THE RELATIONSHIP BETWEEN CLIMATE VARIABILITY AND SMALLHOLDER FARMERS' COMMON BEAN YIELD IN NORTHERN UGANDA

BY

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DECLARATION

I Obong David, declare that this research dissertation entitled "The relationship between climate variability and smallholder farmers' common bean yield in Northern Uganda" is my original work and it has not been submitted to any University for any academic award.

Signature.........…………………………… Date…………………………………………….

APPROVAL

This is to certify that this research dissertation entitled: *'The relationship between climate variability and smallholder farmers' common bean yield in Northern Uganda'* has been undertaken under our supervision and it is now ready for submission.

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I solely stand responsible for any error made in the process of conducting this research dissertation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

AGRA	Alliance for a Green Revolution in Africa
CGIAR	Consultative Group for International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
ENSO	El Nin˜o-Southern Oscillation
ESA	Ecological Society of America
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization Statistical Database
GDP	Gross Domestic Product
GGCA	Global Gender and Climate Alliance
GHG	Green House Gas
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
ITK	Indigenous Technical Knowledge
ITCZ	Inter-Tropical Convergence Zone
LAC	Latin America Caribbean
M&E	Monitoring and Evaluation
NAPA	National Adaptation Programme of Action
NEMA	National Environment Management Authority
NGOs	Non-Governmental Organisations
SSA	Sub Saharan Africa
UBOS	Uganda Bureau of Statistics
UCA	Uganda Census of Agriculture
UNEP	United Nation Environment Programme
UNDP	United Nation Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

ABSTRACT

Climate variability poses detrimental effects on both nature and society, it is a global challenge that requires immediate attention if the world's 9 billion people are to be supported by sustainable use of the environment. The study examined the relationship between climate variability and smallholder farmers’ common bean yield in Northern Uganda. The study's specific objectives were to examine common bean smallholder farmers' perceptions of climate variability, assess the relationship between temperature change and smallholder farmers' common bean yield, and assess the relationship between rainfall variability and smallholder farmers' common bean yield in Northern Uganda. The study employed cross-sectional research and mixed methodology designs involving 160 smallholder farmers actively planting common bean. The sample was selected using stratified, random, and criterion-based purposive sampling techniques. To gather primary data for this study, an interviewer-administered paper survey, focus groups, and in-depth interviews were used. To evaluate quantitative data, descriptive statistics and Pearson correlation were used. Qualitative data was used to validate and supplement the narratives based on the quantitative findings. The findings revealed that common bean smallholder farmers are aware of and have experienced a rise in temperature and rainfall amount over the past 12 years that is unfavourable for the production of common beans. The null hypothesis that there is no significant relationship between changes in temperature and common bean yield is retained. In addition, the null hypothesis that there is no significant relationship between rainfall variability and common bean yield is retained. Thus, the low common bean yield experienced by smallholder common bean farmers in Northern Uganda is a result of other factors that this study did not focus on, like soil conditions, agronomic practices, pests, and diseases, among others. The investigator recommends that public and private agencies and agricultural extension workers tasked with enhancing the potentials of smallholder farmers should use and tap into the farmers' experiences with climate variability to inform climate variability training programmes. Further, build the capacity of common bean smallholder farmers to adapt and mitigate the effects of climate change and variability on common bean production and productivity. The capacity-building process should be holistic and integrate a host of other factors with a bearing on low yield, like soil conditions, agronomic practices, pests, and diseases, among others.

CHAPTER ONE: INTRODUCTION

1.0 Background to the Study

Climate variability refers to the differences in the average state or standard deviations in the occurrence of climate extremes on all spatial and temporal scales above that of discrete weather events because of either internal or natural variability or anthropogenic external forcing. (IPCC, 2018). Climate variability refers to the change in climate that comes because of fluctuations in temperature and rainfall variability that adversely affect crop production, mainly attributed to natural factors and anthropogenic activities like wetland reclamation and deforestation. The variability tends to be random or periodic (Rohli & Vega, 2018). Smallholder farmers are farmers who grow crops, use mostly hand hoes and family labour, and produce crops for subsistence purposes; the surplus is sold to meet basic needs.

Smallholder farmers make up about 2.2 million farmers in Uganda; most of them own an average land size of two to three hectares. The majority (93%) of them depend entirely or partly on family labour and 53% use hand hoes to dig their land (Dalipagic & Elepu, 2014; UBOS, 2014). Smallholder farmers are resource constrained and lack adequate knowledge, which adds more burden and leads to low crop yield. They mainly own their plots of land individually, either by lease or certificate, or under customary law (Jamie et. al, 2016). Smallholder farmers rely solely on rainfed crop production. Therefore, they are at higher risk when there is variability in rainfall because of changes in temperature and rainfall variability.

Global temperatures are rising, and crop production is becoming vulnerable to these temperature variations, which has adverse effects on crop yield (Ottman, 2012: Rosenzweig et al., 2014). The average temperature in the world rose by 0.75^0C over the last century, and it is anticipated to escalate by 2^0C (Eleftheriadis et al., 2017). If global warming, which is mostly attributed to human activities like reclamation of land like draining wetlands and deforestation of vegetative cover is not controlled, global temperatures are likely to reach 1.5^0C between 2030 and 2052 (Masson-Delmotte, 2018). In relation to other parts the globe, particularly those in the global north, Africa is recognized as the most susceptible continent to challenges cause by climate change because of their limited capacity to adapt to the potential impacts of climate change and variability (Niang et al., 2014).

East Africa experiences unique and complex temperature conditions because of differences in topography. For example, in Kenya, places found at higher altitudes like the Kenya Highlands, could be as low as 15^0C while places at lower altitudes, like the coast of East Africa, could reach 29^0C. In Uganda, high altitude places around Mt Rwenzori and Mt Elgon have average temperatures of about 17.4^0C than low altitude places like Northern Uganda where the temperature could reach 34^0C during dry season. (Omondi et al., 2014).

Uganda experience tropical climate mostly as result of the Inter-Tropical Convergence Zone (ITCZ), various topography, geographical area, and water bodies like lakes (Wasswa & Rautenbach, 2018). The country's climate is naturally variable and more prone to disasters caused by high temperature and rainfall variability, like floods and drought occurrences, having an adverse impact on the socioeconomic situations of the population.

Average temperatures in Uganda are predicted to ascend by 1.5^0C in the next 20 years and by 4.3^0C in 2080 because of high population growth, which limits the size of land for settlements and agriculture through the draining of wetlands and deforestation.

Rainfall is the major determinant of agriculture globally, as it is the primary supply of water for growing crop (Heng et al., 2007). Rainfall influences the quantity of soil moisture that crops utilize for their growth (Ngetich et al., 2014). In SSA, climate uncertainties like droughts, torrential rain, and flooding are anticipated to change due to the irregular nature of rainfall (both temporally and spatially). (Case, 2006). For instance, in Kenya monthly rainfall varies greatly between the months of April and November, where droughts surpass 15 days in Machanga and Kindaruma (Kasaki et al., 2015).

In Uganda, rainfall is highly variable (Wasige, 2009), and distribution is unpredictable (Mubiru et al., 2012). The country receives a bimodal pattern of rainfall close to the Equator that transforms into a unimodal pattern as one retreats from the Equator (Asadullah et al., 2008). It has been projected that the annual rainfall in Uganda will increase by 10 to 20% by the year 2100. Northern Uganda receives unimodal rainfall, and the peak is always in August. Precipitation declines drastically in January and February. The annual rainfall ranges between 900 and 1,500 millimeters (Lakor, 2017). The Northern region experiences highly variable rainfall, which alters rainfall patterns and leads to catastrophic weather events like drought that lower crop productivity (Brown, 2007). Much as there are various factors that affect the production of common beans, like soil conditions, agronomic activities, pests and diseases among others, this study only considers variations in temperature and rainfall. The focus on temperature and rainfall variability is because an exploratory study indicates that common bean smallholder farmers seemed to perceive that the low common bean yield is due to changes in temperature and rainfall variability. Climate variability is a global phenomenon that is adversely influencing crop yield (Nadiezhda et al., 2016).

The common bean (Phaseolus vulgaris L.) is one of the most popular edible legume crops globally; about 30 million hectares are planted worldwide annually, including 7.6 million hectares in Africa (CGIAR, 2012; FAO, 2012). In Latin America and the Caribbean (LAC) and Africa it provides proteins for about five hundred million people (Cortés et al., 2013). According to Centro Internacional Agricultura Tropical (CIAT), about 40 million people in the tropics consume common beans, mostly by the poor, as their main daily diet. They have therefore termed "the meat of the poor" because they provide highly nutritious food containing protein, fibre, carbohydrates, vitamins, and micronutrients.

The common bean is among the essential crops that are grown and eaten throughout Uganda. Most of the poor smallholder farmer's households rely on it heavily for their livelihoods (Nkalubo, 2018). However, currently the growth of common beans is retarded by changes in climate. Higher temperatures cause soil moisture to evaporate rapidly, which provides favourable environment for the multiplication of some pests and diseases (Hisali et al., 2011).

The common bean (*Phaseolus vulgaris L.*) normally flourishes at temperatures ranging from 18^0C to 26^0C, with the average rainfall ranging between 560mm to 720mm (Nkalubo & Luyima, 2012). Records indicate that surface temperatures between 28^0C and 35^0C in a few seasons led to some heat stress on Uganda’s bean crop. Low yields of common beans will result from the adverse effects of variations in temperature and rainfall, which are experienced differently by common bean smallholder farmers (Caffrey et al., 2013)

Uganda is among the top producers of common beans in the world, with a yearly production of approximately 464,105 metric tonnes (FAO, 2012). It is the country's second-most-popular grown crop, after maize (Haggblade, 2010). It provides between 20 and 25 percent of protein to Ugandan communities, on average, about 11 to 16 kg of the common beans are consumed per person in a year (Broughton et al, 2003). Even though the amount of common beans consumed by an individual is decreasing in comparison to the previous three decades, when it exceeded 50 kg per person per year in some places (Wortmann et al., 1998a), the high population growth, estimated at 3.5 percent per year, is still increasing total demand (Waithaka, 2012).

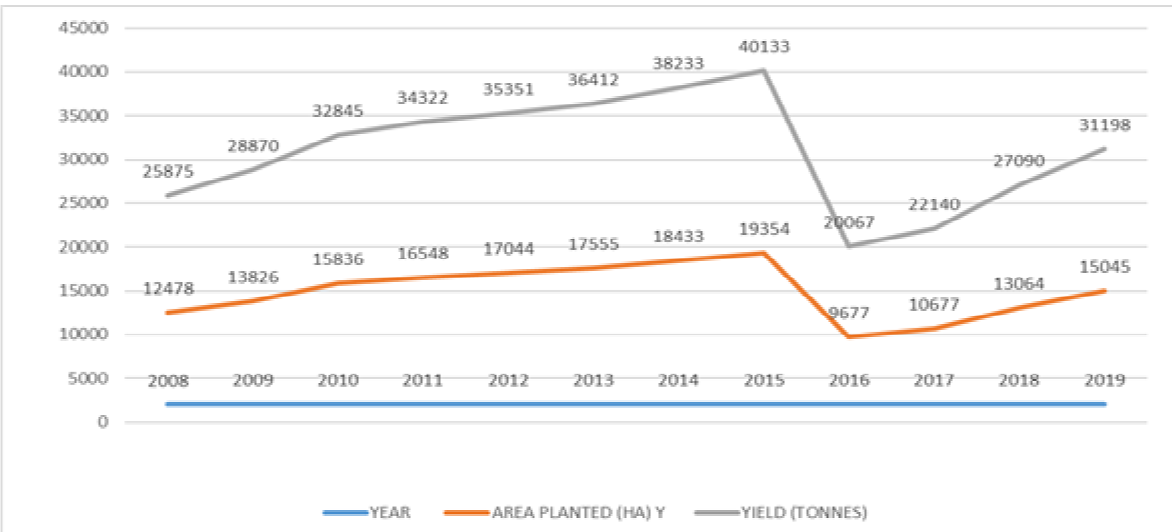

Figure 1.1. *Area of land planted with common bean and the yield of common bean (2008-2019)*

1.2 Statement of the Problem

The majority of the African countries' economies are based on agriculture. According to crop simulation studies, climate change and variability would have a significant impact on most Africa's major crops, resulting in low yields (Niang et al., 2014; Ramirez-Villegas & Thornton, 2015; Thornton et al., 2009). There has been a noticeable rise in temperature in Uganda, with an average of 0.28^{0}C per decade between 1960 and 2010. The remarkable increase was noted in the months of January and February, with the highest temperature rise of 35^{0}C (Republic of Uganda, 2007; 2010). Rainfall onset, cessation, and distribution have also become erratic during and between seasons (IGAD, 2010; Ngetich et. al., 2014). In Northern Uganda, climate change and variability caused changes in temperature and rainfall distribution during and between seasons. This causes unpredictable rainfall onset and cessation, which alter the physiological response of various common bean species, hence some farmers abandon planting some varieties, eventually leading to their extinction (Mustin et al., 2013). It also makes it difficult for smallholder common bean farmers to plan for key activities such as primary and secondary tillage and, timely planting, resulting in fluctuations in crop yield and food insecurity for their households. Anderson and Robinson (2009) According to information obtained from the exploratory study conducted on this problem, currently, agricultural extension workers are training smallholder common bean farmers to practice irrigation, tree planting, and protection of wetlands to cope with and adapt to the change.

Common bean smallholder farmers, especially in Northern Uganda, are resource-constrained; hence, their adaptive capacity to climate variability challenges depends on household, socioeconomic, and institutional characteristics (APTS, 2013). Common bean smallholder farmers have been observed to react and adapt to changes in temperature and rainfall variability based on their locally contextualized knowledge and perceptions of the phenomena (Deressa, 2011; Ferguson & Bargh, 2004). Therefore, this study seeks to gain insights into the magnitude of change in temperature and rainfall variability and the implications for smallholder farmers' common bean yield in Northern Uganda.

1.3 General Objective

The general objective of the study was to examine the relationship between climate variability and smallholder farmers' common bean (*Phaseolus vulgaris l.)* yield in Northern Uganda.

1.3.1 Specific Objectives

The specific objectives of the study were:

(i) To examine the perceptions of common bean smallholder farmers on climate variability in Northern Uganda

(ii) To assess the relationship between change in temperature and smallholder farmers' common bean yield in Northern Uganda

(iii) To assess the relationship between rainfall variability and smallholder farmers' common bean yield in Northern Uganda.

1.4 Research Questions

The study sought to answer the research question below:

(i) What are the perceptions of common bean smallholder farmers on climate variability?

1.5 Research Hypotheses

The study tested the following hypotheses:

(i) Ho: There is no significant relationship between change in temperature and smallholder farmers' common bean yield in Northern Uganda.

(ii) Ho: There is no significant relationship between rainfall variability and smallholder farmers' common bean yield in Northern Uganda.

1.6 Scope of the Study

The scope of this study covered the following aspects: The content scope includes climate variability, which is composed of changes in temperature and rainfall variability as independent variables and common bean yield as the dependent variable. The temperature, rainfall, and yield data for 12 years (2008–2019) were obtained from Gulu Synoptic Weather Station and Gulu District Production Office, respectively. The study was conducted in Northern Uganda.

1.7 Significance of the Study

The findings of the study will directly benefit smallholder farmers by informing them about agricultural production, adaptation practices, and technologies that can effectively cope with changes in temperature and rainfall variability to maximize agricultural productivity in the face of climate change and variability. To policy makers, this study will provide relevant data for making policy decisions in the areas of climate change and variability linked to changes in temperature and rainfall variability that may be used to mitigate the harmful impacts of these factors in Northern Uganda and other regions with comparable climatic conditions. The study findings on the relationship between climate variability and smallholder farmers' common bean yield in Northern Uganda could be used to inform training programs to sensitize and educate smallholder farmers on how to maximize agricultural production, given the change in temperature and rainfall variability, using locally based and contextualized adaptations such as production practices and technologies. The study findings will provide researchers and scholars with relevant data to form a body of literature to inform future research studies on changes in temperature and rainfall variability in Uganda and elsewhere.

1.8 Assumptions of the Study

According to the Cambridge Advanced Learners Dictionary, an assumption is "something that you accept as true without question or proof." Therefore, in this study the following assumptions have been drawn.

1. The respondents will be honest while filling in questionnaires.

2. Changes in temperature and rainfall variability are the major cause of low common bean yield in Northern Uganda.
3. Farmers planting common bean in Northern Uganda have limited access to climate change information regarding changes in temperature and rainfall.
4. Very little coping strategies and adaptation measures on changes in temperature and rainfall variability are known and used by smallholder farmers planting common bean in Northern Uganda.

1.9 Study Limitations and Delimitations

This study focused only on changes in temperature and rainfall variability. However, the growth and productivity of common beans could be influenced by a host of other factors, like soil nutrients, soil water content, soil temperature, weeds, and pests and diseases among others, which this study did not focus on.

Filling out the questionnaire was also affected by the level of literacy of the respondents, as the questionnaire was in English. This was overcome by reading and translating the questionnaire into Acholi, a language understood by the researcher, enumerators, and respondents.

1.10 Operational Definitions

Adaptation: It can be reactive or participatory (IPCC, 2007). According to this study, adaptation refers to steps taken by smallholder common bean farmers to respond to adverse effects of changes in temperature and climate variability.

Adaptive Capacity: This study operationalizes adaptive capacity as the ability of smallholder common bean farmers to respond to the adverse effects of changes in temperature and rainfall variability.

Climate Variability: Climate variability refers to variations in average state and other climate statistics. For example, standard deviations, the occurrence of extremes, and other features of the climate on all spatial and temporal scales surpass individual weather occurrences (IPCC, 2018). Climate variability is defined in this study as a change in the climate caused by temperature and rainfall variability, which has a significant harmful impact on crop production and is primarily attributed to natural factors and anthropogenic activities such as wetland reclamation and deforestation.

Change in Temperature: The study operationalizes changes in temperature as an increase or decrease in temperature perceived by smallholder farmers that may affect their common bean yield.

Mitigation: These are human interventions to reduce GHG emissions to levels that do not adversely cause climate change (IPCC, 2001). This study adopts the IPCC definition of mitigation.

Perceptions: Refer to how our brain extracts information received by our sensory organs from the environment (Forgus & Melamed, 1976). This study operationalizes perceptions as beliefs held by smallholder farmers about how changes in temperature and rainfall variability affect their common beans.

Rainfall Variability: The extent to which rainfall amounts fluctuate over time or across an area. These can have both spatial and temporal dimensions. Areal variability refers to the variation in rainfall amounts at different locations within a region over a specific time, whereas temporal variability refers to the variation in rainfall levels at a specific location over a specific time period (Morale, 1977). This study adopts the definition of Morale.

Resilience to Climate Change: Resilience to climate change refers to smallholder common bean farmers' capacity to maintain their crop production in the face of challenges brought on by negative impacts of climate change.

Smallholder Farmers: Refers to farmers who own small plots of land, usually 1 to 2 hectares each or slightly more, on which they grow subsistence crops and one or two cash crops, relying almost exclusively on family labour and simple tools (Elisa, 2013). This study adopts the definition of Elisa.

Common Beans *(Phaseolus vulgaris)*: These are staple crops grown in East and Central Africa, serving as a food and cash crop (Ssekandi et al., 2015). This study operationalizes common beans as major grain legume crops grown mainly by women in Gulu District for their edible seeds and pods for either home consumption or sale.

Coping strategy: Coping strategies are operationalized in this study as short-term measures taken by smallholder common bean farmers in retaliation to the negative impacts of climate change.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter reviewed climate variability theory and literature relevant to the relationship between climate variability and smallholders' common bean yield in Northern Uganda.

2.1 Climate Variability Theory

This study on climate variability is informed by the theory of anthropogenic global warming (Blast, 2013)

The ***Anthropogenic Global Warming Theory*** postulates that global temperatures are significantly rising because of anthropogenic activities that release GHGs like carbon dioxide, methane, and nitrous oxide to the atmosphere. This theory states that before reaching Earth, solar heat energy passes through the atmosphere before reaching the Earth. Because a large portion of the Earth's atmosphere is transparent, sunlight can enter and travel to the planet's surface, where some of it is soaked up and some are bounced back into space as warmth. The earth's temperature rises because of the GHGs in the atmosphere, such as carbon dioxide, methane, and water vapor, which trap and absorb the reflected heat.

It theorizes that throughout the 20th century, when people carry out activities like deforestation, and burning of wood it increases the concentration of harmful gases like carbon dioxide in the atmosphere by about 50%. Other factors, such as variations in solar energy could elevate the temperature leading to warming of the earth, but these, according to proponents of the theory of anthropogenic global warming, do not provide sufficient justification for the increase in the temperature in the past 30 years. Although, the impact of anthropogenic GHGs is small, they believe that a slight rise in temperature causes more evaporation, which makes soil moisture to evaporate to the space, hence a more rapid rise in temperature.

According to proponents of the Anthropogenic Global Warming theory, the world's climate change and rainfall variation, which result in floods, droughts, low crop yields, species extinction, the development of crop diseases, and famines, are caused by carbon dioxide emitted due to human activities.

This part of the theory is congruent with the research since it contends that human actions, such as the burning of wood and fossil fuels and deforestation, are causing global warming and causing variations in rainfall amount and distribution. Both the IPCC (2007a) and UNFCCC (2007) emphasized that human actions on the environment are responsible for the current rise in temperature and rainfall variability.

2.2 Common Beans Production in Northern Uganda

Agriculture employs over 80% of the people in Northern Uganda and provides the major portion of the food consumed in the region. In addition, it is a sector is severely impacted by climate change and variability. In the region, smallholder farmers who own between a quarter of a hectare and two hectares, use family labour and use rudimentary tools commonly plant common beans. Common is referred to as a woman's crop because it constitutes a major source of food and nutrition security in households in which women with the help of children tend to own small plots, and engage in activities like weeding, harvesting, threshing, and winnowing. However, both men and women are involved in marketing common beans (Mwongera, 2014). Most of the smallholder farmers are in very remote places in the value chain. This makes them sell most of their harvest within their localities or to intermediaries. They lack storage facilities, and most of the harvested common beans are taken to market immediately, which reduces their bargaining power with intermediaries and buyers. They must decide whether to add value or when to market their crops (Dalipagic & Elepu, 2014).

2.3 Climate Variability and Agriculture

In SSA, most people employed in agriculture are smallholder farmers. Tzilivakis et al. (2014) predict that by 2050, there will be 1.5 billion people living in SSA, necessitating tripling of food production to assure food security. If the detrimental effects of climate change and fluctuation are not reduced and adapted to, this may not be possible.

The relationship between climate variability and agriculture is a two-way traffic because climate variability affects the agricultural sector through high temperatures and the low and unpredictable nature of rainfall, while agricultural sector through bad farming practices like bush burning release GHG that destroys the ozone layer (Marasent et al., 2009). In the past thirty years, increase in temperature and rainfall variability have reduced crop yield by 1-5% per decade, and they will continue to cause significant problems for the agriculture sector in the decades to come (Challinor et al., 2014), making smallholder farmers more susceptible to food insecurity.

The majority of Sub-Saharan African (SSA) countries are vulnerable to climate change and variability mainly due to widespread droughts, an overdependence on rainfed agriculture, and a lack of adaptive capacity (IPCC, 1998). Because of these changes, some areas that once supported agriculture are now unproductive, and the onset, duration, and cessation of rain are all unpredictable. (2008) (Lobell et al.).

Uganda is primarily an agricultural country, with the large percentage of its smallholder farmers relying on rainfed agriculture, which is extremely vulnerable to climate change and variability. According to Mc Sweeney et al. (2010), the country's temperature increased by 1.3^0C between 1960 and 2003, the months of January and February experiencing the greatest increase, and by up to 1.5^0C overall between 1900 and 2009, at a rate of roughly 0.2°C per decade (Funk et al., 2012).

Agriculture has been impacted by these climate change and variability-related phenomena. Climate-related effects, damage approximately 800,000 hectares of crops annually with estimated losses surpassing US$47 million (NEMA, 2008); common bean output is also impacted.

2.4 Change in Temperature

Climate change and variability have caused both increases in global-averaged mean annual air temperatures and GHG emissions. The average minimum temperature of the world rose by 1.86^0C over the past century, whereas that of maximum temperature rose by 0.88^0C. (Easterling et al., 1997). As a result, it can be inferred that the minimum temperature rose more than the maximum temperature.

Projection by General Circulation Model and Regional Models (GCMs) shows that temperature in East and Horn of Africa is likely to vary significantly (Bountempo et al., 2014). IPC (2014) has projected a 0.2^0C to more than 0.5^0C temperature increase over East Africa. This increase is likely to elevate the rate of water evaporation, which affects soil moisture availability for most crops.

The Uganda National Adaptation Programme of Action (NAPA) found out between 1960 and 2010, the country's mean temperature rose by 0.28^0C every decade, the major increase noted in the months of January and February, with an increase of 0.37^0C every 10 years (GOU, 2015).

2.5 Variation in Rainfall Amount and Distribution

Climate change and variability are among the most detrimental elements affecting agriculture in the 21^{st} century because they alter the global hydrological cycle, which depends on precipitation.

East Africa's rainfall (Uganda, Kenya, and Tanzania) is marked by considerable inter-annual and decadal variability, resulting in major spatial and temporal variations, related mostly to composite terrain, the presence of large water bodies, for instance Lake Victoria and the Indian Ocean in the east, and the seasonal movement of the ITCZ (Ogallo, 1989). These cause different climates within the region ranging from tropical to arid dry land (Ntale, 2001).

In Uganda, rainfall distribution is primarily determined by the ITCZ, monsoon winds, and humid wind from Congo, as well as ocean surface temperature and topography, particularly the ENSO (Basalirwa, 1995). The ENSO caused more rain in the south of Uganda, resulting in a bimodal rainfall pattern, whereas La Nia caused less rain (Phillips & McIntyre, 2000). According to Yang et al. (2015), relief features such as topography, various vegetation, and water bodies, which determine the native climate, are responsible for significant variation in rainfall distribution across Uganda.

2.6 Perceptions of Smallholder Farmers on Change in Temperature and Rainfall Variability

Smallholder farmers account for 75% of all farmers worldwide (Lowder et al., 2016). They supply over 80% of the food eaten in undeveloped countries (UNEP, 2013). They play an important role in combating global food insecurity, but their agriculture is threatened by temperature and rainfall variability. How smallholder farmers perceive the change in temperature and rainfall variability greatly differs across different agro-ecologies, their ways of farming, gender, and educational level (Ndamani & Watanabe, 2015). For instance, a study conducted in Southern Ethiopia's Geze Gofa District revealed that more than 90% of farmers had observed that the rainfall amount, pattern, and timing had changed and that about 88.73% of farmers perceived that the area's temperature had increased, which resulted in a severe drought (Seguye, 2017).

The perceptions of smallholder farmers determine their ability to adapt to changes in climate and variability. (Bomuhangi et al., 2016). This is because they must first perceive that the climate has changed before they can implement adaptation measures like growing new varieties of crops and using non-farming methods. (Okonya et al., 2013). According to Simane et al. (2016), understanding local perceptions provides a clear road map to adaptation to climate change and variability. However, smallholder farmers' perceptions of changes in temperature and rainfall variability are influenced by socioeconomic and cultural differences, which expose people to diverse attitudes, values, and interests (Weber, 2010). Therefore, how smallholder farmers perceive changes in temperature and rainfall variability and their impacts is influenced by their psychological, educational, and socio-economic differences, which limit their reaction to climate change and variability (Evans et al., 2016).

2.7 The Relationship between Change in Temperature and Common Bean Yield

Common beans (*Phasiola vulgaris l.*) are affected by many abiotic factors. High temperatures are the most serious abiotic stresses, which negatively affect crop production and hamper food security globally (Lesk et al., 2016). It is estimated that every 1^0C rise in seasonal temperature reduces common bean yield by 10–17 percent (Lobell et al., 2011).

Common bean yields typically increase with an increase in temperature until a threshold is reached. Once that threshold is exceeded, it negatively affects biological processes like respiration in plants, seed formation, biomass production, and maturation that consequently reduce common bean yield (Adejuwon, 2004; Lobell et al., 2011). It also makes common beans so prone to diseases, which are common in places with high temperatures. Diseases such as bacterial blight can cause a loss of common bean yield of 10–40 percent, depending on the susceptibility of the variety (Zhang et al., 2009).

Agriculture is a valuable sector for the economic growth of East Africa; for example, it contributes more than 50% of GDP in Burundi, the Democratic Republic of the Congo, Ethiopia, Sudan, and Tanzania but less than 30% in Eritrea, Kenya, and Madagascar (Waithaka et al., 2013). Currently, the East African countries are battling the challenges imposed by high temperatures. This increase in temperature and drought may dwindle the area of land under common bean production or limit water for cultivation (Dharmaji & Huy, 2008). This rise in temperature has detrimental effects on common bean physiological processes such as photosynthesis. (Busch & Sage, 2017).

The common bean is an essential legume crop cultivated in most regions of Uganda. The crop faces many challenges, mainly from high temperatures and rainfall variability. Common beans are impacted by climate change and variability based on the phenological stage and the length of the stress, which affect the yield and quality. (Nadiezhda et al., 2016). This stress is more serious than other abiotic stresses, causing more detrimental to the livelihoods of common bean smallholder farmers in unfavorable environments (Asfaw & Blair, 2014; Beebe et al., 2013).

2.8 The Relationship between Rainfall Variability and Common Bean Yield

Common beans (*Phaseolus vulgaris l.*) are among the most grown legume crops planted and consumed by people in most countries in the world, especially in SSA where it is the staple food crop; about 60 kg of the crop is consumed per person per day (Beebe et al., 2013). The crop provides over 50% of the nutrients like protein, carbohydrates, vitamins, and micronutrients to the poor communities found in third-world countries. However, the greatest portion of production is mainly carried out in rainfed areas where drought is a major problem (CIAT, 2008). It is not only the amount of rainfall that determines the high yield of common beans but also its spatial and temporal distribution, which influences planting dates and the amount of soil water available for the crop. In cases of extreme seasonal rainfall, it causes droughts, and in situations of enhanced rainfall, it causes floods and landslides, isolated thunderstorms, and hailstorms (Okello, 2019).

The rainfall over East Africa shows bimodal characteristics, but this gradually decreases as one leaves the Equator (Conway et al., 2005), which is feature with significant variability between years or after a decade. The inter-annual variability has been the major cause of persistent drought and floods in most countries in East Africa (Bowden & Semazzi, 2007). Seasonal rainfall variability causes a shortage of soil water for common bean production, which reduces the yield and threatens food security (Mumo et al., 2018).

In Uganda, there are regional variations in the amount of rainfall, which has an impact on the crops and cropping systems. Common beans and other annual crops like soybean may be grown only once a year in the northern region because the rainfall is almost unimodal. Crops like common beans can be grown two or more times a year depending on the variety in the southern region where rainfall distribution is bimodal. In Eastern part of Uganda, drought is common, which affects the planting of common beans. (Botai et al., 2014). According to Biyika (2017), the variability in rainfall has caused a shift in areas suitable for crops like common beans, difficulty in forecasting the onset, length of the planting season, and a high prevalence of fungal plant diseases.

In Northern Uganda, common bean production is increasingly becoming a challenge due to the unpredictable rainfall since it provides the primary source of soil moisture crops absorb for other physiological processes like germination and growth to occur, which leads to intermittent and at times terminal drought. This reduces soil moisture, which causes a low common bean yield (Nkalubo, 2018).

2.9 Vulnerability to Climate Variability

Globally, detrimental effects of climate change and variability are noticeable. Although it varies among regions, economic sectors, and social groups, the temperature is rising and rainfall volumes and distributions are changing, making agriculture as a system increasingly susceptible to the effects of climate change and variability (Hinkel, 2011). Research conducted by Epule and George (2019), found that in southwestern Uganda crops that are highly vulnerable are equally sensitive and exposed to climatic factors like changes in temperature and rainfall variability with low capacity to cope and adapt to, while crops that are less vulnerable are less susceptible and exposed to these changes with higher adaptive capacity. The analysis indicates that common beans are the second most vulnerable crop to climate change and variability in the region. According to IPCC (2001), crops will be more susceptible to and unlikely to withstand the undesirable effects of high temperatures and rainfall variability depending on their susceptibility to those variables.

Agriculture as a system may become exposed to climate change and variability when the temperature increases abnormally. This may result in agricultural drought, or when there is variation in rainfall amount and distribution, it can cause flooding and the occurrence of fungal disease. It will also become sensitive to climatic change and variability when smallholder farmers solely depend on rainfall for planting crops. This is due to their inability to access insurance, technology, and information, hence the low yield of crops. For the smallholder common bean farmers to be less susceptible, they must adapt to exposures and sensitivities, for instance, by planting drought tolerant crop varieties, using irrigation, changing planting dates, and deep ploughing (Smit & Wandel, 2006).

2.10 Adaptation to Climate Change and Variability

Climate change and variability are threatening agricultural production. These threats are in the form of high temperatures and rainfall variability. Therefore, adequate information regarding changes in temperature and rainfall variability will help smallholder farmers to adjust their farming practices to maintain high crop yield when face with adverse effects of climate change and variability (Challinor et al., 2014). This information is crucial in developing countries where agriculture is mainly rainfed (Adger et al., 2006).

Adaptation to climate change and variability involves ways to moderate, cope with, and utilize the results of climatic events (UNDP, 2005). For any society to fully adapt to changes in temperature and rainfall variability, all actors must fight for a common goal. For instance, smallholder farmers can implement adaptation on their own (autonomous adaptation), government interventions can promote appropriate and successful adaptation measures (planned adaptation), or people, households, and business organizations can adapt to (private adaptation) (IPCC, 2007). Smallholder farmers too need to anticipate the occurrence of climate change and variability (anticipatory adaptation) or when the effects of climate change have already been experienced (reactive adaptation) (IPCC TAR, 2001)

Studies by Smit and Skinner (2002) indicate that when smallholder farmers fail to adapt to changes in temperature and rainfall variability, their crops will face serious negative impacts of climate change and variability like drought, flood, and an increased occurrence of pests and diseases that cause low yield. When they adapt, they become less vulnerable. In Uganda, for instance, studies show that a greater percentage (97 percent) of agricultural production is rainfed and only three percent is under irrigation (Republic of Uganda, 2006), meaning that the agriculture sector is more vulnerable to the impact of changes in temperature and rainfall variability and that adaptation is key. A study by carried out by Atube et al. (2021), found that the most common adaptation measures in Northern Uganda are fallowing, planting different crop varieties, and planting drought-resistant varieties.

Smallholder common bean farmers' decisions to adapt to climate variables like temperature and rainfall variability differ from place to place and are always determined by socioeconomic, environmental, technical, and organizational factors such as possession of assets, availability of finance, and extension knowledge and advice (Hisali et al., 2011). These factors are vital because other adaptation measures demand that the smallholder farmers possess some physical assets. Asrat and Simane (2017a) emphasized that there are two stages to adaptation that can be practiced by smallholder farmers: realizing that the environment has changed and deciding whether to adapt or not. However, perceptions cannot be relied on because they are not a requisite as they can be influenced by social and economic factors (Maharjan et al., 2011).

2.11 Climate Change and Variability Mitigation

Mitigation is defined as the initiatives taken to minimize or eliminate carbon footprints, which cause global climate change (IPCC 2001). It also refers to any actions taken to reduce anthropogenic emissions or boost GHG sinks.

Africa, as a continent, is estimated to contribute 3.6 percent of GHGs, yet it is highlighted as being hard hit by the negative impacts of climate change and variability because of increases in temperature and rainfall variability (IPPC, 2007). Approximately 17.4% of the global GHGs released into the atmosphere and nearly 28% of its carbon dioxide emissions are caused by human activities like deforestation and draining of wetlands. Deforestation now ranks as the third largest contributor to GHG emissions, after emissions from the energy and industrial sectors. Therefore, mitigation is the only strategy that can save the continent from these negative repercussions of climatic change.

According to Smith et al. (2008), Weldegebriel and Gustavsson (2017), for the smallholder farmers to mitigate GHG effluence in agriculture, different strategies must be employed. For instance, use of renewable energies like solar and wind power, crop-land management, grazing land management, organic soil management, livestock management, and providing possibilities that help reduce carbon emissions by encouraging congested cities to develop sustainable transport like solar-driven vehicles and the use of non-fuel consuming transport like bicycles. Although there are other natural sources of GHGs, such as volcanic eruptions, the majority are emitted by anthropogenic causes.

2.12 Climate Change and Variability Resilience

Resilience refers to the ability to of the smallholder farmers to continue producing crops when hit by environmental stress brought on by climate variables like high temperature and rainfall variability (Folk, 2006). It also refers to the capacity to fully recover after encountering an external shock or stress, such as intense heat or a wide range of precipitation.

Agriculture as a sector is extremely receptive to the negative consequences of climate change and variability. These changes pose both direct and indirect effects; the direct effects include high temperatures and rainfall variability, while the indirect effects include providing favourable environment for the multiplication of pests and disease pathogens. Therefore, agriculturalists in developing countries must significantly change how they practice their agriculture and respond to changes in climate variables like high temperature and rainfall variability so that they attain food security (Muller et al., 2011).

Smallholder farmers are onerous to the impacts of climate change and variability (IFAD, 2012a). IPCC (2014) Part A projects that because of the lower adoption and usage of irrigation for crop production, SSA may be hit hard by the deleterious impacts of changes in temperature and rainfall variability because of over dependence on rainfed agriculture for food, income, and prosperity. According to IPCC (2014) Part B, most smallholder farmers in Sub-Saharan Africa lack access to resources such as credit and cutting-edge agricultural technologies, thereby making it more challenging for them to cope with and adapt to the effects of current and future climate change and variability.

According to Lengnick (2015), a resilient farmer, when confronted with a change in temperature or rainfall variability, has a greater capacity to reduce physical and financial damage, recover from damage more quickly, and change agricultural practices more easily to meet subsequent posibilities created by climate change and variability. For instance, in Gambia, farmers practice intercropping, mixed cropping, and cover cropping alongside soil fertility enhancement using animal, and plant manure (locally made), and mulching to help build resilience. However, accurate climate information should be available to enhance resilience among farmers to adjust their farming practices to confront challenges caused by climate change and variability (Ahmed et al., 2011).

2.13 Theoretical Framework

This study is informed by the top-down theory of perception developed by Gregory (1970). The study adopted the constructive theory of perception as one of the top-down theories of perception.

There are many top-down indirect theories of perception (Gregory, 1970), however, this research study is informed by the constructive theory of perception developed by Gregory (1970).

Perception refers to how an individual organizes, identifies and interprets sensory information in order to understand present information or conceptualize his or her surrounding (Schacter, 2011).

Gregory (1970), on the other hand, stated that perception refers to how our brain uses information received by one or more sensory systems. In this study, the definition by Gregory will be used because it captures all the elements that define what perception is in relation to changes in temperature and rainfall variability. In 1970, Richard Gregory, a psychologist, developed the idea of "top-down processing." Richard Gregory's constructive theory of perception believes that knowledge and experience are the most important factors in making sense of the world.

Richard Gregory's constructive theory of perceptions postulates that for a person to perceive an event, there must be information received from our senses like eyes, ears, and nose, as well as prior knowledge and experience about that event. He contends that because environmental stimuli are inherently confusing to understand, those who rely solely on sensory data may interpret an event incorrectly. Therefore, to draw conclusions about what we perceive, we either need a lot of cognitive information from experiences or stored information. He argues that about 90 percent of what we see is lost before being received by the brain, which makes it hard to draw conclusive conclusions based on our senses alone.

Ou (2017) noted that there are three processes of perceptions: *selection.* Here, a lot of information is received from the environment, and not all of it is necessary. Therefore, it must be filtered. The second stage is organization and *categorization.* This allows us to structure our perceptions so that they can be stored in our memory. The third process is *interpretation.* Here we attach meanings to the selected and categorized information. However, different people interpret the same stimuli differently, leading to different perceptions.

One of the evidences supporting constructive perception is the perpetual constancy, which shows that a high level of constructive processes take place during perception. Gary and Alfred (2012) argue that an unripe green banana outdoor should have the same colour as when it is under the fluorescent lights of a grocery store. Another example is when one reads a word where some letters are tainted with mud or water, like "ST*P." The person will still read it as "STOP" based on past knowledge and experience using top-down processing.

Richard Gregory's constructive theory of perceptions is suitable for this study because he postulates that, for a person to perceive an event, there must be information received from our senses like eyes, ears, and nose, as well as prior knowledge and experience about that event. This is in line with the definition of climate change, which specifies that it is a change in the global atmosphere's composition brought on by human activities in addition to the natural climate variability recorded for three decades (UNFCCC, 2007). In addition, for one to understand that there is climate change and variability, he or she must look at temperature and rainfall data for the past 30 years.

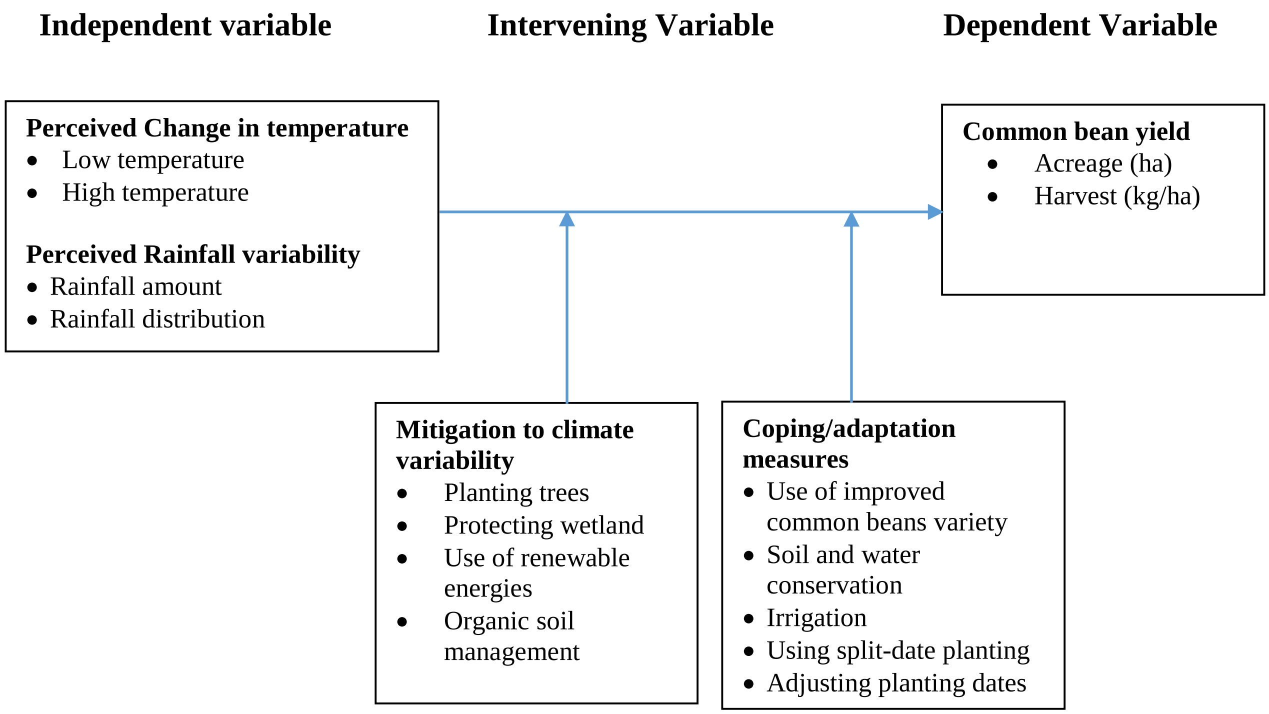

Figure 2.1 *Conceptual Framework of the Relationship between Temperature, Rainfall and Common Bean Yield.*

2.13 Summary of Literature Review

Climate change is a global concern. A projection shows that Africa may be hit hard by the deleterious impacts of changes in temperature and rainfall variability because of over dependence on rainfed agriculture for food, income, and prosperity (IPPC, 2007). These changes have caused either early or delayed rain, increased disease incidences, which are threatening common bean yields (Okonya, 2014). Smallholder farmers are adapting to these changes, but their capability is inadequate because they lack or have inadequate resources like finance and modern agricultural technologies. For instance, most smallholder farmers planting common beans cannot afford irrigation systems to combat drought. There is slow dissemination of information relating to changes in temperature and rainfall variability to smallholder farmers in rural areas which create gap between institutional actors like the government, NGOs, and smallholder farmers who are adversely affected by the change (IPCC, 2007). This makes it hard for smallholder farmers to adapt to those changes. Therefore, based on the literature reviewed, the smallholder farmers are adopting various techniques like planting drought-tolerant and quick-maturing common bean varieties and using soil conservation techniques like mulching to fight the negative effects of these changes on agriculture, but their capacities are limited. To mitigate climate change, both institutional actors and smallholder farmers must work together. No single adaptation measure can be worked on alone. Therefore, one must reinforce the other to guard our crops against the negative impacts of changes in climate, like changes in temperature or rainfall variability.

CHAPTER THREE: METHODOLOGY

3.0 Introduction

This chapter describes how the research was conducted. Specifically, the designs that were used, area of study, population of study, sample size and sampling, instrumentation, data collection, quality control, ethical considerations, and data analysis.

3.1 Research Design

The researcher employed a cross-sectional survey research design. The design allowed the researcher and the four-trained enumerators to collect data from different sub-counties at the same time. In addition, the study employed a mixed methods approach, which involved both quantitative and qualitative methods to collect data. The qualitative data obtained from four focus group discussions and two key informants was used to supplement the narrative on the quantitative findings generated from questionnaires administered to one hundred and sixty sampled respondents, which improved the rigour of the study findings. Thus, the combinational use of quantitative and qualitative research approaches assisted the researcher in gaining insights and understanding of the phenomena through intensive examination and the collection of narrative data (Mills, 2003).

3.2 Area of Study

Northern Uganda receives unimodal rainfall, which runs from mid-March to October and is mainly caused by moist wind from the Democratic Republic of Congo. The study was conducted in Northern Uganda because an exploratory study of the relationship between climate variability and common bean yield indicated that common bean smallholder farmers had complained of low common bean yield for over four years consecutively. The deteriorating common bean yield has caused some smallholder farmers either to abandon common bean production or to allocate their land to produce other crops. Much as the common bean production has been reducing in the last four years, the investigator decided to use data for the last 12 years (2008–2019) to obtain a much better determinant of the relationship between climate variability and common bean yield in Northern Uganda.

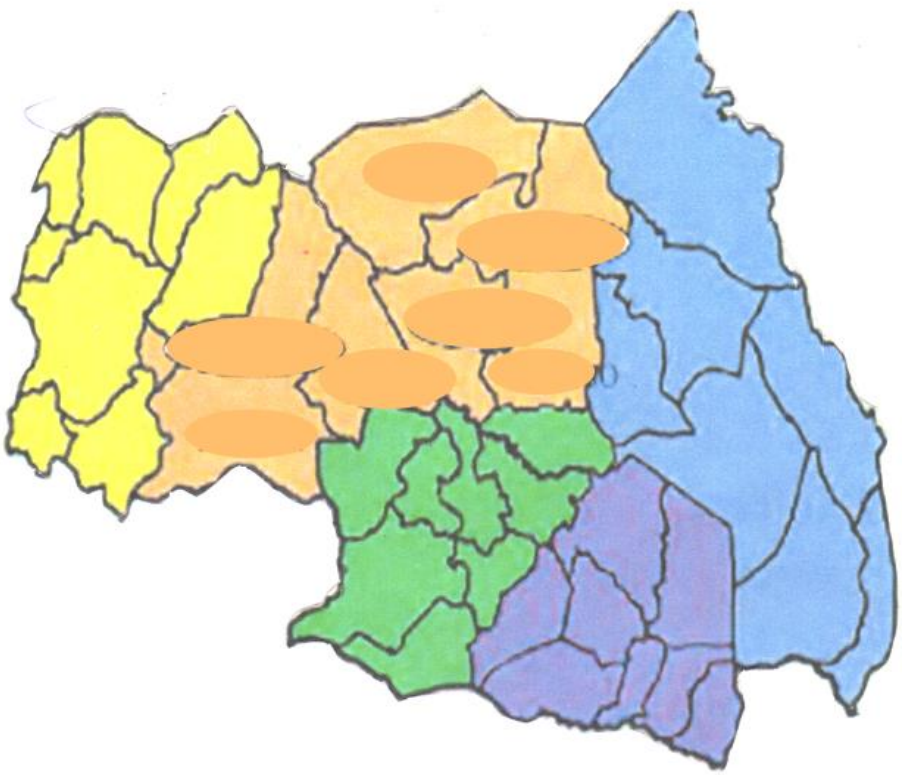

Figure 3.2 *Map of Northern Uganda*

3.3 Study Population

As of the 2014 population census, the population of Northern Uganda was 7,188,139, occupying a land area of 85,391.7 km^2. A report from the African Development Bank indicates that Northern Uganda accounts for 23% of Uganda's smallholder farmers. However, it is a region with the highest poverty rates. Agriculture employs approximately 85% of the people in Northern Uganda, most of whom are smallholder farmers (Gulu District Production Office, 2016). The accessible sample frame was smallholder farmers who plant common beans in Northern Uganda. Therefore, the study population was smallholder farmers actively engaged in the production of common beans in Northern Uganda.

3.4 Sample Size Determination

After purposive sampling of Gulu District in Northern Uganda, a list of 160 smallholder farmers actively engaged in planting common beans in the sub-counties of Awach, Palaro, Bungatira, and Paicho was obtained from Gulu District Production Office. A sample size was selected using the level of precision (0.05). The sample size of 160 respondents was calculated using the formulae by Yemane (1967).

$$sample\ size\ (n) = \frac{\mathrm{N}}{1 + \mathrm{N(e)2}}$$

Where **N**=population size of the respondents, **n** = the sample size of the respondents and **e** = the level of precision (0.05):

$$\frac{267}{1{+}267\ (0.05)}\ ^{2}$$

$$\frac{267}{1.6675}$$

$$n = 160$$

3.5 Sample Size and Sampling

The sample size of one hundred and sixty common bean smallholder farmers was determined from a sample frame of 267 smallholder farmers actively engaged in planting common beans, obtained from Gulu District Production Office using a sampling table of 95% confidence, with a 5% margin of error. The study used a mixture of multi-stage stratified, criterion-based purposive sampling, and simple random sampling techniques. Northern Uganda was stratified into fifteen districts, and Gulu District was purposely selected to participate in this study because it is the only district with available and accessible data on change in temperature, rainfall variability, and common bean yield, which are key constructs and variables in this study.

Gulu District was stratified into 16 sub-counties, and 4, namely Bungatira, Awach, Paicho, and Palaro, were randomly selected to give each sub-county an equal chance to participate in the study and reduce bias in the selection process. 1 extension educator and 1 member of the meteorological personnel were purposely selected because they are considered knowledgeable about the climate and common bean production in Northern Uganda. A list of 267 common bean smallholder farmers, which acted as a sampling frame, was obtained from the production officer at Gulu District. The 160 smallholder farmers actively engaged in planting common beans, 40 in each subcounty, were selected using simple random sampling to give each respondent an equal chance to participate in the study and avoid bias in the respondents' selection process.

3. 6 Data Sources

The study utilized both quantitative and qualitative data collected from common bean smallholder farmers. Quantitative primary data was obtained from 160 common bean smallholder farmers actively planting common beans in Northern Uganda. Quantitative secondary data that constituted retrospective data on temperature and rainfall from Gulu Synoptic Weather Station for 12 years (from 2008 to 2019). Data on common bean yield for 12 years was obtained from Gulu District production office and used for the study. In addition, qualitative data was collected from 1 agricultural extension educator, 1 meteorological personnel from Gulu Synoptic weather station, as key informants, and 32 focus group discussants from the 4 randomly selected sub-counties in Gulu District in Northern Uganda. The use of both quantitative and qualitative data is important in research because the two data types help reinforce the narrative and improve the vigour of the research findings.

3.7 Data Collection Procedure

Quantitative primary data were collected using a questionnaire from 160 smallholder farmers that have been actively planting common bean. Qualitative primary data were gathered from 32 focus group discussants using a focus group discussion guide. An in-depth interview was used to collect qualitative primary data from 1 extension educator and 1 meteorological personnel. Secondary data, which consisted mainly of temperature and rainfall data from 2008 to 2019 (12 years), was mined from datasets obtained from Gulu Synoptic Weather Station. Common bean yield data from 2008 to 2019 (12 years) was obtained from Gulu District production office.

The local government personnel at the selected sub-counties served as the point of entry to the smallholder common bean farmers due to their familiarity and experience closely working with common bean smallholder farmers. The local government system and offices extend all the way down to the village level, in keeping with Uganda's decentralized governance system, which draws services nearer to the people to improve their involvement in solving development issues that affect them.

Four research enumerators were trained for two days by the principal investigator to collect quantitative and qualitative data, with strict observance of respect for human subjects and Standard Operation Procedures (SOPs) set by the Ministry of Health Uganda, to prevent the spread of

COVID-19. All research enumerators wore masks, regularly sanitized their hands, and kept social distance while administering the questionnaires.

The investigator used local government personnel at the sub-county level, like agricultural extension officers, as points of entry to smallholder farmers at the village level. After obtaining the informed consent of the respondents, the investigator scheduled and conducted interviews with the common bean smallholder farmers in the agreed venues, especially at their homes or farms. All the questionnaires were administered, and the information collected from the respondents in one sitting.

3.8 Instrumentation

The study employed three sets of tools for collecting data: a questionnaire, an interview guide, and a focus group discussion guide.

3.8.1 Questionnaires

The questionnaire developed for collecting survey data was sectioned into three parts: demographic characteristics of respondents, common bean smallholder farmers' perceptions of changes in temperature, and rainfall variability that addressed rainfall amount and distribution. The questions on indicators of change in temperature, rainfall variability, causes of high temperatures and high rainfall amounts, and coping strategies used, were rated on a three-point Likert scale of 3=Agree, 2= Disagree, 1=Not sure.

3.8.2 In depth Interviews

An interview guide was developed for collecting qualitative data from two key informants: an agricultural extension educator because they have experience working with farmers, and one meteorological personnel because they have experience working in the weather station and have a deeper understanding of climate change and variability, as key informants at their work offices. Data collected using in-depth interviews focused on climate change variables that included temperature and rainfall data, as well as common bean yield. The instrument was chosen because it allowed the investigator to modify the questions so that useful information was gathered from the respondents.

3.8.3 Focus Group Discussion

A focus group discussion (FGD) checklist was developed for collecting qualitative data from common bean smallholder farmers. One FGD was conducted in each of the four selected sub-counties. Eight participants, composed of both men and women (four males and four females), attended each FGDs. Altogether, thirty-two discussants participated in the focus group discussions. The centrally located venues for FGDs were selected by the common bean smallholder farmers based on their experiences of participation in community meetings. The FGDs were chaired by the researcher, and he recorded the discussion which later he transcribed into English. The FGD collected data on indicators of change in temperature and rainfall, causes of high temperature and high rainfall amounts, and coping strategies for high temperature and high rainfall amounts.

3.9 Data Quality Control

3.9.1 Validity

According to Odiya (2009), validity refers to the capacity of an instrument to gather legitimate and factual data. Seale (2004:74) highlighted seven risks to internal validity, namely history, regression, selection, experimental mortality, maturation, instability, and testing of the instruments. The questionnaire was field tested by a panel of experts that comprised the dissertation research supervisors and three climate change experts with expertise in agricultural extension education and climate change to assess the relevance of the questions to the objectives and research questions by using the Scale Content Validity Index (S-CVI). In this S-CVI, the scales were rated in order of their relevance to the underlying constructs. A two-point rating scale of "relevant" or "not relevant" was used.

$$\text{Content Validity Index (CVI)} = \frac{\text{Number of items rated relevant}}{\text{Total Number of items in the questionnaire}}$$

$$\text{CVI} = \frac{32}{36}$$

0.89

3.9.2 Reliability

Reliability refers to the degree to which a measurement of an event yields a steady and consistent result (Carmines & Zeller, 1979). In addition, it describes the degree to which a research instrument would produce the same findings or information after numerous trials. The reliability of the research tools was field tested by the two research supervisors. The reliability of the questionnaires was improved through pilot testing with twenty smallholder farmers who are actively planting common beans but were not part of the sampled one hundred and sixty respondents to avoid biased responses. The data were entered in SPSS, and analyzed using Cronbach's alpha, only questions with a Cronbach's alpha of 0.7 and above were included in the analysis. The outcome of the reliability test facilitated the rephrasing of some questions to ease understanding by smallholder farmers.

Table 3.1 Reliability analysis for the items on changes in temperature, rainfall amount and distribution

Construct	Anchor Points	Cronbach's Alpha	No. of Items
(i) Changes in temperature		**.923**	**16**
Indicators of Changes in Temperature	Three Point	.933	06
Effects of changes in Temperature on Common Bean Yield	Three Point	.912	04
Coping strategies to change in temperature	Two Point	.924	06
(ii) Changes in rainfall amount and distribution		**.892**	**25**
Indicators of changes in Rainfall Amount and distribution	Three Point	.921	10
Causes of changes in rainfall amount and distribution	Three Point	.862	06
Effects of changes in rainfall amount and distribution on common bean yield	Three Point	.901	04
Coping strategies against changes in rainfall amount and distribution	Two Point	8.85	05
Overall Value/Total		**.907**	**41**

The reliability of the items on changes in temperature was .923 and that on changes in rainfall amount and distribution was .892, which are all above 0.7. The overall reliability was .907.

3.10 Data Analysis

Survey data were entered into Microsoft Excel version 2013, which was used to ease data entry, cleaning, and subsequently transferred to STATA version 14c for data analysis. Descriptive statistics were used to analyze the perceptions of common bean smallholder farmers on changes in climate variability in Northern Uganda. The main variables described were the perceptions of common bean smallholder farmers on changes in temperature and rainfall variability. Information from focus group discussants and key informants, like indicators, causes, and coping strategies, was analyzed using themes and sub-themes, and primarily supplemented with a narrative of quantitative data on change in temperature and rainfall variability. Pearson correlation analysis was used to analyze the relationship between the change in temperature and rainfall variability on smallholder farmers' common bean yield in Northern Uganda. To ensure that the quantitative data meet the standards for quality, correctness, and completeness, they were compiled, sorted, modified, and coded. The statistical significance of the association was determined at $p<0.05$.

Table 3.1 Data Analysis Plan

Objectives	**Research questions**	**Independent variables**	**Dependent variable**	**Relationship**	**Relationship test**
To assess the perceptions of common bean smallholder farmers on climate variability in Northern Uganda	What are the perceptions of common bean smallholder farmers on climate variability?	N/A	N/A	Descriptive statistics Qualitative analysis	Frequencies Percentage, Thematic analysis
To assess the relationship between changes in temperature and smallholder farmers' common bean yield in Northern Uganda	Ho: There is no significant relationship between changes in temperature and smallholder farmers' common bean yield in Northern Uganda.	Temperature	Yield	Association	Descriptive statistic Pearson correlation
To assess the relationship between rainfall variability and smallholder farmers' common bean yield in Northern Uganda.	Ho: There is no significant relationship between rainfall variability and smallholder farmers' common bean yield in Northern Uganda.	Rainfall variability	Yield	Association	Descriptive statistic Pearson correlation

3.13 Ethical Considerations

The ethical issue that was considered in this study included the attainment of an introductory letter from the Graduate School, Kyambogo University for the introduction of the researcher to respondents in the area of the study in Northern Uganda. Informed consent, confidentiality, and use of acceptable language were observed during this study. The issue of informed consent was addressed to ensure that the purposes of the research were properly explained to respondents. Confidentiality was guaranteed by not writing down the names of respondents, and their ages were recorded in ranges. On the other hand, polite languages were used at the time of the interview. The information that was collected and analyzed was purely for academic purposes. However, it may act as a reference for the region and NGOs when dealing with variability and its effects in the region.

CHAPTER FOUR: RESULTS

4.0 Introduction

This chapter presents the results of the study on the relationship between climate variability and smallholder farmers' common bean yield in Northern Uganda. It is composed of five sections: the first section summarizes the sample characteristics, and in the second to fifth sections, the results are presented and discussed in accordance with the study objectives.

4.1 Demographic Characteristics of Respondents

The demographic characteristics of the respondents included gender, age, educational level, marital status, household size, and experience in planting common beans (Table 4.1).

Table 4. 2 Demographic Characteristics of Respondents (N=160)

Demographic characteristics	Frequencies	Percentages
Gender		
Male	75	46.88
Female	85	53.13
Age (years)		
26 to 35	44	27.50
36 to 45	41	25.62
46 to 55	46	28.75
56 to 65	21	13.13
66 and beyond	8	5.00
Educational level		
None	19	11.88
Primary	101	63.13
Secondary	32	20.00
Tertiary Institution	8	5.00
Marital status		
Not married	2	1.25
Married	135	84.38
Separated/Divorced	1	0.63
Widowed/widower	22	13.76
Household size		
3 and less	8	5.00
4 to 6	59	36.88
7 to 10	68	42.50
11 and beyond	25	15.63
Experience in growing common beans (years)		
5 and less	20	12.50
6 to 10	31	19.38
11 to 20	41	25.63
21 and beyond	68	42.50

Table 4.1 above indicates that the majority of common bean smallholder farmers in Northern Uganda are female (53.13%). Most of the respondents are between 46 and 55 years old, with 28.75%. The majority of the respondents have attained primary education (63.13%), a few (5.00%) have attained a university education, and 11.88% have no formal education. 84.38% of the respondents are married, with a household size of 7 to 10 members (42.5%). 42.50% of the respondents have grown common beans for at least 21 years.

The gender proportions of more female respondents (53.13%) planting common beans are greater than those of male respondents (46.88%). This affirms that in Northern Uganda, common beans are taken as "women's crops," since they are considered a staple food crop for most low-income and poor households. It is planted by farmers mostly between 46 and 55 years of age (28.75%) who have 21 and beyond years of experience. The more age and energy a farmer have, the more experience he or she gains in planting common beans, the better and longer a farmer gets to understand the changes in temperature and rainfall variability, the more experienced she or he becomes. Most of the smallholder farmers who grow common beans have attained primary school education, which implies that they may not easily analyze and interpret temperature and rainfall information in printed forms. On average, each of the respondent's households has 7.5 members, which is more than the national average of 4.5 persons (UBOS, 2016) and higher than that of the world, which is 4.9 (Szmigiera, 2021).

4.2 Smallholder Farmers' Perceptions on Climate Variability

Globally, the temperature is changing, especially the trend is towards high temperatures that pose adverse effects on crop yield (Ottman, 2012; Rosenzweig et al., 2014).

4.2.1 Perceptions of Smallholder Farmers on Changes in Temperature

The participants were asked regarding their perceptions of changes in temperature over the last 12 years (from 2008 to 2019), how long ago they noticed the change, and what could be the causes of the change (Table 4.2).

Table 4.3 Perception of Smallholder Farmers on Changes in Temperature

Perceptions on Changes in Temperature	Frequency	Percentage
Have you noticed any changes in temperature in the last 12 years (n=160)		
Yes	150	93.75
No	0	0.00
Not sure	10	6.25
Description of the change (n=150)		
Increased	150	100.00
Decreased	0	0.00
How long did you notice change in temperature (years) (n=150)		
1 to 3 years	16	10.70
4 to 6 years	22	14.70
7 to 9 years	61	40.70
10 to 12 years	51	34.00
Perceived causes of change in temperature (n=160)		
Deforestation	141	88.12
Agricultural activities like bush burning	106	66.25
Destruction of wetlands	65	40.63
Urbanization	11	6.88
Don’t know	7	4.38
Do you agree that changes in temperature cause low yield of common Bean (n=160)		
Agree	160	100.00
Disagree	0	0.00
Not sure	0	0.00

Table 4.2 above illustrate that most of common bean smallholder farmers in Northern Uganda are aware that the temperature has changed in the last 12 years (93.75%) and has increased (100%). However, most of the respondents (40.70%) have experienced the change in temperature in the seven to nine years. This finding is supported by smallholder farmers’ age bracket (see Table 4.1), where the majority of the respondents aged between 26 to 55 years have long experience in planting common beans. This indicates that adult smallholder farmers perceive current climate variability events better because of their long experience. Okonya et al. (2013) also noted that the majority of farmers in the six agro-ecological zones of Uganda have noticed a rise in temperature.

Table 4.4 Table Perceptions of Smallholder Farmers on Change in Temperature

Smallholder Farmers Perceptions on Change in Temperature	Rating indicators of changes in temperature		
Indicators of Change in Temperature	3=Agree	2=Disagree	1=Not sure
Drying of crops' parts before maturity (n=150)	92.67	7.33	0.00
High monthly temperature during planting season (n=150)	80.0	20.0	0.00
Frequent occurrence of crop pests and diseases (n=150)	79.33	19.33	1.33
Increased drying of seasonal water sources earlier than usual (n=150)	66.67	33.33	0.00
Emergence of new weed varieties/types (n=150)	28.67	70.67	0.67
High average daily temperature (n=150)	27.33	72.67	0.00
Effects of changes in temperature on common bean yield			
Cause excessive loss of water from plants	95.00	5.00	0.00
Fasten maturity of common beans (n=160)	88.13	10.63	1.25
Cause stunting of crops (n=160)	84.38	15.63	0.00
Increase occurrence of pests and diseases (n=160)	77.50	22.50	0.00
Coping strategies to changes in temperature			
Deep ploughing to keep soil moisture ((n=150)	67.3	32.66	0.00
Mulching (n=150)	60.0	40.00	0.00
Growing drought tolerant common beans variety (n=150)	59.33	40.00	0.67
Planting quick maturing common beans variety (150)	40.0	59.33	0.67
Watering of crops (150)	0.67	98.67	0.67
Split-date planting	0.00	100.00	0.00

Table 4.3 above shows that most common bean smallholder farmers in Northern Uganda agreed that change in temperature is indicated by drying of crop parts before maturity (92.67%), high monthly temperature during planting season (80.00%), frequent occurrence of crop pests and diseases (79.33%), increased drying of seasonal water sources earlier than usual (66.67%).

The majority of the common bean smallholder farmers pointed out that agricultural activities like deforestation (88.12%), burning vegetation (66.25%), and destruction of wetlands (40.63%) are the major causes of change in temperature (see Table 4.2). This implies that common bean smallholder farmers in Northern Uganda have really experienced adverse impacts of changes in temperature resulting from agriculture related activities on their productivity. This finding is supported by research conducted in the Mt. Elgon region, which found out that over 50% of the smallholder farmers in Kapchorwa, Manafwa districts in Eastern Uganda noted an increase in daily and seasonal changes in temperature, and none of them reported a decrease (Bomuhangi et al., 2016).

In addition, Table 4.3 above indicates that most of the common bean smallholder farmers agreed that changes in temperature have adverse effects on common bean yield, which include excessive loss of water from plants (95%), fastening maturity of common beans (88.13%), stunting of common beans (84.38%), and increased occurrence of pests and diseases (77.50%). Since smallholder farmers can recognize the adverse impact of changes in temperature on common bean yield, this implies that the effects cause big losses to agricultural productivity.

The most common techniques common bean smallholder farmers in Northern Uganda use to cope with and adapt to changes in temperature include carrying out deep tillage to keep soil moisture, mulching, and planting quick-maturing and drought-tolerant common bean varieties (Table 4.3). It is common that to effectively cope with and adapt to changes in temperature, most common bean smallholder farmers employ combinations of different techniques to counter the negative impacts of those changes, since using only one or a limited number of techniques could not be effective. During an interview with an extension worker, he confirmed that they train farmers to practice minimum tillage, use of herbicides for land preparation and weeding, planting more trees, and ridging the seedbed, which explains smallholder farmers' use of a variety of techniques to cope with and adapt to changes in temperature. Nevertheless, most commonly used coping and adaptation measures are on-farm reactive measures. Extant literature confirms that the smallholder farmers in Amuru and Apac Districts of Northern Uganda employ a variety of coping and adaptation measures to cope with and adapt to changes in temperature. These measures include planting different crop varieties (96%) and planting drought-resistant crop varieties (80%). Amuru and Apac respondents' coping and adaptation measures, however, all centered on mitigating the impacts of drought (Atube et al., 2021).

4.2.2 Perceptions of Smallholder Farmers on Rainfall Variability

The researcher examined common bean smallholder farmers' perceptions in Northern Uganda on whether they have noticed the nature and the duration of change in both rainfall amount and distribution, which are summarized in Table 4.4.

Table 5.4 Smallholder Farmers' Perceptions on Changes in Rainfall Amount and Distribution

Changes in rainfall amount (N=160)	Frequencies	Percentage
Has the rainfall amount changed? (n=160)		
Yes	160	100.00
No	0	0.00
Nature of change in rainfall amount (n=160)		
Increased	160	100.00
Decreased	0	0.00
For how long have you noticed the change in rainfall amount? (n=160)		
1 to 3 years	140	87.50
4 to 6 years	18	11.25
7 to 9 years	1	0.63
10 to 12 years	1	0.63
Do you agree that the rainfall distribution has changed? (n=156)		
Yes	156	97.50
No	1	0.63
Not sure	3	1.88
Description of the change in rainfall distribution on common beans (n=156)		
Unfavourable	152	97.44
Favourable	4	2.56
For how long have you noticed the change in rainfall distribution? (n=156)		
1 to 3 years	122	78.21
4 to 6 years	31	19.87
7 to 9 years	1	0.64
10 to 12 years	2	1.28

From the data in Table 4.4 above indicates that smallholder farmers planting common beans in Northern Uganda (100%) recognized that there had been an increase in both the amount and distribution of rainfall received in the last twelve years. They observed that the rainfall pattern does not give distinct onset and end of rainfall season in the last three years. The result shows that rainfall was unfavourable (97.44%) to produce common beans in the last twelve years. Most of the participants testified that they have noticed an increase in rainfall amounts in the past three years (78.21%). These findings are congruent with Mubangizi et al. (2017), who found out that majority of respondents (98%) in the Mt. Elgon region had noticed a change in the pattern of rainfall and that the amount of rainfall was higher than normal. The respondents in Manafwa and Kapchorwa reported that the rainfall was more erratic and that the usual wet seasons have changed over the years (1993–2013). This was also noted in Northern Uganda, where an almost equal number of respondents are planting their common beans in April instead of the traditional mid-March planting season and the majority plant their common beans in June (see Table 4.5).

Table 4.5 Farming Practices Used by Common Bean Smallholder Farmers as a Result of Rainfall Variability

Farming practices resulting from rainfall variability	Frequency	Percentage
Number of times common bean plants are weeded in a production cycle (n=160)		
Once	125	78.13
Twice	33	20.63
Thrice	2	1.25
Number of times common beans are planted in a year (n=160)		
Once	125	78.00
Twice	33	21.00
Thrice	2	1.00
Smallholder farmers' knowledge on month(s) of the year for planting common beans (n=270)		
February	1	0.37
March	50	18.52
April	49	18.15
May	8	2.96
June	110	40.74
July	31	11.48
August	12	4.44
September	9	3.33
Common reasons for planting common bean in the month(s)(n=270)		
To leave the land for the next planting season	71	21.91
To utilize the onset of rainy season	74	22.84
To avoid pest and diseases	58	17.90
To make harvesting time coincide with the dry season	55	16.98
Other reasons	66	20.37

Table 4.5 above indicates that most smallholder farmers in Northern Uganda plant common beans once in a year (78.00%), 21.00% plant them twice a year, and only 1.00% plant them three times a year. The common beans are planted mostly in June (40.74%), and 78.13% weed the common bean once in a production cycle. This implies that the planting season for common beans is more stable in June than other months. Almost an equal number of the respondents plant their common beans in March and April (18.52% and 18.15%), respectively. This is because the onset of the first rainy season in March is shifting towards April. Therefore, some smallholder farmers wait until April to plant common beans.

The respondents were asked the reasons why they plant common beans in March, April, June, and July. The response of respondents was varied: they want to utilize the onset of the rainy season (22.84%), leave the land for the next planting season (21.91%), avoid pests and diseases (17.90%), make harvest time coincide with the dry season (16.98%), and 20.37% mentioned other reasons like getting food reserves for May/June. Others stated that when they plant common beans in June, they get a good yield. Others said to provide seeds for the next planting season (Table 4.5).

4.2.3 Perceptions of Smallholder Farmers on Rainfall Variability

The researcher examined the indicators, causes, and coping strategies for rainfall amount and distribution. He further examined the perceived effects of changes in rainfall amount on common bean yield (Table 4.6).

Table 4.6 Smallholder Farmers' Perceptions on Rainfall Variability

Smallholder Farmers' Perceptions on Change in Rainfall	Rating perception of change in temperature		
Indicators of changes in rainfall amount	3=Agree Frequency	2=Disagree Frequency	1=Not sure Frequency
High water table (n=160)	84.38	15.63	0.00
Flooding of garden (n=160)	76.88	20.00	3.13
Water logging (n=160)	64.38	35.63	0.00
Drought (n=160)	6.88	86.25	6.88
Causes of the change in rainfall amount			
Amount of humidity in the atmosphere (n=160)	63.52	20.75	15.75
High temperature during wet season (n=160)	48.13	38.75	13.13
Overhead movement of the sun (n=160)	20.63	15.00	64.38
Common indicators of changes in rainfall distribution			
Heavy rainfall (n=156)	94.23	5.13	0.64
More rainy days in a growing season than it used to be (n=156)	91.03	8.97	0.00
Flooding (n=156)	89.74	9.62	(0.64
Rainfall comes or disappears when not expected (n=156)	57.05	40.38	2.59
Drought (n=156)	9.62	83.97	6.41
Few rainy days in a growing season than it used to be (n=156)	8.33	87.18	4.43
Causes of the change in rainfall distribution			
Changes in wind direction (n=156)	80.77	10.90	8.33
Emission of Green House Gasses from human activities (n=156)	66.03	15.38	18.59
Movement of air mass (n=156)	35.26	24.36	40.38
Coping strategies against changes in rainfall amount and distribution			
Deep ploughing (n=156)	74.36	25.00	0.64
Planting quick maturing common beans variety (n=156)	43.59	55.77	0.00
Changing planting date (n=156)	65.38	34.62	0.00
Replanting common beans (n=156)	26.92	73.08	0.00
Split date planting (n=156)	1.28	98.72	0.00
Perceived effects of change in rainfall amount on common bean yield			
Rotting of mature common beans in the garden (n=160)	93.75	6.25	0.00
Excessive bushy growth with few pods (n=160)	87.50	12.50	0.00
Cause stunting of crops (n=159)	36.25	60.00	3.75
Increased occurrence of crops pests and diseases (n=160)	3.13	60.63	36.25

Smallholder farmers planting common beans in Northern Uganda are aware of the indicators of change in rainfall amount; the majority perceive a high-water table (84.38%). More than half perceived flooding (76.88%) and water logging (64.38%) as common indicators of changes in rainfall amount. Only 6.92% noted drought as an indicator of change in rainfall amount (Table 4.6). A key informant confirmed that,

> *"Water logging has been more common than flooding and spread throughout the sub-county. This has affected common bean production because, in waterlogged areas, common beans are deprived of oxygen and turn yellow, which affects their growth and overall performance. High water tables are localized in some places."*

The smallholder farmers planting common beans in Northern Uganda were asked to state their perceptions on causes of change in rainfall amount; their responses showed high humidity in the atmosphere (63.52%) and high temperature during the wet season (48.13%) are common causes of the change in rainfall amount. However, more than half of the respondents (64.38%) were not sure how overhead movement of the sun cause changes in rainfall amounts (Table 4.6). Analysis of the nature of rainfall in the drainage sub-basin of Uganda showed that the major causes of the change in rainfall pattern in Northern Uganda (northern sub-basin) are movement of the ICTZ, moist wind originating from the Indian Ocean, and moisture received from Congo/Zaire basin to the Southwest (Nsubuga et al., 2014).

The respondents were asked how they perceive change in rainfall distribution; almost all (97.50%) of the respondents and all focus group discussion respondents confessed that rainfall distribution has changed, but 0.63% disagreed and 1.88% were not sure of any change. The majority (78.21%) of the respondents perceived that the change happened between one to three years ago; 19.87%

witnessed it between four to six years, 0.64% noted that between seven to nine years, 1.28% witnessed it between ten to twelve years (Table 4.4).

It is true that most of the common bean smallholder farmers in Northern Uganda are aware that rainfall distribution has changed because they were able to state that rainfall has become heavy, flooding is common, the number of rainy days is more than it used to be, and sometimes rain comes or disappears when not expected (Table 4.6). Farmers in Eastern Uganda discovered that the pattern of rainfall had changed, resulting in a late onset, uneven distribution within the season, and an early cessation. They specifically pointed out that the first season had shifted from early March to mid or late March and that it now ends in June instead of May.

However, the respondents asserted that the second season starts in September rather than August and that it now ends in November as opposed to December. In addition, the respondents noted that heavy rainfall, flooding, and water logging are some of the problems caused by changes in rainfall distribution (Kansiime et al., 2013). The respondents stated that changes in wind direction and emissions of GHGs are the major causes of changes in rainfall distribution in Northern Uganda. This shows that smallholder farmers in Northern Uganda are more aware of spatial distribution than temporal rainfall distribution. The emission of GHGs was associated with cutting down trees (Table 4.6). According to Tafess et al. (2013), farmers in Eastern Ethiopia have noticed that rainfall variability has significantly risen over the past ten to twenty years because of showers occurring less frequently or unexpectedly during unusual periods of the year. The long-term productivity of their land was also significantly impacted by flooding, as fertile topsoil was washed away and only hardpan soil remained.

Table 4.6 shows that smallholder farmers who plant common beans in Northern Uganda are already practicing deep ploughing (74.36%), planting quick maturing common bean varieties (43.59%), changing planting dates (26.92%), and replanting common beans (26.92%), while the least effective coping strategy is split-date planting (1.28%). The majority of respondents (98.72%) have never used split-date planting to cope with the change (Table 4.6). Agricultural extension workers stated that they train farmers to practice water conservation measures like deep ploughing, digging trenches, creating drainage channels, and planting on ridges. They also sensitize farmers on site selection to avoid waterlogged places, plant crops upstream, not downstream, and not ploughing along the slope but across. This shows that there is a need for more extension work so that farmers can start adopting modern coping and adaptation strategies to the current change in climate.

The respondents in Northern Uganda are aware of the effects of changes in rainfall amount and distribution on common beans. Most of the respondents mentioned rotting of mature common beans (93.75%) and excessive bushy growth with few pods (87.50%) as common effects of changes in rainfall amount and distribution on common bean yield. More than half of the respondents disagreed with increased occurrence of crop pests and diseases (60.63%) and stunting of the crops (60.38%) being common effects of changes in rainfall amount and distribution on common bean yield (Table 4.6). The entire group of respondents unanimously agreed that the change is unfavourable for planting common beans (Table 4.4).

4.3 The Relationship between Change in Temperature on Smallholder Farmers' Common Bean Yield in Northern Uganda

The investigator examined the relationship between change in temperature and smallholder farmers' common bean yield for the last 12 years (2008–2019) in Northern Uganda.

4.3.1 Descriptive Statistics of Temperature (Min), (Max) and Common Bean Yield

The researcher descriptively analyzed the average temperature (Min) (Max) and common bean for a period of 12 years, that is, from 2008 to 2019. The findings are summarized in Table 4.7.

Table 4.7 Descriptive Statistics of Temperature (Max), (Min) and Common Bean Yield

	Common bean yield (Tonnes) (2008 to 2019)	Temp (Min) (2008 to 2019)	Temp (Max.) (2008 to 2019)
Mean	31,044.67	18.96	30.45
Standard Deviation	6,342.67	0.42	0.38
Median	32,021.5	19	30.35

Table 4.7 indicates that the overall mean of the yield was 31,044.67 metric tonnes between 2008 and 2019; standard deviation was 6,342.67 and median value at 32,021.5 between 2008 and 2019. Similarly, the mean for temperature (Min) and (Max) were 18.96^{0}C and 30.45^{0}C respectively with its corresponding SD and median at (SD T Min 0.42, SD T max 0.38, Median T min=19 and Median T Max= 30.35).

4.3.2 Temperature (Max) and Common Bean Yield Trend over the Last 12 Years (2008 to 2019)

The investigator examined temperature (Max) and common bean yield trends for a period of 12 years (2008 to 2019). The findings are summarized in Figure 4.1.

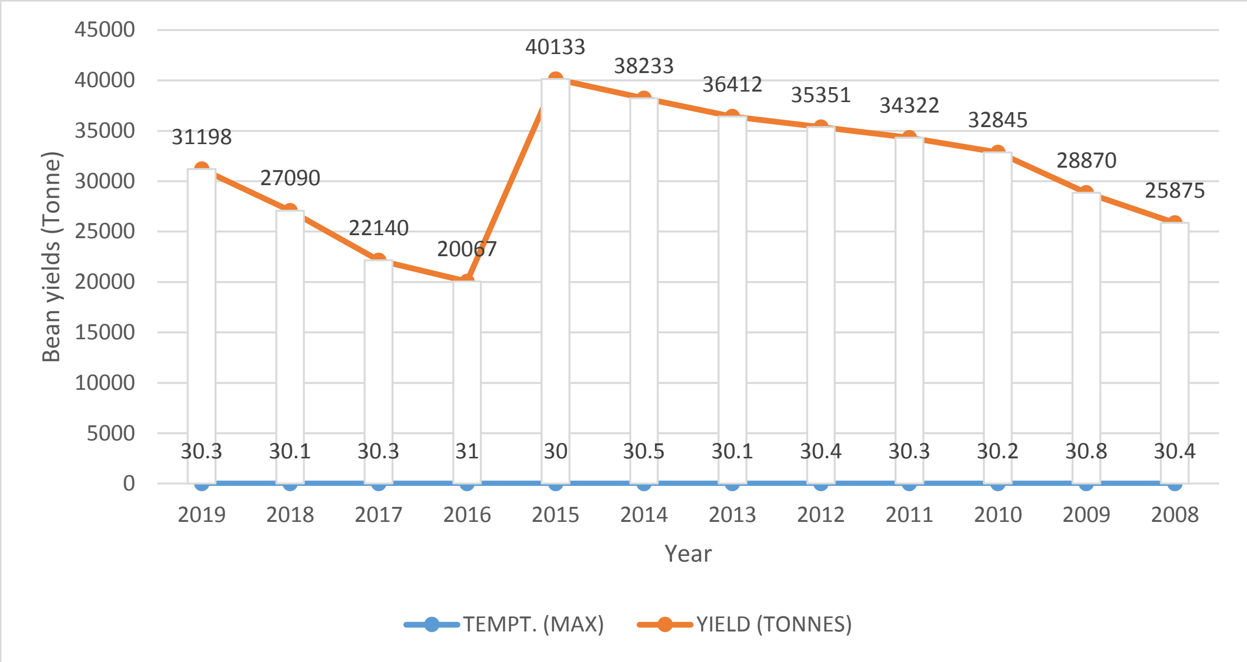

Figure 4.1 *Temperature (Max) and common beans yield trends over the last 12 years (2008-2019)*

The average mean temperature (Max) was 30.45^{0}C and the average mean common bean yield was 31,044.67 metric tons (see Table 4.7). The highest maximum temperature was at 31^{0}C, and the lowest maximum temperature was at 30^{0}C. The highest yield (40,133 metric tons) was recorded at the lowest maximum temperature (30^{0}C). Any increase in the temperature (Max) above 30^{0}C cause low common bean yield. For instance, in the year 2016, the average maximum temperature was at 31^{0}C and the lowest yield of 20,067 metric tons was got (Figure 4.1). However, the optimum temperature for planting common beans ranges from 20^{0}C to 28^{0}C with a maximum of 32^{0}C is required for high yield in Uganda. Temperatures above 32^{0}C will cause poor pods set resulting in yield loss (Nkalubo & Luyima, 2012). The analysis of the area of land planted and common bean yield (2008 to 2019) shows that there was a positive relationship **(**refer to Figure 1.1**).** Therefore, the size of land under common bean production, and other unpredictable factors like rainfall, pests and diseases, and lack of finance identified by the focus group discussants which determines the yield of common beans in Northern Uganda.

4.3.3 Temperature (Min.) and Common Bean Yield Trend over the Last 12 Years (2008 to 2019) in Northern Uganda

The investigator examined temperature (Min) and common bean yield trends for a period of 12 years that is from 2008 to 2019. The findings are summarized in Figure 4.1.

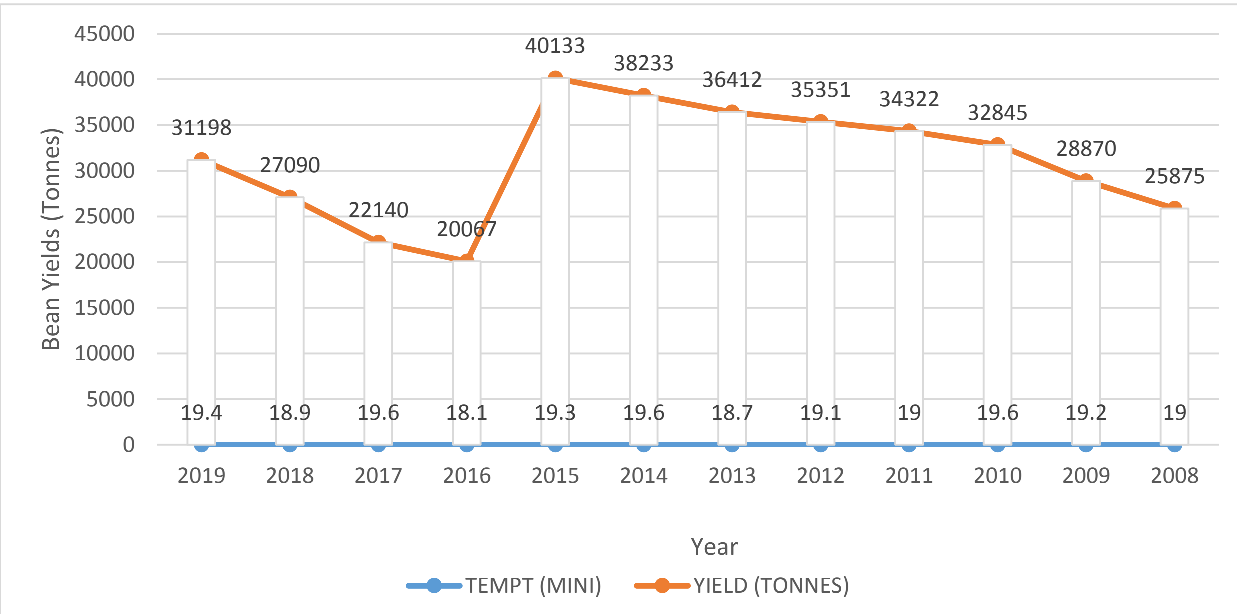

Figure 4.2 *Temperature (Min.) and Common bean yield trends over the last 12 years (2008 to 2019) in Gulu District.*

The mean average temperature (Min) was 18.96^{0}C and the average mean yield was 31,044.67 metric tonnes (see Table 4.7). The result shows that the highest minimum average temperature was at 19.6^{0}C and the lowest minimum average temperature was at 18.1^{0}C (Figure 4.2). The highest yield (40,133 tonnes) was got at the minimum average temperature of 19.3^{0}C. The lowest common bean yield (20,067) was got at the lowest average temperature (Min) of 18.1^{0}C in the year 2016.

Any increase above or decrease below 19.3^{0}C cause low common bean yield (Figure 4.2). However, the optimum growing temperature (Min) for common beans is 15^{0}C, below 15^{0}C will cause poor pods set resulting in yield loss (Nkalubo & Luyima, 2012). The analysis of trend of area of land planted and common bean yield (2008 to 2019) shows that there is a positive relationship (Figure 1.1). Therefore, the hectares of land planted with common beans is among other factors like unpredictable rainfall, pests and diseases, and lack of finance identified by the focus group discussants, which determinethicae the yield of common beans in Northern Uganda.

4.3.4 Relationship between Change in Temperature and Common Bean Yield

The Pearson correlation analysis was conducted to examine the relationship between change in temperature and common bean yield (Table 4.16).

Table 4.8 Relationship between Change in Temperature and Common Bean Yield

Yield	Pearson correlation (r)	Significance (p-value)
Temp (min)	0.319	0.311
Temp (max)	-0.1583	0.6231

Table 4.8 shows a correlation analysis to determine the relationship between change in temperature and common bean yield. The results show that there was a moderately positive relationship (r= 0.319) between temperature (Min) and a negatively low relationship (r= -0.1583) for temperature (Max) when correlated with common bean yield planted by smallholder farmers in Northern Uganda. The significance 2-tailed gives *p*-value of 0.311 (T Min) and *p*-value 0.6231 (T Max), which is greater than 0.05, hence, the Ho (There is no significant relationship between change in temperature and common bean yield planted by smallholder farmers in Northern Uganda) is

retained. Therefore, the study does not provide enough evidence to conclude that there is statistically significant correlation between temperature (min) and (max) when correlated with common bean yield (Table 4.8). This finding is supported by the discussion in focus groups in which common bean smallholder farmers identified unpredictable rainfall as most common problem, followed by pests and diseases and lack of finance among other factors that cause low yield of common beans.

4.4 The Relationship between Rainfall Variability and Common Bean Yield

The investigator assessed the relationship between rainfall variability and smallholder farmers' common bean yield in Northern Uganda for the last 12 years (2008 to 2019) as summarized in Tables 4.10.

4.4.1 Descriptive Statistics of Rainfall and Common Bean Yield

The investigator descriptively analyzed the average rainfall amount and average common bean yield for 12 years (2008 to 2019) as summarized in Table 4.10.

Table 4.8 Descriptive Statistics of Rainfall and Common Bean Yield

	Rainfall (2008 to 2019)	Beans Yield (Tonnes) (2008 to 2019)
Mean	4.66	31,044.67
Standard Deviation	1.28	6,342.67
Median	4.05	32,021.5

Table 4.9 shows that the overall mean yield of common beans was 31,044.67 metric tonnes between the years 2008 and 2019; standard deviation was 6,342.67 and the median value at 32,021.5 between the years 2008 and 2019. Similarly, the mean for rainfall was 4.66mm with its corresponding SD 1.28 and median at 4.05.

4.4.2 Rainfall Variability and Common Bean Yield Trends for the Last 12 years (2008 to 2019) in Northern Uganda.

The investigator examined rainfall and common bean yield trends for a period of 12 years that is from 2008 to 2019. The findings are summarized in Table 4.2.

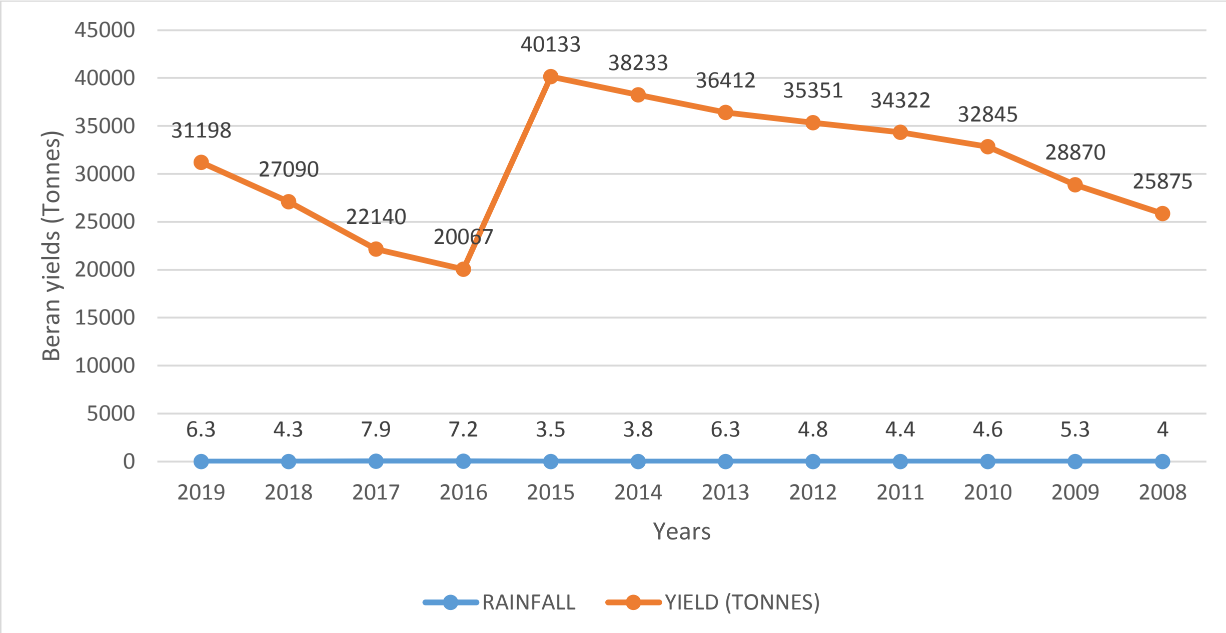

Figure 4.3 *Rainfall and Beans Yield Trends over the Last 12 years (2008 to2019) in Gulu District.*

The average mean rainfall was 4.66mm and the average mean yield of 31,044.67 metric tons (see Table 4.7). The highest average amount of rainfall recorded was 7.9mm and the lowest average was 3.5mm. The highest yield (40,133 metric tonnes) was recorded at the lowest average amount of rainfall of 3.5mm. Any increase in the average amount of rainfall above 3.5mm cause low common bean yield. For instance, in the year 2016, the average maximum rainfall was at 7.2mm and the lowest yield (20,067 metric tons) was got (Figure 4.3). The analysis of trends of area of land planted and common bean yield (2008 to 2019) shows that there is a positive relationship between area of land planted and common bean yield (Refer to Figure 1.1). Therefore, the area of land planted with common beans is not the only factor that causes low yield of common beans, but also other factors like drought, pests and diseases, and lack of finance identified by the focus group discussants, which determine the yield in Northern Uganda.

4.4.3 Relationship between Rainfall Variability and Common Bean Yield

The Pearson correlation analysis was conducted to examine the relationship between rainfall variability and common bean yield (Table 4.10).

Table 4.10 Pearson Correlation on Relationship between Rainfall Variability and Yield of Common Beans

Yield	Pearson correlation (r)	Significance (*p*-value)
Rainfall (mm)	-0.1391	0.667

Table 4.10 indicates a correlation analysis to find the relationship between rainfall variability and common bean yield shows that there was a weak negative correlation (r= -0.1391) between rainfall variability and common bean yield. The significance 2-tailed gives a *p*-value of 0.667, which is greater than 0.05; hence, the Ho (There is no significant relationship between rainfall variability and smallholder farmers' common bean yield in Northern Uganda) is retained. The study does not provide enough evidence to conclude that there is statistically significant correlation between rainfall variability when correlated with common bean yield (Table 4.10). When respondents in focus group discussions and in-depth interviews were asked about their perceptions of the most common problems they face when planting common beans, although the majority perceived unpredictable rainfall as the most common factor, they also mentioned drought, pests, diseases, and lack of finance among other factors that cause low common bean yield in Northern Uganda.

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter presents summaries of study findings, conclusions, and recommendations on the relationship between climate variability and smallholder farmers' common bean yield in Northern Uganda. The investigator also categorized this chapter in accordance with the objectives of the study. Finally, areas for future research on changes in climate are described.

5.1 Summary

The findings are summarized in accordance with the objectives of the study as the perception of smallholder farmers on change in climate, the relationship between change in temperature and smallholder farmers' common bean yield, and the relationship between rainfall variability and smallholder farmers' common bean yield in Northern Uganda.

5.1.1 Demographic Characteristics

Most common bean smallholder farmers are mostly female, between 46 and 55 years of age, attained mostly primary education, married, with a household size of 7 to 10 members, and possess experience in common bean production of 21 years and beyond.

5.1.2 Perceptions of Smallholder Farmers on Change in Temperature

The majority of smallholder farmers planting common beans are aware that the temperature has changed in the last 12 years (93.75%), with an increase in temperature. The change in temperature has been more pronounced in the last four to six years. An increase in temperature is indicated by the drying of crop parts before maturity (92.67%), frequent occurrence of crop pests and diseases, and drying of seasonal water sources earlier than usual. The main causes of the change in temperature are agricultural activities like deforestation (94.00%), burning vegetation (70.00%), and destruction of wetlands (43.33%). In coping with and adapting to the change in temperature, common bean smallholder farmers practice deep tillage to keep soil moisture (67.33%), mulching (60.0%), planting quick-maturing common bean varieties (59.33%), and planting drought-tolerant common bean varieties (59.33%).

5.1.3 Perceptions of Smallholder Farmers on Rainfall Variability

Common bean smallholder farmers have experienced an increase in rainfall (100%) received to unfavourable levels (97.44%) in the last 12 years. The rainfall has been characterized by no clear onset or end of rainfall season. Most indicators of change in rainfall amount include the perceived high-water table (84.38%), flooding (76.88%) and water logging in their farms (64.38%).

The perceived causes of the change in rainfall amount are high amount of humidity (63.52%), high temperature during wet season (48.13%), and overhead movement of the sun (20.63%). Almost all (97.50%) of the respondents and all focus group discussants confessed that rainfall distribution has changed. Smallholder farmers mostly practice deep ploughing (74.36%), planting quick-maturing common bean varieties (43.59%), changing planting dates (26.92%), and replanting common beans (26.92%) to cope with and adapt to rainfall variability.

5.1.4 The Relationship between Change in Temperature and Common Bean Yield

The significance 2-tailed test between change in temperature maximum and minimum and smallholder farmers' common bean yield gives *p*-value of 0.311 (T Min) and p-value 0.6231 (T Max), which are greater than 0.05, hence, the Ho (There is no significant association between change in temperature and common bean yield planted by smallholder farmers in Northern

Uganda) is retained; the study does not provide enough evidence to conclude that there is statistically significant correlation between temperature (min) and (max) when correlated with common bean yield.

4.1.5 The Relationship between Rainfall Variability and Common Bean Yield

The significance 2-tailed between rainfall variability and smallholder farmers' common bean yield gives a p-value of 0.667, which is greater than 0.05, hence, the Ho (There is no significant relationship between rainfall variability and smallholder farmers' common bean yield in Northern Uganda) is retained; the study does not provide enough evidence to conclude that there is statistically significant correlation between rainfall variability when correlated with common bean yield.

5.2 Conclusions

The findings are concluded in accordance with the objectives of the study, as the perception of smallholder farmers on climate variability, the relationship between change in temperature and smallholder farmers' common bean yield, and the relationship between rainfall variability and smallholder farmers' common bean yield in Northern Uganda.

5.2.1 Perceptions of Smallholder Farmers on Change in Temperature

Most smallholder farmers have experienced adverse impacts of changes in temperature resulting from agriculture-related activities on their agricultural productivity. Most of the adaptation measures that smallholder farmers practice tends to be on-farm reactive adaptation measures, not sustainable strategies that are in-built within the environment for long-term adaptation.

5.2.3 Perceptions of Smallholder Farmers on Change in rainfall variability

Most smallholder farmers in Northern Uganda are aware of the change in the amount and distribution of rainfall, with its associated characteristics like abnormally heavy and sometimes unreliable rainfall and common floods. This has prompted the common bean smallholder farmers to mitigate the effects of climate variability by practicing deep ploughing, planting quick maturing common bean varieties, changing planting dates, and replanting common beans.

5.2.3 The Relationship between Change in Temperature and Common Bean Yield

Change in temperature is not a significant factor causing low common bean yield in Northern Uganda. Thus, the low common bean yield experienced by smallholder common bean farmers in Northern Uganda is a result of other factors that this study did not focus on, like soil conditions, agronomic practices, pests, and diseases, among others. The null hypothesis (There is no significant relationship between change in temperature and common bean yield in Northern Uganda) is retained.

5.2.4 The Relationship between Rainfall Variability and Common Bean Yield

Rainfall variability is not a significant factor causing low common bean yield in Northern Uganda. There are a host of other factors not included in this study that could be interactively or individually contributing to low common bean yield in Northern Uganda, like soil conditions, inappropriate agronomic practices used, pest and diseases, among others. The null hypothesis (There is no significant relationship between rainfall variability and common bean yield in Northern Uganda) is retained.

5.3 Recommendations and Implications

The investigator recommends that agencies tasked with building the capacity of smallholder farmers should use and tap into the smallholder farmers' experiences with climate change and variability to inform farmer climate change training programmes. Further, build the capacity of common bean smallholder farmers to adapt to and mitigate the effects of climate change and variability on common bean production and productivity. The capacity-building process should be holistic and integrate a host of other factors with a bearing on low yield like soil conditions, agronomic practices, pests, and diseases among others.

Given the adverse effects of climate change and variability in agricultural production and productivity, issues pertaining to climate change and variability should be handled with farmers' active involvement and utmost urgency to mitigate the impacts of climate change and variability on agriculture.

5.4 Areas for Further Research

The investigator recommends that future research be conducted regarding participation by smallholder farmers in climate change capacity building and training programmes and the impact of such involvement or non-involvement on the production and productivity of smallholder farmers. Research should also be conducted focusing on gender barriers to participation in climate change capacity building and training programmes.

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APPENDIX I

Key: 1 = Relevant, 0 = Irrelevant

ITEM/QUESTION NO.	INDEPENDENT REVIEWERS/EXPERTS			TOTAL RELEVANT	CVI
	A	B	C		
1	1	1	1	3	1.00
2	1	1	1	3	1.00
3	1	1	1	3	1.00
4	1	1	1	3	1.00
5	1	1	1	2	1.00
6	1	1	1	3	1.00
7	0	1	1	2	0.67
8	0	1	1	2	0.67
9	1	1	1	3	1.00
10	1	1	1	3	1.00
11	1	1	1	3	1.00
12	1	1	1	3	1.00
13	1	1	1	3	1.00
14	1	1	1	3	1.00
15	1	1	0	2	0.67
16	1	1	1	3	1.00
17	1	1	1	3	1.00
18	1	1	1	3	1.00
19	1	1	1	3	1.00
20	1	1	1	3	1.00
21	1	1	1	3	1.00
22	1	1	1	3	1.00
23	1	1	1	3	1.00
24	1	1	1	3	1.00
25	1	1	1	3	1.00
26	1	1	1	3	1.00
27	1	1	1	3	1.00
28	1	1	1	3	1.00
29	1	1	1	3	1.00
30	1	1	1	3	1.00
31	0	1	1	2	0.67
32	1	1	1	3	1.00
33	1	1	1	3	1.00
34	1	1	1	3	1.00
35	1	1	1	3	1.00
36	1	1	1	3	1.00

Source: Primary Data, 2019.

The individual item CVI ranged from 0.67 t0 1.00, all the values fall within the acceptable ranges for research purpose.

Items CVI. $= \frac{\text{Number of items rated relevant by all judges}}{\text{Total number of items in the instrument}}$

CVI = $\frac{32}{36}$= 0.89

APPENDIX II

Questionnaire for Smallholder Farmers Growing Common Bean in Northern Uganda

Dear respondent, I am a student of Kyambogo University conducting a survey to investigate the relationship between climate variability and smallholder farmers' common bean yield in Northern Uganda. The information that you will provide shall strictly be used for research purposes only and will be confidential. The identity and personal particulars of participants shall be coded for the research purpose and will not be identifiable. If you agree to participate, please provide the required information with honesty and sincerity based on your perception. Read the instructions for each section and fill out the questionnaire.

Basic information/ Administrative checks

Fill the information on the rows provided to the right-hand side of each item:

01	Questionnaire Number			
02	Date of interview		District	
03	Interviewed by		Sub-county	
04	Checked by		Parish	
05	Date checked		Village/Lc1	
06	Data entered by			
07	Date entered			
08	Respondent ID			

A. Household Characteristics

Tick the appropriate brackets against each item of your choice:

	Respondent Characteristics.
1	Age of the Respondent in years 1:18-25 years ( ) 2: 26-35 years ( ) 3: 36-45 years ( ) 4: 46-55 years ( ) 5. 56-65 years 6. >65 years ( )
2	Gender of the Respondent 1. Male ( ) 2. Female ( )
3	Household size 1. <3 ( ) 2. 4-6 ( ) 3. 7-10 ( ) 4. >10 ( )
4	Education level of Respondent 1. None ( ) 2. Primary ( ) 3. Secondary ( ) 4. Institution ( )
5	Years in growing common bean 1: < 5 years ( ) 2: 6-10 years ( ) 3: 11-20 years ( ) 4: >20 years ( )
6	Marital status: 1. Single ( ) 2. Married ( ) 3. Separated/Divorced ( ) 4. Widow ( ) 5. Widower ( )

For sections B, C, D, E, F, G, H, I, J, K, L, M, N, O, P and Q provide your responses with respect to the area where you are currently growing the common bean. Fill in either by ticking in the bracket in the right hand side or by filling in the spaces provided.

B. Farm Production Characteristics

7. What is the total size of your land under crop production this season? (1 acre = 4,046.86m^2)

1. < ¼ acre ( ) 2. Between ¼ and ½ acre ( ) 3. Between ½ and 1 acre ( )

4. Between 1 acre and 2 acres ( ) 5. Between 2 acres and 4 acres ( ) 6. >4 acres ( )

8. What is the average size of your land under common bean production this season?

1 < ¼ acre ( ) 2. Between ¼ and ½ acre ( ) 3. Between ½ and 1 acre ( )

4. Between 1 acre and 2 acres ( ) 5. Between 2 acres and 4 acre ( ) 6. >4 acres ( )

9. What is the size of your land under common bean this season compared to last season?

1. ( ) Smaller 2. ( ) the same 3. ( ) Bigger

10. Give reason for your response in 3 above

11. How many time(s) do you weed your common bean in a production cycle?

1. Once ( ) 2. Twice ( ) 3. Thrice ( ) 4. Others specify……………………

C. Knowledge on Common Bean Planting Season

12. How many time(s) do you plant common bean in a year?

1. Once ( ) 2. Twice ( ) 3. Thrice ( ) 4. Others (specify)…......................

13. Which are the best month(s) of the year for planting the common bean? **(Tick all that apply)**

1. January ( ) 2. February ( ) 3. March ( ) 4.April ( )

5. May ( ) 6. June ( ) 7. July ( ) 8. August ( )

9. September ( ) 10. October ( ) 11. November ( ) 12. December ( )

14. What are the reasons for planting common bean in the month(s) indicated above?

1. To leave the land for the next planting season ( )

2. To utilize the onset of rainy season ( )

3. To avoid pest and diseases ( )

4. To make harvesting time coincide with the dry season ( )

5. Others (specify)………………………………………………………………………

15. What problem do you face **most** when growing the common bean?
1. Drought ( ) 2. Unpredictable rainfall ( ) 3. Pests and diseases ( )

4. Lack of finance ( ) 5. Others (specify ……………………………….

D. Changes in Temperature

16. Have you noticed any change in temperature in the last 12 years?

1. Yes ( ) 2. No ( ) 3. Not sure ( )

17. Describe the changes?

1. increased 2. Decreased

18. For how long have you noticed the change?

1. 1-3 years ( ) 2. 4-6 years ( ) 3. 7-9 years ( )

4. 10-12 years ( )

19. What are the causes of the change in temperature? **(Tick all that apply)**

1. Deforestation ( ) 2. Agricultural activities like bush burning ( )

3. Destruction of wetlands ( ) 4. Urbanization ( )

5. Don't know ( ) 6. Others specify ………………………………….

E. Indicators of Changes in Temperature

20. What are the indicators of the change in temperature? Use the scale 3= Agree, 2=Disagree, 1= Not sure

G1. Temperature change

s/n	**Temperature change**	**3**	**2**	**1**
1a	High monthly temperature in a growing season			
1b	High average daily temperature			
1c	Frequent occurrence of crop pests and diseases			
1d	Emergence of new weed varieties/types			
1e	Increased drying of seasonal water sources earlier than usual			
1f	Drying of crop parts before maturity			
1g	Others specify			

F. Coping Strategies to Changes in Temperature

21. What are the coping strategies you use during the change in temperature? Use the scale 2=Yes, 1= No

H1. Coping strategies

S/No	**Coping strategies**	**2**	**1**
1a	Growing tolerant common bean variety		
1b	Planting quick maturing common bean variety		
1c	Watering of crops		

1d	Deep ploughing to keep soil moisture		
1e	Mulching		
1f	Split-date planting		
1g	Others (specify)		

I.

Change in Rainfall Amount

22. Do you agree that the rainfall amount has changed?

1. Yes ( ) 2. No ( ) 3. Not sure ( )

23. Describe the change?

1. Increased 2. Decreased

24. For how long have you noticed the change?

1. 1-3 years ( ) 2. 4-6 years ( ) 3. 7-9 years ( )

4. 10-12 years ( )

H. Indicators of Changes in Rainfall Amount

25. What are the common indicators of the change in rainfall amount? 3= Agree, 2= Disagree, 1= Not sure

J1 Rainfall amount

S/No	Indicators	3	2	1
1a	Flooding of garden			
1b	Water logging			
1c	High water table			
1d	Drought			
1e	Others (specify)			

26. What are the causes of the change in rainfall amount? **Use the scale 3= Agree, 2= Disagree, 1=Not sure**

S/No	Causes	3	2	1
1a	High temperature during wet season			
1b	Overhead movement of the sun			
1c	Amount of humidity in the atmosphere			
1d	Others specify			

I. Changes in Rainfall Distribution

27. Do you agree that the rainfall distribution has changed?

1. Yes ( ) 2. No ( ) 3. Not sure ( )

28. Describe the change on common bean production?

1. Favourable for common beans production   2. Unfavourable for common beans production

29. For how long have you noticed the change?

1. 1-3 years ( )   2. 4-6 years ( )   3. 7-9 years ( )

4. 10-12 years ( )

J. INDICATORS OF CHANGES IN RAINFALL DISTRIBUTION

30. What are the common indicators of changes in rainfall distribution? Use the scale

3=Agree, 2=Disagree, 1=Not sure

L1 Rainfall distribution

S/No	Rainfall distribution pattern	3	2	1
1a	Flooding			
1b	Drought			
1c	Heavy rainfall			
1d	More rainy days in a planting season than it used to be			
1e	Few rainy days in a planting season than it used to be			
1f	Rainfall comes or disappears when not expected			
1g	Others specify			

31. What are the causes of the change in rainfall distribution? Use the scale 3= Agree,

2=Disagree, 1= Not sure

S/No	Causes of changes in rainfall distribution	3	2	1
1a	Emission of Green House Gasses from human activities			
1b	Movement of air mass			
1c	Changes in wind direction			
1d	Others specify			

K. COPING STRATEGIES AGAINST CHANGES IN RAINFALL AMOUNT AND DISTRIBUTION

32. What are the coping strategies you use against changes in rainfall amount and distribution? Use the scale 2= Yes, 1= No

M1 Coping strategies

s/n	Coping strategies	2	1
1a	Changing planting date		
1b	Replanting the common bean		
1c	Planting quick maturing common bean variety		
1d	Deep ploughing		

1e	Split date planting		
1f	Others (specify)		

L. Relationship between Changes in Temperature and Common Bean Yield

33. Do you agree that changes in temperature cause changes in yield of common Bean?

1. Yes ( ) 2. No ( ) 3. Not sure ( )

34. How do changes in temperature affect yield of the common bean? Use the scale 3= Agree, 2= Disagree, 1= Not sure

S/No	**Effects of changes in temperature**	**3**	**2**	**1**
1a	Increase occurrence of pests and diseases			
1b	Fasten the maturity of the common bean			
1c	Cause excessive loss of water from the plant			
1d	Cause stunting of the crop			
1e	Others specify			

M. Relationship between Changes in Rainfall Amount, Distribution on Common Bean Yield

35. Do you agree that the change in rainfall amount and distribution cause changes in yield of common Bean?

1. Yes ( ) 2. No ( ) 3. Not sure ( )

36. How do changes in rainfall amount and distribution affect yield of the common bean? Use the scale 3= Agree, 2= Disagree, 1= Not sure

S/No	**Effects of changes in rainfall amount**	**3**	**2**	**1**
1a	Increased occurrence of crop pests and diseases			
1b	Rotting of mature beans in the garden			
1c	Excessive bushy growth with few pods			
1d	Cause stunting of the crop			
1e	Others specify			

THANK YOU

APPENDIX III

Key Informant Interview Guide for Agricultural Extension and Meteorological Officers

Sources of information on changes in temperature and rainfall variability to farmers

(a) Changes in temperature

- (i) Causes of the change in temperature
- (ii) Indicators of change in temperature
- (iii) Coping strategies to changes in temperature.
- (iv) Relationship between change in temperature and common bean yield

(b) Changes in rainfall amount

- (i) Indicators of changes in rainfall amount
- (ii) Cause of the changes in rainfall amount
- (iii) Perceptions on changes in rainfall distribution

(c) Description of rainfall distribution on common bean yield

- (i) Causes of changes in rainfall distribution
- (ii) Indicators of changes in rainfall distribution
- (iii) Coping strategies against changes in rainfall amount and distribution
- (iv) Relationship between changes in rainfall amount, distribution, and common bean yield

THANK YOU

APPENDIX IV

Focus Group Discussion Guide for Common Bean Smallholder Farmers

B. Perceptions on Changes in Temperature

1. Have you noticed any change in temperature in the last 5 years? If **yes**, describe the change?
2. How long have the changes occurred?
3. What are the causes of the changes in temperature?

C. Perceptions on Indicators of Changes in Temperature

1. What are the indicators of changes in temperature?
2. How do you cope with the changes in temperature?

D. Changes in Rainfall Amount

1. Have you noticed any change in rainfall in the last 5 years? If, **yes**, describe the amount?
2. What are the most common indicators of changes in rainfall amount?

3. What are the causes of changes in rainfall amount?

E. Changes in Rainfall Distribution

1. Do you agree that the rainfall pattern has changed? If, **yes**, describe the change?
2. What are the most common indicators of changes in rainfall pattern?

3. What are the causes of changes in rainfall pattern?

F. Relationship Between Changes in Temperature and Common Bean Yield

1. Do you agree that changes in temperature cause changes in yield of common Bean?
2. How do the changes in temperature affect the growing of the common bean?

G. Relationship between Changes in Rainfall Amount, Distribution and Common Bean Yield

1. Do you agree that changes in rainfall amount and distribution cause changes in yield of common Bean?
2. How do the changes in rainfall amount and distribution affect the growing of the common bean?

H. Sources of Water for the Common Bean

1. What is the major source of water for your common bean crop?
2. What is your other sources of water for growing common bean?

THANK YOU