INFLUENCE OF SEASONAL RAINFALL FORECASTS ON MAIZE YIELD IN TONGAREN SUB-COUNTY, BUNGOMA COUNTY, KENYA

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A thesis Submitted in Partial Fulfillment of the Requirements for the Award of the Degree of Master of Science in Climate Change Adaptation and Sustainable Development of Masinde Muliro University of Science and Technology (MMUST)

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DECLARATION AND CERTIFICATION

This thesis is my original work prepared with no other than the indicated sources and has not been presented for a degree in any other university or any other award.

Signature ______________________ **Date:**______________________

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology (MMUST) a thesis entitled: **"Influence of seasonal rainfall forecasts on maize yield in Tongaren Sub-County, Bungoma County, Kenya"**

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DEDICATION

I dedicate this work to my wife and children who were my inspiration.

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ABSTRACT

The two main seasonal rainfall forecasts that are important for maize production in the Tongaren Sub-County are the March, April, May (MAM) and the June, July, August, September (JJAS). The main objective of this study was to examine the influence of seasonal rainfall forecasts on maize yield in Tongaren Sub- County in Bungoma County. The specific objectives were to; determine the trends of seasonal variability of rainfall in Tongaren Sub-County, evaluate the factors influencing utilization of seasonal rainfall forecasts and assessment of the benefits of using seasonal rainfall forecasts on maize crop yield in Tongaren Sub-County. Multi-stage sampling was applied to determine the sample size of 395 maize farmers and descriptive and inferential statistics were used to analyze the data. The research design adopted was descriptive survey. The unit of analysis was individual maize farmer household at the farm level. Excel, SPSS and XL STAT data analysis tools were used in the analysis of the data. The primary data was collected using questionnaires for households' interview, key informant interviews, focus group discussions and observation checklists. Secondary data comprising monthly precipitation of Tongaren for the period spanning between 1985 and 2022 was sourced from Kenya Meteorological Department while the yearly maize yield was provided by Bungoma County Department of Agriculture. Time series plots were done and the trends analyzed by Mann Kendall trend analysis to determine whether the trends were significant or not. Results show that there is significant inter-annual and intra-seasonal rainfall variability. Rainfall variability during MAM and JJAS was found to be 20.7% and 20.6%, respectively. Further results show that there exist varied factors that determine access to and usability of seasonal rainfall forecasts. Among them are; lack of awareness, lack of relevant downscaled climate information, lack of capacity to interpret climate information and late delivery of climate information among others. The result of the correlation analysis showed that rainfall amount had positive relationship with maize yields (correlation of 0.53 for JJAS, 0.4 for March to September and 0.05 for MAM). The study concluded that there was significant rainfall variability which could be linked to fluctuations in maize yields and had the potential to affect future maize production in the study area. The study recommends the following; there should be close collaboration between climate information providers and the users, co-production of climate information, enhancement of timely and accurate weather forecasts and that the climate information availed to the users should be accompanied by agronomic advice.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADS Anglican Development Services

BCIDP Bungoma County Integrated Development Plan

CC Climate Change

CCAFS Climate Change Agriculture and Food Security

CCOF County Climate Outlook Forum

CGIAR Consultative Group for International Agricultural Research

CI Climate Information

CIS Climate Information Service

CSA Climate Smart Agriculture

EA East Africa

ENSO El Niño Southern Oscillation

FtMA Farm to Market Alliance

GIZ Germany Agency for International Development

IITA International Institute for tropical Agriculture

IPCC Intergovernmental Panel on Climate Change

JJAS June, July, August and September

KMD Kenya Meteorological Department

KNBS Kenya National Bureau of Standards

MAM March, April and May

NCCAP National Climate Change Action Plan

NMC National Meteorological Centre

NMS National Meteorological service

OND October, November and December

SMS Short Message Service

SPSS Statistical Package for Social Sciences

UNDESA United Nations Department of Economic and Social Affairs

UNESCO United Nations Educational, Scientific and Cultural Organization

USAID United States International Development Agency

USGCRP U.S. Global Change Research Programme

WMO World Meteorological Organization

WAAPP West Africa Agricultural Productivity Program

DEFINITION OF OPERATIONAL TERMS

Climate: Is usually defined as the average weather condition, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities of temperatures, precipitation, wind, pressure, evaporation and other over a period of time ranging from months to thousands of years. The World Meteorological Organization (WMO) often defines a period of 30 years.

Climate change: Change of atmospheric conditions over a long period of time usually 30 years.

Climate data: Consist of historical and real-time climate observations such as temperatures, rainfall etc. that is analyzed to give climate product.

Climate information: Refers to climate data, climate products, or climate knowledge which sometimes may be accompanied by other relevant information and other services in relation to climate or climate change that are of use to society in decision making.

Climate model: Is a computer program that use quantitative methods to simulate the interactions of important drivers of climate such as atmosphere, oceans, land surface and ice so as to project future climate scenarios.

Climate product: Is a derived synthesis of climate data such as a weekly or seasonal weather forecast.

Climate services: Involve providing climate information in a way that assists decision making by individuals and organizations

Climate variability: Refers to the way in which the climate of a place fluctuates on yearly basis or sometimes seasonally either above or below an established long term average value

Extreme weather event: Refers to an event that is rare within its statistical reference distribution at a particular place and time.

Food insecurity: This is the condition of not having access to sufficient food or food of adequate quality to meet one's basic needs.

Precipitation: Amount of rainfall, snow, sleet or hail that falls to or condenses on the ground received in a specific place in a specified period of time

Rainfall probability of exceedance: Is the probability that the actual rainfall received during a particular season is equal or higher than the estimated seasonal rainfall

Rainfall reliability: This is the consistency and predictability of rainfall amounts and patterns over a specified period and location.

Rainfall variability: Refers to the extent rainfall of a place deviates from an established average value normally for a specified period such as a season.

Seasonal rainfall forecast: Is a prediction of amount and probability of rain likely to be received in a given area in a given future time and usually encompasses the start and end of the season together with the expected distribution.

Smallholder maize farmer: A farmer who engages in maize farming on a small piece of land often with limited resources.

Standardization of rainfall: Is a way of determining whether the rainfall observed is higher or lower than the long-term average in order to identify periods of drought or excess rainfall.

Weather: Refers to instantaneous atmospheric condition in a given place and at a given specific time, and comprises of variables such as temperature, rainfall, wind, humidity, evaporation, atmospheric pressure and humidity.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Seasonal rainfall forecast is a prediction of amount and probability of rainfall likely to be received in a given area in a given future time and usually encompasses the start and end of the season together with the expected distribution. Different sectors have specific climate information needs. For instance, in the agricultural sector, farmers may need information on the onset and cessation of the rainfall season in order to make informed decisions at the farm level (Nkiaka et al.2019, Vaughan and Dessai, 2014) potentially leading to increased yield and reduced losses. Climate information service (CIS) has in the recent past gained attention as a result of challenges brought about by climate change and variability (Diouf et al. 2019). According to Funk et al. (2014) and Funk et al. (2019), one of the challenges of climate change is that seasonal rainfall is becoming less predictable and this affects farm decisions made by farmers.

Many regions continue to experience the impacts of climate change and variability which are manifested as extreme weather events. In Europe, it is the main cause of extreme events such as snow and drought which affects agricultural production (Gimenez and Franco, 2012). In Africa, agriculture is one of the primary economic sectors that support the livelihoods of a large number of people. However, it is highly exposed to weather and climate risks, Aggarwal (2008), Cooper et al. (2008) and Kumar (2011) and transformative changes in some agricultural practices will be required to address the risks of climate change for instance through changing crops, and provision of climate information (CI) which may help in decision making at the farm level (Rippke et al., 2016).

In Sub-Saharan Africa, climate change has manifested as prolonged droughts which affects most agricultural sectors such as maize farming (Funk et al. 2008). According to Macleod (2018) the characteristics of seasonal rainfall such as the rainfall amount across East Africa has experienced frequent prolonged droughts which have had devastating effect on agriculture. In Kenya the seasonal rainfall patterns have become irregular and unreliable as a result of climate change with many areas experiencing long dry spells that reduces agricultural production especially the cereals (Ochieng et al.2016).

A study conducted in Sub- Saharan Africa by Harvey et al. (2019) has revealed that climate information services are generally inadequate characterized by poor coordination and poor observational infrastructure which hinders effective and efficient delivery of climate information (CI) to the potential users.

Despite the fact that considerable studies have been done on the effects of weather/climate on agricultural production, few works have been specific on the effects of climate change on maize production especially at the local level (Ulukan, 2018).This paper sought to unravel an in-depth understanding of this based on specific rainfall seasons in which maize is grown in Tongaren Sub- County.

It is worth to note that in rain-fed agricultural systems, farmers rely heavily on their local knowledge of seasonal rainfall, the timing to match the cropping season with the time over which there is adequate water to meet the demands by the crops is crucial (Radenyel et al., 2019).

The Kenya Government has attempted to minimize impacts through various interventions and responses, such as irrigation infrastructure improvements and water storage structures, and, more recently, through the provision of climate information in addition to policy guidelines and regulations (GoK, 2018). The increase in risks associated with climate related disasters such as droughts require timely and suitable weather forecasts in order to minimize losses and build resilience (FAO, 2013).

In Kenya, there are various policy documents, which touch on climate information services including; Sessional Paper No 3 of 2016 on National Climate Change Framework Policy. This policy outlines strategies for the integration of climate information (CI) into development planning to enhance climate resilient and adaptive capacity. It also stresses on education and creation public awareness of CI and its accessibility for decision making through effective communication strategies. Another important document that talks about CI is the Kenya Climate Change Act of 2016.This emphasizes mainstreaming of climate change actions into strategic areas including agriculture. Similarly the Constitution of Kenya 2010 guarantees the citizens the right to access information such as CI. Other policy documents include; National Climate Change Action Plan of 2013, National Climate Change Response Strategy (NCCRS) of 2010, East Africa Community Climate Change Policy, National Adaptation Programmes of Action (NAPA), Africa Climate Change Policy, draft meteorological bill and policy and Sustainable development goals (SDGs) 12 and 13. At the County level, there is the draft Bungoma climate information service plan (BCISP) of 2024, the

Bungoma County Integrated development plan (BCIDP) of 2013-2017, BCIDP (2018-2022) and BCIDP (2023 – 2027) which provides a framework for provision of climate information.

Provision of climate information has improved in the recent past mostly due to co-production and also due to improved forecasting skills and involvement of private sector; Meadow et al. (2015), Prokopy et al. (2017) and Singh et al. (2018). However, designing transformational adaptation requires robust climate evidence pegged on information on climate risks and vulnerabilities impacting different agricultural based livelihoods at community levels such as maize production, which at the moment are still underdeveloped. Critical gaps which exist in the design of framework to provide climate information such as failure to link maize productivity to the use of CI, limited access, ineffective use of climate-related information for risk management especially among smallholder farmers and inadequate specific context at the local level has been a major problem and this study seeks to address these gaps.

It is against this background that the successful provision of climate services with proven and demonstrated benefits needs to be operationalized at the local level in order to ensure that the maize sector adapts well to the risks posed by the changing climate so as to maximize production.

1.2 Statement of the problem

Smallholder maize farming faces high risk of reduced productivity due to extreme weather events occasioned by climate change and variability. Despite the availability of seasonal rainfall forecasts, there is limited integration of such forecasts in decision-making processes among maize farmers in Tongaren Sub-County (Muita et al. 2021). This coupled with inadequate awareness of existence of CI, ineffective access mechanisms to the seasonal rainfall forecasts and inadequate linkage of forecasts with the maize growing season leads to low yields (Hewitt et al., 2020). Previous studies have analyzed the impacts of rainfall variability on maize yield using yearly rainfall totals without paying attention to the fact that it is only the rainfall that falls within the maize growing season that counts. Thus, this study only analyzed rainfall data between March and September being the period in which maize is grown in Tongaren Sub-County.

1.3 Research Objectives

The main objective was to evaluate the influence of seasonal rainfall forecasts on maize yield in Tongaren Sub - County of Bungoma County in Kenya.

1.4 Specific objectives

The following specific objectives were used to achieve the main objective of the study.

i. To determine the trends of seasonal variability of rainfall in Tongaren Sub-County

ii. To evaluate the factors influencing utilization of seasonal rainfall forecasts for maize production in Tongaren Sub – County.

iii. To assess the benefits of using seasonal rainfall forecasts on maize crop yield in Tongaren Sub - County.

1.5 Research Questions

The following are the questions that guided the study;

i. What are the trends of seasonal variability of rainfall in Tongaren Sub- County?
ii. What are the factors that influence utilization of seasonal rainfall forecasts in Tongaren Sub - County?
iii. What are the benefits of using seasonal rainfall forecasts on maize crop yield in Tongaren Sub- County?

1.6 Justification of the study

The findings from this study will be crucial to farmers in their decision making on what activity to undertake on their farms since forecasts which are released on specific timescales can help in achieving preparedness and disaster risk reduction.

According to the World Bank (2016), provision of weather forecasts and advisories that are relevant to the local conditions play a central role in efforts to combat adverse effects of climate change, climate variability and also erratic weather patterns. Furthermore, providing farmers with relevant climate information on seasonal rainfall can help them have informed crop choice and decide on the planting period to optimize yield and minimize crop failure risks based on extreme weather and climate events return periods and trends (Venkatasubramanian et al*.,* 2014).

The findings of this work on rainfall trends will be crucial for planning and designing the county's climate variability adaptation and mitigation strategies, to ensure that climate variability impacts are well managed in maize production so as to reduce food insecurity.

If the problem of not accessing and using seasonal rainfall forecast is not addressed, it is likely that maize farmers will continue to incur huge losses bearing in mind that rainfall variability is an annual phenomenon that we have to contend with.

1.7 Scope of the Study

This study focused on Tongaren Sub - County of Bungoma County. The study was carried in all the six (6) wards of the Sub – County namely; Mbakalo, Naitiri/Kabuyefwe, Milima, Ndalu, Tongaren and Soysambu/Mitua. The unit of analysis comprised small -scale maize farmers since the maize produced is largely produced by this category of farmers who rely on seasonal rainfall. The data from both Bungoma County agriculture department and KMD covered a period from 1985 to 2022.Wihin this period; there were some good records of rainfall data and also improved availability of seasonal rainfall forecasts. The rainfall data considered in this study was the seasonal rainfall covering the period between March to May (MAM) and June to September (JJAS) only since this is the time maize is grown in the study area. The rainfall data from KMD between 1985 and 2022 had undergone data quality control to make it suitable for analysis. The research work covered a period of 8 months.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of literature from previous. The review focusses on access to seasonal rainfall forecast amongst the farmers, climate information service needs, challenges to effective use of seasonal rainfall forecasts, as well as the various ways in which improvement in the use of seasonal rainfall forecast in building resilience in maize production can be achieved in Tongaren Sub - County. The chapter also covers a conceptual framework that shows how the independent, dependent and intervening variables are related.

2.2 Seasonal variability of rainfall

According to UNESCO (2019), most agricultural systems depend on rainfall as the main source of water. This makes rain- fed agricultural systems to be highly sensitive to spatio-temporal rainfall variability. In a study by Donat et. al. (2016) it was found that global warming is already driving increases in rainfall extremes. Their results resonate well with the study by Lehman et. al. (2015) which found that global warming has so far enhanced the number of record- breaking rainfall events in terms of variability. These studies intimated that the frequency of extreme rainfall on daily basis has become common over most land areas. Because of the inconsistencies in the weather patterns Jamal et. al. (2017) conducted a study and concluded that knowledge of climate and rainfall variability is vital for urban planning and rural land use.

Many studies have been conducted in various places and the results show that there is widespread rainfall variability. For instance in Bangladesh, there is a decrease in dry months in monsoon and pre-monsoon and an increase in the wet months (Shamsuddin, 2009). Elsewhere in Bundelkhand region of India, Som and Dey (2022) found that precipitation during summer and winter seasons exhibited high levels of variability. Moreover a study conducted in South-West USA by Karanja et al. (2023) revealed that there exists rainfall variability across various seasons mostly brought about by various atmospheric systems such as ENSO. Similarly, a study done in Ethiopia by Lewis (2017) found that apart from rainfall amount, its distribution in a given season is very critical in crop growth and yield. Seasonal precipitation variability in Europe has also been studied and the results show that there is rainfall variability across the seasons brought about by both natural and anthropogenic forces (Nikolaos and Stott, 2022). In Uganda a study conducted there showed that on the seasonal scale, there is increasing erratic onset and cessation of rainfall seasons across the country in recent years; coupled with increasing frequency of droughts (GOU, 2007).

Rainfall in Kenya exhibits variability on year to year and season to season basis. Most parts experience two rainfall seasons that alternate with dry seasons. The two rainfall seasons are the long rainfall season which is concentrated between March to May and the short season which occurs from September to early December (Gitau,et al. 2012). A study by Palmer et al. (2023) has revealed that precipitation trends in Kenya are projected to remain highly variable and uncertain. It has also been observed that uneven seasonal distribution of rainfall exposes crops to frequent dry spells that may lead to reduced productivity (Barron et al., 2003). In another study in Baringo, Kenya by Ednah et. al. (2018) analysis of spatial variability in rainfall trends found that there was inter-annual rainfall variability across different agro- ecological zones.

All these studies show that there is seasonal rainfall variability in many regions of the world and this variability will likely affect rain-fed agriculture. However, most of these studies have not pointed out how beneficial CI is to the farmer and also how climate information can be integrated in farmers' decisions especially at the local scale. The study aimed at addressing these.

2.3 Accessibility to seasonal forecasts by farmers

It is crucial that once the forecast has been generated, it be accessed immediately by the users due to the perishable nature of weather forecasts, otherwise it may not be useful. It is also important that there be a two-way information delivery so as to give room to feedback (Naab et al.2019, Slavova and Karananasios, 2018).

Uptake of climate information (CI) including seasonal rainfall forecast in Sub Saharan Africa (SSA) is still low as compared to other regions of the world (Ochieng et al 2017). According to him the low uptake of CI has been attributed to many factors including; awareness of CI, accessibility, poor communication of forecasts, inappropriate use of language, illiteracy and culture. Potential users cannot realize benefits from services that they are unaware of. Where potential users are aware of the existence of CI, poor understanding of forecasts because the content and format are too technical and not clearly explained can lead to low uptake (Ochieng et al 2017). Lack of access to communication devices such as radios, televisions and mobile telephones used in transmitting forecast can also limit who is able to use this information. Challenges in accessing forecast information may be compounded by gender, with female farmers having lower access to CI than their male counterparts (Oyekale, 2015, Carr et al. 2016). According to Wilhite et al. (2014), access to and ability to interpret and use the climate information in decision-making processes, are important to users for building resilient livelihoods. In another study by Ziervogel, Garderen and Price (2016) it was found that is important to have access to usable weather information that is considered alongside the socio-economic context. Furthermore, failure to access, understand, and/or translate weather information into appropriate action by users might result in adverse impacts (Gautier et al. 2016; Peters 2015). In another study by Gandure et al. (2013), seasonal weather forecasts need to be of high quality and context-specific and must deal with current and expected weather trends and their impacts. The study also intimated that lack of access to early seasonal weather forecasts and unreliability of seasonal forecasts is a barrier to promoting risk reduction and adaptation action. Current and future studies should therefore link access to and utilization of CI to specific crops and demonstrate the benefits derived from such use in order to encourage and promote utility of CI in agricultural production.

2.4 Climate Information Services

According to Lugen (2017), climate information services may be defined as services that provide climate information in a way that assists decision-making by individuals and organizations. Studies conducted by Daron,et al. (2015) and Ranger et al (2010) found that the usability of weather and climate information is largely dependent on the ability of scientists to provide information that is fit-for-purpose and produced in formats that can be integrated into decision-making processes. It should be noted that the high-quality climate information services are critical in empowering decision-makers to better manage activities in such areas as agriculture, public health, water resources, energy production, disaster risk reduction and other sectors that are important for national development (WMO, 2017). It has been found that climate information services are meant to provide the science-based and user-specific information for managing risks and exploiting opportunities created by climate variability and change, thereby helping society to become more resilient in coping with the increasing impacts of climate change (UNDESA, 2016). To achieve this goal there has to be in place a well-structured system of availing CI to the users promptly. A study conducted by Hewitt et al. (2012) and IPCC (2013) revealed that the recent developments in the provision of weather and climate information have created opportunities to better integrate scientific information into decision-making.

The United Nations Climate Change Secretariat (UNCCS, 2019) has intimated that climate risks such as temperature shifts, precipitation variability, changing seasonal weather patterns contribute to heightened vulnerability across multiple sectors including agriculture in many countries. According to Miles et al. (2006), changes in climate directly impact resource management and can be costly, thus underscoring the need for a steady and accurate flow of climate-related information to help decision makers prepare for and adapt to evolving conditions. In order to ensure access to climate information services, several initiatives have been put in place to facilitate production and dissemination of climate information to stakeholders (Hewitt et al.2012).

In Europe there are well established institutions in place with the responsibility of ensuring CI is readily available to various users (Thepaut et al. 2018). One such institution is the Copernicus Climate Change which provides free and open access to climate data and information used for a variety of purposes (Thepaut et al.2018). According to Chandni et al. (2018), climate information generated through multi-stakeholder processes that involve participatory approaches to interpreting climate information (e.g. Participatory Scenario Planning in Kenya) and those that have direct economic utility for end users (e.g. agro-meteorological advisories for crop yields in Maharashtra, India) have local resonance and high potential for increased uptake.

In Africa, climate information is essential for the achievement of the Sustainable Development Goals (SDGs) specifically due to the links between development outcomes, weather and climate risks (Griggs et al., 2021). According to Dayamba et al. (2018) and Tall et al. (2018), the Global Framework of Climate Services (GFCS) has implemented several projects in many African countries aimed to facilitate timely delivery of contextual climate information to stakeholders through a collaborative participatory process. However, despite continued investments in climate modeling and the growing provision of climate services across Africa there often remains a mismatch between available information and what is needed to support on-the-ground decision-making.

In a study by Cooper et al. (2008), which focused on rain-fed farming systems in Sub-Saharan Africa, the ability of decision-makers to utilize short-term information and manage current climate risks is a precursor to better management of future climate risks. However, there are relatively few cases of long-term climate information for decision-making (Jones et al*.,* 2015; Nidumolu et al., 2016), implying that there are issues around the relevance, provision and usability of climate information on longer time scales.

Furthermore, the African Centre of Meteorological Application for Development (ACMAD) initiative has implemented several projects aimed at producing forecasts of an appropriate timeline that are most suitable to decision-making in the agricultural sector (Ogallo, 2012).

In Kenya, the Government has drafted the National Framework for Climate Services (NFCS) which will enhance coordination, facilitation and collaboration among institutions to ensure development and incorporation of science-based climate information and prediction into planning, policy and practices for all climate-sensitive socioeconomic sectors (GOK, 2023). The framework has been launched awaiting operationalization.

Despite the shortcomings in the provision of CIS, farmers still require certain critical information for them to make the right decisions in their farming activities.

2.5 Factors influencing use of seasonal rainfall forecast

Usability of climate information depends on the level and quality of interaction between information producers and users (Lemos et al. 2012) as well as how the information resonates well with processes of decision-making (Singh, et al. 2016). Climate information must be relevant to local needs for it to be useful to the intended user. Research has shown that, barriers in climate information utility and uptake stem from inadequate understandings around how and why end users make decisions. Despite the growing volume of climate information across many regions, Waagsaether and Ziervogel (2011) found that there remain substantial gaps between the information held by CIS providers and institutions and that which is required to inform decision making.

Thus, there remains nagging and practical barriers which impact the utility and uptake of climate information.

According to Hewitt et al. (2017), integrating long-term climate information into decision-making remains a challenge, largely because the information is highly uncertain and, particularly in current formats, harder to be adopted by the users in decision making. On the same issue, Kates, et al. (2012) through their study found that, combining short and long-term can contribute to transformative change since it can aid decision-making across spatial and temporal scales. To understand better the barriers to effective use of CIS by farmers, various researchers have conducted some studies which are highlighted under the sub topics as given hereunder below:

2.5.1: Involvement of all Stakeholders

According to Ambani and Percy (2014) a multi-stakeholder participation at different stages of climate information delivery is quite necessary. A recent study in Europe has contended that there are increasing calls to embrace a truly collaborative, process-oriented, and user-driven approach that enables the use of integrated climate information thereby increasing its usability and uptake (Daniels et al. 2020). For instance in Germany and Sweden, Conde and Lonsdale (2015) found that there is a widespread consensus that the establishment and implementation of adaptation strategies based on climate information requires the involvement of different stakeholders and innovative ways to unite their efforts, commitments and knowledge so that each can contribute in their own way. Similarly studies conducted in the United Kingdom by Lowe et al. (2009) put direct engagement with the stakeholders in first position for improving decisions made in the social and other human dimensions.

In the United States of America (USA), Averyt et al. (2018) found that the Federal Climate Adaptation Programs such as the National Oceanic and Atmospheric Administration's Climate Adaptation Partnerships have emphasized the need to engage stakeholders at all levels to produce relevant scientific knowledge

Moreover a study in Africa conducted by Bremer and Meisch (2017) revealed that attempts are now being made to involve users in the knowledge production process of climate information in order to address climate change challenges. For instance farmers in West African countries have been capacitated in the use of participatory and inclusive approaches that will allow various stakeholders from national and regional levels to work in synergy for effective implementation and successful achievements in Climate Smart Agriculture (CSA) actions (Bayala et al. 2020).

In a study by Rigby et al. (2022) in the East African region on various stakeholders in climate services showed a complex network of stakeholders within the climate services ecosystem, each with their own foci that dictate their information needs and use.

In Kenya a study by Ageyo and Muchunku (2020) revealed that the Government has put in place very good policies on climate services and also partnered with many Non-Governmental organizations (NGOs) and other actors to drive the agenda on access to and utilization of CI. However, poor dissemination of scientific knowledge on climate change hinders the capacity for Kenyans to follow the ambitious policies set by the government (Ageyo and Muchunku, 2020).

2.5.2 Capacity to interpret climate information

Misunderstanding the content and the accuracy of a weather forecast may lead to missed opportunity to plan and prepare for adverse conditions and therefore fail to take advantage of favorable conditions. According to Manjula and Rengalakshmi (2015) lack of skill in interpreting and understanding the forecasts and other CIS also remain a big challenge for many users. Furthermore, (Ziervogel et al., 2008) found that there exists difficulty in interpreting CIS and how climatic conditions interact with non-climatic variables such as soil moisture to affect livelihoods directly through sowing dates, and disease incidences.

Stern and Easterling (1999) argued that climate forecast users will likely understand new information better and accept it more fully if they can interpret it and understand the information being communicated. According to Solomon and Dole (2009) and DeGaetano et al. (2010), climate models have become more capable of generating useful information over seasonal to century time scales. According to the studies, these advances have stimulated the use of climate information and are escalating its demand. In their study on the barriers to CI access and use in Africa and India, Lemos et al. (2012) and Singh et al. (2016) found that there is a disconnect between CI producers and the users arising from lack of capacity to interpret the CI information.

2.5.3 Locally relevant downscaled climate information

Bunyan et al. (2015) established that there exists a lack of locally generated relevant downscaled climate information in many regions which has continued to hamper the usage of CIS in decision making especially amongst smallholder farmers. According to Manjula and Rengalakshmi (2015) seasonal climate forecasts are in probabilistic language, which are difficult to understand. Furthermore, they do not provide details like location of rains, the timing, lead times, duration and rainfall volumes which are key to decision making. However, the shortfalls listed above are currently being addressed by CIS providers. This problem is exacerbated by the fact that climate data are sparse in many parts of the world especially in Africa and that long-term reliable observations (>30 years) are only present in some countries, such as South Africa (Singh et al. 2017). It is disturbing to note that in some countries such as Democratic Republic of Congo, there are no long-term station data sets. Worse still, a study by Conway and Schipper (2011) revealed that where models converge, current rainfall trends and physical interpretations often counter IPCC multi-model projections.

In another study by USAID (2014) it was found that due to low capacity to provide locally relevant downscaled climate information in many countries, the quality and type of information supplied are not sufficient for the complex decision-making needs of end users.

2.5.4 Linkages of CI with individual perceptions and traditional knowledge

Lack of linkages of CI with individual perceptions and traditional knowledge has also been pointed out as an impediment in the provision of climate information services. For instance, Manjula and Rengalakshmi (2015) while conducting a study on climate information in India pointed out that there were no diverse knowledge systems that could be successfully integrated to improve decision making.

They hinted that, this gap could be because traditional knowledge tends to be held by older member of a community while CI is communicated to younger farmers. It was also found that in Africa, perceptions of climate variability as held by farmers may differ from meteorological data and this may constrain uptake of CI when planning for uncertainty and risks (Osbahr, et al. 2011). In a study by Le et al. (2021), it was showed that lack of integration of local resources and indigenous knowledge with advanced technologies in CI provision also affects its utilization and suggested that integration of indigenous climate information and scientific knowledge would support farmers' climate adaptation responses. In Kenya farmers also rely on indigenous knowledge which helps them to determine how the season will be. For instance a study conducted by Kagunyu (2016) in Northern Kenya revealed that occurrence of drought or floods can be determined by observation of intestines of slaughtered animals or shedding of leaves by some plant species.

2.5.5 Timely dissemination of CI information to the user

According to Haigh et al. (2015), the timing of forecast delivery affects the ability to use it in some policy areas for example in agriculture management. In Sub-Sahara Africa, studies have highlighted the need to avail timely CI to smallholder farmers as this could improve the usability of the same (Nkiaka et al., 2019, Antwi-Agyei et al. 2020). In another study, Okoro et al. (2016) found that poor access to timely CI and too many climate information at a time from different CI providers can also be a constraint to the use of such information. Similar study in Ghana by Phili*p* et al. (2021) found that the use of CI is affected by the time such information reaches them.

2.5.6 Social factors in gender disparity

The way either gender utilizes CIS differ to some extent. For instance, according to the study by Singh (2014), Nicholson et al. (2015) and Ndeye et al. (2019), men are main ‘receivers’ of CI because they tend to own mobile phones and interact with extension officers more than their female counterparts. Furthermore, it is often shown that women are at a relatively greater risk of experiencing negative effects of, and face greater barriers to adapt to climate change (Vincent et al., 2014). According to Partey et al. (2020) women within households get lower access to CIS. Cultural beliefs also play a role in the use of climate information. For example the occurrence of extreme climate events such as drought and lightning are deemed to be associated with supernatural power. According to Spear et al. (2015) some people tend to link such events to some divine power. This may lead to lack of trust by consumers in the CI availed to them as intimated by Haigh et al. (2014). Furthermore, diverse communities have a unique way of looking at issues based on social status. For instance a study conducted in USA by Joslyn and LeClerc (2016) revealed that social-political orientation is a determinant of perceptions of climate science.

2.5.7 Communication and dissemination challenges of CI

Difficulty in reaching remote areas and delay in communicating climate information has been identified as one of the challenges to effective use of CIS (Manjula and Rengalakshmi, 2015). Moreover, access to relevant CI remains a barrier to some communities and the increase in CI availability has not been supported by adequate growth in institutional architecture that helps in enabling capacity building to interpret and communicate this information (Ziervogel et al., 2008). Le et al. (2021) also found that language barriers mainly with television and radio are also a reason for not using or not effectively using climate change information amongst farmers. According to World Bank (2016), various CIS dissemination channels have shown some attribute deficiencies that formal communication channels need to have. Some of these are; lack of accuracy, timeliness, lack of trust and language barriers amongst others. Through research by Hampson et al. (2015), it has emerged that radio and mobile phones are the preferred mode of disseminating CIS amongst farmers and pastoralists. It was also pointed out by Okoro et al. (2016) that use of wrong channel and language barrier in disseminating climate information can also be a big problem in CI utilization.

2.6 Improving effectiveness and use of seasonal rainfall forecast

In order to improve CIS, the Global Commission on Adaptation (GCA) underscores the human, environmental, and financial imperatives to take action to build the climate resilience of communities, the environment, and economies (GCA, 2019). The World Economic Forum (WEF, 2020) has stated that, extreme weather, climate action failure, and natural disasters are the top three global risks in terms of likelihood, with climate action failure as the top global risk in terms of impacts. Observational data of elements of the weather and climate system are key to the understanding of ongoing weather patterns and climate trends and also in the development of weather forecast and climate modeling.

Chandni et al. (2018) while studying the utility of weather and climate information for adaptation decision-making in Africa and India found that participatory approaches to designing and interpreting climate information promotes its uptake for use in decision-making. They also stated that there has to be development of an effective early warning system (EWS) for climate-related disasters across regions which can enable users of CI to plan and prepare before the onset of a disaster. According to Chandni et al. (2018) there is need to build mutual trust in the context of information provision and mode of delivery and contextualizing climate information to local contexts and realities since tailored climate products and information are being increasingly recognized as important for enabling climate-resilient decision-making in different sectors, particularly for vulnerable communities such as farmers dependent on rain-fed agriculture systems. In another study by (Lobo et al*.,* 2017) it was found that efforts to improve use of weather and climate information need to factor in timing of information delivery in the decision-making cycle. Okoro et al. (2016) suggested various ways in which improvement in the use of CI can be achieved. Among these were; use of local languages in disseminating CI, ensuring reliability of information, ensuring relevance of information to target audience. They also found that; use of audio visual aids, training of CI communicators, provision of timely CI, strengthening of agricultural extension delivery system and co-production of CI between scientists, farmers and indigenous technical knowledge (ITK) can be very useful in improving the use of CI amongst farmers.

2.6.1Climate information services dissemination methods

At the county level, some of effective ways through which CI can be communicated to the users may include; local radio and TV stations, social media, mobile phones through SMS, county climate outlook forums (CCOFs), trained climate intermediaries and county *barazas* amongst others. In a study by Kirui et al. (2012), it was found that, radio, print media, short mobile messages, TV and contact with informed people on climate information are various CI dissemination channels. The study showed that radio was a major dissemination channel of CI because of its accessibility, wider coverage and its ability to use vernacular languages. In another study by Oyekale (2015), it was found that the medium of CI transmission can be directly linked to gender disparity in access of CI.

Moreover, McOmber (2013) intimated that information disseminated through ICT is rarely accessible to women since majority of these communication assets are dominated by men.

2.6.2 Mainstreaming of seasonal rainfall forecasts in decision making

It has been demonstrated by (Sarah and Paul (2022) that in regions with pronounced climate variability such as seasonal and inter-annual variability in rainfall, the seasonal climate forecasts issued in advance may enhance planning and management decisions to benefit vulnerable communities. According to Alexander et al. (2019), Block and Goddard (2012) and Kirtman et al. (2014), seasonal climate forecasts have been developed widely in an effort to guide decision-making in order to take appropriate steps against climate variability. Even though improvements are being made in the way forecasts are developed, Millner and Washington (2011) and Scheufele (2013) have observed that this may not be a guarantee that there will be higher adoption rates. Similarly, Soares et al. (2018) have postulated that multiple factors influence value of a forecast including the forecast accuracy which increases socio-economic level, economic and political factors, institutional linkages, co-production and access amongst others. Furthermore, perceived value of the forecast includes expected profit, and other benefits such as the risks to be avoided (Millner and Washington, 2011).

According to Mase and Prokopy (2014), trust has proven to be a key factor in facilitating the adoption of seasonal climate forecasts, particularly when shared by trusted agricultural advisors. It has been found out by Wong-Parodi and Babcock (2020) that effective two-way communication and public engagement can also help build trust among local entities, which may be more vulnerable to climate variability or hold high levels of trust in traditional methods diminishing their use of scientific forecasts.

2.7 Influence of Rainfall Variability on Agricultural Production

According to Kiem and Austin (2013), inaccessibility to climate information services especially by the smallholder maize farmers has been identified as a major undoing and constraint in managing climate-related risks.

According to Adamgbe et al. (2013) the effect of climate change on agriculture has been studied widely and it has been found out that most of the tropics and equatorial regions of the world have their agricultural yields determined more by the amount of rainfall received and stored by soil than by the air temperature. However, according to Mukiibi (2001), the magnitude of rainfall is less critical to farmers' production than distribution through a season.

When the rainfall is insufficient, the economies of countries that depend on rain-fed agriculture perform poorly. Studies by Haile et al. (2011) have found that, nearly one third of African population depends on food production which is largely dependent on rainfall and therefore face chronic food insecurity when the rains fail. In their study on the impacts of rainfall variability on agriculture in Africa, Boko et al. (2007) found that, yields from Africa's rain -fed farm production could decrease by 50% by the year 2020. In line with this finding, it had been asserted earlier by Monadjem and Perrin (2003) that rainfall trends were also important for optimizing the spatial distribution and adaptability of different agricultural enterprises

The economy of East African region heavily depends on rain-fed agriculture which is prone to the negative impacts of climate variability. A study by Adhikari et al. (2015) established that there has been a decline in the long rainfall season between March and May, and the resultant moisture deficit has resulted in decreased crop yield of long-life grains, such as maize, across the East African region.

According to Adamgbe et al. (2013) variability in rainfall characteristics has a greater potential to crop failure and majorly in food crop yield including maize and hence food insecurity in most Sub Saharan (SSA) countries in Africa. The Sessional Paper No.5 of 2016 on National Climate Change Framework Policy reported that the climate in Kenya was changing at an alarming rate that was likely to affect sustainable development in the country. According to Jones (2001), effectiveness to address climate change impacts can be achieved through adaptation strategies.

Kenya is adversely affected by climate change and variability which are likely to affect agricultural production. A study by Kabubo-Mariara and Karanja (2007) found that, precipitation was positively correlated with net crop yield. Similarly, Wilfrey et al. (2018) while investigating the effect of climate change on maize productivity in Kenya found that precipitation and temperature affects maize production. According to Dikko et al. (2013) the effect of rainfall are diverse ranging from designs of agricultural systems to erosion control mechanisms. Furthermore, Nyandiko et al., (2013) found that in Lower Eastern Kenya region, inter annual rainfall variability had a major impact to farming activities resulting into food insecurity among the vulnerable communities.

2.8 Climate Change Risks in Agriculture

According to Filipovic (2020), water is a basic natural resource in plant production, because it plays a significant role in germination, growth, transpiration, the transformation of starch into sugar, and the absorption of nutrients.

Understanding major climate risks is crucial in efforts to reduce farmers' vulnerability. It has been reported by IPCC that climate change has significantly affected global agriculture in the 21st century and their assessment reports indicates that most countries will experience an increase in average temperature, more frequent heat waves, more stressed water resources, desertification, and periods of heavy precipitation (IPCC 2007, IPCC 2014). Various studies for instance, Bilham (2011) have shown that temperature had more impact on crop yields than rainfall whereas Jones & Thornton (2003) showed that maize production in Africa and Latin America would reduce by 10% by 2055 and recommended that climate change effects should be assessed at household level so that the poor who depend on agriculture can be targeted for advice.

In the Western Balkan region, studies by Gocic and Trajkovic (2014) on the risks posed by climate change in the agricultural sector showed that increasing occurrence of drought, which mainly occurs in the summer months, has been identified as a major risk for region's agriculture. In the same Balkan area, extreme temperature changes in 2011 led to crop failure due to frost damage (CARE, 2015).

In Europe, a study by Trnka et al. (2004) has revealed that an increase in temperature variability will increase yield variability and also result in a reduction in mean yield. Moreover, a study by Schär et al. (2004) has showed that the projected increases in temperature variability over Central Europe may have severe impacts on the agricultural production in this region. In another study in the same area, Jørgen et al. (2002) found that, warming is expected to lead to a northward expansion of suitable cropping areas and a reduction of the growing period of crops such as cereals.

In Enugu, Nigeria, Okoro et al. (2016) found that amongst climate risks farmers are exposed to include; high mortality of crops and livestock, increase in soil erosion, loss of pastures, poor yield of crops, reduction of soil nutrient and increase in pests and diseases. According to the IPCC (2014) report and Vinke (2017), climate change has adversely affected the agricultural production in East Africa (EA) and is expected to get worse in future.

Several other studies in East Africa by Adhikari et al. (2015) and Muchuru et al. (2019) show a negative impact of climate change on agricultural production and food security in the region. Studies by Muchuru et al. (2019) also show that frequent occurrence of extreme heat events and increasing aridity will have several adverse repercussions on the entire agricultural system in East African region. Furthermore, it has been projected by Niang (2014) that the climate-related risks are expected to be even more severe in the 21^{st} century in East Africa as temperature in this region is projected to rise much faster than the rest of the world (2 – 4ºC. Moreover, a study conducted by Jeetendra et al. (2021) reveals that East Africa region, experience recurrent drought stress induced primarily by higher temperature and poor annual rainfall distribution leading to a prolonged dry period. The same study also revealed that East Africa region experiences some flooding incidences resulting from isolated heavy rainfall events leading to water logging that has adverse consequences to the crops.

In Kenya, the National Climate Change Action Plan (2018-2022) has intimated that greater risks are to be expected in the agricultural sector due to climate change. Amongst these are; l**ess** days for crop growth, more frequent and severe droughts, erratic weather patterns which disrupt agricultural planning, increased flooding of agricultural land and more pests.

2.9 Climate Information Services Providers

Regional climate centres have taken a central role in ensuring that CI is availed to ever increasing demand. For example, in India, Parija and Mishra (2015) have intimated that recently, private climate information service providers have gained prominence in the forecasting space, attributed partly to their vast and superior observational networks and computational facilities as well as their flexibility because they are unhampered by constraints that potentially affect government responses.

According to Daly and Dessai (2018) regional hubs, including the Intergovernmental Authority on Development Climate Prediction and Applications (ICPAC), the Agro meteorology, Hydrology, Meteorology (AGRHYMET) Regional Centre, and the Southern African Development Community Climate Services Centre (SADC-CSC), provide additional support and coordination across countries in Africa. ICPAC disseminates early warning climate hazard information to East African countries while AGRHYMET provides information on food security and environmental issues for countries in the Economic Commission of West African States (ECOWAS). According to Patt et al. (2007), the Southern Africa Regional Climate Outlook Forum and the Greater Horn of Africa Regional Climate Outlook forum (GHACOF) provide CI in these regions. There is also the African Centre of Meteorological Applications for Development (ACMAD).

In Kenya, the Kenya Meteorological Department (KMD) is mandated to collect and store climate data in the country (Meteorology Bill, 2023). KMD is also charged with coordinating and managing the climate information provision framework. At the county level, KMD operates a decentralized climate service with county meteorological offices communicating localized meteorological services including seasonal forecasts through accessible channels (Barrett et al., 2020). According to Singh et al. (2018) and Prokopy et al. (2017), provision of climate information has improved in the recent past mostly due to co-production and also due to improved forecasting skills and involvement of private sector. In the recent past, it has been reported by Dinku et al. (2018) that the ENACTS (Enhancing National Climate Services) initiative has come on board and it ensures that, climate information products that are relevant to farmers' local needs are generated and disseminated through online "Map rooms." Climate Change directorate of Kenya also provides CI to the public in addition to its role to oversee climate change issues in the country. The current study would come up with recommendations on how the CI providers can work well with the users of such information in order to improve decision- making based on available climate information.

2.10 Maize Production in Bungoma County

Despite the heavy investment by the Kenya government in agricultural sector, maize yield remains low and marginal. According to the study by Adijar et al. (2010), Bungoma County produced only an average of 10 bags of 90kg maize per acre. However, maize production in the county has been on an upward trend over the last few years increasing at an annual average rate of about 9.7%, but it is still not sufficient as per capita consumption is around 1.5 bags of 90kgs making the annual consumption requirement to be 3,737,690 bags, while production is at 2, 962,830bags (98,761 Ha. (BCIDP, 2013-2017). Furthermore, (BCIDP, 2018-2022), reported that most of the agricultural activities including maize growing are rain-fed, meaning that farmers only Plant during the rainy seasons and therefore climate information is required to guide production.

2.11 Policy and Legislative Framework

At the moment, Kenya still lacks a comprehensive climate services and only relies on some pieces of policies and legislations some of which are still in draft form. Meteorological and related services currently provided by KMD are limited in scope and face strategic challenges due to lack of a national institutional coordination arrangement and policy, inadequate technical infrastructure and proliferation of independent entities providing unregulated climate services (NFCS, 2023). Some of the policies and regulatory legislations that attempt to address matters to do with climate services include; the National Climate Change Framework Policy (2016), the United Nations Framework Convention on Climate Change (1992), the National Framework for Climate Services (2023), the Global framework for Climate Services (2009), the

Climate Change Act (2016) amended in 2023, and the draft Meteorological Bill (2023). At the County level, there is the Bungoma County Climate Change Action Plan (2023-2027).

The National Climate Change Framework Policy (2016) provides for generation and management of Climate Change knowledge and information combined with effective communication strategies to enhance awareness among various sectors and the communities at large.

The United Nations Framework Convention on Climate Change (1992) aims at promoting the cooperation in training and creating public awareness related to Climate Change and encourages coordinated provision of climate information. It also addresses issues related to promotion of scientific and technological innovations on matters on climate systems and Climate Change and ensures that the public access streamlined information on Climate Change and its effects on various sectors.

Underscored by the ever increasing devastating and recurrent negative episodes of weather and climate events experienced, the Kenya Government developed the National Framework Convention on Climate services (NFCS, 2023) whose main mission is to improve national climate services. One of the goals of this framework is to enhance the capacity to generate and use CI and products such as weather forecasts in order to build resilience to Climate Change. However, the NFCS is yet to be operationalized.

The Climate Change Act (2016) provides a regulatory framework for enhanced response to Climate Change. Its objective is to promote Climate Change resilience and ensure there is sustainable development in Kenya. The framework also aims at mainstreaming Climate Change responses into planning and decision making in various sectors and has put forward mechanisms of climate change adaptation and mitigation.

For there to be smooth running of meteorological affairs in the Country, there is the draft Meteorological Bill (2019) that proposes the establishment of Kenya National Meteorological Authority which shall regulate, coordinate, monitor, manage, provide and control meteorological services. The authority will provide advisory services that include weather and climate outlooks, weather and climate forecasts, warnings related to weather and climate and any other climatological advice.

At the County level there is the Bungoma County Climate Action Plan (2023-2027). This plan gives a roadmap to the implementation of climate actions based on CI especially at the community level to build resilience against Climate Change impacts. Under this framework, the County Government has prioritized strategies which entail promotion of climate smart agriculture and dissemination of climate information and awareness creation on sustainable agriculture in key sectors such as maize production.

All these policy regulations will ensure that CI services are strengthened so that consumers of CI get the much desired information that will assist in making the right decisions.

2.12 Theoretical Framework

In studying the role of seasonal rainfall forecasts on maize production, the decision-making theory was applied. Decision making theory is a theory of how rational individuals should behave under risk and uncertain situations. Deciding is making a choice between alternative courses of action. A rational farmer can decide on farm operations based on the prevailing or expected weather and climatic conditions and availability of climate information services becomes handy. Climate change is characterized by high levels of uncertainty, and this uncertainty can influence farmers' decision making. According to Camerer et al. (2005), agricultural decision making has historically been dominated by economists who tended to rely on normative mathematical models and behavioral theories driven by assumptions of human rationality that emphasized utility maximization. Furthermore, Kurt et al. (2020) has showed that given that agricultural decision making is key to the economic livelihood of the farmers making these decisions, an economic approach is commonly used in studying this domain. Using a traditional economic framework, individuals are assumed to be rational actors with perfect information about choice alternatives that make decisions that will maximize their utility using all the information available.

2.13 Conceptual Framework

Figure 2.1 below is a conceptual framework that guided the study on theinfluence of seasonal rainfall forecasts on maize yield in Tongaren Sub- County. The conceptual framework gives an illustration of how various variables in the study interacts. The main dependent variable is maize yield. This framework shows how maize yield is influenced by independent variables in the presence of intervening variables. The resulting dependent variable is the farmers' farm-level decisions which are based on the rainfall forecasts.

In this study, the main independent variable was the seasonal rainfall forecast whereby the amount of rainfall forecasted in a season directly determines maize yield. The other independent variables that influence the use of seasonal rainfall forecasts include; social factors, mode of forecasts dissemination, capacity to interpret rainfall forecasts, appropriate communication channels to disseminate forecasts, access to seasonal rainfall forecasts and interest in CI among others. These independent variables are important because they determine whether the maize farmer is well enabled to apply the forecasts or not. Mediating variables included; climate change and variability, crop diseases and pests, soil fertility and relevant Government policies and frameworks on climate services which all affect maize production either directly or indirectly.

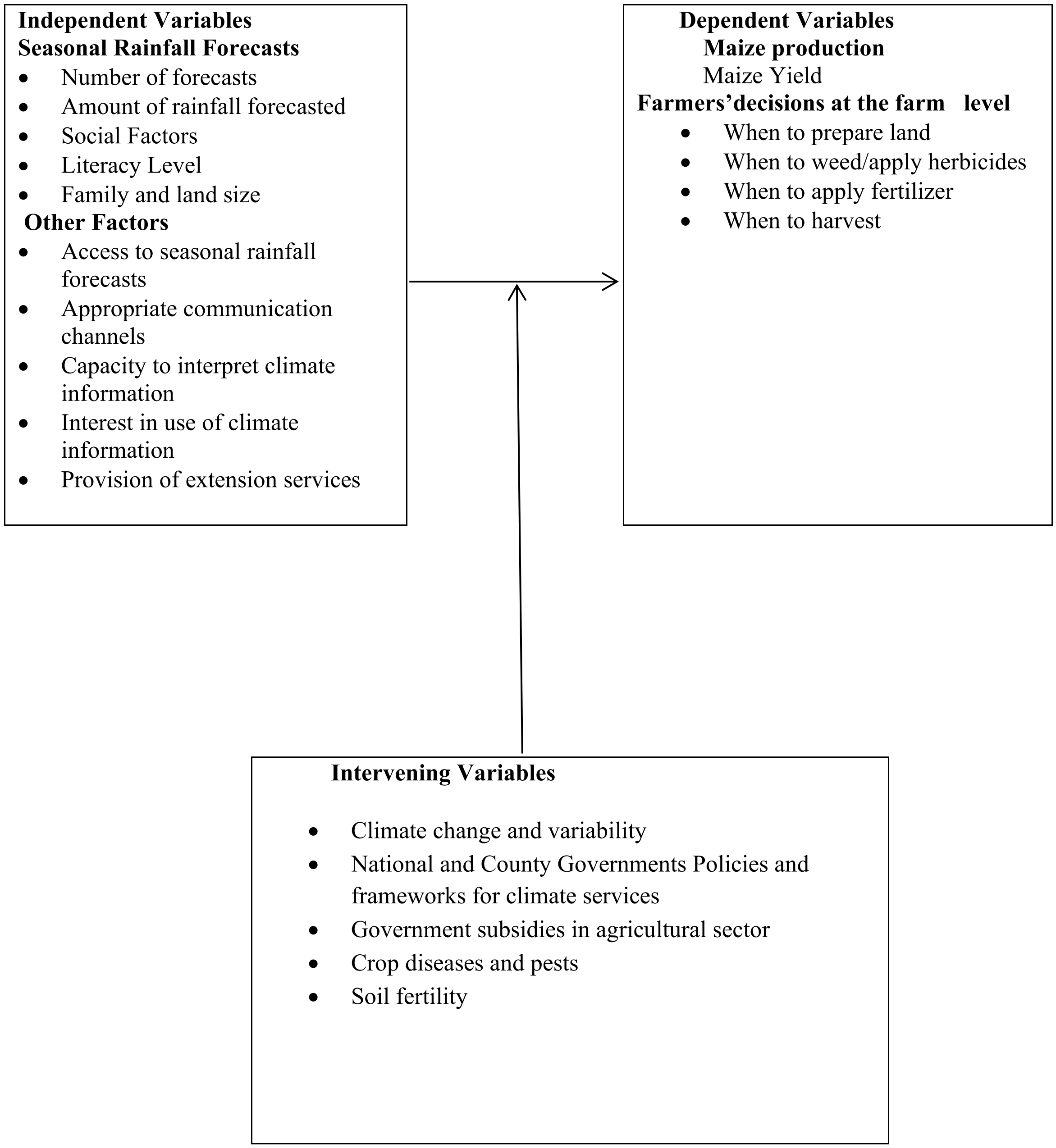

Figure 2.1: Conceptual Framework

Source: Author, 2024

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the description of the study area, research design, sampling procedures, population size, sample size and research instruments amongst others. The chapter further outlines the methods, techniques and procedures used to collect, analyze and present data based on the objectives of the study. Lastly the chapter briefly describes the limitations and delimitations as well as ethical issues on the manner of conducting the study.

3.2 Study Area

Tongaren Sub – County is found in Bungoma County in the larger Western part of Kenya. It covers an area of 378.4Km^2 and has a population of 100,343 people out of which 33,602 people engage in maize growing (KNBS, 2019). The Sub- County is located to the Far East of Bungoma County (Figure 3.1). It lies between latitude 0.66394ºN to 0.88603ºN and longitude 34.80166ºE to 35.06785ºE. This Sub- County has the following wards, Mbakalo, Naitiri/Kabuyefwe, Milima, Ndalu, Tongaren and Soysambu/Mitua. The Sub - County is majorly rural with headquarters at Tongaren market centre. The Sub- County is also the bread basket of Bungoma County. It has fertile loam soil that supports agricultural production especially maize growing. Tongaren Sub-County is the leading producer of maize in Bungoma County. In the recent past the average acreage of land under maize production has been 23,280 ha and maize yield of an average of 1,020,124 bags per year (Bungoma County department of agriculture, 2023).The Sub- County has two major rivers namely, river Nzoia and river Kiminini and several streams. The Sub-County has one hill called Naitiri hill. In terms of climate, the Sub- County has a warm tropical climate with mean maximum temperatures ranging between 24 ºC and 30 ºC and mean minimum temperatures ranging between 14.0 ºC and 18.5 ºC. The area receives over 1000mm of rainfall per year most of which falls in the afternoons and evenings. Figure Figure 3.1 shows the location of Tongaren Sub-County within Bungoma County.

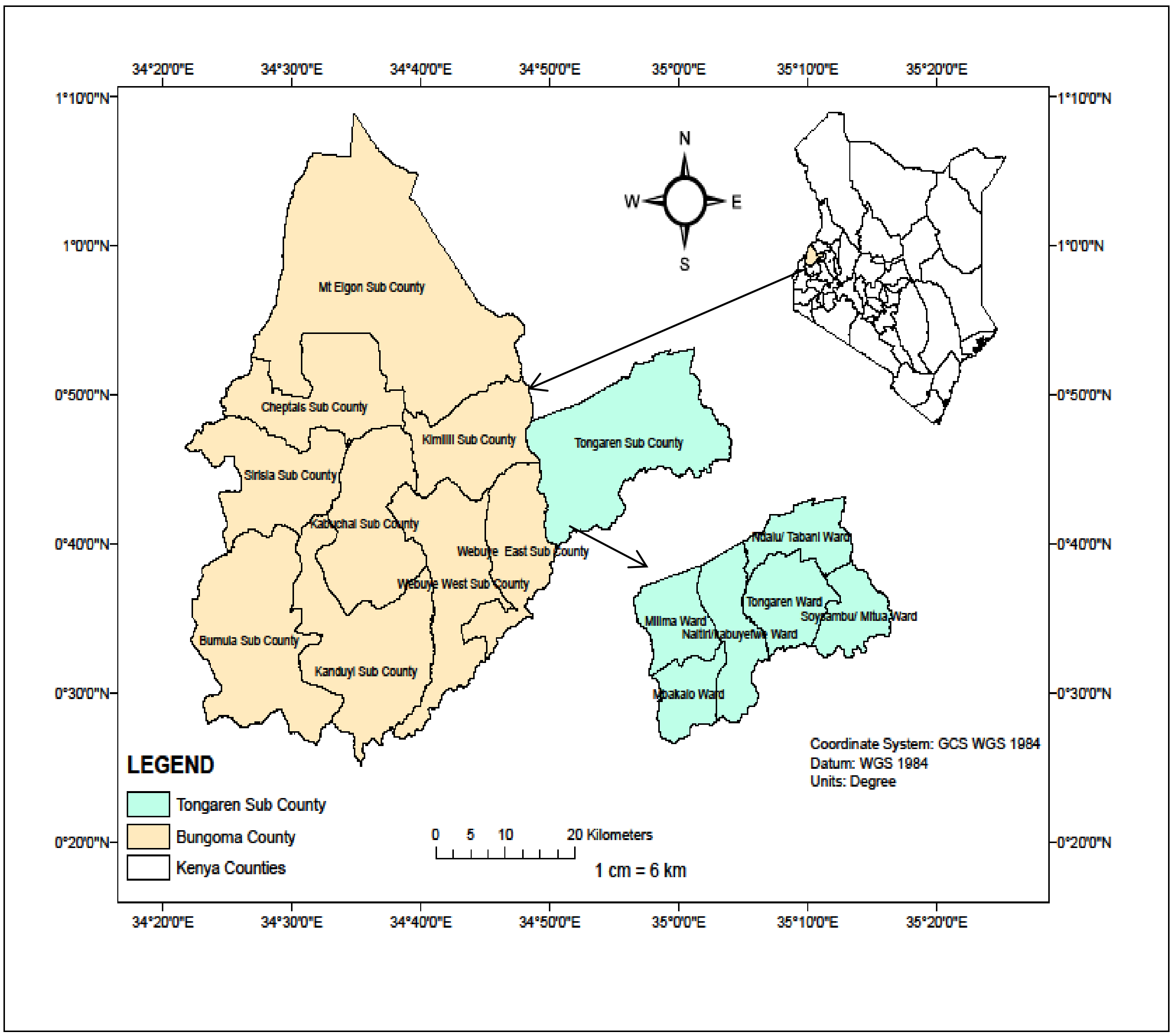

Figure 3. 1: Map of Tongaren Sub - County in Bungoma County showing location of study area
Source: Author, 2024

3.3 Research Design

This focused on a plan, strategy and framework that were used for conducting the research. According to Kothari (2004), research design is the strategy specifying which approach will be used for gathering and analyzing the data and also includes a plan that specifies the sources and types of information relevant to the research problem. Based on specific objectives, the research designs adopted are outlined in the Table 3.1.

Table 3. 1: Summary of Research Designs and Data Analysis Methods

Specific objective	Measurable indicators	Research design	Data analysis method
i.To determine the trends of seasonal variability of rainfall in Tongaren Sub - County.	Rainfall trends	Correlational	Time series analysis using Mann Kendall trend test
ii. To evaluate the factors influencing utilization of seasonal rainfall forecasts for maize production in Tongaren Sub - County	Literacy level, Age,sex,economic Activities, land Size,mode of dissemination of forecasts	Descriptive Survey	Use of descriptive and inferential statistics
iii. To assess the benefits of using seasonal rainfall forecasts on maize crop yield in Tongaren Sub - County	Maize yield	Descriptive Survey	Use of correlation, descriptive and inferential statistics

Source: Author, 2024

3.4 Target population

According to the Kenya National Bureau of Statistics (2019) census report, Tongaren Sub - County has 33,602 people maize farmers. Thus, 33,602 people represented the target population. The basic unit was individual maize farmer at the farm level. In this study, six (6) wards were involved. These were; Ndalu, Soysambu/Mitua, Tongaren, Naitiri, Milima and Mbakalu. The number of maize farmers targeted in each ward were; 59, 107, 47, 56, 61 and 65 respectively.

3.5 Sources of Data

Primary data comprised information collected from the field by use of a questionnaire and key informant interview guides, observation checklist and focus group discussions (FGDs). The secondary data specifically maize yield was sourced from Bungoma county department of agriculture and climate data that is precipitation from the Kenya meteorological department. Since maize is a crop that grows within certain altitudes and Tongaren sub- County being a high altitude area, all high altitude maize varieties grown within the study area were considered.

3.6 Sampling Procedures

This section presents the method or procedure that was used in the study to determine a suitable sample which represents the whole population. The study used multi-stage procedure to identify the study sample. In the procedure, proportionate technique (Etican et al. 2017) was used to determine sample size for each ward. The individuals living in a particular village formed a distinct cluster from the others.

For the key informants purposive sampling was applied whereby technical people were selected to give relevant information in their areas of specialization and for the focus group discussions, the study applied convenience sampling technique

All the sampling techniques used in the study are presented in Table 3.2 below.

Table 3.2: Summary of population unit

Study population unit	Sampling method	Sampling size	Data collection tool
Maize farmers	Multistage	395	Questionnaire
Agriculturalists	Purposive	5	Questionnaire, Interview
KMD	Purposive	3	Interview
Disaster Management	Purposive	3	Interview
Stakeholders (Solidaridad , FtMA, ADS, GIZ)	Snowball	6	Interview
Focus Group Discussions	Purposive	2	Questionnaire

Source: Author, 2024

3.7 Sample Size

The study used a sample size calculated from equation (1) whereby proportional allocation was applied to determine the number of respondents from each ward. The study applied the formula by Yamane (1967) to determine the sample size.

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

where n= Sample size

N= Population size

e=Level of precision which is 0.05%

n=33602/⟦1+33602∗0.05⟧^2

=395

From a target population of 33602 maize farmers and by application of the above equation, this study used a sample size of 395 maize farmers. Table 3.3 below gives the actual number of people who participated in the survey as per the wards in Tongaren Sub-County.

Table 3.3 Distribution of Sample Size

Ward	**Number of maize farmers**	**Sample**
Ndalu	5000	59
Soysambu/Mitua	9102	107
Tongaren	4000	47
Naitiri	4800	56
Milima	5200	61
Mbakalu	5500	65
Total	**33602**	**395**

Source: Author, 2024

3.8 Research Instruments

Various research instruments were employed to capture the desired data and information. Among them were; Household interviews (HHI), key informant interview (KII), Observation checklist and Focus group discussions (FGDs).

3.8.1 Questionnaires

Primary data from maize farmers in the field was collected by use of household semi structured questionnaire (Appendix I) that was administered to the males and females from the sample obtained from the target population of maize farmers. The questionnaire was both open and closed self-made and contained items such as demographics, attitudinal items and factual items. The questionnaire aimed at obtaining information to evaluate the factors that influence maize farmers to apply seasonal rainfall forecasts and also sought information from maize farmers to assess the benefits of using seasonal rainfall forecasts on maize yield.

The questionnaire was administered personally with the help of research assistants to individual respondents. This was advantageous because it enabled the researcher to establish a good working relationship with the and also build trust.

Before the actual collection of qualitative research data, the instrument, in this case the questionnaire was subjected to pilot testing. This testing is important because it established the content validity and reliability of the instrument (Kothari, 2004) and also helped to improve questions, format and the scales. In the piloting, the study used 40 respondents who were picked randomly from three wards in Tongaren Sub- County.

3.8.2 Key Informant Interview

Key informants questionnaire interviews (Appendix II) were conducted targeting various groups or organizations engaging in improvement of agriculture especially maize growing in Tongaren Sub - County. This targeted those who had been involved in improvement of maize productivity within the study area and what they were doing to counter the effects of climate change and variability on maize production. These gave an assessment on how climate change and variability has impacted maize production in the Sub-County. Key informant interview schedule was advantageous because it enabled the researcher to interact directly with those who had first-hand information on maize production in the Sub-County. This was also a quick way of gathering the data.

3.8.3 Observation Checklist

A checklist (Appendix III) on key items related to seasonal rainfall forecasts and maize yield in Tongaren Sub -County was developed and each item was discussed and counterchecked with the checklist. The checklist targeted to capture the secondary data of rainfall amount and maize yield recorded for each year in the study area for the period running from 1985 to 2022. This research instrument was preferable because it gave the researcher an opportunity to quickly confirm the availability of the data that was required for the study.

3.8.4 Focus Group Discussions (FGDs)

A focus group discussion is a research instrument where selected groups of people discuss given topics or issues in-depth. In this study the topical issue under discussion was the influence of seasonal rainfall forecasts on maize crop yield in Tongaren Sub - County. The Focus Group Discussion Guide (Appendix IV) was used to obtain data on the trends of seasonal rainfall and maize yield and the effects climate change and variability has had on maize productivity. In this study, FGDs involved two groups; one which comprised a group of eight agricultural experts and three meteorological experts and the other group comprising of nine elders drawn from the study area. This research instrument was preferred because the researcher was able to gather the information required in a short duration of time.

3.9 Validity and Reliability of Research Instruments

It is very important for research instruments to produce the desired or intended information that is in accurate form in order to draw valid decisions. Since precision and accuracy are crucial issues in research, this study used validity and reliability as two key concepts to assess the accuracy in the research processes that were undertaken.

3.9.1 Validity

The study investigated the suitability of the instrument to measure what it was supposed to measure in line with the stud. A pilot study was conducted in three wards of Kanduyi Sub-County where forty (40) subjects participated. The wards were, Bukembe West, Khalaba and Sang'alo East. The participants from these wards were not to take part in the actual and final study in Tongaren Sub- County. The results obtained from piloting process assisted the researcher in fine tuning the instruments by eliminating items that were not valid. The validity of the instrument in this study was guaranteed by ensuring that the items in the questionnaire were related to each objective of the study (content validity). This was further augmented by jury opinion whereby opinions from recognized experts were sought.

3.9.2 Reliability

The study investigated whether the instrument (questionnaire) yielded the same results when it was repeatedly used by the researcher for consistency of the measurements under the same circumstances. Reliability of the instrument was assessed using the split-half (50-50 split) reliability test whereby the questions in the questionnaire were split into two parts and the responses from the respondents correlated. It was ensured that each half had at least ten questions for it to be viable as a test. Thereafter, correlation was used to compute the split-half coefficient (R) which was calculated from the relationship;

$$R = \frac{2r}{1 + r}$$

(2)

where,

R = the split-half coefficient, and

r = the actual correlation between the two matched halves of the instrument.

A split-half coefficient of 0.7 or more qualifies the instrument as reliable (Spearman-Brown, 1910). The value of r as computed from two matched halves was 0.80. Putting this value of r in the above formula, the result is:

R= 2*0.80/1+0.8

=0.89

Thus R computed was 0.89 and this qualified the instrument as reliable.

3.10 Data Collection

The primary data and secondary data used in this study were collected for the period between 1985 and 2022.

3.10.1 Primary Data

Primary data comprising demographics and perceptions among others was obtained from the field survey by use of questionnaires, key informant interviews, observation checklists and focus group discussions. The data was used for objective two in evaluating the factors influencing utility of seasonal forecasts for maize production in Tongaren Sub- County. The data from the survey was also used for specific objective three to assess the benefits of using seasonal rainfall forecasts on maize yield. A structured questionnaire was administered to selected households who engage in maize growing. The questionnaire was divided into various sections to capture specific type of data namely; household personal details, household income, agricultural land use practices, farm characteristics such as land size, maize yield and various climatic factors that affect maize production. This data was analyzed by use of statistical analysis packages.

3.10.2 Secondary Data

Secondary climate data for specific objective one on determining rainfall trends in Tongaren Sub-County was obtained from Kenya Meteorological Department. This comprised monthly rainfall totals sourced from the department's data archives for the period running from 1985 to 2022. This data was analyzed by time series analysis techniques. The other data required was the annual data of maize yield for Tongaren Sub-County which was obtained from Bungoma County department of agriculture for the same period. The data was also analyzed by time series analysis technique.

3.11 Data Processing and presentation

The section covers the procedures used to obtain the results of the study. The collected data was prepared for analysis through editing, cleaning and coding. Consistency of climatic data was also performed by use of single mass curve method. Descriptive and inferential statistics were employed to analyze the data. Since this study aimed to analyze rainfall data from the field, the basic statistical analysis of measures of central tendencies such as means and measures of dispersion such as standard deviation and variance were calculated. The rainfall analysis was done through time series analysis and Mann Kendal trend analysis. In time series analysis, the rainfall amounts were plotted against the period (time). Trend lines were also inserted to indicate the general rainfall trend whether increasing or decreasing. Furthermore, the rainfall amounts were standardized and the anomalies plotted on a graph in order to determine the years that had less or more rainfall as compared to the long term means. The significance of the rainfall trends was then established by the use of Mann Kendall trend analysis.

Calculation of percentages and frequency distributions were also done. The study considered two seasonal rainfall forecasts that is, March, April and May (MAM) and June, July, August and September (JJAS) the reason being that the rainfall in these months coincide with the maize growing period and benefits its production right from sowing up to maturity. The rainfall data was analyzed using XL-STAT, excel whereas the data obtained by interviews was analyzed by statistical package for social sciences (SPSS) statistical packages. The analysis involved computation of frequencies, means, correlation coefficients, and standard deviations. For objective one, the rainfall data was analyzed using XL STAT and excel packages. For objective two, questionnaire for household interview was administered to the respondents whereby they were asked to indicate the factors that influence maize production by choosing from a list of choices. The information was then analyzed using XL STAT and SPSS statistical packages. Similarly, information on the most preferred communication channels for CI was obtained by questionnaire for household interview where by the respondents were to give their answers by choosing from a list of choices that had been ranked. Lastly, the third objective was achieved through analysis of data that was obtained also through the questionnaire for household interview. They chose their answers from a list of five choices. The data was then analyzed using XLSTAT and SPSS packages. The collected data and the results were presented in form of pie charts, tables, time series graphs and bar graphs.

3.11.1Trend Analysis

Trend gives general direction in which the graph of a time series appears to be going over a long interval of time. The trend analysis was important as it depicted graphically any change in rainfall and maize yield over the study period. In this case, values were plotted on a time series and a line of best fit plotted The trend indicated whether there was an increase, decrease or stagnation of rainfall amount in Tongaren Sub- County amongst maize producers. Trend analysis was performed by use of Mann Kendall trend test method at 95% confidence level and significance level of 0.05. Mann-Kendall test is premised on two hypotheses i.e., the null hypothesis (H_O) and the alternative hypothesis (H_a) where,

Ho: There is no trend in the series.

Ha: There is a trend in the series.

If the computed p-value is greater than the significance level (alpha) = 0.05, one cannot reject the null hypothesis Ho because $p > 0.05$. On the other hand, if computed p-value is less than the significance level which is 0.05 then one rejects the null hypothesis since there will be a significant trend in the series.

3.11.2 Analysis of Mean

Analysis of the means was computed using statistical packages. In this case, seasonal and annual rainfall means were computed using the arithmetic mean formula.

$$\bar{x} = \frac{1}{n}\sum x_i \quad (3)$$

where,

$\bar{X}$ = long term mean of rainfall

n =number of years or months

x_i =rainfall amount in a month or a year

Further analysis of the means was applied to determine whether we had a negative or positive trend in the rainfall amounts over the years. To achieve this, rainfall data was split into two equal parts then computing the means as well as the variances of the two divisions. This method uses the t-test for the difference between two means to reveal whether the trend is significant or not. The formula for the student t-test for the difference between two means is given by:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad (4)$$

where,

t is the student test

$\bar{X}_1$ and $\bar{X}_2$ are means of the two divisions

n_2 and n_2 are sizes of the two divisions

S is the average variance given by:

$$S = \frac{S_1 + S_2}{2} \quad (5)$$

where,

S_1 and S_2 are variances of the two divisions

It should be noted that,

If $\bar{X}_2 > \bar{X}_1$ then there is a positive trend

If $\bar{X}_2 < \bar{X}_1$ then there is a negative trend

If $X_2 = \bar{X}_1$ then there is no trend

3.11.3 Homogeneity Test

Data inhomogeneity may lead to incorrect computations and conclusions in climatic time series analysis. Homogeneity test checks the consistency and the accuracy of data by identifying outliers or deviations from other related parameters. This study made use of single mass technique to establish homogeneity of the rainfall data. The cumulative values of rainfall were computed in a forward manner and then plotted against time. According to Pinzari et.al. (2018), straight or almost straight line plotted indicates that the data was consistent. The homogeneity test for this study yielded an almost straight line signifying that the rainfall data used was homogeneous.

3.11.4 Analysis of variance

Inter-annual and intra-seasonal variability (coefficient of variation) was computed using the relationship below:

Coefficient of variation (V) = $\frac{SD}{\bar{\bar{X}}}\ X\ 100$ (6)

where,

V = coefficient of variation (variability)

SD = standard deviation

$\bar{X}$= is the mean

3.11.5 Rainfall Anomalies

To compute the rainfall anomalies, the difference between total rainfall either for a year or a season and long term mean (LTM) was divided by the standard deviation. These anomalies are indicative of the departure from LTM with the negative values representing periods of below normal rains whereas positive values indicate the above normal rains usually characterized by flood risks.

The Standardized Anomally Index (SAI) is a statistical tool used to assess the variability of climate data, like temperature or precipitation by comparing it to its long-term average. It quantifies how much specific value deviates from the norm, expressed in terms of standard deviations. This allows for the identification of usually wet or dry periods, or warming or cooling trends.

It is calculated by subtracting the long-term average from the observed value and then dividing the result by the standard deviation of the observed values over the same period.

SAI indicates a value above the long-term average, while a negative SAI indicates a value below the average. The magnitude of the SAI indicates the extent of the deviation.

Table 3.4: Standardized Anomaly Index for Rainfall

Rainfall Anomaly Index (RAI)	RAI value category/class
>2.0	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.84 to – 0.99	Near normal
-0.84 to -1.28	Moderate drought
-1.28 to -1.65	Severe drought

Source: Van Rooy, (1965)

3.11.6 Correlation Analysis

Correlation coefficient gives the degree of relationship between two variables. This method was used to determine the relationship between rainfall and maize yield. The Pearson's correlation coefficient formula was used to compute correlation value. The formula is given below:

$$R_{XY} = \frac{\sum \frac{(X-\bar{X})\,(Y-\bar{Y})}{N}}{\sqrt{\left(\frac{\sum (X-\bar{X})^2}{N}\right)\left(\frac{\sum (Y-\bar{Y})^2}{N}\right)}} \qquad (7)$$

where,

R_{XY} is the coefficient of correlation,

N is the total number of observations,

$\bar{X}$ is the mean of variable X,

$\bar{Y}$ is the mean of variable Y

Using the Pearson's formula,then the guide to make conclusions are;

If R_{XY} = 0 then there is no relationship between the stations rainfall patterns.

If $R_{XY} > 0$ then they are positively correlated

If $R_{XY} < 0$ then they are negatively correlated

3.11.7 Rainfall Probability of Exceedance

Rainfall probability of exceedance is the probability that a given total accumulated over a given duration will be exceeded in any given time interval. The forecast interpretation tool (FIT) was used to analyze seasonal rain forecasts in order to determine whether the rainfall amount received during the season was sufficient to support maize growth. The rainfall seasons of interest were MAM and JJAS The probability of exceedance is calculated using Wolfram formula given by:

$$P = 1 - e^{N_a T_p} \tag{8}$$

where,

P = Probability of exceedance

N_a = Average annual occurrences

T_p = Prediction time period

Exceedance probabilities were plotted against precipitation values for the period spanning 1985 up to 2022.

3.12 Ethical Issues

The ethical considerations in this study included seeking permission to conduct research from research committee at Masinde Muliro University of Science and

Technology. A research permit was also sought from the National Council of Science, Technology and Innovation (NACOSTI). Also permission to conduct research in Tongaren Sub -County was sought from the County Government of Bungoma. On the issue of confidentiality, the respondents were assured through writing that, the information they gave was to be used only for the purpose of the research and they would not be required to be identified in any way whatsoever in form of either name, address, place of work or in any other form of personal identification. The respondents were also asked to participate in the study voluntarily and no forms of coercion or persuasion were to be applied. Other peoples' intellectual contributions in this study were acknowledged by always citing their work.

3.13 Limitations of the Study

It was anticipated that the following factors would affect the study adversely:

It was feared that some respondents were not willing to participate or respond positively out of the fear that some of the questions may not be suitable based on their religion and culture. This problem was addressed by establishing rapport with the community members through interacting and discussing.

There was also the issue of confidentiality where the respondents were cagey about revelation by the researcher of the responses to the third party. This problem was solved by the researcher assuring the respondents that all that was contained in the filled questionnaires would be treated with the highest confidentiality and that nothing would be divulged to the third party. Furthermore, the respondents were asked not to write their names on the questionnaire against their wish. Maize yield depends on other factors such as soil fertility, farm inputs etc. However this study focused only on seasonal rainfall which is the key factor and this was another limitation which was solved by recommending that other factors in future research on maize yield be considered.

3.14 Assumptions of the Study

The following are the assumptions that were made during the course of the study:

I. The respondents sampled in the study area were a true representation of the entire population.

II. All the respondents gave accurate, valid and reliable information.

III. The findings of the study gave a true picture of the situation on the ground.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents results and discussion of the findings of the study. The chapter covers social demographic aspects of the respondents, the trends of seasonal rainfall, factors influencing utilization of seasonal rainfall forecasts, the benefits of using seasonal rainfall forecasts on maize crop yield, data homogeneity test and rainfall probability of exceedance.

4.2 Social Demographic Characteristics of Respondents

This section presents the results of social aspects from 356 maize farmers who responded in the field. This represented 90.1% return rate of the questionnaires.

4.2.1 Gender of the Household Head

Gender plays a vital role in determining the roles an individual may be assigned in accomplishing a given task. Figure 4.1 shows the distribution of gender amongst the respondents.

Figure 4.1 shows that majority of the respondents (58.4%) were male while 41.6% were female. This implies that the gender distribution of maize farming households in Tongaren Sub County is fairly well balanced even though the male gender seems to be more than their female counterparts. This result suggests that most of the households in Tongaren Sub-County are male-headed.

The significant percentage of female gender in maize production also confirms an earlier research in Ghana by Doss (2006) that found that the share of women in the labor force has a significant impact on the national food availability and positively influences domestic maize productivity. According to Beuchelt & Badstue (2013), men and women are affected differently by climate information and climate change. As compared to men, women face more challenges in uptake of technologies that are embraced in climate smart- agriculture (CSA) practices (FAO, 2013). Furthermore, gender characteristics are key determinants of technology adoption (Fisher and Kandiwa, 2014). With this in mind, there is need to design gender- responsive tools and technologies that are suitable for either gender which will enable the users to access and utilize climate information such as seasonal rainfall forecasts.

According to the study on smallholder farmers in Malawi, Henriksson et al. (2021), access to climate information, such as weather forecasts, has been identified as a potential enabler for improved adaptation but such access and utilization seem to be strongly gendered. This finding affirms the fact that gender is very crucial in determining access and utilization of seasonal rainfall forecasts. According to the socio-cultural norms that define women's and men's labour roles, this can also influence the resources and decisions under their control, affecting their differing climate information needs and demand. A study by Jost et al. (2015) found that access to forecasts seems to have gender dimensions, with men reportedly having more access due to their control of the radio in the rural households.

Another fact which may be linked to gender as a factor in access to and use of CI is that women generally are engaged in many social gatherings hence they are likely to share CI information with others and this sharing may boost the dissemination of CI. Studies by Assefa et al. (2020) and Slavchevska et al. (2021) on the relationship between yield and gender of smallholder farmers have shown that male farmers may achieve better yield outcomes than female farmers because cultural norms give them better land ownership and farming management rights. It is therefore important to understand gendered preferences to seasonal rainfall forecasts access and utilization in order to adapt appropriately to weather fluctuation and climate change challenges on maize growing.

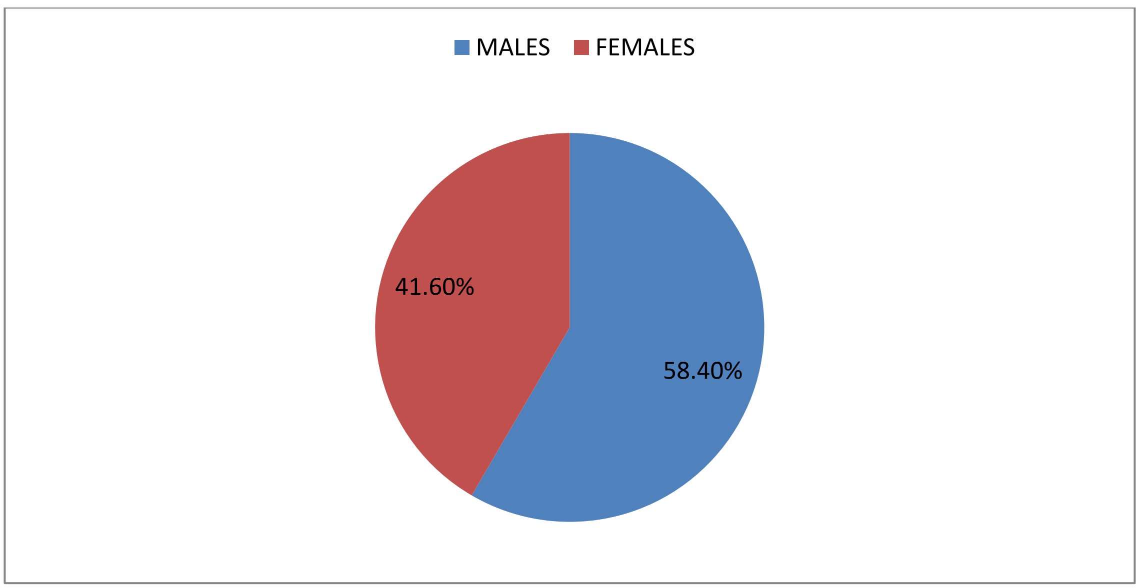

Figure 4.1 Distribution by gender
Source: Author, 2024

4.2.2: Age Distribution

Respondents were asked to state their ages in order to determine the age distribution of those directly engaged in farming. Figure 4.2 shows the distribution of age amongst the 356 respondents. Figure 4.2 shows that majority of maize farmers' age in Tongaren-Sub-County falls between ages 36 and 65 years representing 71.7%. Those in the age bracket of 36-45 years take the lion's share at 28.4%. This is probably due to their youthfulness which helps them to adopt to technology and modern ways of farming.

Those who fall in the age bracket of 46 to 65 years constitute an appreciable percentage of 43.3%. This age bracket has individuals who are mature and this research finding is consistent with that of Beyene and Muche (2010) that found that as age of a household increases farmers acquire more knowledge, skills and experience that enables them to be more food secure. This study did not test whether farmers in the age bracket 46 to 65 years had the knowledge, skills and experience that made them more food secure. Hence the study recommends that these be tested in future research works.

Information communication technology (ICT) is increasingly becoming the common method of relaying climate information to the users (Hampson et al., 2014; Mittal, 2016). The 46-65 age bracket of the smallholder maize farmers in the Study area own ICT gadgets such as mobile phones and these have probably enabled the farmers to have access to weather forecasts such as seasonal rainfall forecasts which in turn help them in decision-making.

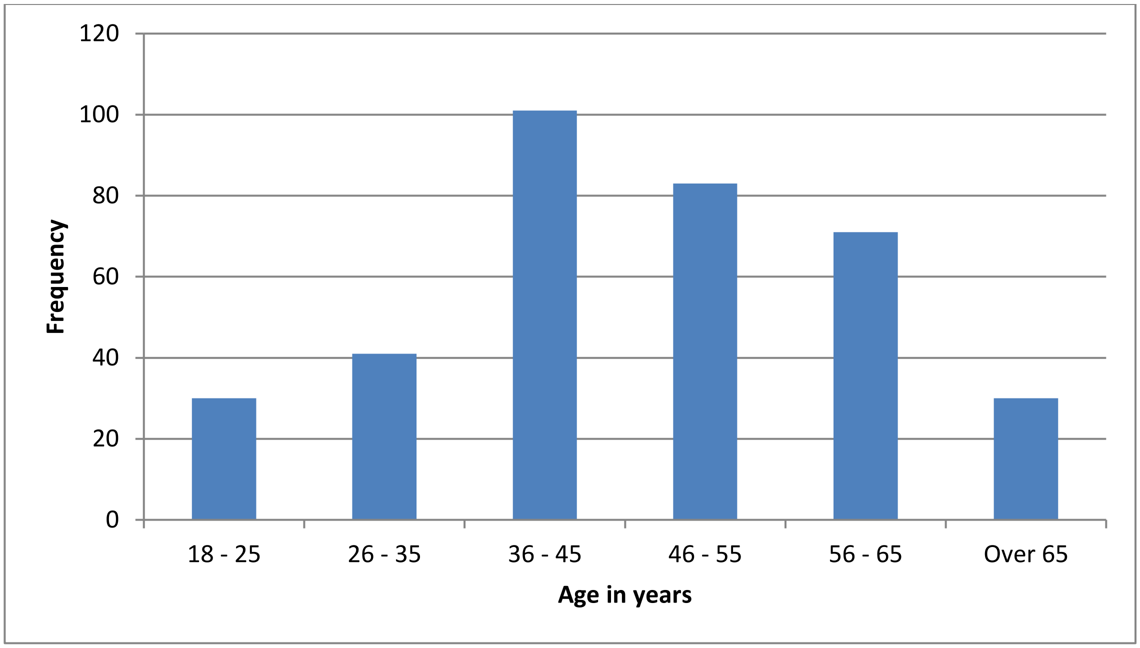

Figure 4.2 Age distribution

Source: Author, 2024

4.2.3 Level of Education

The study sought to establish the level of education attained by the maize farmers in Tongaren Sub-County and the findings are given in Table 4.1 below.

Table 4.1: Education level attained by respondents

Education level	Frequency	Percentage
Primary	60	16.9
Secondary	191	53.6
Tertiary	85	23.9
University	20	5.6
Total	**356**	**100**

Source: Author, 2024

The study established that 16.9 % of the respondents had attained primary level of education while 53.6% had attained the secondary level. 23.9% and 5.6% of the respondents had attained tertiary and university levels respectively. The findings indicate that majority of the maize farmers are literate. The level of formal education attained by the maize farmer can influence the yield by taking appropriate farm decisions (Ariningsih et al. 2021). Since majority of the respondents had formal education, they had the ability to read and possibly interpret seasonal rainfall forecasts and the application of the information had the potential to help the farmers improve the maize yield. Further research need to be done in order to relate the maize yield and the level of education so as to have a better understanding of the correlation between the two.

4.3 Specific Objective One: Trends of Seasonal Variability of Rainfall

The specific objective was on how to determine the trends of seasonal variability of rainfall. Based on the fact that precipitation is projected to remain highly variable and uncertain, this study sought to establish precipitation trends in the study area since most of the smallholder maize farmers in the area rely fully on rainfall for their maize production.

4.3.1 Data Homogeneity Test

The single mass curve technique (Alexandersson, 1986) was used to test the consistency of the rainfall data from 1985 to 2022 and this is depicted in Figure 4.3 below which shows the plot with a diagonal almost straight line which indicates that the rainfall data that was used in the study was homogenous and consistent. The credibility of the data was therefore proved and was suitable to be used in analysis in the study.

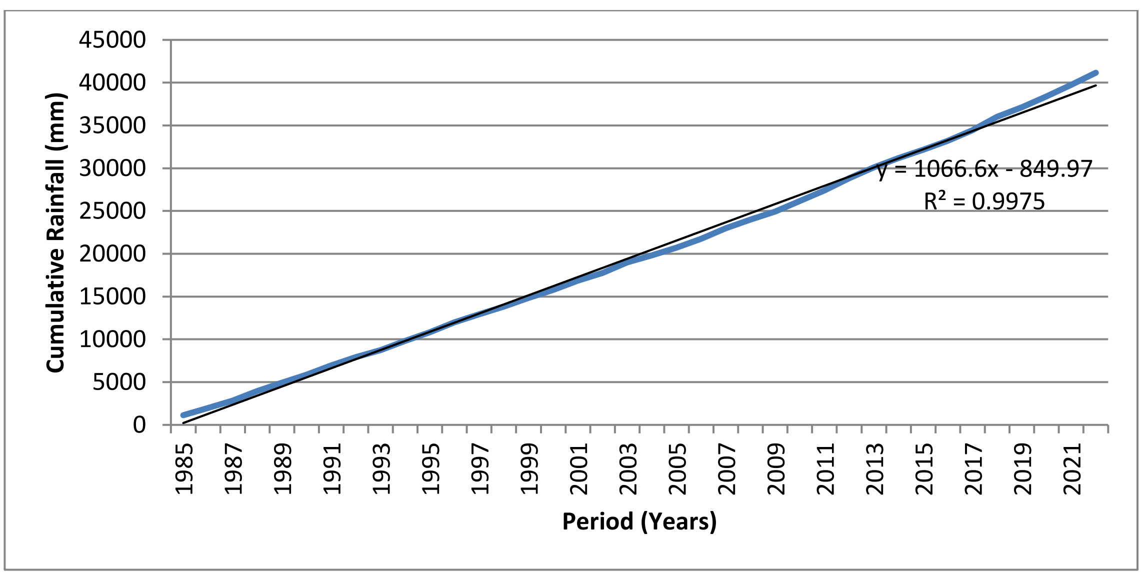

Figure 4. 3: Single mass curve

Source: Author, 2024

Figure 4.3 above depicts a plot of Tongaren Sub-County, March to September cumulative rainfall covering the period 1985 to 2022. The period March to September is very important because it is the period in which maize is grown in the study area. The linear trend line plotted has the form of y=mx + c which is the general equation of a straight line. This conforms to what Pinzari et al. (2018) postulated in the use of mass curve to ascertain homogeneity of data. In the equation, m is the slope or gradient of the line and c is the y- intercept or where the line crosses the y- axis. Coefficient of determination (R^2) value was also computed. R^2 value represents the best fit and it shows the percentage of rainfall information that is explained by the variation in the independent variable (in this case time). The value of R^2 lies between 0 and 1 and it shows how closely the estimated values of the trend line correspond to the actual data (Muthama et al.2008). A trend line whose value is close to 1 is most reliable and vice versa. Figure 4.3 gives R^2 value of 0.9975 (99.75%) which was very high meaning that variance in rainfall associated well with time showing strong relationship, hence the trend line was reliable and the data was homogenous and fit to be used in the analysis.

4.3.2 Summary of Rainfall Statistics

Rainfall variables including highest, lowest, mean, coefficient of variation as well as standard deviation were computed in order to investigate rainfall variation in the study area.

Rainfall summaries were computed based on observed rainfall data to determine highest, lowest and mean annual and seasonal rainfall as well as the standard deviation and coefficients of variation (CV). The statistics for two rainfall seasons that are important for maize growing in the study area were computed. These were the March, April and May (MAM), rainfall season and the June to September (JJAS) rainfall season. These two seasons were considered because it is during these seasons that maize is mostly grown in the study area. From Table 4.2, it can be seen that the mean annual, MAM, JJAS and March to September rainfall in Tongaren Sub- County for the period under study was 1442.1mm, 488.7mm, 594.5mm and 1083.2 mm respectively. These amounts are sufficient to support maize growing.

Results further showed that the highest annual rainfall registered was 1944.3mm whereas MAM and JJAS seasons had their highest values as 822.7mm and 851.2 mm respectively. The lowest annual rainfall recorded over the years was found to be 1039.0mm recorded in 1986. The lowest rainfall recorded for MAM season was 338.7mm recorded in 1992 and that of JJAS was 398.9mm recorded in 1986. Although there was some low amount of rain recorded over the seasons, the amount was still adequate to grow maize. The results clearly indicate that rainfall amounts vary within seasons and across various years. These results are in agreement with those by earlier studies for instance, Kurgat and Gitau (2023), Aditya (2021) and Ongoma et al. (2017).

Table 4. 2: Rainfall statistics between 1985 to 2022

	Annual	**MAM**	**JJAS**	**March to September**
Lowest	1039.0	338.7	398.9	824.9
Highest	1944.3	822.7	851.2	1550.2
Mean	1442.1	488.7	594.5	1083.2
Std. Dev	206.7	101.28	122.8	176.0
Coeff. of variation	0.14	0.207	0.206	0.16

Source: Author, 2024

4.3.3 Inter -Annual Rainfall Trends and Variability

In order to determine trends of rainfall, the observed rainfall data from 1985 to 2022 was plotted against time. Figure 4.4 shows inter-annual rainfall trend and variation over Tongaren Sub-County.

Figure 4.4 shows a general increasing trend in rainfall over the years. The findings concur with those of Muthoni et al. (2019) that showed a significant increasing trend in the annual rainfall over most parts of East Africa. It can be seen from the figure that most of the years registered over 1000mm of rainfall. This amount can support the growing of maize. As depicted in Table 4.2 the average annual variability of 14.0% was computed and this variability could affect maize growing in the study area whereby in the years when rainfall is more, the maize yield is expected to be also more and vice versa. The results of this study resonates well with those of Andrew et al. (2012) that found rainfall in Kenya vary on annual basis.

This variation in rainfall amount is likely to have an impact on the maize output. According to Sujariya et al. (2019), the amount of rainfall and its distribution in a given season is critical in affecting crop growth and its production. The computed value of variability signifies that the study area is likely to experience instances of extreme events such as droughts and floods. Mann Kendall's trend analysis yielded a p- value of <0.0001 (alpha=0.05) for the annual rainfall trends. Since this p-value was less than the alpha-value, it was concluded that inter-annual rainfall variability exhibited a significant trend. The computed moderate R^2 implies that up to 46.9% of the information on rainfall anomalies was attributed to the time and hence a medium correlation between them meaning rainfall was showing an increment over time.

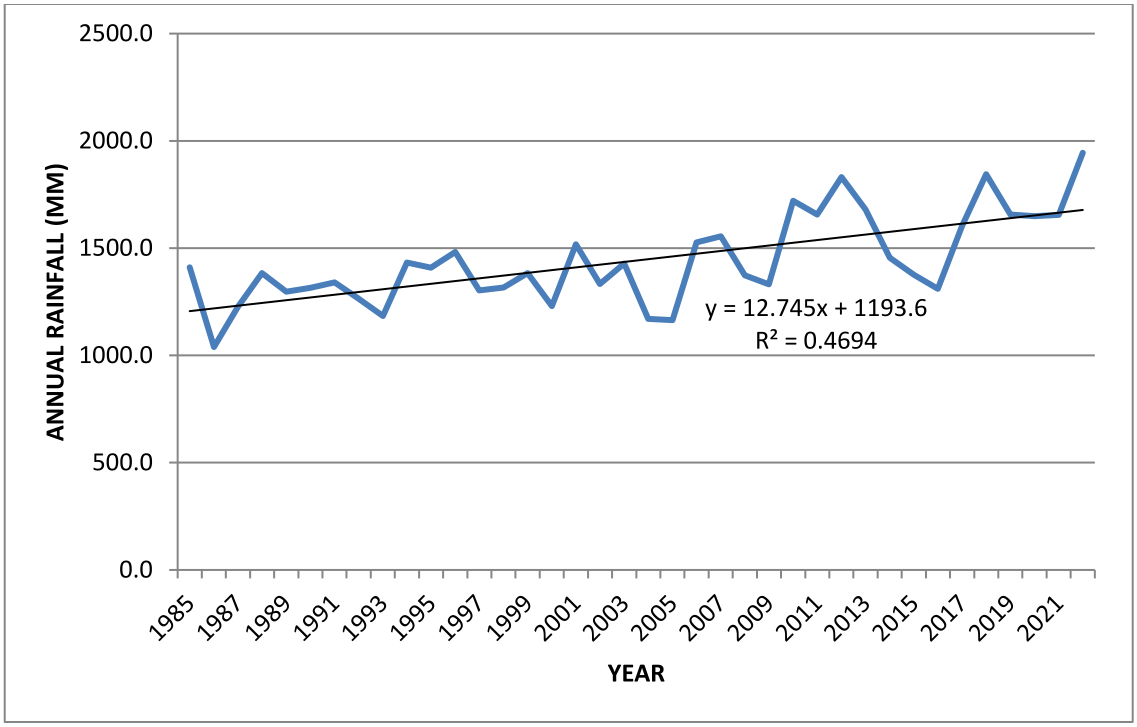

Figure 4. 4: Inter-annual rainfall trend and variation over Tongaren
Source: Author, 2024

The observed rainfall data was also subjected to normalized analysis and Figure 4.5 gives a normalized analysis of the observed data.

Normalizing or standardizing precipitation is a mathematical computation in which the mean or average precipitation for a given period over a long- term record is subtracted from the observed precipitation for a chosen period of time and the result divided by the standard deviation of precipitation for the same period over a long- term record. The resulting value is called an anomaly and is useful for identifying wet and dry periods which can be linked to climatically influenced patterns such as flooding and agricultural production. A positive anomaly indicates more precipitation (wetness) whereas a negative anomaly indicates less precipitation (dryness). The implication of this is that during the periods when there is high rainfall amount, maize yield is likely to be enhanced whereas during the periods there is less rainfall, maize yield is likely to decline since most of the maize grown in the study area is rain-fed.

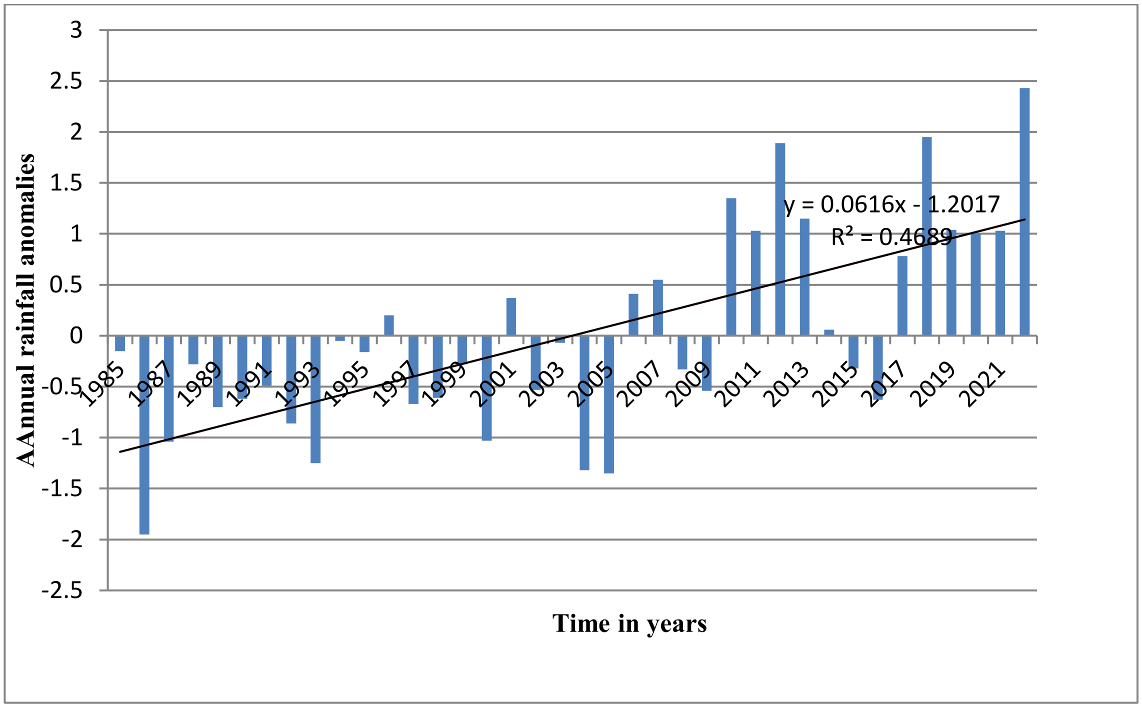

Figure 4.5 Normalized annual rainfall
Source: Author, 2024

From Figure 4.5, negative values indicate the years when the observed rainfall was below the long term annual means whereas the positive values indicate when the observed rainfall was higher than the long term means. The smallest anomaly was -0.05 registered in 1994 whereas the largest anomaly was 2.4 registered in 2022. This implies that the year 1994 recorded the least drop in the annual rainfall based on the long term mean whereas the year 2022 recorded the highest rainfall increase based on the long term mean. Further analysis of the data reveals that there were more years (23years) that recorded less rainfall whereas 15 years recorded more rainfall. The impact of this could have caused the variation in maize yield.

Although 1997 was an El Niño year, the anomaly was negative (-0.67) due to low rainfall that was experienced early in the year, which totaled to 1,303 mm way below the 1985-2022 annual mean of 1,424 mm. The computed moderate R^2 implies that up to 46.9% of the information on rainfall anomalies was attributed to the time and hence a medium correlation between them meaning rainfall was showing an increment over time.

Since the results show that more years recorded less rainfall, this is likely to be the scenario even in future due to climate change. Therefore the County Government of Bungoma needs to put in place strategies like establishment of irrigation practices that can be used to reduce overdependence of maize farming on rainfall. This will ensure that during periods of prolonged dryness, maize can still be produced.

4.3.4 Correlation between Annual Rainfall Variation and Maize Yield

To understand better the impact of rainfall variability on maize yield, a correlation between the anomalies and the maize yield was performed and the results are shown in Figure 4.6.

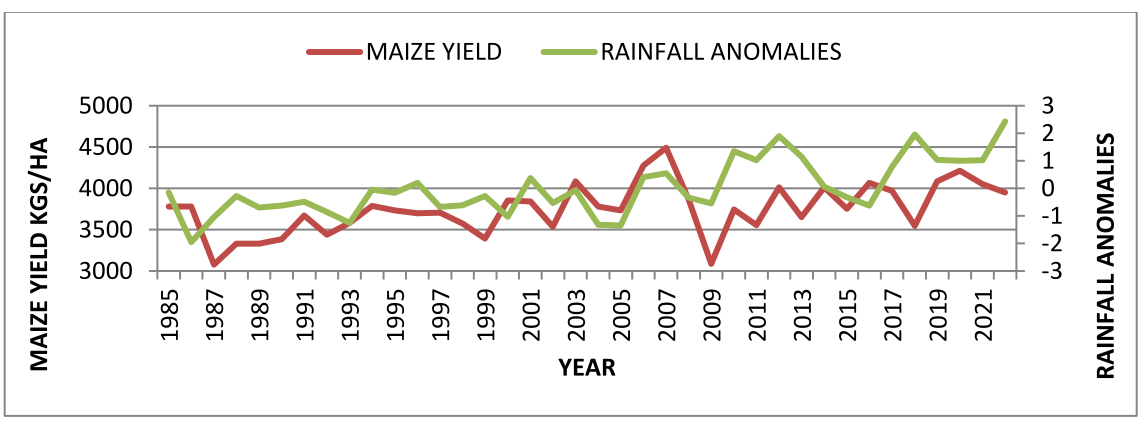

Figure 4.6: Correlation between annual rainfall anomalies and maize yield
Source: Author, 2024

From Figure 4.6, both rainfall and maize yield varied across the years from 1985 to 2022. Close scrutiny of variation in the rainfall anomalies in some years were in phase with variation in maize yield whereas other years were not. For instance in the year 2012 when there was a positive anomaly meaning more rainfall than the mean value, there was an increase in maize yield. However for a year such as 2018 when there was a positive anomaly, maize production was low. It can be deduced that in some instances, there exists a positive correlation between maize yield and rainfall variability whereas in other instances there is a negative correlation between the two. This could be attributed to some intervening variables such as soil fertility or crop diseases and pests among others which vary from time to time and have a huge impact on maize production.

4.3.5 Seasonal Rainfall Variability during MAM

Figure 4.7 gives the results that depict a general increasing trend in rainfall in Tongaren Sub- County during the March, April and May (MAM) rainfall season. This result seems to be in agreement with studies that show an increase in MAM rainfall over East African region (Otte et al.2017 and IPCC 2014) but contradicts the recent research results that pointed out that MAM rainfall in most places is showing a reduction (Cattan et al.2018). However, computed p-value (alpha=0.05) was 0.127 indicating that the increase in rainfall during MAM season was insignificant. It can also be deduced from Figure 4.7 that MAM rainfall amount and distribution in the study show significant variation as with time.

Results from analysis of rainfall data during the March, April, and May (MAM) season imply that the increasing rainfall trend though small is likely to enhance production of maize in the study area with the yield expected to increase in future. Since the increase in rainfall over MAM is insignificant, other avenues of increasing maize yield can be employed for instance by planting drought tolerant and early maturing maize varieties. The selection of such maize varieties is possible if maize farmers are given the seasonal rainfall forecasts in advance in order for them to make informed decisions. Computed R^2 value of 0.1234 implies that 12.34% of variation in rainfall during MAM rainfall season is explained by the time. However the regression between the independent variable (time) and dependent variable (rainfall) shows a weak relationship. This explains the fact that MAM seasonal rainfall is not dictated by time alone but rather by rainfall bearing systems such as Inter-Tropical convergence zone (ITCZ), high pressure cells such as Mascarine and the El Niño phenomena among others (Parhi et al. 2016).

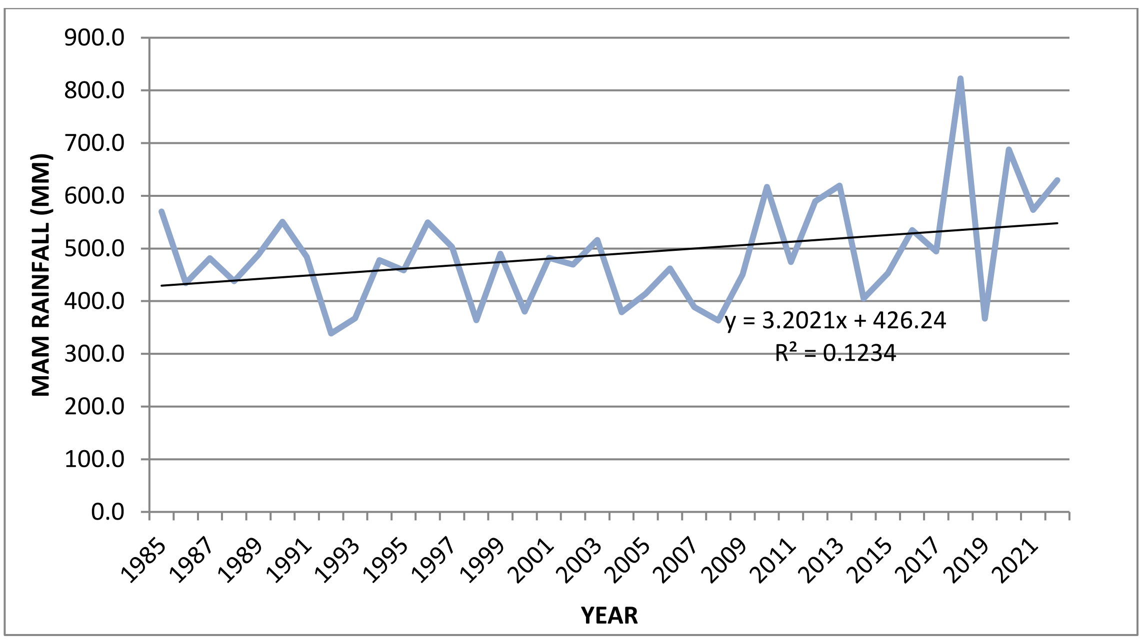

Figure 4.7: Seasonal variability of rainfall over Tongaren during MAM
Source: Author, 2024

Normalized, negative values indicate the years when the observed rainfall was below the long term seasonal mean whereas the positive values indicate when the observed rainfall was higher than the long- term mean. The smallest anomaly (-0.003) was recorded in 1989 whereas the largest anomaly (3.29) was registered in 2018. This implies that the year 1989 recorded the least drop in the MAM rainfall based on the long term mean (488.7mm) whereas the year 2018 recorded the highest rainfall increase based on the same long term mean. The lowest rainfall (338.7mm) during the season was recorded in 1992 whereas the highest rainfall (822.7mm) during the season was recorded in 2018. The low amount of rainfall led to low maize yields of 3438kgs/ha which was below the average annual yield of 3749kgs/ha. This affirmed the fact that maize production and yield is dependent on climatic factors such as the seasonal rainfall (Li et al., 2019).

The MAM rainfall data was also used to establish the extent of variation within the observed values and a coefficient of variation (0.207) was obtained. This implies that variation amongst the observed data was 20.7%. This is a significant variability according to Araya and Stroosnijder (2011) who observed that a coefficient variation (CV) of greater than 30% signifies a high variation. Variation of rainfall across the years of 20.7% has the potential to alter maize growing thus affecting the yield. When there is an increase in rainfall amount there is likely to be an increase in maize yield and vice versa. Using the same data, a standard deviation of 101.28 was computed. A high standard deviation means that values are generally far from the mean, while a low standard deviation is indicative of values being clustered close to the mean. The computed standard deviation (101.28) is a large value and this implies that the MAM rainfall data is more spread out hence each value or score is far from the mean. The anomaly values were used to produce graphical representation and this is shown in Figure 4.8.

The plotted anomalies in Figure 4.8 exhibits a slight general increase in the MAM rainfall in Tongaren Sub-County for the period from 1985 to 2022. The results show that there were 22 years that recorded lower rainfall than the long-term MAM seasonal mean. Similarly, 16 years recorded more rainfall than the long-term MAM mean for the season.

Although some years recorded lower rainfall amounts than the seasonal mean, the rainfall was still sufficient to support maize growing. Further scrutiny of Figure 4.8 reveals that inter-seasonal rainfall variability across the MAM rainfall season is a regular occurrence which is likely to affect maize production. The findings of this study agrees with that of Omondi et al. (2014) which found that variability of rainfall has a major impact on the future sustainable socio-economic development especially on agriculture.

The derived trend line shows an increasing trend in rainfall variability with a computed R^2 value of 0.1088. This implies that only approximately 10.9% of variation in rainfall can be linked to time and this was actually a weak relationship between the two variables. Thus, the study findings suggest that rainfall variability during MAM is influenced more by other factors (e.g., ITCZ) than by time as postulated by Parhi et al. (2016).

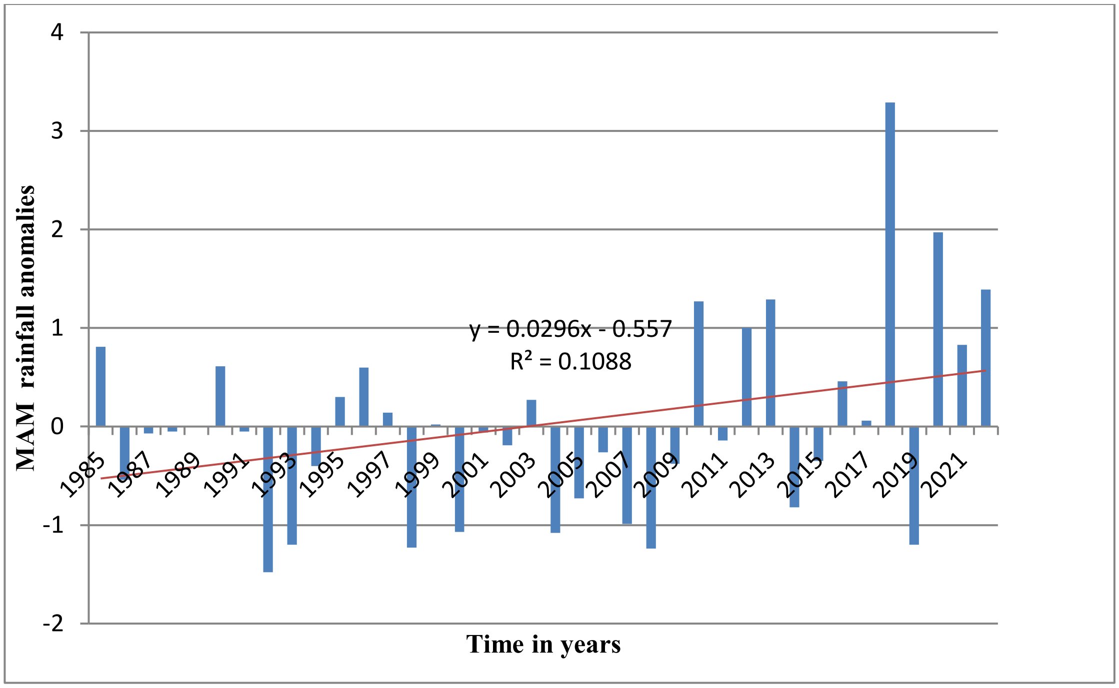

Figure 4.8: Normalized MAM rainfall

Source: Author, 2024

4.3.6 Correlation between MAM Rainfall Variation and Maize Yield

To understand better the impact of rainfall variability on maize yield, a correlation between the anomalies and the maize yield between 1985 and 2022 was performed and the results are shown in Figure 4.9.

From Figure 4.9, both rainfall and maize yield varied across the years from 1985 to 2022. Close scrutiny of Figure 4.9 shows that variation in the rainfall anomalies for some years were in phase with variation in maize yield whereas other years are not. For instance in the year 2003 when there was a positive anomaly of 0.83 meaning more rainfall than the mean value, there was an increase in maize yield to 4086 kg/ha from 3537 kg/ha which was realized in 2002 when there was less rainfall. This was a clear indication that maize yield has a direct correlation with rainfall amount.

The findings of this study are in agreement with those of Muriithi et al. (2023) which found that rainfall variability influences maize output. However it is noticed that in some instances, there exists a positive correlation between maize yield and rainfall variability whereas in other instances there is a negative correlation between the two. This could be attributed to some intervening variables such as soil fertility or crop diseases and pests among others which vary from time to time and have the potential to affect maize yield.

The findings affirm that rainfall pattern is not consistent and this will continue to cause uncertainty among the maize farmers who rely on the rainfall. It is has been shown in Figure 4.9 that higher amounts of rainfall did not imply higher maize yield. This finding resonates well with that of Adam et al. (2020) which demonstrated that climatic conditions cannot support high yields of crops alone. In times of low rainfall but higher maize output such as in 2007, it can be said that maize farmers may have applied adaptation strategies that were successful thus boosting their maize yield. It is recommended that relevant stakeholders and government put in place strategies such as awareness programs and enhance provision of relevant climate information that can help the maize farmers cushion themselves from vagaries of climate change and variability. More studies need also to be carried out to determine the inconsistencies in maize yield and the amount of rainfall.

Analysis of correlation between total rainfall during MAM season and maize yield posted a weak positive correlation coefficient of 0.05.

The result of this study agrees with those of Ifabiyi and Omoyosoye (2011) which found that total rainfall amount determines the overall maize yield. The findings of this study shows that MAM rainfall played an insignificant role on the maize yield and this leads to a conclusion that other factors such as soil fertility and pests among others played a major role in determining maize yield.

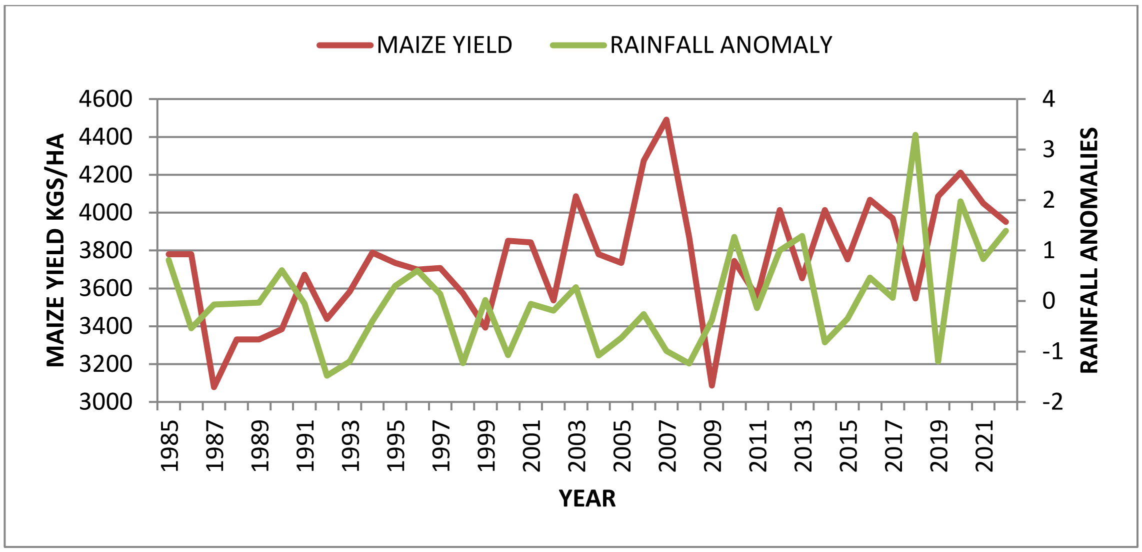

Figure 4.9: Correlation between MAM rainfall anomalies and maize yield

Source: Author, 2024

4.3.7 Seasonal Rainfall Variability during JJAS

The rainfall received during June, July, August and September (JJAS) season is very important as it supports the subsequent growth stages of maize; hence this rainfall determines whether maize yield will be good or poor. Analysis of rainfall data during the June, July, August and September (JJAS) season is shown in Figure 4.10.

Figure 4.10 gives the results that depict a general increase in rainfall in Tongaren Sub-County during the June, July, August and September (JJAS) rainfall season. The seasonal totals across the years range from a low of 398.9mm in 1986 to a high of 851.2 mm in 2007. The mean rainfall (594.5mm) was computed for the entire period. A standard deviation (122.8) was computed for this season. These values imply that rainfall within JJAS also varies with variability of 20.6 %. Since maize grown in this area is majorly rain-fed, maize yield is likely to be affected with years that have high rainfall values within JJAS season expected to record high maize yield and vice versa. However, computed p-value (alpha=0.05) was 0.000 implying that there was a trend but was not significant. Regression of the independent variable (rainfall variability and the independent variable (time) show that there was up to about 35.1% (R^2=0.3513) of variation in rainfall that could be explained by time. This was somehow significant(medium correlation) meaning that in addition to the rainfall bearing systems upon which JJAS rainfall depend on, the time of the year was also an important factor.

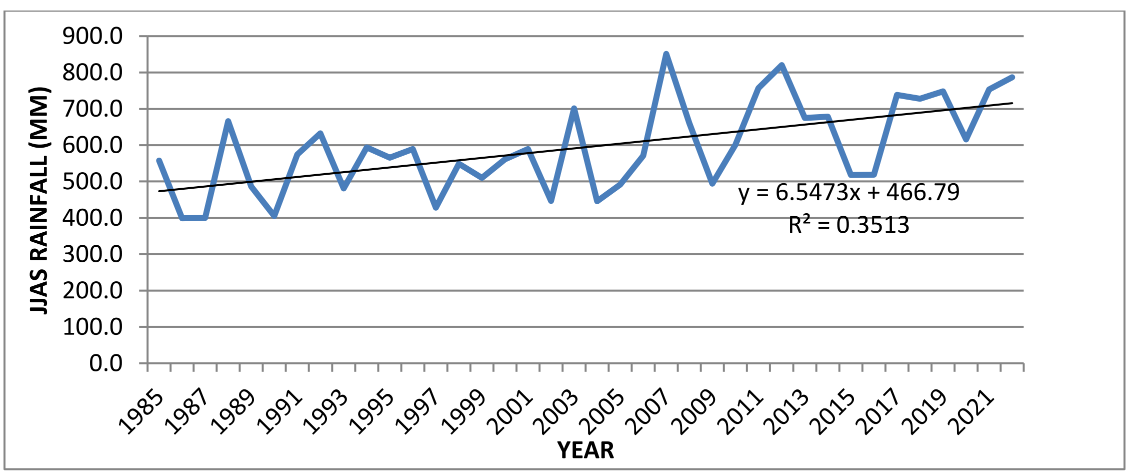

Figure 4. 10: Seasonal variability of rainfall over Tongaren during JJAS
Source: Author, 2024

Rainfall anomalies were also computed and the results presented in Figure 4.11. Figure 4.11 shows that across the period under review, rainfall was either above normal or below normal. Above normal rainfall was recorded in 1988, 1992, 1994, 2003, 2007, 2008, 2010, 2011, 2012, 2013, 2014, 2017, 2018, 2019, 2020, 2021 and 2022. During the above normal episodes the lowest anomaly was 0.00 in 1994 while the highest was 2.09 in 2007. Years that recorded below normal rainfall during JJAS rainfall season were, 1985, 1986, 1987, 1989, 1990, 1991, 1993, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2004, 2005, 2006, 2009, 2015 and 2016. Below normal rainfall lowest anomaly was -0.04 recorded in 1996 and 2001 whereas the highest anomaly in this category was -1.58 in 1987.

The illustration in Figure 4.11 shows that there were more years (21) which had below normal rainfall especially between 1985 and 2006. This finding agrees with that of Hillier and Dempsey (2012) who had found that there was a reduction in the JJAS rainfall in the recent decades. Maize data used in the analysis show that between 1985 and 2022 maize output averaged 3748 kg/ha with a maximum output of 4491 kg/ha recorded in the year 2007 and a minimum output of 3078 kg/ha recorded in the year 1987. The production of maize increased significantly between the years 2011 (3555kg/ha) and 2022 (3951kg/ha). Similarly the period between 2011 and 2022 saw an increase in the amount of rainfall received except for 2015 and 2016. This finding suggests that there was a positive correlation between the amount of rainfall and the maize output.

From Figure 4.11 it can be seen that there is an increasing rainfall trend in Tongaren Sub-County during JJAS rainfall season with the slope of the trend line pointing in the positive direction. Further scrutiny of Figure 4.11 shows that rainfall anomalies oscillate around the mean value almost in equal measure. The years which had the lowest and highest rainfall values can easily be identified from the graph. Fluctuations in the amount of rainfall during JJAS rainfall season is likely to affect the ability of farmers to plan and may undermine investment in the maize sector thus negatively impacting on their livelihood and food security. Computed R^2 value was 0.3434 meaning that 34.34% of rainfall anomalies experienced were associated with time factor hence this was a medium correlation. This shows that time of the year in terms of when certain rainfall bearing systems is important as the strength of these systems determines the amount of rainfall that will be received.

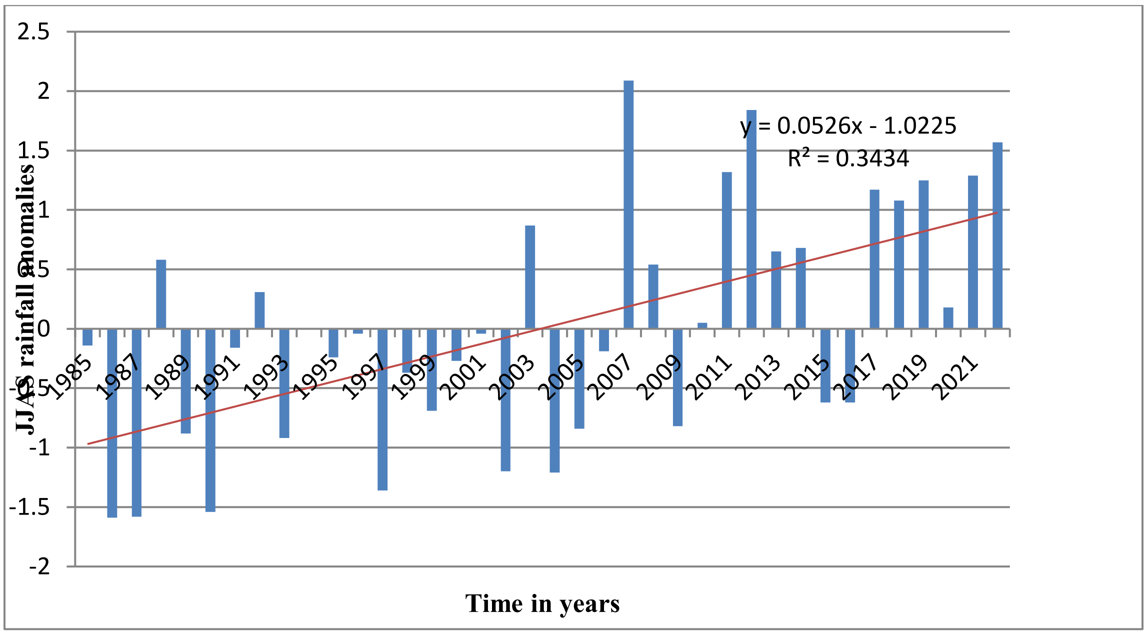

Figure 4. 11: Normalized JJAS rainfall

Source: Author, 2024

4.3.8 Correlation between JJAS Rainfall Variation and Maize Yield

In order to determine the impact of rainfall variability on maize yield, a correlation between the anomalies and the maize yield was performed and the results are shown in Figure 4.12.

From Figure 4.12, both rainfall and maize yield varied across the years from 1985 to 2022. Close scrutiny of Figure 4.12 shows that variation in the rainfall anomalies for some years were in phase with variation in maize yield whereas other years were not. For instance in the year 2007 when there was a positive anomaly of 2.09 meaning more rainfall than the mean value, there was an increase in maize yield to 4491 kg/ha from 4275 kg/ha which was realized in 2006 when there was less rainfall. This was a clear indication that maize yield has a direct correlation with rainfall amount. The findings of this study are in agreement with those of Muriithi et al. (2023) which found that rainfall variability influences maize output. However it is noticed that in some instances, there exists a positive correlation between maize yield and rainfall variability whereas in other instances there is a negative correlation between the two. This could be attributed to some intervening variables such as soil fertility or crop diseases and pests among others which vary from time to time.

The computed result indicates that there was a significant positive correlation of 0.53 between the JJAS rainfall and the maize yield. The result of this study shows that the rainfall received between June and September counts more in regards to overall maize yield than the March to September rainfall. Most of the growth stages such as maize flowering and tussling occur between June and September and these growth stages require good rainfall amounts. This could be the reason why the correlation between maize yield and rainfall amount is higher in this period. Since the rainfall received between June and September correlates well with maize yield, it is necessary for the climate information providers to give the maize farmers the seasonal forecast early enough to enable them make the right agronomic decisions that can help them improve on the maize yield.

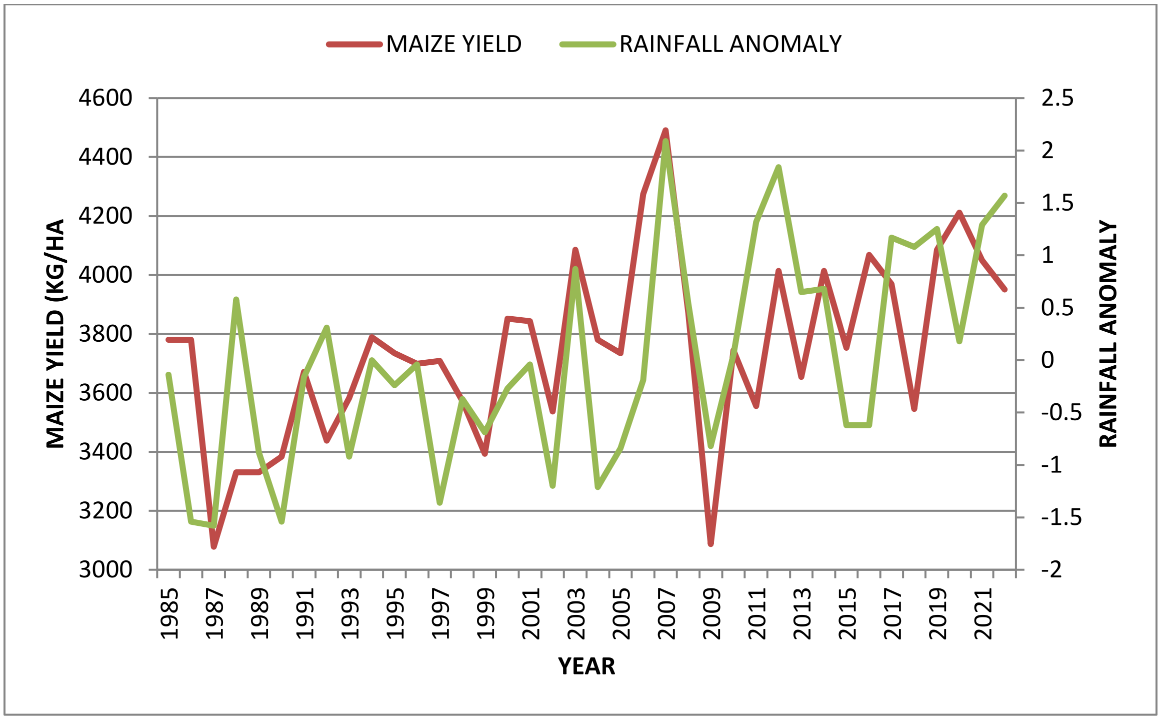

Figure 4.12: Correlation between JJAS rainfall anomalies and maize yield
Source: Author, 2024

The findings show that rainfall pattern is quite erratic and this will continue to bring uncertainty among the maize farmers who rely on the rainfall. It is has been shown in Figure 4.12 that higher amounts of rainfall did not imply higher maize yield. This finding resonates well with that of Adam et al. (2020) which demonstrated that climatic conditions cannot support high yields of crops alone. In times of high rainfall but lower maize output such as in 1988, it can be said that possibly some other agronomic factors contributed to this for example an increase in maize crop diseases and post-harvest losses. It is recommended that relevant stakeholders and government put in place strategies such as awareness programs and enhance provision of relevant climate information that can help the maize farmers cushion themselves from vagaries of climate change and variability. More studies need also to be carried out to determine the inconsistencies in maize yield and the amount of rainfall.

4.3.9 Seasonal Rainfall Variability between March and September

The season spanning between March and September is very crucial in the growing stages of the maize crop. The cumulative rainfall received during this season was analyzed and the results presented in Figure 4.13 below.

Figure 4.13 gives results that depict a general increase in rainfall in Tongaren Sub-County during the March to September rainfall season. The seasonal totals across the years range from a low of 824.7mm in 2004 to a high of 1550.2 mm in 2018. The mean for the entire period was found to be 1083.2 mm. A standard deviation of 176.04 was computed for this season. These values imply that rainfall within this period also varies and a variability of 16.0 % was computed. Since maize grown in this area is majorly rain-fed, maize yield is likely to be affected with years that have high rainfall values within March to September season having likelihood to record high maize yield and vice versa. According to Mendoza et al. 2014), maize crop is likely to fail if rainfall is less than 300mm during the growing season. The mean rainfall of 1083.2mm received in the study area between March and September is far beyond the threshold of 300mm and this is why maize continues to be grown in Tongaren Sub-County. Figure 4.13 shows a general increasing trend of rainfall amount during this rainy season. However, computed p-value (alpha=0.05) was 0.000 implying that there was a trend but was not significant. Furthermore, computed value of R^2 value was 0.3788 meaning that 37.9% variation in rainfall is explained by time factor. This implies there was medium relationship between seasonal rainfall and the time in which it was recorded. The finding also implies that if other factors influencing maize production were favourable it was expected maize yield to increase with increase in rainfall.

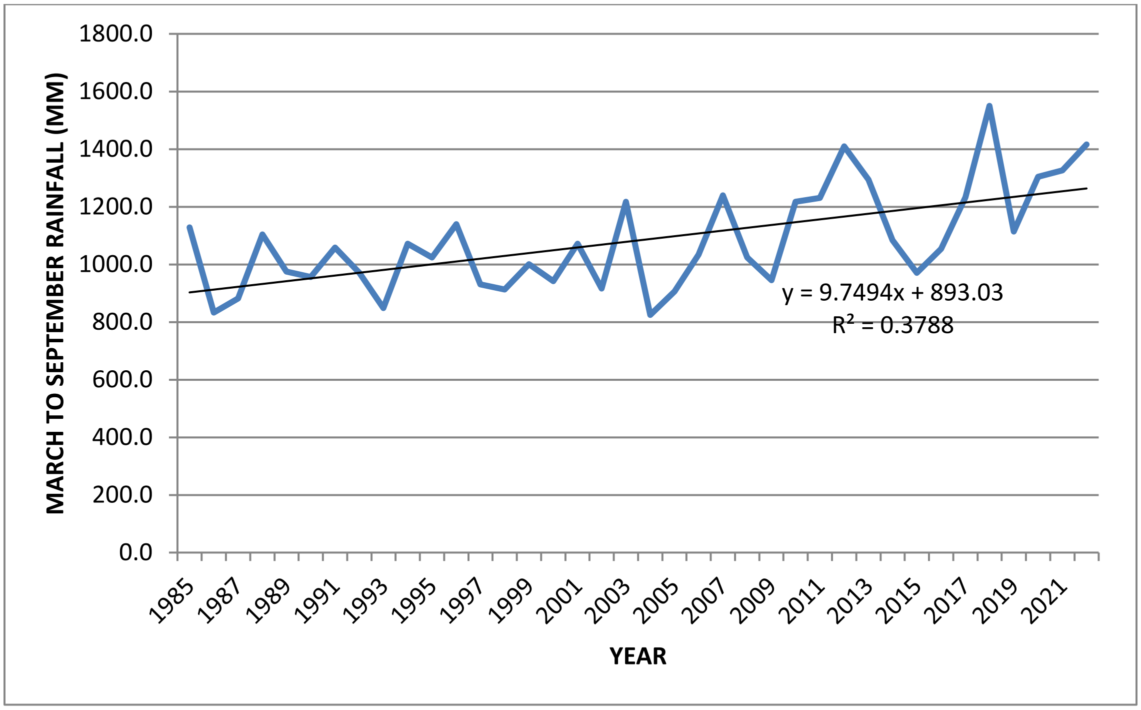

Figure 4.13: Seasonal rainfall variability between March and September
Source: Author, 2024

Rainfall anomalies across the period under review were computed and the result shown in Figure 4.14.The rainfall was either above normal or below normal. Above normal rainfall was recorded in 1985, 1988, 1996, 2003, 2007, 2008, 2010, 2011, 2012, 2013, 2014, 2017, 2018, 2019, 2020, 2021 and 2022. During the above normal episodes the lowest anomaly was 0.00 in 2014 while the highest was 2.65 in 2018. Below normal rainfall lowest anomaly was -0.06 recorded in 1994 and whereas the highest anomaly in this category was -1.47 in 1999.

From Figure 4.14 it can be seen that there is an increasing rainfall trend in Tongaren Sub-County during March to September rain season. Further scrutiny of Figure 4.14 shows that rainfall anomalies oscillate around the mean value. The years when there was the lowest and highest rainfall values can easily be identified from the graph. For instance it can be seen clearly that the year 2018 recorded the highest rainfall while the lowest rainfall indicated by an anomaly of -1.47 was recorded in the year 2004. The years showing positive anomalies gives an indication of enhanced rainfall with a possibility of good maize harvest and vice versa. The Computed R^2 value was 0.3691 meaning that 36.9% variation in rainfall was contributed by the time factor and this was a medium correlation.

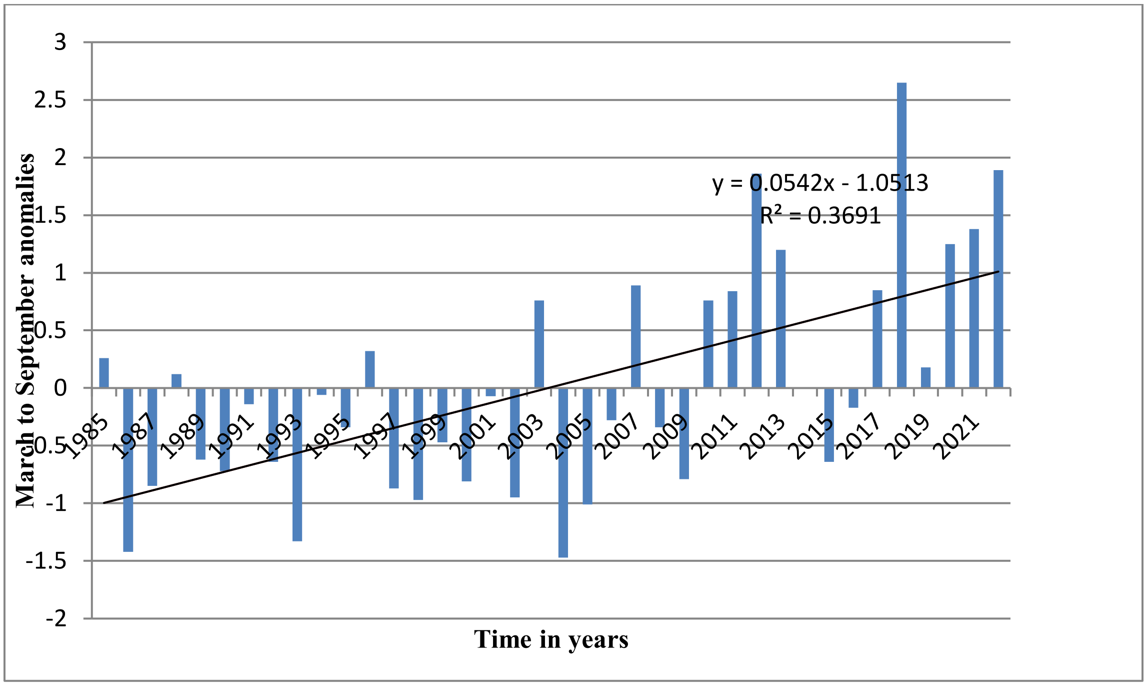

Figure 4.14: Normalized March to September rainfall
Source: Author, 2024

4.3.10 Correlation between March to September Rainfall Variation and Maize Yield

Comparison between rainfall variability and maize yield reveal both positive and negative correlations as depicted in Figure 4.15.

From Figure 4.15, both rainfall and maize yield varied across the years from 1985 to 2022. Close scrutiny of Figure 4.15 shows that variation in the rainfall anomalies for some years were in phase with variation in maize yield whereas other years were not.

There was highest maize crop yield in 2007 and 2020 of 4491 kilograms and 4212 kilograms per hectare respectively. During the same period, rainfall anomaly received was 0.89 and 1.25 respectively. On the other hand, the minimum maize yield harvested was in 1987 (3078kg/ha) and 2009 (3087) respectively. During the same period, rainfall anomaly received was -0.89 and -1.25 respectively. This shows that there is a positive correlation between rainfall amount and the maize yield. The findings of this study corroborates with the findings by Jones and Thornton, (2003) which confirmed that depending on the amount and how rainfall is spread during maize development, the effects to yields realized is tremendous. However there were some years that exhibited negative correlation between maize yield and rainfall amount during March to September rainfall season. For instance in 2006 and 2016, the amount of maize harvested was high that is 4275 kg/ha and 4068 kg/ha respectively yet in these two years the rainfall that was received was below the long term average. The rainfall anomalies of -0.17 and -0.28 were recorded respectively. This means that maize yield is not controlled only by the amount of rainfall but by other non-climatic factors such as amount of fertilizer applied, crop diseases, land acreage under maize production among others. Because of this, the study recommends that future studies on maize yield should look at multiple factors simultaneously and come up with details on how each one of the factors affect maize production.

Correlation between March to September rainfall and the maize yield was 0.4. Analysis conducted on the maize yield trend gave a p-value (alpha=0.05) of 0.001 a slight increasing trend in the maize yield over the years. With the increasing rainfall trend from the analysis, it is predicted that the increasing maize trend will be maintained in future.

However, it is to be noted that maize yield does not depend only on rainfall amount but also on other factors.

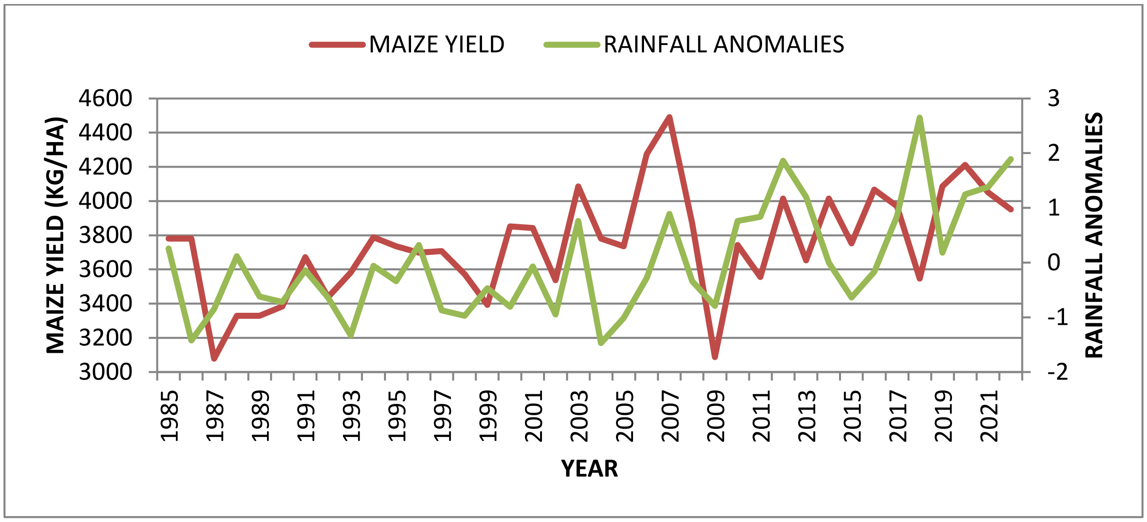

Figure 4.15: Correlation between March to September rainfall anomalies and maize yield
Source: Author, 2024

Table 4.3 shows a summary of correlations between the rainfall amount and maize yield between 1985 and 2022.

Table 4.3 Summary of correlations between rainfall and maize yield

Season	Correlation
MAM	0.05
JJAS	0.53
March to September	0.4
Annual	0.38

Source: Author, 2024

4.3.11 Rainfall reliability

Rainfall reliability for various seasons in Tongaren Sub-County were computed and the results given in Table 4.4. Reliability of rainfall across the seasons was calculated by subtracting variability from one. According to Ayoade (1998), the less variable the total rainfall is, the more reliable it is.

Table 4.4 shows rainfall having high reliability. The computed reliability values in terms of percentage for MAM, JJAS, March to September and annual were, 79.3, 79.4, 84.0 and 85.7 respectively. This implies that although rainfall varies within the seasons and annual basis, the rainfall is reliable and can support maize growing in the study area. Earlier studies by Bals et al. (2008) and IITA (2004) had indicated that rainfall variability can have profound impact on maize crop yield especially in rain- fed agriculture and that higher variation in rainfall above the mean leads to maize yield fluctuations.

Table 4.4 Summary of rainfall reliability

Season	**Rainfall reliability (%)**
MAM	79.3
JJAS	79.4
March to September	84.0
Annual	85.7

Source: Author, 2024

4.3.12 March to May Rainfall Probability of Exceedance

Rainfall probability of exceedance for March to May (MAM) rainfall was plotted against time from 1985 to 2022 and the results shown in Figure 4.16. It is to be noted that a season is considered wet when the probability of exceedance is equal to or above 80% whereas a dry season has probability of exceedance equal to or below 20% which denotes below normal rainfall (Zinyengere et al. 2011). According to Du Jean Plessis (2003), maize requires 350-450mm of rainfall during growth and development stages.

From Figure 4.16 the probability of exceedance of rainfall between 360mm to 460mm in the study area ranges from 60% to 100%. This implies the rainfall received during MAM is sufficient to support growth and development of maize. In a similar study by Mzezewe et al. (2013), it was established that seasonal rainfall amount of 450mm is indicative of a successful growing season and described it as a threshold rainfall amount. The results depicted in Figure 4.16 imply that maize can do well in Tongaren Sub-County as the threshold amount of 450mm of rainfall is met. Figure 4.16 also show that there is an inverse relationship between the rainfall expected during MAM and rainfall probability of exceedance. As the expected rainfall during MAM increases, the rainfall probability of exceedance reduces and vice versa. Thus, the findings of this study agree with that of Butu et al. (2020).

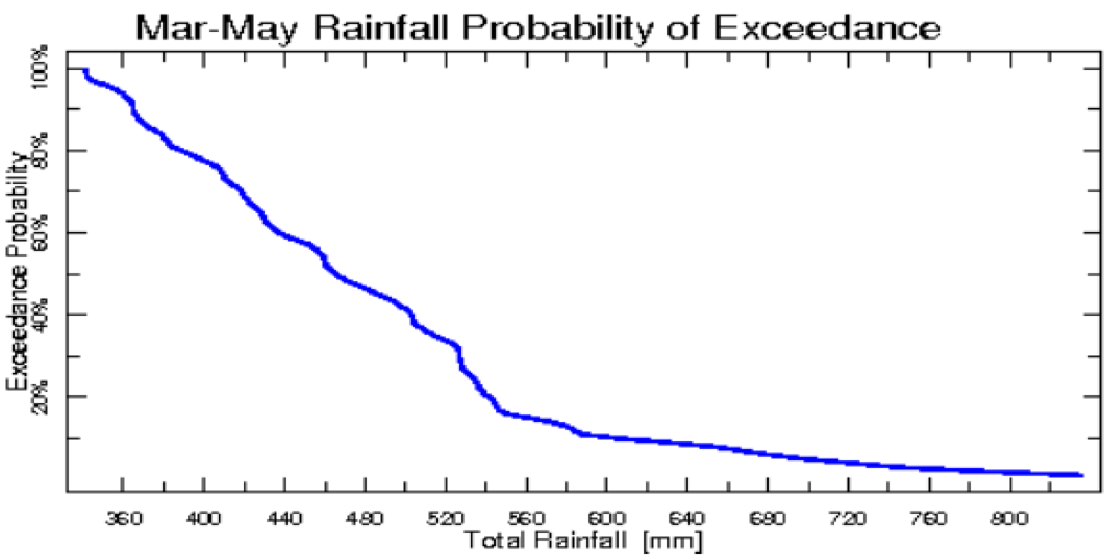

Figure 4.16: MAM rainfall probability of exceedance
Source: KMD, 2024

4.3.13 JJAS Rainfall Probability of Exceedance

Rainfall probability of exceedance for JJAS was plotted against time from 1985 to 2022 and the results shown in Figure 4.17. From Figure 4.17, the probability of exceedance of rainfall between 320mm and 500mm ranges from 70% to 100%. This implies that there was a high likelihood that the study area was to receive rainfall ranging from 320mm to 500mm between 1985 and 2022. From the analysis, the rainfall received during JJAS season is normally less than the MAM rainfall. However, this amount of rainfall received during JJAS is still sufficient to support growth of maize in the area. Based on these results,it can be concluded that smallholder farmers who depend on rain- fed agriculture are assured of growing maize in the area in any given year. Further scrutiny of Figure 4.17 reveals that the rainfall probability of exceedance reduces as the expected rainfall amount increases. The result of this study also concurs with those of Butu et al. (2020) which found that there was an inverse relation between rainfall probability of exceedance and the amount of rainfall.

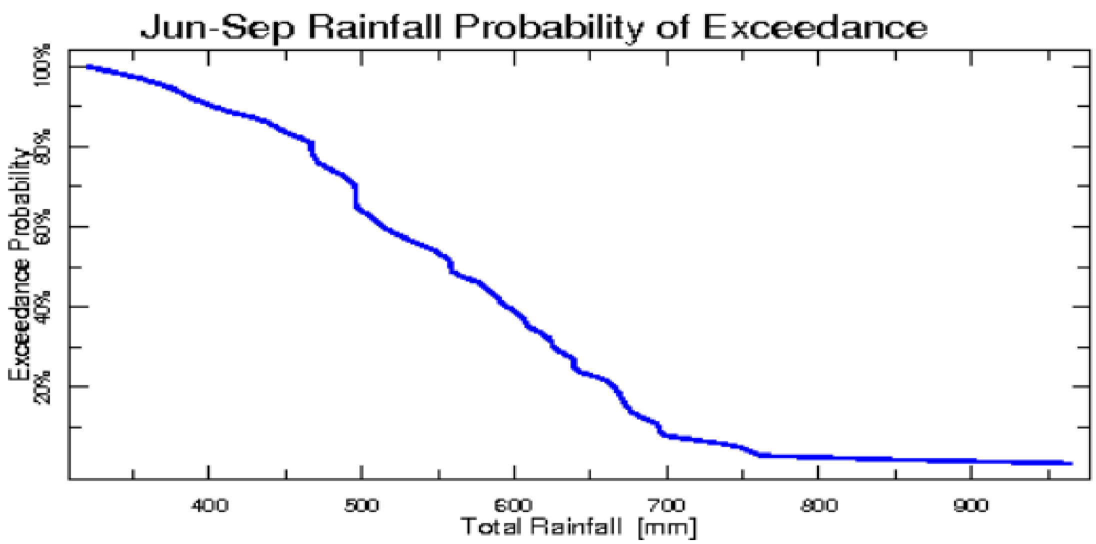

Figure 4.17: JJAS rainfall probability of exceedance

Source: KMD, 2024

The rainfall trends as established by the study during MAM and JJAS rainfall seasons was supported by the FGDs and KIIs whereby the participants stated that there has been a slight increase in the rainfall in the recent past. They also stated that the rainfall patterns have become quite erratic during the maize growing season.

Findings from FGDs and KIIs also showed that there exists a relationship between the amount of rainfall received and the maize yield. Participants stated that whenever there is sufficient rainfall, the maize yield is high and vice versa.

4.4 Specific Objective Two: Factors Influencing Utilization of Seasonal Rainfall Forecasts for Maize Production

The main focus was to evaluate the factors influencing access to and utilization of seasonal rainfall forecasts. The respondents were given a questionnaire whereby they were asked to state some of the factors that hinder them from accessing and utilizing seasonal rainfall forecasts in producing their maize.

4.4.1 Education Level Attained by the Maize Farmer

Findings shown in Table 4.5 reveals that 75% of the respondents stated that education level was a factor on their ability to access and utilize seasonal rainfall forecasts. This is a relatively a high percentage suggesting that most of the farmers felt that formal education enables them to read and interpret CI. Another 25% of the respondents stated that education level was not a factor that influences use of seasonal rainfall forecasts. A study by Kirimi et al. (2013) showed that majority of farmers stated that level of education was an important requirement in maize production. Therefore the findings of this study agree with this. Furthermore, findings from FGDs and KIIs indicated that education level was vital in ensuring better interpretation of climate information. It can be deduced that formal education provides an avenue to acquire some useful knowledge and skills that can be used to help one to read and interpret climate information which eventually leads to informed decision-making. Good education amongst maize farmers is also likely to enable them put into use good agronomic practices that are likely to boost their maize yield. This implies that educated farmers embrace the use of CI for better decision-making.

Table 4. 5: Education level as a factor influencing use of CI

Outcome	Frequency	Percentage
Yes	182	75
No	61	25
Total	**243**	**100**

Source: Author, 2024

4.4.2 Land Size Put to Maize Production

The findings of the survey on land put to maize production is shown in Table 4.6.

It is shown in Table 4.6 that majority of farmers (43.3%) in Tongaren Sub-County own land ranging between 6 and 10 acres. Cumulatively those who own land between 1 and 20 acres constitute 80.1% of the population. This indicates that most of the maize in the Sub-County is produced by smallholder farmers. The result of this study in regards to land size and crop production is concordant with the findings by Deininger et al. (2017) which found that most smallholder farmers own small pieces of land for food production. According to a study by Nkuba et al. (2023), it was found that land size is a factor among farmers when it comes to decision- making whether to use or not to use weather forecasts.

Table 4. 6: Land size under maize production

Land size (Acres)	Frequency	Percentage
1 - 5	42	11.8
6 - 10	154	43.3
11 - 20	89	25.0
21 – 50	59	16.5
Over 50	12	3.4
Total	**356**	**100**

Source: Author, 2024

This study did not correlate the farm size with the usage of seasonal rainfall forecasts. However a comparison between the acreage of land put to maize farming and the amount of maize yield for the period between 2018 and 2022 was performed and the results are presented in Table 4.7.

Table 4.7: Comparison between maize yield and land acreage

Year	Land acreage (hectares)	Maize yield (90kg bags)
2018	29000	1143889
2019	29300	1330000
2020	19296	902066
2021	19326	869667
2022	19481	855000
Total	**116403**	**5100622**

Source: Author, 2024

Table 4.7 shows that in 2019, when the acreage increased to 29300 hectares from 29000 hectares in 2019, maize yield also increased to 133000 -90kg bags from 1143889- 90kg bags recorded in 2018. Similarly in 2020 when the acreage dropped to 19296 hectares from 29300 hectares in 2019, the maize yield reduced from 133000- 90 kg bags in 2019 to 902066 -90kg bags in 2020. This finding is in agreement with that of Terence et al. (2022) which showed that as acreage under maize cultivation in East Africa increases, maize yield also increases This indicates that if other factors influencing maize yield are favourable, then the higher the acreage put under maize production, the higher the yield. However, this is not always the same (Santpoort, 2020). This study analyzed data for land acreage under maize and maize yield for only five years. The study therefore recommends further research which should cover more years. Moreover, detailed research should also be carried out on how land acreage under maize can influence use of seasonal rainfall forecasts.

4.4.3 Accessibility to Seasonal Rainfall Forecasts

Summary of the results for this survey showing the number of maize farmers who access seasonal rainfall forecasts in Tongaren Sub-County is given in Table 4.8.

Table 4. 8: Access to seasonal rainfall forecast

Outcome	**Frequency**	**Percentage**
Yes	243	68.3
No	113	31.7
Total	**356**	**100**

Source: Author, 2024

Table 4.8 shows that 68.3 % affirmed that they access seasonal rainfall forecast whereas 31.7% said that they did not access it. This finding is contrary to that of Serra & McKune (2016) that showed that only a small number of farmers in Kenya access and use climate information. This number is modest and may be due to barriers like use of inappropriate communication channels which make it difficult to access and use such information. Findings from a study by ECA (2021) showed that access to climate information helps to lower the adverse impacts of climate change through promoting sufficient preparedness and informed decision –making by farmers, hence building resilience to climate change and variability.

Accessibility to and use of seasonal rainfall forecasts is likely to boost maize productivity since the information can help them in decision –making for instance identifying sowing dates, choosing the right crop varieties and harvesting time. As observed in the recent study by Ouedraogo et al. (2018), in Senegal, accessibility to and use of climate information helped the farmers make tactical decisions before, during, and after the farming seasons. The percentage of those farmers who access seasonal rainfall forecasts is low and needs to be improved. This can be achieved through innovative ways of disseminating the forecasts directly to the users such as sending directly the forecasts to farmers' mobile phones.

However, it should be noted that accessing seasonal rainfall information does not necessarily guarantee its usage.

4.4.4: Awareness of Availability of Seasonal Rainfall Forecasts

The study sought to establish whether maize farmers were aware of availability of seasonal rainfall forecasts. Figure 4.18 shows the response of maize farmers who indicated that lack of awareness of availability of seasonal rainfall forecasts was a factor contributing to use of seasonal rainfall forecasts. Figure 4.18 shows that 52.5 % of the respondents indicated that lack of awareness of the availability of seasonal rainfall forecasts was a factor in utilization of seasonal rainfall forecasts. Another 47.5% of the respondents stated that lack of awareness of availability of seasonal rainfall forecasts was not a factor. This finding imply that a significant number of respondents believed that awareness on seasonal rainfall forecasts is vital and can influence decision – making at the farm- household level. This is evidence that there is a potential for reliable CI which when put to use can improve crop yields. Findings from FGDs and KIIs also showed that lack of awareness on existence of CI among maize farmers leads to low uptake of such information.

The finding is in agreement with study by Onauphoo and Sanga (2023) that showed that a good number of farmers fail to use climate information due to lack of awareness and this may expose farmers to the risks of climate change. According to Madumere (2017) and Bahauddin et al. (2013), increased personal knowledge and awareness influences change in attitude and behavior which eventually promotes decision- making. This significant number of people who stated lack awareness on availability of climate information such as seasonal rainfall forecast suggests that climate information givers have not put in more effort to ensure people are informed about such information. However, awareness may not lead to use.

Climate information if applied well may help the user to plan and this lack of awareness amongst maize farmers in Tongaren Sub-County will affect maize production since rainfall in this area has been found to be variable. This lack of awareness may also be a pointer to the disconnect that exists between the producers of climate information and the users as postulated by (Lemos, Kirchhoff, & Ramprasad, 2012; Singh, Urquhart and Kituyi, 2016).

The climate information producers are urged to come up with ways of creating awareness of the availability of seasonal rainfall forecasts and improve on ways of dissemination of seasonal rainfall forecasts so that more farmers can access and use it.

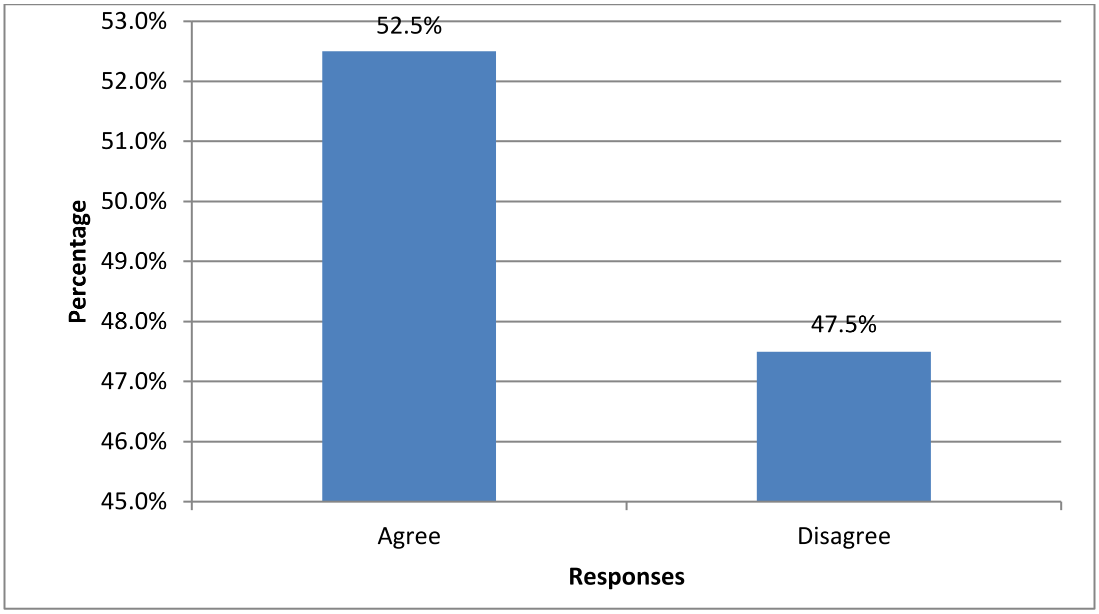

Figure 4.18: Response on lack of awareness of availability of forecasts
Source: Author, 2024

4.4.5 Relevant downscaled climate information

Locally downscaled climate information is important as this can give some information which enable the user may make appropriate decisions. Results as depicted in Figure 4.19 reveal that (51%) of Tongaren Sub-County maize farmers indicated lack of relevant downscaled climate information as one of the factors that make them not to use seasonal rainfall forecasts while 49% were of contrary view. This finding is in agreement with that of Bunyan et.al. (2015) which found that unavailability of downscaled climate information was a hindrance in using climate information. This result implies that there is a need for climate information producers to ensure that they downscale their products to the local level for such information to be useful in decision- making by the users. Indigenous climate information need to be incorporated as this comprises locally observable indicators which can be directly linked to climate.

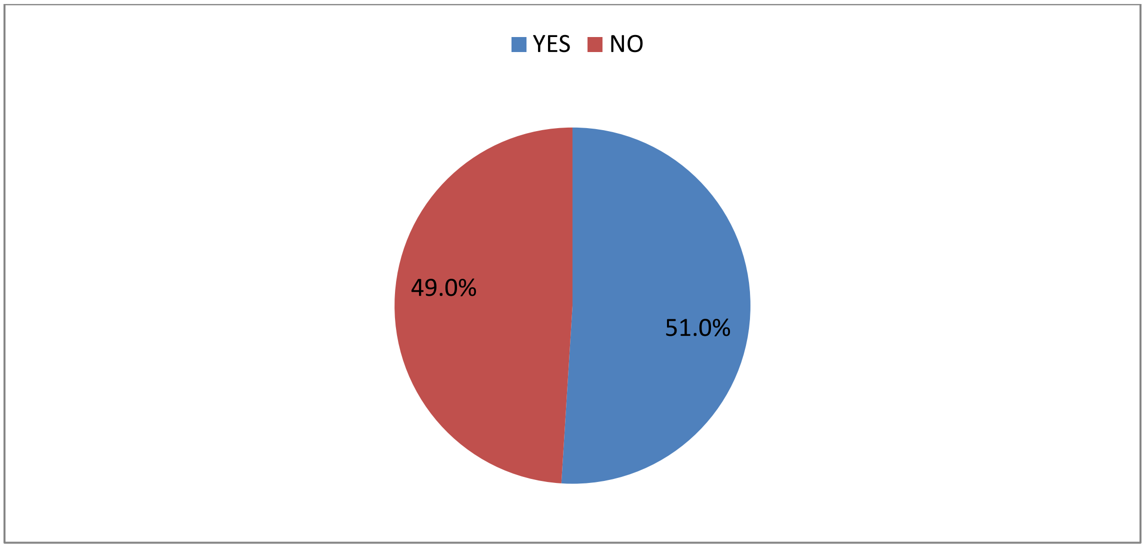

Figure 4.19: Response on relevant downscaled climate information

Source: Author, 2024

4.4.6 Capacity to interpret climate information

Findings shown in Table 4.9 shows that 53% of the respondents said they lacked capacity to interpret climate information. Similarly, 47% of the respondents indicated that they had capacity to interpret it. This finding resonates well with that of Ziervogel et al. (2008) which revealed that most people lack the capacity to interpret CI and this limits utility of such information. According to Gadgil et al. (2002), the users can only change their behavior for instance when and what to plant if they can interpret correctly climate information. Since a significant percentage of farmers have difficulties in interpreting the CI it implies that even if this information is availed to them, they cannot utilize it fully. Thus, capacity building in CI interpretation needs to be an integral part of climate information service plan (CISP). This can be one way of boosting the uptake of CI since they can understand well the climate information. In addition there should be deliberate effort to disseminate information to farmers at local levels through strengthening of extension services and coming up with strategies such as farmers field schools, organizing field days, making use of chiefs' barazas and other means. All efforts to improve the ability of maize farmers to interpret seasonal rainfall forecasts should be put in place as soon as possible so that the information can help them make informed decisions in maize production.

Table 4.9: Capacity to interpret climate information

Outcome	**Frequency**	**Percentage**
Yes	167	47
No	189	53
Total	**356**	**100**

Source: Author, 2024

4.4.7 Timeliness for Delivery of Climate Information to User

Findings in Figure 4.20 show that 243 representing 68.3% stated that late delivery of seasonal rainfall forecasts was a factor influencing its use. They felt that seasonal rainfall forecasts should be availed in good time for them to make informed decisions. Another 31.7% of the respondents were of contrary opinion. This finding was concordant with other studies by Antwi et al. (2020), Nkiaka et al. (2019) who highlighted the need for timely climate information for effective decision making to address climate shocks as their studies had shown that many farmers did not use CI due to late delivery of the same to them. Due to the fact that, rainfall is variable, the farmers are likely to suffer losses thus reducing maize productivity. The findings of this study is also in tandem with Manjula and Rengalakshmi (2015) which found that the time frame involved in availing CI to the users is quite insufficient for decision making.

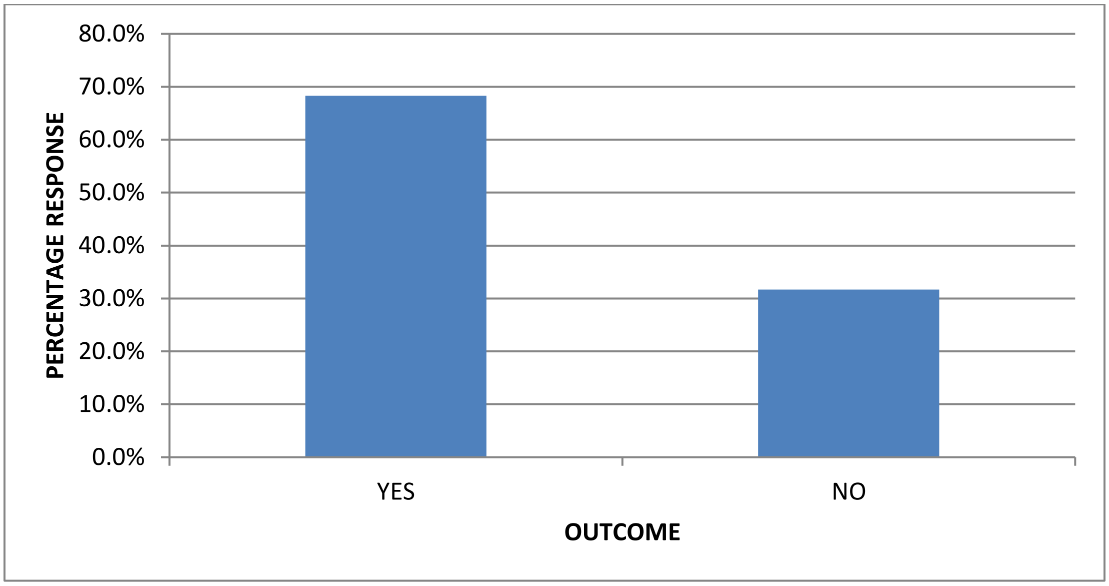

Figure 4.20: Response on timeliness of delivery of climate information
Source, Author, 2024

4.4.8 Communication Channels

Respondents were asked to indicate the most preferred communication channels through which they receive seasonal rainfall forecasts because successful usage of CI can only be achieved if the right communication channel is used in dissemination of information. This was to be done by ranking the channels whereby the most preferred channel was assigned rank 1. Figure 4.21 gives their responses. Figure 4.21 shows that majority of people preferred receiving seasonal rainfall forecasts through radio at 25.6%. This was followed by cellphone at 18.5%. A study by Amwata et al. (2016) in Makueni and Kajiado had yielded results, which were consistent with the current study.

Other studies by (Amegnaglo et al., 2017, Serra and McKune, 2016, Henriksson et al. 2021) also showed that the radio was the most preferred mode of CI communication. They had found that smallholder farmers highly depended on radio as their main source of climate information. In a similar study, Oyekale (2015) linked high access of CI through radio to low cost hence widespread, trust and use of vernacular languages which ensures wide reach. Those who accessed CI by internet were at 9.0%. This attests to the fact that people are now starting to embrace technology and that more people can potentially access information through internet. Findings from Figure 4.21 also reveal that the percentage of those who received CI through newspapers and other print media was quite low at 2.1% and 1.4% respectively. Newspapers and other print media are not accessed easily in the rural set up and in most cases they are seen as the preserve for the elites and those living in urban centres. The results imply that most people are likely to miss the benefit of CI even if it is available just because the channel of communication is inappropriate to them. The channels of communication which are most preferred by the maize farmers such radio need to be enhanced by opening community based radio stations which broadcast in local vernacular languages. This will ensure the number of farmers who access the forecasts information grows. Furthermore, maize farmers need be encouraged to use the channels which are perceived to be less popular like the newspapers. This may be achieved by availing newspapers that are printed in local languages and at subsidized prices. These efforts will enhance accessibility to CI which may eventually lead to higher utilization of climate information.

Findings from FGDs and KIIs also revealed that the radio was the most preferred means of accessing climate information.

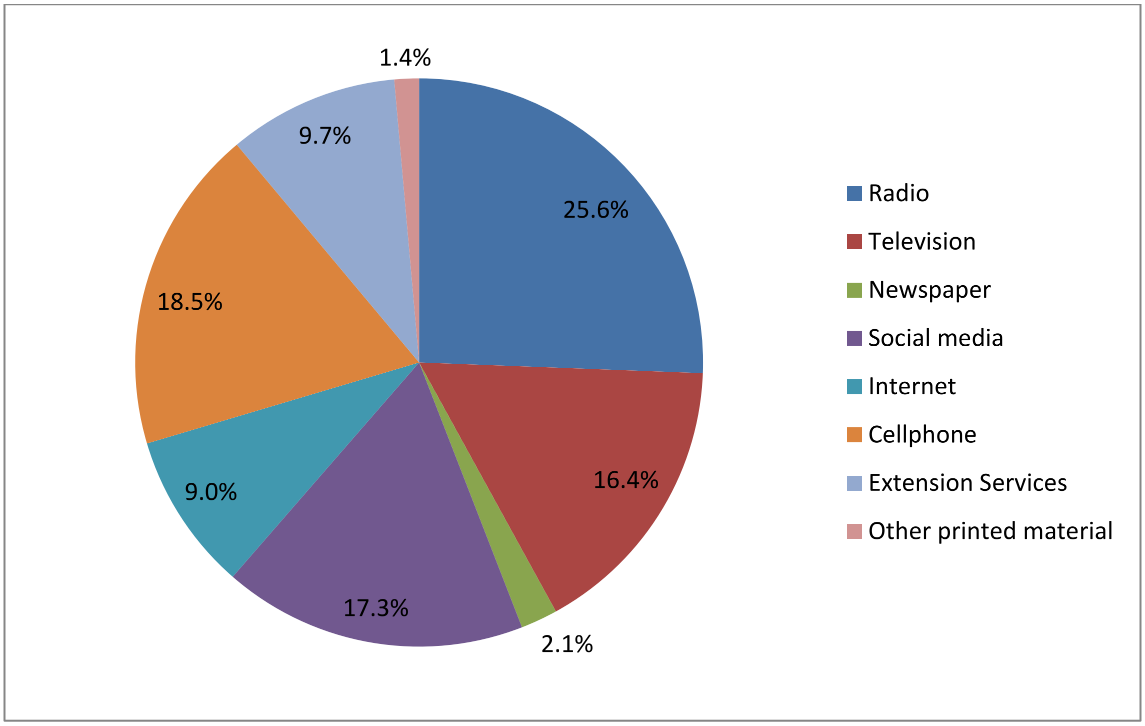

Figure 4.21: Climate information communication channels
Source: Author, 2024

4.4.9 Suitability of Language

This study sought to establish whether the language used in describing seasonal rainfall forecasts influences use of seasonal rainfall forecasts or not. From Figure 4.22, 10.1% of the respondents felt that language was a barrier in regards to accessibility and usability of seasonal forecasts while 89.1% did not. Although the percentage was low, the results concur with that of Nkuba (2023) and Ziervogel and Downing (2004) that showed that language barrier is a hindrance to accessing and utilization of CI among many users. Similar study by Amano et al. (2016) had found language to be a serious barrier to knowledge transfer with potential to cause serious gaps in the information available.

The result confirms that education levels of most people were high and they had little trouble in understanding the language in which the CI is communicated in mostly English and Kiswahili. Again, with proliferation of FM radios which mostly use local languages to reach their audience when disseminating weather information, the language barrier has drastically reduced. It should also be noted that CI can as well be disseminated through schools by teaching the children who in turn will share the information with parents and this is a good way of introducing them to this knowledge. However for the 10.1% who stated that language is a barrier, CI producers need to package CI in the local language which is easily understood. This will be in line with what Muema et al. (2018) studied and found that climate information is only useful when they can be accessed in a form easily understood by the farmer. Furthermore, study by Antwi-Agyei et al. (2021) has shown that dissemination of CI through local languages is the most preferred among rural households.

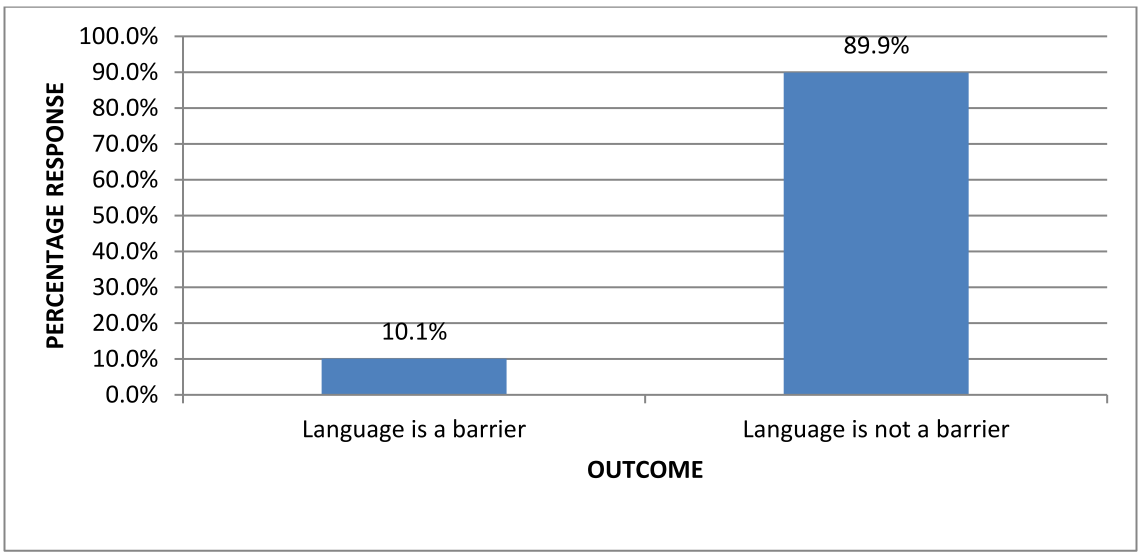

Figure 4.22: Response on language suitability
Source: Author, 2024

4.4.10 Perception on Accuracy of Climate Information

The study also sought to establish the perception of maize farmers concerning the accuracy of seasonal forecasts. Figure 4.23 shows that 71.6% of the respondents stated that the accuracy and reliability of seasonal rainfall forecasts are very important when it comes to the uptake of CI while 28.6% were of contrary opinion. This finding resonates well with that of Muita et al. (2021) which showed that perception by many farmers on the accuracy and trust of CI influences the use of such information in Kenya. Accuracy and reliability of CI builds the confidence level amongst the users. Climate information givers need to strive to make the seasonal rainfall forecasts as accurate as possible in order to build more confidence in the users of such information.

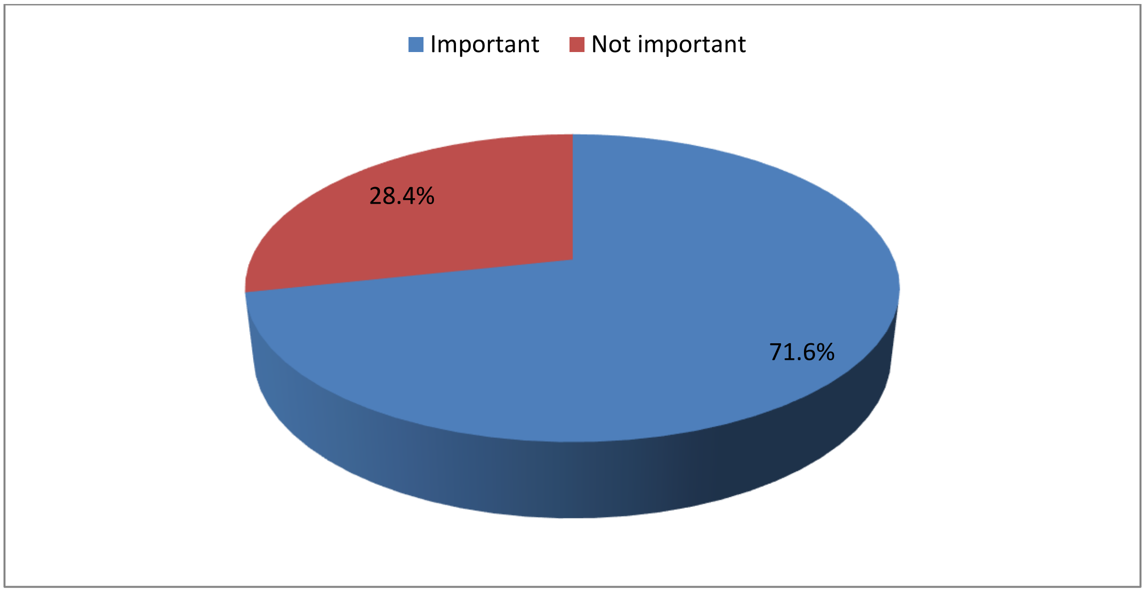

Figure 4.23: Perception on accuracy of climate information
Source: Author, 2024

4.4.11 Interest in use of climate information

This study sought to find out whether interest one holds in climate information was a factor in using seasonal rainfall forecasts among maize farmers in Tongaren Sub-County. The results in Figure 4.24 show that 51.7% indicated that interest to use CI is indeed a factor. Another 48.3% of the respondents expressed the view that interest in climate information was not a factor in determining utilization of CI. They expressed the feeling that lack of involvement of the community in producing CI makes them have low interest in using a product that their input has not been considered. This result concurs with earlier studies by Patt and Gwatta (2002) and Nyadzi (2020) who intimated that majority of farmers use seasonal forecasts based on their interests and whether such forecasts are fused with local knowledge, the so called indigenous technical knowledge (ITK) or not. The findings are also in consonance with those by Ambani and Percy (2014) who found that many farmers use climate information is based on the interest they have. In order to build interest to use CI, among the maize farmers, this study recommends that climate information producers should involve maize farmers in all stages of developing a seasonal rainfall forecast. Such involvement may be through collection of climatic data such as rainfall which is eventually used in producing the forecasts.

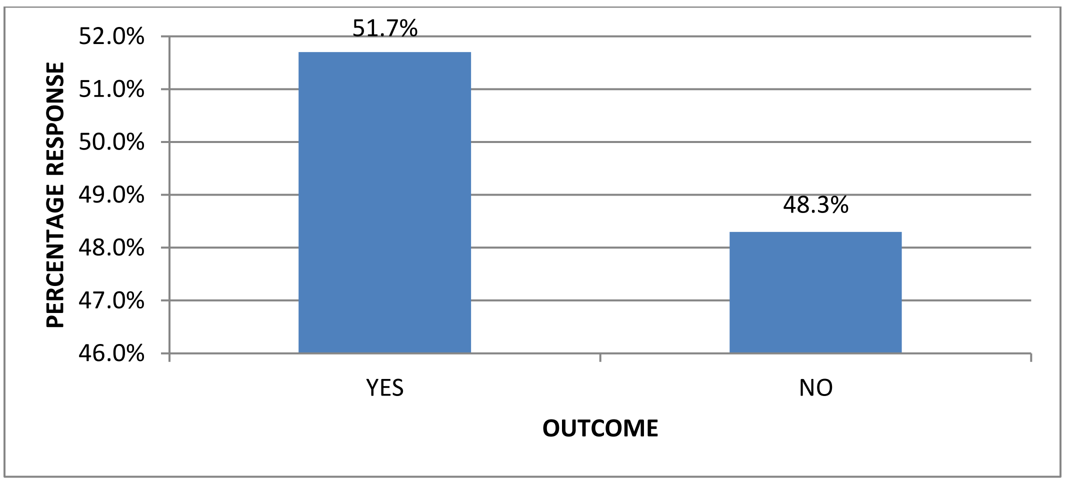

Figure 4.24: Response on interest in using climate information in maize production
Source: Author, 2024

4.4.12 Sources of climate information

Findings in Figure 4.25 show that 45.2% of the respondents indicated that too many sources of climate information such as social media and the internet were a hindrance to the utilization of CI since they tend to confuse them as they give conflicting information about the weather forecast of the same place. Another, 54.8% of the respondents felt that the sources of CI were not a factor that determines use of seasonal rainfall forecasts. The result from the current study is in agreement with that of Haigh et al. (2015), which showed that source of CI among many users is a factor in determining whether it will be used or not. This can be attributed to trust among the maize farmers and the CI producers. Moreover, Mudombi and Nhamo (2014) intimated that climate information should be reliable, trusted and understandable for farmers to utilize it in climate change adaptation. Based on the findings, there is need to streamline the sources of CI so that only those CI producers who have been authenticated by the Government are allowed to issue weather forecasts to the public. This will reduce confusion among the users of such information.

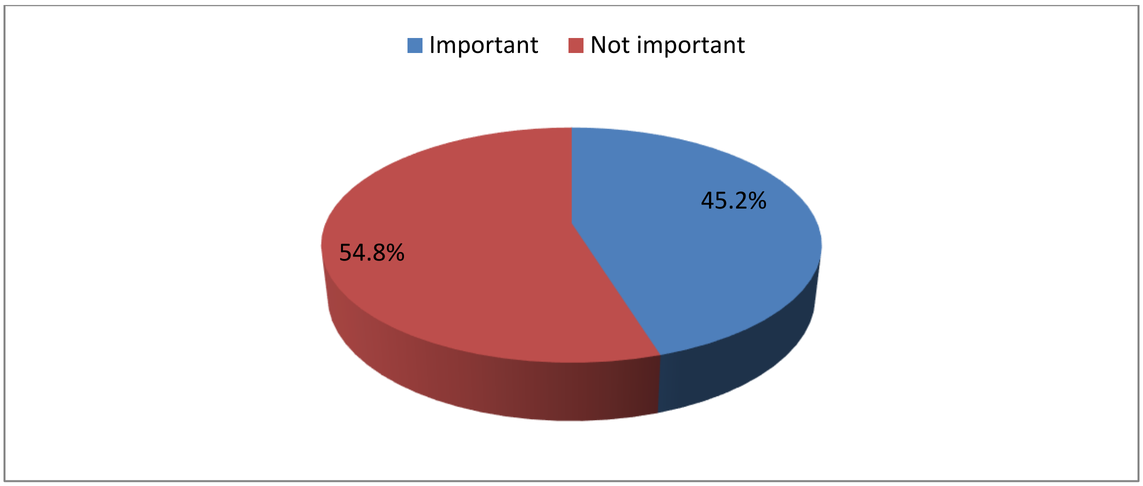

Figure 4.25: Response on sources of climate information used in maize production
Source: Author, 2024

4.5 Specific objective three: Benefits of using seasonal rainfall forecasts on maize yield in Tongaren Sub-County

This study sought to assess the benefits of seasonal rainfall forecasts on maize yield. The respondents were asked to state whether they agreed or disagreed with the statements given to them. The findings are presented in Figure 4.26. The figure shows the percentage of responses from the respondents who agreed or disagreed with the statements given to them.

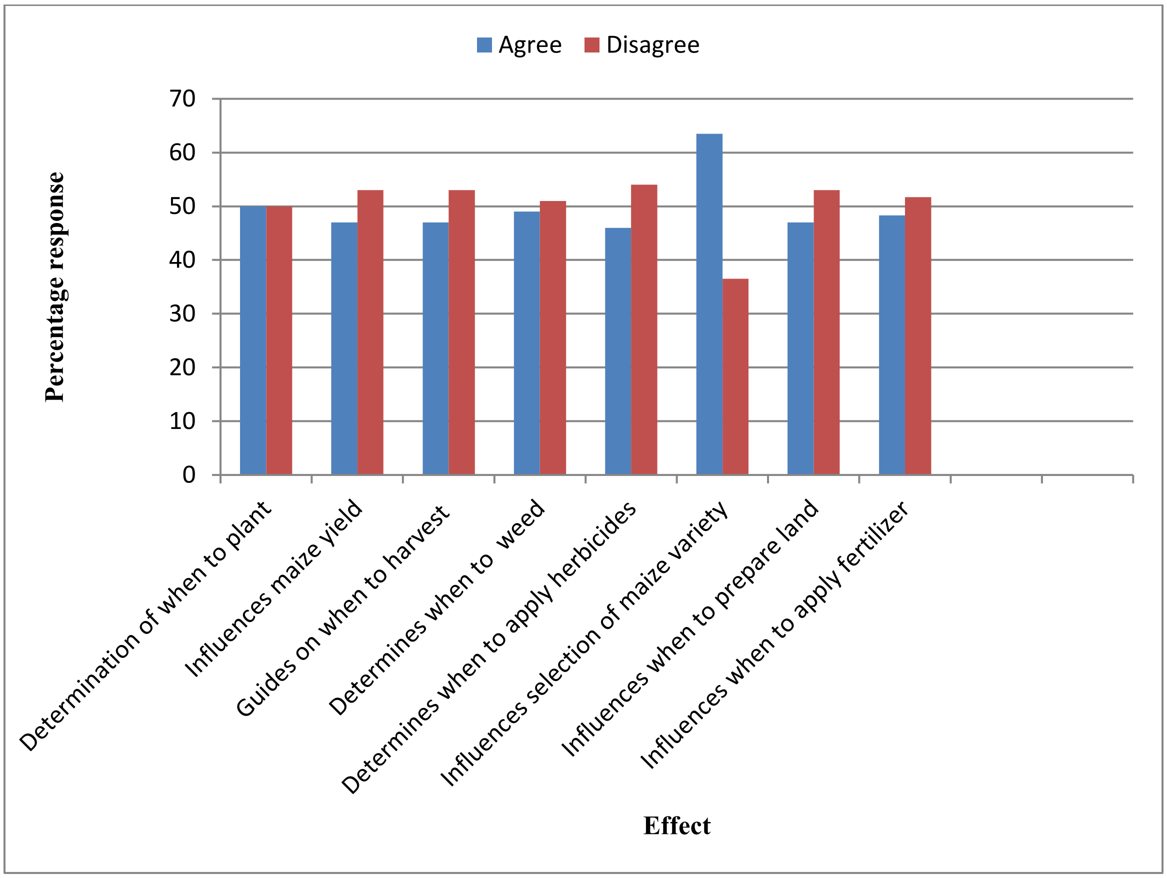

Figure 4.26: Benefits of using seasonal rainfall forecast on maize yield
Source: Author, 2024

4.5.1 Determination of when to Plant

Results in Figure 4.26 show that seasonal rainfall forecasts influences various farm activities.. In regards to when to plant maize, 50% of the respondents agreed that onset of seasonal rainfall determines when to plant their maize crop. These findings corroborates with Reche et al. (2008) findings that showed determination of planting dates among many farmers were farm management strategies that reflected application of seasonal rainfall forecasts in semi-arid areas of Kenya. Moreover, Guido et al. (2020) in the study on impact of seasonal forecasts in Sub- Saharan Africa found that seasonal rainfall forecasts were crucial in guiding many farmers on planting dates. Although farmers were of the opinion that seasonal rainfall forecasts play a major role, in decision –making weather patterns are quite erratic. This was affirmed during FGD when a famer said "*nowadays, it is becoming more difficult to predict the future rains in our area due to climate change"*. The other 50% of the respondents who do not rely on seasonal rainfall forecasts when determining when to plant should be encouraged to do so because applying the information contained in the forecast will help them put in place better adaptation strategies to counter the risks posed by climate change.

4.5.2 Influence of seasonal rainfall forecasts on maize yield

The respondents accounting for 47% agreed that seasonal rainfall received plays a big role in determining maize yield while 53% of the respondents disagreed with that statement. This finding corroborates well with that of Bahiru et al. (2020) in which many farmers stated that forecasted rainfall over growing season adversely affects rain-fed crop production due to its associated risks such as delay on onset, early cessation and dry spells. The results on correlation between rainfall and maize yield show that whenever there was high rainfall recorded during the rainy season, maize yield was also high and vice versa. This finding explains the fact that seasonal rainfall forecast when applied by the farmer is likely to help such a farmer in decision- making for instance in choosing the right maize varieties and when to plant. The right choice of maize varieties to be planted and when are crucial as these will determine the yield. The percentage of maize farmers who stated that seasonal rainfall forecasts influences their maize yield is relatively low. This implies that few farmers use seasonal rainfall forecasts and this study recommends sensitization of the farmers to create awareness among them on the benefits of using seasonal rainfall forecasts.

4.5.3 Harvesting time

Maize farmers were asked to state whether seasonal rainfall forecasts had any influence in determining when to harvest their maize. 47% of the respondents indicated that seasonal rainfall forecasts are very crucial in determining when to harvest their maize while another 53% indicated that seasonal rainfall forecasts had no influence. The finding of this study is in agreement with those of White et al. (2017) which found that farmers use climate forecasts to reduce their vulnerability to the impacts of climate risks such as droughts and floods by timing appropriate time to harvest. This is because weather prevailing at the time of harvesting will determine the amount of maize that will be destroyed because of rotting due to excess water. Most farmers prefer to harvest their maize during the dry weather. This will reduce post- harvest losses. The dry weather will also enable the farmers take their maize produce to the market. When there is a lot of rainfall, most of the rural roads where most farmers live are rendered impassable hence; it makes transportation difficult and cumbersome.

The results show that fewer farmers rely on seasonal rainfall forecasts as compared to those who do not when it comes to utilization of seasonal rainfall forecasts. Therefore this study recommends the intensification of training on how to interpret seasonal rainfall forecasts and also enhancement of dissemination of the forecasts so that many maize farmers can have access to CI because such information will help them make good farm-level decisions.

4.5.4 Weeding and application of herbicides

The response indicated that 49% of the maize farmers stated that seasonal rainfall forecasts determines when to carry out weeding while 51% stated that the forecasts did not have any influence. On the other hand, 46% of the maize farmers stated that seasonal rainfall forecasts helped them in application of herbicides while 54% indicated it did not. Weeding and application of herbicides are normally carried out during the time when there is little rainfall as this ensures that there is no re-emergence of weeds and also to ensure that the herbicides are not washed away by the rain water. The finding concurs with that of Reche et al. (2008) where a good number of farmers stated that application of fertilizers, herbicides and other farm activities were dependent on seasonal forecasts in Kenya. Farmers are normally cautious on what farm activity to undertake in order to realize full advantage of the prevailing weather. For instance, they would prefer to weed or apply herbicides when there is little rainfall as opposed to when there is heavy rainfall. There is need to enhance awareness among maize farmers on the need to utilize seasonal rainfall forecasts in most of the farm activities.

4.5.5 Selection of maize varieties

A significant percentage of the respondents (63.5%) felt that seasonal rainfall forecast is important in selecting maize variety to be planted. This finding concurs with that of

Guido et al. (2020) which showed that many farmers select seed varieties and determine when to plant them based on seasonal forecasts in each cropping season. This is very important because different maize varieties do well in certain weather conditions. Some maize varieties thrive when there is plenty of water whereas others still do well when there is just a little rainfall since they are drought resistant. The result shows that a good number of maize farmers (36.5%) do not care much about the weather conditions when selecting maize varieties to be grown yet weather information could help them select maize varieties such as early – maturing or late- maturing to be planted. This is likely to compromise the maize yield which may contribute to food insecurity since inability to use climate information such as seasonal rainfall forecasts may reduce their ability to manage climate risks. It is therefore necessary that maize farmers be trained on how to interpret CI and at the same time be encouraged to use it always as this will help them in applying better adaptation strategies against climate change.

4.5.6 Land preparation

The results show that 50% of the respondents indicated that seasonal rainfall forecasts helps them to determine when to prepare their land in readiness to grow their maize while 50% of the respondents indicated that they do not depend on it. The finding of the study concurs with that of Philip et al. (2021) which found that a significant number of farmers use climate information in making decisions related to land preparation. Most of the prefer using tractors to plough their land since this is faster and saves time. Good timing to prepare land is important because this is an activity that should be undertaken before the onset of the seasonal rains. This is preferable because farm machinery can be deployed and be maneuvered well when the land is still dry as opposed to when the land is wet as this makes deployment and use of machinery cumbersome. In order for more maize farmers to benefit from seasonal rainfall forecasts, there is need for CI producers to train them on how to interpret CI and ensure that CI information is accessible to them in good time for planning purposes.

4.5.7 Fertilizer application

From the survey, 48.3% reported that application of fertilizer on their maize farms is dependent on the seasonal rainfall while 51.7% indicated that they did not rely on seasonal rainfall forecasts. The finding concurs with the studies carried by Belay et al., (2017) and Dewi and Whitbread (2017) which showed that a good number of farmers rely on climate information to carry out farm management activities such as application of fertilizer and that they are better placed to improve their crop yield and adapt well to climate change shocks. Application of fertilizer at the right time is crucial as this is one way in which fertility of the soil is conserved and maintained. Timing on when to apply fertilizer to crops is important as this enables the maize plants to fully utilize the applied fertilizer. It is preferred to apply the fertilizer when there is less rainfall as this will reduce the leaching of the fertilizer. Seasonal rainfall forecast is therefore critical since information on when there will be more or less rainfall is given and this may help the farmers in making the right decision on farm management activities.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This section gives a summary of the findings, conclusions, recommendations as well as suggestions for further research based on the findings.

5.2 Summary of the Findings

The study sought to determine the trends of seasonal variability of rainfall in Tongaren Sub-County. This was done by looking at temporal variation of rainfall within two rainy seasons that directly affect maize farming in this area. The analysis was done for the March- April-May (MAM) and the June- July –August-September (JJAS) rainfall seasons. From the findings it was found rainfall to be variable in the area. For the MAM season, a mean value 488.7mm of rainfall was computed implying that maize can be grown in this area. However, a high value of standard deviation of 101.28 was calculated implying that rainfall deviates from the mean value significantly. This deviation was also supported by the fact that during this season, there were normalized deviations of between -1.48 and +3.29. A significant value of rainfall variability of 20.7% was computed for the MAM rainfall.

During the June-July-August –September season, rainfall was also found to be variable. Within the season, the average rainfall was found to be 594.5 mm which was more than that for the MAM season. Standardized rainfall anomalies ranged between -1.58 and + 2.09. The standard deviation was found to be 122.8 whereas rainfall variability was

20.6%. As in the case for MAM, the rainfall variability in JJAS has the potential to influence maize production.

The respondents stated that lack of awareness (52.5%) on climate information was a barrier in accessing and utilization of seasonal rainfall information making them to be uncertain on the expected seasonal amounts. Due to this uncertainty, most of them could not plan well. They also stated that there was inadequate climate information in the area. Those who were in support of this were at 51%.

Other factors that affected utilization of seasonal rainfall forecasts were also mentioned and they included: low capacity to interpret climate information (53%), late delivery of climate information to the user (68.3%), perception on the accuracy of climate information (71.6%), level of education (25%) and low interest in climate information due to their non-involvement in the process of producing them (51.7%). Out of the number of people who accessed seasonal rainfall forecast, 46.5 % stated that they did not use the information.

The study also assessed the benefits of using seasonal rainfall forecasts on maize yield. The result revealed that most of the activities at the farm level depend on the seasonal rainfall forecasted. Some of the identified farm activities based on the seasonal rainfall that influenced maize yield included, determination of when to plant maize (50%), timing of maize harvesting (47%), determination of when to weed (49% and apply herbicides (46%), selection of the maize varieties to be grown (63.5%), preparation of land (50%), application of fertilizers (48.3%). However some of the maize farmers were of the opinion that seasonal rainfall forecasts do not affect their activities. During the focus group discussion, the participants expressed the need to have regular, timely and accurate seasonal rainfall forecasts that can enable them take appropriate decisions that can boost maize yield. They also emphasized the need for such forecasts to be accompanied with agronomic advisories.

5.3 Conclusion

The following conclusions were made based on the findings of the study.

i. On the determination of seasonal rainfall trends, the findings demonstrate that rainfall exhibits a slight increasing trend both for MAM and JJAS rainfall seasons. For the two seasons there is both inter- seasonal and intra-seasonal variability which may be linked to climate change. The variability in rainfall is likely to affect maize yield since majority of the maize farmers wholly depend on the rainfall.

ii. On specific objective two, some of the factors that influenced their access to and utilization of seasonal rainfall forecasts were; low capacity to interpret climate information, lack of relevant downscaled climate information, use of unsuitable communication channels, late delivery of CI to users, perception of accuracy of CI, low interest in using CI, too many sources of CI, level of education and use of unsuitable language. This finding demonstrates the fact that climate information providers have not done much in ensuring that their products are accessed and utilized by various targeted users.

iii. In regards to specific objective three on the benefits of using seasonal rainfall forecasts on maize yield, the smallholder maize farmers indicated that the seasonal rainfall forecasts influences when; to plant maize, to harvest maize, to weed and apply herbicides, to prepare land, and when to apply fertilizer.

5.4 Recommendations

The study recommends the following;

i. The county Government of Bungoma to explore possibilities of empowering the maize farmers to adopt new and cheap sustainable technologies of irrigation. Promotion of irrigation will ensure that rainfall variability does not have huge impact on maize production.

ii. Climate information should be co-produced by CI producers and farmers and that local indigenous knowledge integrated. This will encourage utilization of CI.

iii. Climate information providers need to enhance timely and accurate forecasts and these should be accompanied by agronomic advice for better decision-making.

iv. Climate information ought to be disseminated through channels that can be easily accessed by the local farmers.

v. Government agencies in conjunction with local leaders ought to sensitize and create awareness among maize farmers on the importance and benefits of using seasonal rainfall forecasts in their planning since the information can help them reduce climate related risks on maize production.

5.5 Suggestions for Further Research

i. Research to be conducted on all other major climatic parameters such as temperature, evaporation, winds which affect maize crop production in order to establish their impact on the crop.

ii. Extensive research ought to be carried out on non-climatic factors such as farm inputs, diseases and pests among others and establish how they affect maize production in Tongaren Sub-County.

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APPENDICES

APPENDIX I: QUESTIONNAIRE- RESPONDENTS INTERVIEW GUIDE FOR HOUSEHOLD

Dear respondent,

This questionnaire is meant to gather information on the influence of seasonal rainfall forecasts on maize yield. The purpose of this study is purely academic. Kindly fill the questionnaire as truly and honestly as possible. The information given will be highly and strictly confidential and will be used only for the purpose of the study. In case any of the questions are deemed to be inappropriate to your circumstances, you are under no obligation to answer them.

SECTION A: DEMOGRAPHIC INFORMATION/ HOUSEHOLD CHARACTERISTICS

Kindly select your age bracket from the choices given by ticking (√) in the appropriate space.

Age (years)	**Tick (√)**
18-25	
26-35	
36- 45	
46- 55	
56-65	
66 and above	

(a) Please tick mark (√) your current main source of income

Source of income	**Tick (√)**
Farming	
Formal employment	
Others (specify)	

(b) If your answer in 2(a) above is farming, please tick mark (√) in the appropriate space the type of crop farming you engage in.

Type of crop	**Tick (√)**
Maize	
Beans	
Tea	
Coffee	
Sugar cane	
Others (specify)	

(c) If your answer in 2 (b) above is maize farming, Please indicate how long you have practiced its farming by putting a tick mark (√) against the appropriate choice.

Time practiced maize farming (Years)	**Tick (√)**
Below 1 year	
1 - 5	
6 - 10	
11 -20	
21- 30	
Over 30 years	

(d) For the maize you grow kindly indicate by putting a tick mark (√) the main purpose for engaging in its production.

Purpose of growing maize	**Tick (√)**
For family consumption	
For commercial purpose	
Both family consumption and commercial purpose	
Others (specify)	

(a) Kindly indicate the size of the land you or your family owns by putting a tick mark (√) against the land size.

Land size (acres)	Tick (√)
Less than (<) 1	
1 - 5	
6 -10	
11 - 20	
21 -50	
Over 50	

(b) Out of the land size indicated in 3 (a) above, indicate by putting a tick mark (√) against the approximate land size that is put to maize farming.

Land size (acres)	Tick (√)
Less than (<) 1	
1 - 5	
6 -10	
11 - 20	
21 -50	
Over 50	

Please, indicate the type of your land ownership by putting a tick mark (√) in the spaces given.

Nuclear family owned ( )

Family/clan land ( )

Leased ( )

Government owned but allowed to farm ( )

Squatter ( )

Others (specify) ( )

Kindly tick mark your staple food (√)

Staple food	Tick (√)
Maize	
Rice	
Sorghum	
Cassava	
Potatoes	
Beans	
Others (specify)	

When preparing your land for planting maize, kindly indicate by putting either YES or NO the method you use.

Method of land preparation	**YES/NO**
Traditional methods	
Modern mechanized methods	
Both traditional and mechanized methods	
Others (specify)	

(a) Please indicate with a tick mark **(**√)   if you use irrigation in maize farming.

Yes ( ) No ( )

(b) If your answer in 7 (a) above is yes, please tick mark **(**√) in the appropriate place the source of the water for irrigation.

Source of water	**Tick (√)**
River	
Dam	
Borehole	
Harvested rain water	
Others (specify)	

Approximately how many 90kgs bags of maize do you harvest in an acre of land? **Tick**

1-5 ( ) 6-10 ( ) 11-15 ( ) 16-20 ( ) 21-25 ( ) 26-30 ( ) Over 30 ( )

Kindly indicate your gender by putting a tick mark (√)   in the appropriate space.

Male ( ) Female ( )

Please indicate your marital status by putting a tick mark (√)   against the choices given.

Single ( )

Married ( )

Widowed ( )

Separated ( )

Divorced ( )

Kindly indicate the number of people in your household by a tick mark (√)

Number of people	Tick (√)
1-5	
6-10	
11-15	
16-20	
Others (specify)	

SECTION B: CLIMATE INFORMATION

What is your understanding of the impacts of climate change in the context of maize yield? Please indicate by a tick mark (√).

Farmer's Perception	Tick (√)
High temperature	
Low temperature	
Excessive sunshine	
Increased floods occurrences	
Increased drought occurrences	
Low rainfall	
Increased pests	
Erratic rain patterns	
Late planting	
Strong winds	
Insufficient food and water supply	
Increased maize yield	
Reduced maize yield	
Others (specify)	

In this section you are required to give your opinion on the weather parameters that mostly affect maize yield by choosing from the choices given. Please do this by putting a tick mark (√) in the appropriate space.

1. Highly agree 2. Agree 3.Neutral 4. Disagree 5. Highly disagree

Climate variable	1	2	3	4	5
High temperature					
Low temperature					
Excess rainfall (floods)					
Drought					
Excessive sunshine					
Strong winds					
Hailstorms					
Others (specify)					

You have been given the following options:

1 = Low 2 = Medium 3 = High 4 = Very high.

Kindly indicate with a tick mark (√) how frequent the following occur in your area.

Phenomenon	1	2	3	4	5
High temperature					
Low temperature					
Excess rainfall (floods)					
Drought					
Excessive sunshine					
Strong winds					
Hailstorms					
Increase in pests and diseases					
Soil erosion					
Others (specify)					

In your opinion how would you describe the following in the recent past? Indicate by tick mark (√)

Climate variable	Yes (√)	No (√)
Rainfall amounts have increased		
Rainfall amounts have decreased		
Temperatures have gone up		
Temperatures have gone down		
There is no change in the rainfall amounts		
There is no change in the temperatures		
Have no idea in the change of rainfall and temperature		
Others (specify)		

In light of the impact of climate variability, how would you describe the yield of maize in your area in the recent past? Do this by putting a tick mark (√) in the appropriate place.

Increased ( ) Reduced ( ) Not changed ( ) No idea ( )

SECTION C: INFORMATION ON FACTORS THAT AFFECT ACCESS AND USE OF CLIMATE INFORMATION

The following are some of the factors that affect access to and utilization of climate information. Kindly tick mark (√) the ones that apply to you.

Constraint/limitation	Tick (√)
Lack of awareness	
Lack of relevant downscaled climate information	
Low capacity to interpret climate information	
Late delivery of climate information to the user	
Unsuitable (wrong) communication channels	
Perception on the accuracy (reliability) of climate information	
Level of education	
Low interest because of lack of involvement of the community	
Others (specify)	

In your opinion if all the issues listed in (1) above were addressed would you use the climate information availed to you? Kindly tick Yes or No

Yes ( ) No ( )

What is your preferred source of climate information? The sources have been ranked with the most preferred source having rank1. Kindly tick mark (√) in the appropriate box.

Source of climate information	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8
Radio								
Television								
Newspapers								
Social media								
Internet								
Cellphone								
Extension services								
Others (specify)								

SECTION D: INFORMATION ON BENEFITS OF SEASONAL RAINFALL FORECASTS ON MAIZE YIELD

You are required to indicate the benefit of seasonal rain on maize yield in your area. To do this, kindly tick in the appropriate box using the choices given.

1. Highly agree 2. Agree 3. Highly disagree 4. Disagree 5. Neutral

Benefit	**Tick (√)**				
	1	**2**	**3**	**4**	**5**
Determines when to plant maize					
Influences maize yield					
Guides on when to harvest maize					
Guides on when to weed					
Determines when to apply herbicides					
Influences selection of maize variety					
Influences when to prepare land					
Influences when to apply fertilizer					
Determines when to take maize to the market					
Has no effect on maize yield					
Others (specify)					

APPENDIX II: KEY INFORMANT INTERVIEW GUIDE FOR STAKEHOLDER ENGAGEMENT FROM DIFFERENT ORGANIZATIONS

Organization		Response
Mission		
Objective		
Scope		
1	Do you experience rainfall variability in this area? Answer by Yes or No	
2	Have you heard of climate change and climate variability? Answer by Yes or No	
3	How long have you been engaged in efforts to boost maize production in Tongaren sub-county?	
4	What have been your major achievements and successes in regards to boosting maize yield in Tongaren sub- county?	
5	Do you incorporate climate information in your activities aimed at boosting maize yield? Answer by Yes or No	
6	In your view do you think climate information especially seasonal rainfall forecast affects maize yield? Explain briefly	
7	In your opinion would you say that rainfall has increased or reduced in the recent past?	
8	What is your observation as far as maize yield over the years is concerned? Is there an increase or a decrease?	
9	Is there any relationship between the amount of rainfall received within a season and the amount of maize produced? Kindly explain briefly	

10.(a) Do you access any climate information in your area of operation? Tick Yes or No

Yes…………. No…………..

b) If your answer in 10 (a) is yes, kindly list the various climate information you access

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

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

11. **(a)** What are some of the sources of climate information that you rely on?..

....
....
....

b) From your list above, and in your opinion which source of climate information is the most reliable?

……………………………………………………………………………………..

12.(a) What are some of communication channels that are used to disseminate climate information in your area of operation?

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

b) In your opinion, which channel of communication is the most appropriate in disseminating climate information? You may list more than one channel.

13. What are some challenges you face in accessing and utilizing climate information?

i. ………………………………………………………………………………………..

ii. ……………………………………………………………………………………….

iii ……………………………………………………………………………………….

iv ……………………………………………………………………………………….

v ………………………………………………………………………………………..

vi ……………………………………………………………………………………….

vii ………………………………………………………………………………………

viii
………………………………………………………………………………………………..

ix Others (specify)
……………………………………………………………………………….

14 (a) Can you be able to quantify the impact of seasonal rainfall on maize yield? Kindly tick either Yes or No

Yes………………   No………………

b) If yes, how are the impacts? Kindly tick against your choice

i. Severe ………….

ii. Moderately severe …………..

iii Very severe …………

15. What is the approximate size of the farm for growing maize? Kindly tick.

i. 1 - 5 acres ……………

ii. 5- 10 acres…………..

iii. 10 - 20 acres ……….

iv. 20 - 30 acres

v. 30 – 50 acres

vi Over 50 acres

16. In your opinion do you think seasonal rainfall forecasts can help in boosting maize yield? Explain briefly.

APPENDIX III: OBSERVATION CHECKLIST

Kindly tick mark (√) in the appropriate box.

NO.	ITEM	YES	PARTIALLY	NO
1	Availability of seasonal rainfall forecasts			
2	Availability of historical rainfall data			
3	Availability of weather/climatic advisories/alerts			
4	Availability of maize yield data			
5	Availability of number of maize farmers			

APPENDIX IV: FOCUS GROUP DISCUSSION GUIDE (YOUTH, ELDERS, AND WOMEN)

The main agenda will be to discuss the impact of seasonal rainfall forecasts on maize yield in Tongaren Sub – County.

Discuss the trend of maize yield in Tongaren Sub – County over the years.

Discuss rainfall trends in Tongaren Sub- County over the years.

Discuss the impact of rainfall variability on maize yield in Tongaren Sub – County.

What are some of the sources of climate information in Tongaren Sub – County?

Which are the various communication channels by which climate information is disseminated in Tongaren Sub – County?

From the discussions above which channel (s) do you deem to be the most appropriate to disseminate climate information?

Discuss some of the challenges you face in accessing climate information.

In case you access climate information do you use it? If yes/no give your reasons.

In your opinion do you think there is any relationship between rainfall amount received and maize yield? Support your answer.

What are other factors that affect maize yield in Tongaren Sub- County?

Is the maize grown in Tongaren Sub – County rain-fed or irrigated?

Is the maize grown in Tongaren Sub- County done on small scale, large scale or both?

Discuss various ways in which maize yield can be improved in Tongaren Sub- County.

APPENDIX V: RESEARCH LICENSE

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