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Are Large-Scale Farmers Better Than Small-Scale Farmers? Evidence from Maize Farmers
using Uganda National Panel Survey (UNPS), 2010-2018

By
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DECLARATION

I, Mugabi Ephraims Kook, do hereby declare that the work presented in this dissertation is my original work and except where acknowledged, no part of it or its whole has been submitted to any other University/Institution for an award.

Signature 

Date 30/09/2026

Mugabi Ephraims Kook

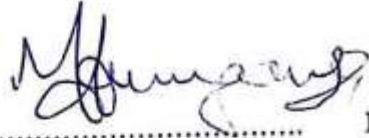
APPROVAL

This dissertation has been done under my supervision and has been submitted with my approval

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DEDICATION

I dedicate this work to my beloved mother Moly Medias Kemitooma Koruragire (Mrs), thank you so much for all the sacrifices, unending prayers, all the support and care and most importantly believing in me always. This is purely for you. God will always bless you.

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LIST OF ABBREVIATIONS AND ACRONYMS

CSA	Climate Smart Agriculture
CWUE	Crop Water Use Efficiency
EAs	Enumeration Areas
EMS	Extension Management Systems
FLPs	Farmer Learning Platforms
FOT	Fertilizer Optimization Tool
ICT	Information and Communication Technologies
IPM	Integrated Pest Management
IWUE	Improve Irrigation Water Use Efficiency
NAADS	National Agricultural Advisory Services
NEC	National Enterprise Cooperation
NGO	Non-government Organizations
NOAA	National Oceanic and Atmospheric Administration
NPA	National Planning Authority
OWC	Operation Wealth Creation
PCP	Physiochemical Properties
SO	Service Outsourcing
SP	Self-Purchase
SSA	Sub-Saharan Africa
TFP	Total Factor Productivity
UHFPS	Uganda High Frequency Phone Survey
UNPS	Uganda National Panel Survey
UPDF	Uganda People's Defence Forces
UPS	Uganda Prisons Services,
WB	World Bank

ABSTRACT

This study investigates the comparative effectiveness of small-scale and large-scale maize farmers in addressing maize production in Uganda, utilizing data from five waves of the Uganda National Panel Survey (UNPS) spanning 2010 to 2018. The primary aim was to assess the factors influencing maize production among small-scale and large-scale farmers, with specific objectives examining the effects of farm inputs, demographic, biophysical and regional factors on maize harvest quantities.

Employing fixed effects regression models, the analysis was conducted separately for small-scale farmers (n=5,485), large-scale farmers (n=206), and a pooled sample (n=5,691). Results reveal significant disparities in production patterns and input effectiveness between the two groups. Small-scale farmers dominate Uganda's maize production sector (over 96% of producers) but achieve lower average annual harvests (268.1 kg) compared to large-scale farmers (520.3 kg). However, when small-scale farmers access fertilizers and pesticides, their production increases substantially by 52.8 kg and 71.5 kg respectively. Among small-scale farmers, regional location significantly influences production, with Northern and Western regions outperforming Central Uganda by 55.1 kg and 63.7 kg annually. Customary land tenure reduces production by approximately 25 kg compared to freehold tenure. Counterintuitively, farmers using traditional seeds produce significantly more maize than those using improved seeds across both categories, small-scale farmers using traditional seeds harvest 67.9 kg more, while large-scale farmers harvest 322.2 kg more annually. For large-scale farmers, sandy loam soils increase production by 373.4 kg compared to sandy clay loam soils.

The study concludes that small-scale farmers are not inherently less productive but are constrained by limited access to inputs, insecure land tenure, and inadequate institutional support. Recommendations include revising agricultural support programs to include small-scales, strengthening land tenure security, improving fertilizer subsidy distribution, expanding integrated pest management training, and developing regionally targeted interventions. These findings contribute to evidence-based agricultural policymaking aligned with Sustainable Development Goal 2 (Zero Hunger) and highlight the need for context-specific strategies that recognize the complementary roles of both small-scale and large-scale farmers in achieving maize production in Uganda.

CHAPTER 1 : INTRODUCTION TO THE STUDY

1.1 Background of the study

Countries worldwide have committed to ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture by 2030 under Sustainable Development Goal 2 (SDG 2) (United Nations, 2015). However, progress towards achieving zero hunger remains slow. According to the Food and Agriculture Organization et al. (2019), nearly 2 billion people are moderately food insecure, with 135 million severely food insecure. The Global South, particularly Sub-Saharan Africa (SSA), remains the most affected region, with increasing numbers of food-insecure people since 2015 (Food and Agriculture Organization et al., 2017). Islam et al. (2021) predict that SSA will experience the slowest progress towards improvements in food security.

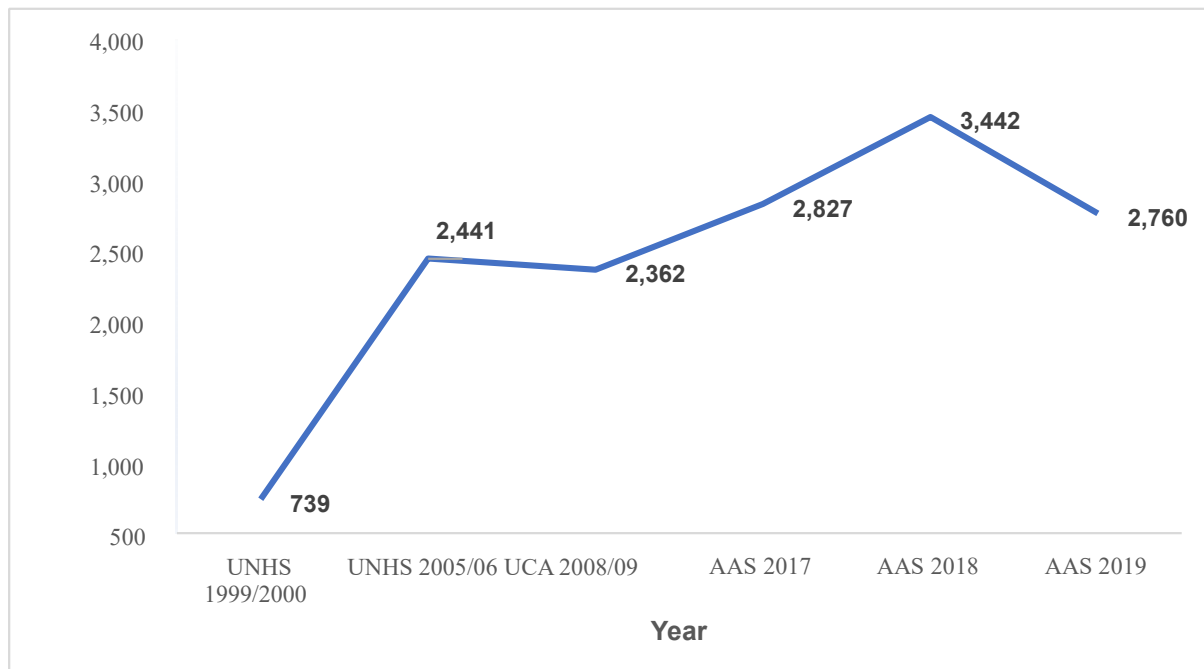
Although Africa's land resources have the potential to produce 100 million tons of grain annually, the continent struggles to achieve this potential. About 364 million people on the continent are either moderately or severely food insecure (Wudil et al., 2022). More than 50 million people in Africa require emergency aid every year, with over 60% of the World Food Program's aid directed to Africa (Aboaba et al., 2020). According to the World Bank's 2021 report, 7.2 million people in East Africa are at risk of hunger, with 26.5 million facing severe food insecurity (World Bank, 2022).

Uganda, like other Sub-Saharan African countries, is not spared from this wave of food insecurity. In 2019, nearly 70% of Uganda's population were classified as either moderately or severely food insecure (Food and Agriculture Organization, 2019). The ninth round of the Uganda High Frequency Phone Survey (UHFPS) indicated that 48% and 11% of the country's population are moderately and severely food insecure, respectively (Atamanov et al., 2022). The burden on Uganda's food system is evident due to increasing population, heavy reliance on natural weather conditions, and the slow pace of mechanization in the agricultural sector (Food and Agriculture Organization, 2024). Additionally, the sector is dominated by small-scale farmers who primarily engage in subsistence farming and are largely not market-oriented.

Maize, a crucial agricultural product, significantly contributes to alleviating poverty and improving food security in many African countries (Chune, 2022). In Uganda, maize is a staple food for many households (Epule et al., 2021) and is produced by over three million farmers cultivating less than 0.5 hectares of land (Daly et al., 2016). According to the Uganda Bureau of Statistics (UBOS, 2020), maize is cultivated by 69% of agricultural households during the

first season and 48% during the second season, covering a combined area of approximately 1.9 million hectares. By 2019, total maize production reached 2.8 million tons, with an average annual yield of 1.6 tons per hectare. However, this yield remains well below the potential of 5 tons per hectare reported in the Agricultural Sector Strategic Plan (MAAIF, 2020).

Figure 1-1: Maize production trend ('000 MT), 1999/2000-2019



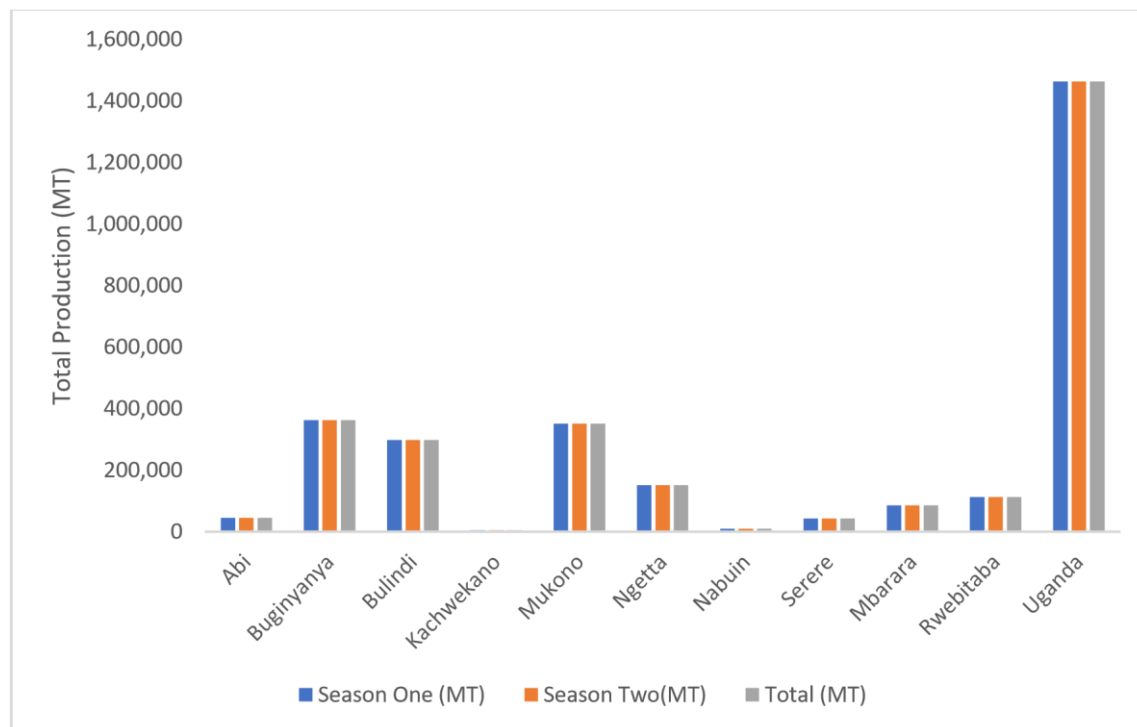
Source: Annual Agricultural Survey (AAS) 2019 Report

The crop not only serves as a staple food but also significantly boosts financial cash flow for farmers. Most farmers sell their surplus maize to millers, generating income to meet other financial needs. Additionally, maize can be processed into various products, such as corn flour, corn oil, and animal feed (Danso-Abbeam et al., 2018). The benefits of maize production in Uganda extend beyond the country, impacting the East African Community through exports to various neighboring countries (Chune, 2022).

1.2 Methods of Measuring Maize Production in Empirical Studies

Maize production has been measured using various approaches in empirical agricultural research, depending on the study's objectives, data availability, and analytical framework. The choice of measurement method has important implications for comparability across studies and the interpretation of findings (Doss, 2006). Understanding these measurement approaches is essential for contextualizing the present study and situating its contribution within the existing body of literature.

Figure 1-2: Production of maize by ZARDI 2019



Source: Computations from Annual Agricultural Survey (AAS) 2019 Report

The most common approach to measuring maize production is output-based, where production is quantified as the total physical quantity harvested. Studies typically measure maize output in kilograms, metric tons, pounds, or bags. The choice of unit depends on the study context and the nature of the data available. In Uganda, the Uganda National Panel Survey (UNPS) measures maize production in kilograms, using farmers' self-reported harvest quantities for each plot and season (UBOS, 2020). Similarly, Mbatuusa (2026) measured maize productivity in kilograms to examine the relationship between fertilizer use and maize yields, finding that inorganic fertilizer users achieved 29.7% higher yields than non-users. Osewe et al. (2023) employed output-based measures in their panel data assessment of sustainable intensification practices among small-scale maize farmers in Uganda.

Output-based measures offer the advantage of direct comparability and are intuitive for both researchers and policymakers. However, they are sensitive to measurement error, as farmers may inaccurately recall or estimate harvest quantities (Doss, 2006). Additionally, output measures alone do not account for variations in input intensity, land quality, or production efficiency, making them less suitable for assessments of productivity per unit area.

Yield-based measures express maize production per unit of land area, typically as kilograms per hectare (kg/ha) or metric tons per hectare (MT/ha). This approach is widely used to assess agricultural productivity and compare performance across farmers, regions, and countries. In Uganda, the Uganda Bureau of Statistics (UBOS, 2020) reports maize yields in metric tons per

hectare, with the national average yield estimated at 1.6 tons per hectare. Nekesa (2024) used yield per hectare to examine the effects of land management practices on maize production in eastern Uganda, finding that the Kyoga plain agro-ecological zone benefited more from inorganic fertilizer and pesticide use compared to the highland zone.

Yield-based measures are preferred for assessing productivity and efficiency because they account for land area variations and facilitate comparisons across studies and contexts. However, yield measures do not capture total production and may be misleading if farmers cultivate different land sizes or if land quality varies significantly across plots (Debertin, 2012).

Total Factor Productivity (TFP) measures the efficiency with which all inputs (land, labor, capital, materials) are transformed into output. This approach goes beyond simple output or yield measures by accounting for multiple inputs simultaneously. In maize production studies, TFP is typically estimated using production functions or frontier models. Studies in Uganda have applied stochastic frontier analysis and data envelopment analysis to examine technical efficiency in maize production (Osewe et al., 2023; Zizinga et al., 2022). However, TFP measurement is data-intensive and requires detailed information on all inputs, which is often unavailable in household surveys.

This study adopts output-based measures, measuring maize production as the total quantity harvested in kilograms per farmer per year, consistent with the Uganda National Panel Survey (UNPS) data. This approach was chosen for several reasons. First, the UNPS provides total harvest quantities in kilograms for each plot and season, making this the most direct and reliable measure available. Second, the measure aligns with the primary research question comparing total production between small-scale and large-scale farmers. Third, it allows for straightforward interpretation of policy implications. Fourth, previous studies using the same data have adopted comparable approaches (Mbatuusa, 2026; Osewe et al., 2023).

To address potential measurement error associated with self-reported data, the study follows standard practice by using multiple survey waves to average out measurement error, applying appropriate statistical techniques (fixed effects regression), winsorizing extreme values to reduce the influence of outliers, and documenting data quality and missing data procedures (Doss, 2006; UBOS, 2020).

The agricultural sector in Uganda is characterized by a dualistic farming structure. Small-scale farmers are individuals or families who operate small plots of land, typically less than two hectares (approximately 5 acres), primarily engaging in subsistence production for household

consumption. They rely heavily on family labor, traditional farming methods, and have limited access to modern inputs such as improved seeds, fertilizers, pesticides, and mechanization. They constitute the overwhelming majority of agricultural households in Uganda (Balya, 2014; Rigg et al., 2016; von Braun & Mirzabaev, 2015).

In contrast, large-scale farmers operate on two or more hectares of land (approximately 5 acres or more), typically engage in commercial production, and have greater access to mechanization, improved seeds, fertilizers, and other productivity-enhancing inputs (Zhu et al., 2018). While large-scale farmers are fewer in number, they often benefit from economies of scale, better market access, and stronger institutional support. According to Balya (2014), approximately 85% of those involved in agriculture are small-scale farmers (less than 5 acres), 12% are medium-scale farmers (5–15 acres), and 3% are large-scale farmers (more than 15 acres).

Despite the recognized importance of maize production in Uganda, there remains limited empirical evidence comparing the productivity and performance of small-scale versus large-scale maize farmers. While extensive research has examined factors influencing maize production (Mbatuusa, 2026; Nekesa, 2024; Osewe et al., 2023), few studies have disaggregated the analysis by farm scale to determine whether the determinants of productivity differ between these two groups. Furthermore, much of the existing evidence focuses on specific inputs, particular geographical areas, or smallholder farmers only, with relatively limited comparative analysis on a national scale.

Given that small-scale farmers constitute approximately 85% of agricultural households in Uganda yet face significant constraints in accessing inputs and support services, understanding whether and how productivity differs between small-scale and large-scale farmers is critical for designing effective agricultural policies. The absence of such comparative evidence presents an important knowledge gap because policies designed to increase maize production may produce different outcomes across farmer categories. Without a clear understanding of these differences, agricultural interventions may not adequately address the constraints limiting the production potential of the majority of farmers.

This study addresses this gap by investigating whether large-scale farmers achieve higher maize production than small-scale farmers and identifying the factors that contribute to productivity differences between the two groups. Using longitudinal data from the Uganda National Panel Survey (UNPS) spanning 2010 to 2018, the study provides empirical evidence on the relative

contribution of key farm inputs, demographic characteristics, and biophysical and regional factors to maize production across the two farmer categories. The findings contribute to the evidence base for agricultural policy and input-support interventions, highlighting the importance of considering differences in farmers' production scale and resource constraints when designing interventions intended to increase maize productivity and promote more inclusive agricultural development in Uganda.

1.3 Problem Statement

Given its contribution to food production, household livelihoods, and the agricultural economy, maize production remains an important priority in Uganda's agricultural development agenda. According to the Uganda National Panel Survey (UNPS) 2018/19 report, maize production totalled 1,892,879 tons from an area of 1,450,366 hectares, with average yields of 1.31 tons per hectare, well below the potential yield of 5 tons per hectare (Uganda Bureau of Statistics [UBOS], 2020). Maize is cultivated by 69% of agricultural households during the first season and 48% during the second season (UBOS, 2020).

However, Uganda's agricultural sector continues to be predominantly characterised by small-scale farmers, many of whom operate under significant resource constraints. Evidence indicates that the use of improved agricultural inputs among Ugandan farmers remains relatively low. According to the UNPS 2018/19 report, only 8.5%–9.7% of maize farmers use improved seeds, 4.4%–5.5% use inorganic fertilizers, and 10.4%–16.5% use pesticides (UBOS, 2020). This low adoption rate is particularly pronounced among small-scale farmers (Mbatuusa, 2026).

Empirical studies in Uganda have demonstrated that improved seed, fertilizer, and other agricultural inputs are associated with increased maize yields. Mbatuusa (2026) found that inorganic fertilizer significantly increases maize productivity, with users achieving 29.7% higher yields than non-users at 5% significance level. Organic fertilizer was also positively associated with maize productivity, yielding 17.8% higher maize productivity among users. However, much of the existing evidence focuses on smallholder farmers or specific geographical areas, with relatively limited comparative evidence on whether the contribution of these inputs differs between small-scale and large-scale maize farmers (Mbatuusa, 2026; Nekesa, 2024). The absence of such comparative evidence presents an important knowledge gap because policies designed to increase maize production may produce different outcomes across farmer categories. It is against this background that this study investigates the effects of selected farm inputs on maize production among small-scale and large-scale farmers in Uganda

using econometric analysis of longitudinal panel data from the Uganda National Panel Survey (Ponzini et al., 2022; UBOS, 2020).

1.4 Objectives

The primary aim of this study was to assess the factors influencing maize production among small-scale and large-scale farmers in Uganda. Specifically, the study aimed to:

1. Examine the effect of farm inputs such as the use of improved seeds, irrigation, fertilizer use, and pesticides, on maize production.
2. Analyze the effect of demographic factor, specifically, the gender of household head on, maize production.
3. Assess the effect of biophysical and regional factors, such as soil types, topography, and tenure system, on maize production

1.5 Hypotheses

Maize production in Uganda, a crucial element of both food production and economic stability, is influenced by a complex interplay of factors. The following proposed hypotheses aim to unravel these influences to enhance productivity for small-scale and large-scale farmers alike. This section explains the hypotheses examined under each of the objectives as suggested above.

H₁₁: The use of improved seeds is positively associated with higher maize production for both small-scale and large-scale farmers compared to traditional seeds.

H₁₂: The use of fertilizers is positively associated with higher maize production for both small-scale and large-scale farmers.

H₁₃: The use of pesticides is positively associated with higher maize production for both small-scale and large-scale farmers.

H₁₄: The crop stand (pure stand) is positively associated with higher maize production compared to mixed stands for both small-scale and large-scale farmers compared to mixed stand

Objective two: Analyze the effect of demographic factors such as education levels, gender, and age of a farmer for both small-scale and large-scale farmers on maize production.

H₂₁: Female farmers are associated with higher maize production for both small-scale and large-scale farmers compared to male farmers.

Objective three: Assess the effects of other factors such as soil types, rainfall, and temperatures, on maize output

H₃₁: Freehold land tenure system is significantly associated with higher maize production for both small-scale and large-scale farmers compared to other land tenure systems.

H₃₂: Sandy clay loam soil type is significantly associated with higher maize production for both small-scale and large-scale farmers compared to other soil types.

H₃₃: Irrigation as a source of water is significantly associated with higher maize production for both small-scale and large-scale farmers compared to other sources such as rainfall.

H₃₄: Hilly land areas are of the farm significantly associated with higher maize production for both small-scale and large-scale farmers compared to other types.

H₃₅: Central region is associated with higher maize production for both small-scale and large-scale farmers compared to other regions.

1.6 Scope of the study

Maize is a pivotal crop in Uganda's agricultural sector, with over 90% of farmers engaged in its cultivation (Kaizi, 2023). Despite the diversity of cereals grown across the regions, maize remains a dominant staple in food production due to its adaptability and high yield potential. This prominence underscores its critical role in ensuring maize production and supporting the livelihoods of millions of Ugandans. The analysis conducted in this study is based on data from Uganda's National Panel Survey of 2010 - 2018, which provides comprehensive information on agricultural activities for both agricultural seasons of that year. These dataset offers valuable insights into farming practices, input usage, and the socio-economic characteristics of farmers, facilitating a detailed examination of the factors influencing maize production. By leveraging this robust dataset, the study aims to identify key determinants of maize production variations and provide evidence-based recommendations to enhance productivity among small-scale and large-scale farmers in Uganda.

1.7 Theoretical and Conceptual Framework

1.7.1 Theoretical Framework

This study is grounded in the neoclassical theory of production, specifically the multivariable production function framework originating from Cobb and Douglas (1928) and later extended by Solow (1957). The production function, expressed in its general form as $Q = f(X_1, X_2, X_3, \dots, X_n)$ where Q represents output and $X_1 \dots X_n$ represent various inputs, posits that the maximum output achievable from a production process is determined by the combination and intensity of inputs employed, given the existing state of technology. In agricultural economics, this framework has been extensively applied to understand how different factors combine to generate crop output (Debertin, 2012). For maize production specifically, the production function can be specified as $Y = f(L, K, M, S, E, T)$ where Y is maize output, L represents land-related factors, K represents capital inputs, M represents material inputs (seeds, fertilizers, pesticides), S represents soil characteristics, E represents environmental conditions, and T represents technology and management practices. Following Hayami and Ruttan's (1985) induced innovation theory, agricultural productivity is understood as a function of both technical inputs and the institutional and environmental context within which farming occurs, recognizing that output is shaped not only by directly applied inputs but also by the characteristics of the land, the farming system, and the socioeconomic environment.

1.7.2 Conceptual Framework

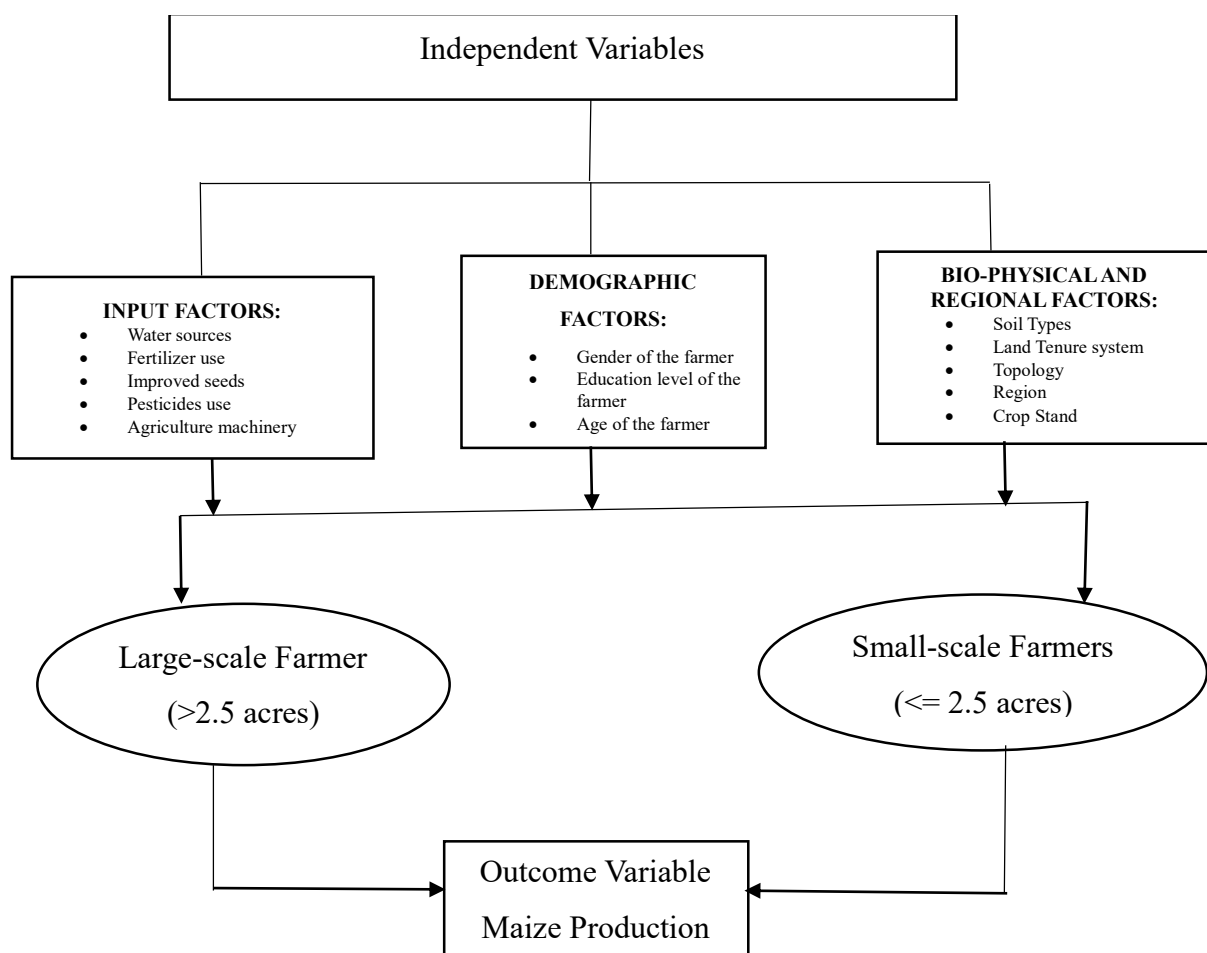
The conceptual framework presented on Figure 1-3 below was a conceptualization of this study and it presents an interplay of the selected factors on maize production in Uganda. The factors have been divided into three broad categories, that is, input, demographic, and biophysical variables. The use of advanced agricultural inputs like irrigation, fertilizers, and machinery is critical for modernizing agriculture and boosting productivity. Irrigation systems ensure consistent water supply, crucial in mitigating the risks associated with erratic rainfall patterns. Fertilizers replenish essential nutrients in the soil, fostering healthier plant growth and higher yields. Agricultural machinery reduces labor intensity and increases efficiency, allowing for more timely planting and harvesting, which directly contributes to higher production levels. Empirical studies globally and regionally support the positive impact of these inputs on crop yields, reinforcing the notion that their adoption can significantly enhance maize production in Uganda.

Biophysical factors such as soil quality, rainfall, and temperature are also fundamental determinants of agricultural productivity. Different soil types have varying capacities to retain

nutrients and water, directly affecting plant growth. Rainfall patterns influence water availability for crops, with both excessive and insufficient rainfall posing challenges to optimal maize production. Temperature ranges also play a critical role, as extreme temperatures can inhibit plant development and reduce yields. By analyzing the impacts of these biophysical factors, farmers can adopt appropriate management practices to mitigate adverse effects and enhance maize productions. Understanding these environmental variables is essential for developing strategies to improve agricultural outcomes in Uganda

Education, gender dynamics and other demographic factors significantly influence maize production. Educated farmers are better equipped to adopt modern agricultural practices, manage resources efficiently, and make informed decisions, leading to increased productivity. Conversely, gender disparities often limit women's access to resources such as land, credit, and agricultural inputs, and reduce their decision-making power, hindering overall productivity.

Figure 1-3: Conceptual Framework



Addressing these gender imbalances and enhancing educational opportunities for farmers are crucial for improving maize productions and achieving sustainable agricultural growth in Uganda. With such variables in the modelling process, the study emphasized inclusive and effective strategies for enhancing maize production in the country.

1.8 Significance of the Study

There are several benefits that can be derived from the results of the study including but not limited to:

- i. By identifying the key factors that enhance maize production for both small- and largescale farmers, the study can help increase crop yields, contributing to greater food availability. Besides, maize is a staple food whose improved production can ensure a steady supply of this essential crop, enhancing dietary diversity and nutritional intake in the country.
- ii. The study also provides empirical data that policymakers can use to formulate effective agricultural policies and interventions tailored to the needs of small-scale and largescale farmers. Understanding the impact of different inputs on maize production can guide the allocation of resources and investments in agricultural infrastructure and services.
- iii. Insights from the study can promote the adoption of efficient and sustainable farming practices, enhancing overall agricultural productivity and sustainability. The findings can inform agricultural extension programs aimed at educating farmers about the benefits of using irrigation, fertilizers, and modern machinery.
- iv. The study also contributes to the academic body of knowledge on agricultural productivity, providing a basis for further research and scholarly inquiry. It demonstrates the practical application of national survey data in addressing real-world agricultural challenges, showcasing the value of data-driven research.

1.9 Structure of the dissertation

The rest of the dissertation is organized as follows, chapter two presents a comprehensive examination of existing literature on the effect of different production factors on maize production for both small-scale and large-scale farmers. Chapter three describes the methodology that was adopted in by the study to examine the contribution of several production factors to maize production in Uganda. Chapter four presents results of the study with a detailed

discussion while chapter five presents a summary, conclusions and recommendations arising from the research.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

This chapter examines evidence on maize production and associated factors as documented by other scholars. It is divided into two sections; the first section discusses the relationship between scale of production and maize production while the second section sets out to present a detailed effect of each of the factors on maize production.

2.2 Farm Size and Maize Production

The relationship between farm size and maize production is multifaceted, influenced by factors such as productivity, environmental impact, and economic efficiency. Research indicates that larger farms tend to achieve higher productivity and efficiency, particularly in maize cultivation, while also reducing environmental burdens associated with chemical fertilizer use.

A large-scale farmer is typically defined as an agricultural producer who operates extensive farming operations, typically operating at least 2 hectares of land (Rigg et al., 2016) and adopts advanced farming techniques (Zhu et al., 2018). The scale of farm production contributes significantly to grain production, achieving higher yields compared to small household farms, and are associated with reduced greenhouse gas emissions and improved soil carbon storage. Muyanga & Jayne, (2019) argue that small farms (0-3 hectares) showing lower productivity, while larger farms (20-70 hectares) exhibit significantly higher productivity due to better mechanization and input use intensity. Hou et al., (2021) also added that larger maize farms benefit from modern agricultural methods, leading to increased yields and reduced carbon footprints compared to smaller operations. Furthermore, Huan & Zhan, (2022) asserted that larger farms adopting agricultural production services (APSs) tend to use less chemical fertilizer, promoting environmental quality. Hou et al., (2021) indicated that the carbon footprint associated with maize production decreases as farm size increases, indicating more efficient resource utilization on larger farms.

On the other hand, small-scale farmers are individuals or families who operate small plots of land (less than two hectares of land), primarily for subsistence or local market production and normally rely on family labor and local resources for production (von Braun & Mirzabaev, 2015). They play a crucial role in global maize production, more so in developing countries

(Azadi et al., 2023). Despite their importance, small-scale farmers face numerous challenges, including limited access to technology, financial resources, and market opportunities, climate changes, and water scarcity (Dhillon & Moncur, 2023). Small farms also play a vital role in local economies, particularly when supported by appropriate agricultural policies and practices. Chen et al., (2022) argued that the efficiency gains from reallocating resources among small farms are modest, suggesting that small-scales can still be productive through the use of hired machinery service. While small-scale farmers are vital for maize production and rural economies, their potential is often hindered by systemic challenges. Addressing these issues through supportive policies and technological access is essential for enhancing their productivity and sustainability.

2.3 Factors affecting maize production

2.3.1 Input Factors

The use of advanced agricultural inputs like irrigation, fertilizers, and machinery is critical for modernizing agriculture and boosting productivity. In this section, the study takes a closer look at these factors where they have been examined describing their interplay on maize production.

Water Sources

Irrigation refers to the application of water to crops through artificial means such as sprinklers, canals, or drip systems to supplement natural rainfall. It positively impacts maize production by ensuring a consistent water supply, particularly in areas with irregular rainfall or drought conditions, leading to improved growth and higher yields. This enables year-round farming, increasing production and reducing dependency on seasonal rainfall.

Research shows that the shadow price of irrigation water for maize grain in Italian farms averages 0.29 €/m³, significantly enhancing crop productivity and economic viability (Buttinelli et al., 2024). In arid regions like Egypt, using saline agricultural drainage water and drip irrigation can optimize maize water use, achieving high yields under challenging conditions (Ahmed et al., 2024). Additionally, innovative irrigation methods like trailing perforated pipes have been found to enhance irrigation efficiency and maize production, with higher water use efficiency and crop yields compared to traditional methods (Sayed et al., 2023). GadedjissoTossou et al., (2019) in West Africa, found that the use of irrigation reduces yield variability and increases expected profits for small-scale maize farmers. Chimbishi,

(2022) also found a positive impact between farmer-led irrigation farming initiatives and maize production among small-scale farmers. On the other hand, Msengi & Akyoo, (2023) found no better outcomes in maize production after the use of irrigation in their production activities. This mixed experience on the contribution of irrigation on maize production warranted a study of this nature to assess the effect of irrigation on maize production.

This study hypothesized that Irrigation is a key factor that significantly affect maize production

Fertilizers use

Fertilizers are substances that are added to soil or plants to provide essential nutrients and improve their growth and productivity. They can be natural (organic) or synthetic (inorganic) and are critical for modern agriculture, especially in areas with nutrient-depleted soils or intensive farming practices. Fertilizers significantly boost maize production by supplying essential nutrients like nitrogen, phosphorus, and potassium, which enhance plant growth, root development, and grain yield. Proper use of fertilizers can improve soil fertility and enable higher productivity, especially in nutrient-depleted soils.

Farooq et al., (2022) is emphatic about the role of fertilizers in enhancing agricultural production. The authors argue that customized fertilizers containing primary, secondary, and micronutrients tailored to specific crops and soil types can significantly improve crop yield and sustainability. Additionally, the application of nano fertilizers, which release nutrients gradually, can lead to controlled nutrient release, improved crop yield, and reduced environmental impact, although challenges like phytotoxicity need to be addressed (Jithendar et al., 2024). Furthermore, the long-term use of organic fertilizers has been shown to increase soil fertility, stabilize nutrient content which highlights the importance of organic and organomineral fertilizer systems in maintaining stable crop yields over time (Zolkina, 2023). Overall, the strategic use of fertilizers, including customized, nano, and organic options, is essential for maximizing agricultural production while minimizing environmental degradation and ensuring sustainable food production (Singh et al., 2022).

In Sub-Saharan (SSA) fertilizer use averages to only 8 kg nutrients ha⁻¹ annually, underscores the need for increased nitrogen inputs to restore soil fertility and boost crop production (Hickman et al., 2020). This low fertilizer use has been linked to chronic maize production

(Adzawla et al., 2024; Dimkpa et al., 2023). Complementary interventions like integrated soil fertility management are essential to maximize the effectiveness of fertilizer application and improve profitability in small-scale farming systems in Africa (Kanyamuka et al., 2018). Although use of fertilizers remain low in Uganda, high profitability and production has been seen among maize farmers that applied fertilizers in their production process (Adong et al., 2019). This emphasizes the importance of optimizing fertilizer use based on soil types to achieve higher yields and profitability on small-scale farms in East Africa (Kiwia et al., 2022).

The study hypothesized that the use of fertilizers is fundamental for maize production among both small- and large-scale maize farmers.

Improved Seeds

Improved seeds are crop seeds that have been scientifically developed or selected to provide better performance compared to traditional or local varieties. The seeds are considered to be of high quality, pest resistant, drought and stress tolerant, and are perceived to grow faster. They are a key component in modern agriculture, particularly in maize production and are extensively used in efforts to achieve sustainable food production, especially in regions with increasing population and environmental challenges.

The use of improved seeds in different countries has affected maize farmers differently. For example, in India, certified seeds are highlighted as essential for sustaining productivity amidst climate change, with a focus on achieving higher seed replacement rates (Balkrishna, et al., 2024). In Ethiopia, the availability and adoption of improved seeds are emphasized to increase crop productivity and ensure maize production, with quality seeds contributing significantly to total production (Abebaw et al., 2023). Research in other parts of Africa underscores the impact of improved maize seeds on harvests and crop failure probability, showing that uncertainty about seed type can significantly affect the benefits of improved seeds on farmers' yields (Bulte et al., 2023). Furthermore, a study in Ethiopia reveals that increased use of improved seeds per hectare leads to a substantial increase in grain crop productivity, highlighting the importance of quality seeds in agricultural development (Abebe et al., 2022).

The study hypothesized that use of improved seeds positively affects maize production for both small-scale and large-scale

Pesticides and Agriculture Production

Pesticides are chemical or biological agents used to prevent, control, or eliminate pests such as insects, weeds, fungi, or rodents that can harm crops. Pesticides improve maize production by protecting crops from pest-related damage, thereby reducing yield losses and ensuring healthier plants. When applied appropriately, they help maximize productivity, but overuse or misuse can harm the environment and reduce long-term soil fertility.

According to Khan et al., (2023), the use of pesticides is inevitable in agriculture as it enhances agricultural production by protecting crops from pests and diseases, thus ensuring an adequate food supply to meet consumer demand. In SSA, Michelson et al., (2022), argued that the quality of mineral fertilizers and pesticides available to small farmers is essential for increasing economic returns and understanding agricultural productivity. Mueller et al., (2022) highlighted concerning practices among farmers, including limited knowledge on pesticide application, misinterpretation of label instructions, non-compliance with pre-harvest intervals, and the mixing of different pesticides, which can pose risks to farmers' health and reduce food quality. Addressing these issues is crucial to ensure safe agricultural productivity, sustainable maize production, and the protection of human health in Uganda's farming communities (Andersson & Isgren, 2021). Although this study did not explore best practice on the use of pesticides, the study examines the effect of using pesticides in maize production in the country. The study hypothesized that application of pesticides positively affects maize production for both small-and-Large-Scale farmers

Agricultural machinery

Agricultural machinery refers to tools, equipment, and machines such as tractors, planters, harvesters, and plows used to perform various farming activities more efficiently. Like other agriculture inputs, farm machinery also plays a crucial role in enhancing agricultural productivity. It enhances maize production by reducing labor costs, saving time, and improving the efficiency of operations like planting, irrigation, and harvesting. This leads to higher productivity and allows farmers to cultivate larger areas, ultimately boosting overall yields.

Strengthening the agricultural sector through mechanization not only improves production but also contributes to sustainable economic growth, emphasizing the need for policies supporting local manufacturers to make machinery a preferred choice for farmers and agro-food processors (Daum et al., 2024). High-capacity machinery encourages reallocation of other farm inputs leading to high grain production (Meng et al., 2024). In Western Kenya, the use of farm machinery, such as chisel harrows, led to increased maize productions, with adopters achieving

higher yields compared to non-adopters, thus improving production (Mumah et al., 2024). Zhou et al., (2020) also found significantly increased farm yields among maize farmers for all quantiles, with low-productive farmers benefiting more relative to high-productive farmers, ultimately reducing yield inequality and variability. In Uganda the use of different tillage practices, such as conventional and minimum tillage, influences vegetative growth and maize production highlighting the importance of appropriate machinery selection for optimal productivity (Lawrence et al., 2020). There has however been limited target examination of the use of farm machinery on maize production among the different groups in the country which informed a study of this nature.

While access to agricultural machinery is widely recognized as a critical determinant of farm productivity, the prevalence of its use among maize farmers could not be reliably identified within the national panel survey data utilized in this study.

2.3.2 Demographic Factors

Gender of the household head

The gender of the household head refers to whether the primary decision-maker and provider in a household is male or female. The gender of the household head can affect maize production as male-headed households often have better access to resources such as land, labor, and agricultural inputs, which can lead to higher productivity. Female-headed households, on the other hand, may face challenges due to limited access to these resources, impacting their production capacity.

Gender gaps in agricultural productivity have been a prevalent issue in various regions, as highlighted several studies. Research in Kenya reveal significant productivity disparities favoring male farmers over female farmers (Andele et al., 2024). In Uganda, research indicates that female-managed plots tend to have lower productivity compared to male-managed plots, with a gender gap productivity attributed to structural advantages favoring male farmers (Julien et al., 2023; Miriti et al., 2023). Additionally, female-headed households in maize production tend to earn less income, highlighting the need for targeted training programs and improved access to credit for women in agriculture (Chune, 2022). Furthermore, perceptions within the maize value chain indicate that female farmers tend to rate value chain actors more highly, emphasizing the importance of gender dynamics in agricultural interactions (Citaristi, 2023). The author also notes that strengthening women's land ownership rights is also crucial, as

ownership rights have been found to enhance productivity significantly, showcasing the importance of gender equality in land tenure for agricultural development in Uganda. However, disaggregation of the effect of gender by farm(er) size lacking necessitating this study.

The study tested the hypothesis that gender dynamics influence maize production, with disparities in access to resources and decision-making power.

Education Level

Education level refers to the highest level of formal schooling completed by an individual, such as primary, secondary, or tertiary education. The education level of a farmer influences maize production as more educated farmers are likely to adopt modern farming techniques, effectively use inputs like fertilizers and pesticides, and access agricultural information, leading to improved productivity. Conversely, less educated farmers may rely on traditional practices, which can limit yields.

Farmer education, including formal, non-formal, and informal education, has been found to contribute to increased farm production by enhancing farmers' skills, knowledge of modern farming methods, and adaptation to new technologies (Biru & Korgitet, 2019). Formal education introduces farmers to new technologies and better farming methods which positively impacts farm production (Biru & Korgitet, 2019). In Africa, research indicates that higher levels of education, particularly at the secondary and post-secondary levels, significantly increase the use of agricultural inputs like improved seeds, fertilizers, and access to credit services. This leads to higher per capita consumption expenditure and reduced poverty among small-scale farmers in countries such as Ethiopia, Malawi, Nigeria, and Tanzania (Kirui, 2019). In Uganda, Owuor et al., (2020) reported that public investment in education positively impacts agriculture sector output, promoting the adoption of new technologies. These findings underscore the significance of education in driving agricultural productivity and improving the welfare of farmers in Uganda, especially at the small-scale level.

This study's demographic analysis is limited to the gender of the household head, as other demographic characteristics could not be consistently linked to respondents across all waves of the Uganda National Panel Survey data.

Age of the Farmer

The age of the farmer refers to the number of years the individual engaged in farming has lived, which can influence their experience, decision-making, and labor capacity. The age of

the farmer affects maize production as younger farmers may have more physical energy and be more open to adopting modern farming techniques, while older farmers often rely on traditional methods and benefit from their years of farming experience. Both factors can influence productivity levels differently.

In China and the U.S, research demonstrates that older farmers tend to be less productive than younger ones, with farmers over 65 being up to 10% less efficient than those under 25 (Fried & Tauer, 2016; Ren et al., 2023). In Africa, age plays a significant role in agricultural productivity among small and large-scale farmers in Africa. For example, Nwandu, (2022) found that younger male and female farmers tend to have higher levels of formal education, access to credit, and engage in farm production. Additionally, a study by Olawunmi, (2012) in Ogun and Ekiti States of Nigeria revealed that age significantly affects farm productivity, with older farmers showing lower levels of productivity. In Kenya and Malawi, Lele & Agarwal, (1990) found that large farms, which often have younger farmers, tend to achieve higher yields per hectare due to better access to modern inputs and technology, ultimately leading to increased productivity. Therefore, promoting the involvement of younger farmers through education, access to resources, and technology can enhance agricultural productivity among both small and largescale farmers in Africa.

2.3.3 Biophysical and Regional Factors

Soil Types

Soil types refer to the various classifications of soil based on their physical and chemical properties, such as texture, structure, and nutrient content (e.g., sandy, clayey, loamy). Soil types affect maize production by influencing water retention, drainage, and nutrient availability. For example, loamy soils, which are well-drained and nutrient-rich, are ideal for maize cultivation, while sandy or clayey soils may require additional inputs to support optimal growth.

In Africa, diverse agro-ecological zones feature various soil types such as Ferralsols, Acrisols, and Lixisols, with soil fertility depletion posing a threat to maize production for small-holder farmers (Bationo et al., 2012). Small-scale farms in sub-Saharan Africa exhibit high diversity, with soil heterogeneity impacting the performance of Integrated Soil Fertility Management (ISFM) technologies tailored to enhance resource use efficiency (Tittonell, 2008). The variability in management practices results in distinct soil fertility classes, influencing the response to fertilizer applications (Chikowo et al., 2014) which in turn affect agricultural

production. Additionally, the adoption of new maize varieties with tolerance to low soil fertility is crucial for improving productivity among small-scale farmers, who face constraints such as low soil fertility, drought, and pests (Ribeiro et al., 2017). In Uganda, small-scale farmers face challenges with soil suitability for maize production, with only 13% cultivating highly suitable land, leading to forgone production and limited gains (Gourlay & Kilic, 2023). Understanding soil types provides a better understanding of the suitability of the soil for maize production and is likely to affect small-and large-scale farmers differently which necessitates a study of this nature

The study hypothesized that soil types significantly affect maize production irrespective of scale of production.

Land Tenure System

A land tenure system is the social, legal, and economic framework that determines who can use land, for how long, and under what conditions, defining the relationship between people and the land they cultivate. This system of land ownership is critical for maize production because secure tenure provides farmers with the long-term confidence to invest in soil improvements and infrastructure, which are essential for sustaining high maize production. Furthermore, documented tenure rights serve as collateral, enabling farmers to access the credit needed to purchase productivity-enhancing inputs like improved seeds, fertilizers, and pesticides.

Land tenure systems in Uganda are formally categorized into four coexisting types, customary, freehold, mailo, and leasehold, with customary tenure governing approximately 84% of land holdings (Deininger & Ali, 2008), yet this system often fails to provide small-scale farmers with the formal documentation needed to leverage land as economic collateral (Place, 2009). The insecurity inherent in Uganda's land tenure arrangements, particularly the overlapping ownership and use rights on mailo land and the ambiguous nature of customary holdings, has been identified as a critical impediment to agricultural investment, as farmers with uncertain tenure rights have significantly lower incentives to invest in longterm productivity enhancements such as trees, soil conservation, and manure application (Deininger & Ali, 2008). Consequently, the absence of secure, documented land rights constrains maize farmers' access to agricultural credit, with banks requiring titled land as collateral, while simultaneously discouraging the land-related investments necessary for sustainable productivity

improvements, thereby directly undermining maize output for both small-scale and large-scale farmers (Aha & Ayitey, 2017).

It was hypothesized that land tenure system affects maize production differently for both small- and large-scale farmers.

General Topography

Topography refers to the physical shape and features of the Earth's surface, including the distribution of landforms such as hills, valleys, slopes, and flat plains. In agricultural research, topography is commonly categorized based on landscape position, including hilly, flat, gentle slope, steep slope, and valley classifications, which collectively determine drainage patterns, water accumulation, soil depth, and the redistribution of soil organic matter and nutrients across farm fields through erosion and deposition processes.

The impact of topography on maize production is well-documented globally, with research demonstrating that topographic variability accounts for up to 78% of crop yield variability through its direct effects on soil moisture availability, nutrient distribution, and root zone development (Kravchenko & Bullock, 2000). In Uganda specifically, land suitability assessments have identified slope and elevation as critical factors for maize cultivation, with studies in Luwero District revealing that areas with favorable topographic conditions are essential for achieving optimal maize productivity (Lwasa et al., 2014). Furthermore, research on maize yield vulnerability across Uganda indicates that topographic position interacts with climatic and soil factors to shape spatial patterns of agricultural productivity, with implications for both small-scale and large-scale farming systems (Epule et al., 2017).

The study hypothesized that topography (farm terrain classification) is significantly associated with maize production for both small-scale and large-scale farmers in Uganda.

Region of Residence

Maize production in Uganda varies significantly across regions due to differences in climate, soil fertility, and farming practices. While the central and eastern regions lead in production, western and northern regions are increasingly contributing due to expanding agricultural investments and improved farming techniques.

Climatic conditions among others are major explainer of maize production across the different regions in the country. While some regions may experience increased rainfall during agricultural seasons, others face severe droughts, which can significantly impact maize yields. For example, the northern region is more vulnerable to droughts due to lower precipitation levels and poorer soil quality compared to the south (Epule et al., 2017). Timing and distribution of rainfall during the growing season are crucial, as irregular rainfall patterns can lead to water stress and reduced production (Babyenda et al., 2023). Additionally, temperature also plays a pivotal role in maize production across the regions with areas on high-altitudes experiencing faster warming rates (Kikoyo & Nobert, 2016) which undoubtedly affect maize output.

Further still, the country can be broadly divided into different agro-ecological zones such as the highlands, flat plains, and wetlands, each with distinct soil types and moisture levels. For instance, the eastern highlands are more suitable for crops like coffee and bananas, while the flat plains and valleys are better suited for maize and other cereals (Bernard, 2018). Research has also shown that soil degradation and low fertility are widespread in Uganda, particularly in the northern regions, where poverty and lack of access to fertilizers exacerbate the problem (Epule et al., 2017) affecting maize productivity.

This variation warranted an investigation on how regions of residence affect maize productivity. The study hypothesized that region of residence is a crucial factor for maize production regardless of the scale of production

Crop Stand

Crop stand refers to the cropping system used on a plot, specifically whether a crop is grown alone or in combination with other species. In this study, crop stand is categorized as either pure stand, where maize is cultivated as the sole crop on the plot, or mixed stand, where maize is grown together with other crops such as beans, groundnuts, cassava, or other species on the same piece of land during the same growing season.

The choice between pure stand and mixed stand cropping systems has significant implications for maize productivity among Ugandan farmers. Research conducted in drought-prone areas of Uganda (Rakai and Nakasongola districts) demonstrated that intercropping maize with beans reduced maize yields by 16% to 25% compared to pure stand maize cultivation (Semalulu et al., 2022). This yield reduction occurs due to increased competition between crop species for limited resources including water, nutrients, and light, with maize being the dominant

competitor often suppressing companion crops. The same study found that the benefit-cost ratio was highest for sole maize, indicating that pure stand maize production was more profitable than intercropping systems when considering economic returns from maize alone (Semalulu et al., 2022). The profitability advantage of pure stands was particularly pronounced when combined with other productivity-enhancing practices such as early planting and inorganic fertilizer application.

Further evidence from eastern Uganda indicates that while intercropping is widely practiced by small-scale farmers as a risk management strategy, pure stand maize production consistently yields higher maize output per unit area (Mugisa et al., 2020). Farmers in high potential areas with reliable rainfall and access to inputs tend to adopt pure stands to maximize maize yields, whereas those in marginal areas with poor soil fertility or erratic rainfall often prefer mixed stands to spread risk and ensure some harvest even if one crop fails. Additionally, pure stands offer farmers simpler management options, more uniform crop maturity, greater efficiency in input application, and greater flexibility in herbicide and pesticide use compared to mixed cropping systems (Kaizzi et al., 2012). However, it is important to note that while pure stands maximize maize yield per unit area, intercropping systems may still be preferred by resource-constrained farmers for their ability to provide dietary diversity, improve soil nitrogen through legume integration, and stabilize income across seasons.

2.4 Summary of the reviewed Literature and the knowledge gap

In the previous sections, this study attempted to conduct an elaborate, though not exhaustive, review of the literature linking several agricultural production factors to maize production. While the evidence presented in this chapter indicate potential variations in agricultural production among small- scale and large-scale farmers, this evidence is document in different context other than Uganda. There are several reasons that warrant a comparative analysis of these groups of farmers in Uganda including varying access to production factors such as land and farm inputs whose access may not be similar to other contexts. The study contributes to the existing body of literature by rigorously examining the suggested input factors, farmer demographics, biophysical and regional factors affecting Ugandan farmers. The analysis was disaggregated by the scale of production, providing insights into the differences and challenges faced by small-scale versus large-scale farmers. Through this approach, the study highlighted specific areas where interventions could improve agricultural productivity and sustainability in Uganda.

CHAPTER 3 : METHODOLOGY

3.1 Introduction

This chapter discusses the study design used for this study, target population and sample size used, data management and list of all the variables used. It also discusses the data analysis levels, states the model and fully describes it, stating the reasons for its choice, discusses the ethical considerations and the limitations of the study.

3.2 Study design

This study adopts a longitudinal research design based on five waves of the Uganda National Panel Survey (UNPS), covering the period from 2010/11 to 2018/19. Specifically, the study utilizes data from the 2010/11 (Wave II), 2011/12 (Wave III), 2013/14 (Wave IV), 2015/16 (Wave V), and 2018/19 (Wave VII) survey rounds. The UNPS is implemented by the Uganda Bureau of Statistics (UBOS) as a nationally representative panel survey designed to generate information on household socioeconomic characteristics, agricultural activities, employment, income, consumption, and welfare over time. The panel structure enables households to be followed and re-interviewed across successive survey rounds, thereby providing repeated observations on the same households and allowing changes in household and agricultural characteristics to be examined over time. The initial UNPS panel was drawn from the 2005/06 Uganda National Household Survey, from which 3,123 households were selected for the panel. In subsequent rounds, households were tracked over time, including households formed through splits from the original panel households.

The longitudinal nature of the UNPS makes the data particularly suitable for this study because it permits the examination of changes in maize production and farmer characteristics across different periods. In addition, the agricultural component of the survey provides detailed information on landholdings, plots, crops cultivated, agricultural inputs, production, and other farm characteristics. These data enable the study to identify maize-producing households and compare production outcomes between small-scale and large-scale maize farmers over time. The use of multiple survey waves further allows the analysis to distinguish between variations observed across farmers and changes occurring within farmers across survey periods.

3.3 Target population and Sample size

The target population for this study consisted of all agricultural households engaged in maize production across Uganda, divided into two groups based on their scale of production. Small-scale farmers were defined as agricultural households operating on less than one hectare of land dedicated to maize cultivation, constituting approximately 85% of all farming households

in Uganda. These farmers typically engage in subsistence production, rely heavily on family labor, and have limited access to modern agricultural inputs and institutional support (Rigg et al., 2016; von Braun & Mirzabaev, 2015). Large-scale farmers were defined as agricultural households operating on more than one hectare of land dedicated to maize cultivation. While this group represents a small proportion of agricultural households (approximately 3%), they typically engage in commercial production and have greater access to mechanization, improved seeds, fertilizers, and other productivity-enhancing inputs (Zhu et al., 2018).

The sampling frame for this study was derived from the Uganda National Panel Survey (UNPS), implemented by the Uganda Bureau of Statistics (UBOS). The UNPS is a nationally representative longitudinal household survey designed to generate information on household socioeconomic characteristics, agricultural activities, employment, income, consumption, and welfare over time (Ponzini et al., 2022; UBOS, 2020). The initial UNPS panel was drawn from the 2005/06 Uganda National Household Survey, from which 3,123 households were selected using a stratified two-stage sampling design. In subsequent rounds, households were tracked over time, including households formed through splits from the original panel households. The survey employs a stratified random sampling design, with strata defined by region (Central, Eastern, Northern, and Western) and urban/rural classification (UBOS, 2020).

The final analytical sample comprised 5,691 observations from 5,485 small-scale farmers and 206 large-scale farmers across five waves of the UNPS (2010–2018). The distribution shows that small-scale farmers consistently dominate the sample across all survey waves, accounting for over 96% of all observations, which reflects the actual structure of Uganda’s agricultural sector (UBOS, 2020). The largest number of observations came from the 2010 wave (1,764 observations, with 1,699 small-scale and 65 large-scale farmers), followed by 2015 (1,473 observations, with 1,456 small-scale and 17 large-scale farmers), 2013 (971 observations, with 927 small-scale and 44 large-scale farmers), 2011 (843 observations, with 801 small-scale and 42 large-scale farmers), and 2018 (640 observations, with 602 small-scale and 38 large-scale farmers). The variation in sample sizes across waves reflects factors such as panel attrition, survey design gaps, data availability, and household splits (Ponzini et al., 2022; UBOS, 2020). The panel is unbalanced, meaning not all households are observed in all waves; however, the fixed effects regression model is well-suited to unbalanced panel data as it uses within-household variation over time to identify the effects of time-varying variables while controlling for time-invariant unobserved household characteristics (Wooldridge, 2010).

3.4 Data Management

The data used in this study comprised several standalone datasets, each collected independently from farmers as separate data points. Using a household identification variable as the unique identifier, all sub-datasets related to the agriculture theme were merged into a single agriculture dataset for all the waves under study. Similarly, the same approach was applied to all household-level sub-datasets to create a universal household dataset for each wave. The resulting datasets (agriculture and household-level) were then merged into one comprehensive dataset for analysis purposes. From this merged dataset, records were filtered to retain data exclusively for agricultural households engaged in maize production, using crop identification variables. Table 1 below presents a complete description of all variables included in the analysis.

Table 3-1: Description of Independent Variables

Label	Variable	Codes/vale	Type
Outcome	UNPS Waves	1. 2010	Nominal
		2. 2011	
		3. 2013	
		4. 2015	
		5. 2018	
	Maize production (kg)	NA	Continuous
	Land grown to maize	0. Less than 2.5 Acres	Binary
		1. Greater than or equal to 2.5 acres	
Input factors	Water Sources	0. Rainfall	Binary
		1. Irrigations	
	Fertilizer use	0. No	Binary
		1. Yes	
	Use of Improved Seeds	0. No 1. Yes	Binary
	Pesticide Use	0. No 1. Yes	Binary
Demographic Factors	Gender of a farmer	0. Male	Binary
		1. Female	
Biophysical and Regional Factors	Soil Types	0. Sandy loam	Nominal
		1. Sandy Clay Loam	
		2. Black Clay	
		3. Others	
	Land Tenure System	0. Free Hold	Nominal
		1. Lease Hold	
		2. Mailo	
		3. Customary	
	General Topology	0. Hilly	Nominal
		1. Flat	
		2. Gentle Slope	
		3. Steep Slope	
	Region	0. Central	Nominal
		1. Eastern	

	2. Northern	
	3. Western	
Crop stand	0. Mixed Stand	Binary
	1. Pure Stand	

3.5 Data Analysis

The analysis was conducted at three levels, that is, univariate, bivariate, and multivariable analysis. The univariate analysis provided an overview of all variables included in the study, summarizing the characteristics of maize producers and highlighting patterns in regional distribution, land tenure, farming practices, and input use. The bivariate analysis explored the relationships between maize production and each explanatory variable individually, helping to identify which factors were associated with differences in production between small-scale and large-scale farmers. Finally, the multivariable analysis examined the combined effect of all explanatory variables on maize production, allowing for a clearer understanding of the key determinants that influence yields for both small- and large-scale farming systems.

3.6 Multivariable analysis

To examine the factors influencing maize production among small-scale and large-scale farmers in Uganda, this study estimated a panel fixed effects regression model. The model is specified to account for the panel structure of the Uganda National Panel Survey data, where multiple observations (waves) are nested within the same farming households over time. The fixed effects modelling approach was preferred for its ability to prevent the omitted variable bias by allowing unobserved individual specific characteristics to correlate with the independent variables. The paradigm's insensitivity to the distribution assumption of the outcome variable also made it more attractive for use in the study. Lastly, it is worth noting that fixed effect models ignore the correlation structure of the predictor variables relaxing the adverse effect that would have been raised in the event of multicollinearity.

$$\begin{aligned}
Y_{itj} = & \alpha_{ij} + \beta_1 Gender_{itj} + \beta_2 Fertilizer_{itj} + \beta_3 Pesticides_{itj} + \\
& \beta_4 CropStand_{itj} \\
& + \beta_5 SeedType_{itj} + \beta_6 Tenure_{itj} + \beta_7 SoilType_{itj} + \beta_8 \\
& WaterSource_{itj} + \beta_9 Topography_{itj} + \beta_{10} Region_{itj} + \\
& \varepsilon_{itj}
\end{aligned}$$

$j = 1, 2, 3; t = 1, 2, 3, 4, 5; i = 1, 2, 3, \dots, n$

Where j is the scale of production; t is the specific national panel survey wave; and i is the sampling unit in any given survey

The model was estimated separately for three samples:

1. Small-scale farmers only
2. Large-scale farmers only
3. The pooled sample of all farmers

Dependent Variable:

- Y_{itj} = Annual maize harvest (in kilograms) for household i at time t and j scale of production

Independent Variables:

- $Gender_{itj}$ = Gender of household head (0 = Male, 1 = Female)
- $Fertilizer_{itj}$ = Use of fertilizers (0 = No, 1 = Yes)
- $Pesticides_{itj}$ = Use of pesticides (0 = No, 1 = Yes)
- $CropStand_{itj}$ = Crop stand type (0 = Pure Stand, 1 = Mixed Stand)
- $SeedType_{itj}$ = Seed type (0 = Improved, 1 = Traditional)
- $Tenure_{itj}$ = Tenure system dummies (Leasehold, Mailo, Customary, Other, with Freehold as reference)
- $SoilType_{itj}$ = Soil type dummies (Sandy Loam, Black Clay, Other, with Sandy Clay Loam as reference)
- $WaterSource_{itj}$ = Water source dummies (Irrigation, Swamp, with Rainfall as reference)
- $Topography_{it}$ = Topography dummies (Flat, Gentle Slope, Steep Slope, Valley, with Hilly as reference)
- $Region_{itj}$ = Regional dummies (Eastern, Northern, and Western, with Central as reference)
- Error Components:
- α_{ij} = Household-specific fixed effect capturing time-invariant household characteristics
- ε_{itj} = error term varying across households and time

Coefficients:

β_1 to β_{10} represent coefficients estimated for each explanatory variable.

3.7 Ethical Considerations

This study utilized publicly available data from the World Bank Microdata Library, ensuring compliance with ethical standards. As the data was obtained from an open-access source, there was no direct contact with participants, and no additional data was collected. This approach minimized privacy concerns and adhered to ethical guidelines for secondary data analysis.

3.8 Limitations of the Study

The Uganda National Panel Survey (UNPS) is conducted with a focus on measuring progress toward key indicators such as poverty levels, service delivery, employment, and governance. Although agricultural activities were included in the survey, they were not the primary focus, which limited the depth of analysis on agricultural practices. Consequently, this study could not incorporate analysis of critical agricultural variables, such as community-level extension services, market information, and detailed biophysical factors, which are essential for understanding agricultural production.

Additionally, the study employed list wise deletion to handle missing data, whereby observations with missing values on any of the variables included in the regression models were excluded from the analysis. This approach was necessary because the fixed effects regression model requires complete data for all variables included in the model. While list wise deletion is a common and accepted approach in panel data analysis, it may introduce bias if the missing data are not missing completely at random (MCAR). If missingness is systematic, for example, if farmers with lower production or limited resources are more likely to have incomplete records, the estimates may be biased toward households with complete data, potentially underestimating or overestimating the true effects of the explanatory variables. Although the proportion of missing data was relatively small (less than 5% for most variables), the cumulative effect of listwise deletion across multiple variables resulted in the exclusion of some observations, reducing the analytical sample from the full set of maize-producing households. Future research could employ multiple imputation or other advanced missing data techniques to address this limitation and assess the robustness of the findings

CHAPTER 4 : PRESENTATION AND DISCUSSION OF RESULTS

4.1 Introduction

This chapter presents the findings of the study, organized according to the research objectives outlined in Chapter 1. The analysis proceeds in three stages. First, descriptive statistics are presented to summarize the characteristics of small-scale and large-scale maize farmers in the sample. Second, the results of the fixed effects regression models are presented, showing the determinants of maize production for each farmer category and the pooled sample. Third, the findings are discussed in relation to existing literature and their implications for agricultural policy in Uganda are examined.

4.2 Distribution of Study Variables Analysis Results

Maize production among small-scale producers shows moderate fluctuations across the regions between 2010 and 2018. In 2010, production levels were fairly similar across regions, ranging from 262.70 in Western to 296.97 in Northern, giving a national average of 272.02. Production increased slightly in 2011, reaching a peak national average of 307.07, largely driven by improvements in the Eastern and Northern regions. However, in 2013 there was a noticeable decline in the Central region (188.61), while Eastern and Northern regions recorded higher values (364.86 and 356.51 respectively). By 2015, Western experienced a sharp increase (372.05), although Eastern dropped significantly. In 2018, production levels across all regions converged to a narrower range (approximately 235–268), with the national average falling to 240.47, indicating an overall decline compared to earlier years and suggesting possible constraints affecting small-scale productivity over time.

Table 4-1: Trends in Average Maize production among small and largescale famers in Uganda-2010-2018 in Kilograms

Scale of production	Region	2010	2011	2013	2015	2018
Small Scale Producers	Central	268.74	293.55	188.61	237.65	257.92
	Eastern	267.24	313.51	364.86	188.61	235.70
	Northern	296.97	325.34	356.51	304.41	236.08
	Western	262.70	293.36	266.38	372.05	268.20
	Total	272.02	307.07	266.39	254.71	240.47
Large Scale Producers	Central	275.36	345.35	591.01	600.75	553.28
	Eastern	231.95	388.51	367.92	571.67	1980.82
	Northern	362.13	316.41	70.50	818.50	266.20
	Western	222.49	810.04	362.00	1375.00	904.89
	Total	269.08	516.34	476.70	712.32	918.72

In contrast, maize production among large-scale producers demonstrates much larger variability and generally higher production levels across the study period. In 2010, production was relatively moderate, with Northern recording the highest value (362.13) and Western the lowest (222.49). Production increased substantially in 2011, particularly in the Western region (810.04), raising the national average to 516.34. In 2013, Central experienced a dramatic rise (591.01), though Northern dropped sharply (70.50), indicating uneven performance across regions. By 2015, production expanded significantly in several regions, especially Western (1375.00) and Northern (818.50), pushing the national average to 712.32. The most striking change occurs in 2018, where the Eastern region records an exceptionally high value (1980.82), driving the national average up to 918.72. Overall, the data suggests that large-scale producers experience greater growth potential but also higher variability, likely due to differences in investment levels, technology use, and scale of operations.

Table 4.2 provides a comparative statistical summary of small-scale and large-scale maize farmers across key characteristics. It reports the mean, standard deviation, minimum and maximum values, and the number of observations for variables such as maize harvest output, regional distribution, land tenure, soil characteristics, and farming practices. The last two columns present the results of t-tests that assess whether the differences between small-scale and large-scale farmers are statistically significant.

Small-scale farmers constitute the majority of the sample, accounting for 5,485 out of 5,691 observations. Their average annual maize harvest is 268.1 kilograms, with considerable variability (Std. Dev. 317.4 kg) and harvest levels ranging from 12.5 kg to 3,252.5 kg. Most small-scale farmers are located in the Eastern (35%) and Central (30%) regions, followed by the Western (18%) and Northern (17%) regions. The gender distribution is fairly balanced, with 51% of respondents being female. In terms of land tenure, freehold (44%) and customary (44%) systems dominate among small-scales, while leasehold and Mailo tenure systems are relatively uncommon. Regarding natural conditions, the most common soil type is sandy loam (39%), followed by sand clay loam (30%), and farming largely depends on rainfall (95%) rather than irrigation. Most farms are located on flat (49%) or gently sloping (40%) land. The adoption of modern agricultural inputs remains relatively low among small-scale farmers, with 14% using improved seeds, 9% using fertilizers, and 9% applying pesticides.

Table 4-2: Distribution of Study Variables

Variable	Small-Scale Farmers					Large-Scale Farmers					Pooled					Group Differences	
	Mean	Std. Dev.	min	max	N	Mean	Std. Dev.	min	max	N	Mean	Std. Dev.	min	max	N	t-statistic	p-Value
Annual Maize Harvest (in kilograms)	268.1	317.4	12.5	3252.5	5485	520.3	704.73	17.3	3300	206	277.3	342.4	12.5	3300	5691	-10.475	0.000
<i>Water Source</i>																	
Irrigation (Yes = 1, No = 0)	0.02	0.13	0	1	5485	0.03	0.17	0	1	169	0.02	0.13	0	1	5654	-1.313	0.189
Rainfall (Yes = 1, No = 0)	0.95	0.23	0	1	5485	0.96	0.20	0	1	169	0.95	0.23	0	1	5654	-0.695	0.487
Swamp wetland (Yes = 1, No = 0)	0.04	0.19	0	1	5485	0.01	0.11	0	1	169	0.04	0.19	0	1	5654	1.733	0.083
Overall Use of Fertilizers (Yes = 1, No = 0)	0.09	0.29	0	1	5485	0.15	0.35	0	1	206	0.10	0.29	0	1	5691	-2.533	0.011
Seed Type (Improved Seeds = 1, Traditional Seeds = 0)	0.14	0.34	0	1	5485	0.22	0.42	0	1	206	0.14	0.35	0	1	5691	-3.492	0.001
Use of pesticides (Yes = 1, No = 0)	0.09	0.28	0	1	5485	0.16	0.37	0	1	206	0.09	0.28	0	1	5691	-3.765	0.000
Gender of Respondent (Male = 0, Female = 1)	0.51	0.50	0	1	5410	0.48	0.50	0	1	203	0.51	0.50	0	1	5613	0.884	0.377
<i>Soil Types</i>																	
Sandy Loam (Yes = 1, No = 0)	0.39	0.49	0	1	5485	0.27	0.45	0	1	205	0.38	0.49	0	1	5690	3.331	0.001
Sand Clay Loam (Yes = 1, No = 0)	0.30	0.46	0	1	5485	0.23	0.43	0	1	205	0.30	0.46	0	1	5690	2.059	0.040
Black Clay (Yes = 0, No = 0)	0.17	0.37	0	1	5485	0.20	0.40	0	1	205	0.17	0.38	0	1	5690	-1.028	0.304
Other (Yes=1, No = 1, No = 0)	0.14	0.35	0	1	5485	0.30	0.46	0	1	205	0.15	0.36	0	1	5690	-6.142	0.000
<i>Tenure System</i>																	
Freehold (Yes = 1, No = 0)	0.44	0.50	0	1	5485	0.36	0.48	0	1	206	0.44	0.50	0	1	5691	2.211	0.027
Leasehold (Yes = 1, No = 0)	0.05	0.22	0	1	5485	0.06	0.24	0	1	206	0.05	0.22	0	1	5691	-0.795	0.427
Mailo (Yes = 1, No = 0)	0.04	0.20	0	1	5485	0.10	0.30	0	1	206	0.04	0.20	0	1	5691	-4.041	0.000
Customary (Yes = 1, No = 0)	0.44	0.50	0	1	5485	0.26	0.44	0	1	206	0.44	0.50	0	1	5691	5.121	0.000
Other (Yes = 1, No = 0)	0.03	0.16	0	1	5485	0.21	0.41	0	1	206	0.03	0.18	0	1	5691	-15.227	0.000
<i>General Topology</i>																	
Hilly (Yes = 1, No = 0)	0.05	0.21	0	1	5485	0.08	0.28	0	1	205	0.05	0.21	0	1	5690	-2.451	0.014
Flat (Yes = 1, No = 0)	0.49	0.50	0	1	5485	0.26	0.44	0	1	205	0.48	0.50	0	1	5690	6.454	0.000
Gentle Slope (Yes = 1, No = 0)	0.40	0.49	0	1	5485	0.45	0.50	0	1	205	0.40	0.49	0	1	5690	-1.464	0.143
Steep Slope (Yes = 1, No = 0)	0.04	0.18	0	1	5485	0.05	0.23	0	1	205	0.04	0.19	0	1	5690	-1.397	0.163
Valley (Yes = 1, No = 0)	0.02	0.15	0	1	5485	0.15	0.35	0	1	205	0.03	0.17	0	1	5690	-10.384	0.000
<i>Region</i>																	
Central (Yes = 1, No = 0)	0.30	0.46	0	1	5485	0.45	0.50	0	1	206	0.31	0.46	0	1	5691	-4.562	0.000
Eastern (Yes = 1, No = 0)	0.35	0.48	0	1	5485	0.26	0.44	0	1	206	0.35	0.48	0	1	5691	2.763	0.006
Northern Region (Yes = 1, No = 0)	0.17	0.37	0	1	5485	0.11	0.31	0	1	206	0.17	0.37	0	1	5691	2.323	0.020
Western (Yes = 1, No = 0)	0.18	0.38	0	1	5485	0.18	0.39	0	1	206	0.18	0.38	0	1	5691	-0.200	0.842
Crop Stand (Pure Stand = 1, Mixed Stand = 0)	0.61	0.49	0	1	5485	0.58	0.49	0	1	206	0.61	0.49	0	1	5691	0.757	0.449

Large-scale farmers form a much smaller group with 206 observations, but they produce substantially higher maize output. Their mean annual maize harvest is 520.3 kilograms, with a much larger variability (Std. Dev. 704.73 kg) and production ranging from 17.3 kg to 3,300 kg. Large-scale farmers are more concentrated in the Central region (45%), followed by the Eastern region (26%), with smaller shares in the Western (18%) and Northern (11%) regions. Compared to small-scales, they rely less on customary tenure (26%) and somewhat more on Mailo (10%) and other tenure arrangements (21%). Soil conditions differ slightly, with fewer farmers reporting sandy loam soils and a larger proportion reporting other soil types. Large-scale farmers also show higher adoption of modern agricultural inputs, including improved seeds (22%), fertilizers (15%), and pesticides (16%). Similar to small-scales, their production remains heavily dependent on rainfall (96%), although they are somewhat more likely to operate in valley areas (15%) and on hilly terrain (8%).

The pooled sample, which combines both groups, includes 5,691 observations and reflects the overall characteristics of maize farmers in the dataset. The average maize harvest in the pooled sample is 277.3 kilograms, with a standard deviation of 342.4 kg, and production ranging from 12.5 kg to 3,300 kg. The regional distribution closely resembles that of small-scale farmers, with 35% located in Eastern Uganda, 31% in Central, 17% in Northern, and 18% in Western. Similarly, the tenure structure in the pooled sample is dominated by freehold (44%) and customary (44%) systems, reflecting the strong influence of small-scales in the dataset. Most farmers rely on rainfall (95%) for maize production, and farms are commonly situated on flat (48%) or gently sloping (40%) land. The adoption of modern inputs remains relatively low overall, with only 14% using improved seeds, 10% applying fertilizers, and 9% using pesticides. Overall, the pooled statistics largely mirror the characteristics of small-scale farmers due to their overwhelming representation in the sample, even though large-scale farmers achieve higher average production levels.

4.3 Fixed Effects Model Results

Table 4.3 presents results of the fixed effects regression models estimating the determinants of maize production for small-scale farmers, large-scale farmers, and the pooled sample. Before interpreting the estimated coefficients, it is important to examine the diagnostic statistics to assess the reliability and explanatory power of the models.

Table 4-3: Fixed Effects Model Results for Predictors of Maize Production among Small-and Large-Scale Farmers and the Pooled Model

Average annual harvest (kilograms)	Small-scale Production				Large-scale Production				Pooled			
	Coef.	St. Err.	t-value	p-value	Coef.	St. Err.	t-value	p-value	Coef.	St. Err.	t-value	p-value
Irrigation (vs Rainfall)	-60.547*	34.596	-1.750	0.080	35.425	315.147	0.110	0.911	-75.445**	35.822	-2.110	0.035
Swamp (vs Rainfall)	-6.611	23.244	-0.280	0.776	-38.136	529.913	-0.070	0.943	-20.509	24.582	-0.830	0.404
Fertilizer Use (Yes vs No)	52.842***	15.456	3.420	0.001	236.197	174.633	1.350	0.178	74.377***	16.073	4.630	0.000
Seed Type (Traditional vs Improved)	67.877***	12.811	5.300	0.000	322.195**	158.989	2.030	0.045	92.62***	13.329	6.950	0.000
Pesticides (Yes vs No)	71.535***	16.425	4.360	0.000	13.736	162.577	0.080	0.933	88.007***	17.006	5.180	0.000
Gender (male vs female)	7.283	8.542	0.850	0.394	-40.057	102.369	-0.390	0.696	2.904	8.954	0.320	0.746
Sandy Loam (vs sandy clay loam)	-4.455	10.477	-0.430	0.671	373.443**	156.646	2.380	0.018	6.317	11.016	0.570	0.566
Black Clay (vs Sandy clay loam)	-1.578	13.183	-0.120	0.905	210.466	234.489	0.900	0.371	5.137	13.854	0.370	0.711
Other (vs Sandy clay loam))	-19.653	14.205	-1.380	0.167	128.246	215.848	0.590	0.553	-15.264	14.811	-1.030	0.303
Leasehold (vs freehold)	-21.799	20.536	-1.060	0.289	194.952	218.016	0.890	0.373	-7.677	21.344	-0.360	0.719
Mailo (vs freehold)	-15.251	23.580	-0.650	0.518	76.36	239.472	0.320	0.750	11.048	24.056	0.460	0.646
Customary (vs freehold)	-25.003*	14.388	-1.740	0.082	280.155	211.444	1.320	0.187	-12.438	15.086	-0.820	0.410
Others (vs freehold)	40.158	27.873	1.440	0.150	88.716	371.089	0.240	0.811	73.941***	27.997	2.640	0.008
Flat (vs Hilly)	-23.834	21.691	-1.100	0.272	-196.385	233.465	-0.840	0.402	-80.617***	22.310	-3.610	0.000
Gentle Slope (vs Hilly)	-40.792*	21.576	-1.890	0.059	-257.241	221.353	-1.160	0.247	-91.371***	22.225	-4.110	0.000
Steep Slope (vs Hilly)	-32.182	30.607	-1.050	0.293	-164.303	396.894	-0.410	0.680	-69.022**	31.626	-2.180	0.029
Valley (vs Hilly)	-92.898***	34.969	-2.660	0.008	-579.858	393.549	-1.470	0.143	-114.925***	35.110	-3.270	0.001
Eastern (vs Central)	25.884*	15.668	1.650	0.099	-1.077	191.121	-0.010	0.996	26.33	16.364	1.610	0.108
Northern (vs Central)	55.105***	19.087	2.890	0.004	-173.134	217.350	-0.800	0.427	39.879**	19.935	2.000	0.046
Western (vs Central)	63.693***	14.011	4.550	0.000	60.595	188.803	0.320	0.749	60.865***	14.686	4.140	0.000
Crop Stand (Mixed vs Pure)	64.001***	9.246	6.920	0.000	-116.932	147.643	-0.790	0.430	65.921***	9.703	6.790	0.000
Constant	224.623***	23.609	9.510	0.000	482.865**	227.586	2.120	0.036	266.314***	24.424	10.900	0.000
Sigma u	32.68708				359.70005				16.714405			
Sigma e	313.211				601.95462				333.26032			
Rho.	0.01077391				0.26311839				0.00250913			
Mean dependent var	268.146	SD dependent var	318.264		Mean dependent var	520.236	SD dependent var	721.556	Mean dependent var	275.607	SD dependent var	339.761
R-squared	0.032	Number of obs	5410		R-squared	0.32	Number of obs	165	R-squared	0.04	Number of obs	5575
F-test	8.579	Prob > F	0.000		F-test	3.118	Prob > F	0.000	F-test	11.14	Prob > F	0.000
Akaike crit. (AIC)	77552.07	Bayesian crit. (BIC)	77697.2		Akaike crit. (AIC)	2596.02	Bayesian crit. (BIC)	2664.35	Akaike crit. (AIC)	80608.61	Bayesian crit. (BIC)	80754.37
	*** $p < .01$, ** $p < .05$, * $p < .1$				*** $p < .01$, ** $p < .05$, * $p < .1$				*** $p < .01$, ** $p < .05$, * $p < .1$			

For the small-scale farmer model, the overall F-test ($F = 8.579$, $p < 0.001$) indicates that the explanatory variables jointly have significant explanatory power in predicting maize harvest. The small R^2 for small-scale farmers is typical in household-level agricultural production models where output is affected by multiple unobserved factors such as weather shocks, management practices, and pest outbreaks. The variance components further show that most of the variation in maize production occurs within households rather than between households, indicating that time-varying factors play an important role in shaping production outcomes.

For the large-scale farmer model, the explanatory variables are also jointly significant as shown by the F-statistic ($F = 3.118$, $p < 0.001$). The model explains a larger share of the variation in maize production ($R^2 = 0.32$), suggesting that the included variables capture a substantial portion of productivity differences among large farms. However, the relatively small number of observations in this group limits the statistical precision of some coefficient estimates.

Similarly, the pooled model confirms that the explanatory variables jointly influence maize production ($F = 11.14$, $p < 0.001$), although the explanatory power remains modest. The pooled results therefore provide an overall picture of the determinants of maize productivity across farm types. Having established that the models are statistically valid, the discussion now turns to the interpretation of the significant coefficients.

4.3.1 Results from the Small-Scale Farmers Model

The results show that regional location has a positive and significant influence on maize production among small-scale farmers, particularly in the Northern and Western regions relative to the Central region.

Specifically, small-scale farmers located in the Northern region harvest approximately 55 kilograms more maize annually than those in the Central region, while farmers in the Western region harvest about 63.7 kilograms more maize annually compared with those in Central Uganda. These findings suggest that agro-ecological conditions such as rainfall patterns, soil fertility, and land availability may be more favorable for maize cultivation in these regions.

Similar regional productivity differences have been documented in Uganda, where variations in agro-climatic conditions significantly influence crop yields (Dercon et al., 2009). This implies that regional-specific strategies are essential to enhance maize productivity. These findings

therefore support the study hypothesis that the geographical region where a farm is located significantly influences maize production.

The results indicate that customary land tenure has a negative and statistically significant effect on maize production relative to freehold tenure.

In particular, small-scale farmers operating under customary tenure produce approximately 25 kilograms less maize annually compared with those farming under freehold tenure. This suggests that weaker land ownership security may discourage long-term investments in land improvement, such as soil fertility management and infrastructure development.

This finding is consistent with previous research indicating that secure land tenure encourages farmers to invest more in land productivity (Place, 2009). The implication is that strengthening land tenure security could improve agricultural productivity among small-scale farmers. Consequently, the results support the study hypothesis, which proposes that the land tenure system is significantly associated with maize production.

The results further show that irrigation has a negative and significant effect on maize production relative to rainfall-based farming.

Specifically, farms using irrigation produce approximately 60.5 kilograms less maize annually than farms relying on rainfall. This counterintuitive result may reflect the fact that irrigation is often used in areas experiencing unfavourable rainfall conditions or environmental constraints.

Similar patterns have been observed in developing-country agriculture where irrigation is adopted as an adaptive strategy in areas with lower natural productivity (You et al., 2011). The implication is that irrigation infrastructure alone may not guarantee higher productivity without complementary investments such as improved seed varieties and soil management practices. These findings also support the hypothesis that the primary water source is significantly associated with maize production.

The results indicate that farms located on gentle slopes produce approximately 40.8 kilograms less maize annually compared with farms on hilly terrain, while farms located in valley areas produce approximately 92.9 kilograms less maize. These findings suggest that certain landforms may be associated with poor drainage, waterlogging, or soil erosion, which negatively affect maize productivity.

Previous studies have highlighted the importance of landform characteristics in determining soil fertility and crop performance (Food and Agricultural Organization [FAO], 2013). The implication is that land management and soil conservation practices are critical for improving productivity in less favorable terrains. The findings are in line with the study hypothesis which proposed that farm topography significantly influences maize production.

The results show that fertilizer use has a positive and statistically significant effect on maize production.

Small-scale farmers who apply fertilizers produce approximately 52.8 kilograms more maize annually than farmers who do not use fertilizers. This finding highlights the productivity enhancing role of soil nutrient management in maize farming systems.

Previous research in Sub-Saharan Africa has consistently shown that fertilizer application significantly improves crop yields (Sheahan & Barrett, 2017). The implication is that policies aimed at improving farmers' access to fertilizers, such as subsidy programs or improved distribution systems, could substantially increase maize productivity. These results therefore support the study hypothesis which states that fertilizer use is positively associated with higher maize production.

The results further indicate that pesticide use positively and significantly affects maize production.

Specifically, small-scale farmers who use pesticides harvest approximately 71.5 kilograms more maize annually compared with those who do not use pesticides. This suggests that pest management plays an important role in protecting crop yields and improving farm productivity.

These findings align with studies showing that pest infestations significantly reduce crop yields in Sub-Saharan Africa and that pesticide use can mitigate these losses (Liverpool-Tasie et al., 2017). The implication is that strengthening access to crop protection technologies could enhance maize productivity among small-scale farmers. Thus, the study hypothesis that pesticide use increases maize production.

Seed choice also significantly influences maize production among small-scale farmers. The results show that farmers using traditional seeds produce approximately 67.9 kilograms more maize annually than those using improved seeds. While this result appears

counterintuitive, it may reflect the fact that improved seeds often require complementary inputs such as fertilizers and irrigation to realize their yield potential.

Previous studies have documented similar findings where improved seed varieties fail to outperform traditional seeds when complementary inputs are limited (Doss, 2006). The implication is that seed adoption programs should be accompanied by improved access to fertilizers and extension services. As a result, the findings do not support the study hypothesis, which predicted that improved seeds would increase maize production.

Overall, the results highlight that regional conditions, farming inputs, land tenure arrangements, and farm management practices play critical roles in shaping maize productivity among small-scale farmers in Uganda. The findings suggest that policies aimed at improving input access, land tenure security, and location-specific agricultural support programs could significantly enhance small-scale maize production.

4.3.2 Results from the Large-Scale Farmers Model

Among large-scale farmers, fewer variables appear statistically significant, although some important factors still influence maize harvest. The results show that sandy loam soil and traditional seed use have positive effects on maize harvest among large farms.

In terms of soil characteristics, farms located on sandy loam soils produce approximately 373.4 kilograms more maize annually compared with farms on sandy clay loam soils. This result highlights the importance of soil texture and fertility in determining agricultural productivity. Sandy loam soils typically provide better drainage, root penetration, and nutrient availability, which are particularly beneficial for maize cultivation. Similar findings have been reported in agronomic studies showing that maize yields are significantly higher in well-drained soils with balanced texture (FAO, 2013).

Seed type also plays an important role in maize productivity among large farms. The results indicate that farms using traditional seeds produce approximately 322.2 kilograms more maize annually compared with those using improved seeds. This may reflect the possibility that large farms select seed varieties based on specific agro-ecological conditions or that improved seeds require complementary inputs that are not consistently applied. Previous studies have shown that the productivity advantage of improved seeds often depends on the availability of complementary inputs such as fertilizers and irrigation (Doss, 2006).

These findings suggest that soil quality and seed selection remain critical determinants of productivity even among larger and more commercial farms. The results imply that policies focusing on soil management practices and appropriate seed selection strategies could enhance maize productivity among large-scale producers.

4.3.3 Results from the Pooled Model

The pooled model, which combines both small-scale and large-scale farmers, identifies several important determinants of maize productivity across the entire sample. The results show positive effects for the Northern and Western regions, fertilizer use, pesticide use, mixed cropping, traditional seed use, and other tenure arrangements, while irrigation and several topographic conditions have negative effects on maize harvest.

Regional effects remain significant in the pooled model. Farmers located in the Northern region produce approximately 39.9 kilograms more maize annually than those in the Central region, while those in the Western region harvest about 60.9 kilograms more maize annually. These results reinforce the importance of agro-ecological conditions and regional differences in shaping agricultural productivity. Similar regional disparities in crop productivity have been documented in Uganda's agricultural sector (Benin et al., 2007).

Land tenure also affects production outcomes. Farms operating under other tenure arrangements produce approximately 73.9 kilograms more maize annually compared with freehold tenure systems. This may reflect institutional or commercial farming arrangements that enable larger production scales and better access to resources.

Topography plays a significant role in determining productivity outcomes. Compared with hilly terrain, farms located on flat land produce approximately 80.6 kilograms less maize annually, those on gentle slopes produce about 91.4 kilograms less, those on steep slopes produce about 69 kilograms less, and those in valleys produce approximately 114.9 kilograms less maize. These results highlight how landform characteristics can influence soil drainage, erosion patterns, and overall crop performance.

Input use remains one of the strongest determinants of maize productivity in the pooled sample. Farmers who use fertilizer produce approximately 74.4 kilograms more maize annually, while those who use pesticides harvest about 88 kilograms more maize annually. These findings strongly support the literature emphasizing the importance of agricultural input adoption in

improving crop yields in Sub-Saharan Africa (Sheahan & Barrett, 2017; Liverpool-Tasie et al., 2017).

Cropping systems also influence productivity. Farmers practicing mixed cropping produce approximately 65.9 kilograms more maize annually than those practicing pure stands, suggesting that crop diversification may enhance soil fertility and reduce production risks.

Finally, seed choice remains a significant determinant of maize productivity. Farmers using traditional seeds produce approximately 92.6 kilograms more maize annually than those using improved seeds. While this finding appears counterintuitive, previous studies have noted that improved seeds often require complementary inputs such as fertilizers and irrigation to realize their full productivity potential (Doss, 2006).

Taken together, the pooled results confirm that regional conditions, land characteristics, agricultural inputs, cropping practices, and seed choice are important determinants of maize productivity. The findings suggest that improving access to inputs, promoting appropriate farming practices, and addressing agro-ecological constraints could significantly enhance maize production in Uganda.

Table 4-4: Summary of Significant study hypotheses

Hypotheses	Small-scale	Large-scale	Pooled	Conclusion
H11: Seed Type	Yes	Yes	Yes	Fully confirmed
H12: Fertilizer Use	Yes	No	Yes	Partially confirmed
H13: Pesticide Use	Yes	No	Yes	Partially confirmed
H14: Irrigation	Yes	No	Yes	Partially confirmed
H21: Crop Stand System	Yes	No	Yes	Partially confirmed
H31: Soil Type	No	Yes	No	Partially confirmed
H32: Land Topology	Yes	No	Yes	Partially confirmed
H33: Land Tenure System	Yes	No	Yes	Partially confirmed
H34: Regional Location	Yes	No	Yes	Partially confirmed

Note: Fully Confirmed: A hypothesis is classified as fully confirmed when the estimated coefficient was statistically significant ($p < 0.05$) and in the expected direction for all three samples (small-scale, large-scale, and pooled). Partially Confirmed: A hypothesis is classified as partially confirmed when the estimated coefficient was statistically significant ($p < 0.05$) and in the expected direction for some but not all of the three samples.

The results summarized in Table 4.4 indicate that several hypotheses receive empirical support, although the effects vary across farm scales. Seed type emerges as the only determinant that is fully confirmed, showing significant effects on maize production among small-scale, large-scale, and pooled farmers. In contrast, most other factors are partially confirmed, reflecting differences in how production determinants operate across farming systems. For example, fertilizer use and pesticide application significantly increase maize production for small-scale farmers and in the pooled sample, but their effects are not statistically significant for large-scale farms. Similarly, irrigation, crop stand, regional location, and land topology show significant effects mainly among small-scale farmers and in the pooled model, indicating that these factors are particularly relevant in small-scale production systems.

Other production determinants exhibit scale-specific effects. Soil type is significant only among large-scale farmers, suggesting that soil conditions may play a stronger role in determining productivity where farming operations are more intensive. Likewise, land tenure arrangements show partial support, with customary tenure affecting small-scale farmers and other tenure arrangements influencing production in the pooled sample. Overall, these results highlight that maize productivity in Uganda is shaped by a combination of farm management practices, agro-ecological conditions, and institutional factors, but their influence varies between small-scale and larger commercial farms.

The partial confirmation of most hypotheses suggests that agricultural policies should be tailored to different farm scales. For instance, interventions aimed at expanding access to fertilizers, pesticides, and improved crop management practices may be particularly beneficial for small-scale farmers, who constitute the majority of producers. At the same time, improving soil management and land tenure arrangements may help enhance productivity among larger farms. Together, these findings underscore the importance of context-specific agricultural policies to improve maize production and strengthen maize production in Uganda.

4.4 Discussion

This section discusses the study findings in relation to existing literature, examines the implications for agricultural policy in Uganda, and highlights the broader significance of the results for maize productivity among small-scale and large-scale farmers. The discussion is

organized thematically, covering input factors, demographic factors, biophysical and regional factors, and the comparative analysis of small-scale versus large-scale farmers.

4.4.1 Input Factors and Maize Production

Fertilizer Use

The results show that fertilizer use is positively associated with maize production among small-scale farmers, with users producing approximately 52.8 kilograms more maize annually than non-users ($p < 0.01$). This finding is consistent with previous research in Uganda. Mbatuusa (2026) found that inorganic fertilizer significantly increases maize productivity, with users achieving 29.7% higher yields than non-users at the 5% significance level. Organic fertilizer was also positively associated with maize productivity, yielding 17.8% higher maize productivity among users compared to non-users (Mbatuusa, 2026). Similarly, Kanyenyeri (2025) reported that farmers who adopted both improved maize seed and inorganic fertilizer experienced a 185.5% increase in yield, with an average treatment effect on the treated of 735 kg/ha, while those who adopted only inorganic fertilizer achieved yield gains of 137.8% (ATT = 359 kg/ha) compared to non-adopters. Adongo (2023) also identified fertilizer application as a key determinant of maize productivity among smallholder farmers in Lira District. The positive effect of fertilizer use in this study suggests that soil nutrient depletion remains a major constraint on maize productivity in Uganda, and addressing this constraint through fertilizer access could substantially increase output.

However, the relatively low adoption rate of fertilizers (9% among small-scale farmers in this study, consistent with UBOS, 2020 figures of 4.4%–5.5%) indicates significant barriers to fertilizer use. These barriers include high costs, limited availability, inadequate extension support, and insufficient farmer knowledge on fertilizer application methods. Kanyenyeri (2025) found that fertilizer misapplication, including wrong application methods, applying below the Abuja Declaration target of 50 kg/ha, and below the recommended optimal rate of 125 kg/ha, led to significant yield reductions of 21%, 28%, and 35%, respectively. Moreover, combined forms of misapplication further intensified yield losses, with the greatest loss of 34% occurring when fertilizer was applied below the Abuja target using wrong methods. Notably, the results indicated that applying fertilizer within the recommended midrange (50–125 kg/ha) significantly increased maize yield by 16%. This underscores the importance of not only access to fertilizers but also proper application practices.

The finding that fertilizer use was not statistically significant among large-scale farmers in this study may reflect the fact that large-scale farmers, despite having greater access to inputs, may not achieve the same marginal returns as small-scale farmers. This could be due to diminishing returns to fertilizer application at higher levels, or because large-scale farmers already operate closer to the technical frontier where marginal gains from additional input use are smaller. Nandaula (2024) found that smallholder maize farmers had technical efficiency of 56.7%, suggesting they could still improve output by 43.3% while maintaining the same input levels. This considerable efficiency gap indicates that small-scale farmers have substantial room for improvement through better input use and management practices, whereas large-scale farmers may already be operating more efficiently.

Seed Type and Maize Production

The results reveal a counterintuitive finding: farmers using traditional seeds produce significantly more maize than those using improved seeds across both farmer categories, small-scale farmers using traditional seeds harvest 67.9 kg more, while large-scale farmers harvest 322.2 kg more annually. While this result appears contrary to expectations, it aligns with recent research on seed certification in Uganda. Kanyenyeri (2025) found that farmers who adopted both improved maize seed and inorganic fertilizer experienced the greatest yield gains, but those who adopted only improved maize seed achieved yield gains of 138.5% (ATT = 698 kg/ha) compared to non-adopters. This suggests that improved seeds do have potential to increase yields, but only when accompanied by complementary inputs. The finding that traditional seeds appear to outperform improved seeds in this study may reflect the fact that farmers using improved seeds often lack access to, or fail to apply, the complementary inputs required to realize their full potential. Mbatuusa (2026) found that the interaction effect between fertilizer use, pesticide use, and seed type was statistically insignificant, likely due to low adoption of these complementary inputs by farmers.

The implications of this finding are significant for agricultural policy. While promoting improved seed varieties remains an important strategy for increasing agricultural productivity, such promotion must be accompanied by efforts to ensure that farmers have access to complementary inputs and knowledge of appropriate agronomic practices. Van Campenhout et al. (2025) found that seed sample packs positively influenced farmers' perceptions, but farmers who received them tended to recycle harvested grain as seed, leading to productivity losses.

This suggests that seed delivery systems should focus not only on distribution but also on ensuring that farmers understand the importance of purchasing fresh seed each season.

Pesticide Use

The results indicate that pesticide use positively and significantly affects maize production among small-scale farmers, with users harvesting approximately 71.5 kilograms more maize annually compared with non-users ($p < 0.01$). This finding aligns with studies showing that pest infestations significantly reduce crop yields in Sub-Saharan Africa and that pesticide use can mitigate these losses. Osewe et al. (2023) highlighted that pesticide use is significant in controlling emergent pests and diseases, which are increasingly prevalent due to climate change and the spread of pests such as fall armyworm.

However, studies have also highlighted concerning practices among Ugandan farmers, including limited knowledge on pesticide application, misinterpretation of label instructions, non-compliance with pre-harvest intervals, and the mixing of different pesticides, which can pose risks to farmers' health and reduce food quality. Addressing these issues is crucial to ensure safe agricultural productivity and sustainable food production. Andersson and Isgren (2021) documented that small-scale farmers in Uganda often engage in risky pesticide use practices due to limited knowledge and inadequate extension support, highlighting the need for integrated pest management training programs.

Irrigation

The results show that irrigation has a negative and significant effect on maize production among small-scale farmers, with farms using irrigation producing approximately 60.5 kilograms less maize annually than farms relying on rainfall. This counterintuitive result may reflect the fact that irrigation is often used in areas experiencing unfavorable rainfall conditions or environmental constraints, where farmers may be trying to compensate for poor growing conditions. Studies in developing-country agriculture have documented that irrigation is often adopted as an adaptive strategy in areas with lower natural productivity (You et al., 2011), which may explain why irrigated farms in this study appear to have lower production.

Furthermore, irrigation alone may not guarantee higher productivity without complementary investments such as improved seed varieties, fertilizer application, and soil management practices. Many small-scale farmers in Uganda lack the technical knowledge and financial resources to use irrigation systems effectively, resulting in suboptimal water management and

limited productivity gains. The negative effect may also reflect the fact that irrigation is primarily adopted by farmers in drought-prone areas where rainfall is insufficient for reliable maize production, and even with irrigation, yields may not match those in areas with favorable rainfall conditions.

Crop Stand Systems

The results indicate that farmers practicing mixed cropping produce significantly more maize than those using pure stands, approximately 64 kilograms more annually among small-scale farmers ($p < 0.01$). This finding aligns with the complementary interactions between maize and legume crops, where legumes fix nitrogen in the soil, reducing the need for inorganic fertilizer while improving soil fertility. Semalulu et al. (2022) found that intercropping maize with beans reduced maize yields by 16% to 25% compared to pure stand maize cultivation in drought-prone areas of Uganda, suggesting that the benefits of mixed cropping may depend on specific agro-ecological conditions.

However, the positive effect of mixed cropping in this study may reflect the fact that well-designed intercropping systems can enhance productivity through complementary resource use, improved soil fertility, and reduced pest pressure. Mugisa et al. (2020) reported that while intercropping is widely practiced by small-scale farmers as a risk management strategy, pure stand maize production consistently yields higher maize output per unit area in high-potential areas with reliable rainfall and access to inputs. This suggests that the productivity advantage of mixed cropping over pure stands observed in this study may reflect the specific conditions of the sample, including the prevalence of small-scale farmers in resource-constrained environments.

4.4.2 Demographic Factors

Gender

The results show that gender of the household head does not have a statistically significant effect on maize production in any of the models ($p > 0.05$). This finding contrasts with previous research in Uganda, which has consistently documented gender gaps in agricultural productivity. Julien et al. (2023) found that female-managed plots tend to have lower productivity compared to male-managed plots, with a gender productivity gap attributed to structural advantages favoring male farmers. Miriti et al. (2023) also documented significant productivity disparities favoring male farmers over female farmers in Uganda. The absence of a significant gender effect in this study may reflect the fact that the fixed effects regression

model controls for time-invariant household characteristics, including gender-related structural advantages that may not vary over time.

Alternatively, the finding may suggest that gender differences in maize productivity have diminished over time due to targeted interventions to support women farmers. Government programs such as Operation Wealth Creation (OWC) and the e-voucher subsidy programme have aimed to improve access to inputs for all farmers, which may have helped to reduce gender-based disparities. Nandaula (2024) found that gender of the household head had a significant effect on economic efficiency but not technical efficiency, suggesting that while women may face constraints in input markets and resource allocation, they are equally capable of achieving technical efficiency when they have access to comparable resources.

4.4.3 Biophysical and Regional Factors

Land Tenure System

The results show that customary land tenure has a negative and statistically significant effect on maize production among small-scale farmers relative to freehold tenure, with farmers operating under customary tenure producing approximately 25 kilograms less maize annually ($p < 0.10$). This finding is consistent with previous research indicating that secure land tenure encourages farmers to invest more in land productivity (Place, 2009). Deininger and Ali (2008) found that the insecurity inherent in Uganda's land tenure arrangements, particularly the overlapping ownership and use rights on mailo land and the ambiguous nature of customary holdings, has been identified as a critical impediment to agricultural investment.

A qualitative study by Akullo et al. (2025) in Mbale, Bukedea, and Luwero districts found that land fragmentation, tenure insecurity, and land commodification are intensifying land-use conflicts and redefining household food security strategies. This underscores the urgency of land reform to provide secure tenure rights for small-scale farmers. Alobo et al. (2012) found a positively significant premium for leasehold title as opposed to other forms of titled agricultural land, recommending that land policy promote the leasehold system while addressing the double ownership structure under mailo tenure.

Regional Location

The results indicate that regional location has a positive and significant influence on maize production among small-scale farmers, particularly in the Northern and Western regions relative to the Central region. Small-scale farmers in the Northern region harvest approximately 55

kilograms more maize annually than those in the Central region, while farmers in the Western region harvest about 63.7 kilograms more maize annually. These findings suggest that agro-ecological conditions such as rainfall patterns, soil fertility, and land availability may be more favorable for maize cultivation in these regions.

Mbatuusa (2026) found lower maize yields in the Northern and Eastern regions relative to the Central region, and higher productivity recorded in the Western region. Nekesa (2024) found that the Kyoga plain agro-ecological zone benefited more from inorganic fertilizer and pesticide use compared to the highland zone, suggesting regional differences in the effectiveness of agricultural inputs. Babyenda et al. (2023) found that Eastern Uganda is likely to be the region most affected by climate variability, while beans and banana are likely to be more affected compared to maize and cassava.

Soil Type

Among large-scale farmers, sandy loam soils have a positive and significant effect on maize production, with farms on sandy loam soils producing approximately 373.4 kilograms more maize annually compared with those on sandy clay loam soils ($p < 0.05$). This finding highlights the importance of soil texture and fertility in determining agricultural productivity, particularly for larger farms where intensive cultivation may deplete soil nutrients more rapidly. Sandy loam soils typically provide better drainage, root penetration, and nutrient availability, which are particularly beneficial for maize cultivation.

The fact that soil type was not significant among small-scale farmers may reflect the smaller plot sizes and more varied soil conditions on small farms, where the effect of soil type may be confounded by other factors such as management practices, input use, and family labor. Additionally, small-scale farmers may be more likely to select plots based on soil suitability, whereas large-scale farmers may cultivate larger areas with more variation in soil conditions.

4.5 Comparative Analysis: Small-Scale vs Large-Scale Farmers

The central question of this study was whether large-scale farmers achieve higher maize production than small-scale farmers in Uganda. The findings provide a nuanced answer to this question.

In terms of absolute production, large-scale farmers achieve substantially higher average annual harvests (520.3 kg) compared to small-scale farmers (268.1 kg). This difference is statistically significant ($t = -10.475$, $p < 0.001$) and represents a nearly two-fold productivity gap. However,

this absolute difference does not necessarily indicate that large-scale farmers are inherently "better" or more efficient. Nandaula (2024) found that smallholder maize farmers had technical efficiency of 56.7%, suggesting that farmers could still improve output by 43.3% while maintaining the same input levels. This considerable efficiency gap indicates that small-scale farmers have substantial room for improvement through better access to inputs, improved management practices, and enhanced institutional support.

The analysis reveals that small-scale farmers demonstrate significant productivity responses when they have access to inputs. When small-scale farmers use fertilizers, their production increases by 52.8 kg; when they use pesticides, production increases by 71.5 kg. This suggests that the productivity gap may be more a function of differential access to inputs and institutional support than inherent differences in farming ability. Kanyenyeri (2025) found that farmers who adopted both improved maize seed and inorganic fertilizer experienced a 185.5% increase in yield (ATT = 735 kg/ha), with the highest productivity gains observed from the combined use of modern inputs. This underscores the importance of comprehensive input adoption for productivity enhancement.

Furthermore, the finding that traditional seeds outperform improved seeds among both groups suggests that the current agricultural technology delivery system may not be adequately serving either group. Mbatuusa (2026) found that the interaction effect between fertilizer use, pesticide use, and seed type was statistically insignificant, likely due to low adoption of these complementary inputs by farmers. This is particularly concerning given that improved seeds are often promoted as a key strategy for increasing agricultural productivity, yet the low adoption of complementary inputs limits their effectiveness.

In terms of policy implications, the findings suggest that strategies aimed at improving small-scale farmers' access to inputs and support services may be more effective for achieving national maize production targets than focusing exclusively on large-scale farmers. This is particularly important given that small-scale farmers constitute approximately 85% of agricultural households in Uganda (NARO info Hub, 2014) and demonstrate significant productivity responses to inputs. Adongo (2023) found that key determinants of maize productivity included farm size, fertilizer application, source of maize seeds, proximity to roads, and group membership, highlighting the importance of addressing these factors for smallholder farmers.

4.6 Summary

The results of this study demonstrate that maize productivity in Uganda is shaped by a complex interplay of input factors, demographic characteristics, and biophysical and regional factors, with effects that vary significantly between small-scale and large-scale farmers. While large-scale farmers achieve higher average production, small-scale farmers show significant productivity responses to input adoption, suggesting that the productivity gap is largely driven by differential access to inputs and institutional support rather than inherent differences in farming ability. These findings have important implications for agricultural policy, highlighting the need for comprehensive, context-specific strategies that address the diverse constraints and opportunities facing maize farmers in Uganda.

CHAPTER 5 : SUMMARY OF FINDINGS, CONCLUSIONS, RECOMMENDATIONS, AND AREAS FOR FURTHER RESEARCH

5.1 Introduction

This chapter presents a discussion on the summary of results from the study conducted, the conclusions made and evidence-based recommendations. The study also highlights the areas that still need further research.

5.2 Summary of Results

This study investigated the factors influencing maize production among small-scale and large-scale farmers in Uganda using data from the Uganda National Panel Survey (UNPS) spanning 2010 to 2018. The analysis employed fixed effects regression models to examine the effects of input factors, demographic characteristics, and biophysical factors on maize harvest quantities. The study sample comprised 5,485 small-scale farmers and 206 large-scale farmers, reflecting the dominance of small-scale farmers in Uganda's maize production system.

The results revealed significant differences in production patterns between the two groups. Small-scale farmers produced an average of 268.1 kilograms of maize annually, with considerable variability across regions and over time. Large-scale farmers, despite their smaller numbers, achieved substantially higher average production of 520.3 kilograms per year, though with even greater variability. Adoption of modern agricultural inputs remained low overall, with only 14% of farmers using improved seeds, 10% applying fertilizers, and 9% using pesticides. The vast majority (95%) of farmers relied entirely on rain-fed agriculture.

The regression analysis identified several key determinants of maize production that varied by farm scale. Among small-scale farmers, regional location, land tenure arrangements, water source, topography, fertilizer use, pesticide application, crop stand system, and seed type all showed statistically significant effects on production. For large-scale farmers, soil type and seed type emerged as the primary significant factors. The pooled model confirmed that regional conditions, land characteristics, agricultural inputs, cropping practices, and seed choice are important determinants of maize productivity across the entire farming population.

5.3 Conclusions

Based on the findings, this study draws the following conclusions:

First, the government's current strategy of channelling support primarily to large-scale farmers may compromise the equity and efficiency perspectives, thus crippling the abilities of small-scale farmers to contribute to the overall national food production abilities. Small-scale farmers constitute over 96% of all maize producers and demonstrate significant productivity responses to inputs when they can access them. Excluding this majority from support programs undermines the very maize production goals the government seeks to achieve.

Second, the productivity gap between small-scale and large-scale farmers is not immutable. Small-scale farmers may produce lower on average not because they are inherently less capable, but because they are unable to access the necessary inputs, services, and institutional support that drive productivity. The study found that when small-scales access fertilizers and pesticides, their production increases substantially, by 52.8 kilograms and 71.5 kilograms respectively.

Third, the finding that traditional seeds outperform improved seeds across both farmer categories exposes a fundamental failure in the agricultural technology development and delivery system. Improved seeds are being promoted without the complementary inputs and management practices required to realize their potential, leaving farmers, both small and large, better off with traditional varieties.

Fourth, regional disparities in maize production suggest that a one-size-fits-all national strategy, focused on a few institutional farms, cannot address the diverse agro-ecological and socioeconomic conditions across Uganda. The Northern and Western regions significantly outperform the Central region, indicating that location-specific constraints and opportunities must be addressed if production disparities are to be addressed.

5.4 Recommendation

The study found that small-scale farmers in the Northern region produce approximately 55.1 kilograms more maize annually than those in the Central region, while farmers in the Western region produce about 63.7 kilograms more maize compared to those in Central Uganda. These regional disparities reflect differences in agro-ecological conditions, farming practices, and institutional support. The study recommends that,

- The Government of Uganda must immediately revise the presidential directive to include small-scale farmers in agricultural support programs, recognizing that excluding 96% of farmers is economically inefficient and cannot achieve national maize production.
- The Ministry of Agriculture should develop regionally targeted support programs that build on the demonstrated productivity of small-scales in Northern and Western Uganda, rather than concentrating all resources on institutional farms.

The study revealed that small-scale farmers operating under customary tenure produce approximately 25 kilograms less maize annually compared to those farming under freehold tenure. This productivity gap suggests that tenure insecurity undermines investment in land improvement and productivity-enhancing practices.

- The Ministry of Lands should accelerate formalization of customary land rights in high potential agricultural areas, enabling small-scales to access the same tenure security that institutional farmers enjoy.
- Agricultural support programs should be designed to reach customary tenure farmers regardless of their formal land documentation, recognizing that waiting for land reform before supporting small-scales is impractical and unjust.

Among large-scale farmers, those farming on sandy loam soils produce approximately 373.4 kilograms more maize annually compared to those on sandy clay loam soils. This substantial productivity difference highlights the critical role of soil texture and fertility in determining maize yields.

- Soil testing services should be made accessible to all farmers, enabling both small and large-scale producers to make informed decisions about soil management and crop selection.

The study found that small-scale farmers who apply fertilizers produce approximately 52.8 kilograms more maize annually than non-users. This significant productivity gain demonstrates the transformative potential of fertilizer adoption, yet adoption rates remain below 10 percent nationally.

- The government should redesign the current fertilizer subsidy program to ensure that subsidized fertilizers reach all farmers (including small-scale farmers) on time and in appropriate quantities. Past programs have been criticized for late delivery and inadequate coverage.

The results indicated that small-scale farmers using pesticides harvest approximately 71.5 kilograms more maize annually compared to non-users. This substantial yield gain underscores the importance of pest management in protecting crop output.

- Training programs on integrated pest management should be expanded to reach small-scales through farmer field schools, making pest management knowledge available to all farmers regardless of scale.
- Research on water-use efficiency and drought-tolerant varieties should be strengthened to reduce maize production's vulnerability to rainfall variability. Even with expanded irrigation, most farmers will continue to rely on rain-fed production for the foreseeable future.

The study found significant negative effects of various topographic conditions on maize production. Compared to hilly terrain, farms on gentle slopes produce approximately 40.8 kilograms less maize, and valley farms produce about 92.9 kilograms less maize annually. These findings highlight how landform characteristics influence drainage, erosion, and overall crop performance.

- Land use planning at district level should consider topographic suitability when promoting maize cultivation, advising farmers on crops best suited to their specific landform conditions.

Farmers practicing mixed cropping produce approximately 64 kilograms more maize annually than those using pure stands, suggesting that crop diversification enhances productivity through complementary interactions between crops

- Extension services should actively promote well-designed mixed cropping systems that have been validated through research. Rather than encouraging specialization, programs should recognize the productivity and risk management benefits of diversified farming systems.

5.5 Areas for Further Research

First, the counterintuitive finding that traditional seeds outperform improved seeds requires investigation into whether this reflects problems with seed quality, inadequate complementary input use, poor adaptation of improved varieties, or farmer selection biases.

Second, the negative productivity effect of irrigation among small-scale farmers deserves research attention to determine whether this reflects selection bias, inadequate water management, poor infrastructure quality, or insufficient complementary inputs.

Third, the mechanisms through which land tenure affects productivity should be examined, focusing on whether customary tenure constrains specific investments and whether tenure formalization programs lead to changed investment behavior.

Fourth, the regional productivity differences documented warrant investigation into the relative contributions of agro-ecological conditions, infrastructure access, market integration, and institutional quality.

Fifth, research on climate change adaptation in maize production should be prioritized given Uganda's vulnerability to climate variability, examining how changing rainfall patterns affect optimal planting dates and variety choices.

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DO- FILE

use "Analysis Data.dta", clear

```
lab var year          "Pannel Year"
lab var mult_win      "Winsorized panel weights" lab var farm_scale
"Scalae of production based on total area planted" lab var seas_1
"Season one havest in killograms" lab var seas_2          "Season two
havest in killograms" lab var ann_harvest          "Total harvest for two
season"
lab var h2q3          "SEX" lab var region
"Region of Residence" lab var a2q7
"Tenure system"
lab var a2q16          "What soil type is this parcel?" lab var a2q18
"What is the main water source to this parcel?" lab var a2q19          "In
general, what is the topography of this parcel?" lab var fert_use
"Did you use any fertilizer on the parcel/plot?" lab var a3q22
"Did you use any pesticides onthe parcel/plot?" lab var a4q8
"Type of stand of the crop"
lab var a4q13          "What type of seed did you purchase?"
```

*for outliers

```
* Install winsor2 if not available capture which winsor2
if _rc != 0 {      ssc install
winsor2, replace
}
```

```
* Process multiple variables at once
winsor2 ann_har, replace cuts(1 99) trim // Creates _w variables
```

```
* For interpolation with panel data xtset year // Set panel structure foreach var of varlist
ann_harvest {
ipolate `var' year, gen(`var'_ipolate) by(year)
}
```

*Summay Tables (Descriptives)

```
* Distribution of Study Variables in the tabstat format
asdoc tabstat ann_harvest region_1 region_2 region_3 region_4 h2q3 ///
tenure_1 tenure_2 tenure_3 tenure_4 tenure_5 ///
soil_1 soil_2 soil_3 soil_4 ///
water_1 water_2 water_3 ///
topology_1 topology_2 topology_3 topology_4 topology_5 ///
```

```

    fert_use a3q22 a4q8 a4q13 if farm == 0, ///      statistics(mean sd
min max count) columns(statistics) format(%9.3f) ///
save(summary.doc)

```

* Get Distribution of Study Variables in the tabstat format

```

asdoc tabstat ann_harvest region_1 region_2 region_3 region_4 h2q3 ///
    tenure_1 tenure_2 tenure_3 tenure_4 tenure_5 ///
    soil_1 soil_2 soil_3 soil_4 ///      water_1 water_2 water_3
///      topology_1 topology_2 topology_3 topology_4 topology_5
///

```

```

    fert_use a3q22 a4q8 a4q13 if farm == 1, ///      statistics(mean sd
min max count) columns(statistics) format(%9.3f) ///
save(summary.doc)

```

```

asdoc tabstat ann_harvest region_1 region_2 region_3 region_4 h2q3 ///
    tenure_1 tenure_2 tenure_3 tenure_4 tenure_5 ///
    soil_1 soil_2 soil_3 soil_4 ///      water_1 water_2 water_3 ///
topology_1 topology_2 topology_3 topology_4 topology_5 ///      fert_use
a3q22 a4q8 a4q13 , ///      statistics(mean sd min max count)
columns(statistics) format(%9.3f) ///      save(summary.doc)

```

*model (Scale of Production, large scale and small scale)

```

by farm_scale, sort : xtreg ann_harvest ipolate i.region i.h2q3 i. a2q7 i.a2q16 i.a2q18 i.a2q19
i.fert_use i.a3q22 a3q22 i.a4q8 i.a4q8 i.a4q13, pa

```

*Pooled

```

xtreg ann_harvest ipolate i.region i.h2q3 i. a2q7 i.a2q16 i.a2q18 i.a2q19 i.fert_use i.a3q22
a3q22 i.a4q8 i.a4q8 i.a4q13, pa

```