor as reflected in Table 3 below and this partly explains the low millet production in the district.

Table 4.3: Major tilling methods used by millet farmers in Pallisa district by Sub County (Survey data, May 2023)

Sub county	Major method of tilling used		
	Hand hoe	Oxen	Tractor
	Row (%)	Row (%)	Row (%)
Opwateta	3.9	96.1	0.0
Kibale	93.3	6.7	0.0
Putiputi	50.0	50.0	0.0
Apopong	43.5	56.5	0.0
Kameke	17.8	82.2	0.0
Pallisa	97.8	2.2	0.0
Olok	62.8	37.2	0.0
Agule	91.1	8.9	0.0

Most of the farmer's intercrop millet with other crops refer to (Table 4) especially farmers interviewed in Kibale sub-county (100%), followed by Pallisa Sub County 97.8%, Kameke 82.2%, Olok 76.7%, Opwateta 70.6%, Putiputi 68.2%, Agule 62.2% while 58.7% for Apopong. In Table 4, the study results showed that there were many farmers growing millet as a standalone crop in Apopong Sub County (41.3%), followed by Agule 37.8%, Putiputi 31.8, Opwateta 29.4, Olok 23.3, Kameke 17.8, Pallisa 2.2% while Kibale had 0.0% of all the interviewed farmers. In Figure 3 below we also see millet planted as a stand-alone crop.

Table 4.4: Major method of production used by millet farmers in Pallisa district (Survey data, May 2023)

Major method of millet production		Stand-alone crop	Intercropping
		Row N %	Row N %
Sub county	Opwateta	29.4	70.6
	Kibale	0.0	100.0
	Putiputi	31.8	68.2
	Apopong	41.3	58.7
	Kameke	17.8	82.2
	Pallisa	2.2	97.8
	Olok	23.3	76.7
	Agule	37.8	62.2

Figure 3: A field of millet planted as a stand-alone crop

4.2.2 Size of land cultivated

In Table 5 below the study revealed; the average cultivated land in the study area was 1.0 acres while the largest cultivated garden during the study measured up to 8 acres. The mean land cultivated was 2.3 acres for Opwateta Sub County, Olok, 2.9, Kibale 1.9, Apopong 1.8, Putiputi 1.5, Kameke 1.6, Pallisa 1.4, while Agule was 1.6. The maximum land cultivated in Opwateta was 8 acres, Kibale 4.0 acres, Putiputi 4.0, Apopong 4.0 acres, Kameke 6.0 acres, Olok 6.0 acres, Pallisa 3.0 acres, while Agule was 4.0 acres. The minimum cultivated land in Opwateta was .5 while for the rest of the sub-counties the minimum cultivated land was 1.0

Table 4.5: Average acreage cultivated by farmers under millet (Survey data, May 2023)

		Average acreage cultivated			
		Mean	**Maximum**	**Minimum**	**Mode**
Sub county	Opwateta	2.3	8.0	.5	1.0
	Kibale	1.9	4.0	1.0	2.0
	Putiputi	1.5	4.0	1.0	1.0
	Apopong	1.8	4.0	1.0	1.0
	Kameke	1.6	6.0	1.0	1.0
	Pallisa	1.4	3.0	1.0	1.0
	Olok	2.9	6.0	1.0	1.0
	Agule	1.6	4.0	1.0	1.0

4.2.3 Millet varieties cultivated

Majority of millet farmers grew native varieties, with Apopong Sub County leading with (100%) as seen in table 6 below. In Opwateta 98%, 97.8%in Pallisa and Kibale, 86.4 in Putiputi, 84.4% in Kameke, 83.7% in Olok while 73.3% planted native varieties in Agule. However, there were some farmers among those who were interviewed who cultivated improved varieties. the biggest number was from Agule sub county with 26.7%, followed by Olok subcounty 16.3%, then Kameke came third with 15.6%, Putiputi followed with 13.6%, Kibale and Pallisa at 2.2% and lastly Opwateta with 2.0.

With respect to preference, the most local varieties grown in Pallisa district include Etanganyikat (matures fast and resistant to drought), Omududu (purplish in color while in the garden and tends to blackish when dry), Erowa (brownish when dry), and Obeet (whitish while in the garden).

Table 4.6: Varieties of millet planted by the farmers in the study area (Survey data, May 2023)

Sub county	Which millet varieties do you grow?	
	Native variety	**Improved varieties**
	Row N %	**Row N %**
Opwateta	98.0	2.0
Kibale	97.8	2.2
Putiputi	86.4	13.6
Apopong	100.0	0.0
Kameke	84.4	15.6
Pallisa	97.8	2.2
Olok	83.7	16.3
Agule	73.3	26.7

4.2.4 Weeding of millet

Weeding millet is often done using hand hoes (97.0%) with family labour dominating the activity, though a very small number of respondents use selective herbicides (3.0%). Millet farmers attributed failure to use selective herbicides to high level of poverty. The use of selective herbicide in weed control occurred in Agule (20.0%), Apopong (2.2%) and Opwateta (2.0%). The rest of the percentages account for millet farmers who used hand hoes to weed their millet.

Table 7: Major sources of labour used to work on millet fields (Survey data, May 2023)

Sub county	Major source of labour		
	Family labour	**Hired labour**	**Both**
	Row N %	**Row N %**	**Row N %**
Opwateta	27.5	41.2	31.4
Kibale	95.6	4.4	0.0
Putiputi	65.9	9.1	25.0
Apopong	87.0	4.3	8.7
Kameke	82.2	4.4	13.3
Pallisa	80.4	0.0	19.6
Olok	62.8	2.3	34.9
Agule	51.1	20.0	28.9

In table 7 above 27.5% of the households use family labour, 41.2% use hired labour while 31.4 use both family and hired labour in Opwateta while 95.6% of farmers in Kibale sub-county use family labour and 4.4% use hired labour. In Putiputi sub-county 65.6% households use family labour, 9.1% households use hired labour while 25.0 use both family and hired labour. In Apopong 87.0 households use family labour, 4.3% use hired labour while 8.7% households use both family and hired labour.

In Kameke sub-county 82.2 % of the households use family labour, 4.4% use hired labour while 13.3% use both family and hired labour. In Pallisa sub-county 80.4% of the interviewed farmers used family labour, while 19.6% used both family and hired labour. 62.8% of the interviewed farmers in Olok sub-county used family labour, 2.3% used hired labour and 34.4% of the interviewed farmers used both hired and family labour. In Agule sub-county 51.1% of the interviewed farmers used family labour, 20.0% used hired labour while 28.9% used both family and hired labour. Children mostly comprise the labour used by the millet farmers.

On the other hand, in table 8 below youth comprised the labour force in Olok Sub County, while a high percentage of women comprised the labour in Opwateta (72.5%), Apopong (89.1%), and Pallisa (73.9%). Results show that very few men participated in offering labour in millet production across all the sub counties sampled. In Opwateta sub-county15.7% of the labour is comprised with children, 9.8% youth, 72.5% women and 2.0% men. 93.3% of the labour in Kibale comprised of children, 6.7% women while results showed that youth and men were not active in millet production. 40.9% of the labour was comprised of children, 15.9% youth, 40.9% women while 2.3% were men. In Apopong sub-county.

Table 4.8: Composition of labour that works on millet gardens (Survey data, May 2023)

		Who mostly comprise of the labour			
		Children	Youth	Women	Men
		Row (%)	Row (%)	Row (%)	Row (%)
Sub county	Opwateta	15.7	9.8	72.5	2.0
	Kibale	93.3	0.0	6.7	0.0
	Putiputi	40.9	15.9	40.9	2.3
	Apopong	10.9	0.0	89.1	0.0
	Kameke	62.2	8.9	28.9	0.0
	Pallisa	26.1	0.0	73.9	0.0
	Olok	2.3	55.8	34.9	7.0
	Agule	46.7	13.3	35.6	4.4

Figure 4: A family weeding millet intercropped with maize

4.2.5 Labour availability

The findings show that most of the millet farmers in all the sub counties experience labour shortages as seen in table 9 below. 60.2% of the farmers experienced labour shortages as children were at school. Children were most preferred since they were effective and required low payments. Farmers revealed that dealing with mature people was challenging as they have their own gardens and can have very many programmes with other millet farmers. This competition results in high charges. In Putiputi and Apopong sub-counties majority of the farmers (100%) interviewed agreed to shortage of labour while it was varying across other sub counties. (98% in Opwateta, 95.6% in Kibale, 90.7 in Olok, 84.4% in Kameke and 57.8% in Agule).

Table 4.9: Extent of labour shortage experienced by millet farmers (Survey data, May 2023)

		Sub county							
		Opwateta	Kibale	Putiputi	Apopong	Kameke	Pallisa	Olok	Agule
Labour shortage	Yes	98.0	95.6	100.0	100.0	84.4	100.0	90.7	57.8
	No	2.0	4.4	0.0	0.0	15.6	0.0	9.3	42.2

Generally, as seen in table 9 above, labour shortages were mostly experienced during periods of weeding millet (90.7%) due to high competition for labour. Only a small proportion of millet farmers (9.3%) lacked labour during harvesting. In table 10 below, all the farmers interviewed in Opwateta, Kibale, and Pallisa sub counties experienced labour shortage during weeding range between 56.5% to 100%. There was a big percentage of farmers in Apopong 43.5% who did not have labour, 19.2% in Agule, 5.3 in Kameke, 5.1% in Olok and 4.5% in. Putiputi who lacked labour during harvesting period.

Table 4.10: Stage of production most hit by labour shortage across all the sub counties sampled (Survey data, May 2023).

Stage of millet production	**Sub county**							
	Opwateta	**Kibale**	**Putiputi**	**Apopong**	**Kameke**	**Pallisa**	**Olok**	**Agule**
Weeding	100.0	100.0	95.5	56.5	94.7	100.0	94.9	80.8

Harvesting	0.0	0.0	4.5	43.5	5.3	0.0	5.1	19.2

4.3 Trends of rainfall, temperature and millet production in Pallisa district

This figure integrates annual rainfall, average temperature, and millet production (2011–2021) in Pallisa District. Rainfall shows a fluctuating but generally declining pattern over the years, represented by the blue line. The average annual temperature (red line) demonstrates a slightly increasing trend, indicative of gradual warming. In contrast, millet production per acre (green dashed line) exhibits a downward trend. The visual correlation among these variables suggests that both declining rainfall and rising temperatures could be contributing factors to the decrease in millet yields. The combined visualization highlights the potential compounding impact of climate variability on agricultural productivity in the region.

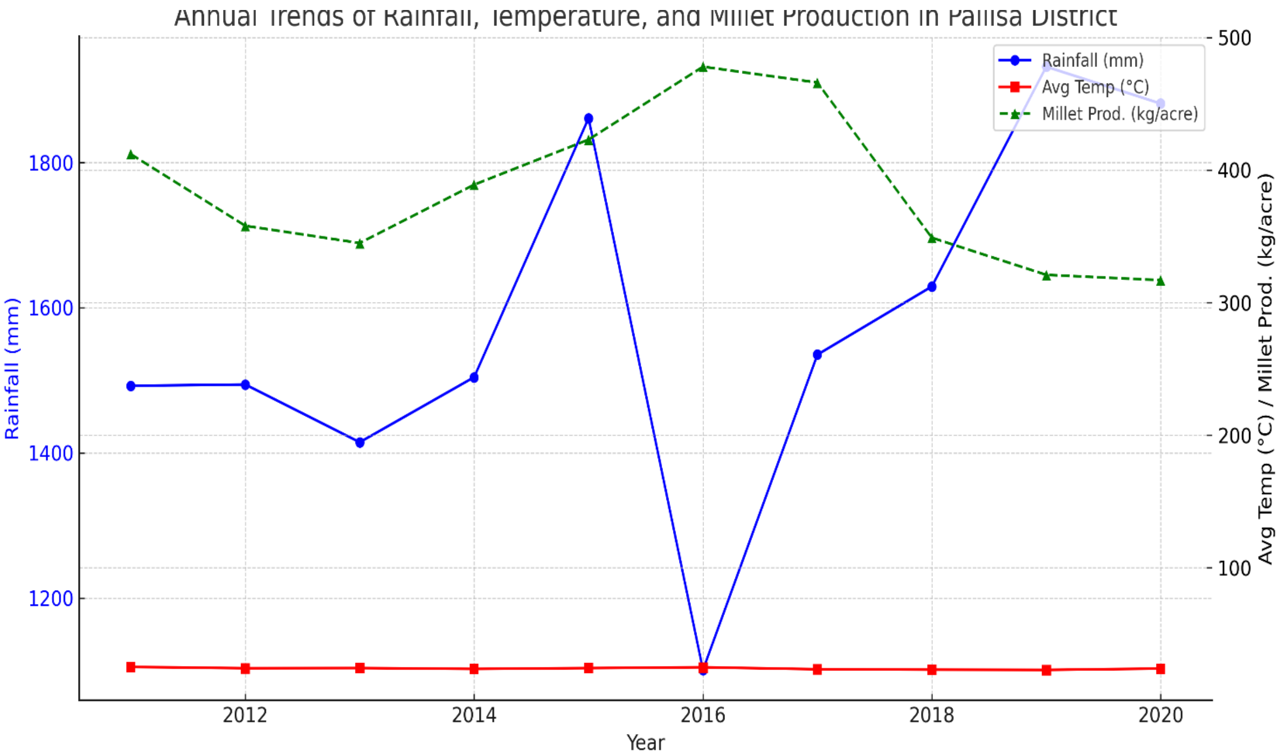


Figure 5: Annual trends of rainfall, temperature, amd millet production in Pallisa District

4.3.1 Trend in rainfall

Rainfall has been unpredictable and fluctuating since 1990 as seen in fig 5 below, with some years registering increasing amounts of rain than the others. During the KII, it was revealed that in the period (1991 to 2021), low rainfall was received 1993, 2000, and 2016, with 2000 experiencing the least rainfall amount. There was a lot of rain in 1996 and 2019. Too much rain received in these years resulted in flooding of many millet fields and many post-harvest losses for millet farmers especially due to incomplete drying. From figure 5 below, rainfall has gone through an increasing trend. This can also be evident from the increasing cases of flooding since 2000, resulting in damage to infrastructure and millet production.

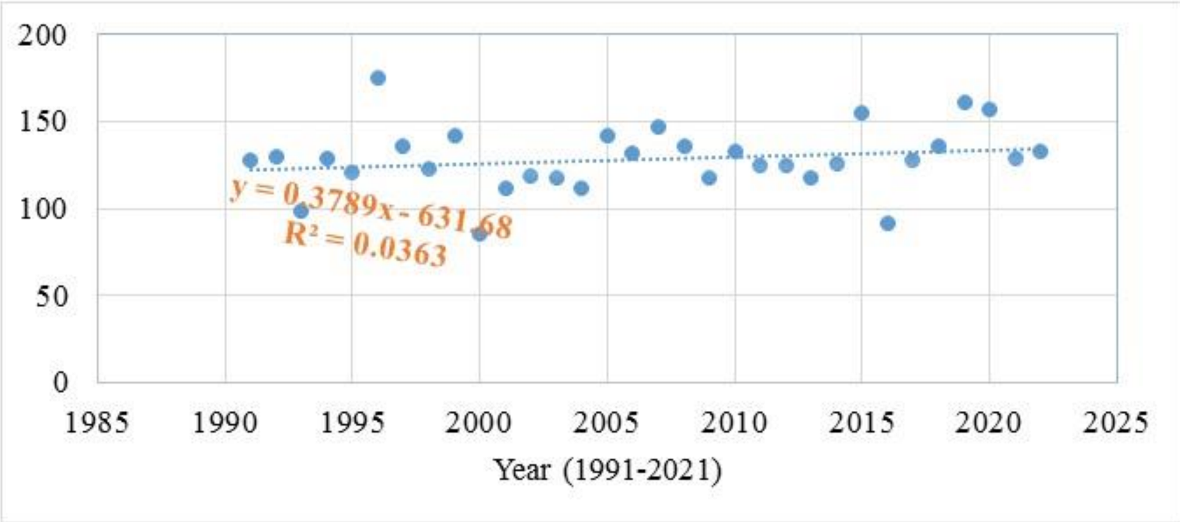


Figure 6: Trend in rainfall received in the sampled sub counties from 1991 to 2021 (Source; UNMA)

Generally, Sen's slope (4.963) showed an increasing trend in rainfall for the period of 32 years (1990-2020). Additionally, Mann Kendall results showed a p-value of 0.1681> 0.05. This revealed that the trend was not significant. Table 11 shows the trend in rainfall for every month for the same period. Trend analysis revealed that some months (August & September) have witnessed a significant increase in the amount of rainfall. There are monthly that have had an increase in the amount of rainfall received, though not significant. However, there are months with a declining trend in the rainfall received since 1990.

Table 4.11: Shows the Mann-Kendall Sens slope of sampled sub counties of Pallisa district

MONTH	Rain Min	Rain Max	Zvalue	Shift	N-value	P-value	Sens-slope	Result
Jan	0	158.7	-0.1946	Downward	32	0.8457	-13.00	Negative
Feb	0.3	186.1	0.11352	Upward	32	0.9096	8.000	Positive
Mar	48.4	313.4	0.37298	Upward	32	0.7092	24.00	Positive
Apr	111.9	332.1	-0.1135	Downward	32	0.9096	-8.00	Negative
May	116.9	306.2	0.68118	Upward	32	0.4958	4.300000e+01	Positive
Jun	51.7	194.8	-0.5351	Downward	32	0.5926	-34.000	Negative
Jul	53.8	192.4	0.34055	Upward	32	0.7334	2.200000e+01	Positive
Aug	100.6	262.1	2.0919	Upward	32	0.03645	130.000	Positive
Sept	23.2	221.8	2.2541	Upward	32	0.02419	140.00	Positive
Oct	79.4	341.5	-0.3081	Downward	32	0.758	-20.00	Negative
Nov	75.2	270.1	0.21081	Upward	32	0.833	1.400000e+01	Positive
Dec	10	227.1	0.60001	Upward	32	0.5485	38.00	Positive

4.3.2 Temperature Trends (1990-2020)

Temperature is required for proper growth of millet though excess temperature affects growth and thus the yield. Maximum and minimum average monthly temperatures depend on the amount of rainfall and the number of days' rainfall has been received in a month. Maximum temperature was experienced in 2000 and 2016. In figure 6 above, results show that some years have been hot with the average monthly Tmax of $>29.0^0$ C in most of the months of the year 2000, 2011. Increased temperature result in heat stress to millet, and sometimes favour multiplication of pests.

Generally, for the period of 30 years, Tmax has witnessed a decreasing trend with the highest temperatures occurring in the 1990s compared to 2010-2020.

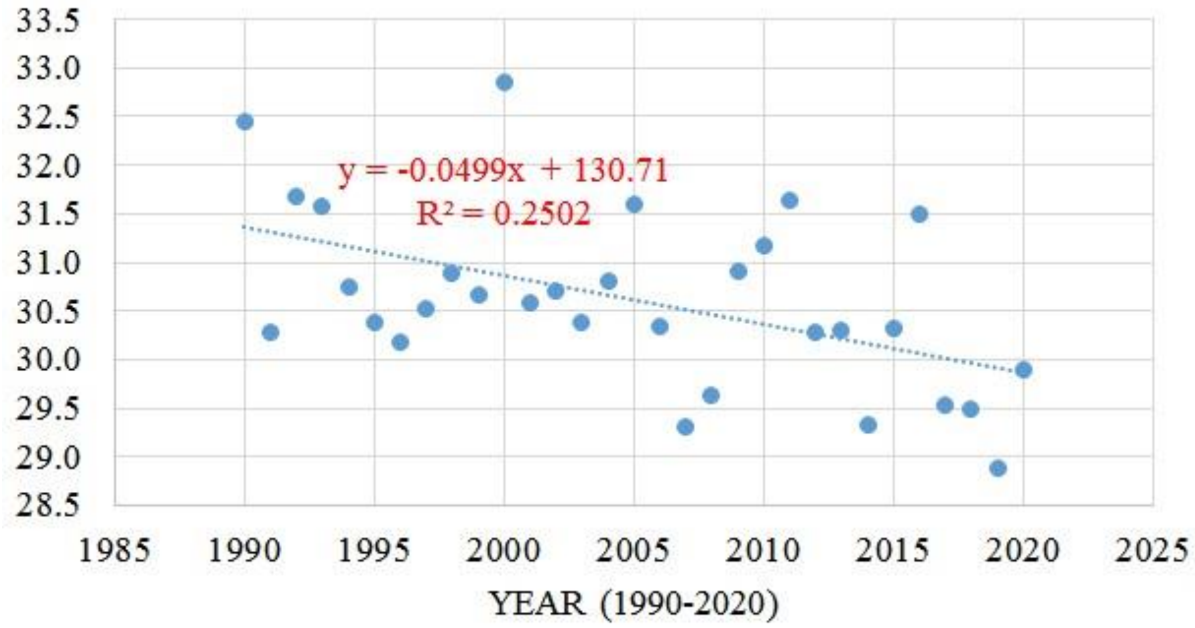


Figure 7: Trend in temperature (Tmax) for the selected sub counties from 1990 to 2020 (*Source: UNMA*)

Generally, in figure 6 above, Sen's slope (-0.6) showed that the maximum temperature has been declining in the study area over the period 1990-2020. The p-value (0.009771) from Mann Kendall analysis revealed that the maximum temperature in the study area has been declining significantly. However, in table 12 below, trend computations for every maximum monthly temperature also revealed a declining trend.

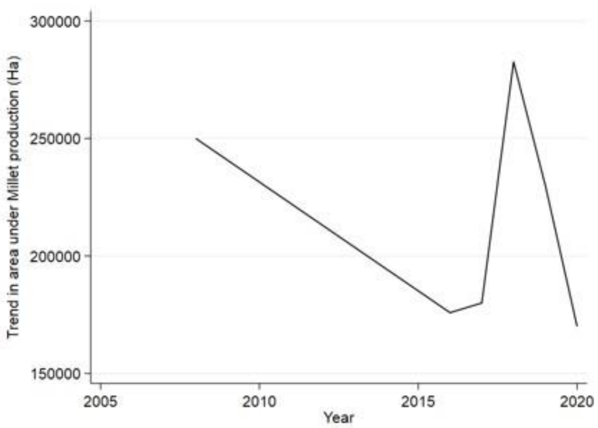
Table 4.12: Shows the Mann-Kendall Sens slope of Tmax for sampled sub counties of Pallisa district

MONTH	TMin	TMax		Zvalue	Shift	N-value	P-value	Sensslope	Result
Jan	29.5	36.1		-0.9358	Downward	31	0.3494	-56.000	Negative
Feb	28.5	36.1		-1.9054	Downward	31	0.05672	-113.000	Negative
Mar	24	34.9		-1.8874	Downward	31	0.0591	-112.00	Negative
Apr	24.5	33.8		-2.0596	Downward	31	0.03943	-122.00	Negative

May	24.6	33.9		-1.0392	Downward	31	0.2987	-62.00	Negative
Jun	26.2	32.2		-1.4977	Downward	31	0.1342	-89.00	Negative
Jul	27.4	32.5		-1.2084	Downward	31	0.2269	-72.000	Negative
Aug	27.5	33.5		-2.3667	Downward	31	0.01795	-140.00	Negative
Sept	27.6	33.1		-1.1246	Downward	31	0.2608	-67.00	Negative
Oct	25.3	32.2		-1.7034	Downward	31	0.08849	-101.00	Negative
Nov	29.2	33.9		-1.1739	Downward	31	0.2404	-70.00	Negative
Dec	30	35.8		-0.9536	Downward	31	0.3403	-57.0	Negative

4.3.3 Trend in area cultivated under millet

The area cultivated under millet production has been decreasing since 2018 when 282607 hectares were registered. Records show that 2020 registered the lowest number of hectares planted as seen from figure 7 below, this can be attributed to changes in climatic condition over time among other factors.



Area planted under Millet (Ha)	Year
249987	2008/09***
175874	2016
180000	2017
282607	2018**
230000	2019
170000	2020**

*** *Census data*; ***AAS Estimates*

Figure 8: Showing the trend in the Area cultivated under millet (Source: AAS and Census data)

4.3.4 Trend in millet productivity per acre

The yield per acre as per figure 8 below was traced from 2011 for 10 years. Results showed that millet yield per acre had been unstable since 2011. Results show that the millet yields for the first season (Season A) had been always higher than those of the second season (Season B) (Figure 8). The productivity per acre increased in 2012 with over 6800kg per acre. However, there was a drastic decline of yield per acre in 2013 in both seasons, with the average yield in season A being 4500kg per acre while 300kg per acre being the average yield for season B.

For the first season (Season A), yields were on a declining trend between 2016 with 4800kg per acre and 2020 with 3200kg per acre as average yield. Since 2011, the lowest average yield per acre were recorded in 2022 with 3100 kg per acre in season A and 200kg per acre in season B as average yield compared to the rest of the years under comparison. In general, the yields for Season A had witnessed a steady declining trend from 2016 to 2020. The yield per acre was looked at with respect to sub counties sampled. However, results show that in Opwateta Sub County, the yield for millet declined between 2016 and 2022.

Millet farmers revealed that in the past 10 years, it has been hard to predict the yield due to changes in climate conditions including temperatures yet all the interviewed famers depend on rain-fed agriculture. The yield for millet in 2022 was low, which greatly affected income and food security of many households.

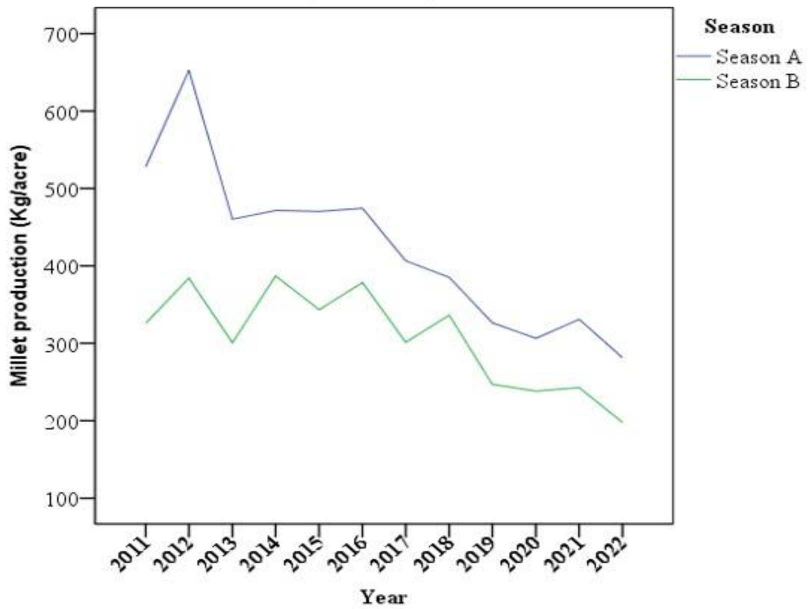


Figure 9: Showing the trend in productivity per acre in for selected sub counties in Pallisa district (*Source: Sub County Data, 2022)*.

It is also evident that the yield per acre has witnessed a declining trend since 2011 as indicated in figure. 8 above

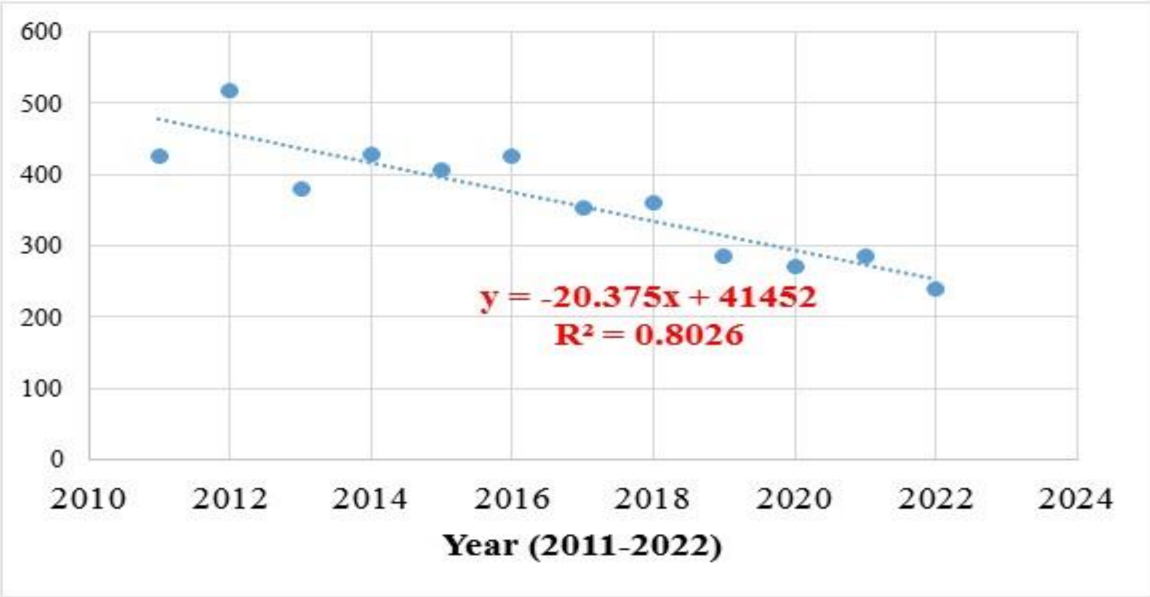


Figure 10: Trend in millet yield for (2011-2022)

The perception of millet farmers was sought on the trend in the yield of millet 10 years back as seen in figure 9 above. However, findings reveal that the yield has seen a declining trend over the last 10 years.

Table 4.13: Millet yield 10 years back and the previous season

	Unit	Sub county							
		Opwateta	Kibale	Putiputi	Apopong	Kameke	Pallisa	Olok	Agule
		Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Millet yield 10 years back	Sacks			4	7	4	6	40	3
	Kgs	341	190	300		200		777	
	Basins			19	3	9	8	5	7
Yield the previous season	Sacks	15		2	2	2	1	5	6
	Kgs	181	111	156	125	350		203	.
	Basins			7	2	3	3	35	11

While in table 13 above, the millet farmers indicated that the selling price per Kg of millet had increased through time. It was noted during the study that the selling price of the previous season was averagely Ugx 2676.

Table 4.14: Average selling price for millet

Selling prices for millet (per Kg)	**Mean**
What is the average current selling price at which you sold your millet last season	2676
What was the average selling price of millet 10 years back?	1144

Sen's slope (-22.69) indicated a decreasing trend in the yield per acre of millet for the period 2011-2022. Mann Kendall analysis yielded a p-value = 0.001269< 0.05.

4.3.5 Knowledge on climate variability

In table 15 below, the majority of the interviewed farmers had knowledge about climate variability. With 100% having knowledge about climate variability in the sub counties of Opwateta, Kibale, Putiputi, Pallisa, Olok while 95.6% from Agule and 86.7% from Kameke. 13.3% of the interviewed farmers from Kameke had no knowledge about climate variability and 4.4% from Agule, the rest of the interviewed farmers had the knowledge.

Table 4.15: Below shows the proportion of the farmers with knowledge on climate variability in Pallisa district by Sub County sampled

Sub county	Do you have knowledge or have you ever had about climate variability?	
	Yes	No
	Row percentage (%)	Row percentage (%)
Opwateta	100.0	0.0
Kibale	100.0	0.0
Putiputi	100.0	0.0
Apopong	100.0	0.0
Kameke	86.7	13.3
Pallisa	100.0	0.0
Olok	100.0	0.0
Agule	95.6	4.4

Experience/ duration while growing millet significantly resulted in farmers gaining knowledge on climate variability (p=0.001). Famers with ≥6 years of experience in cultivating millet had more knowledge on climate variability as it was easy for them to draw comparisons.

Table 16: Showing some of the factors affecting knowledge acquisition on climate variability

Pearson Chi-Square Tests

		Do you have knowledge? or have you ever had about climate variability?
Age	Chi-square	7.527 3
	Df	
	Sig.	.057
Sex	Chi-square	.668 1
	Df	
	Sig.	.414
Highest Education level	Chi-square	3.407 5
	Df	
	Sig.	.638
Experience in cultivating millet	Chi-square	19.348 4
	Df	
	Sig.	.001*
Major method of tilling	Chi-square	3.351 1
	Df	
	Sig.	.067
Major method of millet production	Chi-square	.018 1
	Df	
	Sig.	.893
Major source of labour	Chi-square	3.089 2
	Df	
	Sig.	.213

*. The Chi-square statistic is significant at the .05 level.

4.3.6 The use of indigenous knowledge on the climatic factors

A high percentage of millet farmers (76.7%) strongly agreed that they used local knowledge to respond to the weather changes such as violent storms which has become frequent (Table 17). Some farmers base on the direction of wind to tell how the rain will be. It was revealed that the direction of wind is used to tell whether it will rain or whether farmers should expect a dry period. Age of the farmers significantly (df=15, p= 0.028, X^2= 27.047, N=365) explained the level of local knowledge used to respond to weather changes such as violent storms.

Farmers belonging to the 31-40 years' category and above had local knowledge that they could use to respond to storms that were becoming frequent. Gender of the farmer was not an important factor in using local knowledge to respond to storms (df=5, p= 0.238, X^2=0.136, N=365) In (Table 18). Local knowledge was applied in responding to frequent storms irrespective of the gender. Education was not among the factors that significantly influenced the use of local knowledge in responding to the frequently occurring storms (df=25, p= 0.167, X^2= 31.682, N=365). Often local knowledge was transferred informally and thus the level of schooling did not affect how much local knowledge someone had.

Table 4.16: Shows application of indigenous knowledge in climate aspects

Response options	Use of ITK	Local understanding	Local weather experience	Food shortage due to poor seasons	Making of climate dependent decisions (cropping patterns)	Early maturing varieties
response	2.2%	2.2%	2.2%	2.2%	2.2%	2.2%
Strongly agree	76.7%	72.6%	69.0%	66.8%	69.3%	72.1%
Agree	16.7%	21.6%	24.7%	28.2%	24.1%	21.1%
Neutral	3.0%	2.2%	2.7%	2.5%	3.3%	0.8%
Disagree	0.8%	1.4%	1.4%	0.3%	1.1%	3.8%
Strongly disagree	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 4.17: Factors affecting the application of indigenous knowledge in climate variability adaptation

Pearson Chi-Square Tests

		Fast maturing varieties	Use of indigenous knowledge	Food shortage due to poor seasons	Local weather experience	Local underst	Use I
Sex	Chisquare	7.627	1.845	3.990	4.528	3.717	6.780
	df	4	4	4	4	4	5
	Sig.	.106	0.764	0.407	0.339	0.446	0.238
What age range are you in?	Chisquare	37.369	22.408	20.033	33.011	25.054	27.047
	df	12	12	12	12	12	15
	Sig.	0.000*	0.033*	0.066	0.001*	0.015*	0.028*
Major method of tilling used	Chisquare	6.327	12.491	5.350	11.897	10.442	12.678
	df	4	4	4	4	4	5
	Sig.	0.176	0.014*	0.253	0.018*	0.034*	0.027*
Major method of millet production	Chisquare	3.291	17.607	1.730	13.176	14.116	9.807
	df	4	4	4	4	4	5
	Sig.	0.510	0.001*	0.785	0.010*	0.007*	0.081
Education level	Chisquare	17.201	26.140	13.137	20.520		31.682
	df	20	20	20	20	15.484 20	25
	Sig.	0.640	0.161	0.871	0.426	0.748	0.167
Experience in faring millet	Chisquare	43.651	34.937	33.131	35.703		46.070
	df	16	16	16	16	34.670 16	20
	Sig.	0.000*	0.004*	0.007*	0.003*	0.004*	0.001*
Major source of labour	Chisquare	19.254	10.369	7.845	8.109	9.682	11.423
	df	8	8	8	8	8	10
	Sig.	0.014*	0.240	0.449	0.423	0.288	0.325

*. The Chi-square statistic is significant at the .05 level.

4.4 Effects of climate variability on millet

4.4.1 Effects of climatic factors on millet production

4.4.2 Relationship between millet production, temperature and rainfall

A linear regression was performed to establish the relationship between millet production (dependent variable) and the climatic factors (independent variables). Data for ten years (2011 to 2021) were considered for regressions analysis. Basing on the results from the linear regressions, an increase in temperature (T_{max}) by one degree Celsius contributes to a 10.029 Kgs reduction per acre while an increase in the minimum temperature by 1^0C would increase millet production per acre by 45.131 Kgs per acre. This is because the minimum temperature will be close to the temperature (23^0 C) required for proper growth of millet (Gierend *et al.*, 2014). The model depicts that the effect of increase in temperature has not been so significant in reduce the output for millet in the selected sub counties. This is because millet farmers have put in place a number of adaptation strategies. Too much rain also affects the yield of millet as shown in (Table 18).

Table 4.18: Relationship between millet production trend and climatic factors

	Unstandardized Coefficients			
	B	**Std. Error**	**t**	**Sig.**
(Constant)	106.406	1037.242	0.103	0.922
Rainfall	-1.772	1.310	-1.353	0.225
Tmax	-10.029	44.827	-0.224	0.830
Tmin	45.131	54.131	0.834	0.436

a. Dependent Variable: Millet yield

4.4.3 Premature drying of crops

The level of agreement of millet farmers were sought on the effects of climate variability on plant life. Results revealed that majority of millet farmers strongly agreed that climate variability result in premature drying of millet, while very few 2.0% strongly disagreed as seen in (Table 20) below. *It was revealed by one of the respondents that "the drought spells of 2016/17 growing season found when I had planted all my seeds in the dust waiting for the early rains. However, the rain that I was expecting in mid-February came in early May and thus lost all my seeds. Up to now I fear planting in the first season, which has reduced the amount of millet I used to sell to those who brew malwa". A 60 years old female millet farmer added during the in-depth interview that during the same season, she had also targeted the early rains of mid-February. However, millet germinated well but all of it dried prematurely due to excess and prolonged droughts".*

Table 4.19: Perception of millet farmers on premature drying of millet due to drought

		Drought makes the crops to dry prematurely				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
		Row %	Row %	Row %	Row %	Row %
	Opwateta	72.5	25.5	0.0 0.0	0.0 0.0	2.0
	Kibale	100.0	0.0	0.0	0.0	0.0
	Putiputi	97.7	2.3	0.0	0.0	0.0
Sub county	Apopong	60.9	39.1			0.0
	Kameke	91.1	8.9	0.0	0.0	0.0
	Pallisa	87.0	10.9	2.2	0.0	0.0
	Olok	20.9	65.1	9.3	4.7	0.0
	Agule	86.7	13.3	0.0	0.0	0.0

4.4.4 Perception on survival of millet amidst climate variability

In table 20, all the millet farmers interviewed in Kibale Sub County 100% strongly agreed that climate variability results in less survival chances to millet. For the millet farmers in Olok Sub County, 65.1% were indifferent between agree and disagree when asked about the survival chances of millet due to climate variability. Generally, the level of agreement was high in many sub counties.

Table 4.20: Shows the perception on survival of millet amidst climate variability

		There are less survival chances of plants				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
		Row %	Row %	Row %	Row %	Row %
Sub county	Opwateta	23.5	70.6	5.9	0.0	0.0
	Kibale	100.0	0.0	0.0	0.0	0.0
	Putiputi	90.9	9.1	0.0	0.0	0.0
	Apopong	10.9	82.6	6.5	0.0	0.0
	Kameke	71.1	28.9	0.0	0.0	0.0
	Pallisa	80.4	15.2	4.3	0.0	0.0
	Olok	4.7	25.6	65.1	4.7	0.0
	Agule	66.7	6.7	15.6	11.1	0.0

4.4.5 Failure to plant millet due to flooding

When asked about failure to plant millet due to flooding in table 22 below, the views varied across the sub counties. Results show that there were big proportions of millet farmers who could fail to plant due to flooding in Opwateta (88.2%), Agule (82.2%), Kibale (66.7%), Pallisa (67.4%) sub counties. The results further show that there were some sub counties where millet farmers planted with less disruption of floods; Putiputi (all disagreed).

Table 4.21: Failure to plant millet due to flooding

		At times I find it hard to plant due to water logging				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
		Row N %	Row N %	Row N %	Row N %	Row N %
	Opwateta	13.7	74.5	2.0	3.9	5.9
	Kibale	66.7	0.0	15.6	17.8	0.0
	Putiputi	0.0 4.3	0.0	0.0	75.0	25.0
	Apopong	8.9	6.5	4.3	71.7	13.0
Sub county	Kameke		4.4	4.4	46.7	35.6
	Pallisa	67.4	17.4	13.0	2.2	0.0
	Olok	4.7	23.3	32.6	34.9	4.7
	Agule	77.8	4.4	6.7	8.9	2.2

4.4.6 The soils are no-longer able to support plant life

All the millet farmers in Kibale Sub County revealed that the soils are no longer able to support millet production. Farmers who had their soils able to support millet production were in Agule and Olok. 20.9% disagreed in Olok sub-county, 26.7% in Agule sub-county. Majority of the farmers agreed that soils can no-longer support millet production (Table 22).

Table 4.22: The soils are no-longer able to support plant life

Sub county	The soils are no-longer able to support plant life				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	Row N %	Row N %	Row N %	Row N %	Row N %
Opwateta	15.7	64.7	9.8	9.8	0.0
Kibale	100.0	0.0	0.0	0.0	0.0
Putiputi	61.4	34.1	4.5	0.0	0.0
Apopong	8.7	58.7	26.1	6.5	0.0
Kameke	68.9	17.8	2.2	2.2	8.9
Pallisa	73.9	26.1	0.0	0.0	0.0
Olok	27.9	37.2	9.3	20.9	4.7
Agule	33.3	4.4	31.1	26.7	4.4

4.4.7 Farmers consciousness on millet production activities due to hardships in predicting the season

In many sub counties table 23, millet farmers revealed that they were conscious of their activities in the gardens since it was hard to predict the season. Most of the farmers consented that the seasons were not easily predictable. A few interviewed farmers 2.0% in Opwateta, 2.2% in Kibale and Kameke, 9.3% Olok disagreed.

Table 4.23: Consciousness on their activities in millet gardens due to hardships in predicting the season

		I am now conscious of my activities in the gardens since it is now hard to predict the season				
		Strongly agree	Agree	Neutral	Disagree	strongly disagree
		Row N %	Row N %	Row N %	Row N %	Row N %
Sub county	Opwateta	19.6	78.4	0.0	2.0	0.0
	Kibale	97.8	0.0	0.0	2.2	0.0
	Putiputi	97.7	2.3	0.0	0.0	0.0
	Apopong	73.9	26.1	0.0	0.0	0.0
	Kameke	64.4	24.4	8.9	2.2	0.0
	Pallisa	91.3	8.7	0.0	0.0	0.0
	Olok	0.0	55.8	34.9	9.3	0.0
	Agule	93.3	6.7	0.0	0.0	0.0

4.4.8 Perception of millet farmers on reduction of yield per acre

All the millet farmers revealed that at times they plant then suddenly the rains disappear causing a reduction in the yields and this puts them at a loss. The highest percentage of millet farmers in most of the sub counties agreed that the yield per acre had reduced with 100% of the interviewed farmers from Kibale strongly agreeing, 97.7% from Putiputi, 88.9% from Kameke, 82.6% from Pallisa, 70.6% from Opwateta, 55.8% from Olok, 41.3% from Apopong and 8.9% from Agule strongly agreed to a reduction in yields per acre. In Agule Sub County many farmers sampled 51.1%, disagreed when asked whether the yield per acre were declining (Table 24).

Table 4.24: Perception of millet farmers on reduction of yield per acre

		The yields per acre have greatly reduced				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
		Row N %	Row N %	Row N %	Row N %	Row N %
Sub county	Opwateta	70.6	27.5	0.0	2.0	0.0
	Kibale	100.0	0.0	0.0	0.0	0.0
	Putiputi	97.7	2.3	0.0	0.0	0.0
	Apopong	41.3	58.7	0.0	0.0	0.0
	Kameke	88.9	6.7	0.0	2.2	2.2
	Pallisa	82.6	17.4	0.0	0.0	0.0
	Olok	55.8	41.9	2.3	0.0	0.0
	Agule	8.9	6.7	6.7	51.1	26.7

4.4.9 Too much rainfall has also contributed to reduction in yields

Across all the sub counties as seen in table 25, millet farmers interviewed revealed that rainfall lately has become unpredictable and at times is destructive to crops during harvest. The results in table 25 further show that in some sub counties, there was reduction in millet yield due to too much rain. Most of the farmers 89.1% strongly agreed that too much rainfall contributed to a reduction in yields, 80% from Kibale, 77.8% from Agule, 35.3% from Opwateta, 6.7% from Kameke, 6.5 from Apopong and 4.7% from Olok all strongly agreed to the effects of too much rain on yields. Kameke sub-county had the highest percentage of farmers who strongly disagreed to the effect of too much rainfall on yields with 17.8%.

Table 4.25: Too much rainfall has also contributed to reduction in yields

		Too much rainfall has also contributed to reduction in yields				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
		Row N %	Row N %	Row N %	Row N %	Row N %
Sub county	Opwateta	35.3	54.9	0.0	5.9	3.9
	Kibale	80.0	0.0	11.1	8.9	0.0
	Putiputi	13.6	0.0	4.5	75.0	6.8
	Apopong	6.5	13.0	19.6	60.9	0.0
	Kameke	6.7	11.1	22.2	42.2	17.8
	Pallisa	89.1	10.9	0.0	0.0	0.0
	Olok	4.7	27.9	41.9	25.6	0.0
	Agule	77.8	4.4	13.3	4.4	0.0

Majority of the millet farmers (70.7%) in figure 10 strongly agreed that they had the change of planting time due to climate variability. This resulted in a shift in harvesting time further ahead

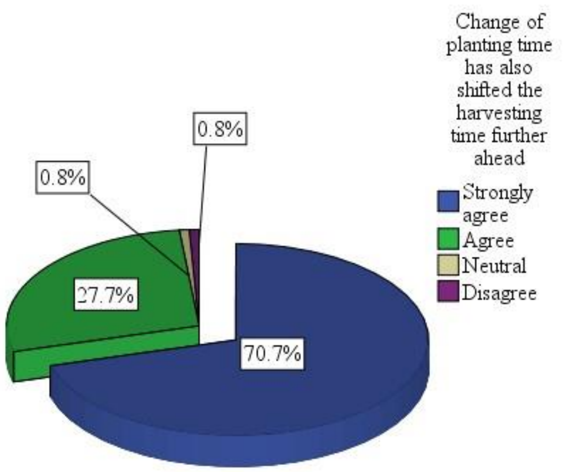


Figure 11: A pie chart showing change in planting time

All the farmers in Kibale Sub County strongly agreed that hailstorms caused total losses especially if it comes in the months they don't expect as seen in table 27 below. 84.8% from Pallisa strongly agreed to the effects, 84.4% from Agule, 73.3% from Kameke, 38.6% from Putiputi, 21.6% from Opwateta, 2.2% from Apopong strongly agreed to the effect of hailstorms. 60.9% of the interviewed farmers from Apopong disagreed to the effect of Hailstorms.

In the production of cereals like millet, hailstorms are a great threat as they thresh the mature seeds from the main plant. Majority (84.4%) of the millet farmers revealed that they registered high post–harvest losses due to high amounts of rain in the months formally known for harvesting. Only a small percentage of the millet farmers did not suffer from such losses. The rest of the farmers were not affected by post-harvest losses due to excess rain which are usually associated with hailstorms in the periods of harvesting.(Table 26)

Table 4.26: Showing the perception of farmers on Hail storms destroying millet

		Hail storms have caused total losses especially if it comes in the months we don't expect.				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
		Row N %	Row N %	Row N %	Row N %	Row N %
Sub county	Opwateta	21.6	64.7	9.8	3.9	0.0
	Kibale	100.0	0.0	0.0	0.0	0.0
	Putiputi	38.6	38.6	22.7	0.0	0.0
	Apopong	2.2	23.9	10.9	60.9	2.2
	Kameke	73.3	24.4	0.0	2.2	0.0
	Pallisa	84.8	15.2	0.0	0.0	0.0
	Olok	0.0	79.1	11.6	9.3	0.0
	Agule	84.4	13.3	2.2	0.0	0.0

4.4.10 Effects of climate variability on crop yield

The yield per acre has reduced in most of the sub counties sampled (Table 27). Results show that most of the farmers in from Kibale sub-county (100%) agreed that yields had greatly reduced due to weather changes, 97.7 from Putiputi sub-county, 88.9% from Kameke Sub County, 82.6% from Pallisa, 70.6% from Opwateta, 55.8% from Olok, 41.3% Apopong, and 8.7% from Agule strongly agreed their yield per acre had reduced. 51.1% of the interviewed farmers from Agule disagreed to the effects. Majority of the millet farmers across all the sampled sub counties noted that rainfall, temperatures, hailstorms and other weather changes were unpredictable and when it comes, it is very destructive, which has resulted in losses to farmers.

Table 4.27: Showing the decrease in yields per acre

	The yields per acre have greatly reduced				
Sub county	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Opwateta	70.6	27.5	0.0	2.0	0.0
Kibale	100.0	0.0	0.0	0.0	0.0
Putiputi	97.7	2.3	0.0	0.0	0.0
Apopong	41.3	58.7	0.0	0.0	0.0
Kameke	88.9	6.7	0.0	2.2	2.2
Pallisa	82.6	17.4	0.0	0.0	0.0
Olok	55.8	41.9	2.3	0.0	0.0
Agule	8.9	6.7	6.7	51.1	26.7

In most sub counties farmers strongly agreed that droughts strongly caused a reduction in yields with 100% from Kibale, 95.6 from Agule, 93.2% from Putiputi, 91.1% from Kameke, 80.4% from Pallisa, 69.6% from Apopong, 54.9% from Opwateta, and 14.0% from Olok. This indicates that droughts are one of the significant effects to most farmer gardens. (Table 28)

Table 4.28: Showing the effects of droughts

		Drought is responsible for yield reduction				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Sub county	Opwateta	54.9	45.1	0.0	0.0 0.0	0.0
	Kibale	100.0	0.0	0.0	0.0 2.2	0.0
	Putiputi	93.2	6.8	0.0	0.0	0.0
	Apopong	69.6	28.3	0.0		0.0
	Kameke	91.1	8.9	0.0		0.0
	Pallisa	80.4	19.6	0.0	0.0	0.0
	Olok	14.0	86.0	0.0	0.0	0.0
	Agule	95.6	4.4	0.0	0.0	0.0

In table 29 below, majority of the farmers from all the sampled Sub-Counties strongly agreed to the effects of too much rainfall on their yields with a reduction in the yields being one of the significant effects. 80.0% of the farmers from Kibale strongly agreed to the effects, 89.1% from Pallisa, 77.8% from Agule, 35.3% from Opwateta, 13.6% from Putiputi, 6.7% from Kameke, 6.5% from Apopong and 4.7 from Olok.

Table 4.29: Showing effects of too much rainfall on yields

		Too much rainfall has also contributed to reduction in yields				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Sub county	Opwateta	35.3	54.9	0.0	5.9	3.9
	Kibale	80.0	0.0	11.1	8.9	0.0
	Putiputi	13.6	0.0	4.5	75.0	6.8
	Apopong	6.5	13.0	19.6	60.9	0.0
	Kameke	6.7	11.1	22.2	42.2	17.8
	Pallisa	89.1	10.9	0.0	0.0	0.0
	Olok	4.7	27.9	41.9	25.6	0.0
	Agule	77.8	4.4	13.3	4.4	0.0

The biggest percentage of farmers indicated that climate variability has greatly resulted in change of planting time and harvesting in all sub counties (Table 30). Farmers revealed that the shift in planting time and harvesting period has affected the activities of the following season.

Table 4.30: Showing Change of planting dates' effect on the harvesting time

		Change of planting time has also shifted the harvesting time further ahead				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Sub county	Opwateta	39.2	60.8	0.0	0.0	0.0
	Kibale	100.0	0.0	0.0	0.0	0.0
	Putiputi	93.2	4.5	0.0	2.3	0.0
	Apopong	80.4	19.6	0.0	0.0	0.0
	Kameke	75.6	24.4	0.0	0.0	0.0
	Pallisa	87.0	10.9	0.0	2.2	0.0
	Olok	4.7	93.0	2.3	0.0	0.0
	Agule	86.7	6.7	4.4	2.2	0.0

In most of the sub counties, millet farmers revealed that the rampant occurrence of hailstorms in months in which they do not expect affected their yield greatly. Hailstorms broke down all the millet stems, or even could destroy all the millet especially if it came when the millet was ripe (Table 31). It was only in Apopong Sub County where the majority of the farmers 60.9% disagreed that hailstorms did not cause total loss.

Table 4.31: Showing the effects of hailstorms on yields

Hail storms have caused total losses especially if it comes in the months we don't expect.

		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Sub county	Opwateta	21.6	64.7	9.8	3.9	0.0
	Kibale	100.0	0.0	0.0	0.0	0.0
	Putiputi	38.6	38.6	22.7	0.0	0.0
	Apopong	2.2	23.9	10.9	60.9	2.2
	Kameke	73.3	24.4	0.0	2.2	0.0
	Pallisa	84.8	15.2	0.0	0.0	0.0
	Olok	0.0	79.1	11.6	9.3	0.0
	Agule	84.4	13.3	2.2	0.0	0.0

Processing of millet often determines the quality of millet supplied to the market and thus the prices offered per Kg. However, millet farmers in most of the sub counties sampled indicated that even after harvest rains destroyed their harvests during the periods of drying. This affected the quality of the harvest and this is as seen in table 32 below. The most affected farmers in all the eight sub-counties were from Kibale with 91.2% strongly agreeing to the effects of rainfall during the drying periods, 82.2% from Agule sub-county, 69.6% from Pallisa, 42.2%, 27.5% from Opwateta, 42.2% from Kameke, 20.5% from Putiputi, 7.0% from Olok while non from Apopong.

Table 4.32: Showing post-harvest losses

		There is high post-harvest losses due to high rains in the months of harvesting				
		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	Opwateta	27.5 91.1	60.8	7.8	3.9	0.0
	Kibale	20.5	2.2	2.2	4.4	0.0
	Putiputi	0.0	13.6	45.5 19.6	20.5 60.9	0.0
Sub	Apopong	42.2	17.4	8.9	13.3	2.2
county	Kameke		33.3			2.2
	Pallisa	69.6	23.9	6.5	0.0	0.0
	Olok	7.0	51.2	23.3	18.6	0.0
	Agule	82.2	17.8	0.0	0.0	0.0

In table 33 below, Pearson chi-square revealed that yield has been significantly affected by the climatic factors identified by millet farmers e.g., drought which makes the crops to dry prematurely, water logging, among other factors. During the KII it was revealed that*, "erratic rains have affected the yield per acre in all the sub counties in the district. Farmers may prepare their fields well, plant and weed for the first time (first weeding) but rain doesn't come as expected. This has often resulted in losses, and such losses scare the youth who would have joined the business". "Water logging only occurs on low lying millet fields. However, when there is a lot of rains, there is flooding of such fields and such severity affects millet growth and yield. Too much water makes the leaves to turn yellow while prolonged droughts have ended up drying millet prematurely", he added*

Table 4.33: Showing some of the climatic factors affecting millet yield in the study area

Pearson Chi-Square Tests

Factors affecting yield per acre		Sadden disappearance of rain	Unpredictable season	aterlogging Instances	Loss of soil fertility	Difficulty to plant due to water logging	Less plant survival chances	Crops dry prematurely
The yields per acre have greatly reduced	Chi-square	73.879	40.339	38.711	93.215	60.313	135.118	80.475
	df	12	12	16	16	16	12	16
	Sig.	0.000*	0.000*	0.001*	0.000*	0.000*	0.000*	0.000*

*. The Chi-square statistic is significant at the .05 level.

4.4.11 Incidences of pests

Farmers revealed that climate induced pests have become rampant across the entire sub counties sampled (table 35). It was reported that pests affected all the varieties; both native and the improved varieties. Most common pests included but not limited to grasshoppers, locusts, butterflies, shoot fly, stem borer among other.

Table 4.34: Showing pests and disease incidence

Sub county	Pest and disease incidence has become prevalent				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	Row N %	Row N %	Row N %	Row N %	Row N %
Opwateta	31.4	68.6	0.0	0.0	0.0
Kibale	100.0	0.0	0.0	0.0	0.0
Putiputi	100.0	0.0	0.0	0.0	0.0
Apopong	82.6	17.4	0.0	0.0	0.0
Kameke	71.1	22.2	0.0	6.7	0.0
Pallisa	69.6	30.4	0.0	0.0	0.0
Olok	46.5	51.2	2.3	0.0	0.0
Agule	73.3	13.3	11.1	2.2	0.0

In table 34 above, millet farmers in all sub counties indicated that pests were common during the periods of high temperatures. Majority of the farmers from all the sub-counties, 100% from Kibale and Putiputi strongly agreed that pests and disease prevalence had increased, 82.6% from Apopong, 73.3% from Agule, 71.1% from Kameke, 69.6% from Pallisa, 46.5% from Olok, and 31.4% all strongly agreed to an increase in pests and diseases. None of the interviewed farmers from all the sampled sub-counties strongly disagreed to an increase in pests and disease occurrence.

Climate induced pests have significantly affected the productivity of native varieties of millet yet they are the most commonly grown in all the sub counties sampled. (Table 36) The majority of the farmers without financial resources have ended up leaving their gardens go fate. A 45 years old female from Kameke Sub County during the in-depth interview revealed that*, the high yield of all the crops grown millet inclusive can only be obtained per acre if one sprays the crops. "The leaves of my millet were eaten by pests and the harvest was not good. I was expecting to get about 300Kgs of millet from one Musiri (acre) but I ended up getting 3 basins (about 50Kgs). This was not enough for the purposes intended (selling and home consumption)", she added.*

Table 4.35: Showing the effects of climate induced pests on the productivity of native varieties of millet

Pearson Chi-Square Tests

		Lack of seeds for planting next season	Abandonment of gardens	Pest and pest and disease control	Costs on disease incidence
Our native varieties are not yielding well amidst the variability in climate	Chisquare	50.513	112.223	48.859	92.551
	df	16	16	12	16
	Sig.	0.000*	0.000*	0.000*	0.000*

The Chi-square statistic is significant at the .05 level.

4.5 Adaptation and factors affecting adaptation

4.5.1 Adaptation

Adaptation is key for the sustainability of production of millet. Results show that millet farmers are already adapting to climate variability since millet is an important crop as seen in table 35 below. Millet farmers have tried as much as they can to adjust to the planting dates, hire labour to help manage weeds, intercropping to minimize total loss due to dependence on one crop, as well as sowing millet during dry periods so that it germinates on first rains. Since millet does not ripen at once, some millet farmers have resorted to picking every ripe finger to avoid the unforeseen uncertainties.

During the survey, one millet farmer in Opwateta Sub County said "*I bought seeds at Ugx 1500 per Kg and sowed it all but since there was no rain, not even drizzles, all of it did not germinate. I was forced to borrow from my fellow farmers, thus starting a season with already part of the harvest meant to clear the debt despite the uncertainty in yield".*

Table 4.36: Adaptation strategies used by millet farmers

	Fertilizer Application	Irrigation	Early planting	Intercropping	Early harvest	Labour hire	Season based planting	Intercropping millet	Seed preservation	Introduction of drought resistant millet
Strongly agree	12.3	11.2	30.1	46.6	26.3	43.3	63.3	20.3	37.8	27.7
Agree	4.9	0.0	30.4	37.0	15.1	24.4	31.0	12.1	36.4	13.7
Neutral	2.7	0.3	10.1	3.8	6.0	6.8	0.8	12.1	5.5	3.8
Disagree	41.6	40.0	26.3	7.4	46.3	23.0	4.4	36.4	17.3	31.5
Strongly disagree	38.4	48.5	3.0	5.2	6.3	2.5	0.5	19.2	3.0	23.3

Other adaptation strategies used by millet farmers include the use of selective herbicides to control the weeds, reducing the time spent in the millet gardens so that it is used to do other activities (diversification) in livelihood sources (Table 38).

Table 4.37: Showing other adaptation strategies used by millet farmers

	Drought Resistant varieties	Native millet resistant varieties to heavy rainfall	Native millet varieties and soils fertility	Diversification n in livelihood sources).	Hard to predict the season	Government intervention	Use of selective
Strongly agree	30.7	29.9	28.8	49.9	70.1	24.1	14.2
Agree	18.1	28.8	17.3	28.8	19.7	12.3	3.8
Neutral	33.7	11.0	5.2	9.3	7.7	3.8	3.0
Disagree	15.1	28.8	44.1	11.8	1.6	29.9	44.9
Strongly disagree	2.5	1.6	4.7	0.3	0.8	29.9	34.1

4.5.2 Factors affecting adaptation

The use of an adaptation measure depended on a number of factors as shown in table 39. Education level significantly (*p=0.010*) determined whether a farmer sow millet during the dry period so that germination takes place when the first rains come. People with basic education sow their seeds during the dry periods to target the earliest rains. Sowing of millet during the dry period was not significantly dependent on farming experience (*p=0.152*) and the acreage cultivated (*0.493*).

However, the method of tilling land significantly influenced the decision to adapt by sowing during the dry periods *(p=0.000),* adjusting to planting dates *(p=0.000).* The average acreage cultivated significantly *(p=0.038)* resulted in farmers adapting by harvesting every ripe millet finger to avoid total loss due to hailstorms. Millet farmers who cultivated 2 acres or less easily picked the ripe millet fingers as opposed to those that cultivated millet fields greater than 2 acres (Table 37 and Tables 38).

Table 4.38: Showing factors affecting the use of the various adaptation strategies

Pearson Chi-Square Tests

		Fertilizer use	igation	Early Sowing	Intercrop	omplete harvest	Labour hire	lanting date shift
Sex	Chisquare	8.743	8.649	12.250	8.836	5.119	11.178	12.388
	df	4	3	4	4	4	4	4
	Sig.	.068	.034*	.016*	.065	.275	.025*	.015*
Age	Chisquare	17.399	7.908	24.891	9.969	17.570	15.894	27.556
	df	12	9	12	12	12	12	12
	Sig.	.135	.543	.015*	.619	.129	.196	.006*
Education level	Chisquare	24.563	14.245	37.484	17.700	60.070	29.499	42.246
	df	20	15	20	20	20	20	20
	Sig.	.219	.507	.010*	.607	.000*	.078	.003*
Methods of millet production	Chisquare	9.455	6.960	20.593	76.481	13.199	10.680	15.666
	df	4	3	4	4	4	4	4
	Sig.	.051	.073	.000*	.000*	.010*	.030*	.004*
Length practicing crop cultivation	Chisquare	11.619	15.021	21.728	20.787	15.523	44.734	18.115
	df	16	12	16	16	16	16	16
	Sig.	.770	.240	.152	.187	.487	.000*	.317
Millet varieties	Chisquare	3.389	.812	.968	6.736	10.693	7.968	1.201
	df	4	3	4	4	4	4	4
	Sig.	.495	.847	.915	.151	.030*	.093	.878

The Chi-square statistic is significant at the .05 level.

Showing factors influencing the use of other adaptation strategies

Pearson Chi-Square Tests

Adaptation strategy		Which millet varieties do you grow?	Experience in cultivating millet	Method of millet production	Highest Education level	Sex	What age range are you in?
Intercropping	Chisquare	3.696	26.117	20.261	30.722	7.524	23.341
	df	4	16	4	20	4	12
	Sig.	.449	.052	.000*	.059	.111	.025*
Saving seed	Chi-square	6.308	19.576	6.104	28.567	5.994	27.009
	df	4	16	4	20	4	12
	Sig.	.177	.240	.192	.097	.200	.008*
Improved tillage.	Chisquare	3.794	37.724	10.818	47.535	6.113	23.985
	df	4	16	4	20	4	12
	Sig.	.435	.002*	.029*	.000*	.191	.020*
Drought resistant millet varieties introduced	Chisquare	43.791	15.292	5.215	40.787	1.518	18.678
	df	4	16	4	20	4	12
	Sig.	.000*	.503	.266	.004*	.823	.097
Varieties withstanding long drought spells	Chisquare	20.230	23.962	19.348	47.245	2.751	15.754
	df	4	16	4	20	4	12
	Sig.	.000*	.090	.001*	.001*	.600	.203
Native millet varieties to rain	Chisquare	10.637	20.173	20.577	54.740	5.379	15.629
	df	4	16	4	20	4	12
	Sig.	.031*	.213	.000*	.000*	.251	.209

Native millet varieties to low fertility	Chisquare	13.521	16.169	36.026	73.278	2.278	16.542
	df	4	16	4	20	4	12
	Sig.	.009*	.441	.000*	.000*	.685	.168
Diversification in livelihood sources	Chisquare	4.514	23.482	1.227	39.357	7.230	8.690
	df	4	16	4	20	4	12
	Sig.	.341	.101	.874	.006*	.124	.729
Difficulty in predicting seasons	Chisquare	5.034	25.240	5.716	11.864	6.449	23.293
	df	4	16	4	20	4	12
	Sig.	.284	.066	.221	.921	.168	.025*
Research and development	Chisquare	40.785	17.666	22.621	34.641	7.444	24.601
	df	4	16	4	20	4	12
	Sig.	.000*	.344	.000*	.022*	.114	.017*
Herbicides Usage	Chisquare	11.954	46.126	15.743	26.754	8.864	18.043
	df	4	16	4	20	4	12
	Sig.	.018*	.000*	.003*	.142	.065	.114

*. The Chi-square statistic is significant at the .05 level.

In table 39 below, ordinal linear logistic regression was performed to establish the factors that affect the use of fertilizers as an adaptation strategy. The chance of using fertilizers in the millet fields was modeled with level of experience, with the above 6 years of experience being the reference category. However, findings show that farmers with 1-2 years in farming millet had high chances (3.8948) of applying fertilizers to enhance the ability of the soil to support plant growth. This was followed by farmers with 3-4 years' experience of farming millet (odd =2.45).

Farmers with less than one year of farming millet had the lowest chance of applying fertilizers on their millet gardens.

Table 4.39: Showing ordinal logistic regression of sociodemographic characteristics of millet farmers and fertilizer application as an adaptation strategy

Parameter Estimates					
Fertilizer application to boost yields		Estimate	Sig.	Exp.	
Location	AVERAGE_ACREAGE_CULTIVATED	0.223	0.012	1.249624	
	Highest Education level =Primary	-0.582	0.029	0.558691	
	Highest Education level =Secondary	-0.436	0.192	0.646488	
	Highest Education level=Certificate	-0.832	0.089	0.435303	
	Highest Education level =Diploma	-0.346	0.545	0.707716	
	Highest Education level=Degree	-0.737	0.318	0.478643	
	Highest Education level =No formal education	0[a]			
	Experience of farming millet=Less than a year	-0.103	0.956	0.902544	
	Experience of farming millet=1-2 years	1.36	0.005	3.894794	
	Experience of farming millet=3-4 years	0.896	0.006	2.449486	
	Experience of farming millet=5-6 years	0.652	0.033	1.919367	
	Experience of farming millet= Above six years	0[a]			
	Major method of tilling used=Hand hoe	-0.663	0.002	0.51521	
	Major method of tilling used =Oxen	0[a]			
	Major method of millet production=Standalone crop	0.247	0.31	1.280734	
	Major method of millet production =Intercropping	0[a]			
Link function: Logit.					
a. This parameter is set to zero because it is redundant.					

4.6 Discussion of Results

4.6.1 Discussion of results on trends of rainfall, temperature and millet production in Pallisa district

The amount of rainfall received has been fluctuating and unpredictable since 1990. In the period (1991 to 2021), low rainfall was received 1993, 2000, and 2016, with 2000 experiencing the least rainfall amount. There was a lot of rain in 1996. However, there has been months with a significant increase in rainfall received. Maximum temperature was experienced in 2000 and 2016. In these years, there were drought spells. Sen's slope and Mann Kendall analysis (pvalue= 0.009771) showed that the maximum temperature has been significantly declining over the period 1990-2020. The results of Mann Kendal are similar to those reported by Chombo et al. (2020) who found that total rainfall trend in Uganda was positive and significant at the 0.05 level in August and September but it was negative though non-significant in April, May and June. The results also concur with the findings of Alupoti et al. (2024) Overall Uganda has experienced intense and extreme daily rainfall events in the past years during the SON season.

According to African Organic Agriculture Training Manual (2013), millet needs little water after germination, a small amount as the leaves appears, and light rain during the growing period. Moisture stress during flowering through to grain formation reduces yields, as does heavy rainfall. According to Orr et al. (2023), the long rains in Pallisa started in February and finish in July. There used to be a break of three-four weeks in the rains between the end of May and start of June. The short rains start in August and finish in November. Although shorter, these rains were continuous and more reliable (Orr et al., 2023).

However, the study findings are different from those reported by Orr and others, as rainfall in the sampled sub counties of Pallisa district was reported to be very erratic, and often unpredictable. The area cultivated under millet decreased drastically 2008/09 to 2017 and 2019 to 2020. Gierend et al. (2014) also report that area, production and sector value declined steadily between 1992 and 2012 and experienced a sharp drop in 2008 due to political unrest in the Northern region. Millet is grown twice a year, though most preferred is the first season of the year. There has been a lot of uncertainty with the start of the seasons as they were not predictable.

The findings of the study differ from those of Chemonics International (2010) showing that the first planting season begins in March and ends in June, while the second season starts in

September and ends in December. Results also differ from those reported by Gierend et al. (2014) indicating that the first rainy season is generally from March to May, with the second from August to November. Yield per acre has been reducing in Pallisa district for the period 2011-2022. Sen's slope and Mann Kendall analysis indicated a significantly (*p=0.001269*) decreasing trend in the yield per acre of millet for the period 2011-2022.

Compared to the yield of other important crops like maize, rice, and sorghum, the yield for millet was the lowest since 2016-2020. The yield for the second season has been too low compared to that of the first season which could be attributed to the increase in rainfall in the second season. According to UBOS (2020), millet production peaked in 2008/09 (UCA 2008/9). Its decline in the following years was particularly large during the agricultural year 2019 (49 percent reduction compared with 2018). The lower production seems to be caused by a slightly lower yield (0.4 Mt/Ha in 2019 against 0.6 Mt/Ha in 2018) and by a 19 percent reduction in area planted. The production trend for millet indicates a decline in millet production of about 23 percent between UNHS 1999/2000 (UBOS, 2020).

Since the 1990 to 2022, Pallisa has received maximum rainfall ranging from 158.7 to 341.5 mm/month mm. However, this is far below the required amount of rainfall for proper millet growth, as Gierend et al. (2014) notes for proper growth; finger millet requires rainfall ranging from 750 to 1200 mm during the growing season. The increase in rainfall either cause a delay, failure to plant or even rotting of millet/failure to grow well due to excess water. For farmers near wetlands and loamy clay soils, too much rainfall results in water logging with its effects of nutrient leaching, accumulation of pests that prefer low temperatures.

4.6.2 Discussion of results on the effects climate variability on millet production

Majority of millet farmers interviewed had knowledge on climate variability. Farmers with an experience of 6 years or more were more knowledgeable about climate variability as opposed to the new entrants in millet farming. Most of the farmers agreed that the increase in the prevalence of droughts has resulted in premature drying of millet and thus low yield and total losses. Bagagnan et al. (2019) reveal similar finding as their study found out that with regards to vulnerability and severity, nearly 95% of the respondents considered the dryness as the main threat to their farming activities and perceived its consequences as the most severe.

Irregular rainfall distributions may expose the crop to a range of mild to severe intra-seasonal water stresses, which may subsequently affect the yield especially if they occur during the critical stages of flowering and grain filling (Bouba, 2014). Sometimes, the increased amounts of rainfall made farmers to fail to plant millet due to flooding. With majority of the millet farmers citing that the soils can no longer support millet growth without any application of fertilizers, the largest percentage of farmers in all the sub counties sampled were conscious of their activities in the gardens since it is now hard to predict the season.

However, Bouba (2014) notes that the cost of fertilizer prohibits making profit on millet. The costs involved in the purchase and application of fertilizers surpass the cost of producing finger millet in any system in good and poor soil types (Ssebinojjo, 2021). The findings further reveal that climate variability has shifted the harvesting period as a result of change in planting time. In the past, farmers used to plant millet in February and harvest in July (Orr *et al.*, 2003). However, this has changed through time as it depends on the time the first rain comes and the speed with which the millet farmer prepares the field. The shift in harvesting time has resulted in failure to time the following season, post-harvest losses especially if millet is harvested in a rainy period and often vulnerability to being hit by hailstorms. According to the survey by Bouba (2014) late planting resulted in significant yield decreases for maize, sorghum and cotton, but not for millet. However, a short duration variety of millet was better adapted for late planting.

Hailstorms thresh all the millet whether ripe or not, and thus, a loss for food and seed for the following season. The results conform to those reported by The Republic of Uganda (2016) noting that the occurrence and severity of hailstorms are a frequent phenomenon in Pallisa District. The hailstones fall during heavy downpour and these take a period of about 10-30 minutes. The frequency and distribution of hailstorms is primarily caused by changes in the onset of rainy seasons especially after prolonged dry spells, erratic rains and deforestation. Rain was revealed to be unpredictable and sometimes destructive.

Most of the farmers in all the sub counties sampled agreed that there has been an increase in climate induced pests like the army worm and locusts which affect the shoot system and thus the yield. Results concur with the findings reported by The Republic of Uganda (2016) indicating that the occurrence, severity, frequency and distribution of crop pests/animal parasites and diseases are high as compared to the last 10 years in the district. The increased incidences of pests have made farmers to incur costs of pest control through spraying, or leave their gardens to fate.

Weeding of millet requires a lot of labour, yet weeding has to be done at least or 3 times. This conforms with the findings reported by Owere *et al.* (2014) who note that in Kaberamaido for example, during the first rains finger millet was the most important crop and was their main food crop, however, in the second rains maize seemed to be the major cereal probably because of the higher labour requirements associated with finger millet production. However, some farmers noted that the quality of agricultural input dealers should be checked as some could easily sell pesticides and other agricultural inputs without adequate guidance to the farmers.

4.6.3 Discussion of results on methods of adaptation measures

Climate change adaptation and mitigations are essential mechanisms to save the life of the vulnerable communities particularly Africa continent (Gemeda and Sima, 2015). Adaptation is already happening in the sampled sub counties through the various strategies. Owere *et al.* (2014) also reports that millet farmers have developed some coping mechanisms to counter the constraints. Millet farmers have tried to intercrop millet with maize to avoid total losses due to over relying on one crop. Cassava was not preferred as its shoot convers millet and thus the yield reduces. Intercropping of millet with a drought-tolerant legume in general increases productivity of both crops compared to cultivation of a sole crop (African Organic Agriculture Training Manual, 2013).

Intercropping could have serious harm especially if the crops intercropped share the same disease or pests. Results concur with those reported by Atube *et al.* (2022), who reported that the most common climate change adaptation strategies used by smallholders related to varietal adjustments included planting different crop varieties each time. Similar findings were reported by Tenywa, *et al.* (1999) who reveal that inter-cropping and crop rotation are common practices in finger millet production.

In some cases, farmers sow millet during the dry periods and the early rains finds the seed in the soil. Millet used to be sown in February but most of the farmers have adjusted their planting dates since the rains which are meant to come in mid-February are no longer received with certainty. Similar findings were report by Atube *et al.* (2021) who note that the farmers in northern Uganda adapt to climate change by changing the time of planting. In cases of too much rain, farmers are forced to hire additional labour to help in weeding.

Farmers indicated that during the rainy periods, the weeds grow faster and thus compete with millet for nutrients and space. A survey by Aguttu *et al*. (2016) in both Pallisa and Buyende Districts, reveal weeds increase the labour costs and were considered a major limiting factor to finger millet production in the two districts. The most constraining weed species in Pallisa District was Striga hormonthica, which drastically curtailed the crop yields (Aguttu et al., 2016). Failure to weed timely could result in yellowing of millet leaves, and sometimes stunted growth.

In Kibale Sub County, some farmers have resorted to the use of herbicides in weed control and management. This helped such farmers in the control of weeds that were hard to uproot. Many farmers in almost all the sub counties have lessened their time in millet production due to unpredictable weather. Diversification has helped to have some income from other activities which they have used to pay school fees and sustain their families in period of poor millet harvest.

Adaptation is key for the sustainability of production of millet. Results show that millet farmers are already adapting to climate variability since millet is an important crop as seen in table 37 below. Millet farmers have tried as much as they can to adjust to the planting dates, hire labour to help manage weeds, intercropping to minimize total loss due to dependence on one crop, as well as sowing millet during dry periods so that it germinates on first rains. Since millet does not ripen at once, some millet farmers have resorted to picking every ripe finger to avoid the unforeseen uncertainties.

During the survey, one millet farmer in Opwateta Sub County said "*I bought seeds at Ugx 1500 per Kg and sowed it all but since there was no rain, not even drizzles, all of it did not germinate. I was forced to borrow from my fellow farmers, thus starting a season with already part of the harvest meant to clear the debt despite the uncertainty in yield".*

CHAPTER FIVE: CONCLUSIONS ANS RECOMMENDATIONS

5.1 Conclusion

This study has demonstrated that climate variability is significantly influencing millet production in Pallisa District. In line with Objective (i), long-term meteorological data show erratic rainfall patterns and increasing temperature trends, with sub-counties such as Kibale, Pallisa, Kameke, Agule, and Olok experiencing both drought and unseasonal hailstorms.

In response to Objective (ii), the regression analysis (2010–2021) revealed that increases in rainfall and temperature are correlated with reductions in millet yield, although these effects were statistically insignificant due to farmers' adaptive behaviors.

As outlined in Objective (iii), farmers have proactively adapted to climate risks by shifting planting calendars, selectively harvesting millet fingers to mitigate hailstorm damage, intercropping, and hiring labor for weed control. These coping strategies indicate a level of resilience but remain largely informal and unsupported by policy frameworks.

Given Uganda's commitment to the Sustainable Development Goals (SDGs) and the National Climate Change Policy (2015), it is evident that millet farmers in Pallisa require targeted institutional support to enhance their adaptive capacity and sustain millet production in the face of climate variability.

5.2 Recommendations

Objective i – Trends in Rainfall, Temperature, and Millet Production

Policy Recommendation: The Uganda National Meteorological Authority (UNMA) and MAAIF should collaborate to provide localized, real-time weather information to farmers through radio, SMS, and community information centers. This supports evidence-based decision-making and enhances early warning systems.

Objective ii – Effects of Climatic Factors on Millet Production

Policy Recommendation: MAAIF, in collaboration with research institutions such as NARO, should invest in research and breeding of climate-resilient millet varieties, capable of withstanding drought and temperature extremes. These should be disseminated through national programs like Operation Wealth Creation and Parish Development Model.

Programmatic Recommendation: Integrate climate-smart agricultural technologies (e.g., precision planting, water harvesting, improved storage) into district-level extension services, to improve productivity despite climatic constraints.

Objective iii – Adaptation Measures by Farmers

Policy Recommendation: Develop a National Millet Resilience Strategy under MAAIF to mainstream farmer-led adaptation practices such as adjusted planting calendars and intercropping into district development plans.

Community-Level Recommendation: Establish demonstration plots and farmer field schools in each sub-county to promote practical learning on adaptive millet production techniques.

Cross-Cutting

Promote livelihood diversification (e.g., agro-processing, poultry, apiary) through Uganda's Rural Development Strategy to buffer households from millet yield shocks.

Enhance agricultural extension services by increasing recruitment, training, and digital tools for extension workers to deliver timely advice on climate-smart millet farming.

These recommendations align with the Uganda Climate Change Policy, NDPIII (2020/21–2024/25), and SDGs 2 (Zero Hunger) and 13 (Climate Action), and aim to ensure millet farmers in Pallisa District are climate-resilient, food-secure, and economically stable.

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APPENDICES

APPENDIX I: INTERVIEWER ADMINISTERED QUESTIONNAIRE FOR HOUSEHOLDS

Dear participant,

My name is **Oriada Mathias Oseku**, a post graduate student of Busitema University, pursuing a Masters' Degree in Climate Change and Disaster Management. I am currently undertaking a research as one of the pre-conditions. The topic of the research is ***"Impact of Climate Variability on Millet Production in Pallisa District, Eastern Uganda".*** The study is purely for academic purposes and all your responses will be treated with at most confidentiality.

Kindly, complete the questionnaire and return it to the researcher.

SECTION A: BIO-DATA OF RESPONDENTS *(tick the right option or fill the right answer in the spaces provided)*

A1. What age range are you in? (*Please tick under only one of them).*

(a) 21-30 yrs ☐

(b) 31-40 yrs ☐

(c) 41-50 yrs ☐

(d) 51 yrs and above ☐

A2. Sex

(a) Male ☐

(b) Female ☐

A3. Highest Education level (Tick the most appropriate)

(a) Primary ☐

(b) Secondary ☐

(c) Certificate ☐

(d) Diploma ☐

(e) Degree ☐

(f) Masters ☐

A4. How long have you been practicing crop cultivation? (Tick)

(a) Less than a year ☐

(b) 1- 2 years ☐

(c) 3-4 years ☐

(d) 5-6 years ☐

(e) Above six years ☐

SECTION B: The influence of exposure to Extreme temperatures and Precipitation on Millet Production in Pallisa District

Please use the key below to answer the following questions by ticking: (5) for strongly agree (4) for agree, (3) for not sure (2) for disagree (1) for strongly disagree

Likert scales	**1**	**2**	**3**	**4**	**5**
Extreme Temperature					
1. The heat levels have gone up and this has affected my concentration in the garden					
2. Due to frequent drought, millet crops in the gardens fail by drying prematurely					
3. High temperatures have greatly affected the yield levels					
4. Higher temperatures during the flowering stage of lowers the yields by lowering the number, size and quality of grain					
5. Increase in temperature levels has affected the land set up leading to crop failure					
Precipitation					
6. Heavy rains limit my concentration in the gardens					
7. Heavy rains cause floods which destroy millet in the gardens					
8. Too much water makes the millet in the gardens to turn yellowish					

9. Heavy rains have also affected the yields since does not do well when the soils become waterlogged					
10. Too much water affects the roots of the plants directly altering the yield level.					
11. Heavy rains with hailstorms at harvesting time easily sweeps away the grains thereby lowering the quantity and quality of the grain.					

SECTION C: The influence of Seasonal Variations on Millet Production in Pallisa District

Please use the key below to answer the following questions by ticking: (5) for strongly agree (4) for agree, (3) for not sure (2) for disagree (1) for strongly disagree

Likert scales	**1**	**2**	**3**	**4**	**5**
Seasonal Variations					
1. Rainfall lately has become unpredictable and at times is destructive to crops pending harvest					
2. Rain these days start late forcing us to rethink out planting time					
3. Change of planting time has also shifted the harvesting time further ahead					
4. I am now conscious of the my activities in the gardens since it is now hard to predict the season					
5. Due to unpredictable weather, I am forced to lessen on my activities in the garden					
6. I am now not sure of the yield level since it is now hard to get a bumper harvest					
7. At times we plant then suddenly the rains disappear which puts us at a loss					
8. We are now at the mercy of nature since it is hard to predict the season					

SECTION D: Farmers' perception about extreme weather changes and their effect on Millet Production in Pallisa District

Please use the key below to answer the following questions by ticking: (5) for strongly agree (4) for agree, (3) for not sure (2) for disagree (1) for strongly disagree

Likert scales	**1**	**2**	**3**	**4**	**5**
Farmers' Perceptions					
1. Rains that used to come regularly during planting season have now become less frequent					
2. I use my local knowledge to respond to the weather changes such as violent storms which has become frequent					
3. Heavy rains become common leading to waterlogging problems thereby causing crop failure					
4. At times use my own understanding of the weather patterns to carry out activities in my garden.					
5. I read the weather basing on my own experience which I have gained over the years					
6. Poor seasons bringing in memories of food shortage arising for crop failure					
7. I always make decisions on cropping patterns based on my understanding of local climatic conditions					
8. I prefer millet varieties with a short lifespan and are drought resistant					

SECTION E: Millet Production in Pallisa District

Please use the key below to answer the following questions by ticking: (5) for strongly disagree (4) for disagree, (3) for not sure (2) for strongly agree (1) for agree

		Opinion				
	Plant life	**5**	**4**	**3**	**2**	**1**
1.	Drought makes the crops to dry prematurely					
2.	There are less survival chances of plants					
3.	At times I find it hard to plant due to water logging					
4	The soils are no-longer able to support plant life					
	Yields					
5	The yields have greatly reduced					
6	Drought is responsible for their reduction					
7	To much rainfall has also contributed to reduction in yields					
	Extent of Pest and Disease Activity					
8	Pest and disease incidence has become prevalent					
9	Pest have been caused by extreme temperature levels					
10	Now we incur costs on pest and disease control in millet also					
11	I have been forced to leave my millet garden to fate because I cannot afford chemicals for spraying					
	Locally adopted millet varieties					
12	Drought resistant millet varieties have been introduced to us					
13	The varieties can withstand long drought spells					
14	They can also with stand heavy rainfalls when still young					
15	These varieties have responded well to the soils and yields level					

END Thank you for your cooperation

APPENDIX II: INTERVIEW GUIDE FOR PRODUCTION STAFF, CBS STAFF AND FARMER LEADERS

Dear participant,

My name is **Oriada Mathias Oseku**, a post graduate student of Busitema University, pursuing a Masters' Degree in Climate Change and Disaster Management. I am currently undertaking a research as one of the pre-conditions. The topic of the research is ***"Impact of Climate Variability on Millet Production in Pallisa District, Eastern Uganda".*** The study is purely for academic purposes and all your responses will be treated with at most confidentiality.

Questions

1) Lately weather patterns have kept changing, in your opinion what have you noticed?
2) What changes have you noticed in temperature levels, rainfalls patterns and seasonal patterns as well?
3) How have these changes affected millet production?
4) What happens to the millet crops when the rains are too much?
5) What happens to the millet crops when the temperature levels are high?
6) What has been the effect of weather changes on planting time?
7) What has been the effect of extreme temperatures on plant life, yields level and the incidence of pests and diseases
8) How are farmers coping with these changes in terms of land preparation and planting time?
9) What new millet varieties have been introduced to farmers as part of the coping strategy?
10) What lessons have farmers picked that have enabled them to adjust positively and improve millet yields level?
11) In your own opinion, what do you think needs to be done to help farmers improved on millets yields amidst the climatic variability?
12) What have the authorities done to mitigate the effect of climate change on households and leverage the problem by helping farmers to cope and improve on yields level as food security measure?

END Thank you for your cooperation

APPENDIX III: OBSERVATION CHECKLIST

DATE………………………………………………………………….

Land size…………………………………………………………..

Areas of observation…………………………………………………….

Crop management

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Weather changes

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Land preparation

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Yields level

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APPENDIX IV: DOCUMENTARY REVIEW GUIDE

Documents to be reviewed

1. Farm management guide
2. Daily Weather forecast reports
3. Animal health guide
4. Guidelines on climate smart agriculture
5. Guidelines of soil replenishment
6. Post-harvest handling guidelines
7. Farmer forum minutes
8. Monthly production reports
9. Annual production reports

APPENDIX III: RESEARCH WORKSHEET

Purpose of the study________________________________ Date: ____________________________ **Preliminary stage**

1. Sub-County…………………………………………………………………………
2. Season ……………………………………………………………………………...
3. Village………………………… ……………………………………………...

Timelines	1st wk	2nd wk	3rd wk	4th wk	5th wk	6th wk	7th wk.	8th wk	9th wk	10th wk	11th wk	12th wk	13th wk	14th wk	15th wk.	16th wk
Temperature level																
Drought																
Precipitation																
Rainfall																
Wind																
Hail storms																
Floods																

Comment………

APPENDIX VI: MAP OF UGANDA SHOWING THE LOCATION OF PALLISA DISTRICT

PALLISA DISTRICT

APPENDIX VII: MAP OF PALLISA DISTRICT SHOWING THE SUB COUNTIES