Impact of Climate Change Adaptation Strategies on Food Security of Groundnut Farming Households in Yirol East County South Sudan

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By

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DEDICATION

First and foremost, this thesis is dedicated God Almighty, to my father James Achuoth Ahon, my mother Nyalual Bech Yor, and the entire family – my dear wife, Aluel Mabor Chuot, my children, and my siblings.

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DECLARATION

I, Makur James Achuoth hereby declare that the dissertation/thesis Title: "Impact of Climate Change Adaptation Strategies on Food Security of Groundnut Farming Households in Yirol East County", which I hereby submit for the degree of Doctor of Philosophy (Ph.D.) at the University of South Africa, is my own work and has not previously been submitted by me for a degree at this or any other institution.

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I declare that during my study I adhered to the Research Ethics Policy of the University of South Africa, received ethics approval for the duration of my study prior to the commencement of data gathering, and have not acted outside the approval conditions.

I declare that the content of my dissertation/thesis has been submitted through an electronic plagiarism detection program before the final submission for examination.

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ABBREVIATIONS

A/PFS	Agro-pastoral and Pastoral Field Schools
CA	Conservation Agriculture
CAADP	Comprehensive African Agricultural Development Plan
CAD	County Agriculture Department
CCAS	Climate Change Adaptation Strategies
CSA	Climate Smart Agriculture
CAMP	Comprehensive Agricultural Master Plan
CFSAM	Crop and Food Security Assessment Mission
COP	Conference of Parties
FAO	Food and Agriculture Organization
FCS	Food Consumption Score
FFS	Farmer Field Schools
FGD	Focused Group Discussion
GERICS	Climate Service Center Germany
HDDS	Household Dietary Diversity Score
INGO	International Non-Governmental Organization
IPC	Integrated Food Security Phase Classification

IPCC	International Panel on Climate Change
MHDAM	Ministry of Humanitarian Affairs and Disaster Management
NALEP	National Agricultural and Livestock Development Policy
NBHS	National Baseline and Household Survey
NNGO	National Non-Governmental Organization
PH	Post-Harvest
UN	United Nations
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WFP	World Food Programme

ABSTRACT

With projected temperatures rising higher than the rest of the world – and an increase in the occurrence of droughts, floods, and other natural disasters – the people, economy, and ecosystems of Africa are especially vulnerable to the effects of climate change. South Sudan is experiencing substantially warmer and drier weather, and the combination of these effects leads to increasing evapotranspiration and more droughts. The main purpose of this study was to identify adaptation strategies used by groundnut farmers in Yirol East County (District), assess the factors influencing the adoption of these adaptation strategies as well as evaluate the impact of adopted climate adaptation strategies on the household food security of groundnut farmers.Four payams (sub-d istricts) in Yirol East County namely; Adior, Malek, Pagarau, and Yali were targeted for data collection. A sample of 481 respondents was drawn from the total population of 113,052 farming households in the study area. Primary data were collected using structured and semi-structured questionnaires in kobo collect software and focused group discussion (FGD). In this study, objective one used descriptive statistics while objectives two, three, four, and five used inferential analysis from the sampled data. Objective six was analysed qualitatively. Findings of the descriptive statistics show that most of the participants were female as shown by 64.4% while the rest were male as shown by 35.6%. Most of the participants were in the age category ranging from 31 – 45 years as shown by 52.8% out of which 92.9% of the participants were married. However, the majority of groundnut farmers 82.7% had not attained basic education levels. Most of the respondents have been residence in a community for more than 11 years as shown by 60.1%, of which 55.9% with farming experience in years was more than 11 years.

The findings further show that there is a positive and significant relationship between good agricultural practices and distance to market ($r=0.443$; $p=0.000$), knowledge of climate change

adaptation strategy (r=0.286; p=0.000) as well as access to extension services (r=0.257; p=0.000), membership to farmers' group (r=0.294; p=0.000) as well as perceived change in droughts and floods (r=0.146; p=0.001). Other factors such as membership of the farmers' group (r=0.136; p=0.003) and perceived change in droughts and floods (r=0.186; p=0.000) have a positive and significant relationship with farm technology adopted by groundnut farmers in Yirol East County. Nevertheless, the study established that distance to market (r=0.462; p=0.000), knowledge of climate change adaptation strategy (r=0.359; p=0.000), access to extension services (r=0.250; p=0.000) and membership to farmers' group (r=0.432; p=0.000) have a positive and significant relationship with off-farm activities such as business, casual labour and formal employment. The study also revealed that gender of the farmer (r=0.100; p=0.028), experience in farming (r=0.098; p=0.032), length of residence in the community (r=1.000; p=0.000), access to climate and weather information (r=0.117; p=0.01) and perceived change in prevalence of diseases and pests (0.275; p=0.000) have a positive and significant relationship with livestock farming as climate change adaptation strategy. The research further shows that the decision to adopt climate change adaptation strategies (CCAS) is determined by farmers' age, sex, farming experience, farm size, farmers' income, and knowledge level. In addition, the findings showed that climate change adaptation strategies (CCAS) adoption has a significant relationship with food secure status and food insecure status of groundnut farming households. The research has found that four major socio-economic sectors (SES) which include livestock, water, agriculture, environment/forestry, and health care services in the study area are highly sensitive to the impacts of climate change due to high risks of extreme weather conditions.

In light of the findings of this study, a functional climate change adaptation framework was developed for groundnut farming households in Yirol East County but, could as well be used as a

reference tool by the government of the Republic of South Sudan, United Nations (UN) agencies, national and international non-governmental organizations (NNGOs/INGOs) in the country.

Keywords: State, County, Payam, Groundnut farmers, climate change adaptation, hazards, vulnerability, climate risks, and sensitivity.

CHAPTER ONE: INTRODUCTION

1.1 Background of study

Global climate change is a deviation in climatic conditions linked directly or indirectly to human actions that alter the composition of the global atmosphere and are in addition to natural climate variability observed over periods. The impacts of climate change are being felt across the world (Upadhyay, 2019). According to Upadhyay, climate change is a huge threat to all aspects of human development and the achievement of the Millennium Development Goals for poverty reduction. Potential climate change impacts include drought, decline of water quality, floods, changes in soil erosion and desertification, storms, coastal erosion, changes in seawater temperature and salinity, and biodiversity reduction (Balgis, 2010). While efforts to achieve the goals outlined in the 2030 Agenda for Sustainable Development and the Paris Agreement could drive positive changes following nearly a decade of economic growth across Africa, climate change threatens to derail these gains (UNDP, 2010). With projected temperatures rising higher than the rest of the world – and an increase in the occurrence of droughts, floods, and other natural disasters – the people, economy, and ecosystems of Africa are especially vulnerable to the effects of climate change (UNDP, 2010).

Compared with developed nations, developing countries are more vulnerable to climate change (CC) and its variability (Ankrah Twumasi and Jiang, 2021). The projections made in several studies in terms of variations in climatic conditions depict that the rate of incidence and magnitude of some severe climatic events and disasters, including extreme weather events, droughts, floods, rising sea levels, and storms, are more likely to increase (World Bank 2011; Field *et al.* 2012; Twumasi and Jiang, 2020, Ankrah Twumasi and Jiang, 2021,).

Climate change is viewed as one of the gravest threats to the future of humanity. This perspective is accepted in developed countries, which are already committed to policies that take account of climate change at both national and local levels (Niang, 2007). (Levina and Tirpak, 2006) affirmed that methods to assess accrued benefits or avoided damages of adaptation measures are still very much under development. In the recent past, vulnerability measures have been used extensively in interdisciplinary research to explain the degree to which a socio-economic and environmental system suffers from climate change. The popular measure of vulnerability at the earlier stage of theoretical development has been based upon the scientific simulation of economic loss from climate impacts on biophysical conditions of the environment (Ludeña *et al.*, 2015). (Verburg *et al.*, 2010) have emphasized that without appropriate responses, climate change is likely to constrain economic development and poverty reduction efforts and exacerbate already pressing difficulties. Promoting increased resilience to the impacts of climate change is closely intertwined with development choices and actions that cover a variety of sectors, such as energy, agriculture, health, water, and infrastructure. In particular, it is essential to consider both the synergies and trade-offs between adaptation and mitigation activities, including possible negative and positive side effects (UNDP, 2010).

Looking to the future climate in South Sudan, the country's inherent vulnerability will increase with the expected changes in rainfall and temperature. Agricultural production, livestock, and forest resources are expected to be impacted by higher temperatures, while both drought and flooding have negative implications for these activities (UNEP Global Environment Alert Service, 2011, Consequences, 2011). The Inter-governmental Panel on Climate Change (IPCC, 2007), (UNDP, 2010) projections indicate that South Sudan's warming average will be felt 2 ½ times more than the global average by 2050. Climate variability adds a new dimension by substantially increasing the frequency and intensity of existing climatic events such as floods, droughts, and storms (Ajak, 2018, Trenberth, 2005).

South Sudan is experiencing substantially warmer and drier weather, and the combination of these effects leads to increasing evapotranspiration and more droughts. Since 1980, decreasing rainfall has been accompanied by rapid increases in temperature on the order of more than 1°C. This warming, which is two and a half times greater than global warming, is making 'normal' years effectively drier (The Global Environment Facility and UNO Environment, 2018). Average temperatures have increased by around 1-1.5°C since the 1970s, Climate Service Center Germany. South Sudan is affected by climate-induced disasters such as frequent flooding and droughts. The country has registered a decrease in rainfall ranging from 10 to 20 percent since the mid-1970s (Ndakaza *et al.*, 2016). Furthermore, a substantial increase in temperatures has occurred over the past 30 years with the central and southern regions experiencing some of the highest rates of warming in the world (0.4°C per decade).

In South Sudan, groundnut is the most commonly grown type of bean/pea with 33 percent of agricultural households reporting planting some groundnut (NBHS, 2009). Groundnuts, also known as peanuts, play a significant role in South Sudan's agricultural sector, contributing approximately 15% to the national GDP. The agricultural sector employs around 80% of the population, highlighting its importance as a primary livelihood source for many households in the country. While groundnuts are grown in all states (Provinces), the FAO/WFP special report (Security, Republic and South, 2024) shows that the percentage of cultivated area varies: 36 percent in Lakes, 30 percent in Western Bahr-El-Ghazal, 27 percent in Northern Bahr-El-Ghazal, 23 percent in Central Equatoria, 20 percent in Warrap and 16 percent in Western Equatoria. Groundnuts, mainly Red Beauty and Mr. Lake varieties, are usually cultivated on sandier soils and, after cereals; they represent the most important contribution to the households' diets in these areas, where they are also the main cash crop (Special Report – 2021, FAO/WFP, 2022).

According to the FAO/WFP report, groundnuts and cassava are the two major non-cereal crops grown in the country. Groundnuts, with a short growing season and the possibility to be used as both staple and cash crops, are an important safety net crop for farming households in the northern states where cassava does not grow. Groundnuts are also a major cash crop for farmers, especially in southern cropping areas where the longer rainy season allows for two harvests per year (Special Report - 2021 FAO/WFP, 2022). Particularly in Lakes, Central Equatoria, and Northern Bahr-El-Ghazal, groundnut is an important cash crop, but the crop is widely cultivated across all regions of the country.

1.2 Problem Statement

South Sudan has experienced changing climate conditions and weather patterns over the past several decades. Average temperatures have increased by around 1-1.5°C since the 1970s (GERICS 2015, USAID 2016a, UNEP 2018, PREPdata 2018 (USAID, 2019). While temperatures have already increased since the 1950s, the rate of increase has increased significantly in the past three to four decades. The increase in maximum temperatures is slightly higher than the increase in average temperatures, elevating the incidence of extreme heat conditions. According to South Sudan's Nationally Determined Contribution Report (2021), GHG emissions from domestic production are mostly from the agriculture and livestock sectors, followed by the petroleum and service sectors. In terms of resource consumption, industry and hotels, restaurants, and other service sectors account for the greatest amount of GHG emissions, along with the agriculture and livestock sectors. A gradual increase of GHG emissions has been observed over the years in South Sudan, from both a domestic production and resource consumption perspective. Emissions due to domestic production and resource consumption have been increasing at rates of 1.22 percent and 1.14 percent per annum, respectively. The slow rise in GHG emissions over the years parallels South Sudan's slow economic and population growth (The Republic of South Sudan, 2021). The change in weather patterns and resulting impacts on the environment affect agricultural yield and livelihoods of the communities especially in Jubek State of South Sudan. For decades now, these effects have been occurring due to greenhouse gases (GHG) accumulated in the atmosphere leading to increased records of atmospheric air temperature and changes in rainfall patterns (Achuk, Koske and Gathuru, 2022).

In a country like South Sudan, about 83% of the population depends on agricultural direct livelihood that is livestock keeping (pastoral) and cropping which heavily rely on rainfall. This has made South Sudan more vulnerable to climatic variations and, hence economic productivity constraints (Achuk, Koske and Gathuru, 2022). However, the Buenos Aires program of work adopted at COP 10 emphasizes the further implementation of specific activities that would enhance countries' understanding of climate change impacts, their specific vulnerabilities, and their ability to cope with and adapt to climate change (Levina and Tirpak, 2006).

In this study, an attempt has been made to investigate the impact of existing climate change adaptation strategies on groundnut performance as used by local groundnut farming households in the study area. However, more future research will be required in this area since an impact cannot technically be adequately assessed in one study. Groundnut (*Arachis hypogaea L.*), also known as peanut, is an important crop for Smallholder farmers in Africa, providing both food and cash income.

In addition to the negative impacts of the protracted conflict, communities in South Sudan are also experiencing the negative effects of a changing climate (The Global Environment Facility and UNO Environment, 2018). However, despite the myriad of challenges, little attempt or no concerted efforts is made by the government of the Republic of South Sudan to evaluate the effects of climate change on rural households as well as identify and evaluate the impact of adopted climate change strategies by local farmers, though some of the adaptation strategies are in the process of being implemented.

1.3 Significance of Study

Although there are no existing records currently that show any research conducted in South Sudan, more specifically on the impacts of climate change on groundnut farming households in South Sudan, it is apparent that groundnut farmers are among the most affected by climate variability, which is associated with decreased groundnut yield. This phenomenon is, therefore, the motivation behind this study to identify adaptation strategies used by groundnut farmers in Yirol East County (District), assess the factors influencing the adoption of these adaptation strategies as well as evaluate the impact of adopted climate adaptation strategies on the household food security of groundnut farmers. Besides the aforementioned key objectives, the ultimate aim of this study is to develop a functional climate change adaptation framework not only for groundnut farming households in Yirol East County but also for use by the government of the Republic of South

Sudan, United Nations (UN) agencies, national and international non-governmental organizations (NNGOs/INGOs) in the country.

1.4 Gaps/Originality of the study and Contribution to the body of knowledge

Abundant research has been conducted concerning the characteristics of smallholder farmers in Africa and sub-Saharan Africa. However, there is limited research on the characteristics of groundnut farmers in the Eastern African region and South Sudan in particular (Sinare *et al.,* 2021). Moreover, few studies have focused on the impacts of adaptation strategies on crop produc tivity and food security (Diallo et al., 2020). Further research has gaps in knowledge that needs to be filled, lack of government support, inadequate extension service and low income (Ajayi 2020). (Berhanu and Wolde, 2019) further highlighted lack of knowledge and input, and low levels of investment in infrastructure and irrigation. In addition, though the government of the Republic of South Sudan, together with humanitarian agencies had always used an integrated food security phase classification (IPC) to determine household food security status based on the scale and severity of acute food insecurity proxy indicators, it has not been sufficient enough to address the challenges and accurately determine food security status of particular groups such as groundnut farming households. Conceptually, the study developed a localized, crop-specific Climate Change Adaptation Framework for groundnut farming households in Yirol East County that integrates ecosystem services, socio-economic sectors, vulnerability/sensitivity, risk, institutional adaptive capacity, and adaptation options. The conceptual framework further demonstrated how ecosystem-based adaptation, livelihood resilience, and institutional governance can be operationally combined into a single framework suitable for fragile and conflict-affected agricultural systems. This particular framework has filled a conceptual gap by shifting from generic agricultural adaptation models to a context-specific, empirically grounded framework tailored to a single commodity and socio-ecological setting. Further, the study introduced a replicable, participatory methodology for adaptation planning in data-scarce settings by combining Grounded Theory, Focus Group Discussions (FGDs), and the Constant Comparative Method (CCM). During focus group discussion, the study developed and applied a six-step analytical sequence (ecosystem service identification, vulnerability assessment, risk assessment, institutional analysis, adaptation option identification, framework synthesis) that can be transferred to other climate-vulnerable regions. The study further demonstrated the value of inductive, stakeholder-driven theory generation for producing operational adaptation frameworks where quantitative datasets are limited. Empirically, the findings of this research enabled not only the documentation of distinctive characteristics of groundnut farmers in Yirol East County but also articulated climate change adaptation strategies used by groundnut farmers in Yirol East County. It is, therefore, speculated that the findings of this research will address existing gaps in terms of the food security status of groundnut farming households in Yirol East County. Not only that, but the wealth of information also generated by this research will further be used as a valuable reference tool by the government, research partners, and other humanitarian agencies in the country.

1.5 Research aims and objectives

The study aimed to assess the impact of climate change adaptation strategies on the household food security of groundnut farmers in Yirol East County (District) and develop an adaptation framework that if implemented will help improve the output, income, and food security of the groundnut farmers in the study area.

1.5.1 Specific objectives

(i). The specific objectives of the study were:

(ii). To assess the socio-economic and demographic factors influencing the level of climate change awareness among the groundnut farmers in Yirol East County (District).

(iii). To identify the climate change adaptation strategies used by groundnut farmers in Yirol East County (District).

(iv). To analyse the socio-economic and institutional factors influencing the adoption of climate change adaptation strategies among groundnut farmers Yirol East County (District).

(v). To examine the relationship between climate change adaptation strategies and household food security among groundnut farmers in Yirol East County (District).

(vi). To assess the food security conditions of groundnut farming households in relation to climate variability and adaptation practices.

(vii). To develop a localized climate change adaptation framework which if implemented would improve agricultural productivity, household income, community resilience, adaptive capacity, and sustainable food security of groundnut farming households in Yirol East County.

1.6 Research questions

The research hypothesis sought to answer the following research questions:

(i). What are the socio-economic and demographic factors influencing the level of climate change awareness among the groundnut farmers in Yirol East County (District)?

(ii). What are the climate change adaptation strategies used by groundnut farmers in Yirol East County (District)?

(iii). What are the determining factors of climate change adaptation strategies used by groundnut farmers in Yirol East County (District)?

(iv). What is the impact of climate change adaptation strategies on the household food security of groundnut farmers in Yirol East County (District)?

(v). What is the food security status of the groundnut farmers in Yirol East County (District)?

(vi). Is there any existing climate change adaptation framework to help improve the output and income of the groundnut farmers in the study area?

1.7 Limitations and delimitations

1.7.1 Limitations

The limitation of this study is the fact that focused group discussion (FGD) for the development of climate change adaptation framework was conducted only with stakeholders from the concerned national ministries in Juba, the capital city of South Sudan, and thus, rural groundnut farmers from the study sites only participated in the general survey. However, although the FGDs were limited to national-level stakeholders, the study remains valuable because it integrates policy perspectives with empirical data from groundnut farmers. The use of household survey data ensures that the findings are grounded in local realities and still provide relevant, context-specific insights for decision-making.

1.7.2 Delimitations

The choice of groundnut crop as the major focus of this study was influenced by the fact that despite sorghum being a leading staple food crop (leading cereal crop) in the study area, groundnut (legume) as a second major food crop is rapidly gaining momentum in terms of its commercialization as a cash crop in the study area.

1.8 Definitions

Ecosystems services (ES): In the context of this research include; agriculture (crops and livestock), fisheries, forest, fresh water, nutrient cycling, soil formation, climate regulation, pest regulation, pest control, and nutrition.

Socio-economic sectors (SES): in Yirol East County and/or in South Sudan, these sectors include agriculture, Forestry, fisheries, livestock, public health, and education facilities among others.

Vulnerability: This can be considered as a function of risk, danger levels, level of exposure, or adaptive responses available. One can also distinguish between:

Biophysical Vulnerability – Focuses on the ecological processes related to vulnerability, namely the susceptibility and exposure to environmental changes –Indicators to measure this type of vulnerability include extended growth period, wet/dry season, risk of flooding, etc.

Social Vulnerability – Focuses on the political, socio-economic, cultural, and institutional aspects of vulnerability – Indicators to measure this type of vulnerability include education levels, income, poverty rate, social capital, extent of livelihood diversification, land, etc.

Risk = likelihood × consequence*:* The likelihood refers to the probability of a projected impact occurring, and consequence refers to the known or estimated outcomes of a particular climate change impact Some of the related risks manifest through major extreme weather events such as drought, floods, wildfires, and heat waves.

Adaptive Capacity: The ability of a system to adjust in response to projected or actual changes in climate. While assessing the sensitivity of ES-SES to the impacts and/or the potential impacts of climate change on the household food security of rural farmers, the adaptive capacities of groundnut farmers are also assessed.

Adaptation: Is a process by which strategies to moderate, cope with, and take advantage of the consequences of climatic events are enhanced, developed, and implemented.

Adaptation Policy Framework*:* Is a structured process for developing adaptation strategies, policies, and measures to enhance and ensure human development in the face of climate change, including climate variability.

Adaptive-capacity approach*:* Is one of several conceptual and analytical approaches that can be applied to adaptation projects.

1.9 Conceptual framework

The conceptual framework integrates the Sustainable Livelihoods Approach (for vulnerability/resilience dynamics, (Serrat, 2017) with Sen's Entitlement Theory (for food access, (Devereux, 2001) and Resilience Theory (for adaptive capacity, (Van Breda, 2001), all grounded in climate adaptation theory, (Malloy *et al.*, 2020) and the FAO food security framework, (Ecker and Breisinger, 2012). Nevertheless, a simplified conceptual framework developed for this study is based on the six main climate change adaptation strategies adopted by rural farmers in the study area. This conceptual framework has two major outcomes.

Outcome 1: is that if a combination of two or more of the listed strategies is perceived to have a negative influence on household food security, the tangible result is reduced crop yield, subsequently resulting in increased household vulnerability.

Outcome 2: if a combination of two or more climate change adaptation strategies is perceived to have positive influence on household food security, the tangible result will be improved resilience, food availability, and access at the household level, which in turn results in an overall improvement in food security status at the household level. However, it is worth noting that despite the improved food security status of rural households as a result of notable climate change adaptation strategies, any further exposure to adverse effects of climate change may increase the household's vulnerability levels, hence, jeopardizing all the efforts that have been made to improve the household food security of the target rural populations, making the same households slide back to food insecure status once again (Figure 1).

The conceptual framework

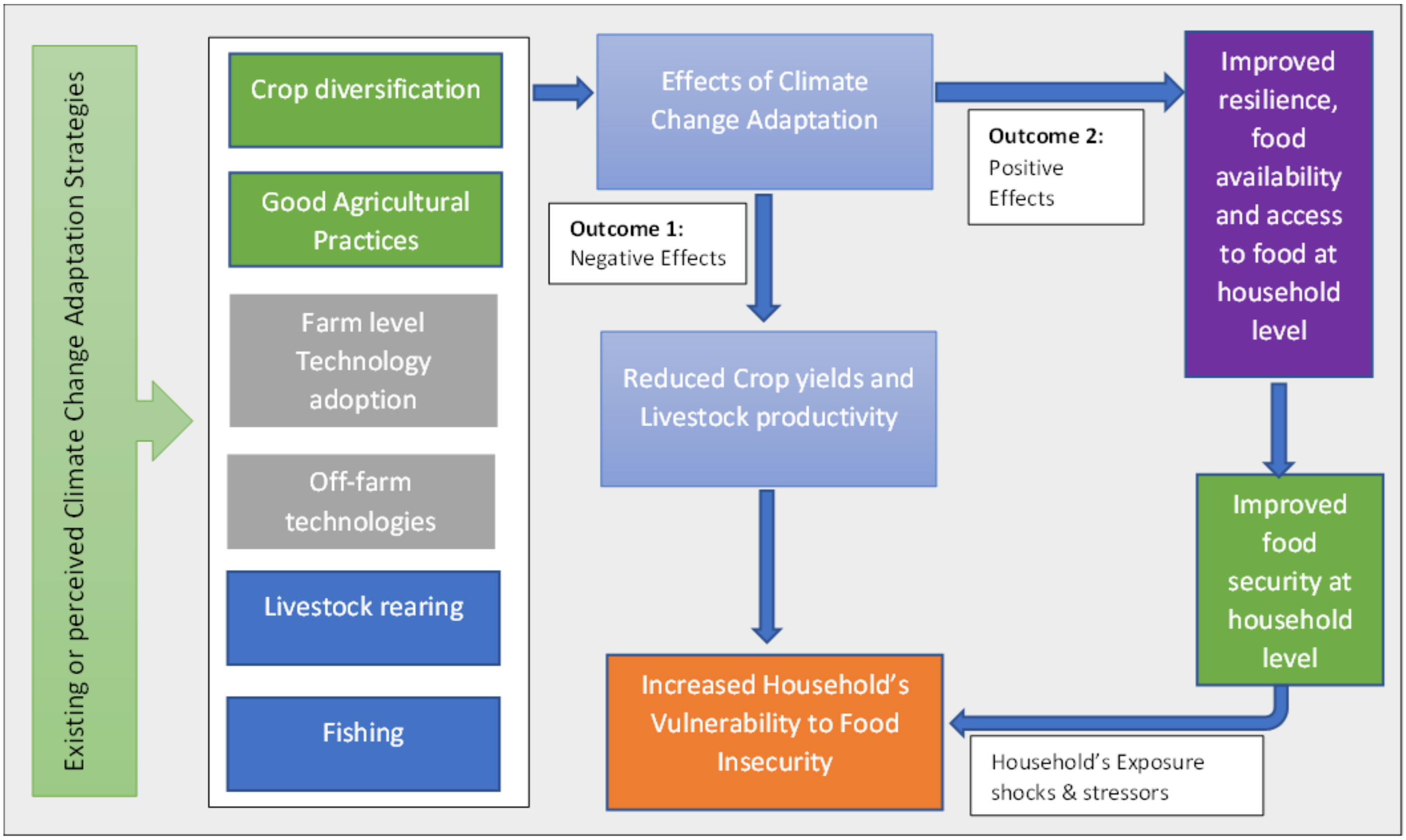

Figure 1. 1 Climate change adaptation strategies and their effects on household food security

1.10 Chapter arrangement in the thesis

In this research dissertation, the chapters and the sections are presented as follows:

Chapter 1. Introduction:

Presents the background information, statement of the problem, significance of the study, gaps/originality of the study, and contribution to the body of knowledge,

research objectives, research questions, limitations and delimitations, definitions, the conceptual framework, and finally, chapter arrangements.

Chapter 2. Review of the body of literature:

This chapter covers the literature review and the theoretical framework

Chapter 3. Research methodology:

This chapter discusses the introduction, description of the study area, study population and design, survey data, sampling, validity and reliability, data collection, data analysis, and ethical considerations.

Chapter 4. Results and Discussion

This chapter presents and discusses the results of data analysis as per the six research objectives

Chapter 5. Conclusion and Recommendations

This chapter presents the conclusion of the study based on the results of analysis and gives recommendations for further research activities.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The literature review in this study is informed by the objectives of the study. Research objectives were developed in such a way that each objective addresses a specific research question. In a nutshell, the body of literature has been thoroughly explored based on research objectives. This chapter on literature review briefly discusses the climate change adaptation strategies, factors that influenced the choice of climate change adaptation strategies by rural farmers, measuring the food security status, and finally the impact of climate change impact on the food security of rural households. The discussion in the literature review is summarized in the research's theoretical framework (Figure 2.1).

Earlier studies have shown that South Sudan has a remarkable potential for sustainable growth through agriculture. The agricultural sector plays a major role in South Sudan's economy, accounting for 36% of its non-oil gross domestic production with 80% of households depending on cultivation as their primary source of livelihood ('South Sudan Agricultural value chain – challenges and opportunities, 2020). Groundnuts are an important crop in South Sudan, both for food and cash. Groundnuts are cultivated in most of the states of South Sudan, although Western, Central, and Eastern Equatoria States are the top three groundnut-producing states. Groundnuts are traded in various forms and utilized for direct consumption and processing (Groundnut, Chain and Opportunities, 2013). Early research (UNDP, 2023) has shown that groundnuts, also known as peanuts, play a significant role in South Sudan's agricultural sector, which contributes approximately 15% to the national GDP. The agricultural sector employs around 80% of the population, highlighting its importance as a primary livelihood source for many households in the country (Maxwell and Santschi, 2012).

2.2 Theoretical Framework of the Study

The theoretical framework of the study is based on South Sudan's National Adaptation Programme of Action (NAPA, 2016), which articulates the contributing factors to the current vulnerability of local populations to climate variability (Figure 2.1). South Sudan's NAPA highlighted key contributing factors that include; warmer and drier weather conditions, agricultural practices that contribute to greenhouse gas emission, reduced rainfall, reliance on rain-fed subsistence agriculture, increased deforestation and soil erosion, reduced water quality and quantity, limited technical capacity to understand and predict climate change, and limited institutional capacity to cope with climate change. Effects of these contributing factors include reduced crop yields and livestock productivity, which eventually increases households' vulnerability to food insecurity. By adopting good agricultural practices, local households can be able to reverse the effects of climate variability through improved resilience and households' food security. This is congruent with findings of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change which concludes that increasing temperatures and changing precipitation patterns are already reducing agricultural productivity across many parts of Africa, particularly in regions dependent on rain-fed agriculture (IPCC, 2023). High levels of interannual rainfall variability and their effects on water resources in Africa can provide illustrative examples of climate–environment–society interactions. The most pronounced example of variability has been the multi-decade decline in rainfall over the Sahel where the 1961–90 average is about 25% drier than earlier decades (Hulme et al., 2001) with dramatic consequences for river flows in the region (Adger *et al.,* 2023). It is on the basis of these theories that this research has conceptualized the theoretical framework (Figure 2.1), leading to the development of localized climate adaptation framework for groundnut farming households in the study area (Figure 4.9).

The Theoretical Framework in this study (Figure 2.1) integrates four major theories that include National Adaptation Programme of Action (NAPA, 2016), vulnerability theory by (Gumel, 2022) which states that vulnerability comprises three components in the system i.e. System's exposure as an external component in form of climatic variability, the internal component or dimension in form of system's sensitivity, as well as system's adaptive capacity to that exposure and sensitivity, adaptive capacity theory that links exposure and sensitivity of the system with adaptive capacity of local communities and systems (Engle and Nathan, 2011) and finally, the sustainable livelihood theory (Badewa and Dinbabo, 2023). The SLA is a participatory framework premised on the recognition of human capabilities and assets that should be supported through interventions to improve the quality of life. Its human centered approach to livelihoods complexities identifies areas of intervention, with a specific focus on assets, strategies, and outcomes toward improving the quality of life.

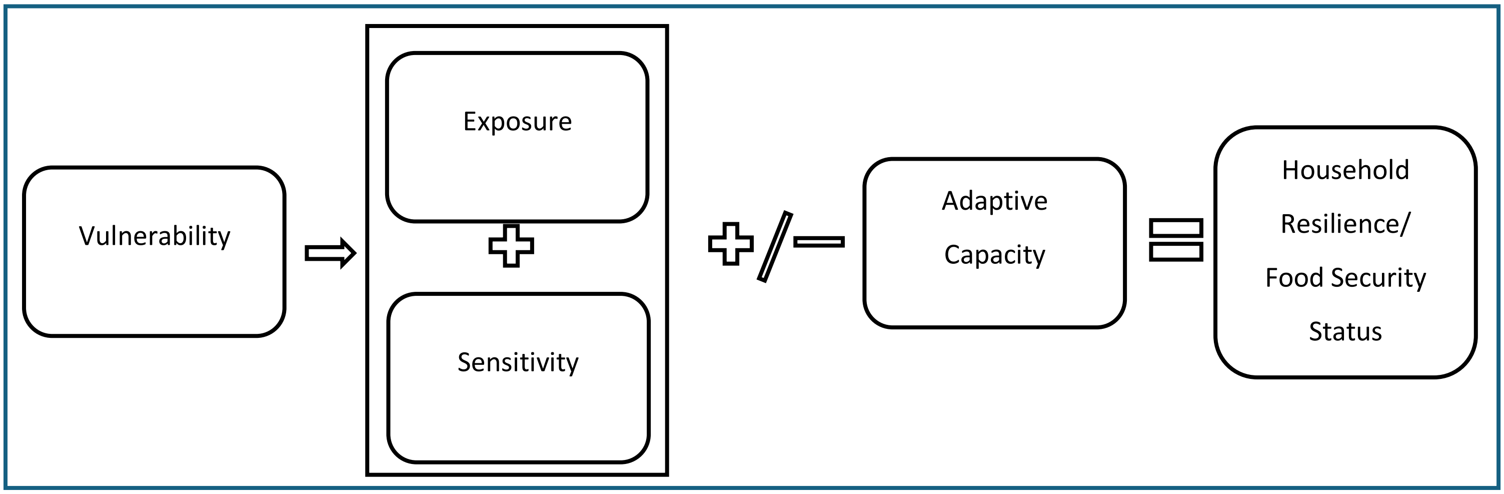

Figure 2. 1 Theoretical framework showing contributing factors influencing the current household's vulnerability to climate variability.

2.3 Socio-Economic Characteristics of Rural Farmers

(FAO, 2016) noted that about two-thirds of the developing world's 3 billion rural people live in about 475 million small farm households, working on land plots smaller than 2 hectares. In Latin American countries, smallholder farms often tend to be over 2 hectares, as in Nicaragua where the average small farm size is 5 hectares. But this is not always the case. In the Plurinational State of Bolivia, small farmers cultivate on average, 0.89 hectares (FAO, 2015).

In Africa, smallholder farms can be relatively larger, but only marginally. In many low-income countries in sub-Saharan Africa, agriculture continues to generate between 20 and 50 percent of the gross domestic product (GDP) and thus agriculture remains central to the growth process in many countries (Proctor, 2014). Arguably, farming methods are still largely traditional, partly because farmers lack finance modern agricultural technology, and know-how to inject into their farming-related activities (Otekhile and Verter, 2017). Kenyan smallholders farm 0.47 hectares and in Ethiopia the average small farm size is 0.9 hectares (Proctor, 2014). Smallholder families live on farms, which in many countries are significantly smaller than 2 hectares. The average size of a smallholder farm in Bangladesh and Vietnam is 0.24 and 0.32 hectares respectively. In South Sudan, the cultivated average area for sorghum ranges from 0.38 hectares to 0.49 hectares, while the groundnut area ranges from 0.48 to 0.59 ha (Security, Republic and South, 2024). Such patterns are very important in understanding influence of the socio-economic factors on farmers' ability to adopt certain range of climate adaptation strategies, especially in the context of developing and low-income countries like South Sudan. The small subsistence farm sizes or land holdings with limited or no farm technologies reduce the farmers' choices to adopt a varied number of climate change adaptation strategies so as to enable them cope with adverse effects of climate variability and change climate change, subsequently resulting in protracted food insecurity at household levels. According to the Food and Agriculture Organization, many are poor and food insecure and have limited access to markets and services. However, many rural areas become socio-economically more attractive when young farmers and new businesses are encouraged to set up, thus reinforcing a virtuous cycle of development (European Commission, 2017). Nevertheless, off-farm activities such as small businesses enhance farmers' ability to adopt a variety of climate change adaptation strategies at farm level. On the contrary, small farms are treated as an unwanted phenomenon and as impediments to rural growth. They are seen to have low efficiency and productivity, with weak integration into markets, which results in insufficient household income (Borychowski *et al.*, 2020). This too affects rural farmers' ability to adapt to new climate change adaptation technologies especially in the developing world and sub-Saharan Africa in general.

2.4 Climate Adaptation Strategies

Adaptation is a process by which individuals, communities, and countries seek to cope with the consequences of climate change (Ebi, Lim, and Aguilar, 2004). Adaptation is adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. Adaptation is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and adaptation, private and public adaptation, and autonomous and planned adaptation (Levina and Tirpak, 2006). Adaptation to the adverse impacts of climate change is urgent and indispensable to safeguard development gains and to address the needs of the poor and the vulnerable (UNDP, 2010). (Verburg *et al.*, 2010) indicated that changing climate and weather patterns are predicted to have severe negative impacts on food production, food security, and natural resources. Without appropriate responses, climate change is likely to constrain economic development and poverty reduction efforts and exacerbate already pressing difficulties. Especially countries with economies rooted in climate-sensitive sectors such as agriculture, fisheries, and forestry are expected to be hit hardest (Verburg *et al.*, 2010).

Effective adaptation requires an approach that incorporates both policy and investment issues into the planning and decision-making processes. However, no one solution will adequately address effective adaptation, including market forces (UNDP, 2010). Since the conference of parties number 7 (COP 7), when three specific funds were created to support the implementation of various measures that facilitate vulnerability assessment and adaptation, adaptation has become an increasingly important component of the international climate change dialogue. The Buenos Aires program of work adopted at COP 10 emphasizes the further implementation of specific activities that would enhance countries' understanding of climate change impacts, their specific vulnerabilities, and their ability to cope with and adapt to climate change (Levina and Tirpak, 2006). Investments in risk-based actions are fundamental to reducing the environmental, social, and economic costs of climate change. In its Fourth Assessment Report, the IPCC (2007) recognizes that some adaptation is occurring, but on a very limited basis, and affirms the need for extensive adaptation across nations and economic sectors to address impacts and reduce vulnerability (Balgis, 2010).

Climate-induced risks are critical for both EA and SA as these regions represent the last frontiers of global poverty, with large populations and recent economic development. This makes adaptation critical to safeguard agricultural production and diminish the adverse impacts of climate change on farmers' livelihoods. Studies in both regions show that adoption of adaptation strategies depends on numerous factors, including economic, social, political, and institutional environments (Asia *et al.*, 2021). Adaptation is becoming increasingly important in climate negotiations and implementation, and integral to the fifth assessment report (AR5) are the terms incremental and transformational adaptation—sometimes referred to as a "paradigm shift" as in the Green Climate Fund Governing Instrument (FAO, 2022). Incremental adaptation refers to actions where the central aim is to maintain the essence and integrity of the existing technological, institutional, governance, and value systems, such as through adjustments to cropping systems via new varieties, changing planting times, or using more efficient irrigation (Noble *et al.*, 2015). In this study, climate adaptation by rural farmers is associated with adoption of good agricultural practices (GAPs), use of off-farm technologies and institutional capacity strengthening.

2.5 Factors influencing the choices of climate change adaptation strategies

A study conducted by (Ojo and Baiyegunhi, 2018), shows that access to credit is a major determinant in the adoption of adaptation strategies; about 57% of the sampled households had access to credit. Farmers may thus be aware of climate change, but the degree of awareness of its short and long-term causes and consequences may vary among the farmers. In the same vein, some farmers may not perceive climate change and its effects while others may not be bothered. For example, age, low level of education, ignorance, lack of information; lack of credit facilities, and off-farm activities could be the reasons for farmers' low level of perception of climate change (Ojo and Baiyegunhi, 2018). Access to institutional facilities such as timely support from extension services, farmer cooperatives, and government and non-governmental organizations, along with the knowledge of adaptation options, largely determines the choice of adaptation strategies. Social factors such as gender can fundamentally govern the choice of adaptation strategies (Asia *et al.*, 2021).

Previous studies have concentrated on determinants of adaptation strategies rather than integrating mitigation measures practiced by farmers. Existing studies about determinants of climate change adaptation in Ethiopia are limited to verifying the effects of socio-demographic and economic variables of adaptation strategies (Regasa and Akirso, 2019).

2.6. Measuring Food Security Status of Rural Farmers

Food and nutrition security is the realization of everyone’s right to regular and permanent access to food of good quality, in sufficient quantity, without compromising access to other basic needs, and based on food practices that promote health respect cultural diversity, and are environmentally, culturally, economically, and socially sustainable (Gubert *et al.*, 2010). Two components of food security are availability (through domestic production, storage, and or trade), and food accessibility (through home production or purchase in the market) (Mbukwa, 2013). The Food Consumption Score (FCS), a tool developed by WFP, is commonly used as a proxy indicator for access to food. It is a weighted score based on dietary diversity, food frequency and the nutritional importance of food groups consumed (Ndakaza *et al.*, 2016). Food security status can also be measured using the Household Dietary Diversity Score (HDDS). According to (Ngema, Sibanda and Musemwa, 2018), the Household Dietary Diversity Score (HDDS) is the number of food groups consumed over a given reference period. This is an attractive proxy indicator.

2.7. Impact of Climate Change on Household Food Security of Rural Farmers

Major impacts of climate change on agriculture are consequences of temperature increase, changes in rainfall patterns, and increases in the levels of CO_2 within the atmosphere (Bosire *et al.*, 2018). According to (McCarthy and Vlek, 2012), its long-term impact on food security and environmental sustainability is continuously gaining attention, particularly in Sub-Saharan Africa (SSA). This is partly because the potential impacts of CC on agriculture are highly uncertain. The process of global warming shows no signs of abating and is expected to bring about long-term changes in weather conditions. These changes will have serious impacts on the four dimensions of food security: food availability, food accessibility, food utilization, and food system stability. Although rapid improvements in agricultural productivity and economic growth over the second half of the twentieth century brought food security to broad swaths of the developing world, other regions did not share in that success and remain no better off today – and in some cases worse off – than they were decades ago (Burke and Lobell, 2010).

Agriculture is highly exposed to climate change, as farming activities directly depend on climate conditions. The pattern of the effects of climate change is dependent on latitude, altitude, type of crop grown, and livestock reared (Rohat *et al.*, 2019).

Some direct impacts of climate change on agricultural systems include; seasonal changes in rainfall and temperature, which could impact agro-climatic conditions, altering growing seasons, planting and harvesting calendars, water availability, pest, and disease populations; alteration in evapotranspiration, photosynthesis, and biomass production; and alteration in land suitability for agricultural production. (Hailegiorgis, Crooks and Cioffi-Revilla, 2018). High variation in environmental factors such as temperature, rainfall, and others affect crop growth negatively and certain crops get positively affected due to changes in environmental factors.

Global atmospheric concentrations of CO_2, CH_4, and N_2O have increased markedly due to industrialization (Human Activities) (Tian *et al.,* 2015). Atmospheric concentrations of CO_2, and CH_4, in 2005 exceeded the natural range over the last 650,000 years. IPCC has identified some relevant areas of concern as temperature changes. The IPCC assessment group further concluded that large-scale warming approximately 3.5°C and above, will increase the likelihood of rigorous, pervasive, and irreversible impacts which will be difficult for people to adapt (Ekah *et al.*, 2023).

The world's most vulnerable people depend on agriculture for their well-being, but climate change poses a serious threat to agricultural productivity in many countries because of rising sea levels, changes in rainfall patterns, and more extreme and frequent weather events (FAO, 2022).

Climate change has a serious and pervasive effect on our ecology, which can harm human health and food production. Health issues can augment death rates, have an impact on the food supply, and lower labor output (Edu, Fadiji and Osho-Lagunju, 2021) as cited in NOAA, (2021).

Climate change is intensifying food insecurity across sub-Saharan Africa, and leading to changes in yield and area growth, higher food prices, reduced calorie availability, and growing childhood malnutrition. Early research had projected the crop yield, especially in key staples, in the region to decline by 5–17% by 2050 due to rising temperatures and rainfall volatility. Successive weather shocks, such as droughts and floods, significantly raise food insecurity, particularly in countries where agricultural productivity is already below the global average (Okoronkwo *et al.*, no date).

The impact of climate change is felt all over the world, and smallholder farmers face more risks due to unpredictable weather patterns (Harvey *et al.,* 2018). Temperatures continue to rise in the world, and globally, median temperatures are estimated to rise by 4.1◦C by the end of the 21st century. Increases in temperature and other extreme climate events affect crop productivity (Ndiwa *et al.*, 2024), Climate change has arisen as a global concern with catastrophic consequences for agricultural livelihoods and rural people, ranging from droughts to floods, altering the supply, availability, quality, access, and stability of food systems. By 2050, climate change is anticipated to result in millions of people facing starvation, malnutrition, and poverty [5], with developing countries and small-scale farmers in Sub-Saharan Africa, such as Ethiopia, being particularly vulnerable due to their socioeconomic situations (Darge *et al.*, 2023)

Amongst others, climate change causes droughts, pest infestation, and low yield. To reduce the impact, small-scale farmers use traditional adaptation strategies. While adaptation is a locally specific issue, approaches used may differ significantly not only from one location to another but also from one farmer to another (Maiwashe and Khoza, 2023). The main climate change impacts related to water resources are increases in temperature, shifts in precipitation patterns and snow cover, an increase in the frequency of flooding and droughts, and an increase in evapotranspiration rate over continents and water bodies (Wellstead, 2023). In responding to the problem of climate change governments will need to act to change how societies produce and consume goods and services (Mendelsohn, 2006).

2.8. Chapter summary

This chapter presented a comprehensive review of the literature relevant to climate change adaptation strategies among rural farming households, with particular emphasis on groundnut farmers in Yirol East County, South Sudan. Guided by the study objectives, the review synthesized global, regional, and local evidence on climate change adaptation, moving from established knowledge to the specific contributions intended by the current study. The chapter critically examined existing empirical and theoretical literature, identified key research gaps, assessed methodological approaches used in previous studies, and highlighted areas requiring further investigation.

The review was organized into several key thematic areas, including the theoretical framework underpinning the study, the socioeconomic characteristics of rural farming households, climate change adaptation strategies, determinants of adaptation strategy choice, approaches to measuring household food security, and the effects of climate change on household food security. Through this analysis, the chapter established the conceptual and empirical foundation for the study and provided justification for the research focus. Overall, the literature reviewed adequately informed the study objectives, research questions, and methodological approach adopted in the investigation.

CHAPTER 3: METHODOLOGY

3.1. Introduction

This chapter presents the study area, research design, research methods, and data analysis procedures employed in the study. The data were analyzed using descriptive statistical techniques. A sample size of 396 respondents was drawn from a total population of 125,613 households, of which 113,052 (90%) were farming households. The chapter further discusses the primary data sources, data collection instruments, validity and reliability of the research instruments, focus group discussions, descriptive and inferential analyses, the ordered logistic regression model, and ethical clearance procedures adopted in the study.

3.2 Study area

The research was conducted in Yirol East County of Lakes State of South Sudan (Figure 2). Geographically, Yirol East County is an administrative area in Lakes State, South Sudan. The county borders Panyijar County in the North, Rumbek East County in the Northwest, Yirol West County in the West, Awerial County in the South, Bor South County in the Southeast, and Twic East County in the East. The County headquarters is in Nyang town.

Administrative map of Yirol East County

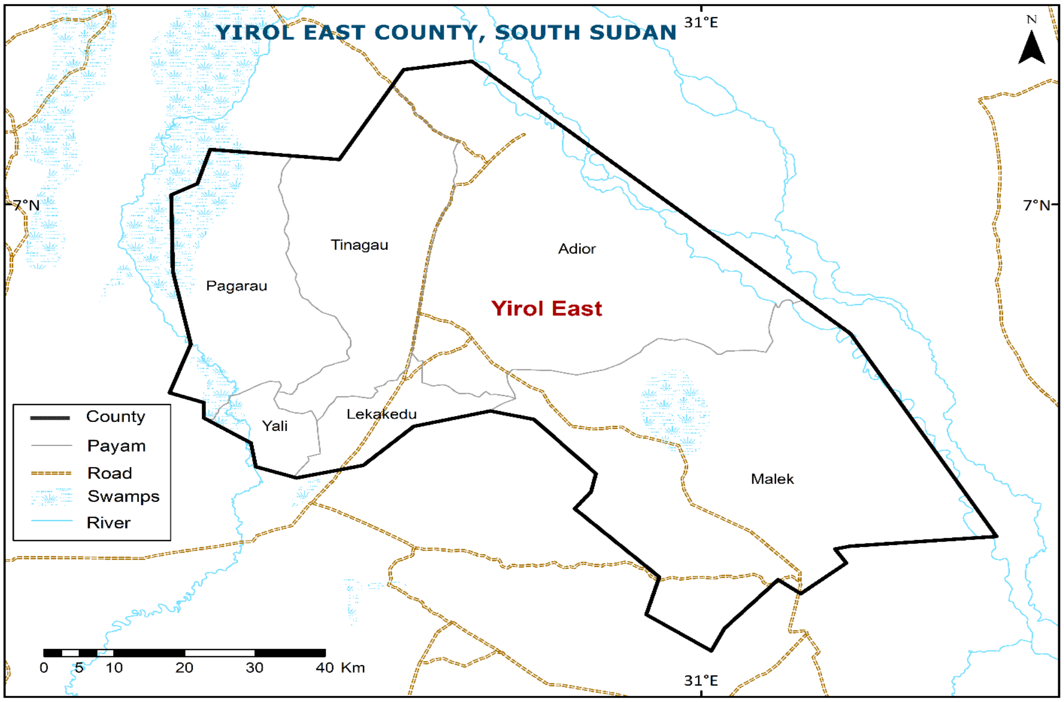

Figure 3. 1 Map of Lakes State showing four payams (study areas) in Yirol East County shaded with orange, green, light green and dark grey.

Based on the South Sudan Livelihood Zones map, (FEWSNET, 2013), Yirol East falls under livelihood zone two (02) known as "Iron stone plateau agro-pastoral". This livelihood zone is concentrated within the great Iron Stone plateau and covers parts of Bahr El Ghazal, Lakes, and Western and Central Equatoria States. The most important food crops are sorghum, millet, cowpeas, green gram, groundnut, sweet potatoes, and vegetables such as okra. Maize, cassava, and other crops such as pumpkins are grown on a small scale in specific areas. Cattle, goats, and a few sheep are the main livestock reared in this zone. Some poultry is also kept, but in very small numbers, for household consumption.

It lies at an altitude of 800 to 1,000 meters (2,600 to 3,300 ft) above sea level, with mountains in the southern part of the zone and a cover of acacia forest and scrub and deciduous broad-leaved woodlands. Shea butternut "lulu", mahogany, and bamboo are the main source of natural products available to local inhabitants. The zone has sandy clay soils, which are moderately fertile and tend to be shallower towards the north of the zone, with low water retention capacity; however, they do support a wide variety of crops. Average rainfall is about 1,100-1,300mm per annum, in a single season from March to November. The maximum temperature reaches 40° Celsius in March falling to about 19° Celsius in July.

3.3 Research design

According to (Akhtar, 2016), research design can be considered as the structure of research, it is the "Glue" that holds all the elements in a research project together, in short, it is a plan of the proposed research work. A research design is the arrangement of conditions for the collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy and procedure".

According to (Van der Merwe,1996), quantitative research is a research approach aimed at testing theories, determining facts, demonstrating relationships between variables, and predicting outcomes. Quantitative research uses methods from the natural sciences that are designed to ensure objectivity, generalizability, and reliability (Weinreich, 2009). On the other hand, "qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret phenomenon in terms of the meaning people bring to them" (Benzin and Lincoln, 2003).

In this study, both quantitative and qualitative research methodological choices were applied during the data collection and analysis processes.

3.4 Research methods

3.4.1. Population

Yirol East County is composed of six payams (Local municipalities) namely, Adior, Lekhakudu, Malek, Tinagau, Pagarau, and Yali. Based on an assessment of farming households by the Food and Agricultural Organization of the United Nations (FAO) in 2022, the population of Yirol East County is 125,613 households out of which 113,052 (90%) are farming households. The total population of groundnut farming households in the selected four payams (local municipalities) according to the County Crop Monitoring Committee (CCMC) report of 2021 is 48,865 (Table 1).

According to the FAO crops inventory report of 2021, groundnut production leads in Yirol East County, accounting for 39% of all crops grown under the traditional sector in the County. Based on the FAO assessment in 2021, ground nut covers 11,024 hectares of land compared to sorghum, which covers 10,459 hectares of land area. Four payams namely; Adior, Malek, Pagarau, and Yali will be covered by this study. The four payams have been selected because of (i) the presence of internally displaced people (IDPs) from neighboring states. The influx of IDPs exerts more pressure on meagre food resources of the host population and therefore worsens the food security situation in the area. This prompts local households to explore a range of climate change adaptation strategies to enhance crops productivity and (ii) Majority of farmers in these locations produce ground nuts as a second main crop after sorghum though there are little variations in terms of soil characteristics and weather changes, which slightly affect crops performance in each location.

3.4.2 Sample size of the study

3.4.2.1 Survey data

The sample for this study was drawn out of 48,865 groundnut-farming households as shown in the table below.

The sample population is calculated following Slovin's formula, written as;

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

Where, n is the sample size, "N" is the population size, and "e" is the level of precision, which is 0.05, the study population was drawn from selected payams. Inserting the population in the formula gave a sample size of 396 respondents to be selected for the study as shown in table 1 below. However, during the actual data collection exercise, a total of 481 households was interviewed in the selected four payams (Table 3.1).

Table 3. 1 Population of groundnut farming households in the selected Payams (local municipalities), sample size, and the actual number of respondents

S/N	Payam (Local municipality)	Population of groundnut farming households	Sample size	Percentage (%)	Actual # of respondents	Percentage (%)
1.	Pagaraau	10,700	87	22	56	12
2.	Yali	12,640	103	26	203	42
3.	Adior	14,815	119	30	151	31
4.	Malek	10,710	87	22	71	15
Total		**48,865**	**396**	**100**	**481**	**100**

3.4.2.2 Sampling techniques

In this study, systematic random sampling was used to obtain the sample number of households. As determined by Slovin's formula above, the proposed sample size was 396 households in four Payams. However, a total of 481 respondents (table 1, which is 21% above the initially proposed sample size) participated in the actual survey. Key reasons for larger sample size in this study include compensation for non-response and missing data, increased statistical power, increased reliability and more importantly, for better representation of population heterogeneity. Nevertheless, the County Agriculture Department (CAD) office shared a list of all households that are engaged in groundnut production in each of the selected Payams. During the field survey, the systematic random sampling procedures were as follows:

(i) The population size of each Payam was divided by the sample size of each Payam to get the sampling interval (SI). However, the sampling intervals varied from one Payam to another depending on the population of households in a given Payam.

(ii) To obtain a representative sample of respondents in each Payam, an enumerator randomly picked any number known as the random number (r) from the list for instance between 1 and 5 and started counting. If, for example, number 5 is picked as a random number, then, an enumerator counts from number 5 and picks the fifth household for the interview.

(iii) The sampling interval was added to the starting household to select the 2nd household, the sampling interval was again added to the 2nd household to select the 3rd household, and the process went on until the required number of households were interviewed.

NB: In some situations where the number of households in a particular Payam was less than the calculated sample size, all households in Payam were interviewed.

3.4.2.3 Primary data sources

Three main tools used to collect the data were questionnaires, designed in kobo collect software. The main type of questionnaire deployed in this study included a semi-structured individual interview questionnaire. The research questions addressed six objectives of this research, which mainly focused on adaptation strategies to climate change.

3.4.2.4 Data collection tool/ instrument

Semi-structured questionnaires in kobo collect software for personal interviews were used in this study to collect data. The structure of the questionnaire was informed by the research questions and specific objectives of the study. During the survey, a total number of 481 were interviewed by the selected Payams of Pagarau, Yali, Adior, and Malek. One enumerator was assigned to two locations. In this case, one enumerator covered Pagarau and Yali Payams which are close apart while the other enumerator covered Adior and Malek respectively. The data collection exercise covered ten (10) working days in December 2023. Both primary and secondary sources were used for data collection.

3.4.2.5 Validity and Reliability

According to Bannigan and Watson (2009), the validity is concerned with the meaning and interpretation of a scale while reliability is essentially concerned with 'error in measurement' (McDowell and Newell 1996, p. 37) i.e., how consistently or dependably does a measurement scale measure what it is supposed to be measuring (Polit & Hungler 1995). Validity is trying to explain the truth of research findings as explained by Zohrabi, (2013). According to Kubai (2019), Validity is measured using both theoretical and empirical evidence. Theoretical assessment is where an idea of a construct is translated or represented into an operational measure. In this study, the data collection instrument was validated by an expert in the field of agricultural economics to technically check the validity of the tool.

Concerning the reliability of data, Cronbach, 1951, as cited by Kubai (2019) defined reliability as a measure of consistency between different items of the same construct. It measures the consistency within the instrument and questions on how well a set of items measures a particular characteristic of the test. Single items within a test are correlated to estimate the coefficient of reliability. However, Dependability Audit was used to test the reliability for this study. The research data and proposal were shared with Influx Research Consultants who independently reviewed the entire research process, including research design, data collection procedures, interview guides, coding procedures and data analysis decisions

3.4.3 Focus Group Discussion

Besides the household survey, one focused group discussion (FGD) was held in Juba, the capital city of South Sudan. Purposive sampling was applied to select target participants for the Focus Group Discussion (FGD). FGD interview guide was developed – refer to Annex 3, section 5. Since survey data was collected from groundnut farmers in the field, the FGD targeted government officials in the concerned Directorates and from line Ministries concerned with policy formulation and enactment. A total of seven participants representing six technical institutions (Table 3.2.), were drawn from the national line ministries, one national university, one UN agency (FAO), and one national Non-Governmental Organization (NGO). These include the National Ministry of Agriculture and Food Security (MAFS), the Ministry of Humanitarian Affairs and Disaster Management (MHDAM), the Ministry of Environment and Forestry (MEF), the University of Upper Nile, the Food and Agriculture Organization of the United Nations (FAO) as a technical UN agency that supports the national government and one national non-governmental organization (NGO) the Capacity Development and Training Initiative (CDTI).

Table 3. 2 List of Focus Group participants

Name of institution	**No. of participants**
1. National Ministry of Environment and Forestry (MEF)	1
2. National Ministry of Agriculture and Food Security	1
3. Ministry of Humanitarian Affairs and Disaster Management (MHDAM)	2
4. Food and Agriculture Organization of the United Nations (FAO)	1
5. University of Upper Nile	1
6. Capacity Development and Training Initiative (CDTI)	1
Total	**7**

3.5 Data analysis

Before entering the data into appropriate statistical software such as Statistical Package for Social Sciences (SPSS) or STATA, the data were cleaned and coded. The research objectives informed the model of analysis and statistical software used for data analysis. Both quantitative and qualitative approaches were used to analyse data for survey data and FGD data respectively. The quantitative approach largely involved descriptive analysis while the qualitative approach mainly used thematic analysis.

3.5.1. Descriptive analysis

Descriptive statistics are used to summarize data in an organized manner by describing the relationship between variables in a sample or population (Vikas Yellapu, 2018). In this study, the Statistical Package for Social Science (SPSS) version 29 software was used for descriptive analysis. The data was summarized into frequency tables, graphs, and pie charts.

3.5.2. Inferential analysis

Inferential Statistics are all about generalizing from the sample to the population, i.e., the results of the analysis of the sample can be deducted to the larger population, from which the sample is taken. It is a convenient way to conclude the population when it is not possible to query every member of the universe (Rashid, 2021). In this study, objective one used descriptive statistics while objectives two, three, four, and five used inferential analysis from the sampled data. Data for objective six - development of the climate change adaptation framework for groundnut farming households was analysed qualitatively, deploying thematic analysis.

3.5.3 Measurements of the Research objectives

To assess the socio-economic and demographic factors influencing the level of climate change awareness among the groundnut farmers in Yirol East County.

A household questionnaire survey in Kobo collect software was used to collect relevant data on the socio-economic characteristics of groundnut farmers from the target respondents. During data analysis, using the Statistical Package for Social Science (SPSS) software, descriptive statistics was used to describe the socio-economic characteristics of groundnut farmers in Yirol East

County. In addition, computer software (STATA) was employed to run the ordered logistics regression model.

Ordered logistics regression model

The ordered logistics regression model (Liddell and Kruschke, 2018) was used to analyze the determinants of farmers' level of awareness of climate change and its impact in the study area. The ordered logistics regression model is deemed appropriate since the dependent variable is more than 2 options and is in ordinal form. The Likert scale was used to assess the level of awareness of climate change and its impact among the groundnut farmers in the study area. For example:

The level of awareness of climate change and its impact (dependent variable) was classified as:

1. Not aware at all (where a farmer has never heard about climate change from any source)
2. Very low (where a farmer has heard about climate change but not employing any adaptation strategy)
3. Good (where a farmer has appreciable knowledge about climate change and employs one/two adaptation strategies)
4. Excellent (where a farmer has very good knowledge about climate change, its impacts, and employing two or more adaptation strategies).

The responses of farmers to the level of awareness questions were used to classify farmers into the above respective scales. Independent variables included the demographic and socio-economic characteristics of the farmers such as:

1. Age of the farmer (number/continuous variable)
2. Gender of the farmer (Male=1; Female=0)
3. Years of Education of the farmer (number/continuous variable)
4. Experience in farming (number/continuous variable)
5. Farm size (ha) (number/continuous variable)
6. Access to finance (YES=1; NO=0)
7. Access to government support (YES=1; NO=0)
8. Farm visits by extension officer/year (number/continuous variable)
9. Distance to agriculture district office (number/continuous variable)

10. Received agricultural training/workshop about climate change (YES=1; NO=0)

U_n represents the strength of the survey respondent *n*'s feelings or opinion on the survey.

The model is specified as below:

$$y_i = \alpha + \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \ldots\ldots \beta_k x_{ki} + \mathcal{E}_i \qquad (1)$$

Where; U_n represents the strength of the survey respondent *n*'s feelings or opinion on the survey, y_i = is the dependent variable: the level of awareness of climate change and its impact among the groundnut farmers in the study area. $\alpha = 0.5$ and $\beta = 0.75$.

Independent variables (IV), x_1 = Age of the farmer (number/continuous variable), x_2 = Gender of the farmer (Male=1; Female=0), x_3 = Years of Education of the farmer (number/continuous variable), x_4 = Experience in farming (number/continuous variable), x_5 = Farm size (ha) (number/continuous variable), x_6 = Access to finance (YES=1; NO=0), x_7 = Access to government support (YES=1; NO=0), x_8 = Farm visits by extension officer/year (number/continuous variable), x_9 = Distance to agriculture district office (number/continuous variable), x_{10} = Received agricultural training/workshop about climate change (YES=1; NO=0) and μ_i = is the error term for the latent (unobserved variables).

Given that U_n represents the strength of the survey respondent *n*'s feelings or opinion on the survey. Assume that there are cutoffs of the level of opinion in choosing a particular response for the above choices if the person chooses:

1, if $U_n < a$
2, if $a < U_n < b$
3, if $b < U_n < c$
4, if $c < U_n < d$
5, if $U_n > d$,

for some real numbers a, b, c, d.

Therefore, defining $U_n = \beta z_n + \mathcal{E}, \mathcal{E} \sim$ Logistic, then the probability of each possible response is:

Prob (choosing2) = Prob ($a < U_n < b$)

Prob ($a - \beta z_n < \mathcal{E} < b - \beta z_n$).

$$= \frac{1}{1+ exp(-b - \beta zn))} + \frac{1}{1+ exp(-(a - \beta zn))} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

The ordered logit model has a continuous, unmeasured latent variable Y*, whose values determine what the observed ordinal variable Y equals. Therefore, in the population, the continuous latent variable Y* is equal to:

$$Y_i^* = \sum_{k=1}^{k} \beta_k x_{k_i} + \varepsilon_i = z_i + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

To identify the climate change adaptation strategies used by groundnut farmers in Yirol East County

During the data analysis, descriptive statistics were used to analyze objective two and objective five data. The results of quantitative research are translated into information or data, which can express either quantity or quality. The data that express a quantity are called quantitative data or variables, while those that express a quality are called qualitative (categorical) data or variables. Classification according to gender (male/female), family income (low/middle/high), and education level (low/middle/high) are examples of qualitative or categorical variables (Morcillo, 2023).

In this study, descriptive statistics were used to evaluate and identify climate change adaptation strategies used by groundnut farmers in the study area. Correlation tables were used to establish relationships between variables. Because the data was small, a simple frequency distribution of categorical data was employed during the analysis. Simple counting was carried out on how many cases there were in each category. The frequencies of the categories were expressed as their absolute number or as a percentage of the total. The results of the analysis were presented in bar charts, expressed in percentages. The main climate adaptation strategies that were identified and evaluated include; the application of good agricultural practices, the use of tractor technology, engaging in off-farm activities, and livestock rearing among other key stakeholders. Therefore, the percentage of a given category of climate change adaptation strategy (CCAS) was calculated and expressed as; absolute frequency divided by the total adaptation strategies, multiplied by 100, i.e.,

$$\% \, CCAS = \frac{Absolute \; Frequency \; an \; ith \; adaptation \; strategy}{Total \; Adaptation \; Strategies} \text{ x } 100$$

To analyse the socio-economic and institutional factors influencing the adoption of climate change adaptation strategies among groundnut farmers Yirol East County (District).

The Tobit model is a statistical model that James Tobin (1958) proposed to describe the relationship between a non-negative dependent variable y_i and an independent variable (or vector) x_i. The Tobit model can be described in terms of a latent variable y^*. Suppose, however, that y^* is observed if $y^* > 0$ and is not observed if $y^* \leq 0$. Then the observed y_i will be defined as:

$$[y_i^* = \beta x + \mu \quad \text{if } y^* > 0]$$
$$\{y_{i=0} \quad \text{if } y_i^* \leq 0\}$$

Where: Y = Climate change adaptation strategies adopted by the groundnut farmers

X_1 = Age; X_2 = Sex; X_3 = Marital status; X_4 = Household size; X_5 = Education

X_6 = Experience; X_7 = Farm size; X_8 = Income; X_9 = Knowledge level

The Tobit regression model equation was:

$Y = 1.366 + 0.009X_1 - 0.013X_2 + 0.084X_3 + 0.032X_4 + 0.001X_5 - 0.041X_6 + 0.026X_7 - 0.073X_8 + 0.028X_9.$

The Tobit model is also called a censored regression model because some observations on y^* (those for which $y^* \leq 0$) are censored. Our objective is to estimate the parameters β and σ. In other words, the latent variable y* is observed only observed if Y* > 0. In particular, the actual dependent variable is y = max (0, y*). For example, let Y be the amount of money that an individual spends on tobacco, given his or her characteristics X. Then Y > 0 if the individual is a smoker, and Y = 0 if not.

To examine the relationship between climate change adaptation strategies and household food security among groundnut farmers in Yirol East County (District).

The study employed the endogenous switching probit (ESP) model to evaluate the impact of climate change adaptation strategies on the household food security of groundnut farmers in Yirol East County. An endogenous switching probit (ESP) is a two-stage estimation technique, which addresses the selection bias stemming from both observed and unobserved heterogeneities (Li et al., 2020) and can also estimate two outcome equations. In the first stage, the climate change adaptation strategies (CCAS) adoption function was modeled by analyzing the factors that affect farmers' decisions to adopt CCAS. The second stage estimates both the household food security and insecurity status.

To assess the food security conditions of groundnut farming households in relation to climate variability and adaptation practices.

Because there was no data collected on household food expenditures, descriptive statistics were used to analyze this objective. The results of the analysis were presented in percentages and bar charts. The main parameters assessed in this research objective include;

1. Produced food on farms
2. Having enough food in stock
3. Accessing food in markets
4. Challenges in terms of the movement of food
5. Issues of insecurity on food transportation routes
6. Selling some livestock to access food
7. Having a variety of food sources
8. Having surplus food for sale
9. Having surplus food for sale
10. Borrowing food from friends

11. Lack of food in stock

In this analysis, the same procedures applied in analyzing objective two were repeated here. Simple counting was carried out on how many cases there were in each category. The food security status of a local household, expressed in percentage has been calculated in terms of the absolute frequency of an i^{th} response from individual respondents to specific questions based on the above-listed parameters, divided by the total number of parameters, multiplied by 100. This is simply expressed as;

$$Food\ Security\ Status\ = \frac{Absolute\ Frequency\ of\ an\ ith\ response/parameter}{Total\ food\ security\ parameters} \text{ x } 100$$

To develop a localized climate change adaptation framework which if implemented would improve agricultural productivity, household income, community resilience, adaptive capacity, and sustainable food security of groundnut farming households in Yirol East County.

FGD data was analysed thematically. The focus group discussed five key steps leading to the development of a climate change adaptation framework for groundnut farmers in South Sudan and Yirol East County. The five steps covered during the discussion include the identification of ecosystem services (ES) and the socio-economic sectors (SES), vulnerability assessment and sensitivity analysis, risk assessment, and finally adaptation options that led to the development of a functional climate change adaptation framework (Figure 11). The results of the group discussion were tabulated and presented in tables 20 - 25.

3.5.4 Ethical clearance

Following a successful research proposal defense, the study met the requirements of the UNISA Ethical Clearance Committee and the College of Agriculture and Environmental Science. During the data collection exercise, the researcher(s) ensured that the research project adhered to the values and principles expressed in the UNISA Policy on Research Ethics. The researcher conducted the study according to the methods and procedures set out in the approved application.

Participants’ consent was sought before taking part in the study, and information shared during the field survey and focused group discussions was kept strictly confidential. The study included a consent form to allow participants to participate or withdraw at any time during the study.

The Ministry of Agriculture, Environment and Forestry – Lakes State granted permission for the study to be carried out in the four payams of Yirol East County. The County Agriculture Department (CAD) and the State Ministry of Agriculture, Environment and Forestry will receive feedback in the form of a thesis summary highlighting the key findings of the study.

3.6 Summary of the data analysis

Table 3. 3 Summary of the data analysis

Objectives	**Research questions**	**Data requirements**	**Data analysis**
1- To assess the socio-economic and demographic factors influencing the level of climate change awareness among the groundnut farmers in Yirol East County (District).	What are the socio-economic and demographic factors influencing the level of climate change awareness among the groundnut farmers in Yirol East County (District)?	To understand the socioeconomics and the demographic characteristics of groundnut farmers in the study area.	Descriptive Statistics and ordered logistic regression model (Liddell & Kruschke, 2018).
2- To identify the climate change adaptation strategies used by groundnut farmers in Yirol East County (District).	What are the climate change adaptation strategies used by groundnut farmers in Yirol East County (District)?	To identify and list the climate-smart agriculture practices and farm technologies used by groundnut farming households at the farm level.	Descriptive statistics
3- To analyse the socio-economic and institutional factors influencing adoption of climate change adaptation strategies by groundnut	What are the factors influencing the choice of	Establish the relationship or non-relationships between the variables of the study.	Tobit regression model

Objectives	Research questions	Data requirements	Data analysis
farmers in Yirol East County (District)	climate change adaptation strategies used by groundnut farmers in Yirol East County (District)?		
4- To examine the relationship between climate change adaptation strategies and household food security among groundnut farmers in Yirol East County (District).	What is the impact of climate change adaptation strategies on the household food security of groundnut farmers in Yirol East County (District)?	Assess the efficacy of existing climate-smart agriculture practices or adaptation strategies used by ground farmers in the study area.	Descriptive Statistics and Endogenous Switching Probit (ESP) model.
5- To assess the food security conditions of groundnut farming households in relation to climate variability and adaptation practices.	What is the food security status of the groundnut farmers in Yirol East County (District)?	Determine the level of food and acquisition production at the household level as a function of food availability as well as elements of accessibility to food by household members for sustained food supply at the household level.	Descriptive Statistics.

Objectives	Research questions	Data requirements	Data analysis
6- To develop a localized climate change adaptation framework which if implemented would improve agricultural productivity, household productivity, household income, community resilience adaptive capacity, and sustainable food security of groundnut farming households in Yirol East County	Is there any existing climate change adaptation framework that if implemented will help the groundnut farming households in the study area to adopt climate-smart practices (strategies) that may eventually be used to cope with the adverse effects of climate change?	Identify, list, and rank existing climate change adaptation options. Develop an adaptation priority list for action planning and implementation.	Qualitative/Thematic analysis -

3.7 Independent variables for the inferential analyses

Table 3. 4 Variables and their measurements and signs

Dependent Variables	**Measurement**	**Expected signs**
Crops diversification	Dummy variable 1 or 0 for whether a household diversifies or not	
Good Agricultural Practices (crop rotation, mulching, fallow cropping, etc.)	Dummy I= adopter or 0= non-adopter	
Farm technology (local hand tools, ox-ploughing, farm machinery/tractors)	Dummy I= adopter or 0= non-adopter	
Off-farm activities (Business/trade, casual labour, formal employment)	Dummy I= adopter or 0= non-adopter	
Livestock (Cattle, sheep goats' poultry)	Dummy I= adopter or 0= non-adopter	
Independent variables		
Gender	Male = 1; Female = 0	+
Age of respondent	Years	+
Household size	Reported Number per household	+
Farming experience	Years	+
Length of residence in the community in years	Years	+
Education level	Number of years spent in school by the household head	+
Farm income	Amount in U$/year	+
Farm size	Acres	+
Land ownership	Dummy, I= own, 0= otherwise	+
Livestock	Tropical Livestock Unit	+
Distance to market	Kilometers	-
Knowledge of Climate Change Adaptation Strategy	Dummy (Yes=1, no=0)	+
Access to extension services	Dummy (Yes=1, no=0)	+
Access to climate and weather information	Dummy (Yes=1, no=0)	+
Membership in farmers' group	Dummy (Yes=1, no=0)	+
Perceived change in droughts and floods	Dummy, 1 if experienced, 0 if not	+

Dependent Variables	Measurement	Expected signs
Perceived change in planting seasons	Dummy, 1 if experienced, 0 if not	+
Perceived change in the prevalence of diseases and pests	Dummy, 1 if experienced, 0 if not	+
Perceived climatic variability of rainfall and temperature	Dummy, 1 if experienced, 0 if not	+

3.8 Chapter Summary

Chapter 3 discussed research design and methods. The following topics were also discussed: the study area, population, sample size, technique, primary and secondary data, data collection tools, and data analysis model. Table 4 below presents the dependent and independent variables.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

The chapter highlights the findings for the data collected using 481 questionnaires. The chapter highlights the results for socio-economic and demographic factors, climate change adaptation strategies, factors influencing the choice of climate change adaptation strategies, impact of climate change adaptation strategies and food security status of the groundnut farmers. The analysis of the data was done using SPSS and STATA. This chapter thus highlights the analysis of the data based on objectives through both descriptive and inferential statistics. The findings are presented in tables, graphs and figures.

The purpose of the study was to assess the impact of climate change adaptation strategies on household food security of groundnut farmers for informed policy recommendations. Specifically, the study sought to assess the socioeconomic and demographic factors influencing the level of climate change awareness among groundnut farmers, to identify the climate change adaptation strategies used by groundnut farmers, to assess factors determining or influencing the choice of climate change adaptation strategies used by groundnut farmers, to assess the impact of climate change adaptation strategies on the household's food security of groundnut farmers, to assess the food security status of the groundnut farmers and develop an adaptation framework which if implemented will help the groundnut farming households in the study area to adopt climate-smart practices (strategies) that may eventually be used to cope with adverse effects of climate change. The study sampled 596 participants out of which 481 participants returned fully filled questionnaires. This gave a response rate of 80.7% which was significant for conducting statistical analysis. This concurs with Fulton (2018) who argued that a response rate above 50% is significant for conducting statistical analysis in research.

4.2 Socio-Economic and Demographic Factors and Level of Climate Change Awareness

The study sought to assess the socio-economic and demographic factors influencing the level of climate change awareness among the groundnut farmers in Yirol East County (District). The socioeconomic and demographic factors included the Sex of the respondent, age of the household head, marital status, education level, years of residence in a community, farming experience years, membership into a farmers' group, farm size, access to finance, family income level, market access, access to agricultural extension services and access to climate and weather information. The descriptive findings are presented in Table 4.1.

Table 4. 1 Findings for Socio-Economic and Demographic Factors (n=481)

Variable (s)		Frequency	Percent
Gender	Male	171	35.6
	Female	310	64.4
Is the respondent the household head	Yes	435	90.4
	No	46	9.6
Age	19-30 years	114	23.7
	31 – 45 years	254	52.8
	46 – 60 years	92	19.1
	Above 60 years	21	4.4
Marital status	Single	12	2.5
	Married	447	92.9
	Divorced	15	3.1
	Separated	7	1.5
Education level	No education	398	82.7
	Primary	60	12.5
	Secondary	13	2.7
	Technical and vocational	7	1.5
	College	3	.6
Years of residence in a community	Less than 1 year	7	1.5
	1-2 years	7	1.5
	3-5 years	52	10.8
	6-8 years	57	11.9
	9-11 years	69	14.3
	Above 11 years	289	60.1
Farming experience in years	1-2 years	7	1.5
	3-5 years	70	14.6
	6-8 years	98	20.4

Variable (s)		Frequency	Percent
	9-11 years	37	7.7
	Above 11 years	269	55.9
Membership to a farmers' group	Yes	162	33.7
	No	319	66.3
Farm size	1-2 feddans	29	6.0
	3-4 feddans	303	63.0
	Above 5 feddans	149	31.0
Access to Finance	Yes	50	10.4
	No	431	89.6
Family income level per year	Less than $360 per year	341	70.9
	$721-1,440 per year	123	25.6
	$361-$720 per year	7	1.5
	Above $1,440 per year	10	2.1
Access to market	Yes	326	67.8
	No	155	32.2
Access to agricultural extension services	Yes	197	41.0
	No	284	59.0
Access to climate and weather information	Yes	266	55.3
	No	215	44.7

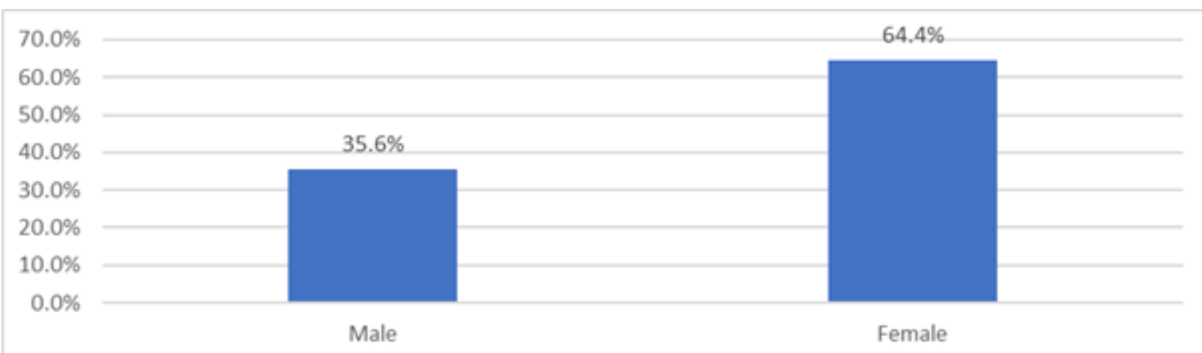

Figure 4. 1 Showing the gender of respondents

From the findings in Table 4.1 and Figure 4.1 above, most of the participants were female as shown by 64.4% while the rest were male as shown by 35.6%. This implies that most groundnut farmers in Yirol East County are female. This could be attributed to the fact that most male counterparts are tasked with other economic activities to support their households. Further, most of the respondents indicated that they were household heads as shown by 90.4% while 9.6% indicated household heads. This implies that most participants were in a position to provide credible information about the subject under study. However, these findings are in contrast with findings from a study conducted in Kenya by (Erick O. *et al.,*2016), which found that the majority of the households (74 percent) were male-headed households. Further, the findings from the study by Gerei et al., (2013) further argued that male farmers dominated groundnut production because more men are likely to engage in groundnut than women due to its economic and commercial value. This is further corroborated by (Tererai *et al.,*2017) who indicated that the sex of the head of household among the sampled households 64% were male-headed and 36% female-headed indicating that the majority of households were male-headed with the minority being female-headed).

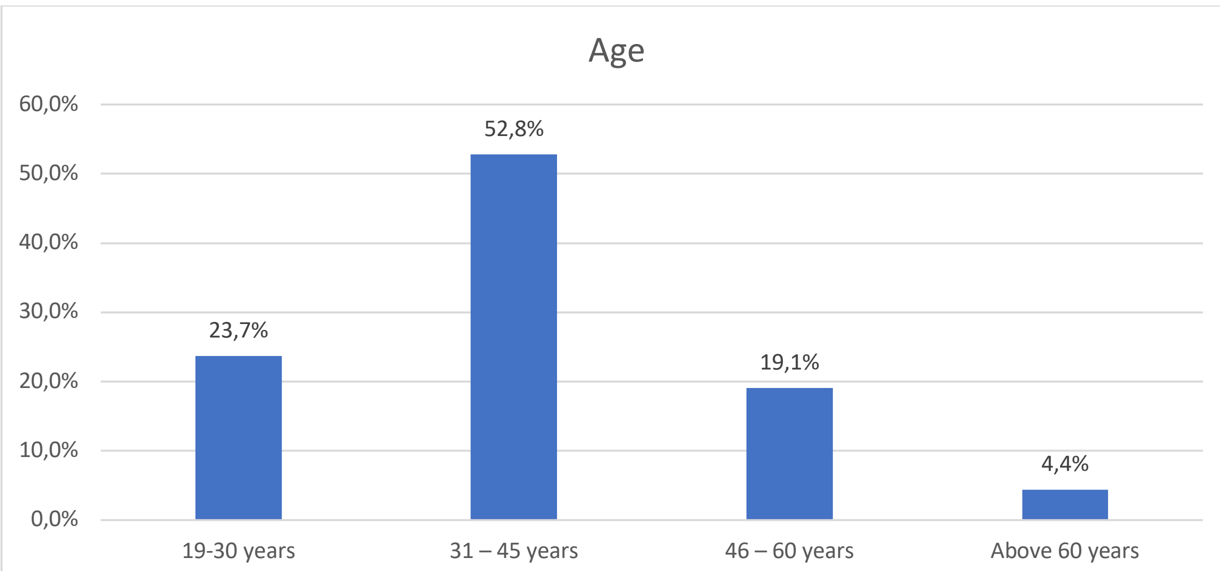

Figure 4. 2 Showing the age of respondents

Regarding the age in Figure 4.2 above, most of the participants stated to be aged 31 – 45 years as shown by 52.8%, 19-30 years as shown by 23.7%, 46 – 60 years as shown by 19.1%, and more than 60 years as shown by 4.4%. These findings are in line with the findings of the study conducted in Nigeria by Girei et al, (2013), which showed that 57 percent numbering 57 were relatively young and fall within the age range of 30 to 40 years while about 45 percent constituting 43 falls within the age range of 41 and above. This implies that young generation aged between 19 and 45 years have dominated the groundnut farming in Yirol East County and in the Sub-Saharan Africa in general.

Based on Marital status, the findings showed that most of the participants were married, as shown by 92.9%. In addition, those divorced indicated to be 3.1%. those who were single indicated to be 2.5% while the separated were 1.5%. This shows that most participants taking part in groundnut farming in Yirol East County are in marriages. Again, these findings agree with findings from a study conducted in Zimbabwe by (Tererai *et al,* 2017), which indicated that 70% of the farmers were married. However, other marital statuses such as single, divorced, and separated were also considered in the study, and credible data was collected from every participant.

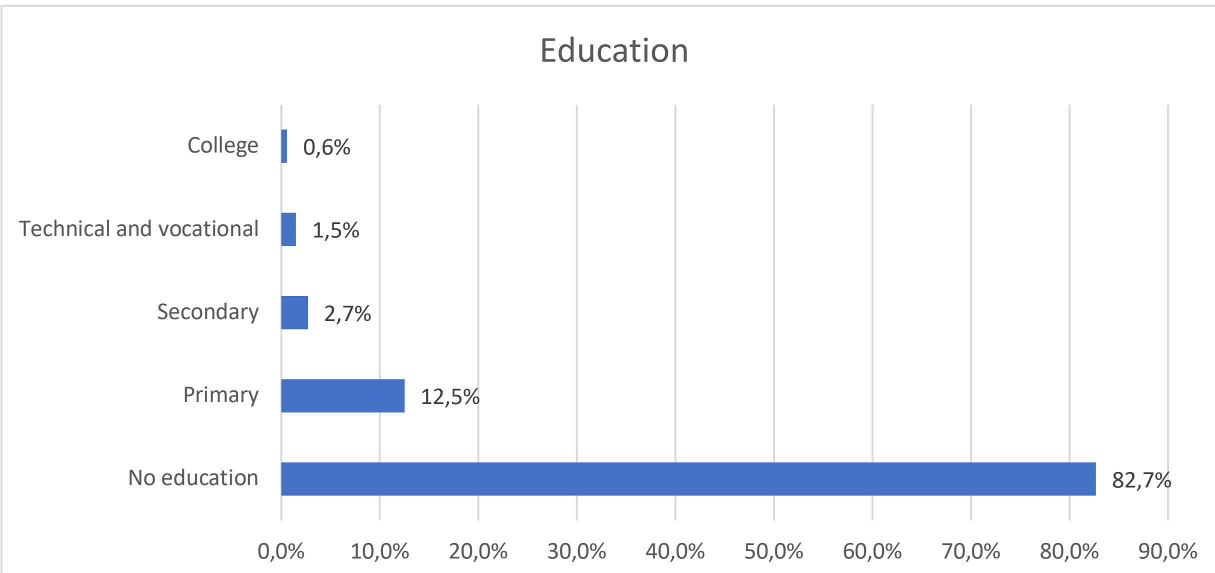

Figure 4. 3 Indicating education levels of respondents

In addition, figure 4.3 indicated no education for most participants as illustrated by 82.7%, primary education illustrated by 12.5%, secondary as illustrated by 2.7%, technical and vocational education as illustrated by 1.5%, and college as illustrated by 0.6%. In contrast, the results obtained from the study by (Girei *et al.,* 2013) show that all the respondents have acquired one form of formal education or the other which is a vital component in technology adoption in agriculture. The research further argued that Education has been discovered to be highly related to the effectiveness of work and economic function, Meskel, 2006, Girei *et al,* 2013, Azihe *et al,* 2019). Further, the econometric model (Saguye,2017) also revealed that household characteristics, sex, level of education, and farming experience positively and significantly influenced the perception of climate change. education is significantly and positively associated with most SAPs (Manda *et* *al,*2015). This implies that groundnut farming in Yirol East County could be done by anyone regardless of their level of education.

In addition, data for the study cut across all the education levels. Education levels can affect farmers' understanding of climate change phenomena, including its causes, impacts, and potential adaptation strategies. Farmers with higher education levels may have a better grasp of climate science concepts and be more aware of adaptation strategies available to them. Further, educated farmers are more likely to have access to information about climate change adaptation strategies through various channels such as extension services, research publications, or educational programs. They may be more informed about innovative techniques and technologies for mitigating climate change impacts on groundnut farming.

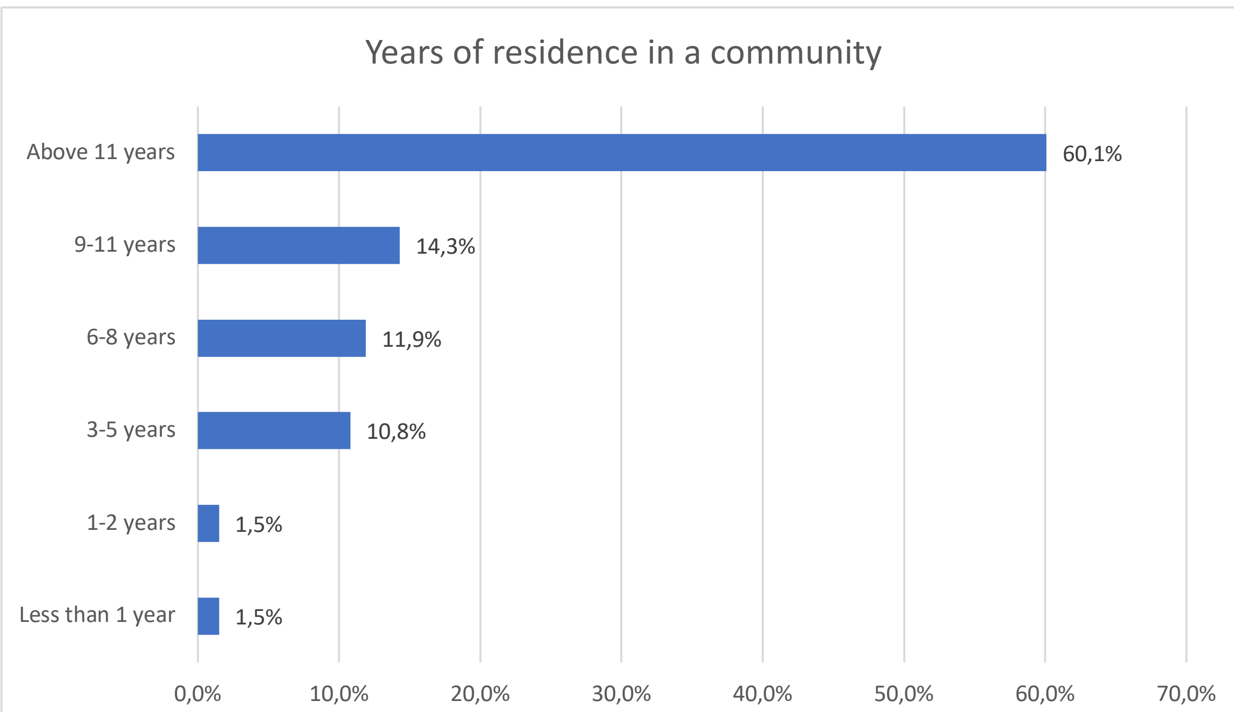

Figure 4. 4 Years of residence in a community

Further, figure 4.4 shows that the majority of respondents have been residents in a community for more than 11 years as shown by 60.1%, for 9-11 years as shown by 14.3%, for 6-8 years as shown by 11.9%, for 3-5 years as shown by 10.8%, for less than 1 year as shown by 1.5% and for 1-2 years as shown by 1.5%. This implies that most participants had resided in the community long enough to provide credible information regarding the study. Farmers who have been residing in the area for a longer duration are likely to possess extensive local knowledge and experience regarding climate patterns, soil conditions, crop management practices, and other relevant factors. In addition, farmers who have lived in the area for an extended period may have already implemented various adaptation strategies to cope with changing climatic conditions.

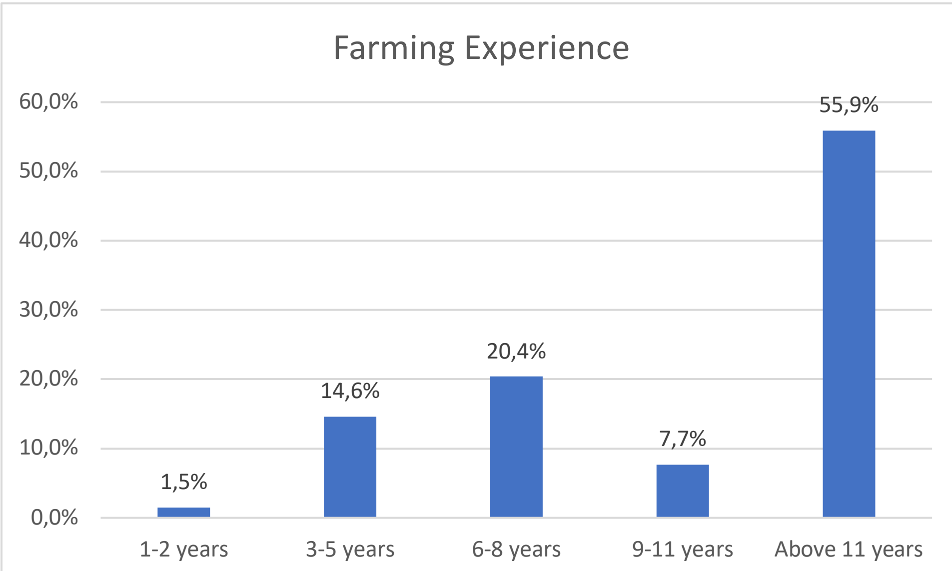

Figure 4. 5 Farming Experience of respondents

The participants in Figure 4.5 also stated that their farming experience in years was 1-2 years as shown by 1.5%, 3-5 years as shown by 14.6%, 6-8 years as shown by 20.4%, 9-11 years as shown by 7.7% and more than 11 years as shown by 55.9%. This implies that most participants had adequate farming experience to be in a position to provide credible information regarding the subject under study. This is because experienced farmers have a deep understanding of local environmental conditions, including climate patterns, soil types, and pest dynamics which is essential for accurately assessing the impact of climate change on their farming practices and food security. In addition, farmers with experience have likely encountered various challenges in the past, including climate variability and their prior experiences in implementing adaptation strategies, such as changing planting dates, utilizing drought-resistant crop varieties, or implementing water-saving techniques, could provide valuable insights into effective strategies for coping with climate change. These findings are in agreement with findings from a study conducted by (Girei *et al,* 2013) which found that farmers have a mean farming experience of 11.5 years. Farming experience would to a large extent affect farming decisions and farming experience has a positive relationship with technical efficiency. This implies that, the more experienced a farmer, the more efficient the farmer might be in the use of productive resources. Another study conducted in South Africa by (Siphesihle and Lelethu, 2020), further corroborated the findings of this research which indicated that most respondents have 11 years of farming experience and 80% of farmers are members of farmer organizations.

Further, most of the participants indicated that despite their long experience in farming, they are not members of a farmers' group (66.3%) with only 33.7% being in farmers' groups, thus, contrasting with findings from the study by Lelethu (2020) above which indicated that 80% farmers were members of farmer organization. This implies that there is a need for effective awareness of the importance of farmers being in groups to be conducted in Yirol East County. This can be done by organizing workshops and conferences for farmers, sponsoring farmer training, and emphasizing the importance of farmer groups in community gatherings. The results also showed that participants farm sizes were 1-2 feddans (6.0%), 3-4 feddans (63.0%) and more than 5 feddans (31.0%). This shows that most participants had adequate farm sizes ranging from 1.26 to 1.68 ha to participate in groundnut farming in Yirol East County. The findings of this study further contrast with the survey results obtained from a study by Girei et al, (2013) which shows that about 74 percent of the respondents cultivated land of about 1 hectare and below. This disparity in the size of land cultivated as small and large indicates that groundnut farming in the study area is likely shifting mainly from small scale and subsistence to a relatively large-scale farming for commercial purposes.

Moreover, from the findings, most of the participants indicated that they have no access to finance as shown by 89.6% while only 10.4% had access to finance. These findings are further corroborated by results of the study conducted in South Africa by Lelethu Mdoda (2020), which indicated that farmers in the study area lack access to credit, with only 8.3% having such access, and the majority of them depend on social grants for farming. This implies that there is a need for the government and other development partners to come up with strategies to ensure every groundnut farmer has access to finance. Farmers often need financial resources to implement climate change adaptation strategies such as switching to drought-resistant groundnut varieties, investing in irrigation systems, or adopting conservation agriculture practices. In addition, access to finance enables farmers to adopt innovative technologies and practices that can enhance their resilience to climate change.

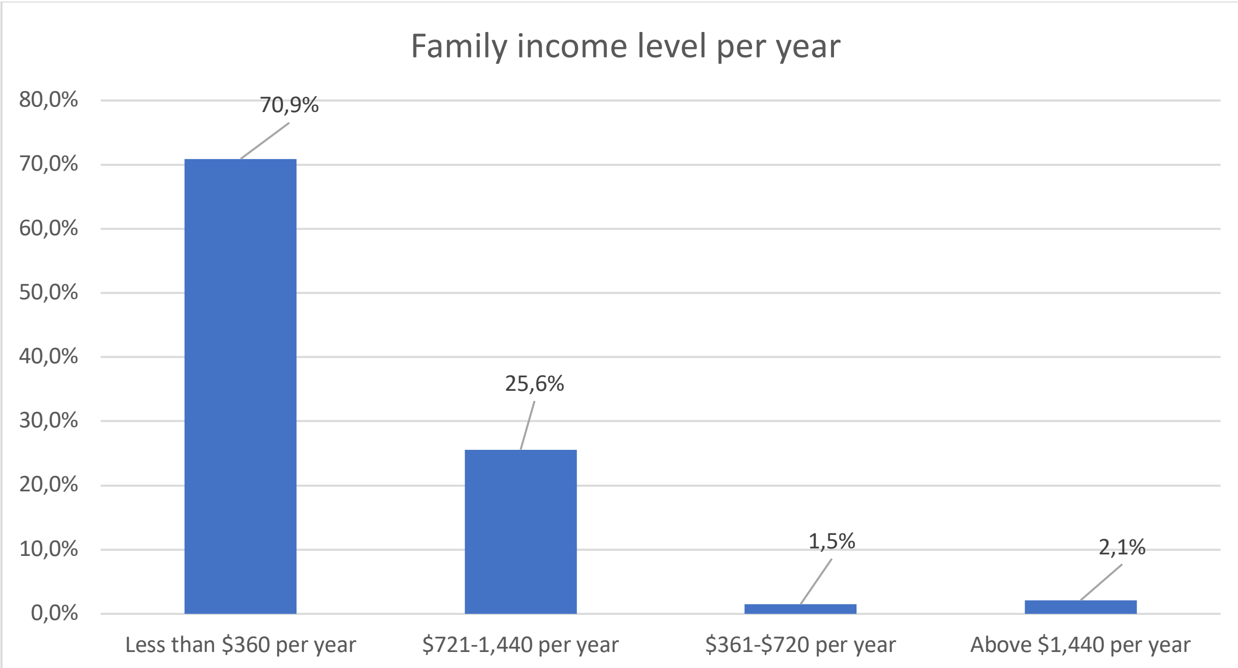

Figure 4. 6 Indicating Family Income Level

Further, the participants in Figure 4.6 indicated that their family income level per year was less than $360 as shown by 70.9%, $721-1,440 per year as shown by 25.6%, $361-$720 per year as shown by 1.5% and $1,440 per year as shown by 2.1%.

Further, the participants indicated that they have access to market (67.8%), have inadequate access to agricultural extension services (41.0%) and have access to climate and weather information (55.3%). This implies that the government and other development partners should continue supporting the groundnut farmers by ensuring they have adequate access to markets, agricultural extension services, and weather information.

4.2 Level of Awareness of Climate Change

The participants were asked to indicate their responses regarding various questions on the level of awareness of climate change. The findings are summarized in Figure 4.7 below.

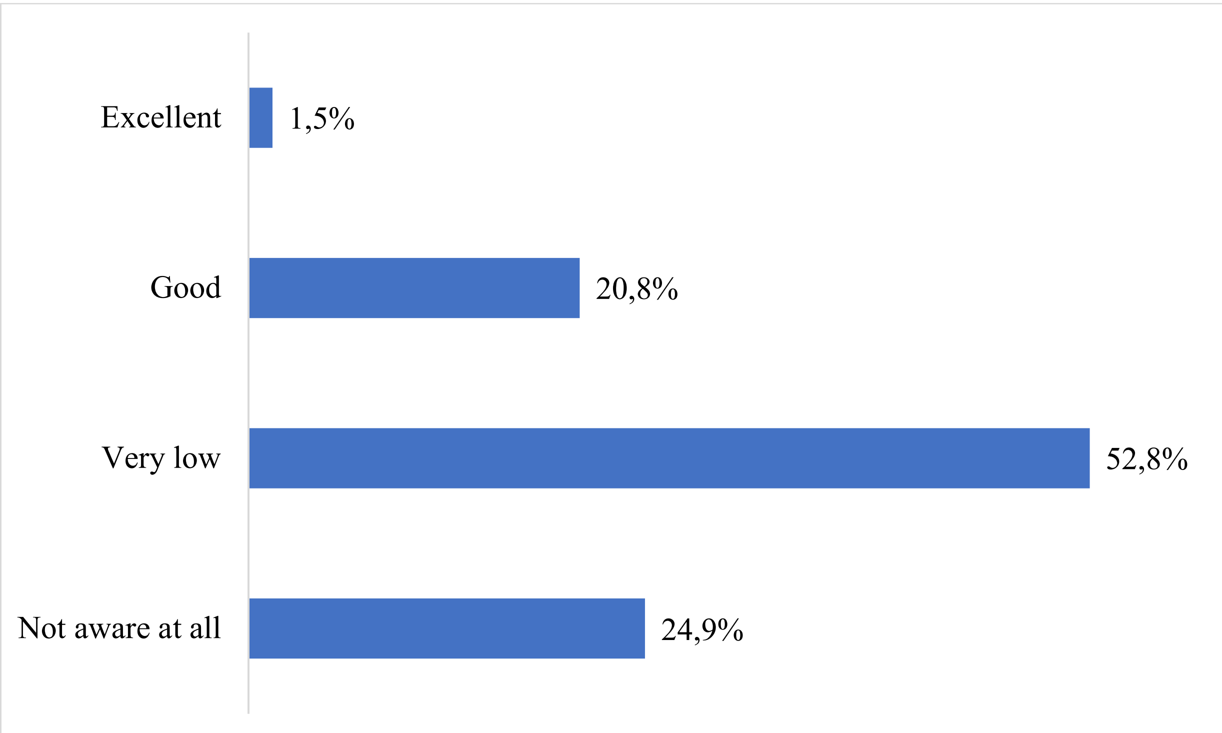

Figure 4. 7 Showing awareness of climate change or its impacts among the respondents

From the findings in Figure 4.7, most of the participants indicated that their awareness was very low (where a farmer has heard about climate change but does not employ any adaptation strategy) as shown by 52.8%. In addition, the participants indicated that they were not aware at all (where a farmer has never heard about climate change from any source) as shown by 24.9%, good (where a farmer has appreciable knowledge about climate change and employing one/two adaptation strategies) as shown by 20.8% and excellent (where a farmer has very good knowledge about climate change, its impacts and employing two or more adaptation strategies) as shown by 1.5%. This implies that most farmers in Yirol East County are either unaware of climate change and its impacts or completely unaware. Hence, there is a need for climate change awareness to be raised among groundnut farmers in Yirol East County to come up with strategies for mitigating its impacts. These results are in contrast with the study results by Lelethu Mdoda, (2020) which revealed that about 94% of farmers were aware of climate variability in the study area and have noticed changes in climatic conditions. This might be attributed to the fact that rural farmers in South Africa have attained adequate basic education levels and have more access to climate information compared to rural farmers in South Sudan where the majority are illiterate as shown in this research. Further, the participants were asked to indicate whether they have experienced drought or floods, any change in the normal planting season, the prevalence of pests or diseases, and variations in rainfall or temperature in the last five years. The findings are represented in Table 4.2

Table 4. 2 Experiences with Various Changes in Climate

Question	Response	Frequency	Percent
Have you experienced droughts or floods for the last five years?	Yes	469	97.5
	No	12	2.5
Have you experienced any change in the normal planting season for the last five years?	Yes	477	99.2
	No	4	.8
Have you experienced a prevalence of pests or diseases in the last five years?	Yes	467	97.1
	No	14	2.9
Have you experienced variations in rainfall or temperature in the last five years?	Yes	478	99.4
	No	3	.6

From the findings in Table 4.2, the participants indicated that they have experienced drought or floods for the last five years as shown by 97.5%, that they have experienced any change in the normal planting season for the last five years as shown by 99.2%, that they have experienced the prevalence of pests or diseases in the last five years as shown by 97.1% and that they have experienced variations in rainfall or temperature in the last five years as shown by 99.4%. This implies there have been changes in climate at Yirol East County for the last five years characterized by drought and floods, changes in the normal planting season, the prevalence of pests or diseases, and variations in rainfall and temperature.

4.3 The Ordered Logistic Regression Model

The study adopted an ordered logistics regression model to establish how socio-economic and demographic factors influence the level of climate change awareness among the groundnut farmers in Yirol East County (District). The level of climate change awareness of the farmer influences the farmer's choice (s) of climate change adaptation strategy (ies) that further impact the household food security of rural farmers. The ordered logistics regression model (Liddell & Kruschke, 2018) was used to analyze the determinants of farmers' level of awareness of climate change and its impact in the study area. The ordered logistics regression model is deemed appropriate since the dependent variable is more than 2 options and is in ordinal form. The Likert scale was used to assess the awareness of climate change and its impact among the groundnut farmers in the study area. The findings are shown in Table 4.3.

Table 4. 3 Ordered Logistic Regression Model Results

Log-likelihood = 662.412			Number of obs = 481 LR chi2 (9) = 270.612 Prob>chi2 = 0.000 Pseudo R2 = 0.487			
	Coef.	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**	
Age of the farmer	.151	.040	3.781	.000	.072	.229
Gender of the farmer	.182	.065	2.794	.005	.054	.310
The education level of the farmer	.123	.057	2.154	.032	.011	.234
Experience in farming	.017	.034	.509	.611	-.050	.084
Farm size (ha)	.058	.057	1.028	.305	-.053	.170
Access to finance	-.138	.126	-1.091	.276	-.386	.110
Access to government support	.341	.076	4.511	.000	.192	.489
Farm visits by extension officer	.181	.063	2.882	.004	.058	.305
Received agricultural training/workshop about climate change	.588	.088	-6.668	.000	.415	.762
[Constant]	1.175	.396	2.965	.003	.396	1.954

Explain the levels of significance example ***< **< *

From the findings in Table 4.3, the Pseudo R^2 was 0.487 which implies that variations in the level of climate change awareness among the groundnut farmers in Yirol East County (District) could be linked to various socio-economic and demographic factors including age of the farmer, gender of the farmer, education level of the farmer, experience in farming, farm size (ha), access to finance, access to government support, farm visits by extension officer and received agricultural training/workshop about climate change.

More precisely, the study established that the age of the farmer (β=0.151; p=0.000), gender of the farmer (β=0.182; p=0.005 and education level of the farmer (β=0.123; p=0.032) have a significant influence on the level of climate change awareness among the groundnut farmers in Yirol East County (District). These results may further imply that farmers' age, gender, and education level matter because they shape how easily farmers perceive, receive, understand, trust, and use climate information. Younger farmers with adequate education levels, and better-connections often learn about climate change faster than elderly farmers whose majority are illiterate which is actually the case of most rural farmers in South Sudan, while gender can affect access to land, extension services, decision-making power, and information channels because younger farmers who are not household heads may not have access to land and decision-making powers though their education levels may help them access more information channels. These findings are consistent with (Ibekwe et al., 2010) which states that Farm size, age, education, occupation and hours spent on farm are important explanatory variables that influenced both farm and off farm incomes.

In addition, the study found that access to government support (β=0.341; p=0.000), farm visits by extension officer (β=0.181; p=0.004), and agricultural training/workshops about climate change (β=0.588; p=0.000) has a significant influence on the level of climate change awareness among the groundnut farmers in Yirol East County (District). Apparently, access to government support, extension officer visits, and climate-change training, all play a great role in farmers' awareness because they are direct pathways for receiving timely, trusted, and practical technical information. Especially for groundnut farmers, these channels also help them connect climate information to real farming decisions such as planting dates, pest control, soil management, and drought preparation remain important climate adaptation strategies among rural farmers. However, the study found that experience in farming (β=0.017; p=0.611), access to finance (β=-0.138; p=0.276), and farm size (ha) (β=0.058; p=0.305 has no significant influence on the level of climate change awareness among the groundnut farmers in Yirol East County (District). The findings imply that demographic and socioeconomic characteristics of the farmers that could be used in predicting the level of climate change awareness among the groundnut farmers in Yirol East County (District) include age of the farmer, gender of the farmer, education level of the farmer, access to government support, farm visits by extension officer and agricultural training about climate change. Truly, these factors cannot have significant influence on the level of climate awareness because for the case of South Sudan, which include farming experience may not be significant to influence climate awareness because most of farmers are subsistent-based, not to mention event access to finance because there are no existing financial institutions that support rural farmers in South Sudan and finally, there is largely absence of government extension services, though the humanitarian organizations do partially support extension services in a limited scale.

4.4 Hypothesis test

Null hypothesis (H_0): Socio-economic and demographic factors do not significantly influence the choice of climate change adaptation strategies used by groundnut farmers that may eventually have impact on household food security in Yirol East County.

Alternative hypothesis (H_a): Socio-economic and demographic factors significantly influence the choice of climate change adaptation strategies used by groundnut farmers that eventually have impact on household food security in Yirol East County.

4.5 Estimating Regression Coefficients

According to Jaren Murphy (UNM, n.d), the principle of maximum likelihood is commonly used to estimate the two unknown parameters in the logistic model:

$$\log = \left(\frac{Pi}{1-\mathrm{pi}}\right) = \alpha + \beta X$$

The maximum likelihood estimates (MLE) of the regression coefficients are estimated
iteratively by maximizing the so-called Binomial likelihood function for the responses, or equivalently, by minimizing the deviance function (also called the likelihood ratio LR chi-squared statistic).

$$\mathrm{LR} = \sum_{i=0}^{n} \{di\ log\ \left(\frac{di}{nipi}\right) + log\ \left(\frac{di}{nipi}\right) + \ log\ (ni - di)\ log\left(\frac{ni - di}{ni - nipi}\right)\}$$

over all possible values of α and β, where the p_is satisfy

$$\log = \left(\frac{Pi}{1-\mathrm{pi}}\right) = \alpha + \beta X_i$$

Stata does not provide the deviance statistic, but rather the Pearson chi-squared test statistic, which is defined similarly to the deviance statistic and is interpreted in the same

manner $X^2 = \sum_{i-1}^{m} (\frac{di - ni\dot{p}i}{ni\dot{p}i\,(1 - \dot{p}i)})^2$

This statistic can be interpreted as the sum of standardized, squared differences between the *observed* number of successes *di* and the *expected* number of successes *ni ˆpi* for each covariate *Xi*. When what we expect to see under the model agrees with what we see, the Pearson statistic is close to zero, indicating a good model fit to the data. When the Pearson statistics are *large*, we indicate a lack of fit.

Therefore:

$\log = (\frac{P}{1-\mathrm{p}}) = 1.175 + (0.151+0.182+0.123+0.017+0.058+-0.138+0.341+0.181+0.588) = 1.175 + 1.503$ Climate Change Adaptation Strategy (CCAS)

Where; Age = X_1, Gender of the farmer = X_2, the education level of the farmer = X_3, Experience in farming = X_4, Farm size (ha) = X_5, Access to finance = X_6, Access to government support = X_7, Farm visits by extension officer = X_8, Received agricultural training/workshop about climate change = X_9.

The p-value for testing H_0: $\beta = 0$ (i.e., the slope for the regression model is zero) based upon the Chi-squared test p-value ($P >|z|$) is 0.000, which leads to rejecting H_0 at any of the usual test levels.

Therefore, based on the results of the ordered logistic regression analysis in this research, the age of the farmer, access to government support, and received agricultural training/workshop about climate change statistically significantly influence the choice of climate change adaptation strategies used by groundnut farmers in Yirol East County. However, other factors which include the gender of the farmer, the education level of the farmer, experience in farming, farm size (ha), access to finance, and farm visits by extension officers do not significantly influence the choice of climate change adaptation strategies.

Note: Pearson's statistics based on the above model is close to zero, which indicates that the model is good to fit the data.

The likelihood ratio test statistics of the logistic regression relationship (LR Chi^2 (9) = 270.612) in this research and p-value (Prob > Chi^2 = 0.000) gives the logistic regression the overall F-statistic that some predictions are important.

4.6 Climate Change Adaptation Strategies

Further, the study sought to identify the climate change adaptation strategies used by groundnut farmers in Yirol East County (District).

Results and Discussion of Descriptive Statistics

The participants were asked to indicate whether they grow different types of crops on their farms. The findings are shown in Table 4.4.

Table 4. 4 Growing Different Types of Crops on the Farm

Response	Frequency	Percent
Yes	481	100.0

From the findings in Table 4.4, the participants indicated that they grow different types of crops on their farm as shown by 100%. This implies that one of the climate change adaptation strategies used by groundnut farmers in Yirol East County (District) is growing different crops on the same farm. Growing different crops is considered a climate change adaptation strategy because it allows farmers to select the more drought-tolerant crops, helping them cope with reduced water availability due to climate change and assisting farmers in improving soil fertility and reducing the need for chemical fertilizers thus mitigating climate change through reduction of greenhouse gas emissions from agriculture. These findings are in agreement with findings from a study conducted by Kachali et al, (2015) which shows that the introduction of appropriate agronomic practices has been able to increase groundnut yields in study villages in Malawi.

The participants were also asked to indicate which types of crops they cultivated on their farm last season. The findings are represented in Table 4.5.

Table 4. 5 Types of crops cultivated in the Farm

	Frequency	Percent
Sorghum	481	100.0
Maize	279	58.0
Millet	337	70.1
Groundnut	467	97.1
Sesame	315	65.5
Green gram	176	36.6

As per the findings in Table 4.5, the different crops cultivated on the farms included sorghum (100%), groundnut (97.1%), millet (70.1%), sesame (65.5%), maize (58.0%) and green gram (36.6%). Other crops specified to have been grown included beans (11.6%), cowpeas (4.0%), cowpeas and vegetables (0.8%) as well as peanuts and cowpeas (0.8%). Growing different crops that have different temperature requirements gives farmers a chance to select the crops that are more suited to the changing temperature patterns in the region and also assists the farmers in reducing the risk of widespread crop failure due to pest or disease outbreaks since some crops are more resistant to certain pests and diseases as compared to others.

Further, the participants were asked to indicate whether they grow these crops on the same piece of land or separately. The findings are illustrated in Figure 4.8 below.

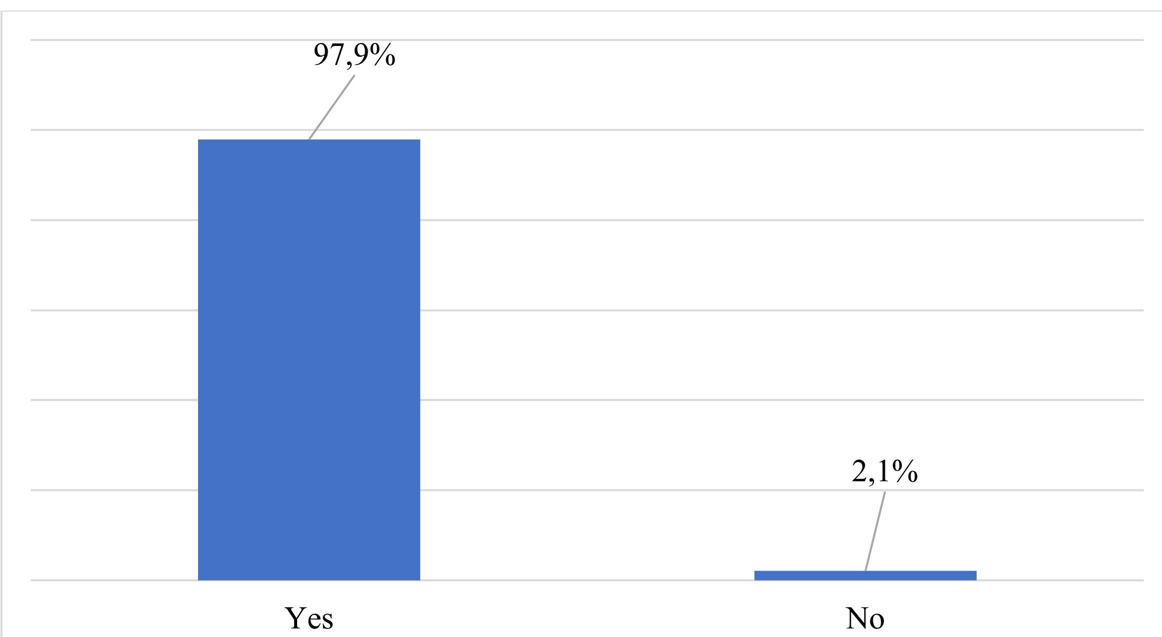

Figure 4. 8 Showing the cropping system adopted by respondents

From the findings in Figure 4.8, most of the participants indicated that they grow crops separately (monoculture) as shown by 97.9% while 2.1% of the participants indicated that crops are in the same piece of land. Separating crops grown is one of the best climate change adaptation strategies because separation allows farmers to focus on cultivating varieties that are better suited to withstand periods of low rainfall, which has been frequent with climate change. In addition, growing crops separately is economically viable because it allows farmers to focus on cultivating high-value crops that are in demand, rather than having to grow a variety of crops that may not be as profitable. However, the risks associated with monocropping practice may also be high should any incident or crop pest or disease outbreak or any other natural hazard wipe out the whole monocrop thus, resulting to serious economic losses to a farmer.

The participants were also asked to indicate whether they apply good agricultural practices, whether they use a tractor or ox-plough, whether they engage in off-farm activities, and whether they keep livestock. The findings are represented in Table 4.6.

Table 4. 6 Other climate change adaptation strategies

Climate Adaptation Strategy	**Responses**	**Frequency**	**Percent**
Applying good agricultural practices	Yes	219	45.5
	No	262	54.5
Use of tractor or ox-plough	Yes	464	96.5
	No	17	3.5
Engaging in off-farm activities	Yes	177	36.8
	No	304	63.2
Keeping livestock	Yes	444	92.3
	No	37	7.7

From the findings in Table 4.6, more than half of the participants indicated that they do not apply good agricultural practices like crop rotation, mulching, fallowing, pest and disease control, and alley cropping on their farm (54.5%) while 45.5% of the participants indicated that they apply good agricultural practices like crop rotation, mulching, fallowing, pest and diseases control and alley cropping in their farm. Application of good agricultural practices are considered climate change adaptation strategies because they assist in the reduction of greenhouse gas emissions from agriculture by optimizing inputs like fertilizer and water. In addition, agricultural practices such as conservation tillage and mulching improve soil health and mitigate the impacts of climate change on agriculture. Healthy soil stores more water, are more resistant to erosion, and sequester carbon, which assists in the reduction of greenhouse gas emissions. Through crop rotation, farmers diversify their income sources and reduce the risk of crop failure due to extreme weather events, such as droughts or floods, which are becoming more frequent and severe due to climate change. Further, adopting IPM and disease control practices assist farmers reduces the use of chemical pesticides and fungicides which help maintain crop health and productivity, even in the face of changing climate conditions that may favor the proliferation of certain pests and diseases.

Furthermore, the participants indicated that they use tractor and ox-plough in their farm as shown by 96.5% while 3.5% indicated that they do not use tractor and ox-plough in their farm. The use of tractors and ox-ploughs allows farmers to plant crops more quickly and efficiently and assists farmers in adapting to changing weather patterns and other climate-related challenges. Using tractors and ox-ploughs reduces the amount of labor required for ploughing and planting, freeing up farmers to focus on other tasks particularly where there is a shortage of labor or where labor costs are high.

Further, the participants indicated that they do not engage in off-farm activities like business, casual labour, or employment as shown by 63.2% while 36.8% indicated to have engaged in off-farm activities like business, casual labour, or employment. Engaging in off-farm activities is a good climate change adaptation strategy as it diversifies include since relying solely on farming is risky due to the unpredictability of weather patterns and the impact of climate change on agricultural productivity. In addition, off-farm activities also provide farmers with access to information and resources that assist them in adapting to climate change as they have access to training programs on climate-smart agriculture practices.

Further, the participants indicated that they keep livestock (cattle, sheep, goats, or poultry or do fishing) as shown by 92.3% while 7.7% of the participants indicated that they do not keep livestock (cattle, sheep, goats or poultry or do fishing). Livestock assists in recycling nutrients in the soil as they provide manure, which is a substitute for fertilizer hance, reducing the need for synthetic fertilizers that contribute to greenhouse gas emissions. Livestock also increases the resilience of the farm to climate change and assists in reducing input costs by providing manure for fertilizer and reducing the need for synthetic fertilizers and pesticides.

the factors influencing climate change adaptation strategies adopted by groundnut farmers

The Tobit regression model was used to determine the factors influencing climate change adaptation strategies adopted by the groundnut farmers in the study area. The findings are illustrated in Table 4.7 below.

Table 4. 7 Tobit Regression Analysis Results

Log-likelihood = 639.754			Number of obs = 481 LR chi2 (9) = 308.018 Prob>Chi^2 = 0.000 Pseudo R^2 = 0.473			
	Coef.	**Std. Err.**	**t**	**$P>\lvert t\rvert$**	**[95% Conf. Interval]**	
Age	.009	.008	1.036	.301	-.008	.025
Sex	-.013	.012	-1.012	.312	-.012	.037
Marital status	.084	.017	4.841	.000	.050	.118
Household size	.032	.021	1.483	.139	-.074	.010
Education	.001	.011	.090	.928	-.022	.020
Experience	-.041	.006	-7.092	.000	-.052	-.029
Farm size	.026	.011	2.299	.022	-.048	-.004
Income	-.073	.011	-6.425	.000	-.095	-.051
Knowledge level	.028	.009	3.310	.001	.012	.045
[Constant]	1.366	.062	21.869	.000	1.243	1.489

Based on the findings in Table 4.7, the Tobit regression model equation was

$Y = 1.366 + 0.009X_1 - 0.013X_2 + 0.084X_3 + 0.032X_4 + 0.001X_5 - 0.041X_6 + 0.026X_7 - 0.073X_8 + 0.028X_9$

Where: Y = Climate change adaptation strategies adopted by the groundnut farmers

X1 = Age; X_2 = Sex; X_3 = Marital status; X_4 = Household size; X_5 = Education

X_6 = Experience; X_7 = Farm size; X_8 = Income; X_9 = Knowledge level

From the findings, it was clear that marital status has a significant influence on climate change adaptation strategies adopted by the groundnut farmers in Yirol East County (β =0.084; p=0.000) and that experience in farming has a negative significant influence on climate change adaptation strategies adopted by the groundnut farmers in Yirol East County (β =-0.041; p=0.000). Further, the study established income of farmers has a negative significant influence on climate change adaptation strategies adopted by the groundnut farmers in Yirol East County (β =-0.073; p=0.000). Further, the findings showed that the knowledge level of farmers has a positive significant influence on climate change adaptation strategies adopted by the groundnut farmers in Yirol East County (β =0.028; p=0.001) and that farm size has a significant influence on climate change adaptation strategies adopted by the groundnut farmers in Yirol East County (β =0.026; p=0.022). However, household size (β =0.032; p=0.139), age (β =0.009; p=0.301), sex (β =-0.013; p=0.312), and education (β =0.001; p=0.928) had no significant influence on climate change adaptation strategies adopted by the groundnut farmers in Yirol East County. This implies that factors significantly influencing climate change adaptation strategies adopted by the groundnut farmers in Yirol East County include marital status, experience in farming, income of farmers, knowledge level of farmers, and farm size.

4.7 Factors influencing the choice of Climate Change Adaptation Strategies Used by rural farmers

Further, the study sought to assess factors determining or influencing the choice of climate change adaptation strategies used by groundnut farmers in Yirol East County (District). The study employed a multivariate probit model because it concurrently models the estimated effect of the set of explanatory variables on each of the adaptation strategies. In this study, the dependent variables are five dummy variables, which include; crop diversification, good agricultural practices, farm technology, off-farm activities, and livestock. All dependent variables are equal to one if the farmer household adopts the adaptation strategy and zero if otherwise. The perceived climate change adaptation strategies and their summary statistics are illustrated in Table 4.6 above.

Table 4. 8 Correlation Matrix

		Gender of the farmer	Age of the farmer	Household size	Experience in farming	Length of residence in the community in years	Education Level of the Farmer	Farmers' Income	Farm size (ha)	Distance to market	Knowledge of climate change adaptation strategy	Access to extension services	Access to climate and weather information	Membership in farmers' group	Perceived change in droughts and floods	Perceived change in planting seasons	Perceived change in the prevalence of diseases and pests	Perceived climatic variability of rainfall and temperature
Gender of the farmer	Correlation (r)	1	.085	.109*	.249**	.100*	-.258**	-.110*	.099*	-.138**	-.067	.150**	.414**	-.088	.035	-.075	-.130**	-.107*
	Sig.		.064	.017	.000	.028	.000	.016	.030	.002	.140	.001	.000	.053	.440	.098	.004	.019
Age of the farmer	Correlation (r)	.085	1	-.309**	.187**	-.046	-.004	.222**	.280**	-.157**	.176**	-.032	-.032	-.041	-.009	-.064	-.041	-.106*
	Sig.	.064		.000	.000	.318	.930	.000	.000	.001	.000	.488	.483	.367	.851	.161	.367	.020
Household size	Correlation (r)	.109*	-.309**	1	.227**	-.094*	.107*	.035	-.019	-.118**	-.122**	-.232**	.134**	-.337**	.084	.204**	.070	.244**
	Sig.	.017	.000		.000	.040	.019	.447	.681	.009	.007	.000	.003	.000	.066	.000	.126	.000
Experience in farming	Correlation (r)	.249**	.187**	.227**	1	.098*	-.106*	.240**	.341**	-.546**	-.307**	-.066	.666**	-.223**	.129**	.074	-.074	.064
	Sig.	.000	.000	.000		.032	.019	.000	.000	.000	.000	.150	.000	.000	.005	.106	.104	.162
Length of residence	Correlation (r)	.100*	-.046	-.094*	.098*	1	.010	.015	.011	-.149**	-.201**	.034	.117*	-.174**	-.046	-.026	.275**	-.023
	Sig.	.028	.318	.040	.032		.820	.750	.813	.001	.000	.455	.010	.000	.312	.563	.000	.617

Education Level of the farmer	Correlation (r)	-.258**	-.004	.107*	-.106*	.010	1	.482**	.008	-.073	.185**	-.202**	-.291**	-.103*	.001	.073	.127**	.094*
	Sig.	.000	.930	.019	.019	.820		.000	.865	.112	.000	.000	.000	.023	.989	.112	.005	.039
Income	Correlation (r)	-.110*	.222**	.035	.240**	.015	.482**	1	.281**	-.258**	.066	-.196**	.050	-.127**	-.090*	-.052	.043	-.045
	Sig.	.016	.000	.447	.000	.750	.000		.000	.000	.148	.000	.275	.005	.048	.259	.348	.329
Farm size (ha)	Correlation (r)	.099*	.280**	-.019	.341**	.011	.008	.281**	1	-.198**	-.065	-.128**	.319**	-.242**	.144**	.083	-.167**	.107*
	Sig.	.030	.000	.681	.000	.813	.865	.000		.000	.153	.005	.000	.000	.002	.070	.000	.019
Distance to market	Correlation (r)	-.138**	-.157**	-.118**	-.546**	-.149**	-.073	-.258**	-.198**	1	.340**	.194**	-.450**	.425**	-.110*	-.063	-.119**	-.055
	Sig.	.002	.001	.009	.000	.001	.112	.000	.000		.000	.000	.000	.000	.016	.167	.009	.232
Knowledge	Correlation (r)	-.067	.176**	-.122**	-.307**	-.201**	.185**	.066	-.065	.340**	1	.109*	-.462**	.257**	-.164**	-.094*	-.169**	-.109*
	Sig.	.140	.000	.007	.000	.000	.000	.148	.153	.000		.017	.000	.000	.000	.039	.000	.017
Access to extension services	Correlation (r)	.150**	-.032	-.232**	-.066	.034	-.202**	-.196**	-.128**	.194**	.109*	1	.043	.623**	.133**	.076	-.132**	.066
	Sig.	.001	.488	.000	.150	.455	.000	.000	.005	.000	.017		.347	.000	.003	.095	.004	.148
Access to climate and weather information	Correlation (r)	.414**	-.032	.134**	.666**	.117*	-.291**	.050	.319**	-.450**	-.462**	.043	1	-.226**	.178**	.102*	.018	.088
	Sig.	.000	.483	.003	.000	.010	.000	.275	.000	.000	.000	.347		.000	.000	.025	.686	.053
Membership to farmers' group	Correlation (r)	-.088	-.041	-.337**	-.223**	-.174**	-.103*	-.127**	-.242**	.425**	.257**	.623**	-.226**	1	-.055	-.080	-.243**	-.111*
	Sig.	.053	.367	.000	.000	.000	.023	.005	.000	.000	.000	.000	.000		.227	.079	.000	.015

Perceived change in droughts and floods	Correlation (r)	.035	-.009	.084	.129**	-.046	.001	-.090*	.144**	-.110*	-.164**	.133**	.178**	-.055	1	.426**	.210**	.495**
	Sig.	.440	.851	.066	.005	.312	.989	.048	.002	.016	.000	.003	.000	.227		.000	.000	.000
Perceived change in planting seasons	Correlation (r)	-.075	-.064	.204**	.074	-.026	.073	-.052	.083	-.063	-.094*	.076	.102*	-.080	.426**	1	.393**	.865**
	Sig.	.098	.161	.000	.106	.563	.112	.259	.070	.167	.039	.095	.025	.079	.000		.000	.000
Perceived change in prevalence of diseases and pests	Correlation (r)	- .130**	-.041	.070	-.074	.275**	.127**	.043	-.167**	-.119**	-.169**	- .132**	.018	-.243**	.210**	.393**	1	.458**
	Sig.	.004	.367	.126	.104	.000	.005	.348	.000	.009	.000	.004	.686	.000	.000	.000		.000
Perceived climatic variability of rainfall and temperature	Correlation (r)	- .107*	-.106*	.244**	.064	-.023	.094*	-.045	.107*	-.055	-.109*	.066	.088	-.111*	.495**	.865**	.458**	1
	Sig.	.019	.020	.000	.162	.617	.039	.329	.019	.232	.017	.148	.053	.015	.000	.000	.000	
Crops diversification	Correlation (r)	.020	-.005	-.030	.074	-.026	-.036	-.052	.000	-.063	-.030	.076	.102*	.017	-.015	-.008	-.016	-.007
	Sig.	.659	.914	.515	.106	.563	.435	.259	.999	.167	.507	.095	.025	.713	.749	.854	.729	.874
Good Agricultural Practices	Correlation (r)	-.051	-.032	-.157**	- .441**	-.096*	-.065	- .399**	-.228**	.443**	.286**	.257**	-.429**	.294**	.146**	.084	-.016	.072
	Sig.	.264	.487	.001	.000	.035	.157	.000	.000	.000	.000	.000	.000	.000	.001	.067	.734	.113

Farm technology	Correlation (r)	-.022	-.010	-.062	.025	-.055	-.075	-.108*	-.025	.037	-.154**	-.001	.054	.136**	.186**	-.018	-.033	-.015
	Sig.	.623	.822	.173	.591	.226	.102	.018	.582	.422	.001	.985	.234	.003	.000	.701	.468	.740
Off-farm activities	Correlation (r)	-.017	-.004	-.162**	-.519**	-.168**	-.158**	-.290**	-.333**	.462**	.359**	.250**	-.476**	.432**	.039	-.073	-.124**	-.104*
	Sig.	.704	.938	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.392	.112	.006	.023
Livestock	Correlation (r)	.100*	-.046	-.094*	.098*	1.000**	.010	.015	.011	-.149**	-.201**	.034	.117*	-.174**	-.046	-.026	.275**	-.023
	Sig.	.028	.318	.040	.032	.000	.820	.750	.813	.001	.000	.455	.010	.000	.312	.563	.000	.617

*. Correlation is significant at the 0.05 level (1-tailed).
**. Correlation is significant at the 0.01 level (1-tailed).

From the findings in Table 4.8, the study established there is an insignificant relation between crop diversification and all other factors (gender of the farmer, age of the farmer, household size, experience in farming, length of residence, education level of the farmer, farmers' income, farm size (ha), distance to market, knowledge, access to extension services, access to climate and weather information, membership to farmers' group, perceived change in droughts and floods, perceived change in planting seasons, perceived change in prevalence of diseases and pests and perceived climatic variability of rainfall and temperature) since their p-values were greater than 0.05. However, the findings showed that there is a positive and significant relationship between good agricultural practices and distance to market (r=0.443; p=0.000), knowledge of climate change adaptation strategy (r=0.286; p=0.000) as well as access to extension services (r=0.257; p=0.000). Further, the findings showed that there is a significant and positive relationship between good agricultural practices and membership to farmers' group (r=0.294; p=0.000) as well as perceived change in droughts and floods (r=0.146; p=0.001). In addition, the study established that household size (r= -0.157; p=0.001), experience in farming (r= -0.441; p=0.000), length of residence in the community in years (r= -0.096, p=0.035), farmers' income (r= -0.399; p=0.000, farm size (r= -0.228; p=0.000) and access to climate and weather information (r= -0.429; p=0.000) has a negative and significant relation with good agricultural practices applied by groundnut farmers in Yirol East County. Nonetheless, the fact that household size, farm experience, and income are negatively correlated with good agricultural practices (GAPs) sounds ironic, but truly, in the context of South Sudan, it is the type of farm technology adopted by rural households that may influence good agricultural practices rather than just the size of a household. Secondly, because most farmers in rural South Sudan are subsistence-based, they largely adopt traditional agricultural practices, including the use of traditional farm tools, and thus, no matter how long they continue practicing traditional farming, this may not influence good agricultural practices (GAPs). Thirdly, rural farmers in South Sudan, especially groundnut farmers, are resource-poor and do not have access to financial services; therefore, farmers' income in cannot positively correlate with good agricultural practices (GAPs). This is in contrast with findings by (Das and Kumar, 2017) which showed that a U-shaped relationship exists between farm size and farm / farmer's income. This argument is supported by the results of focus group discussion presented in tables 24-25 which clearly showed inadequate support to farmers, weak institutional capacities and lack of implementation of government policies among others.

Further, the findings showed that farmers' income (r= -0.108; p=0.018) and knowledge of climate change adaptation strategy (r= -0.154; p=0.001) has a negative and significant relationship with farm technology adopted by groundnut farmers in Yirol East County. This is true because higher income does not always translate to adopting a specific technology more often. In addition, knowledge of climate change adaptation strategy because in South Sudan, most farmers learn such technologies through series of training offered by humanitarian organizations. Further, the findings showed that membership to farmers' group (r=0.136; p=0.003) and perceived change in droughts and floods (r=0.186; p=0.000) has a positive and significant relationship with farm technology adopted by groundnut farmers in Yirol East County. Other variables as shown in Table 7 had insignificant relationship with farm technology adopted by groundnut farmers in Yirol East County.

As per the results in Table 4.8, the study established that distance to market (r=0.462; p=0.000), knowledge of climate change adaptation strategy (r=0.359; p=0.000), access to extension services (r=0.250; p=0.000) and membership to farmers' group (r=0.432; p=0.000) has a positive and significant relationship with off-farm activities such as business, casual labour and formal employment. However, the study found that household size (r= -0.162; p=0.000), experience in farming (r=-0.519; p=0.000), length of residence (r=-0.168; p=0.000), education level (r= -0.158; p=0.001), farmers' income (r= -0.290; p=0.000), farm size (r=-0.333; p=0.000), access to climate and weather information (r=-0.476; p=0.000), perceived change in prevalence of diseases and pests (r=-0.124; p=0.006) and perceived climatic variability of rainfall and temperature (r=-0.104; p=0.023) has a negative and significant relationship with off-farm activities such as business, casual labour and formal employment. The study revealed that gender of the farmer (r=0.100; p=0.028), experience in farming (r=0.098; p=0.032), length of residence in the community (r=1.000; p=0.000), access to climate and weather information (r=0.117; p=0.01) and perceived change in prevalence of diseases and pests (0.275; p=0.000) has a positive and significant relationship with livestock farming as climate change adaptation strategy. However, the study showed that household size (r= -0.094; p=0.04), distance to market (r= -0.149; p=0.001) and knowledge of climate change adaptation strategy (r= -0.201; p=0.000), and membership to farmers' group (r= -0.174; p=0.04) has a negative and significant relationship with livestock farming as climate change adaptation strategy.

The above findings corroborate the findings by (Francis *et al,* 2021), which indicate that factors such as gender, age, household size, farmer-based-organizations membership, farm income, years of education, districts of the location of respondents, farm size, and climate change awareness—statistically and significantly—influenced households' adaptation to the changing climate. The findings by (Francis *et al,* 2021) further elaborate that level of education and age are critical socio-demographic determinants and proxy measures of social identity that scale households' or communities' coping capacity. Educated farmers are in a better position to comprehend climate change and its associated risks.

4.8 Impacts of Climate Change Adaptation Strategies on household food security

The study also sought to assess the impact of climate change adaptation strategies on the household food security of groundnut farmers in Yirol East County (District).

The participants were asked to indicate whether they have observed any change in terms of good harvest or food availability because of growing different types of crops on their farm. The findings are represented in Table 4.9.

Table 4. 9 Change in Terms of Good Harvest or Food Availability

Response	Frequency	Percent
Yes	324	67.4
No	157	32.6
Total	**481**	**100.0**

As per the findings in Table 4.9, the participants indicated that they had observed change in terms of a good harvest or food availability because of growing different types of crops on their farm as shown by 67.4% while 32.6% of the participants indicated that they had not observed any change in terms of a good harvest or food availability because of growing different types of crops in your farm. This implies that growing different crops as a climate change adaptation strategy impacts food availability in most households in Yirol East County. Further, the participants who responded affirmatively were asked to describe the change they observed. They indicated that there is availability of different foods, benefits of eating different varieties of foods, about 30 percent increase, and eating different varieties of foods keeps the body healthy. The findings of this study are in agreement with the findings from a study conducted in Kenya by McCord et al, (2014), which emphasized that crop diversification is one strategy that smallholder farmers may employ to reduce their vulnerability in the face of global environmental change. McCord's research further stressed that diversification not only expands the number of potential crop types for the market but also improves agroecosystem functioning by building redundancy into the agricultural system and allowing for innovation in areas exhibiting impacts of climate variability.

Further, the participants were asked to indicate whether they practice any of the good agricultural practices like crop rotation, mulching, fallowing, pests and diseases control, and alley cropping on their farm resulting in increased harvest or food production. The findings are in Table 4.10.

Table 4. 10 Impact of Good Agricultural Practices on Increased Harvest

Response	Frequency	Percent
Yes	306	63.6
No	175	36.4
Total	**481**	**100.0**

From the findings in Table 4.10, most of the participants indicated that good agricultural practices like crop rotation, mulching, fallowing, pests and diseases control, and alley cropping in their farm result in increased harvest or food production as shown by 63.6% while the rest were of contrary opinion. This implies that good agricultural practices like crop rotation, mulching, fallowing, pests and diseases control, and alley cropping farms result in increased harvest or food production.

Further, the participants were asked to indicate whether they had ever used a tractor or ox-plough on their farm last season and if they had noticed any change in terms of crop yields. The findings are illustrated in Table 4.11.

Table 4. 11 Use of tractor or ox-plough and its Impact

Question	Response	Frequency	Percent
Ever used tractor or ox-plough	Yes	449	93.3
	No	32	6.7
Notice any change in terms of crop yields	Yes	363	75.5
	No	118	24.5

From the findings, most of the participants indicated that they had used a tractor or ox-plough on their farm last season as shown by 93.3% while 6.7% were of contrary opinion. In addition, the participants indicated that because of using a tractor or ox-plough they have noticed some change in terms of crop yields as shown by 75.5% while 24.5% were of contrary opinion. This implies that tractors or ox-ploughs on the farm have resulted in a change in terms of increased crop yields.

In addition, the participants were asked to indicate whether engagement in off-farm activities like business, casual labour, or employment supplements food availability in the family and whether livestock keeping (cattle, sheep, goats' poultry, or fishing) adequately enhances food availability in their family. The findings are illustrated in Table 4.12 below.

Table 4. 12 Impacts of Off-farm Activities and Livestock Keeping

Question	Response	Frequency	Percent
Off-farm activities	Yes	195	40.5
	No	286	59.5
Livestock keeping	Yes	453	94.2
	No	28	5.8

The participants indicated that their engagement in off-farm activities like business, casual labour, or employment supplement food availability in the family as shown by 40.5% while 59.5% were of contrary opinion. In addition, 94.2% of the participants indicated that livestock keeping (cattle, sheep, goats or poultry or fishing) adequately enhances food availability in their family while 5.8% were of contrary opinion. This implies that off-farm activities and livestock keeping as climate change adaptation strategies have adequately enhanced food availability in most households in Yirol East County.

4.9 Endogenous Switching Probit (ESP) Model to evaluate the impact of climate change adaptation strategies on the household food security of groundnut farmers

The study employed the endogenous switching probit (ESP) model to evaluate the impact of climate change adaptation strategies on the household food security of groundnut farmers in Yirol East County. An endogenous switching probit (ESP) is a two-stage estimation technique, which addresses the selection bias stemming from both observed and unobserved heterogeneities (Li et al., 2020) and can also estimate two outcome equations. In the first stage, the climate change adaptation strategies (CCAS) adoption function was modeled by analyzing the factors that affect farmers' decisions to adopt CCAS. The second stage estimates both household food security and insecurity status (Table 4.13).

Table 4. 13 Results of the Endogenous Switching Probit Model

Variable	**Stage 1: CCAS adoption function**		**Stage 2: Household food security Status**			
			Food Secure		**Food Insecure**	
	Coef.	**SE.**	**Coef.**	**SE**	**Coef.**	**SE**
Age	.009**	.008	-.016	.012	-.016	.010
Sex	-.013**	.012	.003	.018	.004	.015
Marital status	.084	.017	-.030**	.025	-.063	.021
Household size	.032	.021	-.087**	.031	-.085**	.026
Education	.001	.011	.071	.016	.024**	.013
Experience	-.041**	.006	.055**	.008	.037**	.007
Farm size	.026**	.011	.003**	.016	.083	.014
Income	-.073**	.011	-.124**	.017	-.060**	.014
Knowledge level	.028**	.009	-.002**	.012	.051	.010
[Constant]	1.366**	.062	1.128**	.091	1.369	.076
Rho			-.109**	.031	-.120**	.003

Note: $p<0.05$ =** Coef. = Regression coefficient; SE=Standard Error

From the findings in Table 4.13, the decision to adopt climate change adaptation strategies (CCAS) adoption function is determined by farmers age (β=0.009**; p=0.008), farmers sex (β= -0.013**; p=0.012), farming experience (β= -0.041**; p=0.006), farm size (β=0.026**; p=0.011), farmers' income (β= -0.073**; p=0.011) and knowledge level (β=0.028**; p=0.009). In addition, the findings showed that climate change adaptation strategies (CCAS) adoption has a significant relationship with food secure status (rho= -0.109**; p=0.031) and food insecure status (rho= -0.120**; p=0.003). This implies that climate change adaptation strategies significantly and positively impact the status of household food security status of adopters by 11% while negatively impacting the household food security status of no-adopters by 12%. Adopting climate change adaptation strategies like crop diversification which includes planting different types of crops alongside groundnuts assist in reducing pest and disease pressure which increases food production and in turn ensures food security. Further, accessing weather information could assist groundnut farmers make informed decisions about planting and harvesting, thereby ensuring food security. These findings are corroborated by the study conducted by (Zakari, *et al,* 2022) which found that adaptation strategies have a positive and significant impact on both household income and food security. The farmers who adopt climate change adaptation strategies are more likely to increase household income by 7721.526 FCFA compared to those households with zero adaptation strategies. Similarly, the adapters have a 7% to 9% more chance to be food secure compared to those who did not adopt strategies (Zakari *et al,* 2022).

4.10 Food Security status of groundnut farmers in Yirol East County (District)

The study sought to assess the food security status of the groundnut farmers in Yirol East County (District). The participants were asked whether they produce food from their farm, whether they usually have enough food in stock that lasts until the next season, whether they access some food through markets, and whether there are challenges in terms of the movement of food commodities in and out of markets. The findings are illustrated in Table 4.14.

Table 4. 14 Aspects of Food Security

Question	Response	Frequency	Percent
Produce food on farms	Yes	457	95.0
	No	24	5.0
Having enough food in stock	Yes	44	9.1
	No	437	90.9
Accessing food in markets	Yes	420	87.3
	No	61	12.7
Challenges in terms of the movement of food	Yes	406	84.4
	No	75	15.6

From the findings in Table 4.14, most of the participants indicated that they produce food from their farm as shown by 95%, that they usually have not enough food in stock that lasts until the next season as shown by 90.9% and that they access some food through markets as shown by 87.3%. In addition, the participants indicated that there are challenges in terms of movement of food commodities in and out of markets as shown by 84.4%. This implies that some households can produce in their farms though the food in stock does not last up to the following season. In addition, it was reported that there are challenges in terms of movement of food commodities in and out of markets.

Further, the participants were asked to indicate whether there are issues of insecurity on food transportation routes, whether they sometimes sell some livestock to access food in times of shortage and whether they have a variety of food sources. The findings are illustrated in Table 4.15.

Table 4. 15 Other Aspects of Food Security

Question	Response	Frequency	Percent
Issues of insecurity on food transportation routes	Yes	385	80.0
	No	96	20.0
Selling some livestock to access food	Yes	425	88.4
	No	56	11.6
Having a variety of food sources	Yes	366	76.1
	No	115	23.9
Having surplus food for sale	Yes	45	9.4
	No	436	90.6
Borrowing food from friends	Yes	60	12.5
	No	421	87.5
Lack of food in stock	Yes	446	92.7
	No	35	7.3

From the results in Table 4.15, the participants indicated that there are issues of insecurity on food transportation routes as shown by 80%, that they sometimes sell some livestock to access food in times of shortage as shown by 88.4% and that they have a variety of food sources as shown by 76.1%. This implies that most households in Yirol East County have a variety of food sources which include selling some livestock to access food. This is despite there being issues of insecurity on food transportation routes. Further, most of the participants indicated that they sometimes have no surplus food to sell in the market as shown by 90.6%, that they do not sometimes borrow food from friends and relatives in times of shortage as shown by 87.5% and that they sometimes completely lack food in stock as shown by 92.7%. This implies that most households in Yirol East County are food insecure, which could be attributed to the fact that households have no surplus food to sell in the market and sometimes they completely lack food in stock.

4.11 Results and Discussion on the Focused Group Discussion (FGD)

Focus group discussion (FGD) involved technical interactive discussion and exchange of relevant information/ideas with participants followed by critical and thematic analysis of the results. Results of Focus Group Discussion (FGD) are presented in tables 20 - 25 below. This entailed detailed discussion of each step which formed the basis for development of localized climate adaptation framework (Figure 4.9). Five key steps in this process include Step 1: The focus group analyzed policies and programs that the government is currently undertaking to adapt to climate change (Table 4.16). Step 2: The group discussion focused on vulnerability assessment and sensitivity analysis for groundnut farming households in a plenary session (Table 4.17 & 4.18). Step 3: The focused group deliberated on the risk factors affecting the groundnut farming households in the study area (Table 4.19). Step 4: The discussion provided the framework for analysis of the adaptive capacity of rural groundnut farmers, Ecosystems Services (ES) – Socio-Economic Sectors (SES) in response to existing or potential impacts of climate change on local communities in South Sudan's groundnut-producing states and Yirol East County (Table 4.20). Finally, step five discussed an adaptation option matrix (Table 4.21).

Table 4. 16 The structure - roles and responsibilities of each team member

Government Line Ministry	**Technical team**	**Roles & Responsibilities**
MAFS	Technical Committees	Handle issues of climate resilience under IGAD known as **Technical Experts**
	The Strategy to Combat Drought and Desertification team.	Management of drought and desertification
	The Technical Working Group (TWG) for the United Nations Convention to Control Drought and Desertification,	Management of drought and desertification
	The Technical Working Group (TWG) for Dessert Locust (DL)	Management of Desert Locus and Fall Army Worm

	and Fall Army Worm (FAW) Control.	
MEF	Technical Committees	Meetings on Biodiversity and Climate Change etc.
	Climate Change Technical Working Group (CCTWG)	Informs the Steering Committee on climate issues and the Committee raises issues to the next high level of authority
MHDAM	Early Warning Technical Working Group (EWTWG)	Early warning
	Disaster Risk Management Committees (DRMCs)	Disaster Risk management and mitigation
	Disaster Risk Reduction Committees (DRRCS) platforms at national and county (District) levels	Disaster Risk management and mitigation
MoH	Technical Committee	Health Early Warning
MoP	Technical Committee	Conflict and Early Warning
South Sudan Meteorological Department (SSMD)	Technical Committee	Weather-related information

Linked with the roles and responsibilities of the technical or adaptation management teams in table 4.16 above, the group further analyzed policies and programs that the government is currently undertaking to adapt to climate change. The results of the group discussion further show key programs undertaken by line ministries which include; identification, analysis, reporting, and communication/dissemination and development of an Anticipatory Action Plan (AAP) among other activities. The policy area in the National Ministry of Environment and Forestry (MEF) covers a range of policies such as the National Adaptation Programme of Action (NAPA), Nationally Determined Contribution (NDC), National Adaptation Program (NAP), Initial Nationally Determined Contribution (INDC), Green House Gas Emission (GHG), the National Biodiversity Strategy Action Plan (NBSAP) and the National Forestry Policy (NFP).

Step 2: Vulnerability Assessment and Sensitivity Analysis*:* In step two, the group discussion focused on vulnerability assessment and sensitivity analysis for groundnut farming households in a plenary session. (Kasperson *et al*., 2000) define vulnerability as a function of risk plus or minus adaptation responses, expressed as *"Vulnerability = Risk (Danger x Exposure) +/- Adaptation*

(Responses / Options)". In this study, the vulnerability and sensitivity analysis aimed at addressing a set of research questions that include; the degree to which the identified ecosystem services and socio-economic sectors (ES-SES) are sensitive to climate change, the adaptive capacity of the national and sub-national line ministries to address existing and potential climate change impacts, an analysis and prioritization of organizational vulnerabilities based on their, sensitivity and adaptive capacities, presence or absence of technical team or adaptation management teams within the concerned department of the ministry, the structure e.g., roles and responsibilities of each team member such as adaptation coordinators within the ministries, the key functions of the technical teams in the respective technical ministries of the government such Ministry of Environment and Forestry, the Ministry of Humanitarian Affairs and Disaster Risk Management, and the Ministry of Agriculture and Food Security respectively e.g., identification of ES-SES and policies and programs that the government currently undertake to adapt to climate change.

Vulnerability assessment in this study discusses biophysical vulnerability which encompasses the ecological processes related to the susceptibility and exposure to environmental changes and the social vulnerability which covers the political, socio-economic, cultural, and institutional processes. The main objective of vulnerability assessment was to evaluate how susceptible communities are to the impacts of climate change (**Bio-physical Vulnerability),** identify the key areas for adaptation planning as well as evaluate existing technical institutions and the socioeconomic structures and institutional processes (**Social Vulnerability**) that have a significant impact on the food security status of groundnut farming households in the study area. During the assessment, the results of focused group discussion further listed projected climate change impacts on the ecosystem services (ES) and the socio-economic sectors (SES) which included extreme weather conditions (drought, flood, heat waves, wildfires, and dust storms, etc.) and outbreak of diseases.

Looking at the degree to which the identified ES-SESs are sensitive to climate change (Table 4.17) below, the results of the focused group discussion show that four main socio-economic sectors (SES) which include livestock, water, agriculture, environment/forestry, and health care services are highly sensitive to the impacts of climate change.

Table 4. 17 Vulnerability Assessment Matrix

Ecosystem Service (ES) or Socio-Economic Sector (SES) - Examples	The degree to which the identified ES-SESs are sensitive to climate change		
	High	**Medium**	**Low**
Livestock	x		
Fisheries			x
Water	x		
Livestock pests' regulation		x	
Agriculture	x		
Environment/Forestry	x		
Land		x	
Seeds		x	
Extension services			x
Trade and marketing			x
Training			x
Coordination and communication			x
Health service	x		
Education service			x

On sensitivity analysis (Table 4.18), other ecosystem services (ES) include pests' regulation, forestry, and land/Soil. Socio-economic sectors (SES) include livestock, fisheries, water, agriculture and environment. Considering the degree of sensitivity from existing stress, ES-SES such as Livestock pests' regulation, land, and seed sectors were considered to be of medium sensitivity to the impacts of climate change while, fisheries, extension services, trade and marketing, training, coordination, and communication are in the scale of low sensitivity to the impacts of climate change.

Further analysis of existing and potential stresses categorized the stress levels into:

(a) existing stresses: these include environmental changes e.g., extreme weather conditions such as prolonged dry spells, drought, heatwaves, floods, an outbreak of crop pests/animal pests, or disease among other stress factors. The result of environmental changes in lude floods, drought, an outbreak of diseases, and socio-economic changes e.g., education levels, income, poverty rate, social capital, the extent of livelihood diversification, and land among others. These stressors result in reduced productive capacity, induced migration, and lack of technology, further resulting in reduced income, induced water-related conflicts between cattle keepers and farmers, reduced production, reduction in soil fertility (increase erosion)-loss of vegetation cover- loss of biodiversity and aggravating poor Soil composition and quality and

(b) Potential stresses: these include increased poverty, resulting in induced communal conflicts, loss of livestock to raid, and risk to lives, low income, low fish catch/volume, reduced household socio-economic security, persistent hunger due to crop failure, increase in crop pest and disease level and low crop yield.

Table 4. 18 Results of the sensitivity analysis for rural/groundnut farmers in South Sudan – Plenary discussion

ES-SES	Existing stress			Potential stress
	Environmental changes e.g., prolonged dry spell, drought, flood, an outbreak of crop pests/animal pests or diseases, etc.)	**Socio-economic changes e.g., education levels, income, poverty rate, social capital, the extent of livelihood diversification, land, etc.)**	**Degree of sensitivity from existing stress (H/M/L)**	
Livestock	Flood and drought, outbreak of diseases	Reduced productive capacity and induced migration	H	Increase poverty – induce communal conflict, loss of livestock to raid and risk lives
Fisheries	Drought	Lack of technology-reduce income	M	Low income-low fish catch/volume
Water	Drought	Induce related water-related conflict between cattle keepers and farmers.	H	
Livestock pests' regulation	Drought and flood	Social capital- induces livestock diseases and death	H	Reduce household socio-economic security

Agriculture	Extreme weather conditions (drought, flood, heat waves, etc)	Reduce production	H	Hunger due to crop failure-increase in crop pest and disease level, low crop yield
Environment/ Forestry	Extreme weather conditions, fire and dust storms	Reduction in soil fertility (increase erosion)-loss of vegetation cover- loss of biodiversity- enhance	H	Reduction in forest and non-forest products - enhance desertification
Land/Soil	Floods and droughts	Poor Soil composition and quality	H	Loss of productivity

Step 3: Risk assessment*:* In step three, the focused group discussion deliberated on the risk factors affecting the groundnut farming households in the study area. According to the Canadian Council of Ministers of the Environment, 2021, Risk = likelihood × consequence. The Canadian Council of Ministers further defines the risks as the probability of a projected impact occurring, and the consequence refers to the known or estimated outcomes of a particular climate change impact.

In this study, risk assessment was carried out to help both the government and communities understand where to focus their adaptation investment and priorities. The results of the risk assessment show that there is a very low probability that the risk of drought may occur in the next five years in the study area, though it is more likely than not that the risks of other extreme weather conditions such as floods will occur in the same period (Table 4.20). However, in contrast, the research shows the probability that the risks of other extreme weather conditions is still very high.

Table 4. 19 The risk assessment matrix for groundnut farming households in South Sudan

		Likelihood scale					
ES-SES	**Potential risk (Climate Change Impact/Consequences)**	1 **There is a very low probability that this risk may occur in the next 5 years**	2 **Less than 50% chance that this risk will occur in the next 5 years**	3 **50/50 chance that this risk will occur in the next 5 years**	4 **More likely than not this risk will occur in the next 5 years**	5 **Very high probability that this risk will occur in the next 5 years**	**Risk Ranking (H/M/L)**
Livestock	Drought and flood					x	H
Fisheries	drought	x					L
Water	Drought					x	H

Livestock pests' regulation	Extreme weather conditions				x		M
Agriculture	Extreme Weather condition					x	H
Environment/Forestry	Extreme Weather condition					x	H

Step 4: adaptive capacity: In step four, the discussion provided the framework for analysis of the adaptive capacity of rural groundnut farmers, Ecosystems Services (ES) – Socio-Economic Sectors (SES) in response to existing or potential impacts of climate change on local communities in South Sudan's groundnut-producing states and Yirol East County. The key institutional capacity areas to be assessed include;

(i) Governance: This includes management structures, policies, and processes to direct organizational activities e.g., licensing, approvals, etc.

(ii) Human resource capacity: Human resource capacity in this research refers to the capabilities (knowledge and skills) of individuals within the organization. Examples include training, recruitment, and staff capacity development

(iii) Technology: Refers to the application of science to adapt to the fast-changing environment. Examples include the use of GIS and other computer software for climate modeling.

(iv) Processes: Refers to standard operating procedures (SOPs) involved in the identified climate change response planning.

During the discussion, the results of analysis show that the national line ministries have adaptive capacities in terms of existing policy frameworks though not implemented. Existing government policies include livestock, fisheries and irrigation policies respectively (Table 4.20). Other sector-led policies include the Comprehensive Agricultural Master Plan (CAMP), comprehensive Africa Agricultural Development Plan (CAADP), National Adaptation Plan of Action (NAPA), National Agricultural and Livestock Extension Policy (NALEP), and the Lan Tenure Policy which is still in draft. Institutional capacities in terms of human resources encompass areas of community training for disaster response. Institutional capacities in terms of technologies include training in areas of geographic information systems (GIS) systems to provide early warning, agropastoral and pastoral field schools (A/PFS), post-harvest (PH) technologies, farmer field schools (FFS), climate-smart agriculture (CSA) practices, conservation agriculture (CA) practices -Ox plough technology, GeoODK for crop and food security assessment missions (CFSAM), Agroforestry practices, Afforestation and Fuel-Efficient stoves. The discussion further articulated key institutional processes that enhance institutional capacities which include coordination meetings organized by the technical committees and working groups. Further, the results of the focus group discussion with key stakeholders showed that the adaptive capacity of the line ministries is anchored on existing technical committees in the respective institutions and the technical roles played by these technical bodies.

Table 4. 20 Technical Bodies and their roles in the line ministries

Line Ministry	**Technical Body/Committee**	**Key roles**
Ministry of Environment and Forestry (MEF)	Steering Committees	Meetings on Biodiversity and Climate Change etc.
	Climate Change Technical Working Group (CCTWG)	Informs the Steering Committee on climate issues and the Committee raises issues to the next high level of authority
		Development of a range of policies such as the National Adaptation Plan of Action (NAPA), Nationally Determined Contribution (NDC), National Adaptation Program (NAP), Initial Nationally Determined Contribution (INDC), Green House Gas Emission (GHG), the National Biodiversity Strategy Action Plan (NBSAP) and the National Forestry Policy (NFP).

Ministry of Agriculture and Food Security (MAFS)	Technical Committees known as **Technical Experts**	Handle issues of climate resilience related policies under Inter-Governmental Authority on Development (IGAD)

Adaptive capacities of the line ministries are also linked to the projects implemented by the government under the Ministry of Agriculture and Food Security (MAFS) to support climate adaptation with funding from the Global Environment Facility (GEF). Examples here include government climate projects implemented in Kapoeta and Terekeka Counties (Districts) and projects on watershed approaches for climate resilience in the agro-pastoral landscapes covering Aweil North and Aweil East Counties (Districts). These also include agriculture and water management projects. In terms of the adaptive capacity of the national and sub-national line ministries to address existing and potential climate change impacts on identified ES-SES, the group discussion results further show that line ministries have policies, but the existing policies are not implemented.

Step 5: Adaptation options: In step five, an adaptation option matrix (Table 25) provided a list of programs and practices which include vaccinations and treatment of livestock, migration, seasonal fishing calendar, agroforestry, smart climate-smart agriculture, conservation agriculture, afforestation, land allocation, and lease program, training and advisory services.

Table 4. 21 Adaptation options matrix for South Sudan

Identified Climate Change Risk or Impact	Institutional Capacity				Adaptation options
	Governance	Human resource capacity	Technology	Processes	
e.g., Prolonged dry spell that affects groundnut yields	e.g., policy	e.g., Community training for disaster response	e.g., GIS systems to provide early warning		
Livestock	Livestock Policy	Exist	A/PFS	Livestock coordination meetings	Vaccinations and treatment, -Migration
Fisheries	Fisheries Policy	Exist	PH technologies	NR coordination Committees	Seasonal fishing-
Water	Irrigation Policy	Exist	N/A	NR coordination Committees	Irrigation Policy
Livestock pests' regulation		Exist			
Agriculture	CAMP, CAADP, Agriculture Sector Policy	Exist	FFS, CSA, CA-Ox plough- GeoODK for CFSAM--	Agriculture TWGs, - NR coordination Committees	Agroforestry, CSA, CA,
Environment/Forestry	NAPA, NAP, etc.	Exist	Agroforestr y practices, Afforestatio	NR coordination Committees	afforestation-

Identified Climate Change Risk or Impact	Institutional Capacity				Adaptation options
	Governance	Human resource capacity	Technology	Processes	
			n, Fuel Efficient stoves		
Land/soil	Land Tenure Policy (draft)	Exist			Land Allocation and lease
Extension service	NALEP	Exist	N/A	Communica tion	Training and advisory services

4.12 Climate Change Adaptation Framework for Groundnut Farmers in Yirol East County.

In this study, the localized climate change adaptation framework for groundnut farming households in South Sudan has been developed based on five key components of climate adaptation and mitigation practices at the household level (Figure 4.9). The five major components that define the framework include the results of the focused group discussion in section 4.6.

Theoretically, the climate adaptation framework comprises five main components which mark key steps to be followed in the vulnerability assessment.

Step 1 of the framework therefore starts by identifying the main ecosystem services (ES) and the socio-economic sectors (SES) that are susceptible and/ or more sensitive to adverse effects of climate change. As shown by the study, the ecosystem services in the study area include land/soils, seeds, pest regulation/biodiversity, and water, while the major socio-economic sectors (SES) include training and extension services.

Step 2: concerned institutions must assess climate risks, hazards and vulnerabilities. This enhances contextual understanding of communities' vulnerability to climate change as well as an extent to which ecosystem services and socio-economic sectors are sensitive to climate risks. This study has shown that the ES-SES are highly susceptible to climate risks such as extreme weather conditions (droughts, floods) and other risk factors. These risk factors further expose local households to high levels of environmental hazards, thus exacerbating their levels of vulnerabilities. These include biophysical vulnerabilities, which encompasses the ecological processes related to the susceptibility and exposure to environmental changes mentioned earlier as well as social vulnerabilities, which involve the political, socio-economic, cultural, and institutional processes that significantly impact on the food security status of groundnut farming households in the study area.

Step 3: Once dynamics of climate risks, hazards and vulnerabilities are well explained and understood in step 2 above, this takes to step 3 in which the climate adaptation status is also assessed. This assessment is twofold as explained in step 4 because in this step, institutions can understand if there is presence or absence of adaptive capacity among rural communities as well as concerned institutions. Here, there are two scenarios.

Scenario 1: In absence of adaptive capacity, this is portrayed by weak or no adaptive capacity all at community or institutional level, thereby, leading to negative impacts on assets and livelihoods of local communities exacerbated by climate shocks such as drought, floods, outbreak of pests and diseases, eventually leading to persistent food insecurity.

Scenario 2: In presence of adaptive capacity, this is portrayed by existing or potential climate adaptation strategies and options. Positive impacts of such existing or potential strategies and options result in a desired change which can be demonstrated by reduced incidence of pests and disease, reduces frequencies of flash floods and droughts. This eventually leads to component 5, enhanced resilience of local communities.

As a good climate adaptation and mitigation practice, an assessment of climate change adaptation status of national institutions and local households at community level is crucial. Critical assessment of climate adaptation status enables appropriate diagnosis of either the presence or absence of adaptive capacities of local communities.

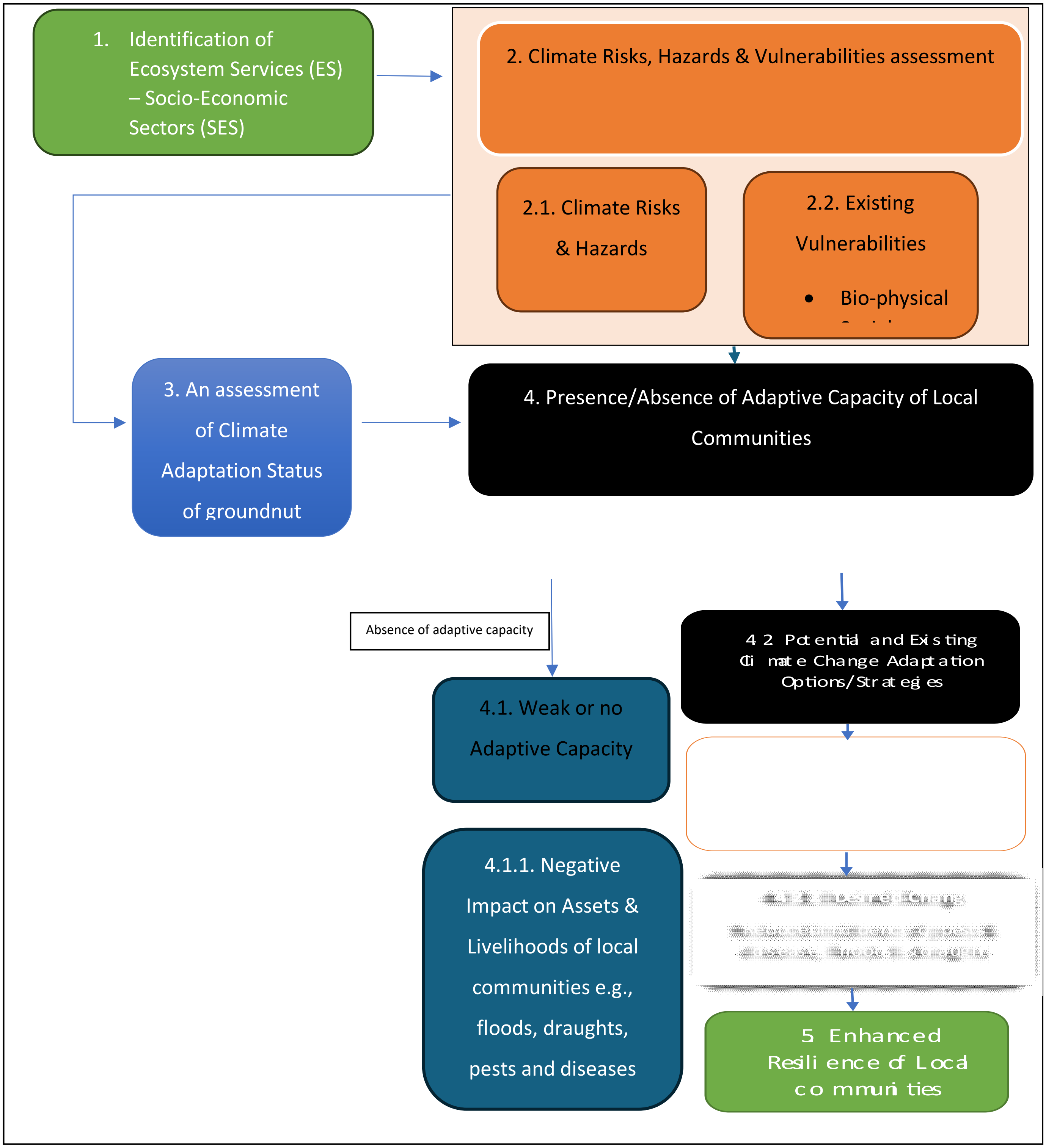

Figure 4. 9 Climate Change Adaptation Framework for Groundnut Farmers Adaptation Framework

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1. Recapping the purpose of the study

South Sudan is experiencing substantially warmer and drier weather, and the combination of these effects leads to increasing evapotranspiration and more droughts. The main purpose of this study was to identify adaptation strategies used by groundnut farmers in Yirol East County (District), assess the factors influencing the adoption of these adaptation strategies as well as evaluate the impact of adopted climate adaptation strategies on the household food security of groundnut farmers. The study aimed to assess the impact of climate change adaptation strategies on the household food security of groundnut farmers and develop localized adaptation framework that if implemented will help improve the output, income, and food security of the groundnut farmers in the study area. The study was conducted in four payams of Yirol East County namely; Adior, Lekhakudu, Malek, Tinagau, Pagarau, and Yali.

5.2. Conclusion of the study

Objective 1: To assess the socio-economic and demographic factors influencing the level of climate change awareness among the groundnut farmers in Yirol East County (District).

The research indicated no education for most participants as illustrated by 82.7%, primary education illustrated by 12.5%, secondary as illustrated by 2.7%, technical and vocational education as illustrated by 1.5%, and college as illustrated by 0.6%. Further, the econometric model (Saguye,2017) also revealed that household characteristics, sex, level of education, and farming experience positively and significantly influenced the perception of climate change.

Objective 2: To identify the climate change adaptation strategies used by groundnut farmers in Yirol East County (District).

Findings of this research show that most farmers grow crops separately (monoculture) as shown by 97.9%. The research also found that more than half of the participants indicated that they do not apply good agricultural practices like crop rotation, mulching, fallowing, pest and disease control, and alley cropping on their farm (54.5%). Further, the participants indicated that they do not engage in off-farm activities like business, casual labour, or employment as shown by 63.2%. In addition, off-farm activities also provide farmers with access to information and resources that assist them in adapting to climate change as they have access to training programs on climate-smart agriculture practices.

Objective 3: To analyse the socio-economic and institutional factors influencing the adoption of climate change adaptation strategies among groundnut farmers Yirol East County (District).

Based on the results of the study, it has been established there is an insignificant relation between crop diversification and all other factors (gender of the farmer, age of the farmer, household size, experience in farming, length of residence, education level of the farmer, farmers' income, farm size (ha), distance to market, knowledge, access to extension services, access to climate and weather information, membership to farmers' group, perceived change in droughts and floods, perceived change in planting seasons, perceived change in prevalence of diseases and pests and perceived climatic variability of rainfall and temperature) since their p-values were greater than 0.05. Further, the findings showed that farmers' income and knowledge of climate change strategy have a negative and significant relationship with farm technology adopted by groundnut farmers in Yirol East County.

Objective 4: To examine the relationship between climate change adaptation strategies and household food security among groundnut farmers in Yirol East County (District).

In this study, participants indicated that they had observed changes in terms of good harvest or food availability because of growing different types of crops on their farm as shown by 67.4. Further the research stressed that diversification not only expands the number of potential crop types for the market but also improves agroecosystem functioning by building redundancy into the agricultural system and allowing for innovation in areas exhibiting impacts of climate variability. Most respondents indicated that they had used a tractor or ox-plough on their farm last season as shown by 93.3%. In addition, the participants indicated that because of using a tractor or ox-plough they have noticed some change in terms of crop yields as shown by 75.5%.

Objective 5: To assess the food security conditions of groundnut farming households in relation to climate variability and adaptation practices.

The research shows that most farmers produce food from their farm as shown by 95%. But despite own production, they usually do not have enough food in stock that lasts until the next season as shown by 90.9% and that they access some food through markets as shown by 87.3%. In addition, the participants indicated that there are challenges in terms of movement of food commodities in and out of markets as shown by 84.4%. In addition, respondents indicated that there are issues of insecurity on food transportation routes as shown by 80%, that they sometimes sell some livestock to access food in times of shortage as shown by 88.4% and that they have a variety of food sources as shown by 76.1%.

Objective 6: To develop a localized climate change adaptation framework which if implemented would improve agricultural productivity, household income, community resilience, adaptive capacity, and sustainable food security of groundnut farming households in Yirol East County.

FGD analyzed the roles and responsibilities of the technical or adaptation management teams, the group further analyzed policies and programs that the government is currently undertaking to adapt to climate change. The results of the group discussion show key programs undertaken by line ministries include; identification, analysis, reporting, communication/dissemination and development of an Anticipatory Action Plan (AAP) among other activities. During the assessment, the results of focus group discussion (FGD) listed projected climate change impacts on the ecosystem services (ES) and the socio-economic sectors (SES) which included extreme weather conditions such as drought, flood, heat waves, wildfires, and dust storms including outbreak of diseases. Further, considering the degree to which the identified ES-SESs are sensitive to climate change (Table 21), the results of the focus group discussion show that four main socio-economic

sectors (SES) which include livestock, water, agriculture, environment/forestry, and health care services are highly sensitive to the impacts of climate change including sensitivity issues. In this study, results of the risk assessment show that the probability risks like other extreme weather conditions are still very high. During the discussion, the results of analysis show that the national line ministries have adaptive capacities in terms of existing policy frameworks though not implemented. Existing government policies include livestock, fisheries and irrigation policies respectively (Table 24). The discussion further articulated key institutional processes that enhance institutional capacities which include coordination meetings organized by the technical committees and working groups. The results of the focus group discussion with key stakeholders showed that the adaptive capacity of the line ministries is anchored on existing technical committees in the respective institutions and the technical roles played by these technical bodies.
Finally, in this study, the climate change adaptation framework for groundnut farming households in South Sudan has been developed based on five key components of climate adaptation and mitigation practices at the household level (Figure 11). The five major components that define the framework include the results of the focused group discussion in section 4.6.

5.3. Recommendations of the study

Objective 1: To assess the socio-economic and demographic factors influencing the level of climate change awareness among the groundnut farmers in Yirol East County (District).

The research indicated no education for most participants as illustrated by 82.7%, primary education illustrated by 12.5%, secondary as illustrated by 2.7%, technical and vocational education as illustrated by 1.5%, and college as illustrated by 0.6%. There is therefore a critical need for customized farmer education both formal and informal because the research further argued that Education has been discovered to be highly related to the effectiveness of work and economic function, (Meskel, 2006, Girei *et al,* 2013, Azihe *et al,* 2019). Further, the econometric model (Saguye,2017) also revealed that household characteristics, sex, level of education, and farming experience positively and significantly influenced the perception of climate change. There is also a need for more frequent gender inclusive training at farm level.

Objective 2: To identify the climate change adaptation strategies used by groundnut farmers in Yirol East County (District).

Findings of this research show that most farmers grow crops separately (monoculture) as shown by 97.9%. The research also found that more than half of the participants indicated that they do not apply good agricultural practices like crop rotation, mulching, fallowing, pest and disease control, and alley cropping on their farm (54.5%). It is recommended that more training of groundnut farmers should be done so that they may understand the importance of mixed cropping and other good agricultural practices/strategies like intercropping because the risks associated with monocropping and non-implementation of good agricultural practices are very high should any incident of crop pest or disease outbreak or any other natural hazard wipe out the whole monocrop, resulting to serious economic losses to a farmer. Further, the participants indicated that they do not engage in off-farm activities like business, casual labour, or employment as shown by 63.2%. It is recommended that farmers are facilitated to access financial services to enable them engage in off-farm activities as it diversifies their coping strategies since relying solely on farming is risky due to the unpredictability of weather patterns and the impact of climate change on agricultural productivity. In addition, off-farm activities also provide farmers with access to information and resources that assist them in adapting to climate change as they have access to training programs on climate-smart agriculture practices.

Objective 3: To analyse the socio-economic and institutional factors influencing the adoption of climate change adaptation strategies among groundnut farmers Yirol East County (District).

Based on the results of the study, it has been established there is an insignificant relation between crop diversification and all other factors (gender of the farmer, age of the farmer, household size, experience in farming, length of residence, education level of the farmer, farmers' income, farm size (ha), distance to market, knowledge, access to extension services, access to climate and weather information, membership to farmers' group, perceived change in droughts and floods, perceived change in planting seasons, perceived change in prevalence of diseases and pests and perceived climatic variability of rainfall and temperature) since their p-values were greater than

0.05. Further, the findings showed that farmers' income and knowledge of climate change strategy have a negative and significant relationship with farm technology adopted by groundnut farmers in Yirol East County. It is therefore recommended that more critical comparative studies are needed to be conducted across the states of South Sudan and in the region so as to further understand the relationships between crop diversification and other socio-economic and demographic factors as well as the relationships between income, knowledge of climate change and the type of technologies deployed by rural farmers.

Objective 4: To examine the relationship between climate change adaptation strategies and household food security among groundnut farmers in Yirol East County (District).

In this study, participants indicated that they had observed changes in terms of good harvest or food availability because of growing different types of crops on their farm as shown by 67.4%. It is recommended that rural farmers must be sensitized to the importance of crop diversification. This critical because (McCord *et al,* 2014) emphasized that crop diversification is one strategy that smallholder farmers may employ to reduce their vulnerability in the face of global environmental change. (McCord *et al,* 2014) further stressed that diversification not only expands the number of potential crop types for the market but also improves agroecosystem functioning by building redundancy into the agricultural system and allowing for innovation in areas exhibiting impacts of climate variability. Further, most of the participants indicated that they had used a tractor or ox-plough on their farm last season as shown by 93.3%. In addition, the participants indicated that because of using a tractor or ox-plough they have noticed some change in terms of crop yields as shown by 75.5%. This calls for promotion and upscaling of ox-plough technology across rural South Sudan.

Objective 5: To assess the food security conditions of groundnut farming households in relation to climate variability and adaptation practices.

The research shows that most farmers produce food from their farm as shown by 95%. But despite own production, they usually do not have enough food in stock that lasts until the next season as shown by 90.9% and that they access some food through markets as shown by 87.3%. This calls for more training of farmers in good agricultural practices as well as post-harvest loss management and control practices. Further the government together with humanitarian agencies need to invest in security and adequate support to county agriculture departments to enhance extension service delivery which may in turn help in increased food production among rural farmers. This may be realized by developing and adopting policies that enhance integrated agricultural practices.

In addition, the participants indicated that there are challenges in terms of movement of food commodities in and out of markets as shown by 84.4%. In addition, respondents indicated that there are issues of insecurity on food transportation routes as shown by 80%, that they sometimes sell some livestock to access food in times of shortage as shown by 88.4% and that they have a variety of food sources as shown by 76.1%. It is recommended that the government must enact existing policies that regulate and facilitate trade of agricultural produce and/or commodities, improve communication networks, security and road infrastructure to allow free movement by local farmers.

Objective 6: To develop a localized climate change adaptation framework which if implemented would improve agricultural productivity, household income, community resilience, adaptive capacity, and sustainable food security of groundnut farming households in Yirol East County.

FGD analyzed the roles and responsibilities of the technical or adaptation management teams, the group further analyzed policies and programs that the government is currently undertaking to adapt to climate change. The results of the group discussion show key programs undertaken by line ministries which include; identification, analysis, reporting, and communication/dissemination and development of an Anticipatory Action Plan (AAP) among other activities. It is recommended that these key roles and responsibilities be thoroughly evaluated to ascertain their relevance, effectiveness and alignment to the right personnel based on experience and qualifications.

During the assessment, the results of focus group discussion (FGD) listed projected climate change impacts on the ecosystem services (ES) and the socio-economic sectors (SES) which included extreme weather conditions such as drought, flood, heat waves, wildfires, and dust storms including outbreak of diseases. Further, considering the degree to which the identified ES-SESs are sensitive to climate change (Table 21), the results of the focus group discussion show that four main socio-economic sectors (SES) which include livestock, water, agriculture, environment/forestry, and health care services are highly sensitive to the impacts of climate change including sensitivity issues. To ensure that negative impacts of climate change are adequately addressed, the government must formulate effective ecosystem service (ES) and socio-economic sectors (SES) protection policies while strengthening existing policies and ensure that these policies are implemented. In this study, results of the risk assessment show that the probability risks like other extreme weather conditions are still very high. It is the recommendation of this study that more research carried out on risk factors and risks analysis including key recommendations on how to address existing and potential risks.

During the discussion, the results of analysis show that the national line ministries have adaptive capacities in terms of existing policy frameworks though not implemented. Existing government policies include livestock, fisheries and irrigation policies respectively (Table 24). The discussion further articulated key institutional processes that enhance institutional capacities which include coordination meetings organized by the technical committees and working groups. The results of the focus group discussion with key stakeholders showed that the adaptive capacity of the line ministries is anchored on existing technical committees in the respective institutions and the technical roles played by these technical bodies. The research recommends a comprehensive review and restructuring of institutional structures to align with roles and responsibilities.

Finally, in this study, the climate change adaptation framework for groundnut farming households in South Sudan has been developed based on five key components of climate adaptation and mitigation practices at the household level (Figure 4.9). The five major components that define the framework include the results of the focused group discussion in section 4.6. An assessment of climate change adaptation policy frameworks of national institutions and local households at community level is highly recommended.

5.4. Limitations of the study

The limitation of this study is the fact that focused group discussion (FGD) for the development of climate change adaptation framework was conducted only with stakeholders from the concerned national ministries in Juba, the capital city of South Sudan, and thus, rural groundnut farmers from the study sites only participated in the general survey. Although the FGDs were limited to national-level stakeholders, the study remains valuable because it integrates policy perspectives with empirical data from groundnut farmers. The use of household survey data ensures that the findings are grounded in local realities and still provide relevant, context-specific insights for decision-making. In addition, the whole process of data collection faced some logistical and financial challenges given the fragile economic situation in South Sudan. However, enumerators eventually ensured timely and quality data collection despite existing challenges.

5.5. Proposed Areas for Future Research

The findings of this study provide several directions for future research on climate change adaptation and food security in South Sudan and comparable contexts. First, future studies should employ longitudinal or panel data approaches to examine how adaptation practices evolve over time and to establish stronger causal relationships between adaptation strategies and household food security outcomes. Such studies would provide deeper insights into the long-term effectiveness and sustainability of adaptation interventions under changing climatic conditions.

Second, there is a need for research that evaluates the relative effectiveness and cost-efficiency of specific adaptation strategies. Comparative assessments of climate-smart agricultural practices, livelihood diversification, livestock integration, and technological innovations would help identify the most impactful interventions for different agroecological and socioeconomic settings.

Third, future investigations should explore the role of institutional and governance factors in shaping adaptive capacity. Particular attention should be given to the effectiveness of extension services, climate information systems, farmer organizations, financial services, and policy support mechanisms in facilitating adaptation among smallholder farmers.

Fourth, additional research is required to examine gender and social inclusion dimensions of climate adaptation. Studies focusing on women, youth, elderly farmers, and other vulnerable groups would enhance understanding of how social inequalities influence access to adaptation resources, decision-making processes, and resilience outcomes.

Fifth, future studies should assess the contribution of emerging digital technologies and climate information services to adaptation decision-making. Research on the use of mobile-based advisory systems, early warning mechanisms, remote sensing technologies, and digital agricultural platforms could provide valuable evidence for strengthening climate resilience in rural communities.

Sixth, given the interconnected nature of climate risks, multidisciplinary studies are needed to investigate the impacts of climate change across agriculture, livestock, water resources, forestry, environmental management, and public health sectors. Such integrated approaches would support the development of comprehensive adaptation strategies that address multiple dimensions of vulnerability.

Finally, future research should test and validate the climate change adaptation framework developed in this study across different geographical regions, farming systems, and livelihood contexts within South Sudan. Comparative studies would help determine the framework's applicability, robustness, and potential for informing climate resilience policies and programs at local and national levels.

Collectively, these research areas would contribute to a more comprehensive understanding of climate adaptation processes and support the design of evidence-based interventions aimed at enhancing resilience, sustainable agricultural development, and food security among rural households.

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ANNEXURES

Section 1: Socioeconomic characteristics of respondents and determining factors to adopt climate change strategies at the household level (Objectives 1 & 3)

<table>
<tr><td colspan="5">1.0 Demographics (Tick as appropriate)</td></tr>
<tr><td>1.1</td><td>Sex of the respondent?</td><td>1=Male |_____|</td><td colspan="2">2=Female |_____|</td></tr>
<tr><td>1.2</td><td>Is the respondent the household head?</td><td>1=Yes |_____|</td><td colspan="2">0=No |_____|</td></tr>
<tr><td rowspan="2">1.3</td><td rowspan="2">What is the age of the household head?</td><td>1 = (< 18 yrs) |_____|</td><td>2 = (19-30yrs) |_____|</td><td>3 = (31 – 45yrs) |_____|</td></tr>
<tr><td>4 = (46 – 60yrs) |_____|</td><td colspan="2">5 = (>60 yrs) |_____|</td></tr>
<tr><td>1.4</td><td>Marital status</td><td>1=Single |_____|
2=Married |_____|</td><td colspan="2">3=Divorced |_____|
4=Separated |_____|</td></tr>
<tr><td>1.5</td><td>Education level</td><td>1=No education |_____|
2=Primary |_____|
3=Secondary |_____|</td><td colspan="2">4=Technical school |_____|
5=College |_____|
6=University |_____|</td></tr>
<tr><td>1.6</td><td>Years of residence in a community</td><td>1 = (< 1yr) |_____|
2 = (1- 2yrs) |_____|
3 = (3-5yrs) |_____|</td><td colspan="2">4 = (6-8yrs) |_____|
5 = (9-11yrs) |_____|
6 = (>11 yrs) |_____|</td></tr>
<tr><td>1.7</td><td>Farming experience in years</td><td>1 = (< 1yr) |_____|
2 = (1- 2yrs) |_____|
3 = (3-5yrs) |_____|</td><td colspan="2">4 = (6-8yrs) |_____|
5 = (9-11yrs) |_____|
6 = (>11 yrs) |_____|</td></tr>
<tr><td>1.8</td><td>Membership in a farmers' group or association</td><td>1 = Yes |_____|</td><td colspan="2">0 = No |_____|</td></tr>
<tr><td>1.9</td><td>Farm size in feddans (60mx70m) = 0.42ha</td><td>1=(<1fddn) |_____|
2=(1-2fddns) |_____|</td><td colspan="2">3=(3-4fddns) |_____|
4 = (>5 fddns) |_____|</td></tr>
</table>

1.10	Access to Finance	1= Yes |_____|	0 = No |_____|
1.11	Family income level per year	1=(<$360/yr) |_____| 2=($361-$720/yr) |_____|	3=($721-1,440/yr) |_____| 4 = (>$1,440/yr) |_____|
1.12	Do you have access to the market?	1= Yes |_____|	0 = No |_____|
1.13	Are you aware of any climate change adaptation strategies?	1=Yes |_____|	0=No |_____|
1.13 (a)	If yes, mention what are these strategies		
1.14	Do have access to agricultural extension services?	1 = Yes |_____|	0 = No |_____|
1.15	Do you have access to climate and weather information?	1=Yes |_____|	0 = No |_____|
1.16	Are you a member of any farmers' group?	1=Yes |_____|	0 = No |_____|
1.17	Have you experienced drought or floods?	1=Yes |_____|	0 = No |_____|
1.18	Have experienced any change in the normal planting season?	1=Yes |_____|	0 = No |_____|
1.19	Have you experienced prevalence of pests or diseases?	1=Yes |_____|	0 = No |_____|

1.20	Have you experienced variations in rainfall or temperature over the few years?	1=Yes |_____|	0 = No |_____|
1.21	**Level of awareness of climate change and its impact on household food security (Please tick one)**		
(a)	Not aware at all (where a farmer has never heard about climate change from any source	1 |_____|	
(b)	Very low (where a farmer has heard about climate change but not employing any adaptation strategy)	2 |_____|	
(c)	Good (where a farmer has appreciable knowledge about climate change and employs one/two adaptation strategies)	3 |_____|	
(d)	Excellent (where a farmer has very good knowledge about climate change, its impacts, and employing two or more adaptation strategies)	4 |_____|	

Section 2: Climate Change Adaptation Strategies (Objective 2)

2.0 Perceived adoption of climate change adaptation strategies (Tick as			
2.1	Do you grow different types of crops in your farm?	1= Yes |_____|	0 = No |_____|
2.1. (a)	If yes, what types of crops?		
(b)	Do you grow these crops in the same piece of land or separately?		
2.2	Do you engage in good agricultural practices like crop rotation, mulching, fallowing, pest and diseases control and alley cropping in your farm?	1=Yes |_____|	0=No |_____|

2.3	Do you use tractor or ox-plough in your farm?	1 = Yes |_____|	0 = No |_____|
2.4	Do you engage in off-farm activities like business, casual labour or employment?	1=Yes |_____|	0 = No |_____|
2.5	Do you keep livestock (cattle, sheep, goats or poultry or do fishing)?	1=Yes |_____|	0 = No |_____|

Section 3: Impacts of climate change adaptation strategies (Objective 4)

4.0 Observed changes due adoption of climate change adaptation strategies			
3.1	Have you observed any change in terms of good harvest or food availability because of growing different types of crops in your farm?	1= Yes |_____|	0 = No |_____|
(a)	If yes, please describe to change you have observed in one sentence		
4.2	Did any of the good agricultural practices like crop rotation, mulching, fallowing, pests and diseases control and alley cropping in your farm result to increased harvest or food production?	1=Yes |_____|	0=No |_____|
4.3	Have ever used tractor or ox-plough in your farm?	1 = Yes |_____|	0 = No |_____|
(a)	If yes, have you notice any change in terms of crop yields?		
(b)	Is the change an increase or a decrease in crop yields?		
4.4	Does your engagement in off-farm activities like business, casual labour or employment supplement food availability in the family?	1=Yes |_____|	0 = No |_____|
4.5	Do livestock keeping (cattle, sheep, goats or poultry or fishing) adequately enhance food availability in your family?	1=Yes |_____|	0 = No |_____|

Section 4: Food security (availability) questions (Objective 5)

3.0 Food availability (Tick as appropriate)			
3.1	Do you produce food from your own farm?	1= Yes |_____|	0 = No |_____|
3.2	Do you usually have enough food in stock that lasts until next season?	1=Yes |_____|	0=No |_____|
3.3	Do you access some food through markets?	1 = Yes |_____|	0 = No |_____|
3.4	Are there challenges in terms of movement of food commodities in and out of markets?	1= Yes |_____|	0 = No |_____|
3.5	Are there issues of insecurity on food transportation routes	1=Yes |_____|	0=No |_____|
3.6	Do you sometimes sell some livestock to access food in times of shortage?	1 = Yes |_____|	0 = No |_____|
3.7	Do you have a variety of food sources?	1=Yes |_____|	0 = No |_____|
3.8	Do you sometimes have surplus food to sell in the market?	1=Yes |_____|	0 = No |_____|
3.9	Do you sometimes borrow food from friends and relatives in times of shortage?	1=Yes |_____|	0 = No |_____|
3.10	Do you sometimes completely lack food in stock?	1=Yes |_____|	0 = No |_____|

Section 5. Objective 6. Climate Change Adaptation questions

FGD Questions

Step1: Identification of Ecosystems Services (ES) – Socio-Economic Sectors (SES) that are relevant to rural groundnut farmers in South Sudan.

Qn 1: What ecosystem services and economic sectors are reliant on, influenced by or dependent on the government or organization strategies, policies and programs?

Qn 2: Make a list of:

(a) Ecosystem services (ES) in Yirol East County e.g. crops/food production, forest products, fresh water, fishing grounds, grazing land etc.

(b) Socio-Economic Sectors (SES) are reliant on ES e.g. agriculture, forestry, fisheries, livestock, public health, education etc.

Qn 3: What are the projected climate change impacts that could affect the shortlisted ES-SES identified in question 2a above?

Qn 4: Does any technical team or adaptation management team exist within the department of the ministry concerned?

Qn 5: If yes, what is the structure e.g., roles and responsibilities of each team member such as adaptation coordinator etc.?

Qn 6: What are the key functions of the technical teams e.g., identification of ES-SES?

Qn 7: What policies and programs is the are government currently undertaking to adapt to climate change?

Step 2 Vulnerability Assessment & Sensitivity Analysis

Qn:1. What is the degree to which the identified ES-SESs are sensitive to climate change?

Qn:2. What is the adaptive capacity of the national and sub-national line ministries to address existing and potential climate change impacts?

Qn:3. Analyze and prioritize organizational vulnerabilities. What is vulnerability based on sensitivity and adaptive capacity?

Step 3: Risk Assessment

Qn:1. What are the key risks to be addressed?

Step4: Assessing Adaptive Capacity

Qn:1. Is there a system for data collection and monitoring, evaluation processes, awareness raising initiatives and policies that encourage, support and require individuals to incorporate climate change risks and adaptation into decision-making?

Qn:2. Does the government integrate the potential impacts of climate change into its departmental policies, plans and program?

Qn:3. Does the government or communities conduct participatory climate risk and vulnerability assessment?

Qn:4. Does the government or communities incorporate climate change risks into enterprise risk management process?

Qn:5. Has the government or community identified potential adaptation options?

Qn:6. If yes, can you briefly explain the identified adaptation options.

Step5: Adaptation Options

Qn:1. What are the potential adaptation options that reduce communities' vulnerability and increase their adaptive capacities, leading to increased resilience?