EFFECT OF CLIMATE VARIABILITY AND CHANGE ON MILLET PRODUCTION IN GWERI SUBCOUNTY, SOROTI DISTRICT, UGANDA

BY

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OCTOBER, 2023

DECLARATION

I **Atim Sarah** declare that this dissertation is my original work and has never been submitted to any institution for award and all sources quoted and referred to herein have been acknowledged in both text and references.

Signed………………………………………… Date……………………………………

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APPROVAL

I hereby certify that this dissertation is an original piece of work organized by the student in the name of **ATIM SARAH** and that the student closely consulted us during the process of her work. I therefore approve it for submission.

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DEDICATION

This work is dedicated to my lovely Father Okot Francis, late mother Alanyo Paulina, sisters, Brothers, my friends and my best friends, Poshan, blessing, David and Jayson for their tireless contribution during the course of this study.

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LIST OF ACRONYMS

ACCRA	-	American Chamber of Commerce Research Association
CO_2	-	Carbondioxide
GCMs	-	General Circulation Models
FAO	-	Food and Agriculture Organization
GDP	-	Gross Domestic Product
IPCC	-	Inter-Governmental Panel on Climate Change
LGP	-	Length of the Growing Period
RCMs	-	Regional Climate Models
NEMA	-	National Environment Management Authority (NEMA)
SON	-	September, October, and November
RCP	–	Representative Concentration Pathways
UNFCCC	-	United Nations Framework Convention on Climate Change
UNMC	-	Uganda National Meteorological Centre

ABSTRACT

The study examined the effect of climate variability and change on millet production in Gweri Sub County Soroti district. The specific objective were; to determine the trend of climate change and variability, assess farmers perceptions on the effects of climate change and climate variability on millet grain yields and to determine farmers adaptation practices to climate change and climate variability in Gweri Sub County, Soroti district. A cross sectional survey was adopted and data collection involved both use of primary data and secondary data. Primary data was collected from 80 households including farmers and extension workers in Gweri sub county Soroti district. Data was analysed using statistical package SPSS version 16. Result show predicted increase in rainfall and mean temperature of gweri sub county by the year 2039 respectively. Respondents acknowledged that rainfall amounts have changed, onset and cessation are dynamic, and a decline in millet yields attributed to climate variability and change was reported. The most prominent coping mechanisms include growing improved crops varieties, mixed cropping planting of 2nd season crops in 1st season and planting of 1st season crops in 2nd season due to change in climate, shifting from water stressed and flood prone areas and adjusting on planting dates and crop diversification.

In conclusion, both climate models, namely RCP 8.5 and RCP 4.5, predict an increase in annual rainfall, with values of 1830.6 and 1651.9 mm, respectively, for the year 2031. This trend is followed by similar peaks in the years 2036 and 2033. Additionally, the same models forecast a sustained and consistent rise in annual mean temperatures for Gweri Sub County, reaching 27.56°C in the year 2039, with similar high levels expected in 2032 and 2035. It's noteworthy that throughout this period, the annual mean temperatures remain within the optimal range of 26°C, favoring the growth of millet. This information was generated with the assistance of the Agricultural Model Intercomparison and Improvement Project (AGMIP), which contributed to the prediction of increased annual rainfall, and data analysis was executed to provide these valuable insights.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

In recent years, there has been a global decline in mean annual total rainfall (Hastrup, 2015). This decline is a consequence of climate change and variability, leading to irregular and unpredictable rainfall patterns, increased hail storms, and extended periods of dry spells in various countries. Among the region's most vulnerable to the adverse effects of these changes in Sub Saharan countries, including Uganda, whose economies heavily rely on climate-sensitive sectors (IPCC, 2007c; Lukwiga, 2009) specifically agriculture. Notably, agriculture plays a crucial role in Uganda's gross domestic product (GDP) (Nandozi et al, 2012). To exacerbate the situation, the IPCC's 2001 report projected a continuing trend of warming, with a potential increase in global average temperature which is two to ten times larger than the observed warming in the 20th century (IPCC, 2005). These projections underscore the urgent need to address climate change and its potential impacts on vulnerable regions like Sub-Saharan countries, particularly Uganda.

Sub-Saharan Africa bears the brunt of the detrimental impacts of climate change on crop production, with a significant focus on the agricultural sector that contributes substantially to GDP (32%), export earnings, and employment (65%) in many of these countries(Gouden, 2017). The majority of impoverished rural inhabitants depend on agriculture for their livelihoods (IFPRI, 2009), exacerbating the vulnerability of these nations. Their weak economies and limited technological resources further impede their ability to adapt to the diverse effects of climate change and variability (IPCC, 2007a). Uganda, in particular, heavily relies on rain-fed agriculture (about 80%), making it highly susceptible to climate change's adverse consequences, particularly for the rural poor who depend on farming for sustenance and income (Kirshen, 2018). The National Adaptation Program of Action (NAPA) for Uganda (Ministry of Water and Environment, 2007) indicates an increasing trend in drought frequency and rainfall variability, directly linked to climate change. GCM-generated data, as reported by Hepworth and Goulden (2008), forecasts a potential temperature increase in Uganda of up to 1.5°C within the next 20 years and up to 4.3°C by the 2080s. While changes in rainfall patterns are less certain, temperature shifts alone are likely to significantly impact water resources and food security in the region.

The food supply situation for vulnerable groups in the sub-Saharan region, particularly in crop production areas, remains a serious concern despite significant improvements. Early and prolonged droughts exacerbate the challenges (Bryan, 2016). Additionally, numerous countries worldwide are grappling with severe localized food insecurity due to factors such as refugee invasions, the concentration of internally displaced persons, and a combination of crop failure and increased poverty (Ringler, 2017). The region's naturally mutable climate, characterized by flooding and negative socio-economic events, has had adverse effects on agriculture and livelihood activities, causing losses for small-scale farmers and residents (Bagaga, 2020).

The impoverished agro-based communities in arid regions face heightened vulnerability to the adverse effects of climate change and variability (IPCC, 2007). These communities rely heavily on rain-fed agriculture or pastoralism for their livelihoods but are often plagued by droughts and floods, which could be exacerbated by climate change. These extreme weather events have disastrous consequences for crop and livestock production, posing a significant threat to the communities' sustenance. Uganda's semi-arid and rid regions are particularly at risk of experiencing these challenges. However, despite these looming threats, there is a scarcity of studies investigating the impacts of climate change on yields of crucial food security crops in this area.

According to Akudugu (2015), the changing climate has significantly impacted household farmers' ability to generate income through millet production, leading to a reduction in surpluses available for sale. This decline in agricultural productivity, coupled with climate variability, has resulted in escalating prices for goods and services, exacerbating food insecurity, particularly among the poor and vulnerable populations. Many countries are witnessing increased pressure on their water resources, including streams, dams, rivers, and underground water sources, as a consequence of climate change. These adverse effects on agriculture and water availability underscore the urgent need to address the challenges posed by climate change to ensure food security and sustainable livelihoods.

The Lake Kyoga basin experiences annual rainfall ranging from about 800mm in the north to 2050mm in the East towards Mount Elgon, with mean temperatures ranging from 23.30°C to 24.20°C. There are two rainy seasons: the first with long rains falling from March to May and the second with short rains from September to November (Obubu, 2021). However, climate variations have led to change in seasons, unreliable rains with erratic onsets, shortened growing periods, and increasing dry spells, posing significant challenges to millet production (Poudel, 2019). Farmers in the area struggle to predict planting seasons due to more frequent droughts and rising temperatures (Alamirew, 2021).

Unpredictable rainfall and prolonged dry spell have had significant effects on crop production, particularly in Soroti district (UNMC, 2022). Fluctuating patterns of rain, increased evapotranspiration, reduced soil moisture, and prolonged droughts have resulted in decreased crop yields (Brown, 2018).

1.2 Problem statement

It is widely acknowledged that climate change affect the agricultural production in Uganda (Wasige, 2009). Studies indicate that mean temperature and annual precipitation are projected to increase by 1.5℃ and 10% by 2050 and by 4.3℃ and 20% by 2100, respectively (McSweeney 2008; ACCRA, 2012); However, there is uncertainty regarding the temporal and spatial variability of precipitation events in Uganda, as reported by the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). The available meteorological data indicates a decrease in precipitation in the country, leading to an increase in soil water stress due to higher evapotranspiration from rising temperatures and reduced precipitation (UNMC, 2022).

The projected changes and on-going climate variability in form of prolonged dry spell has been reflected in declining crop yields across the country. The cropping system in the cattle corridor region mainly the Lake Kyoga plains agro-ecological zone are most vulnerable ecosystems to climate change and thus, there is evidence of the effects of climate variability on crop production. Agricultural communities have continued to experience declining crop yields especially for the staple crops such as millet due to prolonged drought and unpredictable rainfall for instance, between 2008 and 2018, millet production in Soroti district declined by 25% (UBOS, 2018). Similarly, from 2018 to 2020, there was a 15% decrease in millet production, impacting the livelihoods of farmers who heavily rely on agriculture. Gweri Sub County is one of the significant millet food baskets in Soroti district, contributing 63% of millet production, however, farmers have continued to experience declining yields with limited adaptation to the On-going climate variability (Kimono, 2018).

Previous studies (McSweeney 2008; ACCRA, 2012; Schmidhuber and Tubiello, 2007) have explored the various existing adaptation strategies employed by farmers such as crop diversification, improving crop varieties, use of irrigation systems and soil conservation for the improvement of millet growing. However, there is limited information on the trend in temperature and rainfall variability and how farmers are adapting to the climate variability for millet production in the region. Understanding the future trends and how these changes will affect millet grain yields is essential for decision-making and planning appropriate coping mechanisms to improve millet production and enhance community resilience to climate change in the region. The study seeks to explore the coping and adaptive mechanisms being implemented by different farmers in Gweri Sub County to provide valuable insights for guiding effective strategies and actions towards sustainable millet production in the face of climate change and variability.

1.3 General objective

The main objective of the study was to analyse the effect of climate change and climate variability on millet production

1.4 Specific objectives

Specifically, this study sought to attain the following objectives;

i. To establish the trend of climate change and variability in Gweri sub county, Soroti district.

ii. To assess farmers perception on the effects of climate change and variability on millet grain yields in Gweri sub county, Soroti district.

iii. To determine the existing coping and adaption strategies to climate change and variability for millet production in Gweri sub county, Soroti district

1.5 Research questions

The following research questions were central to investigating the research Problem:

i. What are the trends of climate change and variability in Gweri sub county, Soroti district focusing on the time frame from 1980 to 2009?

ii. What are the effects of climate change and variability on millet grain yields in Gweri Sub County, Soroti district?

iii. What are the coping and adaptive strategies to climate change and variability in Gweri Sub County, Soroti district?

1.6 Justification of the study

The Republic of Uganda mortified the adaptation plan of action to advance adaptive abilities of the people. In addition, the United Nations Millennium Development goal number one prioritizes eliminating poverty and starvation due to changing climate and variability. Change in Climate and variability are gradually, increased and frequently impacting on agricultural productivities carried out by the natives. Absence of specific location, research and awareness about potential negative consequences are leading to a delay in addressing future crop yield challenges, with potentially devastating consequences.

Over 70% of Uganda's total population depends on agriculture as their primary source of income, making it a vital sector for the country's economy and food surplus (UBOS, 2022). As per the World Bank, (2013) report, agriculture accounts for 45% of Uganda's gross domestic product (GDP). The Agricultural activities of this kind are likely to be exaggerated by changes in climate and variability. Consequently survey on the intensity and magnitude, diverse changes help different agricultural systems to reform policy and also facilitate resistant communities to adjust to the future change in climate and variability. The agricultural sector together with institutional roles, farmer's perceptions, and continuing coping and adaptation methods provides enhanced understanding of climate change and climate variability to policy makers. Geographically suitable adaptation policies help in classifying gaps that occur in adaptation and recommendations strategies being undertaken by communities in other area. Generating of resilient communities help to decrease variation in climate effects in an area

1.7 The scope of the study

The study was conducted in Gweri sub county Soroti district which borders the district of Amuria to the North, Ngora to the East, Katakwi District to the North East, Serere district to the South, Kaberamaido and lake Kyoga to the West. The district headquarters is located approximately 116 kilometres (72 mi), by road, northwest of Mbale, the nearest large city. The study considered the area because it boarders Awoja swamp and thus suffers from frequent flooding and prolonged drought. The study concentrated on the effect of climate change and climate variability on millet production in Gweri Sub county Soroti district. The study determined the trends of climate change and variability, assessed effects of climate change and variability on millet grain yields, determined the coping and adaptive strategies to climate change and variability in Gweri sub county Soroti district. Climatic projections were considered in the study and 1980-2010 periods was taken as reference period (baseline).

1.8 Significance of the study

The study aimed to explore the potential correlation between climate change and variability and its impact on millet production in Gweri Sub County, Soroti district. By establishing this connection, the research could provide valuable insights to authorities and policymakers, enabling them to develop strategies and interventions to address the challenges posed by climate change on millet farming. Furthermore, the study has the potential to equip researchers with essential skills and knowledge on conducting research related to the effects of climate change and variability on millet farming in the district. This capacity-building aspect could contribute to more informed decision-making and the generation of practical solutions to mitigate the adverse impacts on millet production and the livelihoods of farmers. Additionally, the findings of this study aims to contribute to the existing literature on climate change and variability's influence on millet production. The study serve as a valuable reference point for future researchers who wish to delve deeper into this subject matter, facilitating a better understanding of the challenges faced by millet farmers in the context of changing climatic conditions. By adding to the body of knowledge, the study contribute to advancing research in this area and foster more effective measures to address climate-related issues affecting millet production in the region.

1.9 Conceptual frame work

Change in climate is unavoidably reflection that changes the level of production. Some of underlying causes leading to decrease in produce are the change in climate and climate variability. This conceptual framework contains the dependent variable which is millet production which depends on the independent variable known as climate change. Therefore climate change through temperature and rainfall can disrupt millet availability, household income, increased production, improved standards of living, increased education and improved infrastructure. Through this can be improved through government intervention, constant research and community sensitization.

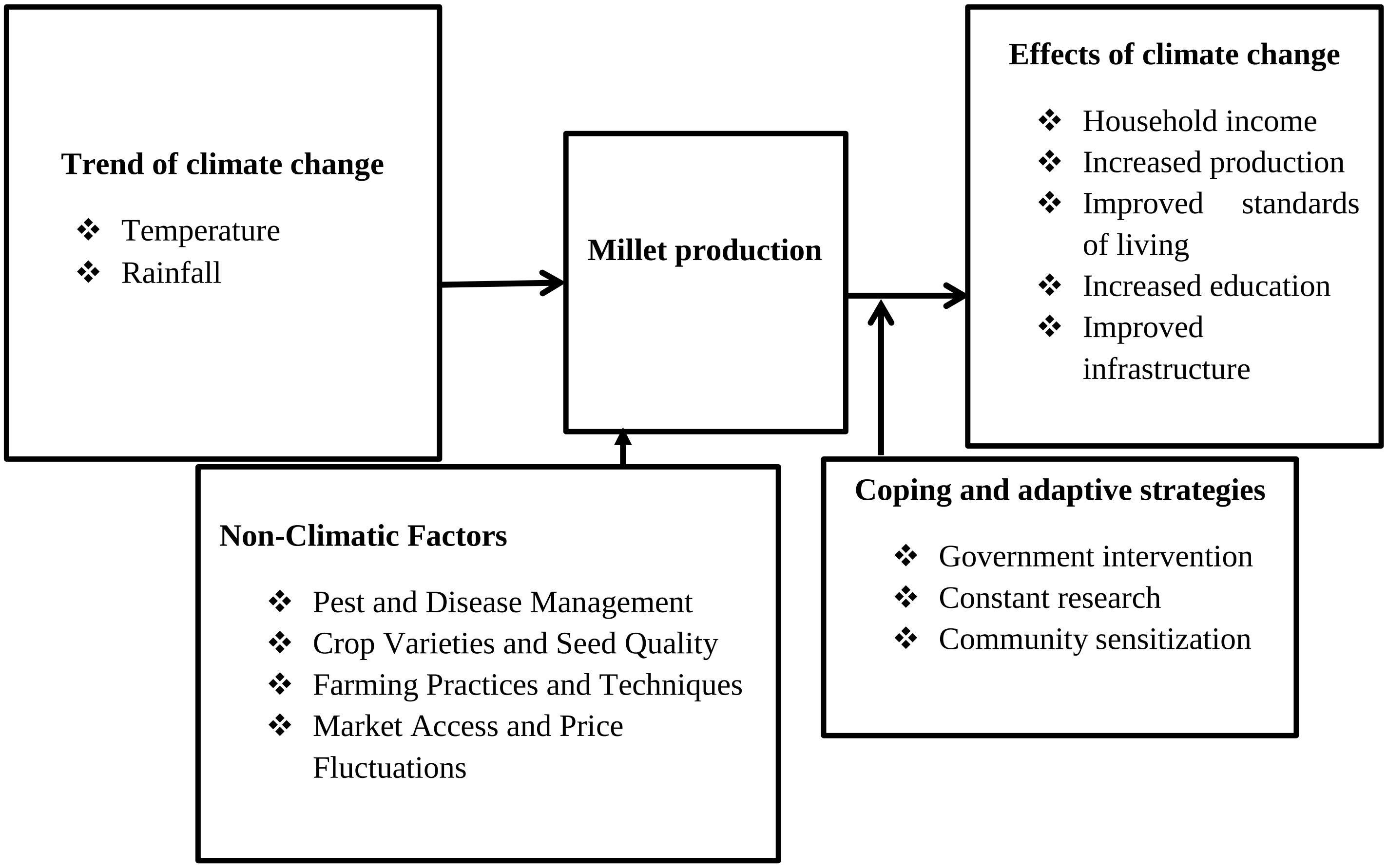


Figure 1.1: Conceptual framework

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Climate change is characterized as a significant change in the climate that can be discerned through statistical analyses, such as changes in average weather conditions or properties of variability, and persists for an extended period. It encompasses modifications in the climate over time, irrespective of whether they arise from natural fluctuations or are influenced by human activities (IPCC, 2007). As per the United Nations Framework Convention on Climate Change (UNFCCC), climate change pertains to shifts in the climate system that can be directly or indirectly attributed to human actions, resulting in changes in the global atmosphere's composition, and these changes go beyond what is naturally observed in comparable timeframes (UNFCCC, 2013).

2.2 Climate patterns and trends in variability and change

Climate change is arguably the most pressing global challenge of the 21st century, and its impacts are particularly pronounced in African countries due to their geographical location (mainly at lower latitudes), reliance on climate-sensitive sectors like agriculture, limited income, and inadequate capacity to adapt to changing climatic conditions and variability (Loftus, 2018). Over the 20th century, Africa has already experienced an average annual mean temperature increase of approximately 0.5°C, and climate models project further warming of 3°C to 4°C in the future (Eriksen, 2018). Despite contributing less than 5 percent of total global carbon dioxide emissions, African countries bear a disproportionately high burden of the effects of climate change. This disparity highlights the significant gap between their contribution to greenhouse gas emissions and their vulnerability to climate impacts. While African nations have relatively low carbon footprints, they face severe challenges in adapting to and coping with the consequences of a changing climate. This imbalance underscores the urgent need for international cooperation and support to address the vulnerabilities of African countries to climate change. Bridging this gap requires assistance in building resilience, implementing adaptation strategies, and supporting sustainable development in the face of climate-related challenges. By recognizing and addressing this gap, the global community can work together to achieve a more equitable response to climate change and ensure a sustainable future for all.

Changing climate perhaps is the most significant problem affecting the world in the 21st century, and it's mostly experienced in African countries because of its geographical exposure (that is, most African countries are located at the lower latitudes), dependence on climatic-sensitive sectors for example agriculture, inadequate income, inadequate capacity to adapt to the changing climate and variability (Loftus, 2018). Average annual mean temperature of approximately 0.5°C has been noticed in Africa during the 20th century. Climatic model estimates that in Africa the annual mean temperature will increase from 3°C to 4°C (Eriksen, 2018). Africa countries contribute less than 5 percent of total carbon dioxide to the atmosphere which is –equivalent to the global greenhouse emissions.

Projection predicts change in rainfall in South Africa (SA) result into prolonged drought, while in east Africa will experience increased precipitation. That is to say in South Africa rainfall will decline from June-August and for East Africa it will increase from December-February. Threat of weather events such as flooding, prolonged drought is projected in East Africa (Eriksen, 2018). Temperature increased to 0.5°C in the past century across the world and is projected to increase from1.5°C to 5.8°C by 2100 (Houghton, 2018). The increasing temperature trend noticed in South Africa is constant with the world's trend throughout the 20th century. (Anderson, 2018) also asserted that temperature in this region increased by over 0.5°C. Between 1988 and 1992 Southern Africa experienced over fifteen drought events, impacting negatively on the economy of the area through decreasing agricultural production and intensifying food insecurity (Bittman, 2019). Prudhomme (2018) projected an increase in annual temperature from 1.5 to 2.5° C in 2050 in the south of SA and in the north of SA an increase from 2.5 to 3.0° C, relative in 1961-1990. (Anderson, 2018), projected increased rainfall variability intra-and inter-years for ESA region.

According to ACCRA (2012), climate projections indicate that the world's surface mean temperature is expected to rise significantly, with estimates ranging from 1.0°C to 6.0°C by the year 2100. Similarly, Eschenbach (2013) estimates a temperature increase of 1.8°C to 4.0°C during the same timeframe. Regions in the tropics are particularly vulnerable, facing challenges such as increased and prolonged droughts, stronger winds, and more frequent dry spells. The direct exposure to intense sun rays throughout the year further contributes to the warmer temperatures in these regions. Alexander (2013) also highlights that the world's annual mean temperature is projected to rise considerably, reaching as high as 4.0°C to 6.0°C by 2080. The increase in temperature, even at a lower estimate of 1.5°C, poses significant dangers to crop production. Despite the various studies providing climate projections and temperature estimates, there seems to be a disparity in the magnitude of temperature increase indicated by different sources. Additionally, the specific impacts of these temperature changes on agricultural practices and ecosystems may require further investigation and research.

Kilembe, (2012) asserted that most climatic projections show incidences in temperature rise of hot days and nights during climatic change. Furthermore annual mean temperature is projected to occur by 15 to 43% during the hot days in 2060 and 2090 by 18 to 73%. Current climate projections show decrease in temperature during days and nights and are considered as "cold". (Wasige, 2009) asserted that in 2090 there will be very rare extremely maximum emissions scenario as viewed in various projections. The projected fluctuations in annual mean temperature exhibit variations that necessitate a deeper understanding at the local level.

Assessments of projected changes in precipitation yield inconclusive and mixed findings. Alexander (2013) suggests that precipitation could decrease by 10% to 40%, while other studies indicate an increase ranging from 5% to 40% by 2100 in Africa. Sultan (2013) argues that areas in the tropics and high latitude regions may experience increased rainfall due to evapotranspiration, leading to a potential rise in rainfall occasions by -8% to +46% in 2090. In contrast, parts of the Horn of Africa are projected to experience a decrease of 10% in precipitation by 2050. Additionally, Bashaasha (2012) predicts a potential annual precipitation rise of 1% to 15% in 2090, with a simultaneous decrease in heavy rainfall occasions. However, the reliability of the model's results regarding precipitation remains uncertain, as they vary between different areas and even within the same region (Lobel, 2013).

According to Subash et al. (2010), the onset of rain demonstrates a significant hindered tendency, occurring at a frequency of approximately 2.8 percent deviating from the mean, with fluctuations observed over 30-year periods. Such variations in the timing of rainfall can have detrimental effects on crop growth, leading to crop destruction, low yields, and even crop failure. Late or early onset of the rainy seasons can be particularly disastrous for agriculture. Furthermore, the differences in the onset of rainfall vary across different regions, such as the monsoon region and the Western Ghats, where the variation can be as long as a month or more. On the other hand, the North Western desert region experiences relatively consistent patterns of rainfall onset. These variations in onset timings suggest that geographical influences play a role, with weaker and limited associations observed in some areas (Moron, 2013).

Todd (2013) emphasized that the outcomes derived from both Regional Climate Models (RCMs) and General Circulation Models (GCMs) provide compelling evidence of significant climate change and climate variability events. These models project that weather conditions, both on regional and global scales, are likely to become more erratic compared to current conditions. Some of the notable changes include variations in precipitation onset dates, hindered or failed precipitation events, and an increase in the frequency and intensity of extreme weather phenomena like hailstorms and flooding. These changes could have detrimental effects on crop yields and agriculture. Furthermore, in Sub-Saharan regions, climate variability is evident with shifts in rain patterns, prolonged droughts, sudden rain spells, and heatwaves occurring during rainy seasons. These climatic shifts pose further challenges to agriculture and highlight the need for adaptation strategies to cope with the changing environmental conditions (Miller, 2012).

2.3 Effect of climate change and variability on millet grain yield.

Jawoo (2013) highlights that, climate variability will strongly impact agriculture, especially in rain-fed agrarian systems. This influence will be felt in regions suitable for agriculture due to changes in growing seasons' duration and potential reductions in crop yields. For instance, a projected 4°C temperature rise is expected to cause crop yields to decline by 15% to 80% (Eschenback, 2013). While many temperate regions may benefit from the changing climate through extended growing seasons, land expansion, and warmer temperatures, certain areas in Africa are projected to experience negative effects (Marshall, 2009). These observations emphasize the significant consequences of climate shifts on agriculture, necessitating increased attention to risk assessment in African agricultural systems under a changing climate. Different studies indicate various impacts on agricultural productivity due to climate change, with some changes occurring as early as the next two decades (Lobel, 2013). The specific findings and details of the mentioned studies and their projections on agricultural productivity are not explicitly provided in the given information.

Sultan (2013) emphasizes that millet plays a crucial role in ensuring food security, not only in Uganda but also in other areas. Historically, millet has been recognized as a climate-resistant crop, capable of adapting to changing climate conditions and variability. However, according to Kilembe (2012), future rises in warm temperatures could lead to changes and reductions in millet crop yields. Vulnerable regions in sub-Saharan Africa require a more comprehensive understanding and quantification of specific site conditions (Eschenback, 2013) to address the impacts of climate change and variability on crop yields. Sultan (2013) further, he points out the urgent need for attention to crop yields affected by climate change and variability. His study acknowledges that projected climates differ from historical records and may have significant implications for millet yields, primarily due to increasing temperatures, which could lead to reduced crop productivity. The specific details and findings of Sultan's study on the projected climate variations and their potential impact on millet yields are not provided in the given information. Further elaboration on the quantified effects and potential mitigation strategies would enhance the understanding of the study's implications.

Ragab (2019) highlights that future agricultural production systems may differ due to technological advancements, farming policies, and development pathways. The highly diversified smallholder farming schemes could adapt to varying agricultural practices, resulting in diverse impacts of climate variations among farmers. Some farmers may be severely affected based on their choices of cropping practices, mix cropping, and other factors (Poudel, 2019). On the other hand, changes in technology, such as adopting drought-resistant crop varieties, may enable farmers to counterbalance the adverse impacts of climate variation and even gain from its effects (Pant, 2019). However, few studies have quantified the variability of these impacts among different smallholders and how future farming productivity will be affected by climate change (Ragab, 2019).

Changing climate and its impact is worldwide however; it’s being in industrialized and developing economies. The effect of climate variation is more austere in developing economies as a result of farmer’s failure to adapt to climate smart agriculture (Kotani 2012). Small-scale farmers, who form a significant portion of the impoverished population in Africa, are confronted with the prospect of devastating crop failures, reduced agricultural productivity, heightened hunger, malnutrition, and disease due to the impacts of climate change and climate variability (Smith, 2018). It is projected that millet yield in Africa may decrease by 10 –20% by the year 2050 or even up to 50% due to climate change and variability.

The fundamental effect of climate change on agriculture is its direct impact on food production. Almost all sectors in agriculture depend on notions of weather and climate whose variability subject rural farmers to production and financial risk (Fussel, 2015). The danger from climate change in Africa, and the rest of the world, includes, increasing temperatures and heat waves, shortfalls in water supply/increasing floods increasing from shortage/excessive precipitation, sea level rise, growing likelihood of conflict and induced environmental and vector borne diseases (Kilembe, 2012). These conditions arising from climate change are bound to compromise agricultural production (crop, livestock, forest and fishery resources), nutritional and health statuses, trading in agricultural commodities, human settlements (especially of agricultural communities), tourism and recreation among others (Wallen, 2019). The variability of temperature, air humidity and total rainfall shows negative signs to agricultural production (Schultz, 2019). These problems have contributed to major loss of production and increase in socio-economic and income vulnerability among farmers. Climate change involves the development of natural resources management strategies that ensures the sustainable usage of soil and water, halt biodiversity decline and deal with developing issues such as demand for renewable energy (Loftus, 2018).

Chen, (2017) acknowledged that, heterogeneous impact of climatic variables on yielding crops depend on crop varieties, seasons of growing crops and the area. Existing studies limits the assessments of intra-regional specific site variations and influences changing climate on yielding crops. Spatial configurations of climate and their impact on yielding crops are essential in detecting the vulnerability and also determining the suitable area for agricultural adaptive strategies on changing climate and variability (Tao, 2018).

Joshi, (2019) assessed the relationship between yielding crops and climatic variables by use of time series analysis, but the study leaves out the heterogeneity impact of changing climate on yielding crops across different spatial sizes within the area and it has limitations in capturing the impact of intra-seasonal dissimilarities of climatic variables on crop grain yield. Poudel (2019) explored the relationships between crop yield and climate variables, as well as the diverse impacts across different growing seasons and altitudes. However, his study did not assess the variations in climate change effects on crop yield within specific geographic regions, and it also faced limitations in fully capturing the influence of daytime temperature versus night time temperature on crop yield.

2.4 Coping and adaptive strategies to climate change and variability

According to Ellram (2019), adaptation refers to the efforts and actions taken by individuals, families, communities, and organizations to monitor changes in conditions or situations, aiming to understand the tangible advantages they may forego. Stanley (2019) emphasizes the significance of climatic conditions in various natural and human activities, with long-term changes potentially leading to significant impacts. Ellram (2019) further, states that recognizing or predicting the concerned effects prompts a careful consideration of possible courses of action or adaptations, taking into account their effectiveness and timing. However, climate change studies that attempted to measure potential effects on agriculture systems often made strong assumptions about the adaptive behavior of communities. For instance, they assumed that farmers would not adjust their practices in response to observed changing conditions. This approach left farmers more vulnerable to worst-case scenarios, as estimates did not consider research on predicting farmer's behavior. Despite limited studies on the matter, some insights into yield ranges and the upper-bound magnitude of economic effects have been gained, but there is a need to further understand the regional distribution of potential impacts (Reilly, 2019).

Alejandro, (2013) asserted that various societies in different areas of the world have frequently practiced different ways of managing mechanisms as a way of reacting to the effect of climate variation. This is done as a way to decrease the influence of dissimilarities and changes in climate on crop yield decrease. According to (Cooper et al., 2008), coping methods such as traditional methods have been often established in different areas and it's conceded from one generation to another generation.

Bardege, (2013) asserted that during drought societies have managed to cope up with climate change and climate variability through harvesting of water from streams , rationing of water, re-use of water for resistance water that is used from laundry to water yields in the botanical parks and nurseries. In addition to the above, societies have also practiced different coping mechanisms for example dependence on communication networks i.e. distribution of information about climate change and climate variability, emotional support, cash loans, petty trade, temporary relocation from one place to another, handcraft making in order to sell and get money (improve on their standards of living) and dependence on friends for support (Kabat, 2012).

Kyekyeku, (2012) asserted that, Communities can also manage climate change impacts by seeking for employment outside husbandry, preservation of pasture, decreasing cattle herds, requesting for nourishment aid and production of citrus as a way to manage the period of famine caused by climate change and climate variability. Communities can manage the effect of altering climate and climate variability through gathering resources from forests for resistance wood, burning of firewood and selling the produce (Carmenza et al., 2011)

Eschenbach, (2013) revealed that climate change adaptation are intercessions or variations that occur to take benefit of the opportunities presented by the climate variation or manage the losses. Agriculture is one of the most important land uses all over the world and crop production covers almost ≈1.2–1.5 billion hectares of land. Husbandry remains extremely sensitive to climate variations and change in many different aspects in numerous localities. Therefore, it has become very critical for stressors in particular areas to successfully cope up with the possible climate threats in the near-future hence enabling communities to endure the pressure to pinpoint and assess alternatives for adaptation.

According to (Gouden, 2017) adaption to climate changes and variations in developing countries are inadequate due to shortage of humanoid and economic development which comprise of limited technology, low level of education, inadequate auxiliary institutions and insufficient access to monetary possessions. In developing countries the above conditions results into high vulnerability state of climate change and climate variability hence effect production of nourishment in the world.

According to Bardege et al. (2013), climate change and climate variability adaptation strategies encompass various forms. The autonomous strategy involves developing and diversifying production, responding to changes in market demands, and ensuring food supply resilience. The anticipatory strategy includes enhancing land management and preparing for shifts in market demands and food supply. Prearranged adaptation involves implementing new agricultural practices, such as introducing new crop breeds, improving water management, altering planting dates, and integrating mixed cropping, livestock rearing, forestry, and fishery sectors at the farm and catchment levels (Ludi, 2009; Marshal et al, 2009). Technological adaptation focuses on adjusting irrigation schemes and optimizing scarce water usage, including the introduction of new crop breeds (Ziervogel, 2010). Public adaptation strategies entail early warnings for droughts and floods and establishing well-equipped institutional frameworks (Vermoulen, et al 2008). In contrast, private adaptation involves relocating to less water-stressed areas or semi-arid zones and seeking alternative employment outside of agriculture (UNDP, 2005). Key coursing adaptation strategies revolve around establishing and facilitating policies and conducting research and distribution of crop varieties and breeds that can better adapt to the changing climatic conditions.

Adaptation to climate change can yield short-term or long-term benefits, whether it is planned or unplanned (Hamilton, 2019). Farmers are informed about the shifting climate and subsequently identify and implement crucial adaptation strategies. Lancaster (2020) emphasizes that people's perceptions of climate change are continuously evolving, leading to various recognized effects, such as the drying of perennial rivers, reduced production of traditional crops in agriculture, an increase in crop diseases, and declining soil fertility. These observations highlight the need for effective and timely adaptation strategies that address the changing climate conditions and their impact on agricultural practices and ecosystems. Farmers must proactively respond to these shifts in climate perception to safeguard their livelihoods and ensure sustainable agricultural productivity and environmental resilience.

Kirshen (2018) emphasizes that climatic parameters show variations at the local level, which is crucial for developing suitable adaptation strategies and improving agricultural productivity. Despite numerous studies, there is no clear and reliable correlation between climate variables and local perceptions. The region's diverse topography leads to disparities in temperature and precipitation, making it challenging for farmers to find tailored solutions for climate change impacts. To address these challenges, downscaling techniques and integrating different measurement units provide more informative insights for proactive agricultural planning. Farmers' perceptions play a significant role in motivating adaptation strategies, and their understanding of local climate is evaluated through statistical analysis. The study adds value to the limited literature on agro-ecological comparisons of climate change and variability. By combining meteorological data with farmers' perceptions, the research offers valuable insights into how farmers comprehend local weather conditions and how these perceptions align or differ from observed climate trends. This holistic approach contributes to better risk management and adaptation strategies in the agricultural sector.

In conclusion, the literature reveals diverse projections on the impact of climate change and variability on millet yields. There are variations in the outcomes of different models, presenting challenges in understanding the precise effects of climate change on millet productivity. Additionally, the responses of communities to these changes and their adaptation strategies differ across regions, reflecting the need for context-specific approaches. Despite significant research efforts, there are gaps in understanding the exact implications of climate change on millet yields and the most effective adaptation measures to manage the impacts of climate change in millet production systems. Further research is required to address these gaps and provide more comprehensive insights into the complexities of climate change effects on millet production and appropriate adaptation strategies.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents information on the background of the study area and it involves; the location of the area, climate, vegetation, soils, Geology, land use and the total population of the area. The chapter also presents different research methodology used to conduct the study including; the research design, data collection methods and data processing and analysis techniques.

3.2 Study area

3.2.1 Location

The study was carried out in Gweri sub county Soroti district. Gweri was selected because it suffered frequent climatic change and variability leading to prolonged droughts, flooding, and dry spell in the past years (2007-2012). Soroti district is found in the eastern region of Uganda, the district approximately covers latitude $1^0$33" and $2^0$23" North, $30^0$01" and $34^0$18" East (figure3.1). The district boarders Lake Kyoga, Kumi district in the south, Kaberamaido to the West Serere to the south and Katakwi district in the North East. Soroti district total land area is approximately 2,662.5 square kilometer, 406 square kilometer is water while 2,256.5 square kilometer land (Okori et al., 2002).

Gweri Sub County was chosen as the study location due to its predominantly rural nature and the primary activities conducted there, which include cattle rearing and crop production. The area's proximity to Awoja River and the neighboring swamp exposes it to various climatic challenges, such as prolonged droughts, flooding, and dry spells. The excess water from Awoja River can overflow into the surrounding villages, leading to the loss of entire crop fields in the area. These climate-related issues make Gweri Sub County a critical location for investigating the potential correlation between climate change and variability and its impact on millet production in Soroti District. By understanding the challenges faced by farmers in this region, the research aims to provide valuable insights for developing strategies and interventions to address the adverse effects of climate change on millet farming and enhance community resilience.

Study area

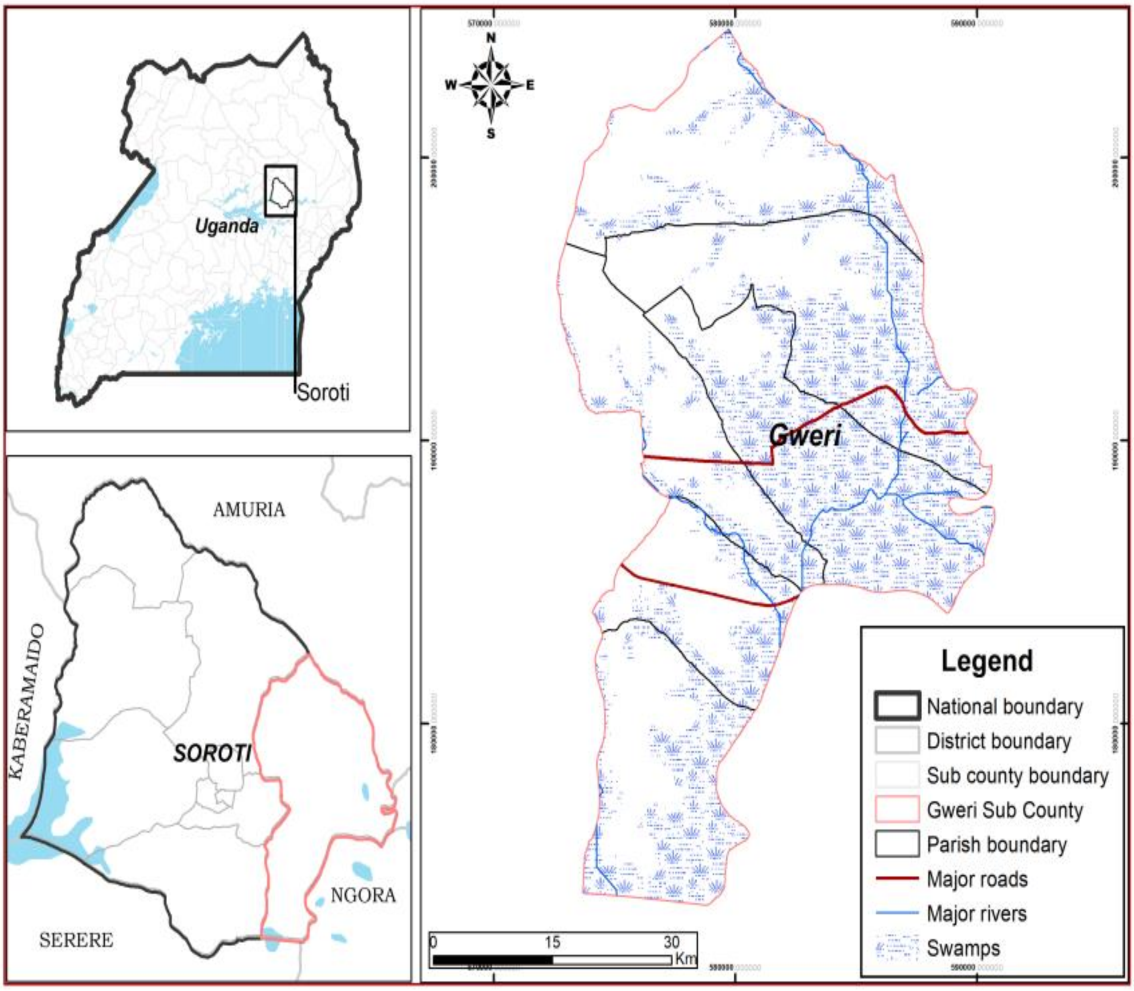


Figure 3.1: Location of Gweri Sub County

3.2.2 Climate

Gweri Sub County's climate is influenced by the presence of a large swamp, river, and wetland surrounding the area. The total annual rainfall in Gweri Sub County ranges from 1000mm to 1500mm. The region experiences two rainy seasons: March, April, and May (MAM) and September, October, and November (SON). The long dry spells occur from the end of November to the beginning of March (Figure 3.2).

In the North East bordering areas of Gweri Sub County, early dry seasons are a common occurrence. This phenomenon is also observed in regions near the lakeshore, where sharp spells of drought are experienced at times (source: Soroti District Local Government, 2022). The area exhibits relatively high humidity during the morning and afternoon hours, which decreases the likelihood of precipitation in the region.

The average annual rainfall received in the area theoretically support crop production. However, the distribution of rainfall poses a constraint as the area receives all the rainfall in one season, which then disperses throughout. Occasional experiences of prolonged drought and uneven rains result in only one crop growing season in the area, as reported by NEMA (2019). This situation hampers crop production and negatively impacts the potential crop yields in the region.

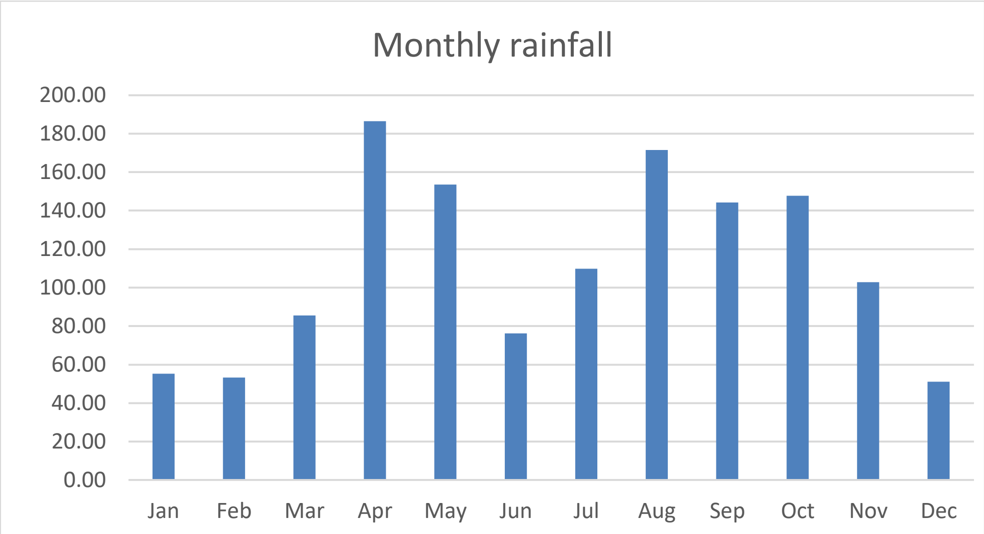


Figure 3.2 shows monthly annual rainfall for Gweri sub county Soroti district

3.2.3 Vegetation

Gweri Sub County in Soroti District is predominantly characterized by concealed savannah grassland, forests, riparian, and savannah woodland. The savannah woodland is typified by open canopy trees, thorny trees, and casual grasses that reach a height of approximately 80 centimeters. Notably, the trees in the savannah woodland are fire-resistant and regenerate after being burnt, with acacia trees often associated with hyparrhenia and combretum savannah. Within the savannah grassland, various grasses such as hyperrhania rufa, imperatum cylindrical, and digitaria scalsria are prevalent (Nkuuhe, 2018). The native inhabitants of the area utilize the vegetation for medicinal purposes, with some of the medicinal plants including steganotaenia species, cyphostemma cyphopetalum, and Lantana camara. Unfortunately, due to human activities like agriculture and infrastructure development, many trees have been cut down, resulting in deforestation. However, in some areas where clearing has stopped, secondary vegetation has begun to emerge. The vegetation in Gweri Sub County grows in soils classified as latosols, which have low fertility and are less productive for agriculture. As a consequence of land clearance for agriculture, the agrarian productivity in these areas is low (FAO, 2018). This situation raises concerns about the long-term sustainability of agricultural practices in the region and emphasizes the importance of conservation efforts to preserve the valuable savannah ecosystem.

3.2.4 Soils

Gweri Sub County in Soroti district is categorized with ferralitic soil which is Sandy sediments and/ or sandy loam. The soils are light textured and superficial with large loam sandy soils steered from various wetlands and swamps. The soils are properly (well) drained and friable. This soil group covers most areas in Eastern Uganda and it embraces different soil types that is black clays and sandy clay loams accompanied with productivity being very low FAO, (2009)

3.2.5 Land use types

The area is characterized with different land use types; rain nourished agriculture is the major activity carried out in the area. Subsistence agriculture is the superseding land use activity carried out in the area and over 90 percent of the total populations are involved in the activity. Crops cultivated in the area are; sorghum, millet, potatoes, maize, ground nuts, cassava, peas, simsim, beans, citrus. The main crops that contribute to household income are; millet, citrus, sorghum, cotton. The area also engages in land use activities such as; fishing, settlement, cattle raring, small scale lumbering, transport and communication.

3.2.6 Socio economic background

According to the Uganda Bureau of Statistics (2014), Gweri Sub County is estimated to have a total population of approximately 31,899. The region has been grappling with high poverty levels, with 62 percent of the population living below the poverty line, as reported by the United Nations Development Programme (UNDP) in 2018. This low socio-economic status negatively affects crop production in the area. The primary sources of income for the residents of Gweri Sub County include the sale of crops, forest products, fishing, and casual labor. Additionally, a smaller percentage of the population engages in trade activities such as brewing and selling alcohol, as well as selling crafts in village markets. These income-generating activities contribute to the livelihoods of the local communities in the region.

3.3 Research design

The study employed a cross-sectional survey design, which is a well-structured research plan that guides the entire research process, from its inception to the final data analysis. This choice was made to allow for the comprehensive collection of respondents' perspectives and relevant data. The research design integrated both qualitative and quantitative approaches, ensuring that data collection methods align with the research aims, objectives, and questions, as well as the available resources. Qualitative research methods included interviews, observations, and document reviews, while the quantitative approach utilized descriptive statistics like frequency tables, graphs, and charts to analyse data. These combined research designs were instrumental in generating in-depth explanations and descriptions of the phenomenon under investigation while maintaining the consistency, reliability, and validity of the study.

3.4 Target population

The target population for this study consisted of youth, farmers, extension workers, and the elderly residing in the area of study. This diverse group of respondents provided valuable insights into various aspects, including the impact of climate change on millet yield, and coping and adaptive strategies. These categories of respondents were selected due to the predominant economic activity in the area being agriculture, with over 70 percent of the total population engaged in the sector. The analysis of the study encompassed both agricultural units and households, which allowed the researcher to comprehensively understand and incorporate the diverse socio-economic data present in the study area. By including this range of respondents, the study gained a more comprehensive understanding of the effects of climate change on millet farming and the strategies employed by different segments of the community to adapt to the changing climate conditions.

3.5 Sample size

Yamane's 1967 sample size formula was employed to determine the sample size in the study area, encompassing youth, farmers, extension workers, and the elderly. The total number of respondents was taken into account during the computation process to ensure an adequate and representative sample size for the study.

To calculate the sample size, Yamane (1967) formula was involved;

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

Where; n denotes sample size, N denotes size of the population, and *e* denotes level of precision.

Level of precision considered was 11.2 percent (for resistance *e* = 0.112).

The estimated population total population for Gweri sub-county is 31,899 persons (UBOS 2014). The projected number of persons in a household was six (6). Therefore 6 were taken as the average number of persons living in a household.

= 31,899

$$= \frac{31{,}899}{6}$$

= 5316.5 households.

Therefore, sample size n is,

$$n = \frac{5316.5}{1+5316.5\,(0.112^2)}$$

$$n = \frac{5316.5}{66.7} = 79.7$$

The sample size is taken as 80.

3.6 Selection of respondents

In the study area, respondents were selected using a combination of random and purposive sampling procedures, following the guidelines by Dillman (2011). Random sampling was employed to ensure that every potential respondent had an equal chance to participate in the study, making it a suitable approach for the rural setting of the sub-county. Furthermore, purposive sampling was utilized based on information provided by local leaders to identify parishes that have been more affected by climate variability in Gweri Sub County. Four parishes were purposively selected using this method. Within each selected parish, a total of 10 random households were chosen from each village, resulting in a total of 20 households per parish and a cumulative number of 80 households across the entire sub-county.

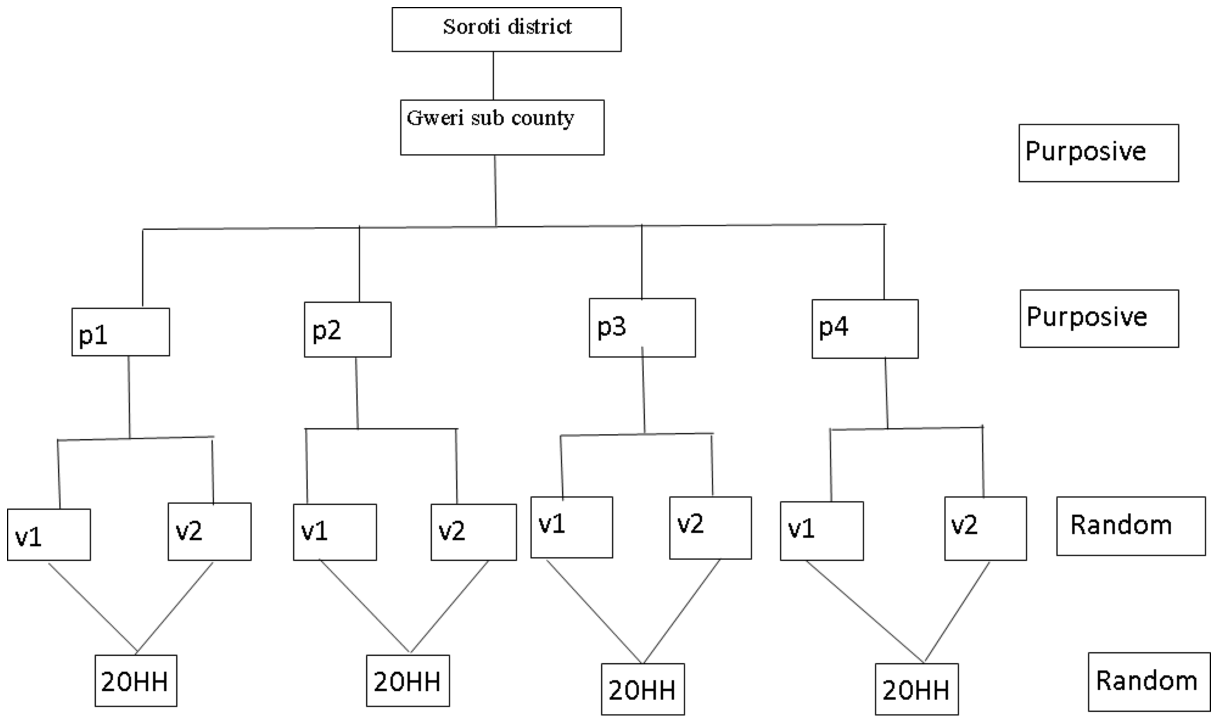


Figure 3.3: Sampling procedure

P – Parish

V – Village

HH- Number of Households

3.7 Data collection methods

The study involved the use of interview guide and questionnaire guide to get the relevant

3.7.1: Interviews

To gather comprehensive information from extension workers, farmers, and elderly individuals, structured interviews were employed. These interviews aimed to delve deeply into various aspects, including their demographic characteristics, observations on trends of climate change affecting millet yield, and the strategies they adopt to manage and adapt to climate changes. Each interview session lasted approximately 50 minutes per respondent, ensuring ample time to capture valuable insights and perspectives from the participants.

3.7.2 Questionnaire

Questionnaires comprised of both open-ended and closed-ended questions which were used in this study. Development of this data collection tool was intended to capture important information on the various socio-economic physiognomies of farmers in Gweri sub-county.

The use of questionnaire helped the researcher to collect information in wider area and gave the respondents freedom and confidence to express themselves. The researcher distributed questionnaires to all individuals engaged in millet farming in Gweri sub-county.

2.7.3 Observation

Observation as a qualitative research method is described as the systematic description of events, behaviors and artefacts in social settings chosen for the study Rossman (2011). On the other hand, Baser, (2006) further explains that observation is a combination of sensation (sight, sounds, smell, taste, and touch) and perception. It also involved systematic close viewing of actions, recording of these actions and most importantly the analysis and interpretation of what has been seen. The study was guided by an observation checklist. This was used to observe the growth of millet. In this process, the researcher took a position of a non-participant observer and recorded the items as they appeared on the checklist which was later interpreted and analysed.

3.7.4 Climatic data collection

Historical climate data for Uganda over the period of 1980-2010 served as the baseline for comparing historical climate data and understanding changes over time, these were obtained from the Uganda National Meteorological Centre (NMC). According to (Hudson and Ruane, 2013) the near-future climate scenario of rainfall and temperatures was generated from 29 GCMs using the procedures described in the Guide for Running the Agricultural Model Inter-Comparison and Improvement Project (AGMIP) Climate Scenario Generation Tools. The GCMs were sourced from the Coupled Model Intercomparison Project 5 (CMIP5). Makerere University and the National Aeronautics and Space Administration Goddard Institute for Space Studies (NASA-GISS), USA, made the model available. The Simple Delta Method was used for statistical downscaling of the GCMs since it preserves the historical patterns of the gridded observations (Hamlet et al. 2010). The near-future climate scenarios were analyzed for two Representative Concentration Pathways (RCPs) greenhouse gas (GHG) emission scenarios: RCP 4.5 and RCP 8.5. Although the RCP 4.5 was considered as the most realistic scenario, this study also considers a catastrophic scenario (RCP 8.5) representing high GHG concentration levels (Chaturvedi et al. 2012) to test the efficiency of the SLWM technologies under extreme conditions. Plotting relative precipitation versus temperature change of 29 model outputs in the future enabled clustering them into five classes of model-predicted conditions namely cool/wet, cool/dry, hot/dry, hot/cool and the middle (assemble mean) (Subash et al., 2016) using an AGMIP developed script.

3.8 Data analysis

The study employed various statistical techniques to obtain socio-economic data from households and agricultural units. The regression model also determined relationships at $P<0.05$ level of significance. The effects on millet grain yield, and the managing and adaptive strategies related to climate change's impact on millet production. Percentages and frequencies were utilized to quantify respondents' perceptions of changing climate. Additionally, standard deviation, means, maximum and minimum values, relative standard deviation, and range were computed for precipitation and temperature data. The data was processed using SPSS version 16.0 and Excel software to meet the study objectives. To analyze annual rainfall and mean temperature for monotonic trends (that is to say one direction, either increasing or decreasing), the non-parametric Mann-Kendall trend test was employed. This rank-based test determined both the statistical significance of the trend and the direction of change. Also the researcher analysed the units of rainfall using the using an AGMIP developed script.

CHAPTER FOUR

PRESENTATION OF FINDINGS

4.1 Introduction

This chapter presents results on the trends of climate change and variability, the effects of climate change and variability on millet grain yields on an intermediate time scale and managing and adaptive strategies to climate change and variability in Gweri Sub County, Soroti district.

4.2 Demographic characteristics of the respondents

The background characteristics of the respondents were analyzed to gain insights into the individuals participating in the study on the impact of climate change and climate variability on millet production. These characteristics encompassed variables such as sex, age, education levels, conjugal status, employment status, household income source, and household size. Understanding these demographic factors provided valuable context for comprehending the respondents' perspectives and experiences concerning the effects of climate change and variability on millet production.

4.2.1 Sex of the Respondents

The data presented in Figure 4.1 revealed a notable gender disparity among the respondents, with 60 percent being male and only 40 percent being female. This gender distribution is of significance in understanding the impact of climate change and climate variability on millet production. By recognizing the different perspectives, roles, and experiences of male and female respondents, the study can gain valuable insights into how climate-related challenges affect millet production differently among genders.

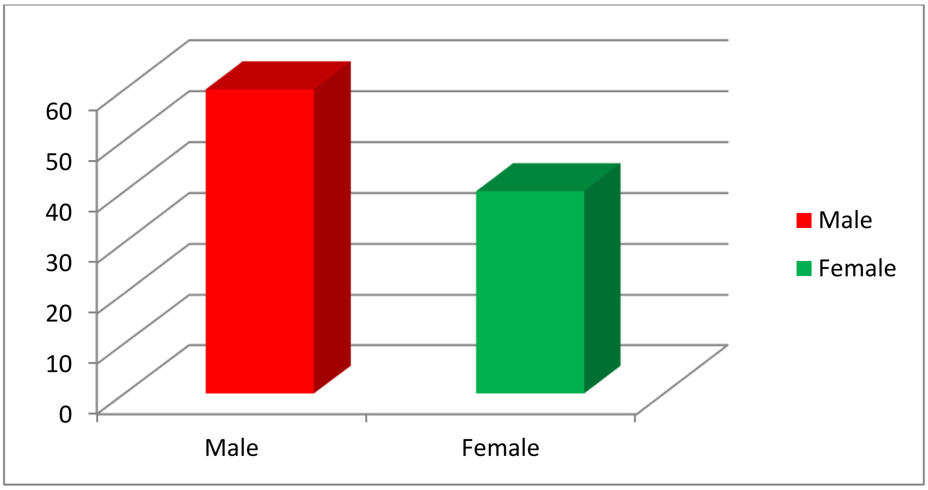


Figure 4.1: Sex of respondents

4.2.2 Age of the respondents

Results from figure 4.2 below shows that 35percent of the respondents were between the age brackets of 34 to 42 years, 30% of the respondents were between the age brackets of 26 to 33 years, further still 23% of the respondents were 43 years and above and only 12% of the respondents were between 18-25 years. This age-wise breakdown holds significance in understanding the implications of climate change and climate variability on millet production. The varying age groups might have distinct perspectives, experiences, and adaptive capacities to cope with the changing climatic conditions that impact millet farming. Older respondents, for instance, might possess traditional knowledge and strategies passed down through generations, but could face challenges in adapting to new and unpredictable climate patterns. On the other hand, younger respondents may be more open to adopting modern agricultural practices but might lack the wisdom gained from years of farming experience.

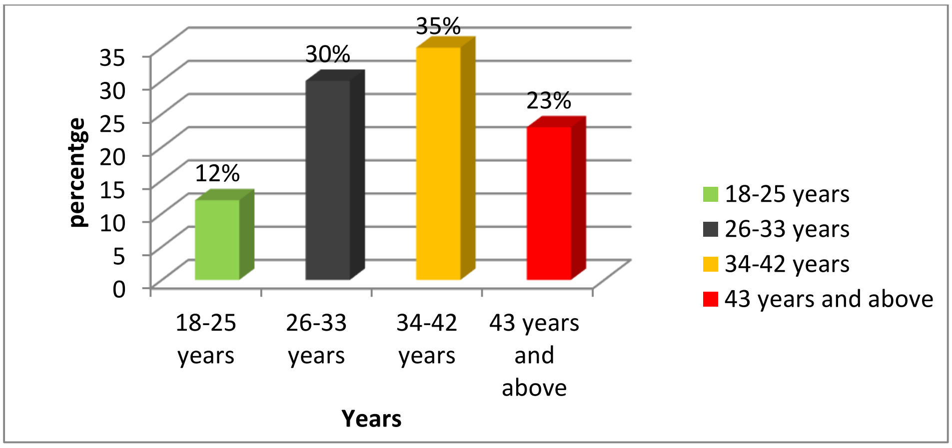


Figure 4.2: Age of respondents

4.2.3 Education levels of the respondents

The data presented in Figure 4.3 provides valuable insights into the educational backgrounds of the respondents. The varying levels of education among respondents, with 42% having attained other tertiary levels of education, 20% holding university degrees, 18% with secondary education, 12% having completed primary education, and only 8% with no formal education, highlight the potential influence of education on farmers' abilities to adapt to climate challenges. Higher educational attainment, particularly at the university and other tertiary levels, may equip farmers with advanced knowledge and skills, facilitating the adoption of innovative climate-resilient agricultural practices. Conversely, those with lower educational levels might face more significant barriers in accessing information and implementing adaptive strategies.

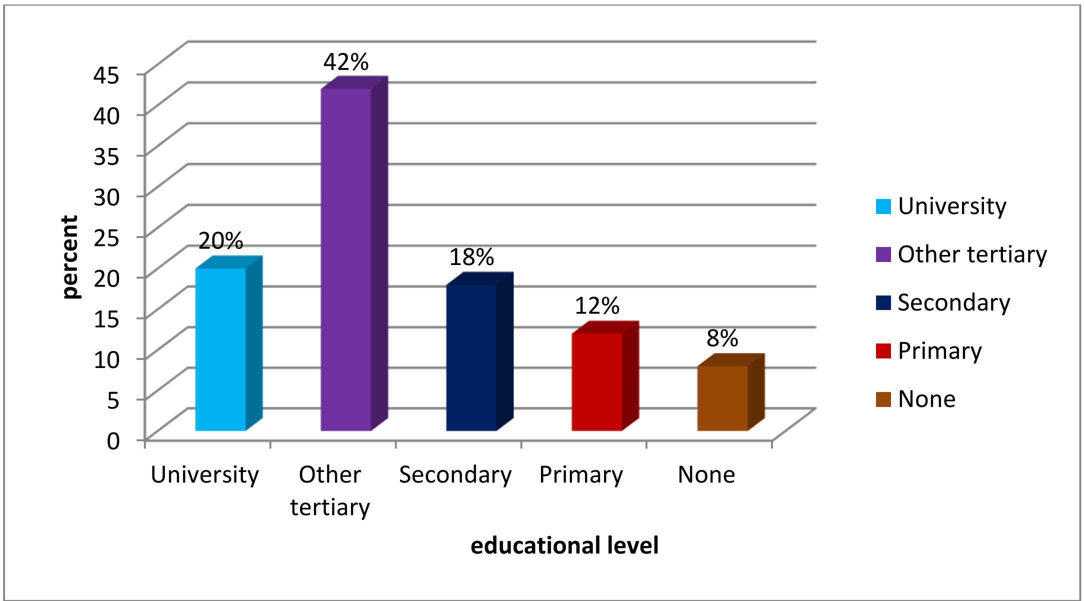


Figure 4.3 Education levels of respondents

4.2.4 Employment status of respondents

The data depicted in Figure 4.4 sheds light on the employment status of respondents in Gweri Sub County. With 52 percent of the respondents being employed and only 48 percent being unemployed, it indicates that a majority of the participants rely on employment as their primary livelihood source. Employment may offer a level of financial stability and access to resources that can help farmers withstand climate-related challenges, such as investing in drought-resistant crops, irrigation systems, or adopting modern agricultural practices. On the other hand, those who are unemployed might face additional vulnerabilities, with limited means to cope with climate uncertainties.

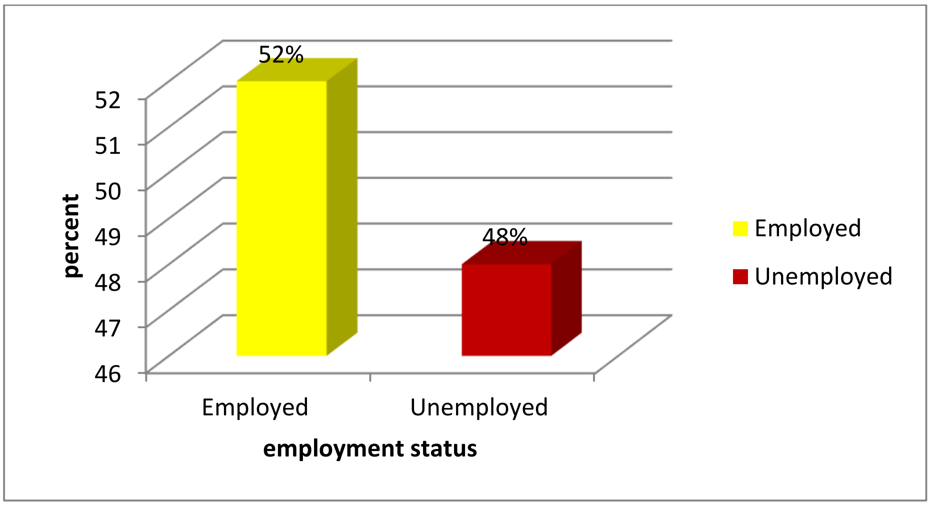
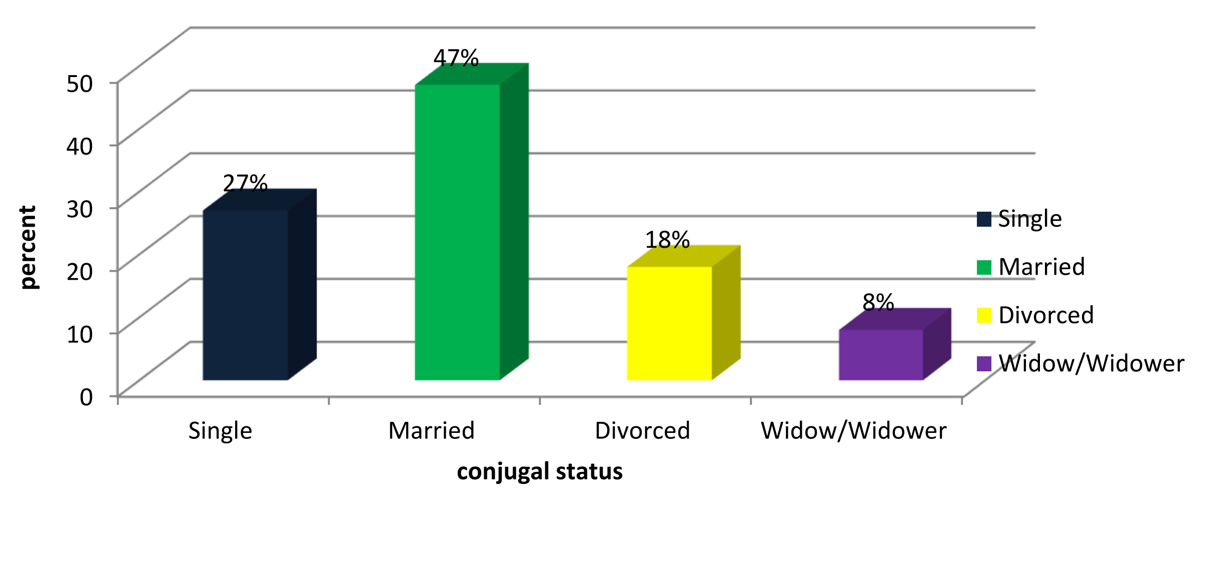


Figure 4.4 Employment status of respondents

4.2.5 Conjugal status of respondents

The conjugal status of the respondents was also important to be considered since the marital status can determine the numbers of respondents who have other responsibilities such as engaging in crop diversification as an adaptation since they have a large family to take care of thus they need to earn a living. Figure 4.5 below shows that 47% of the respondents were married, 27% of the respondents replied single, 18% of the respondents replied divorced and only 8% of the respondents said Widow/Widower. This therefore implied that 47 percent of the respondents were married and this status provides a supportive environment for implementing climate adaptation strategies. With multiple family members working together, there is increased labor availability, enabling the adoption of labor-intensive practices during critical stages of millet production, such as planting and harvesting.

Figure 4.5: Conjugal status of respondents



4.2.6 Source of income

Figure 4.6 below indicates that 40% of the respondents were engaged in farming activities as the source of income, 30% of the respondents were self-employed, 12% of the respondents were business man/woman, 10 percent were civic servants and 8percent of the respondents were housewife. This therefore implies that 40 percent of the respondents were mainly engaged in farming activities for their livelihoods and any climate-related disruptions can have a direct and profound effect on their income and well-being. Changes in temperature, precipitation patterns, and extreme weather events can pose challenges to agricultural practices, affecting crop growth, water availability, and overall farm productivity.

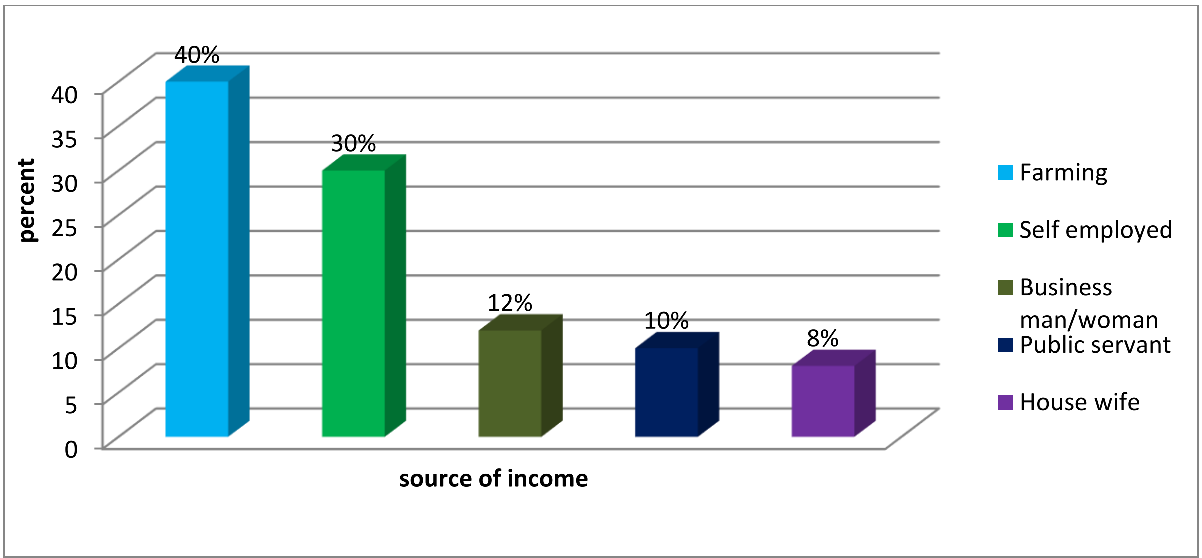


Figure 4.6: Source of income

4.2.7 Size of household members

The researcher was interested in understanding the size of household members and the results in the Figure 4.7 below shows that 35percent revealed that the household size is between 4-6 members, 25% of the respondents revealed that the household size is between 1-3 members, 22% of the respondents revealed that the household size is between 7-10 members and only 18% of the respondents were 10 members. This therefore implies that percentage of the respondents revealed that they were between 4-6 members which signify higher resource demands and consumption needs, making these households potentially more vulnerable to climate-induced challenges. With more family members relying on the farm for sustenance, there could be increased pressure on agricultural resources and a greater need for successful crop yields to meet the household's requirements.

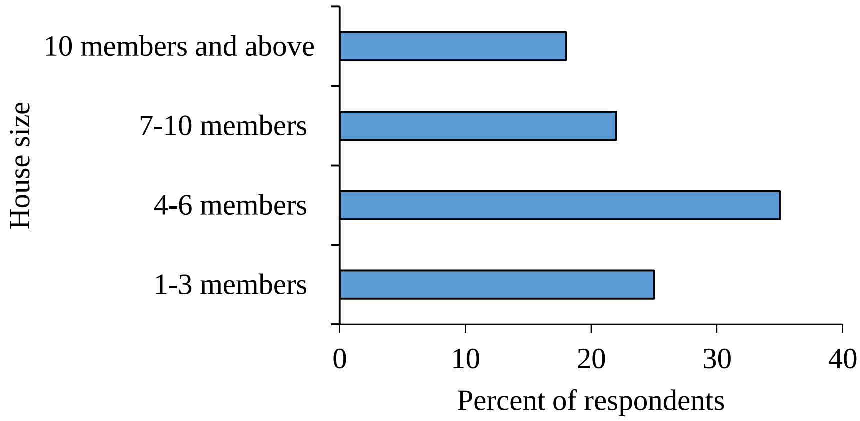


Figure 4.7: Size of households in Gweri Sub County.

4.3 Trends of climate change and variability

4.3.1 Trends of historical annual mean rainfall and mean temperatures (1980-2009).

Figure 4.8 presents the historical annual precipitation and mean temperature data for the period 1980-2009 in the study area. The results show fluctuations in annual rainfall, with notable increases recorded in 1991, 2001, and 1988, while 1993 experienced the minimum rainfall. The variations in annual rainfall are evident from the data. The Uganda National Meteorological Centre (NMC) has documented an average annual rainfall of 1000 mm for Gweri Sub County.

Figure 4.8 illustrates the historical mean temperature data for the period 1980-2009 in the study area. Notably, there was a noticeable rise in temperature in the year 2009, recording

26.44°C, closely followed by 2002 and 2005. In contrast, the year 1985 saw a decrease in the mean temperature with a value of 24.56°C, followed by 1994. On average, the temperature of Gweri Sub County is reported to be 27°C (80.73°F). This temperature trend provides crucial insights into the climatic changes experienced in the region over the specified period.

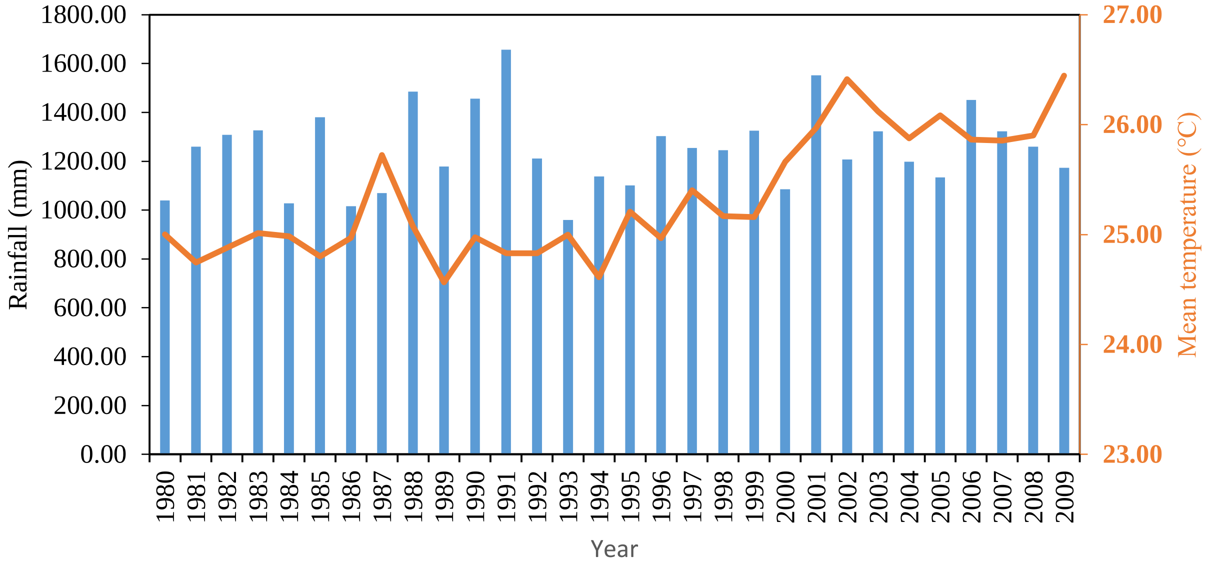


Figure 4.8 Historical annual rainfall and mean temperature (1980-2009) in Gweri Sub County.

Further, results from the trend analysis for the annual rainfall and temperature in Figure 4.9 indicate that all the climate parameters show a significant trend at 5% least significant level i.e. 95% confidence level. The highest rainfall was observed between the year 2000 and 2002 while the lowest in these parameters is noticed from 1992 -1996. The increasing trend in mean temperature has a negative impact on the moisture content for the crop growth i.e. leads to increase in evapotranspiration. The increase in rainfall has two sided impacts; one is an increase in the soil moisture and thus improved soil water requirements for crop growth and on the other side, higher chance of flooding which may destroy the crops and other resources within the study area. Therefore, management should consider both sides of the impact.

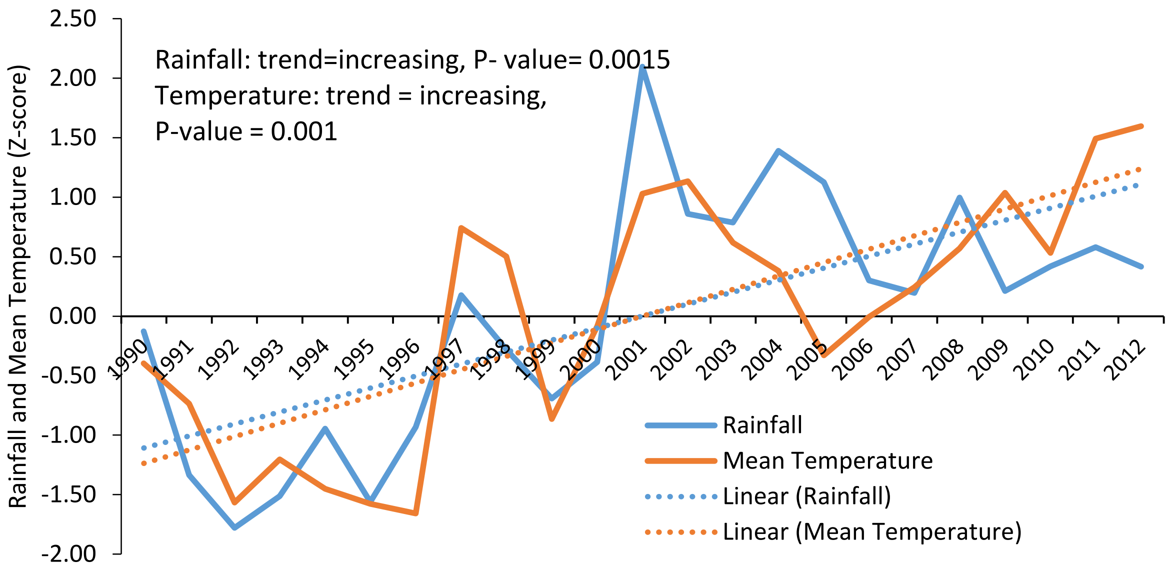


Figure 4.9 Trend analysis of annual rainfall and mean temperature for the study area

4.3.2 Projected climate change and variability in Gweri sub county

Figure 4.10 indicates projected annual rainfall and annual mean temperatures form the year 2010 to 2039 Rainfall is expected to decrease in the year 2023 with 1004.3 followed by 2030. In the year 2031 rainfall is most likely to increase with 1651.9 followed by the year 2036 with 1569.2 and this supports millet production. Annual mean temperature indicates constant increase in the year 2025 followed by 2027 and 2030. In 2032 and 2039 mean temperature is expected to increase highly and this can affect millet grain yields due to increasing temperature. In 2024 and 2026 mean temperature is expected to decrease.

The annual rainfall and annual mean temperature projections depicted in Figure 4.10 for Gweri Sub County were established through a cooperative initiative involving the Agricultural Model Intercomparison and Improvement Project (AGMIP). In this endeavor, 29 Global Climate Models (GCMs) were harnessed to simulate and forecast forthcoming climate conditions specific to Gweri Sub County. These models took into account various greenhouse gas emission scenarios and other pertinent factors relevant to the region's climate.

The combined effect of temperature and rainfall is crucial in determining crop productivity. If the increase in temperature is accompanied by adequate rainfall, it may support plant growth and photosynthesis, leading to positive effects on millet grain yields. The availability of water is a critical factor, as increased temperatures can lead to higher evaporation rates, and if there is insufficient water supply, it can result in heat stress and negatively impact crop yields.

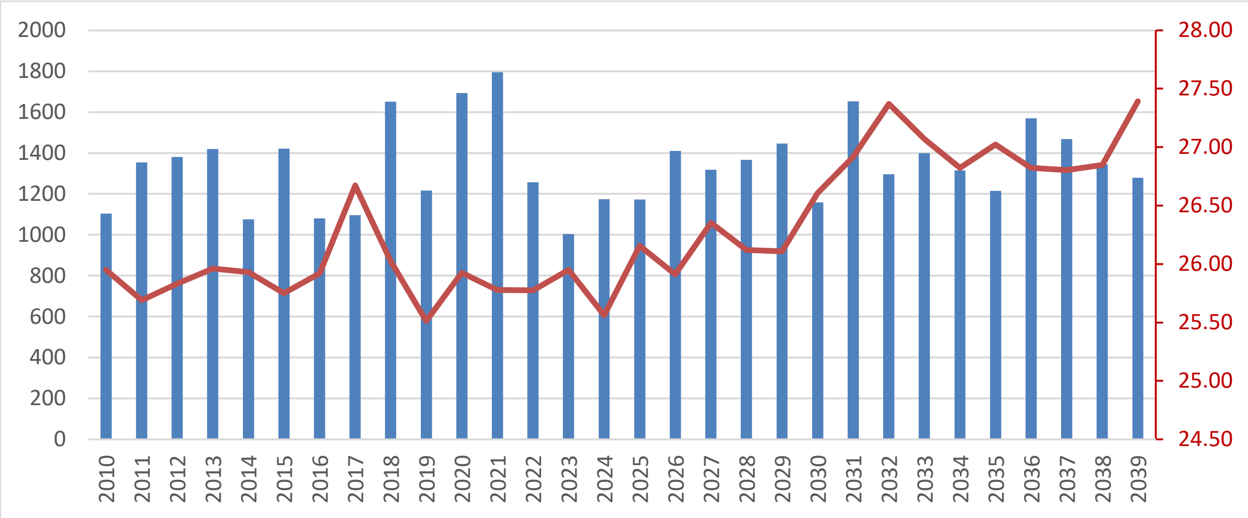


Figure 4.10 Annual rainfall and annual mean temperature

4.3.3 Projected climate change and variability in Gweri sub county

Figure 4.11 illustrates the projected climate change and variability in Gweri Sub County, focusing on two Representative Concentration Pathways (RCPs): RCP 8.5 and RCP 4.5. According to the model, both RCP scenarios forecast an increase in annual rainfall in the year 2031, with RCP 8.5 projecting 1830.6 and RCP 4.5 predicting 1651.9 mm of rainfall. The years 2036 and 2033 are also expected to experience increased annual rainfall under both scenarios. Conversely, the model predicts a decrease in annual rainfall for both RCP 8.5 and RCP 4.5 in the year 2023, with values of 1124.4 and 1004.3 mm, respectively. These projections indicate the potential variability in future precipitation patterns, highlighting the significance of considering climate adaptation strategies to cope with changing rainfall regimes in Gweri Sub County.

These projections are based on a combination of climatic data and regional climate modelling techniques, taking into account specific parameters that characterize Gweri Sub County. These parameters may include historical climatic data for the region, such as temperature and rainfall records over several years.

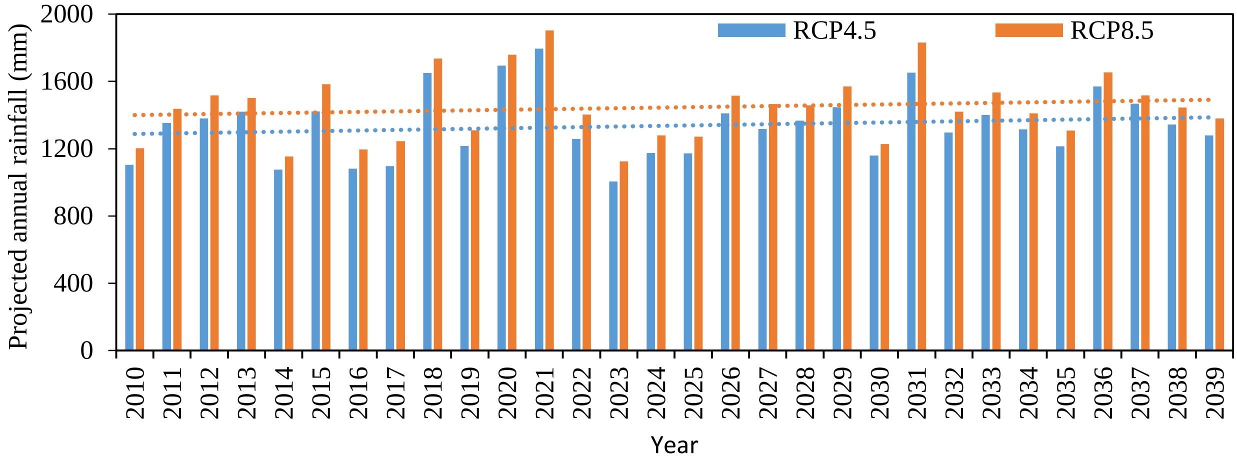


Figure 4.11 Projected annual rainfall variability in Gweri Sub County

4.3.4 Projected annual mean temperature in Gweri Sub County

In the figure 4.12, all models RCP 8.5 and RCP 4.5 predicts a constant increase in annual mean temperature in Gweri Sub County with 27.56 in year 2032, followed by the year and 2039. However since the annual mean temperatures did not go below 26°C, according to Maiti (1996) temperatures continue to be at optimum ranges for millet yield growth and there the area is expected to continue supporting millet growth.

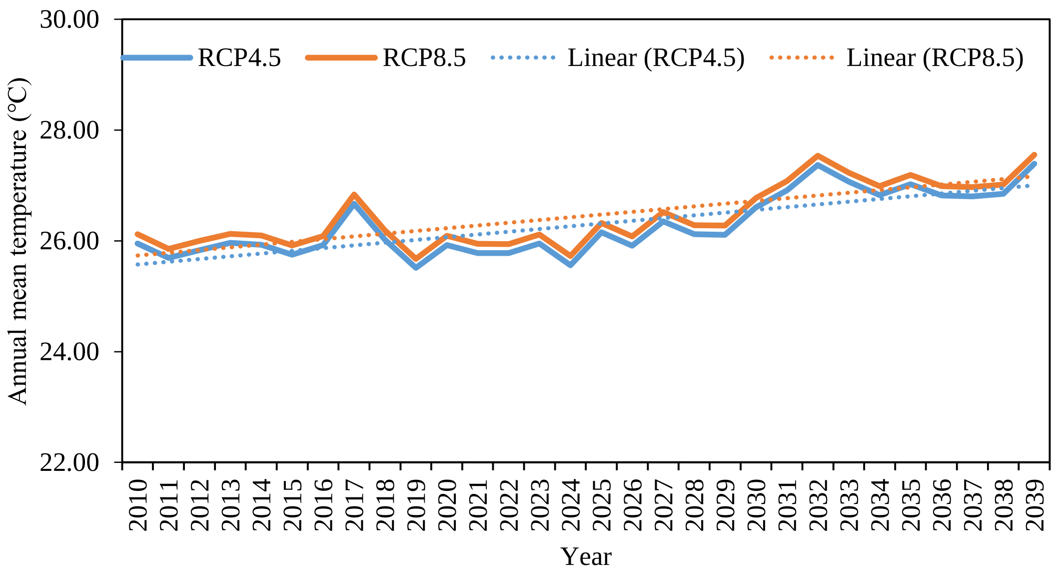


Figure 4.12 Annual projected mean temperatures in Gweri Sub County

4.3.5 Seasonal climate variability

Gweri Sub County has bi-model seasons (two rainy seasons), the first rainy season starts in March, April and May and another one begins from September, October and November. In the season of MAM rainfall is highly received in April as indicated in the RCP 8.5 with 235.02mm, followed by May and March. Whereas in the SON season rainfall is highly received in October as indicated in the RCP 8.5 with 182.26mm followed by September and November. Basing on the interviews conducted, it was found out that people mainly get more yield in the second season (SON) compared to the first season of MAM.

One of the farmers revealed that *"they have two rainy seasons and one in March, April, and May (MAM) and the other in September, October, and November (SON). I've been farming millet for many years, and I've noticed a trend. During the SON season, we usually receive more rainfall, especially in October. This increased rainfall helps in providing adequate moisture for the millet crops, resulting in higher yields compared to the MAM season. The abundant rainfall during SON creates favorable conditions for millet growth and development, leading to a more productive harvest".*

In addition, another farmer revealed that *"in Gweri Sub County, the rainy seasons play a significant role in our millet production. During the MAM season, while we receive some rainfall, it is often not as consistent or substantial as in the SON season. This variability affects our millet crops, and we sometimes face water stress during critical growth stages. However, in the SON season, we typically get more rainfall, particularly in October, which boosts our millet yields. So, we tend to rely more on the SON season for better harvests and income from millet farming".*

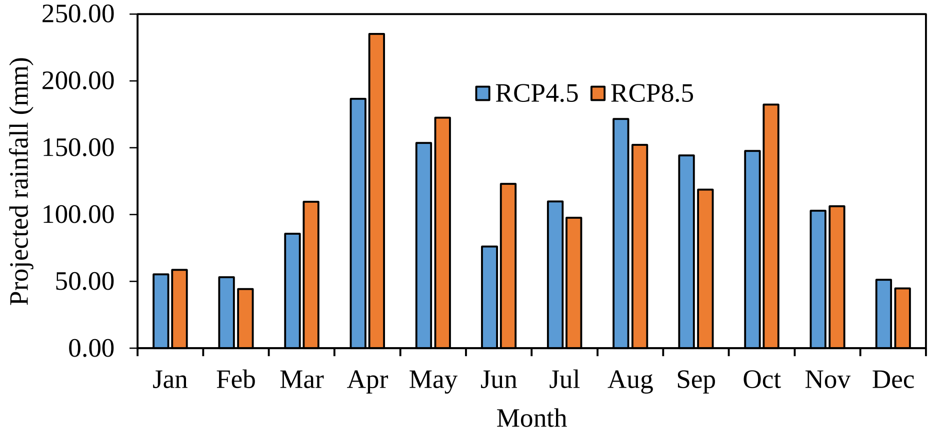


Figure 4.13 Monthly projected rainfall in Gweri Sub County

RCP 4.5 and RCP 8.5 depict a notable upward trend in the mean temperature during the months of January, February, and March, with February in RCP 8.5 showing the highest temperature at 29.03°C, which is favorable for millet production in Gweri Sub County, as indicated in Figure 4.14. Conversely, during the months of May, June, and July, there is a decrease in the mean temperature, with July in RCP 8.5 indicating a significant decrease to 24.81°C, as illustrated in the graph.

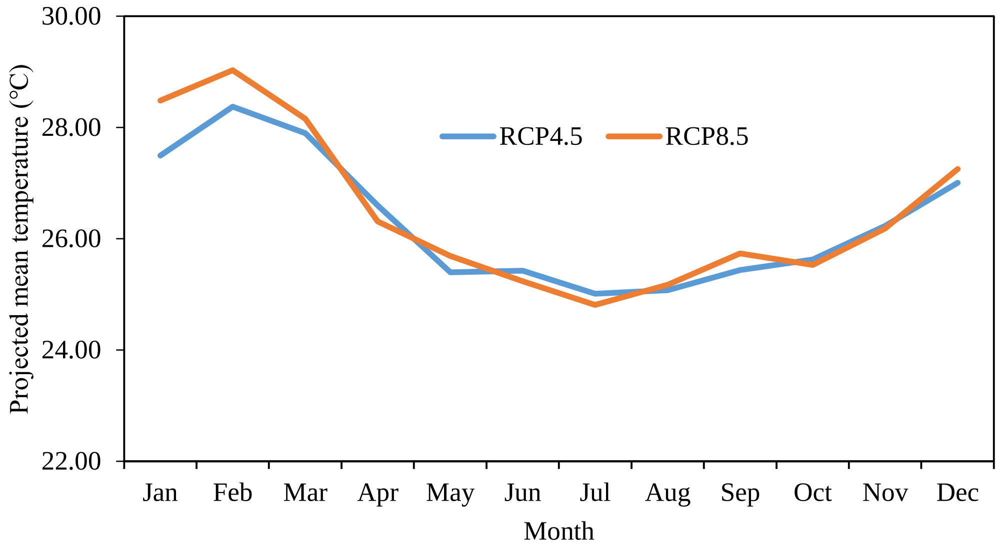


Figure 4.14 Monthly projected temperatures for Gweri Sub County

4.3.6 Climate change signals

In the table 4.1 below indicates an annual rainfall and mean temperature projected for the ensemble mean under RCP 4.5 and RCP 8.5. Increase in rainfall amount is likely to be experienced for all the RCPs, with a relatively higher increase for the RCP. 8.5 (15.8%). An increment in mean temperature is expected with a relatively higher temperature change (1.1 ^{o}C) for RCP 8.5.

Table 4.1 Projected annual change in rainfall and mean temperature

	Reference (1980-2009)	*RCP4.5*	*RCP8.5*
Relative change in rainfall	1248.2 mm	7.2%	15.8%
Δ temperature (℃)	25.3	0.9^{0}c	1.1^{o}c

According to figure 4.15 Monthly rainfall is projected to increase according to the change of rainfall model in the two RCP scenarios. The rainfall pattern is affected during both the dry and rainy season. The dry seasons are likely to receive more rains while the rainy seasons are likely to receive high rain for RCP 8.5 compared to RCP 4.5. The highest increase occurs in January with 98.65mm under RCP 8.5, whereas the lowest decrease is -21.42mm in June under RCP 4.5. The dry months of January, February and December will receive additional rainfall in the two RCP scenarios. The months of May, July, September and November can be seen as transition months with few changes in rainfall compared to the months of January, February and December. Under both scenarios, monthly rainfall is projected to increase, affecting both dry and rainy seasons. Specifically, dry months like January, February, and December are likely to receive additional rainfall, while the rainy months experience even higher rainfall under RCP 8.5 compared to RCP 4.5.

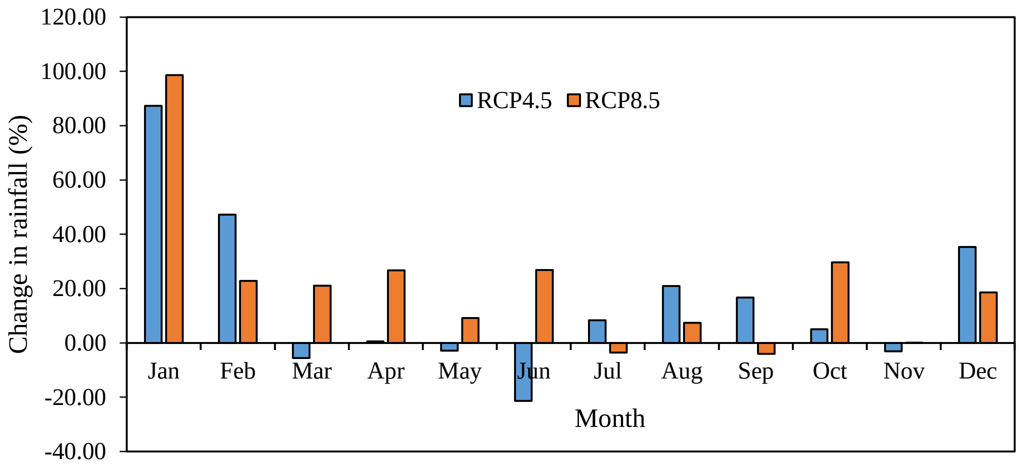


Figure 4.15 Monthly projected changes in rainfall and mean temperature

The researcher was interested in understanding whether respondents had noticed changes in rainfall and mean temperature and the results are presented in the figure 4.16 below. Results indicates 90% respondents noticed changes in rainfall and mean temperature and only 10% of the respondents said that they had not noticed any change in rainfall and mean temperature. This implied that majority of the respondents were aware of rainfall and mean temperature that occurred over the past three decades.

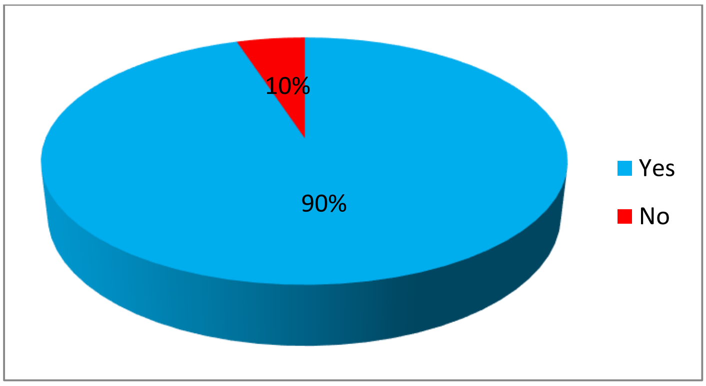


Figure 4.16: Whether respondents noticed changes in climate

4.3.7 Season that has changed most

The researcher was interested in understanding the season that has changed most during the study period. The figure 4.17 below indicates 85% of respondents said wet season (March, April, May and September, October, November) has changed mostly due to rainfall, mean temperature, blustery weather speed direction and humidity among others while 15% of the respondents supported that the dry season (Late November to early March) has changed most due to the various parameters. The observed changes in the wet and dry seasons have implications on agricultural practices, water availability, and overall ecosystem dynamics in the region.

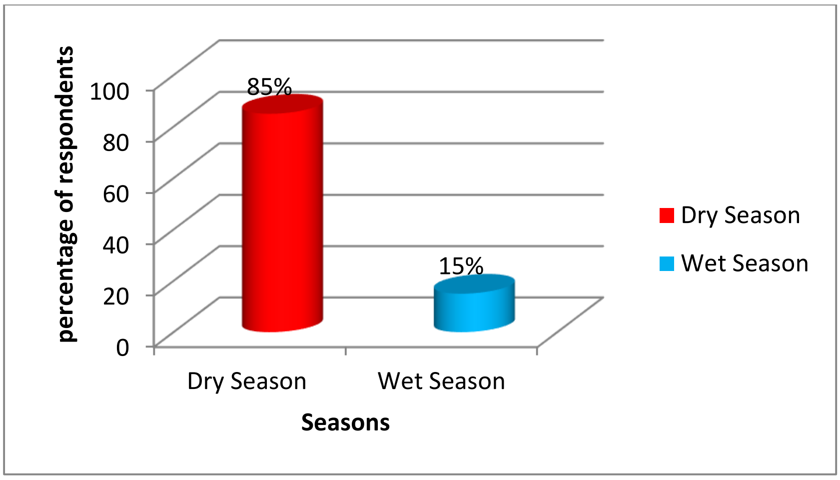


Figure 4.17 Season that has changed most due to parameters

4.3.8 Predictable onset rain currently compared 30 years back

The researcher was interested in understanding predictable onset rain currently compared to 30 years back and the results are presented in the Figure below. Results from the Figure 4.18 above indicates that 68 percent said the onset rain for 30 years back was less predictable/unpredictable, 27% of the respondents acknowledged that the onset rain for 30 years back was predictable and only 5% of the respondents said that they do not know. This therefore implies that percentage of the respondents said that the onset rain was less predictable/ unpredictable.

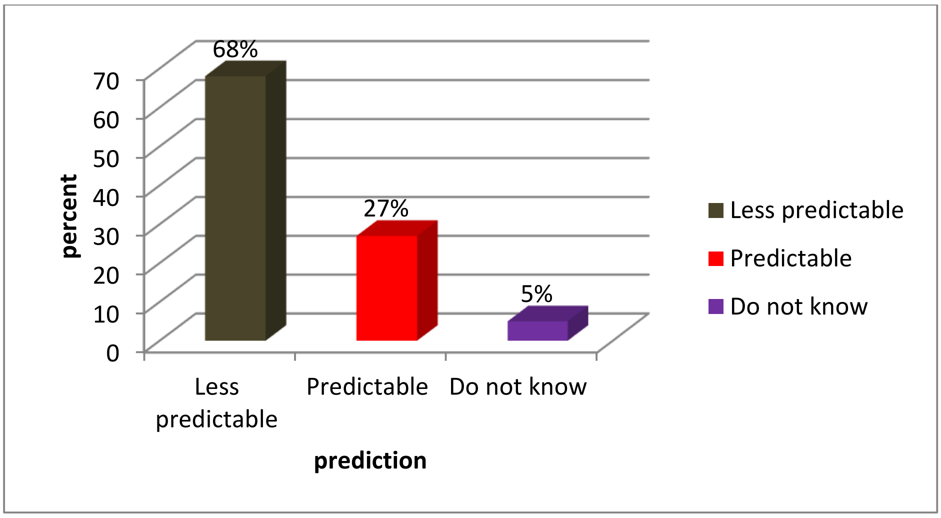


Figure 4.18: Predictable onset rain currently compared to 30 years back

Source: primary data

4.3.9 How frequent information concerning climate change is received

In Figure 4.19, the research findings reveal that a majority of the respondents, accounting for 53%, receive information about climate change on a daily basis. Additionally, 40% of the respondents reported receiving such information on a weekly basis, while only 3% stated they receive it once a month, indicating the least frequency. This suggests that the respondents generally stay updated with information about changing climate conditions on a daily basis. The regular access to climate change information can play a crucial role in enhancing awareness and preparedness among farmers in Gweri Sub County regarding the potential impacts of climate change and climate variability on millet production.

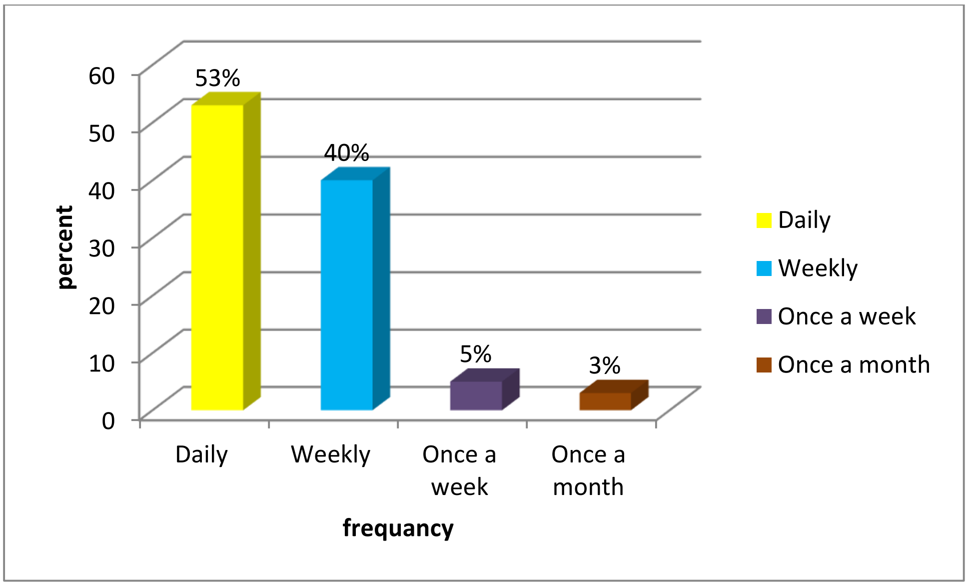


Figure 4.19: How frequent information concerning climate change is received

4.3.10 Media used to receive information concerning climate change

In Figure 4.20, the research findings demonstrate that the primary media source for receiving information concerning climate change among respondents is radio, accounting for 55%. Additionally, 18% of the respondents rely on information shared by members of the village, 15% receive information through seminars and workshops, and only 12% access it through extension workers. This indicates that radio is the most prevalent and accessible medium through which respondents receive information about climate change. Leveraging radio as a widely used platform to disseminate knowledge and provide best practices related to climate change and resilience in millet production. By broadcasting valuable information through radio programs, farmers in Gweri Sub County are equipped with the necessary tools to effectively respond to the effects of climate change on millet production.

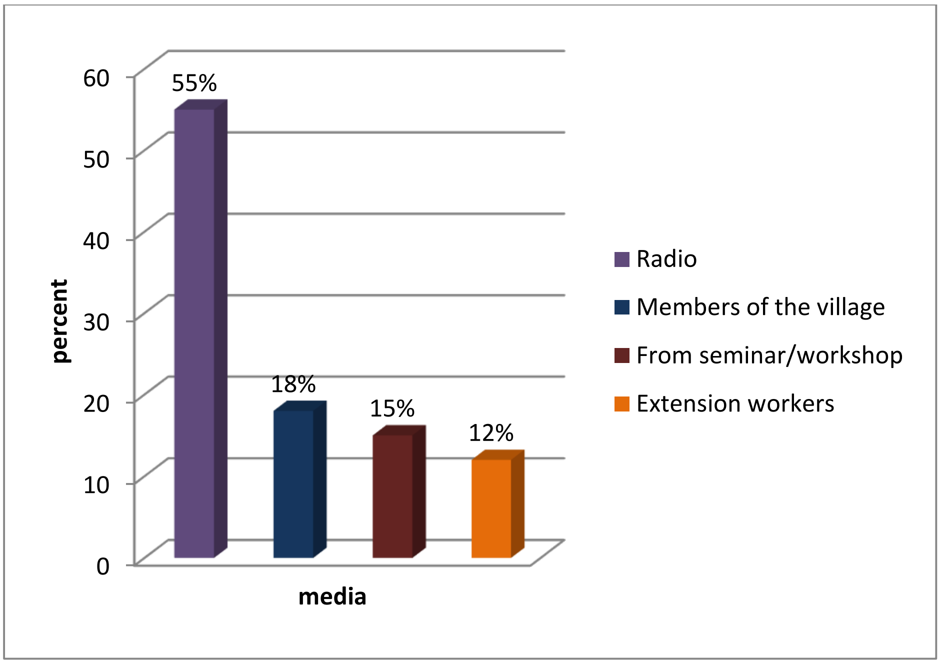


Figure 4.20: Media used to receive information concerning climate change

4.4 Effect of climate change and variability on millet grain yields.

The responses provided by the respondents to the various questions were of paramount importance to the researcher's investigation into the effects of climate change and variability on millet grain yields.

4.4.1 Whether climate change and variability affect millet yields

Based on Figure 4.21, it is evident that the majority of the respondents, comprising 95%, perceive that variations in climate have a significant impact on millet grain yields. Conversely, only 5% of the respondents believe that climate change and variability do not influence millet production. This suggests that the respondents' perceptions are aligned with the notion that changes in climate conditions play a crucial role in affecting millet yields.

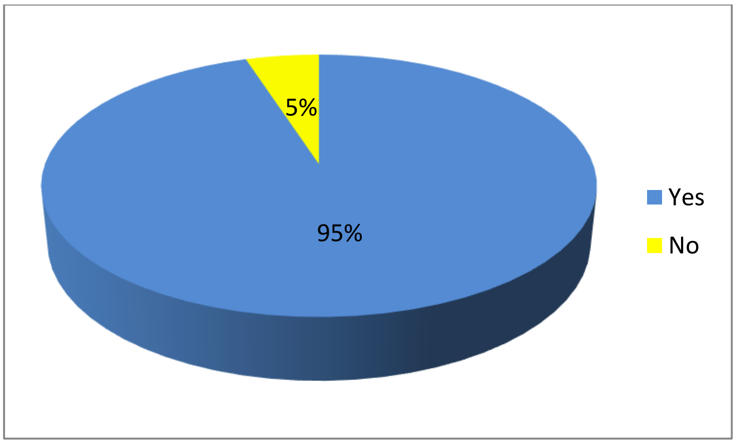


Figure 4.21: Whether climate change and variability affect millet yields

4.4.2 Causes of climate changes to affect millet yields

According to Figure 4.22, cutting down trees was identified by 38% of the respondents as the primary cause of climate change in their area, leading to adverse effects on millet grain yields. The respondents believe that trees play a crucial role in rainfall formation, and their destruction can result in prolonged droughts and dry spells, negatively impacting millet production. Additionally, 23% of the respondents pointed out burning coal, oil, and gas as a significant contributor to climate change due to the production of carbon dioxide and nitrous oxide emissions. Furthermore, 17% attributed increasing livestock farming, 12% mentioned fertilizers containing nitrogen, and 10% referred to fluorinated gases as additional factors contributing to climate change. Overall, the respondents' views suggest that deforestation is the key factor causing climate change in their area, ultimately affecting millet grain yields.

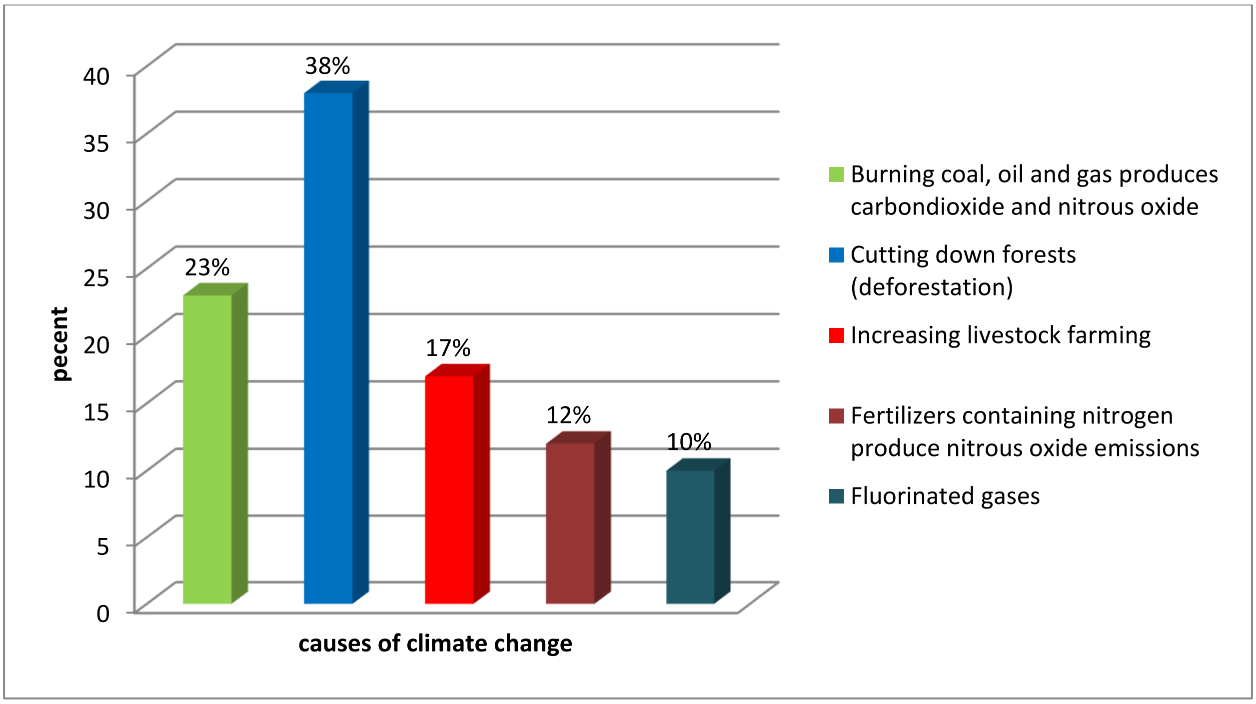


Figure 4.22: Causes of climate changes to affect millet yields

Source: primary data

4.4.3 Climate change and variability affecting millet yields

Based on the findings in figure 4.23, 43% of the respondents identified excessive precipitation as the major factor of climate change and variability that affects millet yields. In contrast, 35% of the respondents highlighted the impact of insufficient rainfall, while 12% pointed out the adverse effects of drought conditions. Only 10% of the respondents indicated floods as a significant factor affecting millet production. These responses collectively demonstrate that the majority of the respondents attribute the adverse impacts on millet yields to the excessive rainfall, implying that too much precipitation is the major factor of climate change and variability influencing millet production in their area.

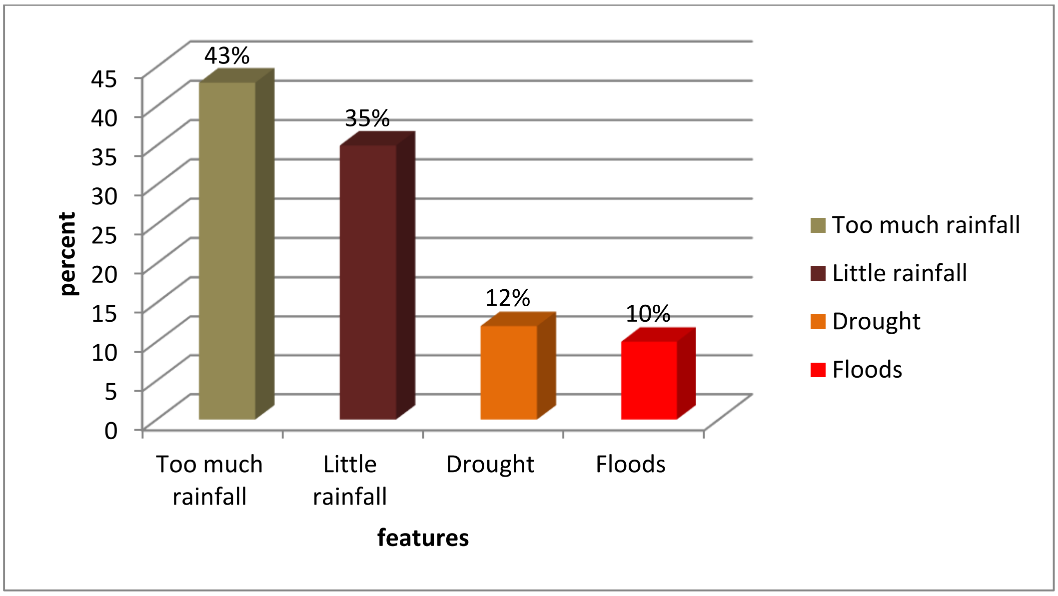


Figure 4.23 climate change and variability affecting millet yields

4.4.4 Effects of climate change and variability on millet grain yields

Results from the Figure 4.24 below shows that 35 percent of the respondents said that major impact of climate change and variability on millet grain yields is that amounts of precipitation have changed, 28 percent said change in precipitation timing, 15 percent of the respondents said precipitation duration has changed, 12 percent of the respondents said that change in millet yields have and only 10 percent of the respondents said millet failure is high. This implies that the major impact of climate change and variability on millet grain yields is that rainfall amounts have changed.

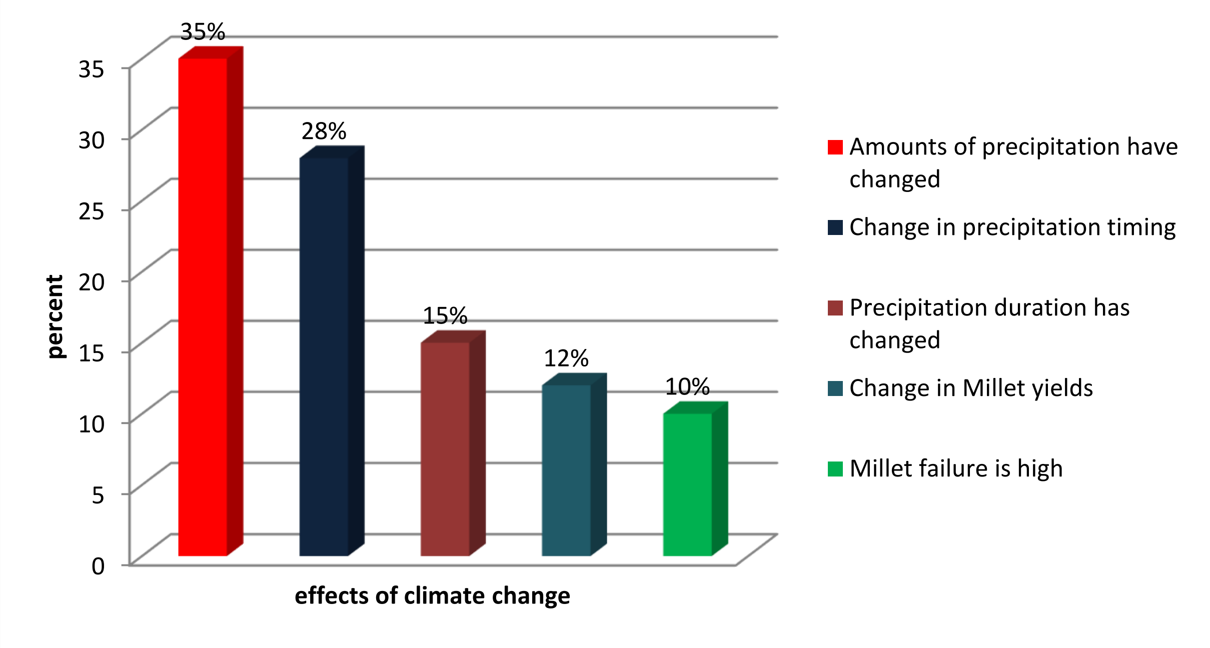


Figure 4.24: Effects of climate change and variability on millet grain yields

4.5 Coping and adaptive strategies to climate change and variability

Respondents were asked to show their responses on various questions. These were important question as they helped the researcher to know about the managing and adaptive strategies to climate change and variability and the findings are presented as below.

4.5.1 How the effects of climate variability and change has been coped up

The data presented in figure 4.25 highlights the coping mechanisms adopted by respondents to deal with the effects of climate variability and change on millet production. Among the respondents, 38% of respondents mentioned that their primary approach during drought was to request water from neighbors located outside of Gweri Sub County, often in neighboring areas close to Lake Kyoga. Additionally, 23% mentioned migration from water-stressed areas, 20% reported seeking assistance from veterinary personnel, 12% practiced water harvesting, and only 7% focused on pasture preservation. These findings indicate that a significant portion of the respondents relies on community support, particularly in times of water scarcity, as a coping strategy to address the challenges posed by climate variability and change on millet production.

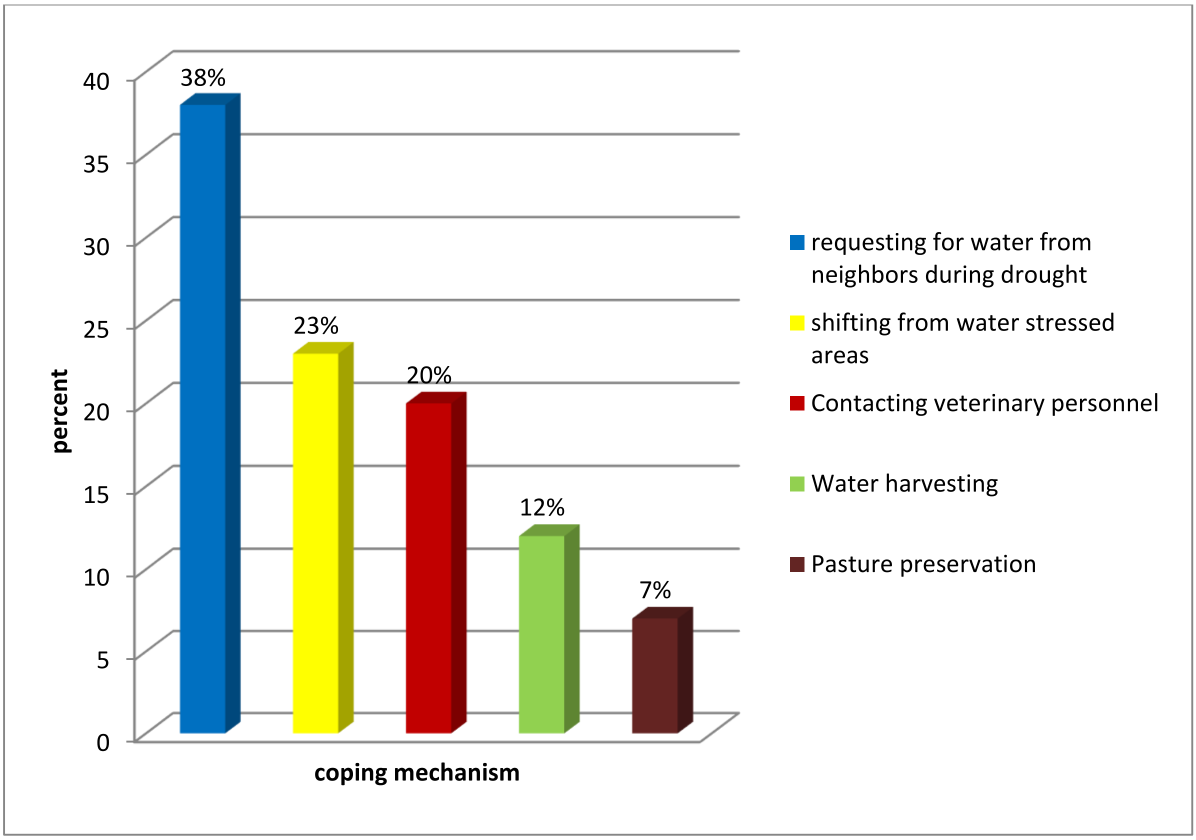


Figure 4.25: How the effects of climate variability and change has been coped up

Source: primary data

4.5.2 Strategies undertaken to decrease effects caused by climate variation

Results from the Figure 4.26 below indicates that 38% of the respondents said mounting improved crop varieties, 23% of respondents said mixed cropping, 20% of the respondents said growing of second season yields in first season and growing of first season yields in second period, 12% of the respondents said shifting from water stressed and flood prone areas.

And only 7% of the respondents said adapting planting dates and diversification of production. This therefore implies that mounting improved crop varieties as the major strategy carry out to decrease the effects caused by climate change and variability

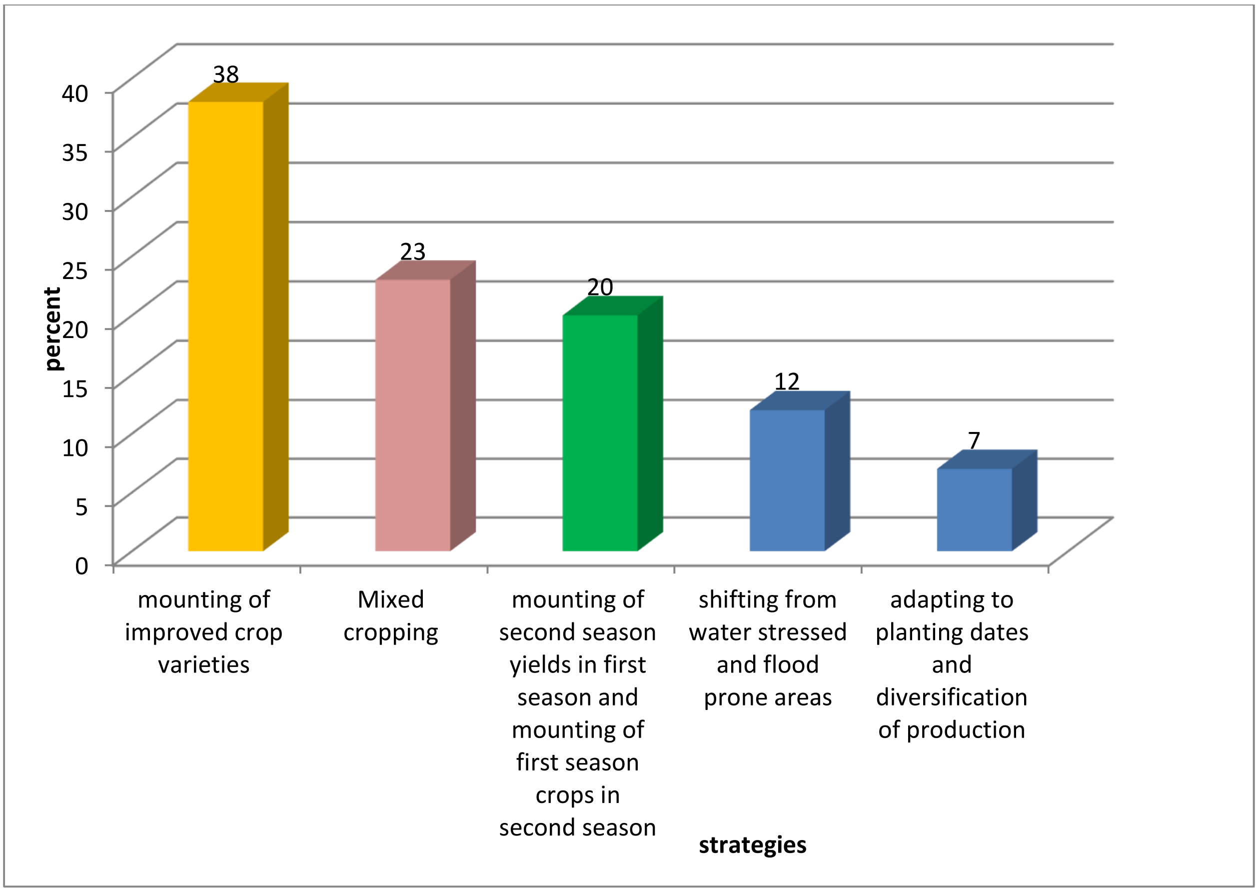


Figure 4.26: Strategies undertaken to decrease the effects of climate change and variability

4.6 Discussion of findings

This section discusses findings on the trend of climate change and variability, the effects of climate change and variability on millet grain yields and managing and adaptive plans to climate change and variability in Gweri sub-county, Soroti district.

4.6.1 Change in rainfall and temperature in Gweri sub-county Soroti district

The findings from this study reveal that a significant percentage of the respondents who participated in the research have noticed changes in climate. Moreover, their views align closely with the information derived from meteorological data. The data collected from meteorological sources seem to be consistent with the observations and perceptions of the respondents regarding climate change and its effects. 85 percent of the respondents acknowledged change in the length of seasons, increase in temperatures; decrease in rainfall; flooding, increased droughts, and robust winds had become regular and severe. As a result, climate change response interventions require involving various people so as to get a holistic understanding of about climatic changes. Particularly Radios are the main old-style medium used in catastrophe management. With insufficient seminar/workshop and low participation of extension workers, radio remains the most frequently used media to receive information concerning climate change and this media is most widely accessible to the underprivileged households. Radios are fundamental media for spreading information especially in under rural areas. Evans, (2018) asserted that households get weather information from numerous media outlets and rural local institutions for resistance radios, newspapers.

The observed trend in annual rainfall indicates fluctuations in precipitation over the years, with notable increases in 1991, 2001, and 1988, while 1993 experienced the least annual rainfall. These dissimilarities point to changes in annual rainfall patterns, reflecting the variability of climate conditions. Todd (2013) noted that in tropical regions, the erraticism in rainfall amounts is largely attributed to the unpredictable shift of the inter-tropical convergence zone, which influences the distribution of rainfall. Similarly, the trend in mean temperature shows fluctuations, with an increase in temperature observed in the year 2009, followed by 2002 and 2005. Conversely, in 1985, there was a decrease in mean temperature, followed by 1994. These temperature variations indicate the variability in climate conditions, with fluctuations in mean temperatures over the years.

4.6.2: Effects of climate variation on millet yields

Figure 4.5 of chapter four, Gweri Sub County experiences two distinct rainy seasons. The first rainy season occurs from March to May (MAM), and the second rainy season takes place from September to November (SON). In the MAM period, the highest rainfall is received in April, with 235.02mm under the RCP 8.5 scenario, followed by May and March. Similarly, during the SON season, the peak rainfall is observed in October, with 182.26mm under the RCP 8.5 scenario, followed by September and November. These findings align with Jawoo's (2013) study, which suggests that changing climate will have diverse impacts on millet production under rain-fed agricultural systems. The variations in rainfall patterns in Gweri Sub County can significantly affect millet growing, potentially leading to fluctuations in millet yields.

According to the data presented in Figure 4.14 of chapter four, both RCP 4.5 and RCP 8.5 scenarios show a relative increase in mean temperatures during the months of January, February, and March. The highest temperatures are observed in February under RCP 8.5, reaching 29.03°C. This temperature range seems to be favorable for the production of millet in Gweri Sub County. However, in the months of May, June, and July, the mean temperatures decreased, with July showing a significant drop in temperature under RCP 8.5, reaching 24.81°C as depicted in the graph. The study findings align with Maiti's (1996) assertion that the projected temperatures fall within the optimum range for vegetation growth, which is between 25°C and 28°C for reproductive growth. This suggests that the temperature conditions in Gweri Sub County could be suitable for millet production, as they fall within the favorable range for the crop's reproductive stage.

Figure 4.24 indicates, 35% of the respondents revealed that the major impact of climate change and variability on millet grain yields is the alteration in rainfall amounts. Several studies corroborate these results, projecting a potential reduction in millet production in the near future. Projections indicate that millet yields may decline by 13% in 2025 and further decrease by 26% in 2050 due to the effects of changing climatic conditions. Additionally, the results from Table 4.24 support these findings, with 28% of respondents acknowledging changes in rainfall timing. This agreement aligns with the assertions made by Marshall et al. (2009), who emphasized that climate change which lead to detrimental effects on millet production, warranting greater attention to assessing the risks posed to African agriculture under a changing climate.

In addition to the above, the study findings revealed that respondents reported various impacts of climate change and variability on millet grain yields. Approximately 15% of the respondents noted changes in rain duration, aligning with Alexander's findings that precipitation changes are unpredictable and present varied results, with some studies projecting an increase in rainfall by 5% to 40% by 2100, while others anticipate a decrease by 10% to 40%, varying across the African continent. Moreover, 12% of the respondents acknowledged changes in millet yields, in line with Kilembe's study, which projected a significant reduction of 26% in millet grain yields by 2050 due to decreased rainfall and increased temperatures. It is anticipated that millet production will decrease by 13% in 2025. Additionally, 10% of the respondents reported high millet failure rates, in agreement with Sultan et al.'s assertions that future climate change will impact millet grain yields differently than in the past, with increasing temperatures gradually reducing crop yields.

4.6.3 The coping and adaptive strategies to climate change and variability

The major coping and adaption strategies to the changing climate and variability in Gweri Sub County include; growing of new and improved crop varieties, mixed cropping, growing of growing of first and second period crops, shifting from water stressed and flood prone areas and adjusting planting dates and diversification of production. The possible reasons for practicing this kind of coping and adaptive strategies are due to increased poverty rate and effects of war that dominated for the last two decades. Ellram (2019) revealed that managing climate variation is achieved through numerous strategies in reaction to climate experts and percentage are the same with that established in the study and these are; food purchasing from the market, shifting, Collecting of wild foods, wage labor in exchange for food, selling of livestock, getting support from relatives and friends, reducing on the number of repasts eaten per day, reducing on the sizes of meals and eating of less desired nourishments.

Findings also revealed that households in Gweri Sub County have engaged in numerous adaptive plans in reaction to the effects of changing climate and these plans include; planting of mixed yields, looking for other jobs outside husbandry, amending dates of planting and diversifying production, growing of new and improved crop varieties, growing of second period crops in first period and growing of second period crops in first period, rearing of enhanced animal breeds hence implying that change in climate has been in existent for long period of time and the people of Gweri Sub County in Soroti district are still experiencing it.

CHAPTER FIVE

SUMMARY OF RESEARCH FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of research findings

Results showed that 90 percent of the respondents had noticed climate changes and climate variability for the last 30 years and they noticed variation in climate through increased temperatures, decreased rainfall, flooding, increased dry spell and heavy-duty winds which had become more recurrent and severe. Radio remains the most commonly used media to receive information concerning climate change and this media is most publicly accessible to the poor household in the area of study.

Results indicated rainfall amounts have changed as the major effect of changing climate and variability on millet produces though also rainfall timing has transformed, the duration of rainfall has changed, change in millet yields accompanied with millet failure has also increased due to increased effects of climate change and climate variability on millet grain yields is that rainfall amounts have changed.

Results indicated range of adaptation and coping mechanisms which has been practiced to manage the effects of climate change and climate variability and these include; mixed cropping, planting or growing of improved and new crop varieties, planting of second period crops in first season and planting first period crops in second period, shifting from water logged and flood prone areas and modifying on planting dates and diversification of millet production

5.2 Conclusion

In conclusion both models, RCP 8.5 and RCP 4.5 predicts an increase in annual rainfall in 2031with 1830.6 and 1651.9 respectively, followed by the year 2036 and 2033 and also the same model predicts a constant increase in annual mean temperature in Gweri Sub County with 27.56 in year 2039, followed by the year 2032 and 2035. According to Maiti (1996) the annual mean temperatures continued to be at the optimal range (26 ^{o}C) favoring the growth of millet. In addition 95% of the respondents reported that changing climate and variability affect millet grain yields and only 5 percent of the respondents reported that variation in climate doesn't affect millet grain yields. This therefore implies that variation in climate impact on millet produce

38 percent of the respondents would ask neighbours for water during drought so as manage to the effect of changing climate and climate variability and also grow improved and new crop varieties as the major strategy undertaken.

5.3: Recommendations

The study recommends establishment of small scale Irrigation schemes to manage the excess rain water that flow in to Gweri sub county soroti district during the rainy season. The floods that run into Gweri Sub County could be collected by excavating of retention basin or construction shallow basin; this retention basin could help to provide additional irrigation reservoirs for the crop field in the area.

The study recommends distribution of climatic information to different agricultural sector, personnel in order to guide in decision making, that is when to plant, harvest. In addition to the above, the department of meteorology is providing the entire public with climatic information about different rainfall event that are to take place in different parts of the country. This could be done by strengthening co-operation between the agricultural official and climate experts in the different areas

The study recommends provision of better and new improved varieties that are resistant to different climatic condition and overwhelmed the effect of variation in climate

The study recommends long term analysis on climate change and climate variability to determine climatic changes that may affect the major crops in the area for resistance

The study recommends additional research to be done in order to absolutely customize Agmip (the agricultural model inter-comparison and improvement project) to be used in Africa study; hence improving the occurrence and stimulation.

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APPENDICES

Appendix 1: Data Set

Year	Annual temp	Rainfall (mm)
2010	26.12	1203
2011	25.86	1436.9
2012	26.00	1517.7
2013	26.13	1500.8
2014	26.10	1153.7
2015	25.92	1582.6
2016	26.09	1195.8

2017	26.84	1244.2
2018	26.19	1735.1
2019	25.68	1309.6
2020	26.09	1757.6
2021	25.94	1903.9
2022	25.94	1403.3
2023	26.12	1124.4
2024	25.73	1279.3
2025	26.32	1271.2
2026	26.08	1514.6
2027	26.52	1466.3
2028	26.28	1458
2029	26.27	1570.6
2030	26.77	1227.8
2031	27.08	1830.6
2032	27.53	1419.5
2033	27.23	1533.9
2034	26.99	1409.3
2035	27.19	1307.9
2036	26.99	1653.9
2037	26.97	1517.1
2038	27.02	1444.7
2039	27.56	1378.9

Month	**Mean temperature (C**	**Monthly rainfall**
Jan	27.50	55.32
Feb	28.37	53.23
Mar	27.90	85.61
Apr	26.60	186.51
May	25.40	153.47
Jun	25.43	76.22
Jul	25.01	109.81
Aug	25.07	171.47
Sep	25.44	144.26
Oct	25.62	147.67
Nov	26.23	102.80
Dec	27.01	51.16

	Rainfall		**Temperature**	
Date	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**
2010	1103.6	1203	25.95	26.12
2011	1353.2	1436.9	25.69	25.86
2012	1380.3	1517.7	25.83	26.00
2013	1419.2	1500.8	25.96	26.13

2014	1076	1153.7	25.93	26.10
2015	1421.4	1582.6	25.75	25.92
2016	1080.5	1195.8	25.92	26.09
2017	1095.5	1244.2	26.67	26.84
2018	1650.7	1735.1	26.02	26.19
2019	1216.8	1309.6	25.51	25.68
2020	1692.8	1757.6	25.93	26.09
2021	1794.4	1903.9	25.78	25.94
2022	1257.5	1403.3	25.78	25.94
2023	1004.3	1124.4	25.95	26.12
2024	1173.8	1279.3	25.56	25.73
2025	1172	1271.2	26.16	26.32
2026	1409.5	1514.6	25.91	26.08
2027	1317.6	1466.3	26.35	26.52
2028	1367	1458	26.12	26.28
2029	1445.9	1570.6	26.11	26.27
2030	1159.1	1227.8	26.61	26.77
2031	1651.9	1830.6	26.92	27.08
2032	1296.1	1419.5	27.37	27.53
2033	1399.8	1533.9	27.07	27.23
2034	1314.3	1409.3	26.82	26.99
2035	1214.5	1307.9	27.02	27.19
2036	1569.2	1653.9	26.82	26.99
2037	1467.3	1517.1	26.80	26.97
2038	1344.2	1444.7	26.85	27.02
2039	1278.1	1378.9	27.39	27.56

	Rainfall			**Temperature**	
Month	**RCP4.5**	**RCP8.5**	**Month**	**RCP4.5**	**RCP8.5**
Jan	55.32	58.68	Jan	27.50	28.48
Feb	53.23	44.41	Feb	28.37	29.03
Mar	85.61	109.70	Mar	27.90	28.15
Apr	186.51	235.02	Apr	26.60	26.31
May	153.47	172.49	May	25.40	25.69
Jun	76.22	123.01	Jun	25.43	25.23
Jul	109.81	97.66	Jul	25.01	24.81
Aug	171.47	152.20	Aug	25.07	25.17
Sep	144.26	118.62	Sep	25.44	25.73
Oct	147.67	182.26	Oct	25.62	25.53
Nov	102.80	106.17	Nov	26.23	26.18
Dec	51.16	44.84	Dec	27.01	27.25

Monthly rainfall for Gweri sub county

					Change	
Month	**Reference**	**RCP4.5**	**RCP8.5**	**Month**	**RCP4.5**	**RCP8.5**

Jan	29.54	55.32	58.68	Jan	87.27	98.65
Feb	36.16	53.23	44.41	Feb	47.20	22.80
Mar	90.67	85.61	109.70	Mar	-5.57	20.99
Apr	185.54	186.51	235.02	Apr	0.52	26.67
May	158.03	153.47	172.49	May	-2.89	9.15
Jun	97.01	76.22	123.01	Jun	-21.42	26.81
Jul	101.34	109.81	97.66	Jul	8.36	-3.63
Aug	141.80	171.47	152.20	Aug	20.92	7.33
Sep	123.60	144.26	118.62	Sep	16.72	-4.03
Oct	140.62	147.67	182.26	Oct	5.01	29.61
Nov	106.12	102.80	106.17	Nov	-3.13	0.04
Dec	37.83	51.16	44.84	Dec	35.26	18.55

Appendix 2: Questionnaire for Respondents

Interview No: ……………………Date: ………………Enumerator: …………………………

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

Introduction:

I am Atim Sarah, a final year student of Kyambogo University pursuing Masters of Arts in Geography of Kyambogo University conducting a research on ***"the effect of climate change and variability on millet production in Gweri Subcounty Soroti district".*** I am conducting this survey with 80 respondents in Gweri Subcounty Soroti district. You have been selected to contribute to this study by answering a few questions that are in this questionnaire. All the responses provided will be kept confidential and used for academic purposes only. I would therefore like to get your permission to ask you some questions about your experience with millet processing.

SECTION A: SOCIO-DEMOGRAPHIC INFORMATION:

Humbly, choose the responses suitable for the questions provided and fill in the blank spaces as required by the questionnaire.

1. Sex of the respondent

a) Male ☐ b) Female ☐

2. Age

18-25 ☐

26-33 ☐

34-42 ☐

43 and above ☐

3. Marriage status

a) Single ☐ b) married ☐ c) divorced ☐ d) widow/ widower ☐

e) Other (specify)………….

4. Highest level of Education;

a) University ☐ b) Other tertiary ☐ c) Secondary ☐ d) Primary ☐ e) None ☐

5. Employment status

a) Employed ☐ b) unemployed ☐

6. Source of household income

(a)Farming ☐

(b)Self employed ☐

(c)Business man/woman ☐

(d)Public servant ☐

(e)House wife ☐

Others specify…………………………………………………………………………….

7. Size of the household

(a) 1-3 Members ☐ (b) 4-6 Members ☐

(c)7-10 Members ☐ (d) 10 Members and above ☐

SECTION B: TRENDS OF CLIMATE CHANGE AND VARIABILITY

6. Have you detected variations in weather in your respective hamlet in the last 30 years?

(a) Yes ☐ (b) No ☐ (c) don't know ☐

7. If yes, specify the elements of climate variation through grading from the highest to the least altered.

(a) Precipitation ☐ (b) Temperature ☐ (c) Speed in wind and direction ☐

(d) Humidity ☐ (f) Cloud cover ☐ (g) Hours of sunshine ☐

(h) Others (specify)……………………………………

8. If yes which of these season has altered to the highest peak?

(a) Dry season ☐ (b) Wet season ☐

(c) Others (specify)……………………………………………

9. How predictable is the rain onset now compared 30 years back?

(a) Predictable ☐

(b) Less predictable/ Unpredictable ☐

(c) Don't know. ☐

10. How frequently do you receive information concerning climate change?

(a) Daily ☐

(b) Weekly ☐

(c) Once a week ☐

(d) Monthly ☐

(e) Once a month ☐

Other

specify…………………………………………………………………………………..

11. Which means of media do you use to receive information concerning climate change

(a) Radio ☐

(b) Newspaper ☐

(c) Members from the hamlet ☐

(d) From seminars/workshops ☐

(e) Extension workers ☐

Others (specify)…………………………………………….

SECTION C: EFFECTS OF CLIMATE CHANGE AND VARIABILITY ON MILLET GRAIN YIELDS

12. Does climate change and variability affect millet yields

Yes ☐ No ☐

11. If yes? What causes climate changes to affect millet yields?

(a) Burning coal, oil and gas produces carbon dioxide and nitrous oxide. ☐

(b) Cutting down forests (deforestation) ☐

(c) Increasing livestock farming ☐

(d) Fertilizers containing nitrogen produce nitrous oxide emissions. ☐

(e) Fluorinated gases ☐

Others
specify………………………………………………………………………….

12. Which features of climate change and variability affect millet yields

(a) Increased precipitation ☐

(b) Decreased precipitation ☐

(c) Drought ☐

(d) Floods ☐

(e) Initial rainfall onset ☐

(f) Late precipitation onset ☐

(g) Initial precipitation cessation ☐

(h) Late precipitation cessation ☐

Others

(specify)…………………………………………………………………………..

13. climate variation effects on millet produce

(a)Amounts of Precipitation have changed ☐

(b) Change of Precipitation timing ☐

(c) Duration of Rainfall has changed ☐

(d) Millet produces have changed ☐

(e) Millet failure is high ☐

Others specify …………………………………………………………………...

SECTION D: COPING AND ADAPTIVE STRATEGIES TO CLIMATE CHANGE AND VARIABILITY IN GWERI SUBCOUNTY, SOROTI DISTRICT?

14. How have you managed to cope up with the effects of climate variability and change in your area?

(a) Requesting for water from neighbours during dry spell ☐
(b) shifting from water stressed areas ☐
(c) Getting in touch with veterinary personnel ☐
(d) Buying nourishment ☐
(e) Stocking of drugs ☐
(f) harvesting of water ☐
(g) Preservation of pasture ☐
(h) Others specify……………………………………………………………………… ☐

15. Which of the following adaptation strategies do you under take to decrease the effects caused by climate alteration and variability on your agrarian production?

(a) Seeking for other employments outside husbandry ☐

(b) Amending on the dates of planting and diversifying production ☐

(c) Planting of Mixed crops ☐

(d) Rearing improved animal breeds ☐

(e) Planting of new and improved crop varieties ☐

(f) Shifting from flood prone and water stressed areas ☐

(g) Planting of season one yields in season two and planting of season two yields in season one ☐

Other specify……………………………………………………………………………

16. Is there anything else you would like to tell me concerning climate change

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

**********Thanks for participating*********