# ASSESSING THE FACTORS INFLUENCING SORGHUM PRODUCTION IN JUR RIVER COUNTY, SOUTH SUDAN

**WILFRED WOL DENG**

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**A DISSERTATION SUBMITTED TO THE FACULTY OF AGRICULTURAL SCIENCES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE AND RURAL DEVELOPMENT OF UGANDA CHRISTIAN UNIVERSITY**

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## ABSTRACT

Sorghum is a staple crop and a key source of food and income for smallholder farmers in South Sudan, yet its productivity remains low and highly variable due to climatic, institutional, and post-harvest challenges. This study was conducted to assess the factors influencing sorghum production in Jur River County, focusing on weather variability, access to agricultural inputs, extension services, and post-harvest losses, and how these factors affect sorghum yield and household income. The objectives were to examine the effect of weather variability on productivity, to assess the influence of access to improved agricultural inputs, to analyze the role of extension services and adoption of improved practices, and to evaluate the extent of post-harvest losses and their impact on income generation. A cross-sectional survey design was adopted, targeting 384 sorghum-farming households selected through a multi-stage sampling procedure. Primary data were collected using structured questionnaires and key informant inputs, while secondary data were obtained from meteorological records and institutional reports. Data were analyzed using descriptive statistics, correlation analysis, multiple regression models, and Analysis of Variance (ANOVA). The findings revealed that climatic conditions significantly influenced sorghum yield, with mean temperature showing a strong positive effect ($B = 852.53$, $p < .001$). Input access had mixed results: while availability of improved inputs enhanced productivity ($B = 630.42$, $p < .001$), improper fertilizer use negatively affected yields. Extension services also showed contrasting effects; while access to extension materials was negatively associated with yield ($B = -1{,}562.96$, $p < .001$), extension worker knowledge and adoption of recommended practices improved productivity ($B = 623.38$, $p = .001$; $B = 16.58$, $p < .001$). Post-harvest handling strongly influenced household income, with improved storage ($B = 2{,}429.90$, $p < .001$) and better transportation ($B = 559.97$, $p < .001$) contributing to higher returns. The study concludes that although sorghum is well adapted to the local environment, inefficiencies in input use, weak extension delivery, and poor post-harvest management limit productivity and income potential. Strengthening farmer access to quality inputs, enhancing context-specific extension services, and improving post-harvest technologies are recommended to improve food security and livelihoods in fragile settings like Jur River County.

## Declaration

I affirm that apart from appropriately cited references to the works of other researchers, this proposal is entirely my own, and no portion of it, in any form, has been previously submitted or presented elsewhere.

**WOL WILFRED DENG**

## Approval

This research proposal has been approved by the undersigned persons a requirement for award of MSc Science in Agriculture and Rural Development (MARD). As the candidate's supervisor, I agree to the submission of this research proposal.

**Dr. John Livingstone Mutyaba**
**Supervisor**

## Dedication

I dedicate this proposal to my family, and friends for the endless love, prayer and support towards my academic journey

## Acknowledgement

Above all, special praises and thanks go to the Most High, Almighty God for enabling me come out with this proposal.

I profoundly appreciate and thank my supervisor **Dr. John Livingstone Mutyaba** for his invaluable guidance and encouragement towards development and completion of this proposal.

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## List of Acronyms and Abbreviations

**AfDB** – African Development Bank

**ANOVA** – Analysis of Variance

**FAO** – Food and Agriculture Organization of the United Nations

**FNS-REPRO** – Food and Nutrition Security Resilience Program

**IFPRI** – International Food Policy Research Institute

**IPC** – Integrated Food Security Phase Classification

**OECD** – Organisation for Economic Co-operation and Development

**SDGs** – Sustainable Development Goals

**SLF** – Sustainable Livelihoods Framework

**SPSS / STATA** – Statistical Packages for Social Sciences / Data Analysis

**USAID** – United States Agency for International Development

**UNECA** – United Nations Economic Commission for Africa

**USD** – United States Dollar

# CHAPTER ONE:

# INTRODUCTION

## 1.1 Background Information

The implementation of the Sustainable Development Goals (SDGs) faces several significant challenges, particularly regarding hunger, food insecurity, and climate change (Xu et al., 2020; Dicks et al., 2019). To achieve the SDGs related to poverty (Goal 1), hunger (Goal 2), health (Goal 3), and climate change (Goal 13), it is essential to adopt a more comprehensive and sustainable approach to agricultural policies and strategies (Xu et al., 2021).

One effective way to tackle these challenges is by enhancing agricultural production globally, which is crucial for reducing food insecurity (Dutta et al., 2020). Organizations like the Food and Agricultural Organization (FAO) and the International Food Policy Research Institute (IFPRI) emphasize that food security is a critical global issue in the 21st century. Ensuring sustainable food security on a global scale requires addressing the disparities in agricultural outputs and yields, particularly among small-scale farms, which are the primary producers of major cereal crops in developing countries (Krupnik et al., 2015; Godfray et al., 2010). Cereal crops such as sorghum, maize, and wheat play a vital role in achieving food security objectives.

Sorghum plays a vital role in global food security as a staple food crop for millions of people in Africa, Asia, and Latin America (Erenstein, 2010). In Sub-Saharan Africa, it is a key cereal crop, representing about 14% of the region's planted food crops (FAO, 2020). Sorghum is a resilient crop that thrives in various agroecological zones, making it an excellent option for smallholder farmers who face challenging climatic conditions. The regional production of sorghum is estimated at 1,127 million tons annually (OECD/FAO, 2019). Its affordability and nutritional benefits make sorghum an essential component in addressing food security concerns in low-income communities.

Jur River County, located in Western Bahr El Ghazal State, South Sudan, is predominantly agrarian, with smallholder farmers relying on subsistence farming for their livelihoods. Sorghum serves as a major staple crop, contributing significantly to household food security and income generation. The county's climate, characterized by alternating wet and dry seasons, provides a suitable environment for sorghum cultivation. However, several challenges, including climate variability, inadequate access to inputs, and poor agricultural extension services, hinder productivity (FAO, 2021). This paper explores the major constraints in sorghum production and identifies potential opportunities for improving agricultural productivity in Jur River County.

Sorghum cultivation in Jur River County is heavily dependent on rainfall patterns, making it susceptible to climate change-induced variability. Erratic rainfall, prolonged dry spells, and increased temperatures significantly affect yields. Studies indicate that sub-Saharan Africa, including South Sudan, has experienced an increase in climate variability, leading to unpredictable growing seasons and increased risks of crop failure (IPCC, 2022). In addition, smallholder farmers in the county struggle with inadequate access to high-quality seeds, fertilizers, and pesticides. The lack of improved seed varieties that are drought-resistant and high-yielding reduces productivity levels. Moreover, the cost and availability of fertilizers remain a significant barrier, limiting farmers' ability to enhance soil fertility and crop yields (World Bank, 2020).

Further, the dissemination of agricultural knowledge and improved farming techniques remains limited in Jur River County. Extension services, which are crucial for educating farmers on best practices, are underdeveloped due to a lack of funding and human resources. Research has shown that effective extension services can increase crop yields by up to 50% when farmers are trained in modern agricultural methods (Gebremedhin & Swinton, 2019). In the same vein, post-harvest losses remain a significant issue due to inadequate storage facilities and poor handling practices. A considerable proportion of sorghum produced is lost during harvesting, drying, and storage. Furthermore, limited access to markets and poor infrastructure restrict farmers from selling their produce at competitive prices, reducing household incomes and discouraging production expansion (FAO, 2021).

## 1.2 Statement of the Problem

Sorghum is the most widely cultivated staple crop in Jur River County, providing both food and income for rural households. Yet, its productivity remains low and unstable, exposing communities to persistent food insecurity and poverty (FAO, 2021). Although sorghum is relatively resilient, production is increasingly constrained by erratic rainfall, prolonged dry spells, and rising temperatures that make yields unpredictable (IPCC, 2022).

Beyond climatic stress, smallholder farmers face limited access to improved seed varieties, fertilizers, and pesticides, while the cost and availability of such inputs remain significant barriers (World Bank, 2020). The agricultural extension system is also weak, with inadequate staffing and limited resources, reducing farmers' adoption of improved practices (Gebremedhin & Swinton, 2019). At the same time, poor storage facilities and inefficient post-harvest handling result in substantial grain losses, while weak infrastructure restricts access to markets and lowers farm-gate prices (OECD/FAO, 2019).

Although these challenges are recognized in policy discussions, little empirical evidence exists on how weather variability, access to inputs, extension services, and post-harvest practices collectively influence sorghum productivity and household income in Jur River County. This knowledge gap limits the development of targeted interventions to support smallholder farmers. Addressing this problem is critical to improving sorghum yields, strengthening rural livelihoods, and enhancing household food security in South Sudan.

## 1.3 Objectives of the Study

### 1.3.1 General Objective

To examine factors influencing sorghum production in Jur River County, South Sudan.

### 1.3.2 Specific Objectives

1. To assess the effect of weather variability on sorghum productivity in Jur River County in Western Bahr El Ghazal.
2. To assess the influence of access to improved agricultural inputs on sorghum productivity in Jur River County in Western Bahr El Ghazal.
3. To examine the effect of agricultural extension services and adoption of improved farming practices on sorghum productivity in Jur River County in Western Bahr El Ghazal.
4. To analyze the extent of post-harvest losses and their effect on sorghum income generation in Jur River County in Western Bahr El Ghazal.

### 1.3.3 Research Questions

1. How does weather variability affect sorghum productivity in Jur River County, Western Bahr El Ghazal?
2. To what extent does access to improved agricultural inputs influence sorghum productivity in Jur River County, Western Bahr El Ghazal?
3. How do agricultural extension services and the adoption of improved farming practices affect sorghum productivity in Jur River County, Western Bahr El Ghazal?
4. What is the extent of post-harvest losses in sorghum farming, and how do these losses affect income generation in Jur River County, Western Bahr El Ghazal?

## 1.4 Justification of the Study

Sorghum is a staple crop in Jur River County, Western Bahr El Ghazal, forming the backbone of household food security and income generation. Despite its resilience, productivity has remained low and unstable due to climatic stress, poor access to inputs, weak extension services, and post-harvest losses (FAO, 2021; World Bank, 2020). These constraints undermine household resilience, increase vulnerability to poverty, and exacerbate food insecurity in one of South Sudan’s fragile agricultural settings.

The relevance of this study lies in its direct focus on the livelihood challenges of smallholder farmers who depend almost entirely on sorghum for subsistence and income. Identifying the factors that constrain production provides evidence-based insights that can guide interventions to improve productivity and strengthen rural livelihoods. The study is also timely given the growing pressures of climate variability (IPCC, 2022) and the need for strategies that enhance both adaptation and sustainability in agricultural systems.

There is also a clear need for research because empirical evidence on how weather variability, input access, extension services, and post-harvest practices jointly influence sorghum production in South Sudan is limited. Existing literature often highlights these challenges in general terms but does not provide locally grounded data to inform decision-making for Jur River County. This study therefore fills a critical gap by providing localized analysis that links production factors with household income outcomes.

Finally, the study contributes to broader development priorities by aligning with the Sustainable Development Goals (SDGs). Specifically, it supports SDG 1 on ending poverty, SDG 2 on achieving zero hunger, and SDG 13 on climate action. By generating knowledge that can inform policies and interventions to enhance sorghum productivity, the study provides evidence that can advance national food security strategies and global development commitments.

### 1.5 Scope and Limitation of the Study

The study focused on identifying and analyzing the key constraints affecting sorghum production in Jur River County, Western Bahr El Ghazal. The scope included the effects of climate variability—such as erratic rainfall, prolonged dry spells, and rising temperatures—on sorghum yields, as well as the role of access to improved agricultural inputs such as drought-resistant seeds and fertilizers. The study also examined the influence of the agricultural extension system on farmers' adoption of improved farming practices, with emphasis on the effectiveness of extension services in enhancing productivity. In addition, the study assessed the extent of post-harvest losses and their effect on income generation for smallholder farmers. The research was geographically limited to Jur River County and focused on smallholder farmers who depend on sorghum as a primary crop for both food security and income.

### 1.6 Limitations of the Study

The study was geographically confined to Jur River County, and the findings may not be directly applicable to other regions of South Sudan or countries with different agricultural contexts. The research relied on data from local farmers, extension services, and post-harvest handling practices, which at times were limited or inconsistent due to inadequate record-keeping and restricted data access. The study primarily focused on constraints to sorghum productivity and did not include broader socio-political or macroeconomic factors that may also affect agriculture in the region. Furthermore, due to time and resource limitations, the study did not conduct experimental interventions but instead relied on observational data and household surveys. Lastly, the limited coverage of agricultural extension services in the county posed challenges in obtaining comprehensive information on their effectiveness..

### 1.7 Definitions of Terms

1. **Sustainable Development Goals (SDGs):** A set of global objectives established by the United Nations in 2015 to address pressing global challenges, including poverty, hunger, health, climate change, and inequality, with the aim of achieving these goals by 2030.
2. **Food Insecurity:** A situation where people are unable to access sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life.
3. **Climate Change:** Long-term changes in temperature, precipitation, and other atmospheric conditions on Earth, often driven by human activities, particularly the burning of fossil fuels, leading to global warming and extreme weather events.
4. **Poverty (SDG Goal 1):** The state of not having sufficient resources to meet basic needs, including food, water, shelter, and education, with a global goal to eradicate extreme poverty by 2030.
5. **Hunger (SDG Goal 2):** The condition of insufficient food availability, which affects a person’s ability to meet their nutritional needs, leading to malnutrition and other health issues.
6. **Health (SDG Goal 3):** The goal of ensuring healthy lives and promoting well-being for all individuals at all ages, including the provision of quality health services and addressing health disparities.

7. **Climate Action (SDG Goal 13):** Global efforts aimed at addressing climate change, including mitigation, adaptation, and reducing greenhouse gas emissions to minimize the negative impacts of climate change on ecosystems and human communities.
8. **Agricultural Productivity:** The efficiency with which agricultural inputs (such as land, labor, seeds, and fertilizers) are used to produce outputs like crops and livestock. Higher productivity is crucial for enhancing food security and economic development.
9. **Food Security:** A situation where all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs for an active and healthy life.
10. **Cereal Crops:** A category of grass plants cultivated for their edible grains, such as sorghum, maize, wheat, and rice, which are staple foods and key contributors to global food security.
11. **Sorghum:** A drought-tolerant cereal crop grown for its edible grain, which serves as a vital food source in many regions, particularly in sub-Saharan Africa, Asia, and Latin America. It is highly resilient to climatic stress, making it suitable for regions prone to drought.
12. **Smallholder Farmers:** Farmers who own or manage small plots of land and typically rely on family labor to produce crops or livestock, often for subsistence or local markets. They face challenges such as limited access to resources, inputs, and markets.
13. **Agroecological Zones:** Regions with similar climatic conditions, soil types, and ecological characteristics that determine the types of crops that can be grown and the agricultural practices suitable for the area.
14. **Climate Variability:** The fluctuation in climate patterns over short to medium timescales, including seasonal shifts in temperature, rainfall, and other weather conditions that affect agricultural productivity.
15. **Drought-Resistant Seeds:** Crop varieties that have been developed or selected for their ability to withstand prolonged dry conditions, which are essential for regions prone to drought or water scarcity.
16. **Agricultural Extension Services:** Services provided to farmers to educate them on modern farming practices, improve agricultural

productivity, and promote the use of new technologies to increase crop yields and resilience to climate change.

17. **Post-Harvest Losses:** The reduction in the quantity or quality of crops after they are harvested due to factors such as improper handling, storage, transportation, and processing. These losses can significantly impact food security and farmer income.

18. **Infrastructure:** The basic physical and organizational structures and facilities needed for the operation of a society, such as transportation networks, storage facilities, and market access, which are crucial for efficient agricultural production and trade.

19. **Sustainable Food Security:** Ensuring that food security is achieved in a manner that meets the needs of the present without compromising the ability of future generations to meet their own needs, particularly in the face of climate change and resource limitations.

20. **International Food Policy Research Institute (IFPRI):** A research institution focused on providing policy solutions for reducing hunger and poverty and improving food security worldwide. It emphasizes the need for evidence-based policies to achieve sustainable agricultural development.

21. **Food and Agriculture Organization (FAO):** A specialized agency of the United Nations that leads international efforts to defeat hunger and improve nutrition and food security. The FAO works with governments and organizations to promote sustainable agricultural practices globally.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Sorghum Production in South Sudan

Sorghum (Sorghum bicolor) is a vital staple crop in South Sudan, playing a crucial role in food security and income generation, particularly for rural households. It is primarily cultivated in the central and eastern regions of the country within subsistence farming systems. Sorghum's adaptability to diverse agro-ecological zones, especially its resilience to drought, makes it an important food source for many South Sudanese communities, especially amid climate variability (FAO, 2020).

The agricultural sector in South Sudan is dominated by smallholder farmers. Despite the importance of sorghum, productivity remains low and highly variable due to several challenges. These include unpredictable rainfall, inadequate agricultural inputs, poor farming practices, and limited access to markets (World Bank, 2020). The slow adoption of modern agricultural technologies, alongside poor infrastructure and weak agricultural extension services, further complicates issues of productivity (Dixon et al., 2018). Climate change has had a significant impact on agriculture in South Sudan, resulting in increased temperatures, erratic rainfall patterns, and prolonged dry spells (IPC, 2022). These changes have disrupted growing seasons and affected crop yields, including sorghum. Although sorghum is generally drought-tolerant, extreme climatic conditions have diminished the reliability of its yields, particularly during periods of water stress and high temperatures (Vetter et al., 2017).

Furthermore, many South Sudanese farmers struggle to access high-quality seeds, fertilizers, pesticides, and other essential agricultural inputs. This limitation has hindered efforts to improve sorghum productivity. The high cost and limited availability of these inputs make it challenging for smallholder farmers to adopt modern farming practices that could enhance their yield potential (World Bank, 2020). Agricultural extension services in South Sudan are also underfunded and underdeveloped, restricting the dissemination of knowledge regarding improved farming practices. This capacity gap is exacerbated by a shortage of trained personnel and financial resources (Gebremedhin & Swinton, 2019), resulting in farmers finding it difficult to implement new technologies that could boost sorghum productivity.

Post-harvest losses represent a significant challenge in South Sudan. Poor storage facilities, inadequate transportation, and inefficient handling of harvested sorghum lead to considerable losses, directly affecting the income of smallholder farmers (FAO, 2021). These losses contribute to food insecurity, as a large portion of the sorghum produced may never reach the market or be consumed. Moreover, access to markets remains limited in many rural parts of South Sudan. Poor roads and infrastructure hinder farmers' ability to sell their crops at competitive prices, diminishing their profitability and discouraging investment in agriculture (OECD/FAO, 2019). Limited market information also hampers farmers' ability to make informed decisions about pricing and trade.

Jur River County, located in Western Bahr El Ghazal State, is one of South Sudan's key agricultural areas. Sorghum is a primary staple crop grown in the county, alongside other crops such as millet and maize. The farmers in this region are predominantly smallholders practicing subsistence agriculture, with sorghum serving as both a food source and a source of income.

The climate in Jur River County is characterized by alternating wet and dry seasons, creating a suitable environment for sorghum cultivation. However, the county is also vulnerable to erratic rainfall patterns and prolonged dry spells, which have been exacerbated by climate change (IPCC, 2022). This variability poses a threat to crop yields and renders sorghum production less predictable, with farmers frequently facing crop failure due to unpredictable weather conditions.

Smallholder farmers in Jur River County encounter significant challenges in accessing improved seeds, fertilizers, and other agricultural inputs. This lack of access limits their ability to enhance productivity and adapt to changing climatic conditions. Additionally, reliance on traditional farming practices, which are often less efficient, further restricts the productivity of sorghum farming (World Bank, 2020).

### 2.2 Weather variability and Sorghum Productivity

Weather variability poses a significant challenge for agricultural production globally, but it is particularly critical in areas like Jur River County, South Sudan, where smallholder farming is essential for food security and livelihoods. In this region, sorghum serves as a staple crop, playing a crucial role in household food security and income generation. However, the increasing unpredictability of rainfall, prolonged dry spells, and rising temperatures due to climate change threaten sorghum productivity, exacerbating food insecurity and poverty (IPCC, 2022).

While studies on the effects of weather variability on sorghum productivity have contributed significantly to understanding how climatic factors affect crop yields, several issues and limitations exist in the research. These challenges can influence the applicability of findings and limit their effectiveness in addressing the problems faced by smallholder farmers, particularly in regions like Jur River County, South Sudan. Below is a critique of common gaps and limitations found across the studies on weather variability and sorghum productivity.

Literature reviewed, particularly those conducted in regions such as India, West Africa, and the U.S., provide insights into how weather variability impacts sorghum productivity, but their applicability to regions like Jur River County in South Sudan is limited. For instance, the climatic and socio-economic conditions of regions like sub-Saharan Africa (particularly South Sudan) differ significantly from regions in Asia or the U.S., where some of the studies were conducted. For instance, while the studies focused on rainfall patterns and drought tolerance in India and Nigeria, they may not accurately reflect the environmental, infrastructural, or socio-economic challenges faced by smallholder farmers in South Sudan, where political instability, weak infrastructure, and a lack of resources significantly impact agricultural practices. However, such studies exhibited failure to adequately consider local socio-economic factors such as access to agricultural extension services, seed quality, or government policies, which may have more profound effects on sorghum productivity than weather variability alone.

Additionally, many of the reviewed studies tend to focus primarily on the climatic factors such as temperature and rainfall but tend to overlook other important constraints that can affect sorghum productivity, especially in developing countries. Hence, constraints like limited access to improved seeds, fertilizers, and market infrastructure are often underrepresented. For example, studies such as those by Naylor et al. (2007) and Badu-Apraku et al. (2019) concentrate heavily on climatic factors without sufficiently addressing the combined impact of economic factors like market access, poor storage facilities, or the weak agricultural extension services, which are critical issues in areas like Jur River County. Further, studies, such as those from FAO (2021), discuss the effects of drought but rarely include the impact of poor post-harvest handling and storage techniques, which significantly exacerbate food insecurity. This is a crucial factor in regions with inadequate storage infrastructure, such as in South Sudan, where much of the sorghum may be lost before it even reaches the market.

As regards the use of localized and longitudinal approaches, the reviewed studies indicate a general rely on short-term data or specific years to understand weather variability, which may not capture the full range of variability over the long term. For instance, studies like those of Lobell et al. (2011) and Schlenker and Roberts (2009) use data from a limited number of years to infer climate impacts, potentially missing out on long-term trends or cyclical weather patterns that could affect sorghum productivity more broadly. It is also worth noting that there is scanty literature on longitudinal or multi-seasonal data, which would better reflect the long-term effects of climate change on sorghum productivity. Long-term studies would allow researchers to differentiate between normal year-to-year variability and the more significant trends resulting from climate change, thus giving farmers a better understanding of future risks. Hence, there is a lack of studies specifically focused on the weather variability impacts on sorghum in South Sudan or Jur River County. Given that South Sudan's agricultural sector is under-researched, especially with respect to sorghum, studies specifically focusing on the local weather patterns, types of sorghum grown, and local farming practices would provide more relevant insights.

In consideration of Adaptation Strategies, while some studies examine adaptation strategies, such as Thornton et al. (2018) focusing on climate-smart practices, the recommendations tend to be generic and not tailored to the needs of smallholder farmers in resource-limited settings. Many studies suggest practices like using drought-resistant varieties, soil conservation, and water-saving technologies but fail to consider whether these practices are feasible or accessible in under-resourced areas. In regions like Jur River County, where access to improved seeds, technology, and training is limited, such strategies might not be immediately applicable. Adaptation strategies often assume that farmers can afford the initial investment in new technologies, such as irrigation systems or drought-resistant varieties. However, in many parts of South Sudan, the financial and infrastructural barriers prevent farmers from adopting these practices, and studies seldom account for these limitations in their recommendations.

Several studies provide generalized solutions to weather variability issues, such as improving irrigation, developing drought-resistant varieties, or enhancing extension services. While these are valuable suggestions, they often fail to take into account the diverse nature of farming systems. For instance, one-size-fits-all Solutions: For example, studies like Parker et al. (2012) and Sharma et al. (2020) recommend improved seed varieties and water management techniques but don't address how these interventions would be tailored to the specific agro-ecological conditions of Jur River County. In reality, not all farming systems or regions within South Sudan would benefit from the same set of interventions, so more localized and participatory approaches are needed. Additionally, many studies fail to involve local farmers or extension services in the design and implementation of solutions. Involving stakeholders ensures that adaptation measures are not only scientifically sound but also contextually relevant and feasible.

As regards gender and social inclusion, reviewed gendered studies like those from Akinmoladun et al. (2020) and Schlenker and Roberts (2009) primarily focus on general effects on productivity without examining how weather variability affects different groups within the farming community. In regions like South Sudan, where women play a critical role in agricultural production, particularly in sorghum cultivation, gendered approaches to understanding weather variability impacts are missing. Research could examine how women's access to resources (such as land, credit, and knowledge) influences their ability to adapt to weather variability. In addition, Inequalities: Social factors such as wealth, education, and access to technology are rarely addressed in these studies. These disparities exacerbate the challenges faced by vulnerable groups like women, youth, and marginalized communities, making it essential for research to consider the socio-economic dynamics that affect the capacity of different groups to respond to weather variability.

It is also worth noting that uncertainty in Predictive Models are still scanty: Studies that use predictive models to project the impacts of climate change on sorghum yield often rely on generalized climate scenarios, which can be highly uncertain. Climate projections vary widely depending on the model, assumptions, and data inputs, making it difficult for farmers to plan for long-term changes in weather patterns. Research should focus on providing more localized and precise climate forecasts to improve farmers' decision-making.

## 2.3 **Access to agricultural inputs and institutional factors on sorghum productivity**

Empirical evidence from Sub-Saharan Africa suggests that access to quality inputs such as improved seeds, fertilizers, pesticides, and extension services is crucial for enhancing agricultural productivity (Smale, Byerlee, & Jayne, 2013). Additionally, institutional factors, including government policies, credit facilities, and market access, influence farmers’ ability to optimize sorghum yields (Barrett, Carter, & Timmer, 2010). The literature review explores existing research on agricultural input accessibility and institutional dynamics, with a focus on their impact on sorghum productivity. The review critically analyzes key theories, empirical findings, and research gaps to contextualize the challenges faced by sorghum farmers in Jur River County.

### 2.3.1 Availability and Accessibility of Agricultural Inputs

Access to agricultural inputs is a key determinant of farm productivity. According to the Input-Output Theory, the quality and quantity of inputs directly influence the output level of agricultural production (Mundlak, 2001). Studies indicate that farmers in developing economies often face constraints related to the availability, affordability, and distribution of inputs (FAO, 2020).

In South Sudan, agricultural input markets remain underdeveloped due to political instability, weak infrastructure, and a lack of commercial agricultural suppliers (UNECA, 2018). Conflict-related disruptions have led to limited seed distribution networks, resulting in farmers relying on low-quality local seed varieties that have lower yields (USAID, 2017). A study by Makau and Oduor (2021) found that in Uganda and South Sudan, informal input-sharing arrangements among farmers serve as alternative access mechanisms, but these remain inefficient in ensuring widespread adoption of improved sorghum varieties. Furthermore, market liberalization policies have had mixed effects on input accessibility. While private sector involvement has increased input availability in some regions, poor market regulation has led to price volatility, making it difficult for smallholder farmers to afford critical inputs (Barrett et al., 2010).

### 2.3.2 Credit and Financial Services for Farmers

Access to agricultural credit plays a significant role in enabling farmers to invest in productivity-enhancing inputs. The Credit Access Theory posits that financial constraints hinder smallholders from adopting capital-intensive agricultural technologies (Zeller & Sharma, 1998). Empirical evidence from Sub-Saharan Africa suggests that access to formal credit services leads to increased adoption of high-yield crop varieties and modern farming practices (Smale et al., 2013).

In South Sudan, financial institutions remain underdeveloped, with rural farmers facing severe constraints in accessing credit for input purchases (UNECA, 2018). A report by the African Development Bank (AfDB) highlights that less than 5% of smallholder farmers in South Sudan have access to formal credit, largely due to the absence of rural banking infrastructure and high loan default risks (AfDB, 2019). Studies in neighboring Uganda suggest that microfinance institutions and cooperative societies have successfully bridged this gap, improving access to inputs and boosting crop productivity (Makau & Oduor, 2021). However, such financial mechanisms remain largely absent in Jur River County.

### 2.3.3 Adoption of Improved Sorghum Technologies

The adoption of improved sorghum varieties and modern agricultural technologies is crucial for enhancing productivity. According to the Diffusion of Innovation Theory, the adoption of agricultural technologies depends on access to information, social influence, and perceived benefits (Rogers, 2003). Research by Langyintuo and Mulugetta (2008) found that in Africa, farmers' willingness to adopt improved sorghum varieties is largely influenced by extension services and demonstration plots. In South Sudan, extension services are severely limited, and the adoption of improved sorghum varieties remains low (UNECA, 2018). Studies in Ethiopia and Kenya show that participatory approaches, such as Farmer Field Schools (FFS), significantly enhance technology adoption rates by providing hands-on training (Van den Berg & Jiggins, 2007). The absence of such programs in Jur County limits the diffusion of knowledge and adoption of improved agronomic practices.

### 2.3.4 The Role of Government and Policy Support

Government policies play a pivotal role in shaping the agricultural sector. According to Institutional Theory, formal institutions, including laws, policies, and regulations, influence economic performance by determining resource allocation and market dynamics (North, 1990). In South Sudan, weak governance and policy inconsistencies have hindered agricultural development (UNECA, 2018). Studies indicate that countries with well-structured agricultural policies, such as Ethiopia and Rwanda, have achieved significant productivity gains through targeted input subsidies and investment in extension services (FAO, 2020). In contrast, South Sudan's agricultural policy framework remains fragmented, with limited state intervention in supporting smallholder farmers (USAID, 2017).

### 2.3.5 Agricultural Extension Services and Farmer Training

The effectiveness of extension services in improving farm productivity is well-documented. Research suggests that farmer training programs increase awareness of improved agricultural practices, leading to higher crop yields (Van den Berg & Jiggins, 2007). However, in South Sudan, the lack of trained extension officers and logistical challenges have resulted in minimal outreach to rural farmers (UNECA, 2018). In Kenya, investment in Farmer Field Schools (FFS) has led to increased adoption of improved crop management practices and higher yields (Van den Berg & Jiggins, 2007). The absence of such structured extension mechanisms in Jur River County has limited farmers' exposure to best agricultural practices.

### 2.3.6 Role of Farmer Cooperatives and Informal Institutions

Informal institutions, such as farmer cooperatives and traditional leadership structures, play a crucial role in agricultural input distribution and market access (Makau & Oduor, 2021). Studies in Uganda show that cooperatives enhance farmers' bargaining power, allowing them to access inputs at lower costs and secure better market prices for their produce (Barrett et al., 2010). However, in South Sudan, the cooperative movement remains weak due to a lack of financial support and organizational capacity (UNECA, 2018).

### 2.4 Post-Harvest losses at farm level

Post-harvest losses represent a significant challenge to global food security, particularly in developing economies where smallholder farmers dominate cereal production. These losses, estimated to range between 20% and 30% of total cereal output, have profound economic and social implications. The Food and Agriculture Organization (FAO, 2021) identifies these losses as a major contributor to food insecurity, reduced farmer incomes, and inefficiencies in agricultural value chains. In sub-Saharan Africa, where agriculture provides employment for over 60% of the population (World Bank, 2022), addressing post-harvest losses is critical for ensuring sustainable agricultural development. The problem is even more acute in conflict-affected regions such as South Sudan, where institutional weaknesses and infrastructural challenges further exacerbate food wastage (USAID, 2021). This review examines the existing literature on post-harvest losses among cereal smallholder farmers, focusing on the causes, impacts, and mitigation strategies.

Several theoretical frameworks provide insights into the underlying factors contributing to post-harvest losses. The Post-Harvest Loss Theory, as conceptualized by Boxall (2002), delineates various loss points along the agricultural value chain, including harvesting, drying, storage, transportation, and processing. Each stage introduces specific risks that contribute to the overall loss burden. Harvesting losses, for instance, often arise from poor timing—either premature harvesting, which results in high moisture content, or delayed harvesting, which exposes crops to pests and adverse weather conditions. Drying losses occur when traditional methods, such as sun-drying on bare ground, lead to contamination and fungal infestation. Storage-related losses, which constitute the largest proportion of post-harvest losses, are frequently attributed to inadequate facilities that expose grains to pests, rodents, and mold growth (Hodges et al., 2011). Transportation losses, while often overlooked, are also significant, particularly in rural areas where poor road infrastructure leads to mechanical damage and spillage.

Institutional factors also play a crucial role in shaping post-harvest outcomes. Drawing on North's (1990) Institutional Theory, it is evident that weak policy frameworks, inadequate enforcement of quality standards, and limited investment in rural infrastructure exacerbate losses. In many African countries, including South Sudan, ineffective regulatory mechanisms allow substandard storage facilities and poor transportation systems to persist. Extension services, which are crucial for disseminating knowledge on best post-harvest practices, remain underdeveloped in many regions. The limited presence of agricultural extension officers constrains farmers' access to information on improved storage technologies and proper handling techniques (Makau & Oduor, 2021).

The adoption and diffusion of innovation, as explained by Rogers (2003), further elucidates why smallholder farmers continue to experience high levels of post-harvest losses. Despite the availability of improved storage solutions, such as hermetic bags and metal silos, their adoption remains low due to financial constraints, lack of awareness, and cultural preferences for traditional storage methods. Empirical studies indicate that when farmers receive targeted training and financial incentives, their likelihood of adopting improved post-harvest management practices increases significantly (Langyintuo & Mulugetta, 2008). However, without sustained institutional support, these gains remain limited.

Environmental and climatic conditions also contribute significantly to post-harvest losses. Unpredictable rainfall patterns, excessive humidity, and temperature fluctuations exacerbate grain spoilage, particularly in regions with inadequate drying facilities. Kumar and Kalita (2017) highlight that high moisture content in stored grains promotes fungal growth, leading to aflatoxin contamination, which not only results in quantitative losses but also poses serious health risks to consumers. In regions like South Sudan, where climate variability is a growing concern, investments in low-cost drying technologies such as solar dryers could substantially mitigate moisture-related losses (FAO, 2020). Comparative studies in Ethiopia and Kenya demonstrate that such interventions have the potential to reduce drying-related losses by over 30%.

The role of storage infrastructure cannot be overstated, as inadequate facilities remain a primary cause of post-harvest losses. Traditional storage methods, including mud granaries and woven baskets, offer limited protection against pests and environmental factors. Studies in Kenya have shown that the use of hermetic storage bags can reduce grain losses by 60% compared to traditional methods (Affognon et al., 2015). However, adoption barriers persist, primarily due to cost and accessibility challenges. In South Sudan, where market linkages remain weak, smallholder farmers struggle to access improved storage solutions, further exacerbating post-harvest losses.

Beyond technical constraints, weak institutional support and policy inconsistencies limit efforts to address post-harvest losses. In contrast to countries like Ethiopia and Kenya, which have implemented targeted subsidies for improved storage technologies, South Sudan lacks comprehensive policy frameworks to support post-harvest management initiatives. Public investment in rural storage infrastructure is minimal, and government-led extension services remain underfunded (World Bank, 2022). Research indicates that strengthening extension service delivery could significantly reduce post-harvest losses by up to 40% (Makau & Oduor, 2021). However, achieving this requires coordinated efforts between government agencies, development organizations, and the private sector.

Despite extensive research on post-harvest losses, several gaps remain in the literature. One critical area that requires further exploration is the impact of conflict on post-harvest management practices in fragile states such as South Sudan. The role of indigenous knowledge in mitigating post-harvest losses also remains underexplored, despite evidence suggesting that traditional grain storage practices can offer cost-effective solutions to smallholder farmers. Additionally, longitudinal studies tracking post-harvest loss trends over time would provide more nuanced insights into the effectiveness of various interventions. Addressing these gaps is crucial for developing context-specific solutions that integrate technological, institutional, and behavioral approaches to post-harvest management.

In conclusion, post-harvest losses among cereal smallholder farmers remain a significant challenge, driven by environmental, institutional, and socio-economic factors. While existing literature provides valuable insights into the causes and mitigation strategies, a more integrated approach that combines technological innovations with policy support is necessary. Future research should focus on context-specific interventions that align with the realities of smallholder farming systems, ensuring that proposed solutions are both accessible and sustainable. Addressing post-harvest losses is not merely a technical issue but a critical component of achieving food security and economic resilience in developing economies.

### 2.5 Theoretical Framework

This was anchored on a comprehensive theoretical framework that is essential for understanding the factors influencing sorghum production and its implications for food security. This study shall integrate elements from the Sustainable Livelihoods Framework (SLF), to provide a holistic approach to the analysis. Therefore, SLF, as developed by Chambers and Conway (1992), provides a foundation for examining how various resources and external factors affect smallholder sorghum farmers. The five key assets—human, natural, financial, social, and physical capital—determine farmers' ability to sustain productivity. Access to essential resources such as land, credit, extension services, and agricultural inputs directly impacts sorghum yields and resilience to climate and market fluctuations.

### 2.6 Conceptual Framework

This study was guided by a conceptual framework that illustrates the relationships between independent, intervening, and dependent variables. The independent variables include socioeconomic factors (age, gender, education level, household size, farm size), weather variability (rainfall, temperature, drought periods), access to improved agricultural inputs (availability and use of drought-resistant seeds, fertilizers, pesticides), agricultural extension services (frequency of extension visits, training, access to materials), post-harvest practices (storage methods, handling, transportation), and institutional factors (credit access, cooperative membership, government support programs).

The intervening variables are agricultural policies and broader climatic factors, which may indirectly influence production outcomes by shaping farmers' access to resources and resilience strategies.

The dependent variables include sorghum productivity (measured as yield per hectare), sorghum quality (measured in terms of grain size, color, moisture content, and farmer self-reported grading of stored grain), and income from sorghum production (calculated from household sales of sorghum, adjusted for yield, post-harvest losses, and market access, including distance to markets and prevailing farm-gate prices).

Each of these variables was operationalized through the household questionnaire. For instance, farmer-reported rainfall, temperature, and drought experiences correspond to weather variability; household responses on seed, fertilizer, and pesticide use reflect agricultural input access; questions on storage practices and post-harvest losses link directly to the post-harvest block of the framework; while farmer-reported sorghum sales and revenues represent the income outcome.

This framework therefore provides a logical pathway for analysis by linking contextual, institutional, and technical production factors to measurable outcomes of productivity, quality, and income from sorghum production.

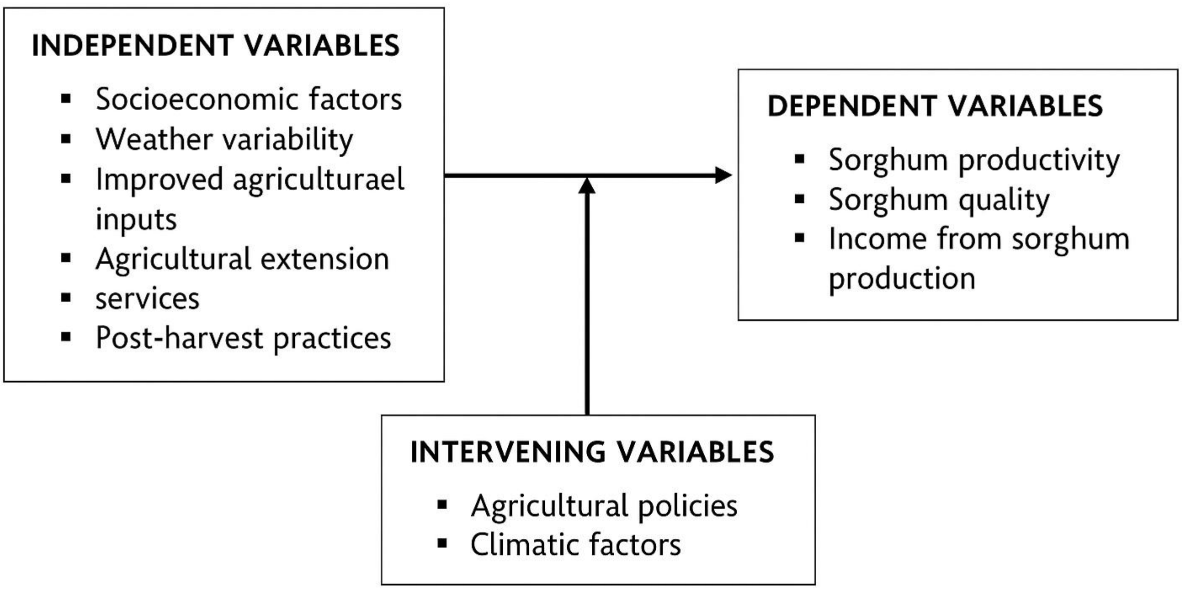


Figure 1. Conceptualized framework

# CHAPTER THREE

# METHODOLOGY

## 3.1 Study Area

The study was conducted in Jur River County. Jur River County is located in Western Bahr El Ghazal State, South Sudan. The county takes its name from the Jur River, a 485-kilometer-long watercourse that originates from the Congo-Nile Divide, near the borders of South Sudan, the Democratic Republic of the Congo, and the Central African Republic. The river flows northeast and merges with the Bahr El Ghazal River before reaching the extensive Sudd wetlands. Jur River County is situated at an approximate latitude of 7.9564°N and a longitude of 27.9793°E, with an elevation of 479 meters above sea level. The terrain of the county primarily consists of the Ironstone Plateau, which is characterized by iron-rich soils with low water retention capacity.

This geomorphological feature contributes to periodic droughts, despite the region's agricultural potential. According to the 2008 census, Jur River County had a population of 127,771, predominantly consisting of the Luwo (Jur Chol) ethnic group, along with minority populations such as the Dinka Marial Bai residing in the northeastern part of the county. The economy is largely agro-pastoral, with local inhabitants engaged in subsistence farming, cattle rearing, and fishing. As of 2018, approximately 75% of households participated in agricultural activities, a figure that increased to 78% by 2021.

Despite this economic involvement, the county has faced persistent food insecurity, often categorized under Crisis (IPC Phase 3) levels. Contributing factors include recurrent insecurity, the displacement of farming communities since 2015, and environmental challenges that impede agricultural productivity. Jur River County's agro-pastoral system supports the cultivation of staple crops such as sorghum, maize, millet, cassava, groundnuts, sesame, and various vegetables. Livestock farming, particularly cattle rearing, plays a crucial role in maintaining soil fertility through the application of manure. Agricultural resilience initiatives, such as the Food and Nutrition Security Resilience Program (FNS-REPRO), have been introduced to enhance productivity by providing improved seed varieties and promoting sustainable farming practices. These interventions have led to increased crop yields and the establishment of cooperative societies focused on seed production and marketing.

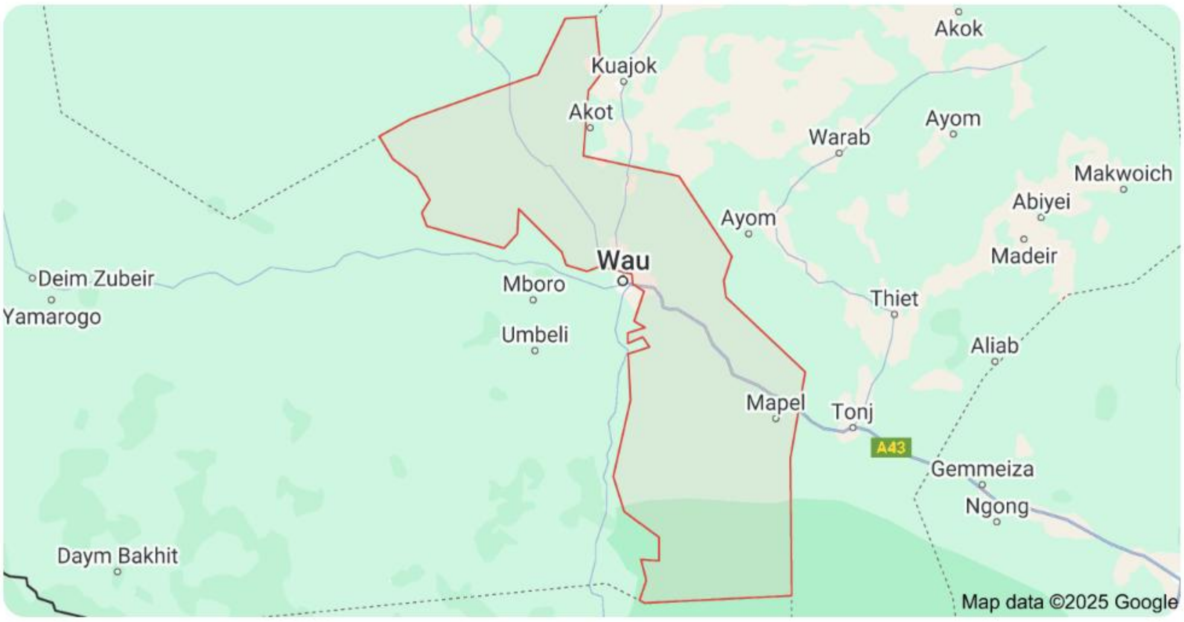


Figure 2. Map of Jur River County

Source: Google Map Data 2025.

### 3.2 Sampling Procedure

The study adopted a multi-stage sampling procedure to select the respondent. First, Jur River County will be purposively selected. Second, Kangi, Rocrocdong, Kuajiena, Marial Baai, and Wau Baai Payams will be purposively selected since they are one of the major Sorghum producing areas in the county. Subsequently, random selection of three Bomas from Payam will be carried out. Finally, simple random sampling method will be used to select the required number of farmers from the selected Bomas. A list of farmers generated with the help of agricultural extension officer in the area will act as a sampling frame from which respondents will be drawn. The sample were proportionately allocated to farmers growing sorghum with assistance from agricultural extension officer in the study area.

### 3.3 Sample Size Determination

The sample size for the quantitative survey was determined using the Cochrane formula, which is widely used for calculating sample size when estimating a single population proportion with a specified level of precision. This approach assumes a simple random sampling design and provides a statistically valid estimate when the population is large or unknown.

Sample size was determined using the Cochrane formulae

$$n = \frac{Z^2 P(1-P)}{e^2}$$

Where *n* = sample size required,

z= 95% confidence interval = (1.96)

e was margin of error (5%)

In applying Cochrane formulae formula for sample size determination, the value of *p* was assumed to be 0.5. This assumption was adopted because no reliable prior estimates of the proportion of households experiencing specific constraints in sorghum production were available for Jur River County or for South Sudan more generally. The use of $p = 0.5$ is statistically justified as it maximizes sample variability and therefore provides the largest possible sample size under conditions of uncertainty. This conservative approach ensured that the study achieved sufficient statistical power to detect significant relationships across variables in the absence of baseline prevalence data.

Where; n= Sample size; Z= confidence level ($\alpha$= 0.05); p= proportion of the population containing the main characteristics of interest; q=1-p and E= allowable error. Since the proportion containing the major characteristics of interest is unknown, p= 0.5, q=0.5, Z=1.96 and E= 0.05. This will result in a sample of approximately 384 respondents.

The study adopted a purely quantitative approach; all questions were structured with categorical, binary, Likert-scale, or continuous response options to allow statistical analysis

### 3.4 Data collection and Analysis

The study used both primary data and secondary data. Primary data will be collected through face-to-face interviews with the help of semi- structured questionnaires which will be administered to the respondents by trained enumerators. Secondary data will be obtained from Metrological weather station, online sources on weather variations and sorghum production in the area of study to mention but a few. Data was coded and entered into relevant software for analysis. STATA (version 15) will be used for data analysis.

#### 3.4.1 Analytical Framework

Specific Objective one: To assess the effect of weather variability on sorghum productivity in Jur River County in Western Bahr El Ghazal.

For the first objective, which sought to assess the effect of weather variability on sorghum productivity, data on rainfall, temperature, drought periods, soil moisture, and rainfall distribution were obtained from both household responses and secondary records. Farmer perceptions of rainfall and drought were first coded into frequency measures and then compared with meteorological data to enhance validity. The continuous variables, such as rainfall in millimeters per month, average temperature in degrees Celsius, soil moisture content in percentage, and rainfall distribution expressed through the coefficient of variation, were fitted directly into descriptive statistics, correlation, and multiple linear regression models. Sorghum yield, recorded as kilograms per hectare, was used as the dependent variable in the regression equation.

**Model Expression**

$$Sorghum\ Yield\ (Y_S) = \beta_0 + \beta_1 Rainfall + \beta_2 Temp. + \beta_3 Draught\ period + \beta_4 Soil\ Moisture + \beta_5 Rainfall\ Distribution.$$

**Specific Objective Two:** To assess the influence of access to improved agricultural inputs on sorghum productivity in Jur River County in Western Bahr El Ghazal.

For the second objective, which assessed the influence of access to improved agricultural inputs, binary responses such as whether or not farmers had access to improved seed varieties were coded as 0 for no and 1 for yes. Fertilizer application was standardized into kilograms per hectare, pesticide use into liters per hectare, and input costs into United States dollars per hectare. Farmer knowledge of inputs, collected through a five-point Likert scale, was transformed into a continuous score that reflected the respondent's level of awareness and application of input technologies. These variables were then analyzed descriptively to provide summaries, correlated with sorghum productivity, and entered simultaneously into a multiple regression model with productivity in kilograms per hectare as the dependent variable.

**Model Specification:**

$$
\begin{aligned}
&Sorghum\ Productivity \\
&\qquad = \beta_0 + \beta_1 Access\ to\ Seeds + \beta_2 Fertiliser\ use + \beta_3\ Input\ cost \\
&\qquad + \beta_4\ Pesticide\ use + \beta_5\ Farmer's\ Knowledge
\end{aligned}
$$

**Specific Objective Three:** To examine the effect of agricultural extension services and adoption of improved farming practices on sorghum productivity in Jur River County in Western Bahr El Ghazal.

For the third objective, which examined the effect of agricultural extension services and adoption of improved farming practices, data on extension visits were quantified as the number of contacts per year, while training was measured in hours received annually. Binary variables such as access to extension materials were coded as 0 for no and 1 for yes, while extension worker knowledge was rated by farmers on a scale of one to five, which was later treated as a continuous predictor variable. Adoption of recommended practices was captured as a percentage of practices applied relative to those promoted by extension services. These responses were summarized through descriptive statistics, analyzed through correlation to show associations with sorghum productivity, and finally incorporated into multiple regression to test the magnitude and direction of their effects on yield.

**Model Specification:**

$$Sorghum\ Productivity = \beta_0 + \beta_1\ Extension\ Viisits + \beta_2\ Training\ Hours + \beta_3\ Extension\ Materials + \beta_4\ Extension\ Knowledge + \beta_5\ Adpted\ Practices$$

**Specific Objective Four:** To analyze the extent of post-harvest losses and their effect on sorghum income generation in Jur River County in Western Bahr El Ghazal.

For the fourth objective, which analyzed the extent of post-harvest losses and their effect on sorghum income generation, binary responses such as type of storage or harvesting method were coded into categorical dummy variables. Training on post-harvest handling was coded as 0 for no and 1 for yes. Continuous responses such as storage duration in days and storage capacity in tons were standardized before entry into the model. Transportation conditions were assessed on a five-point scale and treated as an ordinal predictor. The dependent variable, income from sorghum production, was calculated as the total earnings in United States dollars obtained from sorghum sales, adjusted for reported yields, post-harvest losses, and market access. Descriptive statistics were used to provide summaries, correlation was applied to test relationships between post-harvest practices and sorghum income, and multiple regression was fitted to estimate the relative contribution of each factor to income outcomes.

**Model Specification:**

$$Income\ from\ Sorghum = \beta_0 + \beta_1\ Storage\ Method + \beta_2\ Harvest\ Method + \beta_3\ Post\ harvest\ Training + \beta_4\ Starage\ Duration + \beta_5\ Transportation\ Condition + \beta_6\ Storage\ Capacity$$

In all cases, categorical responses were systematically coded, Likert-type responses were transformed into continuous scales, and continuous measures were standardized into comparable units. This ensured that responses from the household survey were appropriately transformed into variables suitable for descriptive, correlational, and regression analysis, allowing the models to generate robust estimates of the effect of independent variables on sorghum productivity, quality, and income.

### 3.7 Ethical Considerations.

Ethical approval for this study was obtained from Uganda Christian Research Ethics Committee and administrative clearance was also obtained from the areas where data collection was to take place. Informed consent was sought from all participants prior to data collection, and the objectives of the study were explained clearly in the local language to ensure understanding. Participation was entirely voluntary, and respondents were informed of their right to withdraw at any stage without penalty. Confidentiality was maintained by assigning anonymous identification codes to the questionnaires, and no names or personal identifiers were recorded in the dataset. Data collected were securely stored and accessed only by the research team. The study adhered to ethical principles of respect, beneficence, and justice to safeguard the rights and dignity of participants.

# CHAPTER FOUR

## RESULTS AND DISCUSIONS

### 4.0 Introduction

This chapter presents the research findings in four main sections, each addressing a specific aspect of the data analysis. The first section provides descriptive statistics on respondents' demographic and household characteristics in Jur River County, South Sudan. The second section analyses the effects of weather variability on sorghum productivity using both descriptive and inferential statistics. The third section examines the influence of agricultural extension services and the adoption of improved farming practices on sorghum yields. The fourth section assesses the impact of post-harvest losses on household income from sorghum production. This structured approach offers a comprehensive understanding of the key factors affecting sorghum productivity and food security in Jur River County.

This study adopted a purely quantitative design; therefore, all results presented in this chapter are based on structured household survey responses coded into categorical, ordinal, and continuous variables. Analysis was conducted using descriptive statistics, correlation tests, and multiple regression models to assess the relationships between independent and dependent variables.

### 4.1 **Demographic & Household Characteristics**

As indicated in Table 1, all 384 surveyed households reported cultivating sorghum, underscoring the crop's foundational role in household livelihoods across Jur River County. A significant majority (87.5%) reported cultivating sorghum during every agricultural season, suggesting that sorghum serves not only as a staple food crop but also as a principal source of household income. Only 12.5% of households reported cultivating sorghum intermittently, which may reflect challenges related to seasonal variability, input constraints, labour shortages, or unfavourable climatic conditions. These findings point to a high level of uniformity in sorghum production practices throughout the study area. Such consistency provides a strong basis for further investigation into how external factors such as including weather variability, access to agricultural inputs, extension service provision, and post-harvest losses, affect sorghum yields and household incomes.

The gender distribution of household heads reveals that 76.6% are male, while 23.4% are female. Beyond the percentage distribution, gender had important implications for sorghum production outcomes. Male-headed households generally reported higher yields and greater market participation, reflecting their larger average landholdings and greater control over household resources. Female-headed households, by contrast, showed lower average yields and less frequent access to inputs and extension services. These disparities suggest that gender inequalities in access to productive resources directly influence productivity and income. Addressing these gaps is therefore essential for policies aimed at improving sorghum production and strengthening household food security.

This disparity is likely to influence decisions related to sorghum production, as male-headed households generally have greater access to key productive resources such as land, capital, and agricultural extension services. Conversely, female-headed households may face gender-specific constraints—including cultural norms, limited mobility, and unequal access to resources—that hinder their capacity to fully engage in agricultural production. Nevertheless, the presence of a substantial proportion of female-headed households (nearly one-quarter) necessitates, agricultural interventions be gender-responsive. Policies and programs aiming to increase the uptake of improved inputs and agronomic practices must be tailored to address the unique challenges faced by women farmers.

With respect to occupation, an overwhelming majority (90.3%) of household heads are primarily engaged in farming. A relatively small share is involved in business (6.8%) or salaried employment (2.3%), while 0.5% fall into other occupational categories. This occupational structure highlights the community's strong dependence on agriculture as a livelihood source. Consequently, any adverse changes in sorghum productivity—whether due to climatic variability, input limitations, or post-harvest inefficiencies, are likely to have immediate and far-reaching impacts on household welfare. In the absence of diversified income streams, households remain highly vulnerable to agricultural shocks. Conversely, even incremental improvements in yield or reductions in post-harvest losses could significantly enhance household resilience and income levels.

The age distribution of household heads reveals a mean age of 44.1 years (SD = 12.4), indicating that most farmers are in their middle adulthood. This demographic profile combines a wealth of farming experience with a varying degree of physical capacity and receptivity to innovation. Older farmers may possess valuable indigenous knowledge regarding local agro-ecological conditions and traditional farming techniques, yet may be less inclined to adopt new technologies. In contrast, younger household heads may demonstrate a higher willingness to experiment with improved seed varieties or mechanized practices but may lack experiential knowledge in adapting to climate risks. Therefore, extension programs should adopt a stratified approach that addresses both the experiential learning needs of older farmers and the innovation-driven mindset of younger farmers.

Educational attainment among household heads is relatively low, with an average of 3.3 years of formal schooling (SD = 5.0). The high standard deviation suggests a wide disparity in education levels: while some respondents have attained primary or early secondary education, many have no formal education at all. This low educational profile has direct implications for the uptake of agricultural technologies and services. Limited literacy and numeracy skills can hinder farmers' ability to read and interpret instructions on seed packaging, understand appropriate usage of fertilizers and pesticides, and complete credit application forms for agricultural inputs. Additionally, low education levels may limit farmers' capacity to interpret weather forecasts or engage effectively with climate-smart agricultural strategies. To address these challenges, agricultural extension services should prioritize visual, oral, and demonstration-based methods of communication to enhance farmers' understanding and adoption of improved practices.

The average household size reported is 10.0 individuals (SD = 11.3), comprising an average of 5.2 males (SD = 7.1) and 4.8 females (SD = 4.7). Such large and variable household sizes present both opportunities and challenges. On the one hand, larger households can serve as an important source of agricultural labour for tasks such as land preparation, weeding, and harvesting, especially in low-mechanization settings. On the other hand, larger family sizes also increase household consumption needs, potentially reducing the quantity of sorghum available for market sale and, by extension, limiting household income. These dynamics underscore the need for policies that simultaneously enhance productivity and address household-level food security concerns.

**Table 1. Demographic & Household Characteristics**

| Categorical Variables | Category / Unit | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Grow Sorghum | Yes | 384 | 100.0 |
| | No | 0 | 0.0 |
| Grow Sorghum Every Season | Yes | 336 | 87.5 |
| | No | 48 | 12.5 |
| Gender of Household Head | Male | 294 | 76.6 |
| | Female | 90 | 23.4 |
| Occupation of Household Head | Farming | 347 | 90.3 |
| | Business | 26 | 6.8 |
| | Salaried | 9 | 2.3 |
| | Other | 2 | 0.5 |
| **Continuous Variables** | **Unit** | **Mean** | **Standard Deviation** |
| Age of Household Head | Years | 44.1 | 12.4 |
| Education of Household Head | Years of school | 3.3 | 5.0 |
| Household Size (Total) | Members | 10.0 | 11.3 |
| Male Members | Members | 5.2 | 7.1 |
| Female Members | Members | 4.8 | 4.7 |

**Source:** Primary data

In addition to the core findings, the data presented in Table 1 reveal critical insights regarding household responses to climatic variability, particularly during seasons characterized by drought or erratic rainfall. Larger households, in such contexts, may encounter significant challenges in mobilizing adequate labour and financial resources to implement risk-prone adaptive strategies, such as preparing land for a secondary sorghum planting. These constraints can compel households to liquidate limited food stocks prematurely, either to meet immediate consumption needs or to generate income, often resulting in increased post-harvest losses or a glut in local markets that depresses sorghum prices. The relatively high standard deviation in household size underscores the substantial variation in family composition across the sampled population. This heterogeneity implies that policy interventions, such as the distribution of post-harvest storage technologies or input vouchers, should be carefully tailored. A uniform approach risks marginalizing either small or large households by failing to account for differing resource needs and labour capacities.

The overall demographic profile of sorghum-farming households in Jur River County presents a complex landscape that intersects with climatic and institutional constraints to influence production outcomes. The data indicate that sorghum cultivation is a universal practice in the area, predominantly managed by male-headed households, often led by individuals in their midlife years who have attained only minimal formal education. The prevalence of large, but highly variable, family sizes further complicate the household production environment. These demographic characteristics collectively shape how farmers respond to challenges related to weather variability, access to agricultural inputs, extension service delivery, and post-harvest management. For instance, low educational attainment may limit farmers' understanding and application of improved agronomic practices or climate-smart technologies, while larger households may face greater difficulties in allocating resources efficiently, especially during stress periods such as droughts.

Furthermore, the limited effectiveness of current agricultural extension services, particularly those that do not accommodate the low literacy levels of many farmers, may hinder the dissemination and adoption of innovative production techniques. Similarly, the lack of robust post-harvest infrastructure and the widespread knowledge gaps regarding proper grain handling and storage contribute to significant quantitative and qualitative losses. These losses diminish household income potential, even in seasons of adequate rainfall and favorable growing conditions. To enhance sorghum productivity and promote household resilience, development interventions in Jur River County must be informed by these demographic realities. Policies and programs should adopt a differentiated approach, sensitive to household size, educational background, and labour dynamics, in order to effectively address the multifaceted constraints facing sorghum producers in the region.

### 4.2 Weather Variability on Sorghum Yield in the Study Area

Table 2, provides a descriptive overview of key weather variability indicators hypothesized to influence sorghum productivity in Jur River County. With respect to average annual rainfall, data from the 384 surveyed sorghum-producing households reveal that only 3.1% of respondents reported receiving less than 500 mm of rainfall per year. The majority (77.1%) indicated receiving between 500 mm and 1,000 mm annually, while 19.8% reported rainfall in excess of 1,000 mm. These findings are critical in the context of a semi-arid agroecological setting where sorghum is a staple crop, as rainfall levels influence soil moisture availability and affect both germination and vegetative growth phases.

Households that reported rainfall levels between 500 mm and 1,000 mm per annum appear to occupy the optimal agro-climatic zone for sorghum cultivation within the study area. Rainfall amounts below this threshold may expose crops to water stress, adversely affecting yield. Conversely, rainfall exceeding 1,000 mm increases the likelihood of waterlogging or flooding, conditions that can also suppress crop productivity. While the classification of rainfall into categories offers important insights, its influence is better understood when considered alongside regression analysis results. Specifically, average annual rainfall exhibited a positive and statistically significant relationship with sorghum yield ($B = 1{,}241.523$, $p < .001$). This implies that transitions from lower to higher rainfall categories were associated with substantial increases in yield. Quantitatively, each unit increase in the rainfall category corresponded to an estimated gain of approximately 1,241 kg/ha in sorghum output, assuming other variables were held constant. These results underscore the pivotal role that adequate rainfall, especially within the 500–1,000 mm range, plays in determining sorghum productivity in Jur River County.

Beyond total rainfall, the distribution of precipitation during the growing season also emerged as a variable of interest. In the sample, 38.8% of respondents characterized rainfall as evenly distributed, 44.0% as irregular, and 17.2% as unpredictable. An even rainfall pattern denotes consistent precipitation aligned with the crop's growth stages, whereas irregular patterns may deliver sufficient cumulative moisture but include perilous dry spells. Unpredictable patterns are typically associated with prolonged droughts interrupted by abrupt, intense downpours. Despite its theoretical importance, rainfall distribution exhibited a negative yet statistically insignificant effect on sorghum yield in the regression model (B = –69.830, p = .578). Although agronomic reasoning might suggest that even rainfall distributions enhance crop performance more than irregular or unpredictable ones, the empirical findings indicate otherwise. When controlling for total rainfall and other covariates, the distribution of rainfall did not significantly account for variations in yield across households. This suggests that while rainfall distribution may influence short-term agricultural decisions, it was not a consistent determinant of sorghum yield at the population level within the study area.

Farmers in Jur River County reported experiencing an average of 6.0 drought periods over the past five years, with a notably high standard deviation of 19.2. This considerable variation suggests a heterogeneous distribution of drought experiences among households, where some farmers endured multiple episodes of dry conditions, while others encountered relatively few. Such variability underscores the complex and uneven nature of climatic stress across the surveyed population.

**Table 2.** **Weather variability results**

| **Categorical Variables** | **Category** | **Frequency (n)** | **Percentage (%)** |
|---|---|---|---|
| Average Annual Rainfall | < 500 mm | 12 | 3.1 |
| | 500–1000 mm | 296 | 77.1 |
| | > 1000 mm | 76 | 19.8 |
| Rainfall Distribution over Years | Even | 149 | 38.8 |
| | Irregular | 169 | 44.0 |
| | Unpredictable | 66 | 17.2 |
| Average Temperature (°C) During Growing Season | < 20 | 29 | 7.6 |
| | 20–30 | 291 | 75.8 |
| | > 30 | 64 | 16.7 |
| Soil Moisture Deficiency Experienced | Yes | 67 | 17.4 |
| | No | 317 | 82.6 |

| Continuous Variables | Unit | Mean | Standard Deviation |
|---|---|---|---|
| Number of Drought Periods (last 5 years) | Number | 6.0 | 19.2 |
| Estimated Sorghum Yield (kg/ha) | (kg/ha) | 874.3 | 1,940.1 |

**Source:** Primary data

In theory, recurrent droughts are expected to disrupt sorghum production by exerting water stress during critical phenological stages, thereby leading to diminished yields. However, findings from the regression analysis revealed that the coefficient for the number of drought periods was negative (B = –0.335) but not statistically significant ($p = 0.943$). This outcome indicates that, after controlling for key weather-related variables such as average annual rainfall, temperature, and soil moisture deficits, the simple frequency of drought occurrences did not significantly predict variations in sorghum yields among households.

One plausible explanation for this lack of significance is the potential influence of local adaptive practices. Farmers may have employed resilience-enhancing strategies, such as varying planting schedules, diversifying crop varieties, or employing drought-tolerant sorghum strains, which could have cushioned the adverse effects of episodic droughts. Additionally, the observed disparity in the severity and duration of droughts may have rendered the raw count of drought periods an inadequate proxy for measuring true climatic stress. While some farmers might have faced a few intense and prolonged droughts, others may have encountered frequent but less severe episodes. Consequently, the simple numerical tally of drought events may fail to capture the nuanced impacts of drought on agricultural productivity in the region.

Temperature data reported by respondents indicated varied seasonal experiences. Specifically, 7.6% of the sampled farmers reported average seasonal temperatures below 20°C, while a majority (75.8%) experienced average temperatures ranging from 20°C to 30°C. A smaller proportion, 16.7%, reported average temperatures exceeding 30°C. Agronomic literature emphasizes that sorghum is a thermophilic crop, performing optimally under warm conditions. However, extreme heat—particularly when daytime temperatures consistently surpass 30°C to 35°C, can adversely affect crop development, especially if diurnal cooling at night is insufficient to offset the thermal stress (FAO, 2021).

Therefore, the average temperature range of 20°C to 30°C reported by the majority of farmers may represent near-optimal climatic conditions for sorghum growth in this context. Farmers operating within this temperature band likely benefited from enhanced physiological responses in the crop, including accelerated germination, vigorous vegetative development, and efficient grain maturation, all of which contribute to increased yield levels. Consequently, the significant positive coefficient associated with average temperature suggests that, within the observed range, moderate warming during the growing season positively influenced sorghum productivity in the study area.

Regarding soil moisture conditions, only 17.4% of respondents reported experiencing soil moisture deficiency during the growing season, while a substantial majority (82.6%) did not report such challenges. In the regression model, the variable measuring the experience of soil moisture deficiency exhibited a negative coefficient ($B = -314.342$); however, the association was not statistically significant ($p = .209$). This finding suggests that farmers' subjective reports of moisture deficiency did not significantly contribute to explaining variations in sorghum yield after accounting for other climatic variables such as total rainfall, rainfall distribution, drought frequency, and average temperature.

One possible explanation for this result is the discrepancy between farmers' perceptions of soil moisture stress and the actual agronomic thresholds at which such stress materially affects crop productivity. Perceptual bias or differences in farmers' interpretation of soil moisture conditions may have weakened the predictive validity of this variable. Additionally, it is plausible that compensatory factors such as adaptive farming practices, microclimatic variability, or residual soil moisture retention, mitigated the yield-reducing effects typically associated with moisture stress. Thus, while soil moisture deficiency remains a potential threat to yield, its explanatory power in this study was limited when modelled alongside more objectively quantifiable weather-related factors.

#### 4.2.1 Estimated Sorghum Yield

The average estimated sorghum yield among surveyed households was 874.3 kilograms per hectare, accompanied by a notably high standard deviation of 1,940.1 kilograms per hectare. This substantial variation indicates pronounced disparities in sorghum productivity across farming households. While a segment of farmers—particularly those situated in agro-ecological zones with relatively favourable climatic conditions, such as higher and more stable rainfall, reported yields exceeding 2,000 kilograms per hectare, a considerable number of others experienced significantly lower outputs. In many cases, yields fell below the levels necessary to meet subsistence requirements. Such disparities underscore the vulnerability of sorghum production to climate variability, with erratic rainfall and fluctuating temperatures playing a critical role in shaping yield outcomes. The wide dispersion in yield data reflects the broader challenge of sustaining consistent agricultural productivity under increasingly unpredictable weather patterns, particularly in rain-fed farming systems.

#### 4.2.2 Predictor Variables

The model incorporated several key predictor variables to explain sorghum yield variability. These included the constant term, farmers' experience of soil moisture deficiency during the sorghum growing season, the pattern of rainfall distribution over the years, the number of drought periods (dry spells) experienced within the last five years, the average temperature during the sorghum growing season, and the average annual rainfall in the study area. Each of these predictors was selected based on their hypothesized influence on crop performance, reflecting critical aspects of climatic and environmental stressors affecting sorghum production.

#### 4.2.3 Model Fit and Weather Variables as Predictors of Sorghum Yield

Table 3 presents the overall fit statistics of the multiple regression model that examines the influence of key weather variables on sorghum yield. The model produced a multiple correlation coefficient (R) of 0.459, indicating a moderate strength of association between the combined weather predictors and sorghum yield. The coefficient of determination ($R^2$) was 0.211, with an adjusted $R^2$ of 0.200, suggesting that approximately 20% of the variability in sorghum yield is explained by the set of weather variables included in the analysis. These variables comprised average annual rainfall, rainfall distribution over the years, frequency of drought periods, average temperature during the growing season, and experience of soil moisture deficiency.

**Table 3. Model Summary**

| Model | R | R_Square | Adjusted R_Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | 0.459[a] | 0.211 | 0.200 | 1734.8007 |

As shown in table 3, the standard error of the estimate was calculated at 1,734.80 kg/ha, reflecting the average deviation of the observed yields from those predicted by the regression model. This residual variability underscores that while weather factors contribute significantly to yield variation, other agronomic, socio-economic, and management factors likely play substantial roles as well (Lobell et al., 2011; Sultan et al., 2013). Consistent with findings from other studies in semi-arid tropical regions, these results highlight the complexity of sorghum yield determination and the importance of integrating climatic variability within agronomic planning and policy development (Rockström et al., 2014; Tesfaye et al., 2021).

In addition, the dependent variable in the regression model was the estimated sorghum yield (kg/ha), while the key predictors included experience of soil moisture deficiency during the growing season, rainfall distribution over the years, number of drought periods experienced in the past five years, average temperature during the growing season, and average annual rainfall in the area. These variables were selected based on their demonstrated influence on crop productivity, particularly in rainfed systems. Soil moisture stress and recurrent droughts can inhibit plant development and reduce yield, while erratic rainfall and extreme temperatures further compound these effects (Lobell et al., 2014; Sultan & Gaetani, 2016). By incorporating both short-term and long-term climatic indicators, the model aims to capture the multifaceted impacts of weather variability on sorghum production outcomes.

**Table 4: ANOVA Results**

| Model | | Sum of Squares | df. | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 30395568.055 | 5 | 60791173.611 | 20.200 | 0.000[b] |
| | Residual | 1137603648.177 | 378 | 3009533.461 | | |
| | Total | 1441559516.232 | 383 | | | |

Therefore, the analysis of variance (ANOVA) results presented in Table 4 evaluate the overall significance of the regression model in explaining the variability in estimated sorghum yield using key weather-related predictors. The regression sum of squares amounted to 303,955,868.06, while the residual sum of squares was 1,137,603,648.18. This yielded an F-statistic of 20.200, with a corresponding p-value of less than 0.001. These results indicate that the collective influence of the selected weather variables—including rainfall distribution, temperature, drought frequency, and soil moisture deficiency—is statistically significant in explaining variations in sorghum yield across the study area. The very low p-value ($p < .001$) confirms that the model's explanatory capacity is unlikely due to random variation, but instead demonstrates a robust relationship between climatic variability and sorghum productivity. These findings are consistent with previous studies that have established the significant role of climatic factors in determining crop yields in sub-Saharan Africa (Araujo et al., 2021; Lobell & Asseng, 2017).

Table 5 presents the results of the multiple linear regression analysis, highlighting the individual contributions of each weather-related predictor to variations in estimated sorghum yield. This detailed output provides insight into how each variable independently influences sorghum productivity, after controlling for the effects of the other predictors in the model. The unstandardized coefficients (B) reflect the magnitude and direction of change in sorghum yield (measured in kilograms per hectare) for every one-unit increase in the respective predictor variable. By interpreting these coefficients, it becomes possible to identify the most influential climatic factors affecting sorghum performance in the study area, offering valuable implications for climate-resilient agricultural planning and targeted interventions.

#### 4.2.4 Contribution of Weather Predictors to Sorghum Yield

The regression analysis results presented in Table 5 evaluate the individual contributions of weather-related variables to estimated sorghum yield in Jur River County, South Sudan. Among all predictors, average annual rainfall emerged as the most influential factor in explaining yield variability. Specifically, a one-unit increase in the coded average rainfall variable was associated with a significant yield increase of approximately 1,241.5 kg/ha ($B = 1241.523$, $p < .001$). This finding underscores the critical role of overall rainfall amounts in enhancing sorghum productivity in rainfed farming systems, where moisture availability largely determines crop success (Aune et al., 2018).

Average growing-season temperature was also positively and significantly associated with sorghum yield (B = 852.527, $p < .001$). Within the observed range of 20 °C to 30 °C, warmer conditions contributed to an average increase of approximately 853 kg/ha. This result suggests that sorghum in this region benefits from moderate warming when adequate rainfall is present, aligning with existing agronomic evidence that highlights sorghum's adaptability to warm, semi-arid environments (Tesfaye et al., 2015).

In contrast, the distribution of rainfall over time, although theoretically important for crop development stages, showed a negative but statistically significant association (B = –69.830, $p = .008$). However, its practical impact was minimal once other variables, such as total rainfall and temperature, were included in the model. This outcome indicates that while rainfall spread is conceptually relevant, its predictive value may be overshadowed by the total volume of rainfall, especially when water is not a limiting factor throughout the growing season.

The number of drought periods experienced in the previous five years had a negligible effect on yield (B = –0.335, $p = .943$), suggesting that simply counting drought events does not adequately capture the intensity, timing, or duration of water stress on crop performance. This aligns with research cautioning against reliance on crude drought metrics, which may mask intra-seasonal variability and farmer adaptation strategies (Thornton et al., 2014). Likewise, experience of soil moisture deficiency, reported by farmers during the growing season, had a negative but statistically non-significant influence on sorghum yield (B = –314.342, $p = .209$). Although logically tied to water stress, this self-reported variable may lack precision compared to objective weather data, particularly when subject to perception bias or retrospective recall.

**Table 5: Regression coefficients**

| Model | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| | **B** | **Std. Error** | **Beta** | **t.** | **Sig.** |
| 1. Average annual rainfall in the area | 1241.523 | 230.471 | 0.288 | 5.387 | **0.000** |

| | | | | | |
|---|---|---|---|---|---|
| Rainfall distribution over the years | -69.830 | 125.447 | -0.026 | -0.557 | **0.008** |
| Number of drought periods (dry spells) experienced in the last five years | -0.335 | 4.699 | -0.003 | -0.071 | 0.943 |
| Average temperature during the sorghum growing season | 852.527 | 211.778 | 0.213 | 4.026 | **0.000** |
| Experience of soil moisture deficiency during the sorghum growing season | -314.342 | 249.648 | -0.062 | -1.259 | 0.209 |
| **(Constant)** | **-3212.382** | **695.466** | | **-4.619** | **0.000** |

a. **Dependent Variable:** *Estimated sorghum yield (kg/ha)*

In sum, the findings demonstrate that average annual rainfall and average growing-season temperature are the most reliable and statistically significant predictors of sorghum yield in the study area. These results highlight the value of improving farmers' access to real-time climate information, such as rainfall forecasts and temperature outlooks—through community-based weather stations or mobile alert platforms. Meanwhile, factors such as rainfall distribution, drought counts, and perceived moisture shortages, while relevant to farmer experiences, may have limited predictive utility when robust meteorological data are available. Importantly, the model results also suggest that weather variables alone account for only a portion of observed yield variability, reinforcing the need for integrated interventions. Complementary efforts, including access to improved seed varieties, timely planting, soil fertility management, and post-harvest technologies, remain essential to closing persistent yield gaps under variable climatic conditions (Waha et al., 2013). Thus, policy responses should adopt a holistic view that combines climate adaptation with agronomic innovations to enhance smallholder resilience in sorghum-based systems.

### 4.3 Effect of input access on Sorghum Productivity in the Study Area.

The study assessed how access to improved agricultural inputs, specifically drought-resistant seeds, fertilizer use, pesticide application frequency, input costs, and farmer knowledge, affects sorghum productivity in Jur River County, South Sudan, using descriptive and inferential statistical analyses.

The descriptive results presented in Table 6 provide insight into the extent of access to agricultural inputs among sorghum farmers in Jur River County, South Sudan. Regarding the adoption of drought-resistant seeds, a significant majority (82.6%) of the sampled farmers reported having access to these improved seed varieties, while only 17.4% indicated no access. This high proportion suggests that drought-tolerant technologies have gained traction in the region, likely due to their potential to enhance resilience against erratic weather conditions and improve yields under climatic stress (Mabhaudhi et al., 2017). Access to fertilizers also showed notable trends. Among the respondents, 90.1% reported using organic fertilizers, suggesting a strong reliance on locally available and environmentally sustainable nutrient sources. In contrast, only 0.5% relied solely on inorganic fertilizers, while 9.4% used both types. These findings underscore the dominance of organic fertilization practices, which may be attributed to cost considerations, local farming traditions, or limited availability of synthetic inputs (Palm et al., 2014).

In terms of pesticide usage, the data showed considerable variation. About 38.3% of the farmers had never used pesticides, 5.5% applied them seasonally, and the majority (56%) reported regular access and use. The relatively high proportion of regular pesticide users indicates an increasing awareness of pest control as a crucial component in improving sorghum yield, although the large share of non-users may reflect challenges such as affordability, accessibility, or limited knowledge on safe pesticide application (Williamson et al., 2008). When asked to rate their overall perception regarding access to farm inputs, 39.8% of the farmers rated access as good, while 35.9% indicated an average experience. Only 8.3% rated it as poor, and a mere 0.8% classified it as very poor. These perceptions suggest a generally favorable outlook on input access, though a significant portion of farmers still face notable constraints that may hinder optimal production outcomes.

**Table 6: Access to Improved Agricultural Inputs**

| Categorical Variables | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Access to Drought-Resistant Seed | Yes | 317 | 82.6 |
| | No | 67 | 17.4 |
| Access to type of Fertilizer | Organic | 346 | 90.1 |
| | Inorganic | 2 | 0.5 |
| | Both | 36 | 9.4 |
| Access to Pesticides | Never | 147 | 38.3 |
| | Occasionally | 21 | 5.5 |
| | Regularly | 216 | 56.3 |
| Self-Rated Perception towards access of Inputs (1=Very Poor to 5=Excellent) | Very Poor | 3 | 0.8 |
| | Poor | 32 | 8.3 |
| | Average | 138 | 35.9 |
| | Good | 153 | 39.8 |
| | Excellent | 58 | 15.1 |
| **Continuous Variables** | **Unit** | **Mean** | **Standard Deviation** |
| Fertilizer Application Rate | Kg/ha | 97.5 | 24.2 |
| Cost of Agricultural Inputs | USD/ha | 315.40 | 149.20 |
| Estimated Sorghum Productivity | Kg/ha | 2,902.9 | 1,264.6 |

**Source:** Primary data

Quantitatively, the average fertilizer application rate (Table, 6), was found to be 97.5 kg/ha with a standard deviation of 24.2 kg/ha, indicating moderate variability in application intensity among the respondents. The average cost of agricultural inputs was estimated at USD 315.40 per hectare (±149.20), reflecting disparities in expenditure which may correspond to differences in input types, sources, and farm sizes. Furthermore, the average estimated sorghum productivity stood at 2,902.9 kg/ha, with a high standard deviation of 1,264.6 kg/ha, suggesting significant yield variation among the households, potentially influenced by input access, agroecological factors, and agronomic practices. Overall, the descriptive statistics highlight both progress and challenges in the accessibility and use of essential agricultural inputs, with implications for improving sorghum productivity through targeted interventions.

**Table 7. Model output for Access to farm inputs and Sorghum Productivity**

| Model | R | R_Square | Adjusted R_Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | 0.445[a] | 0.198 | 0.186 | 2625.9967 |

a. *Predictors:* (Constant), Perception towards the access to inputs, usage, cost of production per hectare (USD), fertiliser application rate (kg/ha), frequency of pesticide use and access to draught resistant seed varieties.

### 4.3.1 Model Summary of access to Agricultural Inputs and Sorghum Productivity

Table 7 presents the results of the multiple regression analysis conducted to examine the extent to which improved agricultural inputs predict sorghum productivity among smallholder farmers in Jur River County, South Sudan. The model yielded a multiple correlation coefficient (R) of 0.445, indicating a moderate positive association between the combination of improved agricultural input variables and sorghum yield. The coefficient of determination ($R^2$) was 0.198, and the adjusted $R^2$ was 0.186. This suggests that approximately 18.6% of the variance in sorghum productivity can be attributed to the collective influence of the selected predictor variables, namely: farmers' knowledge of agricultural inputs and their usage, cost of agricultural inputs per hectare (in USD), fertilizer application rate (kg/ha), frequency of pesticide use, types of fertilizers applied, and access to drought-resistant seed varieties.

The standard error of the estimate was 2,625.997 kg/ha, which provides a measure of the average deviation of the actual sorghum yields from the values predicted by the regression model. This residual variability reflects the presence of other unaccounted-for factors influencing productivity, despite the inclusion of key input-related predictors in the analysis. Although the model explains a modest proportion of the total variance in yield, the findings highlight the measurable impact of improved input utilization on sorghum output. These results underscore the significance of enhancing farmers' access to and knowledge of modern inputs as a pathway to improving productivity in smallholder farming systems, consistent with earlier studies in similar agro-ecological contexts (Arouna et al., 2021; Mottaleb et al., 2018).

**Table 8. ANOVA for access to inputs and Sorghum Productivity**

| Model | | Sum of Squares | df. | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 63782086.688 | 6 | 106630347.781 | 15.463 | 0.000[b] |
| | Residual | 2585946970.093 | 375 | 6895858.587 | | |
| | Total | 3225729056.781 | 381 | | | |

a. *Dependent Variable:* Estimated Sorghum Productivity in (Kgs/ha)

b. *Predictors:* (Constant), Farmer's perception towards access to inputs, usage, cost of production (USD/ha), Fertiliser application rate (Kg/ha), pesticide usage and access to drought resistant seed varieties.

Therefore, the results from the analysis of variance (ANOVA) presented in Table 8 provide a robust statistical assessment of the overall fit of the multiple regression model, which investigated the collective influence of access to improved agricultural inputs on sorghum yield. The regression sum of squares was 63,978,2086.688, while the residual sum of squares amounted to 258,594,6970.093. The resulting F-statistic was 15.463, with a significance value of $p < .001$. These results indicate that the set of predictor variables measuring access to agricultural inputs—such as drought-resistant seeds, fertilizers, pesticides, and related factors—significantly explains the variation in sorghum yield among smallholder farmers in the study area.

The F-test outcome confirms that the variation accounted for by the regression model is not due to random fluctuations but represents a statistically significant relationship (Field, 2018). The model's significance level ($p < .001$) is well below the conventional alpha threshold of .05, supporting the conclusion that access to improved agricultural inputs exerts a measurable and meaningful effect on sorghum productivity. These findings align with existing empirical literature emphasizing the role of input accessibility in enhancing crop yields, particularly in low-input farming systems prevalent in Sub-Saharan Africa (Sheahan & Barrett, 2017; Mottaleb et al., 2022).

### 4.3.2 Contribution of Access to Agricultural Inputs on Sorghum Yield

Table 9 presents the regression coefficients estimating the effect of selected improved agricultural input variables on sorghum productivity (measured in kg/ha). The analysis employs unstandardized beta coefficients (B) to indicate the expected change in sorghum yield for every one-unit change in the respective predictor variable, holding other variables constant. The results reveal a statistically significant negative relationship between access to drought-resistant seeds and sorghum productivity ($B = -2,583.71$, $p < .001$). This finding is counterintuitive, as improved seed varieties are generally expected to enhance crop performance. However, the negative coefficient may indicate a potential mismatch between the introduced drought-tolerant varieties and the specific agroecological conditions of Jur River County. Factors such as inadequate farmer sensitization, substandard seed quality, or misapplication of agronomic practices may contribute to this outcome (Wossen et al., 2017; Kassie et al., 2015).

**Table 9. Coefficients for improved agricultural inputs and sorghum productivity**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t. | Sig. |
| 1. | Access to drought-resistant seed varieties | -2583.707 | 463.652 | -.338 | -5.573 | **.000** |
| | Fertilizer application rate (kg/ha) | -1.360 | 1.400 | -.046 | -.971 | .332 |
| | Type of fertilizers used | 80.453 | 279.843 | .016 | .287 | .774 |
| | Frequently of use of pesticides for sorghum farming | -484.317 | 151.277 | -.159 | -3.202 | **.001** |
| | Cost of agricultural inputs per hectare (USD) | .006 | .009 | .030 | .648 | .518 |

| | | | | | |
|---|---|---|---|---|---|
| Knowledge of agricultural inputs and their usage | 630.418 | 171.854 | .188 | 3.668 | **.000** |
| **(Constant)** | **2306.985** | **1004.720** | | **2.296** | **.002** |

a. *Dependent Variable*: Estimated sorghum productivity (kg/ha)

The fertilizer application rate, while also showing a negative coefficient (B = -1.36), does not exhibit statistical significance (p = .332). This suggests that increasing the quantity of fertilizer applied does not automatically translate into higher yields. Such a result may stem from inefficient application techniques, poor soil fertility, or an imbalance in nutrient composition that limits nutrient uptake (Vanlauwe et al., 2014). Furthermore, the type of fertilizer used whether organic, inorganic, or a combination does not significantly influence yield outcomes (B = 80.45, p = .774). This finding underscores the importance of integrated soil fertility management and appropriate input combinations over the mere classification of fertilizer type (Sanginga & Woomer, 2009). Effective yield improvements may require not just access to inputs, but also proper timing, method of application, and alignment with broader agronomic systems.

Further, the results of the multiple regression analysis (Table, 9) provide a nuanced understanding of how specific agricultural input-related factors influence sorghum productivity among smallholder farmers in Jur River County, South Sudan. Notably, the frequency of pesticide use was found to have a statistically significant negative effect on yield (B = -484.32, *p* = .001). This inverse relationship suggests that increased pesticide application may be counterproductive, potentially due to phytotoxic effects, the development of pest resistance, or broader ecological imbalances that disrupt beneficial organisms (Aktar et al., 2009; Carvalho, 2017). This finding raises concerns about the quality and appropriateness of pesticide usage and underscores the need for more precise guidance on integrated pest management practices.

In contrast, the cost of agricultural inputs demonstrated a positive but statistically non-significant relationship with sorghum productivity (B = 0.006, *p* = .518). This result implies that increased financial investment in inputs does not inherently lead to better yield outcomes unless such spending is strategically directed and informed by best agronomic practices (Pingali, 2012). It highlights a potential misalignment between input expenditures and agronomic efficiency, suggesting that resource optimization remains a challenge for smallholder farmers in the region. Significantly, perception towards, access to agricultural inputs exhibited a strong positive association with productivity (B = 630.42, $p < .001$). This result affirms that farmers equipped with a sound understanding of input use, including timing, dosage, and application techniques, are more likely to achieve higher sorghum yields. The significance of this relationship underscores the critical role of farmer education, agricultural extension services, and participatory training approaches in enhancing productivity (Anderson & Feder, 2007; Davis et al., 2012). It further supports the argument that knowledge is a key driver of efficient input use and agricultural transformation in fragile settings such as South Sudan.

Overall, the regression outcomes suggest that while access to agricultural inputs appears relatively widespread among farmers in Jur River County, there are substantial inefficiencies in their utilization. The observed negative impact of pesticide use and the non-significant effect of input costs point to a gap between input availability and effective application. These discrepancies may be attributed to limited farmer training, the substandard quality of some inputs, or agro-ecological incompatibility. In contrast, the positive contribution of farmer knowledge to productivity highlights the importance of investing in human capital development through tailored extension and advisory services. Therefore, to enhance sorghum productivity in South Sudan, agricultural interventions should go beyond the mere provision of inputs. Policymakers and development actors should prioritize farmer education, conduct rigorous suitability assessments of available inputs, and promote context-specific agronomic support. Such integrated efforts are essential for translating input access into sustainable yield improvements and resilient livelihoods.

### 4.3 Effect of Agricultural Extension Packages on Sorghum Productivity

As presented in Table 9, Agricultural extension plays a vital role in facilitating the dissemination of knowledge and technologies necessary for increasing crop yields and building farmer resilience (Davis et al., 2021). This study employs both descriptive and inferential statistical approaches to assess the extent to which extension services influence the uptake of improved agronomic practices and their subsequent impact on sorghum productivity. The findings provide empirical insights into the effectiveness of current agricultural interventions and highlight areas for policy and programmatic improvement to support smallholder farmers in achieving sustainable production outcomes.

**Table 10. Agricultural Extension Packages**

| Categorical Variables | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Access to Extension Materials | Yes | 144 | 37.5 |
| | No | 240 | 62.5 |
| Knowledge Level of Extension Workers (1=Very Poor to 5=Excellent) | Very Poor | 0 | 0.0 |
| | Poor | 30 | 7.8 |
| | Average | 123 | 32.0 |
| | Good | 169 | 44.0 |
| | Excellent | 62 | 16.2 |
| **Continuous Variables** | **Unit** | **Mean** | **Standard Deviation** |
| Frequency of extension visits (Number of Extension Visits per Year) | Number | 8.3 | 3.6 |
| Number of Agricultural Trainings Received (last year) | Number | 2.1 | 0.8 |
| Percentage of Recommended Practices Adopted (% adopted) | Percent | 5.5 | 3.9 |
| Estimated Sorghum Productivity | Kg/ha | 1,439.7 | 930.5 |

***Source:*** Primary data

The results presented in Table 10 reveal critical insights regarding the accessibility and quality of agricultural extension services among sorghum farmers in Jur River County. A majority (62.5%) of the respondents reported not receiving extension packages, while only 37.5% indicated they had access to such services. This highlights a significant gap in the dissemination of agricultural knowledge and support to rural farming communities, which could have implications for the adoption of improved practices and overall productivity (Feder, Murgai, & Quizon, 2004). Concerning the perceived knowledge levels of agricultural extension workers, the respondents provided varying evaluations. Specifically, 44.0% of the farmers rated extension worker knowledge as "good," 32.0% as "average," 16.2% as "excellent," and only 7.8% considered it "poor." These findings suggest a generally favourable view of extension personnel, although a small proportion of farmers remain dissatisfied with the quality-of-service delivery.

Further descriptive statistics indicate that, on average, a farmer received approximately 8.3 (±3.6) extension visits per year. The number of agricultural trainings attended by farmers within a year was relatively low, with a mean of 2.1 (±0.8). Farmers adopted an average of 5.5 (±3.9) recommended agricultural practices. Correspondingly, the mean estimated sorghum productivity was 1,439.7 kilograms per hectare, with a relatively high standard deviation of ±930.5, suggesting considerable variation in yield outcomes among farmers. These findings underscore the importance of strengthening agricultural extension systems to increase outreach, enhance farmer training, and promote the adoption of evidence-based practices to boost productivity. Access to consistent and high-quality extension services remains a pivotal component of agricultural development and food security, particularly in post-conflict regions such as South Sudan (Davis et al., 2012).

### 4.4.1 Sorghum Productivity and Model Performance

The mean sorghum productivity among the surveyed farmers was 1,439.7 kg per hectare, with a notably high standard deviation of 2,930.5 kg per hectare. This pronounced variability reflects significant disparities in agricultural performance at the farm level. Such differences may stem from a range of underlying factors, including variations in land quality, differential access to improved agricultural inputs, disparities in farmer knowledge and technical capacity, and broader socioeconomic or institutional influences (FAO, 2021; Mwangi & Kariuki, 2015).

**Table 11. Model summary for agricultural extension packages on Sorghum Productivity**

| Model | R | R_ Square | Adjusted R_ Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .395[a] | .156 | .145 | 2718.4311 |

a. *Predictors*: (Constant), use of recommended agricultural practices

The regression model (Table,11) indicated a moderate relationship between the independent variables—frequency of extension visits, training received, access to extension materials, knowledge of extension workers, and adoption of recommended practices—and sorghum productivity. The multiple correlation coefficient (R = 0.395) shows a moderate positive association, while the coefficient of determination ($R^2$ = 0.156) implies that 15.6% of the variance in sorghum productivity is explained by the model. The adjusted $R^2$ (0.145) supports the model's validity after accounting for the number of predictors.

However, the standard error of the estimate (2,718.43 kg/ha) reflects considerable variability in productivity, possibly due to unobserved farm-level and environmental factors. These findings highlight the partial but meaningful role of agricultural extension packages in influencing sorghum yield outcomes.

**Table 12. ANOVA for Agricultural extension packages on Sorghum Productivity**

| Model | | Sum of Squares | df. | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 512032654.280 | 5 | 102406530.856 | 13.858 | .000[b] |
| | Residual | 2771200355.115 | 375 | 7389867.614 | | |
| | Total | 3283233009.395 | 380 | | | |

a. *Dependent Variable*: Estimated Sorghum Productivity (Kg/ha)

b. *Predictors*: (Constant), use of agricultural extension packages.

The ANOVA results (Table 12), confirm the overall statistical significance of the regression model linking extension service variables to sorghum productivity. The model yielded an F-statistic of 13.858 with a p-value less than 0.001, indicating that the independent variables such as access to extension materials, frequency of visits, training received, knowledge of extension workers, and adoption of recommended practices—collectively have a significant effect on productivity. This implies that at least one of these predictors meaningfully contributes to variations in sorghum yield. The findings highlight the importance of integrated extension interventions in improving farm outcomes (Anderson & Feder, 2007; Davis et al., 2021).

**Table 13. Effects of agricultural extension packages on sorghum productivity**

| Model | | Unstandardized Coefficients B | Std. Error | Standardized Coefficients Beta | t. | Sig. |
|---|---|---|---|---|---|---|
| 1 | Frequency of extension visits | -10.338 | 12.989 | -.041 | -.796 | .427 |
| | Training received (hours of training/year) | -3.076 | 4.056 | -.037 | -.758 | .449 |
| | Access to extension materials | -1562.962 | 303.134 | -.257 | -5.156 | **.000** |
| | Extension worker knowledge | 623.377 | 177.860 | .177 | 3.505 | **.001** |
| | Use of recommended practices (% of practices used) | 16.581 | 4.012 | .213 | 4.133 | **.000** |
| | **(Constant)** | **-1101.320** | **645.148** | | **-1.707** | **.089** |

a. *Dependent Variable*: Estimated sorghum productivity (kg/ha)

The regression coefficients presented in Table 13 offer critical insights into the individual effects of key agricultural extension-related variables on estimated sorghum productivity in study area. The analysis assessed the predictive power of access to extension materials, knowledge level of extension workers, and use of recommended practices. Surprisingly, access to extension materials was found to have a statistically significant negative relationship with sorghum productivity ($B = -1,562.96$, $p < .001$). This counterintuitive result suggests that farmers who reported receiving more extension materials tended to achieve lower yields. Several potential explanations could account for this outcome. First, the materials distributed may have been outdated, generic, or poorly contextualized to the local agroecological conditions, rendering them ineffective (Davis et al., 2021). Second, the finding might reflect a targeting bias, wherein extension agents prioritize less productive or vulnerable farmers for support, thus confounding the relationship between material access and yield performance. Third, the low literacy levels or inadequate technical guidance accompanying these materials could have limited their utility among smallholder farmers (Anderson & Feder, 2007).

In contrast, the knowledge level of agricultural extension workers demonstrated a statistically significant positive influence on productivity (B = 623.38, $p = .001$). This result implies that farmers who perceived their extension agents as highly knowledgeable were more likely to report increased sorghum yields. This underscores the importance of strengthening the human capital of extension personnel, as their technical competence, communication skills, and contextual understanding directly affect the uptake and effectiveness of agricultural innovations (Swanson & Rajalahti, 2010; Spielman et al., 2020). The positive association suggests that farmer confidence in extension workers' expertise fosters better implementation of agronomic advice and decision-making.

Furthermore, the use of recommended agricultural practices was positively and significantly associated with sorghum productivity (B = 16.58, $p < .001$). Specifically, a 1% increase in the proportion of recommended practices implemented was associated with an approximate increase of 16.6 kg/ha in yield. This finding aligns with the theoretical and empirical literature emphasizing the role of improved practices in enhancing agricultural productivity (Abdulai & Huffman, 2014; Kassie et al., 2015). Recommended practices often include timely planting, appropriate spacing, integrated pest management, and improved seed and fertilizer use. Their cumulative effect on productivity suggests that agricultural interventions should not only promote awareness but also remove adoption barriers such as access to inputs, credit, and market linkages, to ensure broad-based impact.

The regression results presented in Table 11 provide insight into the individual contributions of key agricultural extension service variables on estimated sorghum productivity. Specifically, the analysis reveals that frequency of extension visits (B = -10.34, $p = .427$) and hours of training received (B = -3.08, $p = .449$) did not exert statistically significant effects on sorghum productivity at the 5% level. These findings suggest that simply increasing the number of extension visits or the duration of training may not automatically result in higher yields.

This lack of statistical significance implies that the quantity of farmer-extension interaction alone, whether measured by number of visits or training hours, is insufficient to drive tangible improvements in productivity outcomes. Rather, the findings underscore the importance of the quality, relevance, and practical applicability of extension content delivered to farmers. This is consistent with the argument by Anderson and Feder (2007), who assert that the effectiveness of extension services depends not only on frequency but also on how well services are tailored to farmers' contextual needs. Similarly, Davis et al. (2021) emphasize that farmer engagement strategies and the competency of extension agents are more crucial than the volume of contact. Further, the overall regression model points to the importance of other extension-related factors in influencing productivity. Notably, the knowledge level of extension workers and farmers' adoption of recommended practices emerged as more reliable predictors of improved sorghum yields. This aligns with findings from Ragasa and Mazunda (2018), who highlight that capacity building among extension workers and the promotion of practice-oriented interventions tend to have more direct impacts on farm-level productivity.

Interestingly, the analysis also revealed an unexpected negative effect of access to extension materials (discussed in the previous section), suggesting potential challenges in the design, delivery, or utilization of such materials in the local context. The ineffectiveness of non-significant variables such as visit frequency and training hours may point to systemic gaps between service provision and its translation into usable farmer knowledge or action on the ground. Such gaps may be attributed to language barriers, generic messaging, or lack of follow-up and contextual adaptation. These findings carry significant implications for agricultural policy formulation and the design of extension programs in fragile and post-conflict settings like South Sudan. Extension systems must move beyond metrics of reach and embrace approaches that emphasize farmer-centered learning, participatory engagement, and continuous feedback loops. Interventions should prioritize strengthening the competencies of extension staff, enhancing the relevance of training materials, and aligning extension delivery with farmers' real-time challenges and production cycles.

### 4.5 Effect of Post-Harvest losses on Sorghum Income generation

The study examined the effect of post-harvest losses on the income generation from sorghum production in the study area. Both descriptive and inferential statistical methods were employed to provide critical insights into how specific post-harvest handling practices affect the income levels among the sorghum farmers.

**Table 14. Post-Harvest Losses and Income Generation**

| Categorical Variable | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Storage Method | Traditional (open-air/thatched granary) | 373 | 97.1 |
| | Improved (silos/plastic) | 11 | 2.9 |
| Harvesting Method | Manual | 383 | 99.7 |
| | Mechanical | 1 | 0.3 |
| Received Training on Post-Harvest Handling? | Yes | 361 | 94.0 |
| | No | 23 | 6.0 |
| Transportation Conditions | Very Poor | 24 | 6.3 |
| | Poor | 42 | 10.9 |
| | Average | 136 | 35.4 |
| | Good | 128 | 33.3 |
| | Excellent | 54 | 14.1 |
| **Continuous Variable** | **Unit** | **Mean** | **Standard Deviation** |
| Storage Duration before Selling | Days | 81.1 | 50.4 |
| Total Storage Capacity | Tons | 28.1 | 11.7 |
| Income from Sorghum Production | USD/season | 900.40 | 523.20 |

### 4.5.1 Descriptive Analysis of Post-Harvest Practices and Related Indicators

As shown on table 14, the majority of respondents (97.1%) reported utilizing traditional storage techniques, such as open-air drying platforms and thatched granaries, for storing sorghum after harvest. In contrast, only a marginal proportion (2.9%) adopted improved storage technologies, including silos and plastic containers. These findings reflect a continued reliance on indigenous storage methods, which may contribute to post-harvest losses due to their limited capacity to prevent pest infestation and spoilage. Similarly, harvesting practices remained predominantly manual, with 99.7% of the farmers employing hand tools for harvesting sorghum. Only 0.3% of the sampled respondents reported using mechanical harvesting technologies. This pattern underscores the limited mechanization within the sorghum value chain in Jur River County, a factor that potentially affects both efficiency and output quality.

Training on post-harvest handling was relatively widespread, with 94% of the farmers indicating that they had received some form of training. This is a positive indicator of awareness creation and capacity building efforts targeting post-harvest management. Nonetheless, a minority (6%) reported not receiving any such training, signalling gaps in extension service outreach that warrant attention. Regarding transportation conditions, only 14.1% of respondents rated their transport infrastructure as excellent. A significant portion of respondents assessed their transportation conditions as average (35.4%) or good (33.3%). These ratings suggest moderate satisfaction with existing transport facilities but also imply constraints that may hinder timely delivery and market access.

The average duration of sorghum storage before sale was 81.1 days (SD = 50.4), highlighting substantial variability in storage periods among respondents. Similarly, the mean storage capacity was reported at 28.1 tons (SD = 11.7), reflecting disparities in access to adequate and secure storage facilities. These findings suggest unequal distribution of storage infrastructure, which could influence both the quantity and quality of sorghum marketed. Finally, the average seasonal income from sorghum production was USD 900.40, with a standard deviation of USD 523.20. This high degree of variability in income levels points to significant inequality among farmers, potentially shaped by differential access to markets, post-harvest facilities, and production inputs.

**Table 15. Model Summary on the Effect of Postharvest losses on Sorghum Income generation**

| Model | R | R_Square | Adjusted R_Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .433[a] | .187 | .174 | 1656.93348 |

a. *Predictors:* (Constant), key variables used to measure postharvest losses.

### 4.5.2 Model Summary Interpretation

The model summary (Table 15), offers valuable insights into the explanatory strength of post-harvest loss-related variables in predicting household income derived from sorghum production. The correlation coefficient (R) of 0.433 indicates a moderate positive linear relationship between the selected independent variables namely; transportation conditions, storage method, storage duration, storage capacity, harvesting method, and access to training, and the dependent variable, which is sorghum income. This suggests that improvements in post-harvest handling practices are moderately associated with increases in income levels among sorghum farmers.

The coefficient of determination ($R^2$) was found to be 0.187, signifying that approximately 18.7% of the variation in sorghum income can be attributed to the collective influence of the predictor variables included in the model. After adjusting for the number of predictors, the adjusted $R^2$ value decreased slightly to 0.174, indicating a stable and consistent explanatory capacity of the model when accounting for potential model overfitting due to the inclusion of multiple independent variables (Field, 2018)., Furthermore, the standard error of the estimate was USD 1,656.93, reflecting a relatively high dispersion of the observed income values around the predicted values. This indicates the presence of substantial unexplained variation, suggesting that other factors not included in the current model, such as market dynamics, climate variability, access to credit, or household-level decision-making, may also significantly influence sorghum income (Gujarati & Porter, 2009).

**Table 16. ANOVA on the postharvest losses on sorghum income generation**

| Model | | Sum of Square | df. | Mean Square | F. | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 238198280.288 | 6 | 39699713.381 | 14.460 | .000[b] |
| | Residual | 1035026568.882 | 377 | 2745428.565 | | |
| | Total | 1273224849.170 | 383 | | | |

a. *Dependent Variable:* Income from Sorghum Production (USD)
b. *Predictors:* (Constant), Variables measuring Postharvest losses

The results of the Analysis of Variance (ANOVA) (Table 16), indicate that the overall regression model is statistically significant, with an F-statistic value of 14.460 and a corresponding p-value less than 0.001. This finding suggests that the collective set of independent variables related to post-harvest practices exerts a statistically meaningful influence on the dependent variable—income derived from sorghum production. The statistical significance of the model supports the reliability of the regression results and provides a sound basis for interpreting the individual regression coefficients. Consequently, it is appropriate to further examine the contribution of each predictor to determine their specific effects on household income from sorghum farming.

**Table 17. Effect of postharvest losses on sorghum income generation**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t. | Sig. |
| 1 | Storage method | 2429.903 | 532.007 | .223 | 4.567 | **.000** |
| | Harvesting method | -3178.177 | 1741.314 | -.089 | -1.825 | .069 |
| | Post-harvest handling training | 604.359 | 357.834 | .079 | 1.689 | .092 |
| | Storage duration | 2.863 | 1.704 | .079 | 1.680 | .094 |
| | Storage capacity | -2.928 | .928 | -.147 | -3.156 | **.002** |
| | Transportation conditions | 559.972 | 81.148 | .324 | 6.901 | **.000** |
| | **(Constant)** | **-1023.733** | **1719.940** | | **-.595** | **.552** |

a. *Dependent Variable:* Income from Sorghum Production (USD)

The regression coefficients (table 17), provide insight into the extent to which various post-harvest factors influence income from sorghum production in Jur River County, South Sudan. The results indicate that *storage method* has a statistically significant and substantial positive impact on income (B = 2,429.90, $p < .001$). This finding suggests that the adoption of improved storage technologies—such as hermetic bags, silos, or airtight containers—may contribute to an increase in household income by approximately USD 2,430 per season. The underlying mechanism is likely the reduction in post-harvest losses, preservation of grain quality, and the ability to market produce at favourable prices (Adegbola & Gardebroek, 2007; FAO, 2017).

Similarly, *transportation conditions* were also found to exert a positive and statistically significant influence on income (B = 559.97, $p < .001$). This implies that improvements in transportation—such as better road access, availability of vehicles, or reduced transit time—can enhance market participation and reduce spoilage, thereby enabling farmers to access more lucrative markets (Kaminski & Christiaensen, 2014). Conversely, the coefficient for *storage capacity* revealed a statistically significant but negative relationship with income (B = -2.93, $p = .002$). This result appears counterintuitive, as greater storage capacity might be expected to support higher grain volumes and flexibility in marketing. A plausible interpretation is that larger storage facilities may be underutilized or are associated with inefficient storage management. In some cases, producers with larger capacities may delay sales in anticipation of higher prices but end up selling under less favourable conditions due to price volatility or pest infestations (Sheahan & Barrett, 2017). This result underscores the need to further explore the interplay between storage infrastructure and farmer marketing behaviour.

The remaining variables—*harvesting method* (B = -3,178.18, $p = .069$), *post-harvest handling training* (B = 604.36, $p = .092$), and *storage duration* (B = 2.86, $p = .094$)—did not attain statistical significance at the conventional 5% level but were marginally significant at the 10% level. The negative coefficient associated with harvesting method may reflect inefficiencies associated with manual harvesting, though interpretation is limited by the fact that nearly all respondents in the sample employed manual techniques. The positive coefficients for training and storage duration suggest a possible trend whereby exposure to post-harvest handling knowledge and strategic timing in grain sales could improve income. However, their effectiveness likely depends on contextual factors such as training quality, pest management, and real-time market access (World Bank, 2021).

In sum, the findings identify *storage method* and *transportation conditions* as the most salient post-harvest determinants of income among sorghum farmers in the study area. These insights suggest that policies and interventions aimed at improving on-farm storage technologies and rural transport infrastructure may yield significant economic benefits. The mixed or insignificant effects of other variables, including storage capacity and harvesting practices, highlight the complexity of post-harvest systems and the importance of aligning interventions with local realities. Furthermore, although training and storage duration show potential, their impact appears contingent upon broader systemic support, including extension services, access to credit, and market information systems.

# CHAPTER FIVE

# CONCLUSSION AND RECOMMENDATION

## 5.0 Introduction

This chapter presents the concluding remarks and key recommendations arising from the findings of the study. It synthesizes the major insights drawn from the analysis, linking them to the research objectives and questions outlined in the initial chapters. The section provides a concise summary of the study's main conclusions, highlighting the implications of the results for policy, practice, and further research. Additionally, it offers actionable recommendations tailored to relevant stakeholders, with the aim of enhancing decision-making and promoting sustainable outcomes. The chapter concludes by suggesting potential areas for future inquiry to address existing knowledge gaps and to build upon the current study's contributions.

## 5.1 Conclusion

This study set out to investigate the key factors influencing sorghum productivity and household income among smallholder farmers in Jur River County, South Sudan. Using a combination of descriptive statistics, multiple linear regression models, and ANOVA techniques, the study generated empirical insights into how climatic variables, input use, extension services, and post-harvest practices collectively and individually affect production outcomes. The results affirm the centrality of sorghum cultivation to rural livelihoods, with 100% of surveyed households reporting sorghum production and 87.5% cultivating the crop every season. These figures highlight the importance of sorghum not just as a food staple but also as a principal source of household income in the region. The majority of farming households are male-headed (76.6%), and the average household head is 44.1 years old with only 3.3 years of formal education. These socio-demographic characteristics have clear implications for agricultural policy, particularly the need for gender-sensitive programming and tailored capacity-building approaches that cater to adult learners with limited literacy.

Climatic conditions were found to significantly affect sorghum yield, particularly average temperature, which had a statistically significant and positive effect ($B = 852.527$, $p < .001$). Although heat stress is generally perceived as detrimental to crop growth, this study found that Jur River County's distinct diurnal temperature variation created conducive thermal conditions for photosynthesis, grain filling, and overall plant physiological performance. This aligns with sorghum's known resilience to semi-arid climates and its optimal growth range of 20°C to 30°C. Conversely, soil moisture deficiency, as reported by 17.4% of respondents, showed a negative but statistically insignificant relationship with yield ($B = -314.342$, $p = .209$). The lack of statistical significance may be attributed to the use of subjective farmer assessments instead of objective soil moisture measurements. Nonetheless, the findings suggest that temperature is a more influential predictor of yield variability in this particular agroecological context.

The analysis of input use revealed complex and sometimes counterintuitive relationships. For instance, fertilizer application rate demonstrated a negative and non-significant effect on sorghum yield ($B = -1.36$, $p = .332$), possibly due to improper application techniques, unbalanced nutrient compositions, or poor soil health. Similarly, the type of fertilizer used—whether organic, inorganic, or combined—did not have a statistically significant impact on yield ($B = 80.45$, $p = .774$), indicating that classification alone does not capture the dynamics of nutrient uptake and soil-plant interactions. The use of pesticides, on the other hand, had a statistically significant negative effect on yield ($B = -484.32$, $p = .001$), raising concerns about misapplication, pest resistance, and the phytotoxic effects of certain chemical formulations. These findings corroborate prior research (e.g., Aktar et al., 2009; Carvalho, 2017) and emphasize the need for better training in integrated pest management. Notably, farmers' access to inputs and perception of their quality and effectiveness emerged as a strong and statistically significant predictor of productivity ($B = 630.42$, $p < .001$), suggesting that knowledge, trust, and experience significantly influence how inputs translate into actual output.

In the domain of agricultural extension packages, the study presented both expected and surprising findings. The access to extension materials showed a statistically significant negative correlation with sorghum yield ($B = -1{,}562.96$, $p < .001$), which may point to the distribution of generic or poorly contextualized content, low literacy levels among farmers, or a mismatch between the materials and actual field challenges. This paradox suggests that the presence of information is not synonymous with its usefulness or effectiveness. In contrast, the knowledge level of extension workers had a positive and statistically significant effect on yield

(B = 623.38, p = .001), reaffirming that well-trained, knowledgeable agents play a vital role in translating scientific knowledge into farmer practice. Similarly, the use of recommended practices such as proper plant spacing, integrated pest management, and timely harvesting had a significant positive effect on productivity (B = 16.58, p < .001). Interestingly, the frequency of extension visits (B = -10.34, p = .427) and hours of training received (B = -3.08, p = .449) were statistically insignificant, suggesting that the quality and contextual relevance of extension services matter more than their quantity. These findings call for a shift in extension policy—from focusing on coverage metrics to ensuring content quality, participatory learning, and farmer feedback integration.

Post-harvest handling was another critical area investigated, particularly in its contribution to household income. The storage method used by farmers had a highly significant and positive impact on income (B = 2,429.90, p < .001), with improved methods such as hermetic bags, metallic silos, and airtight containers proving effective in reducing losses and preserving grain quality for longer-term storage and better market timing. Additionally, transportation conditions had a statistically significant and positive association with income (B = 559.97, p < .001), highlighting the role of infrastructure in market access and minimizing spoilage. On the contrary, storage capacity showed a statistically significant but negative effect on income (B = -2.93, p = .002), possibly reflecting inefficiencies such as underutilized space or the financial burden of maintaining large facilities. Other factors like harvesting method (B = -3,178.18, p = .069), post-harvest training (B = 604.36, p = .092), and storage duration (B = 2.86, p = .094) were marginally significant, indicating potential for influence under the right enabling conditions, such as targeted training, access to equipment, and reliable market information.

In summary, this research employed a rigorous statistical framework to evaluate the interlinked determinants of sorghum productivity and income, revealing that environmental, institutional, and behavioural factors all play substantial roles. The application of multiple linear regression analysis and ANOVA tests enabled the identification of both significant and marginal predictors, providing a robust empirical foundation for evidence-based policy formulation. The study concludes that while environmental factors such as temperature are favourable for sorghum production in Jur River County, significant inefficiencies in input application, extension delivery, and post-harvest management persist. These inefficiencies limit productivity gains and income potential, particularly in a fragile setting where smallholder farmers face compounding challenges related to infrastructure, education, and climate resilience.

### 5.2 Recommendation

The findings of this study underscore the urgent need for a multifaceted approach to improving sorghum productivity and household incomes in Jur River County, South Sudan. Given the centrality of sorghum to livelihoods and food security, agricultural development programs must prioritize gender-responsive strategies that address existing disparities in resource access. Empowering women farmers through inclusive extension services, targeted input support, and access to credit will help to optimize production outcomes and promote equitable growth within farming communities. Additionally, considering the relatively low formal education levels among household heads, extension services should be redesigned to emphasize participatory, visual, and oral communication methods, thus ensuring that technical knowledge is accessible and actionable for all farmers regardless of literacy levels.

To ensure effective implementation of these recommendations, clear mechanisms are necessary. Increasing productivity under variable climate conditions requires that the Ministry of Agriculture, in collaboration with development partners, strengthen extension delivery through targeted training and demonstration plots. Access to improved inputs can be enhanced through government–cooperative partnerships that provide seeds, fertilizers, and pesticides at subsidized prices, financed by agricultural development funds and donor support. Post-harvest losses should be reduced through investment in community-based modern storage facilities, managed by farmer associations with initial support from government and NGOs. Gender disparities must be addressed by designing resource-access programs that prioritize women farmers, including microcredit schemes and tailored extension packages. These interventions require coordinated funding from national agricultural budgets, international donors, and local cooperatives to ensure sustainability and scalability.

The climatic analysis highlights the importance of recognizing localized agroecological conditions in agricultural planning. While average temperature positively influences sorghum yield, variability in moisture availability and other weather parameters demands the adoption of climate-smart agricultural practices. Policymakers and development partners should promote drought-tolerant crop varieties, water conservation techniques, and community-based climate advisory services to enhance adaptive capacity and resilience against environmental shocks. This approach will be vital for sustaining productivity gains in the face of ongoing climate change challenges.

Input use efficiency emerged as a critical constraint to productivity, with fertilizer and pesticide application practices often failing to yield expected benefits. Therefore, efforts must be intensified to improve farmers' knowledge and skills regarding integrated soil fertility and pest management. Strengthening regulatory frameworks to ensure the quality of agricultural inputs, alongside training programs that emphasize appropriate usage, will be essential in mitigating the negative impacts observed and maximizing input effectiveness. Furthermore, fostering stronger linkages between farmers and certified input suppliers can improve access to high-quality products and reduce reliance on counterfeit or substandard inputs. Additionally, the study's results regarding agricultural extension highlight a paradox: mere access to extension materials does not guarantee improved productivity unless accompanied by skilled, context-aware extension personnel and the promotion of recommended agronomic practices. Extension services should shift from traditional top-down models toward participatory, farmer-centered approaches that adapt to the specific needs and capacities of local communities. Capacity-building for extension workers, co-creation of training content, and continuous feedback mechanisms will enhance the relevance and impact of agricultural advisory services in fragile contexts like South Sudan.

Post-harvest management represents another pivotal area for intervention. Improved storage technologies and better transportation infrastructure were shown to have significant positive effects on household income, indicating that investments in these domains can reduce losses and open new market opportunities. However, the counterintuitive negative association between storage capacity and income suggests that infrastructure expansion alone is insufficient without complementary training in storage management and market timing. Hence, integrated post-harvest strategies combining technological, managerial, and market-based solutions should be prioritized to strengthen the agricultural value chain.

In summary, addressing the intertwined challenges facing smallholder sorghum farmers requires comprehensive, coordinated efforts that integrate socio-economic, environmental, and institutional dimensions. Policymakers and development actors are urged to design interventions that not only increase access to inputs and services but also emphasize effective use, knowledge transfer, and infrastructure development. Such holistic strategies are indispensable for building resilient agricultural systems capable of sustaining livelihoods and enhancing food security in South Sudan.

### 5.3 Key Further Studies

While this study provides valuable insights into sorghum production dynamics in Jur River County, several areas warrant further investigation. Longitudinal research is needed to assess the temporal effects of climatic variability and intervention programs on productivity and income. Additionally, more granular studies focusing on gender-specific constraints and benefits could inform more nuanced and effective gender-sensitive policies. Investigations into the spatial heterogeneity of agroecological factors and market access within and beyond Jur River County would also contribute to tailored agricultural development strategies. Finally, experimental research testing the efficacy of different extension methodologies and post-harvest technologies under local conditions could provide practical guidance for scaling up successful innovations. These future studies will enhance the evidence base necessary for optimizing sorghum-based farming systems in South Sudan and similar contexts.

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## APPENDICES

### APPENDIX 1: Farm/household questionnaire

The purpose of this study is solely academic and particularly to contribute to the understanding of Sorghum Production among farmers in Jur River County in Western Bahr El Ghazal. We kindly request your **voluntary** participation in answering the questions, any information provided will be strictly **confidential.** Tick where appropriate.

**Section A: General Information**

**A1**. Date of interview ______________________________________________

**A2**. Name of enumerator________________________________________

**A3**. Payam __________________________________________________

**A4**. Boma _____________________________________________________

**Section B: Socio-Economic and Institutional Characteristics**

**B1.0** Do you grow Sorghum?

1. Yes [ ]  0 .No [ ]

**B1.2** Do grow Sorghum every season?

1. Yes  0. No

| **B1.3** Gender of Household head | | **B1.4** Age of Household head | **B1.5** Education of Household Head |
|---|---|---|---|
| 1. Male | 0. Female | In years | Number of schooling years |
| | | | |

**B1.6** Household size 0. Female [ ] 1. Male [ ] 2. Total [ ]

**B1.7** Occupation

0. Farming [ ] 1. Business person [ ] 2. Casual Laborer [ ] 3. Salaried Employee [ ] 4. Other, specify……………………..

**B1.8** How long have you been growing Sorghum (years)?.........................

**B1.9** What is the total farm size in acres?..................

**B2.0** What is the size of the land under Sorghum production (feddans)…………………………..?

**B2.1** How far is the nearest farm input market from the homestead (in Km and walking minutes)?.......................Km,……………….walking minutes

**B2.2** Do you belong to a farmer group/ organization in your community? (If **No, skip to B2.8**)

1. Yes [ ]   0. No [ ]

**B2.3** If **Yes**, what is the purpose of the group (s)?

0. Production and marketing [ ] 1.Savings and credit [ ]   2. Religious group [ ] 3. Welfare [ ]   4. If others, Specify………………….

**B2.4** How many Groups do you belong to?………...

**B2.5** If **Not** a group member give reason (s)

....…….……………………………………………………………………………………

**B2.6** Would you like to be a member?

1. Yes [ ] 0. No [ ]

**B2.7** If **No in B2.2**, What hinders you from being a member?

0. High membership fee [ ]   1. Lack of trust with members [ ]   2. Don't meet the quality requirements   [ ] 3. Don't meet the minimum farm size requirements [ ] 4. Lack of time to attend group meeting [ ]   5. If other, specify…………….

**B2.8** Where do you get **information on** fertilizer and pesticide use from? **(Select at most 3 suitable sources)**

0. Other farmers [ ] 1. Agricultural Extension Officer [ ]   2. Pesticide Retailer   [ ] 3. Agrochemical company [ ]   4.Other specify ………………

**B2.9** What is **the highest education level** of the person from whom you get information on pesticide use and pest management (number of schooling years)?......................

**B3.0** How often do you meet with the person from whom you obtain information on fertilizer and pesticide?

0. Daily [ ] 1. At least once per Week [ ] 2. At least once per Month [ ] 3. Annually [ ] 4. Other specify ……..

**B3.1** What kind of relationship do you share with the person from whom you get information on pesticide use?

1. Friend [ ] 2. Neighbors [ ] 3. Relative [ ] 4. Farmer [ ] 5. Other, specify………………

**B3.2** Have you ever received extension services on Sorghum production in the last one year? **(If NO, Skip to B3.5)**

1. Yes [ ] 0. No [ ]

**B3.3** If **Yes**, How many times are you visited by extension officer per month? …………….

**B3.4** Who offered the extension services or technical advice on Sorghum production?

0. Government extension officers [ ] 1. NGO officers [ ] 2. Fellow farmers [ ] 3. Other source (s), specify…………………………….

**B3.5** Have you ever received Credit in the last one year? **(If NO, Skip to B3.8** )

1. Yes [ ] 0. No [ ]

**B3.6** Why did you borrow credit?

0. Purchase farm inputs [ ] 1. Pay school fees [ ]. 2. Purchase property [ ] 3. Pay medical bill [ ] 4. Cover Household expenses 5. If others, specify………………….

**B3.7** What was the source of credit?

0. Commercial Banks [ ] 1. Farmer Group [ ] 2. SACCO [ ] 3. Informal lenders [ ]

4. Microfinance institutions [ ]

**B3.8** If **No** in **B3.5**, give your reasons **(Tick one that is MOST appropriate**)

0. Lack of Collateral [ ] 1. High-interest rate [ ] 2. Defaulted on the previous loan [ ]

3. Not aware of Credit facilities [ ] 4. If other, specify…………………….

**B3.8** Have you ever attended any seminar or training on Sorghum production in the last one year? **(If NO, Skip to B4.4)**

1. Yes [ ] 0. No [ ]

**B3.9** Who offered the training/seminar on sorghum production?

0. Fellow farmers [ ] 1. Government extension officers [ ] 2. NGO officers 3. Others, specify……………….

**B4.0** Did you pay for the training?

1. Yes [ ] 0. No [ ]

**B4.1** If **Yes** in **B4.0**, How much did you pay for the training?.....................

**B4.2** How many times per month did you receive the training on tomato?................................

**B4.3** Which topics were discussed during the seminar or training?

0. Pest management in Sorghum production [ ] 1. Sorghum Value addition methods [ ]

2. Marketing of Sorghum [ ] 3. Production of Sorghum [ ] 4. If other, Specify ………..

**B4.4** Where do you sell Sorghum?

0. Local retailers [ ] 1. Wholesale traders [ ] 3. Cooperative 4. Supermarkets [ ] 5. Processing Companies [ ] 5. Middlemen [ ] 6. Other, specify…………

**B4.5** Why did you choose that buyer?

0. Offer better price [ ] 1. Proximate trader [ ] 2. Consistent and pays in cash [ ] 3. Under contract [ ] 4. Others (specify)…………………………..

**<u>Section C: Climate Variability and Sorghum Yield</u>**

**C.1** What is the average annual rainfall in your area?

a) <500mm

b) 500-1000mm

c) >1000mm

**C.2** How would you describe rainfall distribution over the years?

a) Even

b) Irregular

c) Unpredictable

**C.3** How many drought periods (dry spells) have you experienced in the last five years? ________

**C.4** What is the average temperature during the sorghum growing season?

a) <20°C

b) 20-30°C

c) >30°C

**C.5** Do you experience soil moisture deficiency during the sorghum growing season?

a) Yes

b) No

**C.6** How do you assess the impact of climate variability on your sorghum yield? (Briefly explain) ________________________________________

**C.7** What is your estimated sorghum yield (kg/ha)? ________

## Section D: Access to Improved Agricultural Inputs

**D.1** Do you have access to drought-resistant sorghum seed varieties?

a) Yes

b) No

**D.2** If yes, which varieties do you use? ________________________________________

**D.3** What is your fertilizer application rate (kg/ha)? ________

**D.4** What type of fertilizers do you use? (Select all that apply)

a) Organic

b) Inorganic

c) Both

**D.5** How frequently do you use pesticides for sorghum farming?

a) Never

b) Occasionally

c) Regularly

**D.6** What is the cost of agricultural inputs per hectare (USD)? ________

**D.7** How do you rate your knowledge of agricultural inputs and their usage?

(1) Very Poor

(2) Poor

(3) Average

(4) Good

(5) Excellent

**D.8** What is your estimated sorghum productivity (kg/ha)? ________

## Section E: Agricultural Extension Services

**E.1** How many times do you receive visits from agricultural extension workers per year? ________

**E.2** How many hours of agricultural training have you received in the last year? ________

**E.3** Do you have access to extension materials such as pamphlets, brochures, or digital resources?

a) Yes

b) No

**E.4** How would you rate the knowledge level of extension workers in assisting farmers?

(1) Very Poor

(2) Poor

(3) Average

(4) Good

(5) Excellent

**E.5** What percentage of recommended sorghum farming practices have you adopted? ________%

**E.6** What farming techniques or practices have you adopted based on extension services? (Briefly explain) ________________________________________

**E.7** What is your estimated sorghum productivity (kg/ha)? ________

**<u>Section F: Post-Harvest Losses and Income Generation</u>**

**F.1** What type of storage method do you use for sorghum?

a) Traditional (e.g., open-air, thatched granary)

b) Improved (e.g., metallic silos, sealed plastic bags)

**F.2** What harvesting method do you use?

a) Manual

b) Mechanical

**F.3** Have you received any training on post-harvest handling techniques?

a) Yes

b) No

**F.4** How long do you store your sorghum before selling (days)? ________

**F.5** What is your total storage capacity (tons)? ________

**F.6** How do you transport your sorghum to the market? (Select all that apply)

a) Head/Hand Carry

b) Bicycle/Motorcycle

c) Truck

d) Animal Cart

**F.7** How would you rate the transportation conditions for your sorghum?

(1) Very Poor

(2) Poor

(3) Average

(4) Good

(5) Excellent

**F.8** Have you experienced post-harvest losses in sorghum production?

a) Yes

b) No

**F.9** If yes, what percentage of your total sorghum yield is lost due to post-harvest factors? ________%

**F.10** What are the main causes of post-harvest losses in your farm? (Select all that apply)

a) Pest infestation

b) Poor storage conditions

c) Transportation losses

d) Market delays

e) Other (Specify) ________________________

**F.10** What is your total income from sorghum production per season (USD)? ________

**F.11** What strategies do you use to minimize post-harvest losses? (Briefly explain) ______________________________________

**Conclusion**

Thank you for your time and cooperation in completing this questionnaire. The information you have provided will be crucial in understanding how climate variability, agricultural inputs, extension services, and post-harvest losses impact sorghum production and farmers' livelihoods in this area. Your participation is highly appreciated.

## Appendix 2: Workplan

| Activity | Dec 2024 | Jan 2025 | Feb 2025 | March 2025 | April 2025 | May 2025 | June 2025 | July 2025 | Aug 2025 |
|---|---|---|---|---|---|---|---|---|---|
| Literature review | | | | | | | | | |
| Proposal writing | | | | | | | | | |
| Proposal defense at the faculty | | | | | | | | | |
| Data collection and Analysis | | | | | | | | | |
| Dissertation writing | | | | | | | | | |
| Dissertation submission to Graduate school | | | | | | | | | |

## Appendix 3: Budget

| Activity | Description | Units | Cost/Unit | Total (USD) |
|---|---|---|---|---|
| Proposal Development | Internet services | 4 months | 11.59 | 46.37 |
| | Printing | 50 pages *10 copies | 0.077 | 38.64 |
| | Binding | 5 copies | 0.46 | 2.32 |
| **Sub-total** | | | | **87.33** |
| Data collection and analysis | Printing questionnaire | 390copies, 17 pages | 0.077 | 512.36 |
| | Training enumerators | 5 | 9.27 | 46.37 |
| | Own Transport | | 23.18 | 23.18 |
| | Transport of enumerators | 5 | 23.18 | 115.92 |
| | Training data cleaners | 2 | 8.50 | 17.00 |
| | Stationery | | 30.91 | 30.91 |
| | Enumerator pay | 10 days* 5 | 10.82 | 540.96 |
| | Communication | | 11.59 | 11.59 |
| **Sub-total** | | | | **1,298.29** |
| Dissertation writing | Internet services | 5 weeks | 11.59 | 57.96 |
| | Printing | 100 pages, 8 copies | 0.077 | 61.82 |
| | Binding | 10 copies | 0.77 | 7.73 |
| **Sub-total** | | | | **127.51** |
| Contingencies (20%) | | | | **302.63** |
| Grand-total | | | | $1,815.67 |

**Source of funds: Own funding**

## Appendix 4: Letter of authorization/approval

**Republic of South Sudan**
**Western Bahr El Ghazal State - Wau**
**Secretariat General**
Secretary General – Office

جمهورية جنوب السودان
ولاية غرب بحر الغزال - واو
الأمانة العامة للحكومة
مكتب الأمين العام

No: CM/WBGS/HQRs/SGO/SCR/50.A.1
Date: 29th April,2025

**Subject: - <u>To Whom It May Concern</u>**

This is to certify that; Mr. Wol Wilfred Deng, Student in Uganda Christian University has granted approval with no objection to proceed with his data collection exercise on the topic "Factors influencing sorghum production and food security" in Jur River County to successfully defended his Master of science research.

**This certificate is a testimony to that effect.**

Republic of South Sudan ... Wau
29 APR 2025
29/4/25

**Hillary Claudio Musa**
**Secretary General,**
**Council of Ministers**
**WBGS/Wau**

**Copy to:**

- H.E. Governor-WBGS/Wau
- Executive Director/ Jur River County
- Police Commissioner/ Jur River County
- NSS
- File

Tel: +211928445582 - +211916420819