

MAKERERE



UNIVERSITY

**DETERMINANTS OF THE INTENSITY OF INORGANIC FERTILIZER
AND IMPROVED SEED USE AMONG SMALLHOLDER MAIZE
PRODUCERS IN UGANDA**

BY

KUGONZA SARAH SORO

BBS (MAKERERE UNIVERSITY)

**A DISSERTATION SUBMITTED TO THE DIRECTORATE OF GRADUATE
TRAINING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF MASTER OF
STATISTICS OF MAKERERE UNIVERSITY**

September, 2026

DECLARATION

I, Kugonza Sarah Soro hereby declare that this study is original and has not been submitted for any other degree award to any other University before.

Signature.....

Date: 28/7/2026

Name: **KUGONZA SARAH SORO**

Reg No: **2019/HD06/26665U**

Student No: **1900726665**

APPROVAL

This dissertation has been submitted for examination with the approval of the following University Supervisors:

Muganga Kizito Andrew (PhD)

School of Statistics and Planning

Department of Statistical Methods and Actuarial Science

Makerere University

Signature.....

Date.....

Richard Tuyiragize (PhD)

School of Statistics and Planning

Department of Planning and Applied Statistics

Makerere University

Signature.....

Date.....

DEDICATION

I dedicate this piece of work to my lovely parents, Mr. Kato Felix and Sauya Nyangoma for their support and interest in my education.

ACKNOWLEDGEMENTS

My sincere gratitude goes to the almighty God for the opportunity and abundance of grace that he offered that enabled me to go through this journey successfully.

Special thanks goes to my supervisors Dr. Richard Tuyiragize and Dr. Muganga Kizito Andrew for their guidance and valuable input all through the process of working on this dissertation. Your commitment and sacrifice has made this work possible.

Last but not least I would like to thank all my colleagues and friends with whom we shared knowledge, ideas and fun throughout the course of this study especially Martha Nakawuba and Kiyagga Steven.

TABLE OF CONTENTS

DECLARATION	i
APPROVAL	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF TABLES	vii
LIST OF ABBREVIATIONS	viii
ABSTRACT	ix
CHAPTER ONE: INTRODUCTION	1
1.1. Background to the Study	1
1.2 Statement of the problem	2
1.3 Objectives of the Study	3
1.3.1 Main objective.....	3
1.3.2 Specific objectives.....	3
1.4 Hypotheses	3
1.5. Significance of the study	4
1.6 Conceptual framework	5
1.7. Scope of the study	6
1.8. Structure of the dissertation	7
CHAPTER TWO: LITERATURE REVIEW	8
2.1 Introduction	8
2.2 The Intensity of Maize Production Technology Use	8
2.3 Factors Influencing the Intensity of Inorganic Fertilizer and Improved Seed Use	9
2.3.1 Household and Farm-Related Factors Affecting Inorganic Fertilizer Application Rate and the Rate of use of improved Maize Seed.....	9
2.3.2 Institutional Factors Affecting Inorganic Fertilizer Application Rate and the Rate of use of improved Maize Seed	12
2.4. Summary of the reviewed literature	15
CHAPTER THREE: METHODOLOGY	16
3.0 Introduction	16
3.1 Data source and description	16

3.1.1 Sampling design	16
3.1.2 Target population	16
3.1.3 Sample size.....	17
3.2 Description of the study variables.....	17
3.2.1 Dependent variables	17
3.2.2 Independent variables.....	17
3.3 Data management and analysis	19
3.3.1 Univariate analysis	20
3.3.2 Bivariate analysis	20
3.3.3 Multivariable analysis	20
3.4.4 Model Diagnostics.....	21
3.4 Ethical considerations in this study.....	22
3.5 Limitations of the study	22
CHAPTER FOUR: PRESENTATION AND DISCUSSION OF RESULTS.....	24
4.0. Introduction	24
4.1. Distribution of respondents	24
4.2. Bivariate analysis	28
4.3. Multivariable analysis	31
4.3.1 Time Effects on the Intensity of Input Use	33
4.3.2 Differences and Similarities in the Determinants of Inorganic Fertilizer and Improved Seed Adoption.....	34
4.3.3 Factors influencing the intensity of use of inorganic fertilizer	35
4.3.4 Factors influencing the intensity of improved seed use	37
CHAPTER FIVE: SUMMARY, CONCLUSION, AND RECOMMENDATIONS	39
5.0. Introduction	39
5.1. Summary of results	39
5.2. Conclusion	40
5.3. Recommendations	41
References	43
APPENDICES	48

LIST OF TABLES

Table 3.1: Cross checking variables in the different panels	188
Table 3.2: Description of the variables used in the study	18
Table 4.1 Results of the descriptive summary statistics for pooled data	25
Table 4.2 Results of the descriptive summary statistics for the different years	27
Table 4.3: Results of the Pearson's correlation of improved seed application rate, inorganic fertilizer application rate, and the different explanatory variables	29
Table 4.4: Results of the SURE for the intensity of inorganic fertilizer and improved seed adoption and their factors.....	32

LIST OF ABBREVIATIONS

DAP	Di-ammonium phosphate
ECABRN	East and Central African Bean Research Network
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GPS	Global Positioning System
ISFM	Integrated Soil Fertility Management
Kgs	Kilograms
Kgs/acre	Kilograms per acre
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MICE	Multiple Imputation by Chained Equations
NAADS	National Agricultural Advisory Services
NARO	National Agricultural Research Organization
NDPIII	National Development Plan
NPA	National Planning Authority
SURE	Seemingly Unrelated Regression
SSA	Sub-Saharan Africa
UBOS	Uganda Bureau of Statistics
UNPS	Uganda National Panel Survey
VIF	Variance Inflation Factor

ABSTRACT

Agricultural technology adoption remains central to improving productivity and food security among smallholder farmers in Sub-Saharan Africa. In Uganda, maize is a staple crop, but yields remain below potential due to limited and uneven adoption of yield enhancing inputs such as inorganic fertilizers and improved seeds. This study, therefore, investigated the determinants of the intensity of inorganic fertilizer and improved seed use among smallholder maize producers in Uganda. Data were analyzed from 4,161 farmers captured in the Uganda National Panel Surveys (UNPS) of 2015/16, 2018/19, and 2019/20. Descriptive statistics characterized the farmers, and Pearson correlation coefficient identified potential factors influencing the intensity of inorganic fertilizer and improved seed use. Finally, a Seemingly Unrelated Regression (SURE) model was fitted to examine the determinants of the intensity of use at a 5% level of significance.

The results show that intensity use was higher for improved maize seed than for inorganic fertilizer, with farmers applying an average of 6.07 kg/acre [95% CI: 5.78–6.36] of improved seed compared to 4.51 kg/acre [95% CI: 4.09–4.82] of inorganic fertilizer. The results from SURE model revealed that for inorganic fertilizer application rate, higher intensity of use was positively associated with the application rates of organic fertilizer used (kgs/acre) (Coefficient = 0.922, $p = 0.000$), application rates of Pesticides used (liters/acre) (Coefficient = 1.111, $p = 0.001$), and being male (Coefficient = 0.587, $p = 0.043$), while larger crop area (acres) (Coefficient = -0.204, $p = 0.036$) and residence in the Eastern (Coefficient = -1.349, $p = 0.001$) or Northern (Coefficient = -1.818, $p = 0.000$) regions were negatively associated. In contrast, the intensity of improved maize seed use was positively influenced by application rates of organic fertilizer used (kgs/acre) (Coefficient = 0.013, $p = 0.003$), crop area (acres) (Coefficient = 0.144, $p = 0.000$), extension visits (Coefficient = 0.016, $p = 0.044$), and being male (Coefficient = 0.053, $p = 0.040$).

These findings highlight the importance of strengthening extension services, promoting integrated soil fertility management, and addressing gender and regional disparities to enhance the intensity of input use. Targeted policies that improve women's access to resources and support farmers in less-adopting regions could accelerate sustainable maize productivity growth in Uganda.

CHAPTER ONE: INTRODUCTION

1.1. Background to the Study

Global food security remains a pressing challenge, with the world's population projected to reach nearly 10 billion by 2050, driving food demand up by an estimated 70 percent (FAO, 2022; Osewe et al., 2023). Meeting this demand will require boosting productivity on existing farmland rather than expanding agricultural land, which underscores the critical role of modern agricultural technologies such as improved seeds and inorganic fertilizers (World Bank, 2018). Maize, which accounts for nearly 30 percent of global cereal production and over one billion metric tons annually, is central to these efforts as it provides food and livelihoods for millions worldwide (Chemura et al., 2025; FAO, 2023). While improved maize varieties and complementary practices such as fertilizer use, pest management, and timely agronomic practices hold significant promise for enhancing yields, adoption and effective utilization of these technologies remain low, especially among smallholder farmers in low- and middle-income countries (Miehe et al., 2025; Ruzzante et al., 2021). This persistent gap highlights the need to better understand the factors shaping not just whether farmers adopt such technologies but also the intensity with which they are applied.

In sub-Saharan Africa (SSA), agriculture sustains nearly 72 percent of the population and remains the dominant source of food and income (Kelil et al., 2020). Within the region, maize is the most widely cultivated cereal crop, serving as both a staple food and a major source of income for about 40 percent of the population (Erenstein et al., 2022; Macauley, 2015; Tafesse et al., 2023). Smallholder farmers dominate production, accounting for about 90 percent of agricultural output, often cultivating less than one hectare of land (Osewe et al., 2023). Despite its centrality, maize productivity in SSA has stagnated largely due to low and inconsistent adoption of improved inputs and modern technologies (Miehe et al., 2025).

Uganda mirrors this broader regional pattern, with agriculture employing more than 70 percent of the population and contributing significantly to national GDP (UBOS, 2023). Maize is among the country's most important cereal crops, both for household food security and as a source of foreign exchange, contributing about USD 11.3 million annually to export earnings (MAAIF, 2018b; UBOS, 2019). Yet, productivity levels remain low, with yields averaging only 2.0 to 2.5 metric tons per hectare compared to the potential of 6 to 8 metric tons achievable with improved seed varieties and adequate fertilizer use (FAO, 2017; MAAIF, 2018a; UBOS, 2023). This yield gap is largely explained by farmers' continued

reliance on traditional seed varieties, minimal fertilizer application, and declining soil fertility (FAO, 2022; Midamba et al., 2025). Even with substantial investment in maize innovations by National Agricultural Research Organization (NARO), adoption of improved technologies has been sluggish, rising only marginally from 45 percent to 46 percent between 2016 and 2020 (Akwango et al., 2022). Moreover, many farmers adopt improved seeds with expectations of higher yields but fail to complement them with adequate fertilizer application (Miehe et al., 2025). This persistent mismatch between potential and actual yields highlights the urgency of examining the determinants of the intensity for improved maize seed use and inorganic fertilizers among smallholder farmers in Uganda, as addressing these factors is critical for boosting productivity, food security, and rural livelihoods.

1.2 Statement of the problem

Despite sustained efforts by NARO to introduce improved maize varieties and complementary technologies, significant yield gaps continue to constrain Uganda's maize sector (Akwango et al., 2022). Intensity of improved seed use varieties remains strikingly low, with only about 6% of farmers using them, while fertilizers often lack up to 30% of essential nutrients (Chemura et al., 2025). These challenges persist even as regional trade within East Africa has increased the commercial potential of maize, with exports generating an average of USD 11.3 million annually (FAO, 2023; KilimoTrust, 2022; UBOS, 2023). Limited productivity is attributed to declining soil fertility, reliance on poor-quality saved seed, and limited use of productivity enhancing inputs such as inorganic fertilizers and improved seed (Katuuramu et al., 2020; Lance et al., 2016). As a result, maize production remains largely subsistence-oriented, with average yields of about 2.5 metric tons per hectare, well below the attainable 6 to 8 metric tons, representing a yield gap of nearly 71% (Namirembe & Kisaame, 2023).

Previous studies (Juarez et al., 2025; Midamba et al., 2025; Selejio & Lasway, 2018) on agricultural technology adoption have employed binary logistic and probit models. While these are useful for examining the adoption decision (whether a farmer adopts or not), they fail to capture the intensity of use, which is critical for understanding productivity impacts. Other studies have used Tobit and multivariate probit models to examine adoption intensity (Guye et al., 2024; Manda et al., 2024), but these approaches often rely on cross-sectional data. This reliance on single period observations ignores unobserved, time-invariant heterogeneity among farmers, leading to biased and inconsistent estimates. Moreover, such approaches often model adoption outcomes in isolation, overlooking the potential correlation between different technologies. To address these limitations, the panel Seemingly Unrelated

Regression (SURE) framework provides a more robust alternative by jointly modeling adoption intensity across technologies while accounting for correlated disturbances.

This study therefore employs the panel Seemingly Unrelated Regression (SURE) model to jointly estimate the intensity of inorganic fertilizer and improved seed use. This approach allows the inclusion of both time varying and time invariant variables while accounting for cross equation error correlations, providing a more reliable analysis of the factors influencing adoption among smallholder maize producers in Uganda.

1.3 Objectives of the Study

1.3.1 Main objective

The main objective of this study was to examine the determinants of the intensity of inorganic fertilizer and improved seed use among smallholder maize producers in Uganda.

1.3.2 Specific objectives

The specific objectives of the study were:

- i. To examine the influence of institutional, household, and farm-related factors on the intensity of inorganic fertilizer use among smallholder maize producers in Uganda.
- ii. To assess the role of institutional, household, and farm-related factors in determining the intensity of improved seed use among smallholder maize producers in Uganda.

1.4 Hypotheses

The study tested the following key hypotheses:

H01: There is no statistically significant relationship between farmers' age and the intensity of inorganic fertilizer and improved maize seed use in maize production.

H02: There is no statistically significant difference in the intensity of inorganic fertilizer and improved maize seed use between male-headed and female-headed households.

H03: There is no statistically significant difference in the intensity of inorganic fertilizer and improved maize seed use among farmers with primary, secondary, or higher education and those with no formal education.

H04: There is no statistically significant relationship between household size and the intensity of inorganic fertilizer and improved maize seed use in maize production.

H05: There is no statistically significant relationship between crop area and the intensity of inorganic fertilizer and improved maize seed use in maize production.

H06: There is no statistically significant relationship between the quantity of organic fertilizer applied and the intensity of inorganic fertilizer and improved maize seed use in maize production.

H07: There is no statistically significant relationship between the quantity of pesticides applied and the intensity of inorganic fertilizer and improved maize seed use in maize production.

H08: There is no statistically significant difference in the intensity of inorganic fertilizer and improved maize seed use among farmers in the Eastern, Western, and Northern regions compared with those in the Central region.

H09: There is no statistically significant difference in the intensity of inorganic fertilizer and improved maize seed use between farmers with access to financial credit and those without access.

H10: There is no statistically significant difference in the intensity of inorganic fertilizer and improved maize seed use between farmers who have access to extension training and those who do not.

H11: There is no statistically significant difference in the intensity of inorganic fertilizer and improved maize seed use between farmers who receive extension services and those who do not.

H12: There is no statistically significant difference in the intensity of inorganic fertilizer and improved maize seed use between farmers who are members of farmer groups and those who are not.

H13: There is no statistically significant relationship between distance to local markets and the intensity of inorganic fertilizer and improved maize seed use in maize production.

1.5. Significance of the study

Maize is a key staple in Uganda, contributing to food security, household income, and the agricultural economy (MAAIF, 2018; NPA, 2020). However, yields remain below potential due to limited and inconsistent use of productivity-enhancing technologies such as inorganic fertilizers and improved seed

varieties (Midamba et al., 2025; Selejio & Lasway, 2018). Understanding the determinants of not just adoption but the intensity of use of these inputs is essential for closing yield gaps and advancing agricultural transformation.

This study shifts focus from the traditional binary measure of adoption to the extent of input use. Since benefits from modern inputs are realized only at recommended application levels (Tambo & Mockshell, 2018), the findings will provide actionable evidence for designing interventions that promote optimal rather than minimal use. By examining household, farm-related, and institutional determinants of input intensity, the study offers practical insights for policymakers, extension agents, and development practitioners.

The research also aligns with Uganda's Third National Development Plan (NDPIII) and the Parish Development Model, which emphasize commercialization of smallholder agriculture and greater uptake of productivity-enhancing inputs (NPA, 2020). Results will inform targeted programs such as extension campaigns, farmer group strengthening, or input credit schemes needed to boost maize productivity, reduce poverty, and improve food security.

1.6 Conceptual framework

The intensity of inorganic fertilizer and improved seed use among smallholder maize producers is shaped by household, farm-related, and institutional factors. Prior studies highlight their importance in influencing adoption decisions in Uganda and the region (Midamba et al., 2025; Selejio & Lasway, 2018).

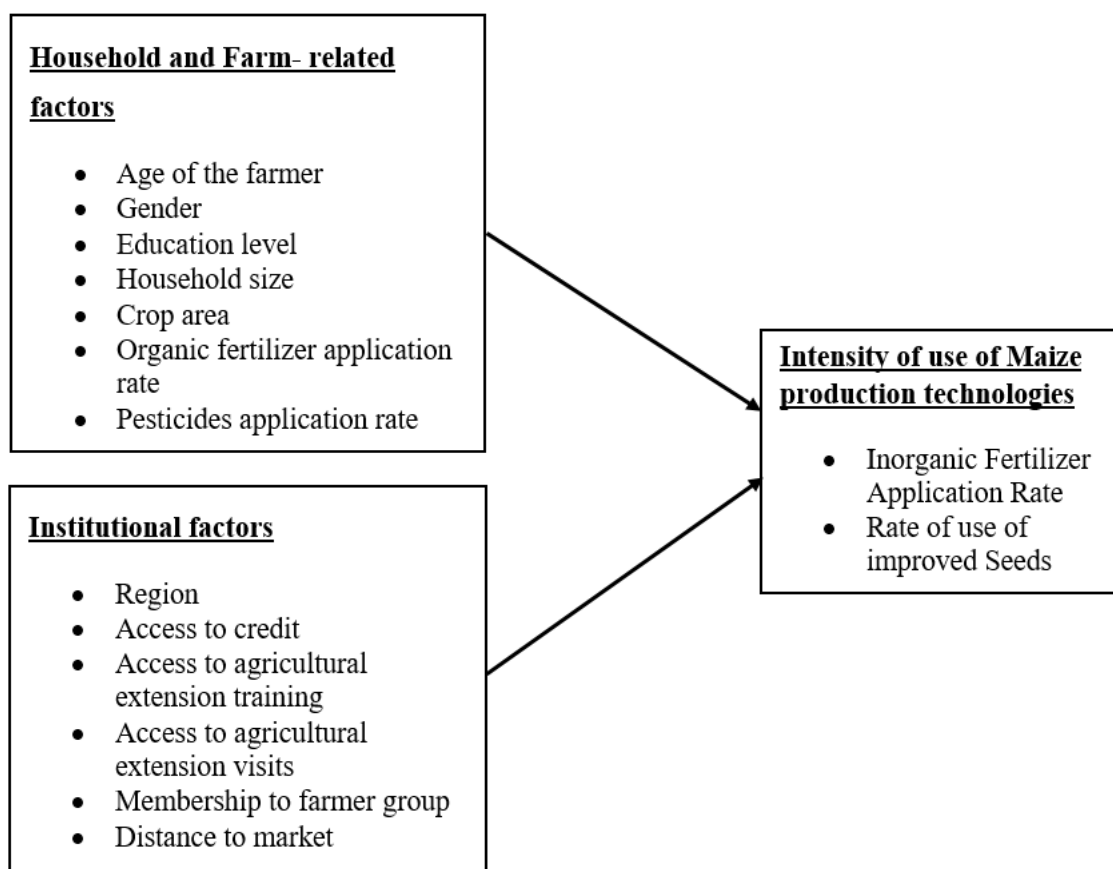
Household and farm-related factors such as education level, household size, crop area, organic fertilizer use, and pesticide use directly influence adoption intensity. Higher education and larger households are generally associated with greater adoption, while gender gaps persist due to unequal access to resources and extension services (Guye et al., 2024; Midamba et al., 2025; Ruzzante et al., 2021). Larger farms spread fixed costs and facilitate experimentation, while complementarities across practices mean farmers who apply organic fertilizer or pesticides are more likely to intensify use of fertilizer and improved seeds (Miehe et al., 2025).

Institutional factors, including access to credit, agricultural extension services, and farmer group membership create enabling conditions by easing liquidity constraints, improving knowledge, and enhancing collective action. Credit access boosts input purchases (Guye et al., 2024; Kipkoge et al., 2025), while extension services strengthen know-how and promote correct input use (Manda et al., 2024).

Farmer groups facilitate information sharing, bulk input purchases, and bargaining power, further enhancing intensity. Regional differences in agro-ecology and market infrastructure also shape adoption patterns (Chemura et al., 2025; Osewe et al., 2023).

This framework therefore, posits that the intensity of inorganic fertilizer and improved seed use among smallholder maize producers in Uganda emerges from the interaction of household characteristics, farm practices, and institutional support systems. Examining these factors provides a nuanced understanding of pathways to strengthen maize production in Uganda.

Figure 1: Figure 1.1: Conceptual framework for the determinants of the intensity of adoption of maize production technologies



Source: Adapted from Selejio and Lasway, (2018) and modified by the researcher.

1.7. Scope of the study

This study examined the determinants of the intensity of inorganic fertilizer and improved maize seed use among smallholder maize producers in Uganda. The study utilized panel data from 4,161 maize farmers captured in the Uganda National Panel Surveys (UNPS) for 2015/16, 2018/19, and 2019/20. The UNPS collects information through four main modules, namely the household, woman, agriculture, and

community modules. The study primarily utilized information from the agriculture and household modules to examine farmers' use of inorganic fertilizer and improved maize seed, together with the household, farm, institutional, and socioeconomic characteristics that may influence the intensity of their use.

Geographically, the study covered smallholder maize farmers across the different regions of Uganda represented in the UNPS. The principal outcomes of interest were the intensity of inorganic fertilizer use, measured by the quantity of inorganic fertilizer applied relative to the cultivated maize area, and the rate of use of improved maize Seed, measured by the quantity of improved seed used relative to the cultivated maize area. The individual maize farmer constituted the unit of analysis. The panel nature of the data enabled the study to account for observations on the same farmers across the three survey waves and to examine determinants of input use intensity over time.

1.8. Structure of the dissertation

The dissertation comprises five chapters. Chapter One presents the background to the study, problem statement, objectives of the study, hypotheses, significance, and the conceptual framework of the study. Chapter Two involves a literature review on the intensity of maize production technology adoption and the factors that influence the intensity of inorganic fertilizer and improved seed use. Chapter Three involves the methodology used including the variables used and the methods of analysis. Chapter Four presents the presentation and discussion of the results. Chapter Five provides the summary of the results, conclusion, and recommendations for further research.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter presents literature on the determinants of the intensity of inorganic fertilizer and improved seed use among smallholder maize producers in Uganda. The review aims to highlight findings from prior studies on factors influencing the intensity of adoption, including household, farm-related, and institutional characteristics. This chapter provides a foundation for understanding the factors that drive adoption behavior and informs the use of a Seemingly Unrelated Regression model to analyze these determinants.

2.2 The Intensity of Maize Production Technology Use

The intensity of use refers to the degree or extent to which farmers utilize specific agricultural technologies, such as inorganic fertilizer and improved maize seeds, typically measured as the quantity applied per unit area (kilograms per acre) (Wongnaa et al., 2018). An improved or modern variety is a new breed variety of a plant species which produces higher yields, quality, and/or provides better resistance to plant pathogens and pests while minimizing the pressure on the natural environment (Chemura et al., 2025). Unlike binary adoption (whether a farmer uses a technology or not), intensity of use captures the continuous variation in usage levels, providing a more nuanced understanding of technology uptake. This is critical because higher intensity often correlates with increased productivity and economic outcomes (Katya et al., 2025; Nchanji et al., 2021). In this study, the two main dependent variables are:

- **Inorganic Fertilizer Application Rate:** The quantity of inorganic fertilizer applied per acre of maize farm (kilograms/acre).
- **Rate of use of improved Seeds:** The quantity of improved maize seed planted per acre (kilograms/acre).

These continuous variables are measured using data from the Uganda National Panel Survey (UNPS), which collects information through questions such as:

- "What type of seed/seedlings did you use for this crop?"
- "What type of improved seed did you use for this crop?"
- "How much seed did you use for this crop? (Quantity)"

- "Did you use any inorganic fertilizer on the parcel/plot?" (Yes/No)
- "What was the quantity used?"

The UNPS also measures the area grown using GPS with two decimal digits and confirms parcel size through farmer estimation in acres. These questions provide data to model the intensity of use behavior, enabling a detailed analysis of how various factors influence the extent of technology use.

The importance of studying intensity of use lies in its impact on agricultural productivity. Recent studies note that partial adoption (low intensity) may not yield the full benefits of technologies, whereas higher intensity can significantly enhance crop yields (Abebe et al., 2020). In Uganda, where maize is a staple crop, understanding the intensity of use is crucial for improving food security and farmer livelihoods (Katuuramu et al., 2020).

2.3 Factors Influencing the Intensity of Inorganic Fertilizer and Improved Seed Use

2.3.1 Household and Farm-Related Factors Affecting Inorganic Fertilizer Application Rate and the Rate of use of improved Maize Seed

Age of the farmer

Age is defined as the number of complete years since a farmer's birth. In my view, younger farmers are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as they are generally more open to modern technologies and less reliant on traditional farming practices compared to older farmers, leading to higher yields. Abebe et al. (2020) in Ethiopia found that younger farmers were more likely to adopt improved maize varieties due to their willingness to embrace innovation. Similarly, Cholo et al. (2023) in Ethiopia noted that older farmers may use inputs less intensively due to risk aversion or reliance on traditional practices. In this study, it is hypothesized that older farmers are less likely to intensively use inorganic fertilizer and improved maize seeds compared to younger farmers, as younger farmers may be more open to using new technologies. The UNPS question used to test this hypothesis is, "How old is the respondent in complete years?"

Sex of the farmer

Gender refers to the state of being male or female, typically associated with the household head. I anticipate that male farmers are likely to apply greater quantities of inorganic fertilizer and improved maize seeds compared to female farmers, as men typically have better access to resources such as land and credit, leading to increased maize yields. Nchanji et al. (2021) in Tanzania found that female farmers

faced constraints in accessing inputs, leading to lower adoption intensity of maize technologies. Aseete et al. (2023) in Uganda also reported that male-headed households used more fertilizers due to greater control over resources. Similarly, Martey et al. (2020) found that in Ghana, gender was significantly correlated with the adoption of improved maize varieties, with male-headed households being more likely to intensively use due to greater access to extension services. In this study, it is hypothesized that male-headed households use maize production technologies more intensively than female-headed households, as male farmers often have better access to resources like land, credit, and extension services. The UNPS question is, “What is the sex of the farmer?” with codes 0 for “female” and 1 for “male.”

Education level

Education level is the highest level of formal schooling attained by the farmer. I expect that farmers with higher education levels are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as education enhances their understanding of modern farming techniques, contributing to higher maize yields. Wongnaa et al. (2018) found that in Ghana, educated farmers were 1.7 times more likely to adopt modern maize production technologies (significant at the 5% level) due to better comprehension of technical information. Cholo et al. (2023) also noted that education positively influenced the adoption of improved seeds in Ethiopia. The hypothesis is that farmers who attained primary, secondary, and higher education are more likely to intensively use inorganic fertilizer and improved maize seeds compared to those with no formal education, as education enhances knowledge and decision-making skills. The UNPS question is, “What was the highest class that was completed?” with codes 0 for “some schooling but not completed P1,” 1 for “completed primary,” 2 for “completed secondary,” 3 for “completed tertiary,” and 4 for “completed university.”

Household size

Household size is the number of members residing in a dwelling unit. I suggest that larger households are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as more family members provide additional labor for farming tasks, resulting in higher maize yields. Abdulaleem et al. (2019) and Abebe et al. (2020) found that in Nigeria, larger household size was positively associated with the adoption of modern maize inputs due to increased labor availability. Ethiopia reported that each additional household member increased the intensity of use of improved common bean seeds by 0.15 units, driven by labor contributions. However, Andaregie et al. (2021) in Ethiopia found no consistent effect, suggesting context-specific influences. This is consistent with Anang and Asante (2020), who found that in Ghana, households with more than five members had a 14% higher adoption rate of

inorganic fertilizers compared to smaller households, attributed to greater labor availability. The hypothesis is that larger households are more likely to intensively use inorganic fertilizer and improved maize seeds due to greater availability of family labor for farm activities. The UNPS question is, “What is the total number of members in the household?”

Crop area

Crop area refers to the land allocated to maize cultivation, measured in acres. I propose that farmers with larger maize crop areas are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as larger land holdings justify greater input investments, leading to increased maize yields due to the fact that larger farms can spread fixed costs over more land and access greater resources for purchasing inputs encourages farmers to use modern technologies more intensively. Nchanji et al. (2021). in Tanzania found that larger land sizes were associated with increased fertilizer and seed use, enhancing maize productivity. Katuuramu et al. (2020) in Uganda also noted that larger crop areas correlated with higher input use. This is consistent with (Arslan et al., 2020) who found that in Ethiopia, farmers with maize crop areas larger than 1 hectare had a 17% higher adoption rate of improved maize seeds compared to those with smaller plots, attributed to economies of scale. In this study the hypothesis is that farmers with larger crop areas are more likely to intensively use inorganic fertilizer and improved maize seeds, as larger farms may justify higher input investments. The UNPS question is, “What was the proportion of land allocated to the crop?”

Organic fertilizer application rate

Organic fertilizer application rate is the quantity of organic fertilizer (such as manure, compost) applied per acre. I anticipate that farmers applying higher quantities of organic fertilizers are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as organic inputs improve soil health, complementing modern technologies and leading to higher maize yields. Kyebogola et al. (2021) found that in Uganda, combining organic and inorganic fertilizers increased common bean yields by 22% compared to inorganic fertilizers alone, due to improved soil health. Similarly, Rurangwa et al. (2020) in Rwanda reported that combined organic and inorganic fertilizer use increased climbing bean yields by 18%, driven by enhanced nutrient availability. The hypothesis is that farmers applying more quantities of organic fertilizers are more likely to intensively use inorganic fertilizer and improved maize seeds, as organic fertilizers complement inorganic inputs by improving soil health. This is consistent with Arslan et al. (2020), who found that in Ethiopia, farmers applying organic fertilizers such as chicken manure gained rates above grain yield of 5.7 t/ha and had a higher adoption rate of improved maize seeds,

attributed to better soil fertility management. The UNPS question is, “What was the quantity used in kilograms?”

Pesticides application rate

Pesticides are classified by different classification terms such as chemical classes, functional groups, modes of action, and toxicity and are used to kill pests and to control weeds. Pesticide application rate is the quantity of pesticides (in kilograms or liters) applied per acre (Tudi et al., 2021). In my opinion I expect that farmers applying higher quantities of pesticides are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as pest control protects crops and encourages investment in inputs, leading to higher maize yields. Tukahirwa (2019) mentions that pesticide application increased yields by reducing pest-related losses. Andaregie et al. (2021) also noted that pesticide use supported higher input adoption in Ethiopia. In this study, it is hypothesized that farmers applying more pesticides are more likely to intensively use inorganic fertilizer and improved maize seeds, as pest control enhances the effectiveness of other inputs. The UNPS question is, “What is the quantity of the pesticides used in kilograms or liters?”

2.3.2 Institutional Factors Affecting Inorganic Fertilizer Application Rate and the Rate of use of improved Maize Seed

Region

A geographical region is an area with common features, such as agro-ecological conditions. I suggest that farmers in regions with better terrain, such as the Eastern and Central regions of Uganda, are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as regional resources enhance adoption and lead to higher maize yields. Katuuramu et al. (2020) notes that regional variations in agricultural practices significantly influence maize yields, with certain regions exhibiting higher adoption rates of improved seeds and fertilizers due to favorable conditions and supportive institutional frameworks. Similarly Nkhata et al. (2021) also reported location-specific effects on technology adoption. Farmers located in regions with better infrastructure are more likely to use inorganic fertilizer application. The hypothesis is that farmers in the Eastern, Western, and Northern regions of Uganda are more likely to intensively use inorganic fertilizer and improved maize seeds compared to those in the Central region, due to regional differences in agricultural support and soil conditions. The UNPS question is, “What is the region?” with codes 1 for “Central,” 2 for “Eastern,” 3 for “Northern,” and 4 for “Western.”

Access to credit

Access to credit refers to a farmer's ability to obtain financial support. I propose that farmers with access to credit are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as financial resources enable them to purchase more inputs, leading to higher maize yields. Midamba et al. (2025), demonstrated that credit access increases the likelihood of adopting inorganic fertilizers. Farmers who are able to secure loans are in better position to invest in inputs that enhance overall productivity and yields. Elsewhere, in Ethiopia farmers who are able to access credit easily meet market demands while adjusting positively to market fluctuations as they are in better position to sustain production (Andaregie et al., 2021). Additionally, Aseete et al. (2023) in their analysis on smallholder farmers in Uganda, noted that credit access boosted improved seed adoption. Financial support is necessary for making investments in modern agricultural practices. The hypothesis is that farmers with access to credit are more likely to intensively use inorganic fertilizer and improved maize seeds, as credit enables input purchases. The UNPS question is, "Did any member of the household access credit for agricultural purposes?" with codes 0 for "no" and 1 for "yes."

Agriculture extension trainings

Agricultural extension trainings are educational programs disseminating knowledge on farming practices. In my view farmers who participate in extension trainings are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as training provides knowledge of modern practices, leading to higher maize yields. In Southern Africa, (Manyanga et al., 2023) acknowledges that agricultural extension training helps farmers improve their skills, ultimately enhancing adoption of sustainable practice such as use of improved seeds. They study emphasized that well structures extension programs enhance improved productivity. Cholo et al. (2023) in Ethiopia also reported that trained farmers adopted improved technologies more intensively. The hypothesis is that farmers with access to extension trainings are more likely to intensively use inorganic fertilizer and improved maize seeds due to enhanced knowledge. The UNPS question is, "Has any member of your household participated in training programs organized by NAADS in the past 12 months?" with codes 0 for "no" and 1 for "yes."

Access to agricultural extension services

Agricultural extension visits involve direct interactions between farmers and extension agents. I expect that farmers receiving frequent extension visits are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as direct guidance from agents encourages intensive adoption and leads to higher maize yields. A study about how farmers learn from extension services by Maertens et al., (2021)

found that in Malawi, frequent extension visits increased fertilizer adoption up-to 88% due to improved knowledge of application techniques with farmers harvesting over 29 kg bags per acre of maize. Atukunda et al. (2022) in their study on increasing farmers' access to aquaculture extension service also noted that extension visits enhanced maize productivity in both central and northern Uganda. The hypothesis is that farmers receiving more extension visits are more likely to intensively use inorganic fertilizer and improved maize seeds due to technical guidance. The UNPS question is, "How many times did someone from NAADS visit any of the household plots in the past twelve months?".

Membership to farmer group

Membership to a farmer group refers to participation in organized groups for agricultural support. I propose that individuals in farmer groups are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as group membership provides access to shared resources and information, leading to higher maize yields. Participation, particularly in well organized groups enhance not only knowledge sharing, but also improves access to credit, and collective purchasing, ultimately increasing adoption of agricultural technologies. In a study on adoption of agro ecological intensification practices in Southern Africa by Manyanga et al. (2023), emphasizes that participation in farmer groups enhances the adoption of agro ecological intensification practices. These platforms foster collective knowledge exchange, resource sharing, and mutual support among the peers. Aseete et al. (2023) in Uganda found that farmer group membership increased technology adoption. These groups give guarantee for farmers that maybe in need of credit to enhance production. In Central and Northern Uganda, Atukunda et al. (2022) also reported productivity gains from group participation. In this study, it is hypothesized that farmers in farmer groups are more likely to intensively adopt inorganic fertilizer and improved maize seeds due to access to inputs and information. The UNPS question is, "Is any member of your household a member of a farmers' group?" with codes 0 for "no" and 1 for "yes".

Distance to market

Distance to market is the physical space from a farmer's location to the nearest market place. I anticipate that farmers closer to markets are likely to apply greater quantities of inorganic fertilizer and improved maize seeds, as proximity facilitates access to inputs, leading to higher maize yields. This stems from the fact that being close to the market reduces transportation costs and time, making it easier for farmers to purchase inputs and access information on market trends and fluctuations, which encourages investment in modern technologies. Recent research on adoption of sustainable agricultural intensification practices mentions that market accessibility is important in the adoption of improved maize and fertilizers so as to

enhance productivity (Katya et al., 2025). Similarly, Nchanji et al. (2021) in Tanzania found that proximity to markets increased fertilizer adoption. In Western Uganda, Midamba et al. (2025) highlights that proximity to markets significantly influences the adoption of inorganic fertilizers, as farmers nearer to market places have improved access to necessary inputs. The study further notes that farmers distant from market places have lower chances of adopting the use of inorganic fertilizers which affects overall yields. Moreover, findings from farmers' preferred traits, production constraints, and adoption factors of improved maize varieties showed that farmers closed to the markets, quickly use new technologies due to reduced cost of travels to distance markets (Ndeko et al., 2025). The hypothesis is that farmers closer to local markets are more likely to intensively use inorganic fertilizer and improved maize seeds due to better access to such inputs. The UNPS question is, "What is the distance to the nearest market in kilometers?".

2.4. Summary of the reviewed literature

The literature review highlights that the intensity of maize production technology adoption, specifically inorganic fertilizer and improved seed use, is influenced by household, farm-related, and institutional factors. Recent studies indicate that younger farmers, male headed households, educated farmers, larger households, and those with larger crop areas tend to use these technologies more intensively. Similarly, organic fertilizer and pesticide use complement inorganic inputs, enhancing adoption intensity. Institutional factors, such as regional differences, access to credit, extension services, farmer group membership, and proximity to markets, also play significant roles. However, most studies focus on binary adoption rather than intensity, limiting insights into the extent of technology use. Additionally, prior studies often use cross-sectional data or simpler statistical methods, which may not account for unobserved heterogeneity among farmers. This study addresses these gaps by employing a seemingly unrelated regression model using UNPS panel data, allowing for a more robust analysis of continuous adoption intensity variables and unobserved heterogeneity among smallholder maize farmers in Uganda.

CHAPTER THREE: METHODOLOGY

3.0 Introduction

This Chapter presents a description of the methodology that was used. It is divided into the data source and description, sampling design, target population, sample size, description of variables, data management and analysis, ethical consideration, and limitations of the study.

3.1 Data source and description

This study relies on secondary data obtained from the Uganda National Panel Survey (UNPS) for the years 2015/16, 2018/19, and 2019/20. The UNPS is part of a series of nationally representative household panel surveys that began in 2009/10 and were subsequently implemented in 2010/11, 2011/12, and 2013/14. The survey is designed and implemented by the Uganda Bureau of Statistics (UBOS). The UNPS collects data through four main modules: household, woman, agriculture, and community. Each wave of the survey is carried out over a twelve-month period to capture seasonal variations in socioeconomic and agricultural activities. To adequately reflect outcomes across cropping seasons, the survey employs a two-visit approach, where each household is interviewed twice within the same year, approximately six months apart. This design allows for more accurate measurement of agricultural production, consumption, and welfare dynamics across Uganda's diverse agro-ecological zones.

3.1.1 Sampling design

A two-stage stratified cluster sampling design was used with regions as the strata. Within each stratum, the enumeration areas which were the primary sampling units were selected with equal probability with implicit stratification by rural/urban and district. Households which were the secondary sampling units were then selected from the selected enumeration areas using simple random sampling. The sample of households selected to be interviewed in 2015/16 UNPS, 2018/19 UNPS and 2019/20 UNPS were 3,300 households respectively where over seventy percent of the households in these surveys are the same followed up in time.

3.1.2 Target population

The target population for this study comprised smallholder farmers engaged in maize production across Uganda. The focus on smallholder farmers is particularly relevant, as they account for the majority of maize producers in Uganda, yet their productivity remains constrained by limited and inconsistent use of

improved agricultural technologies such as inorganic fertilizers and improved seed varieties. By concentrating on maize-producing households captured in the Uganda National Panel Survey (UNPS), the study targets a population that is nationally representative and diverse in terms of socioeconomic, demographic, and institutional characteristics. This ensures that the findings provide a comprehensive understanding of the determinants of technology use intensity among Uganda's smallholder maize farmers, while also generating insights that are relevant for agricultural policy and practice at both regional and national levels.

3.1.3 Sample size

The study focused exclusively on households that reported engaging in maize production. From the UNPS datasets, a total of 4,161 maize farmers were identified and included in the analysis. Specifically, 1,576 farmers were drawn from the 2015/16 wave, 1,404 from the 2018/19 wave, and 1,181 from the 2019/20 wave. After addressing missing observations using the Multiple Imputation by Chained Equations (MICE) algorithm, the final balanced sample comprised these 4,161 maize-producing households.

3.2 Description of the study variables

3.2.1 Dependent variables

The study considered two dependent variables, namely the application rate of inorganic fertilizers (measured in kilograms per acre) and the rate of use of improved seed varieties (measured in kilograms per acre). Both variables were treated as continuous outcomes and were derived from the Uganda National Panel Survey (UNPS) datasets for the years 2015/16, 2018/19, and 2019/20. These indicators capture not only whether a farmer used a given technology, but also the intensity of use, which is critical for understanding the extent to which smallholder farmers invest in productivity-enhancing inputs.

3.2.2 Independent variables

The independent variables included age of the farmer, sex, education level, household size, crop area, organic fertilizer application rate, pesticides application rate, region, access to credit, agriculture extension trainings, access to agricultural extension visits, membership to farmer group, and distance to market.

Table 3.1: Cross-checking variables in the different panels

Study Variables	UNPS 2015/16	UNPS 2018/19	UNPS 2019/20
Dependent variables			
Inorganic fertilizer	YES	YES	YES
Improved seed varieties	YES	YES	YES
Independent Variables			
Age of the farmer	YES	YES	YES
Sex of the farmer	YES	YES	YES
Education level	YES	YES	YES
Household size	YES	YES	YES
Crop Area	YES	YES	YES
Organic fertilizers	YES	YES	YES
Pesticides	YES	YES	YES
Region	YES	YES	YES
Access to credit	YES	YES	YES
Agriculture extension trainings	YES	YES	YES
Agriculture extension visits	YES	YES	YES
Membership to a farmer group	YES	YES	YES
Distance to market	YES	YES	YES

Table 3.2: Description of the variables used in the study

Variable	Question	Codes/Units	Type of variables
Outcome variables			
Inorganic fertilizer	What was the quantity used?	Kgs /acre	Continuous
Improved seed varieties	How much improved seed did you use for this crop?	Kgs /acre	Continuous
Independent variables			
Age of the farmer	How old is (Name) in complete years	Years	Continuous
Sex of the farmer	Sex	1-Female 2-Male	Binary
Education level	What was the highest grade/class that [NAME] completed?	1-No formal education 2-Primary education 3-Secondary education 4-Higher education	Ordinal
Household size	Total number of members in the household	N/A	Continuous
Crop Area	What is the area occupied by the crop?	Acres	Continuous

Table 3.2 (Con't): Description of the variables used in the study

Variable	Question	Codes/Units	Type of variables
Organic fertilizers	What was the quantity used?	Kgs /acre	Continuous
Pesticides	What was the quantity used?	Kgs/liters	Continuous
Region	Region	1-Central 2-Eastern 3-Northern 4-Western	Nominal
Access to credit	If household has received any agricultural related loan	1-No 2-Yes	Binary
Agriculture extension trainings	Has any member of your household participated in training programs organized by NAADs in the past 12 months?	1-No 2-Yes	Binary
Agriculture extension visits	Number of solicited visits from NAADs in the last 12 months	N/A	Continuous
Membership to a farmer group	Is any member of your household a member of a farmer group?	1-No 2-Yes	Binary
Distance to market	What is the distance to the nearest market in kilometers?	Kms	Continuous

3.3 Data management and analysis

Data management and analysis were conducted using Stata 17. For each survey wave, data from the two agricultural seasons were first merged with relevant household-level variables from the household module of the UNPS datasets (2015/16, 2018/19, and 2019/20). The resulting datasets were then appended across waves to create a pooled panel suitable for analysis.

The analysis was then carried out at three stages: univariate, bivariate, and multivariable, to identify the determinants of the intensity of inorganic fertilizer and improved seed use. At the multivariable stage, Seemingly Unrelated Regression (SURE) model was estimated, and appropriate diagnostic tests were conducted to assess model suitability and validity of assumptions.

3.3.1 Univariate analysis

The study began with an assessment of institutional, household, and farm-related characteristics of maize farmers using descriptive summary statistics. For categorical variables, dummy variables were generated prior to analysis. Descriptive statistics were presented separately for each survey wave as well as for the pooled dataset to provide both cross-sectional and longitudinal insights.

3.3.2 Bivariate analysis

At the bivariate level, the Pearson correlation coefficient was used to assess the strength and direction of the linear association between inorganic fertilizer application rate and improved maize seed-use rate. Bivariate associations between each potential explanatory variable and the respective outcome variables were also examined to identify variables for inclusion in the multivariable model. Variables showing statistically significant associations at the 5% level of significance were considered for inclusion in the multivariable analysis. The formula is given as below;

$$\rho(x,y) = \frac{cov(x,y)}{\sqrt{var(x)}\sqrt{var(y)}} \quad (1)$$

ρ = Pearson correlation coefficient

$Cov(x,y)$ = sample covariance of the predictor x and outcome y

$Var(x)$ = sample variance of predictor x

$Var(y)$ = sample variance of the outcome variable y

3.3.3 Multivariable analysis

To examine the determinants of the intensity of inorganic fertilizer and improved maize seed use among smallholder maize farmers in Uganda, a Panel Seemingly Unrelated Regression (SURE) model was employed. The model jointly estimated two regression equations: the first equation examined the determinants of the intensity of inorganic fertilizer use, while the second examined the determinants of the intensity of improved maize seed use. The two equations were specified as:

$$\begin{aligned} FERT_{it} = & \beta_0 + \beta_1 SEX_{it} + \beta_2 EDU(Primary)_{it} + \beta_3 EDU(Secondary)_{it} + \beta_4 EDU(Higher)_{it} + \\ & \beta_5 HHS_{it} + \beta_6 AREA_{it} + \beta_7 ORG_{it} + \beta_8 PES_{it} + \beta_9 REG(Eastern)_{it} + \beta_{10} REG(Northern)_{it} + \\ & \beta_{11} REG(Western)_{it} + \beta_{12} TRN_{it} + \beta_{13} EXT_{it} + \beta_{14} DST_{it} + \beta_{15} 2018/19_{it} + \beta_{16} 2019/20_{it} + \varepsilon_j \end{aligned} \quad (2)$$

$$SEED_{it} = \alpha_0 + \alpha_1 SEX_{it} + \alpha_2 EDU(Primary)_{it} + \alpha_3 EDU(Secondary)_{it} + \alpha_4 EDU(Higher)_{it} + \alpha_5 HHS_{it} + \alpha_6 AREA_{it} + \alpha_7 ORG_{it} + \alpha_8 PES_{it} + \alpha_9 REG(Eastern)_{it} + \alpha_{10} REG(Northern)_{it} + \alpha_{11} REG(Western)_{it} + \alpha_{12} TRN_{it} + \alpha_{13} EXT_{it} + \alpha_{14} DST_{it} + \alpha_{15} 2018/19_{it} + \alpha_{16} 2019/20_{it} + \varepsilon_k \quad (3)$$

Where;

$FERT_{it}$ is the quantity of inorganic fertilizer applied (Kgs/acre) by farmer i in year t.

$SEED_{it}$ is the quantity of improved seed applied (Kgs/acre) by farmer i in year t.

β_0 and α_0 are the intercepts for fertilizer and improved seed, respectively.

$\beta_1, \beta_2, \dots, \beta_{12}$ and $\alpha_1, \alpha_2, \dots, \alpha_{12}$ are the estimated coefficients.

β_{11} 2018/19 and α_{11} 2018/19 =Time dummy variable for the year 2018/2019

β_{12} 2019/20 and α_{12} 2018/19 =time dummy variable for the year 2019/2020

ε_j and ε_k are error terms for fertilizer and improved seed respectively assumed to be correlated:

$$Cov(\varepsilon_j, \varepsilon_k) \neq 0$$

SEX = sex of the farmer, EDU = Dummies for education level, HHS = household size, AREA = crop area, ORG = organic fertilizer application rate, PES = pesticides application rate, REG = Dummies for region, TRN = agricultural extension trainings, EXT = access to agricultural extension visits, and DST = distance to market.

The SURE approach was preferred because the two input-use decisions may be influenced by common unobserved factors, allowing the disturbance terms of the two equations to be correlated. Joint estimation therefore accounts for the cross equation correlation and can improve estimation efficiency. The explanatory variables in the two equations were required to be identical.

A variable was considered statistically significant when its estimated coefficient was significantly different from zero at the 5 percent level of significance.

3.4.4 Model Diagnostics

Multicollinearity test

The Variance Inflation Factor (VIF) test was performed to access multicollinearity in the regression models. This helped to identify possible overlapping effects that may occur due to high correlations among the independents that may make it difficult to distinguish individual impact of the independent variables on the outcome. The VIF for the j^{th} independent is given as below;

$VIF_j = 1/(1-R^2_j)$ where R^2_j is the R^2 value obtained by regressing the j^{th} independent on the remaining independents. The VIF less than ten was considered as an acceptable level of multicollinearity and that variable was included at the multivariable level of analysis.

Goodness of fit (Wald chi-square test)

To evaluate the overall explanatory power of the fitted models, the Wald chi-square statistic was examined. The null hypothesis tested whether all slope coefficients in each equation were jointly equal to zero. A significant Wald chi-square ($p < 0.05$) confirmed that the explanatory variables collectively influenced the intensity of adoption of inorganic fertilizer and improved maize seed, supporting the adequacy of the specified SURE model.

Cross-equation error correlation test

The Breusch–Pagan test of independence was applied to determine whether the error terms across equations were correlated. The null hypothesis assumes independence of the error terms across equations. Rejection of the null ($p < 0.05$) indicated significant cross-equation correlation, justifying the use of the Seemingly Unrelated Regression Equations (SURE) model for joint estimation.

3.4 Ethical considerations in this study

This study used secondary data from the Uganda National Panel Survey (UNPS) datasets of 2015/16, 2018/19 and 2019/20 which is accessible to all stakeholders. Individual information from the subjects was kept confidential during and after data analysis and any piece of information and communication concerning the research study was done only in line with the objectives of the study.

3.5 Limitations of the study

The study relied on secondary panel data from the Uganda National Panel Surveys (UNPS) of 2015/16, 2018/19, and 2019/20. The 2019/20 survey was used as the latest panel in the analysis because more recent panel data from the Uganda Harmonised Integrated Survey (UHIS), covering 2021/22, 2023/24, and 2024/25, were not yet readily available to the public at the time of the study. Consequently, the analysis could not incorporate the more recent survey periods, which may limit the extent to which the findings reflect more recent changes in farmers' input-use behaviour and the agricultural environment.

The use of secondary data also constrained the analysis to variables available in the survey datasets. Consequently, potentially important determinants of the intensity of inorganic fertilizer and improved seed use, such as farmers' risk preferences, social networks, and perceptions of input quality, could not be examined. In addition, the findings are specific to smallholder maize farmers in Uganda and should

therefore be generalized to other crops, regions, or production systems with caution. Despite these limitations, the study provides useful evidence on the factors associated with the intensity of inorganic fertilizer and improved maize seed use among smallholder farmers in Uganda.

CHAPTER FOUR: PRESENTATION AND DISCUSSION OF RESULTS

4.0. Introduction

This Chapter presents results from the three levels of analysis, first the distribution of characteristics of the respondents then variable selection at the bivariate analysis. Finally, Seemingly Unrelated Regression (SURE) model was fitted to factors influencing the intensity of inorganic fertilizer and improved seed adoption among smallholder maize producers in Uganda.

4.1. Distribution of respondents

This section presents the descriptive summary statistics for the study variables, focusing on the characteristics of smallholder maize producers in Uganda across the survey panels of 2015/2016, 2018/2019, and 2019/2020, as well as the pooled dataset. The results are summarized in Table 4.1 and Table 4.2.

Table 4.1 Results of the descriptive summary statistics for pooled data

Variable	N	Mean	SD	Min	Max
Inorganic fertilizers application rate (kgs/acre)	4161	4.51	10.37	0.00	50.00
Rate of use of improved seed (kgs/acre)	4161	6.07	9.57	0.10	120.00
Independent variables					
Age of the farmer	4161	37.99	17.03	18.00	85.00
Sex of the farmer (0=Female, 1=Male)	4161	0.49	0.50	0.00	1.00
Education Level					
1=No education (0=No,1=Yes)	4161	0.17	0.38	0.00	1.00
2=Primary (0=No,1=Yes)	4161	0.48	0.50	0.00	1.00
3=Secondary (0=No,1=Yes)	4161	0.26	0.44	0.00	1.00
4=Higher (0=No,1=Yes)	4161	0.09	0.28	0.00	1.00
Household size(number)	4161	4.80	2.56	1.00	17.00
Crop Area (acres)	4161	11.62	19.82	0.01	90.00
Organic fertilizers application rate (kgs/acre)	4161	18.36	40.87	0.00	120.00
Pesticides application rate (liters/acre)	4161	2.35	1.93	0.20	5.00
Region					
1=Central (0=No,1=Yes)	4161	0.40	0.49	0.00	1.00
2=Eastern (0=No,1=Yes)	4161	0.25	0.43	0.00	1.00
3=Northern (0=No,1=Yes)	4161	0.17	0.38	0.00	1.00
4= Western (0=No,1=Yes)	4161	0.18	0.38	0.00	1.00
Access to credit (0=No,1=Yes)	4161	0.10	0.30	0.00	1.00
Access to Agriculture extension trainings (0=No,1=Yes)	4161	0.15	0.36	0.00	1.00
Agriculture extension visits (number)	4161	2.31	1.85	1.00	12.00
Membership to a farmer group (0=No,1=Yes)	4161	0.10	0.30	0.00	1.00
Distance to market (Km)	4161	1.72	5.33	0.00	50.00

Note: Dummies were created for categorical variables

Source: Generated by the Author

The results in Table 4.1 show that the rate of use of improved maize seed was notably higher than that of inorganic fertilizer application among smallholder farmers in Uganda. On average, farmers applied 4.51 kg/acre of inorganic fertilizer [95% CI: 4.09, 4.82], which is far below the recommended rate of 50 kg/acre for DAP fertilizer (MAAIF, 2019). Similarly, the average quantity of improved maize seed planted was 6.07 kg/acre [95% CI: 5.78, 6.36], which also falls short of the recommended 8–10 kg/acre (FAO, 2017; MAAIF, 2018a). This pattern suggests that while use of improved seed is relatively more common, it is not matched with adequate use of complementary inputs such as inorganic fertilizer. This finding is consistent with Mieke et al. (2025), who emphasize that high yielding maize varieties only

deliver their potential if combined with proper fertilizer use, pest control, timely weeding, and correct planting practices. However, in Uganda many farmers adopt improved seeds with the expectation of achieving higher yields even when applying limited or no complementary inputs.

With regard to other inputs, the average quantity of organic fertilizer applied was 18.36 kg/acre, which is substantially below the recommended rate of 2,000–4,000 kg/acre (MAAIF, 2019). The average use of pesticides was 2.35 litres/acre, with a maximum application of 5 litres/acre.

In terms of demographic characteristics, the average age of farmers was 40 years. Slightly more than half (51%) were female, while the largest proportion (48%) had attained primary education. The average household size was five members, with the largest recorded household having seventeen members.

On average, farmers cultivated 11.62 acres, and the highest proportion of respondents (40%) were from the Central region of Uganda. Market access appeared relatively favorable, with farmers located an average of 1.72 km from the nearest market center.

Financial and institutional support remained limited. Only 10% of farmers reported access to credit, 15% participated in training programs organized by NAADS, 10% were members of farmer groups, and just 2.3% reported soliciting visits from NAADS extension workers.

Table 4.2 Results of the descriptive summary statistics for the different years

Variable	2015/2016					2018/2019					2019/2020				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Inorganic fertilizers application rate (kgs/acre)	1576	6.91	14.66	0.00	50.00	1404	5.05	6.04	0.00	20.00	1181	4.04	6.03	0.00	15.00
Improved seed rate (kgs/acre)	1576	5.89	9.25	0.25	120.0	1404	6.19	9.54	0.25	120.0	1181	6.19	10.00	0.10	120.00
Independent variables															
Age of the farmer	1576	38.04	17.40	18.0	85.00	1404	37.45	16.47	18.0	85.00	1181	38.57	17.17	18.0	85.00
Sex of the farmer (0=Female, 1=Male)	1576	0.48	0.50	0.00	1.00	1404	0.49	0.50	0.00	1.00	1181	0.50	0.50	0.00	1.00
Education Level															
1=No education (0=No,1=Yes)	1576	0.16	0.37	0.00	1.00	1404	0.17	0.38	0.00	1.00	1181	0.19	0.39	0.00	1.00
2=Primary (0=No,1=Yes)	1576	0.46	0.50	0.00	1.00	1404	0.50	0.50	0.00	1.00	1181	0.50	0.50	0.00	1.00
3=Secondary (0=No,1=Yes)	1576	0.27	0.45	0.00	1.00	1404	0.27	0.44	0.00	1.00	1181	0.23	0.42	0.00	1.00
4=Higher (0=No,1=Yes)	1576	0.11	0.32	0.00	1.00	1404	0.07	0.25	0.00	1.00	1181	0.08	0.27	0.00	1.00
Household size (number)	1576	4.75	2.48	1.00	15.00	1404	4.97	2.63	1.00	17.00	1181	4.67	2.56	1.00	14.00
Crop Area (acres)	1576	0.72	0.76	0.05	13.00	1404	12.84	3.92	0.08	90.00	1181	0.94	2.05	0.01	50.00
Organic fertilizers application rate (kgs/acre)	1576	36.00	51.45	0.00	120.0	1404	14.00	36.45	0.00	120.0	1181	12.26	34.28	0.00	100.00
Pesticides application rate (liters/acre)	1576	1.96	1.75	0.20	5.00	1404	2.37	1.98	0.20	5.00	1181	2.85	1.98	0.20	5.00
Region															
1=Central (0=No,1=Yes)	1576	0.47	0.50	0.00	1.00	1404	0.27	0.44	0.00	1.00	1181	0.47	0.50	0.00	1.00
2=Eastern (0=No,1=Yes)	1576	0.35	0.48	0.00	1.00	1404	0.23	0.42	0.00	1.00	1181	0.14	0.35	0.00	1.00
3=Northern (0=No,1=Yes)	1576	0.08	0.28	0.00	1.00	1404	0.28	0.45	0.00	1.00	1181	0.17	0.37	0.00	1.00
4= Western (0=No,1=Yes)	1576	0.10	0.30	0.00	1.00	1404	0.23	0.42	0.00	1.00	1181	0.22	0.42	0.00	1.00
Access to credit (0=No,1=Yes)	1576	0.08	0.28	0.00	1.00	1404	0.11	0.31	0.00	1.00	1181	0.11	0.31	0.00	1.00
Access to Agriculture extension trainings (0=No,1=Yes)	1576	0.14	0.35	0.00	1.00	1404	0.16	0.37	0.00	1.00	1181	0.15	0.36	0.00	1.00
Agriculture extension visits (number)	1576	2.27	1.84	1.00	12.00	1404	2.23	1.74	1.00	12.00	1181	2.47	1.98	1.00	12.00
Membership to a farmer group (0=No,1=Yes)	1576	0.10	0.30	0.00	1.00	1404	0.10	0.31	0.00	1.00	1181	0.10	0.30	0.00	1.00
Distance to market (Km)	1576	1.33	3.75	0.00	50.00	1404	2.13	6.50	0.00	42.00	1181	1.77	5.54	0.00	30.00
Note: Dummies were created for categorical variables															
Source: Generated by the Author															

Table 4.2 presents the descriptive summary statistics of the study variables across the three survey years. The mean application rate of inorganic fertilizers declined consistently from 6.91 kg/acre in 2015/2016 to 5.05 kg/acre in 2018/2019 and further to 4.04 kg/acre in 2019/2020. In contrast, the use of improved seed showed a slight but steady increase, rising from 5.89 kg/acre in 2015/2016 to 6.19 kg/acre in both 2018/2019 and 2019/2020. This divergence suggests that while farmers are increasingly willing to use improved seed, their complementary investment in fertilizer has weakened, which may undermine productivity gains. The average age of farmers remained stable, ranging between 37 and 39 years, while the proportion of male farmers increased marginally from 48% in 2015/2016 to 50% in 2019/2020. Education levels also improved modestly, with the share of farmers reporting primary education rising from 46% in 2015/2016 to 50% in subsequent years. Household size averaged between 4.7 and 5 members, with maxima ranging from 14 to 17 members, showing consistency in household structures across waves. Farm size patterns were less consistent. The average crop area spiked sharply in 2018/2019 at 12.84 acres, compared to less than one acre in 2015/2016 and 2019/2020, suggesting either changes in reporting or possible shifts in land-use patterns during that period. Organic fertilizer application showed a marked decline over time (36.0 kg/acre in 2015/2016 to 12.26 kg/acre in 2019/2020), while pesticide use rose steadily from 1.96 liters/acre in 2015/2016 to 2.85 liters/acre in 2019/2020, pointing to a substitution trend in input use. Regional representation varied across waves, with the central region dominating in 2015/2016 and 2019/2020 (47%) while the northern region accounted for 28% of the sample in 2018/2019. Access to credit remained low but improved slightly from 8% in 2015/2016 to 11% in 2018/2019 and 2019/2020. Similarly, access to agricultural extension trainings remained limited but stable (14–16%), while extension visits averaged about 2–3 per household per year. Membership in farmer groups remained constant at about 10%. Finally, market access showed some fluctuations, with the average distance to the nearest market increasing from 1.33 km in 2015/2016 to 2.13 km in 2018/2019 before declining slightly to 1.77 km in 2019/2020.

4.2. Bivariate analysis

As earlier mentioned in Chapter Three Section 3.3.2, the analysis at this level was aimed at identifying potential independent variables of the intensity of inorganic fertilizer and improved seed adoption for further analysis. The results of the association between the outcomes and each explanatory variable in Pearson's correlation analysis are shown in Table 4.3.

Table 4.3: Results of the Pearson's correlation of improved seed application rate, inorganic fertilizer application rate, and the different explanatory variables

Variables	(1) Improved seed rate (kgs/acre)	(2) Inorganic fertilizers application rate (kgs/acre)	(3) Age of the farmer	(4) Sex of the farmer (0=Female, 1=Male)	(5) Education (Primary)	(6) Education (Secondary)	(7) Education (Higher)	(8) Household size(number)	(9) Crop Area (acres)	(10) Organic fertilizers application rate	(11) Pesticides application rate	(12) Region (Eastern)	(13) Region (Northern)	(14) Region (Western)	(15) Access to credit (0=No,1=Yes)	(16) Access to Agriculture extension trainings (0=No,1=Yes)	(17) Agriculture extension visits (number)	(18) Membership to a farmer group (0=No,1=Yes)	(19) Distance to market (Km)
1	1.00																		
2	0.002**	1.00																	
3	0.01*	-0.02*	1.00																
4	0.02*	0.03*	-0.02	1.00															
5	0.02	-0.01	0.01	-0.02	1.00														
6	-0.02	0.00	-0.02	0.03	-0.57	1.00													
7	0.00*	0.05**	-0.01	-0.01	-0.30	-0.18	1.00												
8	0.03*	-0.02*	-0.01	0.00	0.01	0.02	0.00	1.00											
9	0.12**	-0.09**	-0.01	-0.01	0.02	0.01	-0.05	0.04	1.00										
10	0.05**	0.35**	-0.03	-0.01	-0.01	0.02	0.03	0.01	-0.05	1.00									
11	0.01*	0.02*	-0.01	0.00	0.01	-0.02	0.01	-0.01	-0.01	-0.07	1.00								
12	0.01*	0.03	-0.01	0.01	0.07	-0.01	-0.05	0.05	-0.02	0.17	-0.02	1.00							
13	0.02*	-0.09**	0.05	0.00	-0.03	0.03	-0.02	0.01	0.17	-0.07	0.00	-0.26	1.00						
14	0.00	-0.01	-0.03	0.01	-0.01	-0.02	-0.03	-0.01	0.08	-0.06	0.00	-0.27	-0.21	1.00					
15	0.00*	-0.01*	-0.01	0.01	-0.01	0.02	0.00	0.00	0.03	-0.03	0.00	0.01	-0.01	0.04	1.00				
16	0.02*	-0.01*	0.03	0.01	0.00	0.00	-0.02	0.00	0.01	-0.03	0.02	-0.03	0.02	0.02	0.00	1.00			
17	0.03**	0.00*	0.01	0.00	-0.01	0.00	0.01	0.03	-0.03	0.00	0.03	0.02	0.02	-0.02	0.02	0.02	1.00		
18	-0.01*	-0.01*	0.01	0.01	0.03	0.00	0.00	-0.01	0.00	0.00	-0.02	0.00	0.01	-0.01	0.00	0.58	0.01	1.00	
19	0.00*	-0.01*	-0.01	0.03	-0.03	0.04	0.00	0.03	0.06	-0.02	0.03	0.00	0.05	-0.02	0.00	0.01	0.00	0.01	1.00

Significance: **p < 0.05, *p < 0.2;

Note 1: Dummies were created for categorical variables; Note 2. The analysis was based on all N = 4,161 respondents; Source: Generated by the Author

Relationship between the Intensity of Inorganic Fertilizer and Improved Seed Use

The Pearson correlation analysis showed a positive but very weak association between the intensity of inorganic fertilizer and improved maize seed use (Coefficient = 0.002, $p < 0.05$). Although the association was statistically significant at the 5 percent level, the magnitude of the correlation indicates that the linear association between the two input-use intensity measures was negligible.

To further assess whether joint estimation of the two outcome equations was appropriate, the Breusch-Pagan test of independence was conducted to determine whether the disturbances of the inorganic fertilizer use intensity and improved maize seed use intensity equations were correlated. The results of this test are presented in Section 4.3.

Intensity of Inorganic Fertilizer Use

As shown in Table 4.3, farmer's education level, crop area, and organic fertilizer application rate were significantly associated with the intensity of inorganic fertilizer use ($p < 0.05$). In contrast, farmer's age, sex, household size, and pesticide application rate were not significantly associated with the intensity of inorganic fertilizer use ($p > 0.05$). Nevertheless, age, sex, household size, and pesticide application rate were retained for the multivariable analysis based on their established theoretical and empirical relevance to inorganic fertilizer use.

Among the institutional factors, region was the only variable significantly associated with the intensity of inorganic fertilizer use ($p < 0.05$). Access to credit, participation in extension training, extension visits, membership in farmer groups, and distance to market were not significantly associated with fertilizer-use intensity at the bivariate level ($p > 0.05$). However, these variables were retained for the multivariable analysis because of their established relevance in explaining farmers' input-use decisions.

Intensity of Improved Seed Use

The results in Table 4.3 further show that crop area and organic fertilizer application rate were significantly associated with the intensity of improved seed use ($p < 0.05$). Farmer's age, sex, education level, household size, and pesticide application rate were not significantly associated with improved seed-use intensity at the bivariate level ($p > 0.05$). However, these variables were retained for the multivariable analysis based on their established theoretical and empirical relevance to improved seed use.

With respect to institutional factors, access to extension visits was significantly associated with the intensity of improved seed use ($p < 0.05$). Region, access to credit, participation in extension training, membership in farmer groups, and distance to market were not significantly associated with improved seed-use intensity ($p > 0.05$). These variables were nevertheless retained for the multivariable analysis because of their established relevance to farmers' decisions regarding the use of improved seed.

4.3. Multivariable analysis

Before presenting the regression results, diagnostic tests were conducted to assess the adequacy of the Seemingly Unrelated Regression (SURE) model fitted for both the intensity of inorganic fertilizer use and intensity of improved seed use. Multicollinearity was first assessed using the Variance Inflation Factor (VIF), including the time dummies for 2018/2019 and 2019/2020 (Appendices I and II). All explanatory variables recorded a VIF values below 10, suggesting no serious multicollinearity concerns among the predictors.

The overall adequacy of the fitted equations was confirmed using the Wald chi-square test. For inorganic fertilizer application rate, the test statistic was $\chi^2(19) = 680.78$ ($p < 0.001$), while for the rate of use of improved seed it was $\chi^2(19) = 158.80$ ($p < 0.001$). These highly significant results indicate that, collectively, the predictors explained a significant portion of the variation in the intensity of use in both models.

Finally, the cross-equation error correlation was examined to validate the use of the SURE framework. The estimated correlation between the error terms of the the inorganic fertilizer use intensity and improved maize seed use intensity equations was 0.481. The Breusch–Pagan test of independence yielded $\chi^2(1) = 16.549$ ($p = 0.035$), rejecting the null hypothesis of independent errors. This confirmed that the error terms were significantly correlated across equations, justifying the choice of the SURE model over separate regression estimations.

Taken together, these diagnostic checks confirm that the model is statistically adequate and appropriate for analyzing the determinants of the intensity of inorganic fertilizer and improved seed use among smallholder maize farmers in Uganda. The results of the SURE model for the intensity of inorganic fertilizer and improved seed adoption are presented in Table 4.4.

Table 4.4: Results of the SURE model for the intensity of inorganic fertilizer and improved seed adoption and their factors

Variable	Inorganic fertilizer			Improved seed		
	Coef. ^a	Std. Error. ^b	p-value	Coef. ^a	Std. Error. ^b	p-value
Age of the farmer	-0.002	0.009	0.963	0.001	0.001	0.537
Sex of the farmer (0=Female, 1=Male)	0.587	0.299	0.043*	0.053	0.030	0.040*
Education Level						
1=No education (0=No,1=Yes)✓						
2=Primary (0=No,1=Yes)	0.172	0.42	0.683	0.025	0.042	0.547
3=Secondary (0=No,1=Yes)	0.036	0.465	0.938	-0.039	0.047	0.408
4=Higher (0=No,1=Yes)	1.079	0.625	0.084	0.006	0.063	0.923
Household size (number)	-0.057	0.059	0.326	0.037	0.024	0.129
Crop Area (acres)	-0.204	0.126	0.036*	0.144	0.013	0.000*
Organic fertilizers application rate (kgs/acre)	0.922	0.042	0.000*	0.013	0.004	0.003*
Pesticides application rate (liters/acre)	1.111	0.349	0.001*	0.032	0.035	0.368
Region						
1=Central (0=No,1=Yes)✓						
2=Eastern (0=No,1=Yes)	-1.349	0.390	0.001*	0.012	0.039	0.752
3=Northern (0=No,1=Yes)	-1.818	0.444	0.000*	0.041	0.045	0.362
4= Western (0=No,1=Yes)	-0.057	0.435	0.896	0.020	0.044	0.654
Access to credit (0=No,1=Yes)	0.268	0.502	0.594	0.010	0.051	0.850
Access to Agriculture extension trainings (0=No,1=Yes)	0.039	0.511	0.940	0.074	0.051	0.152
Agriculture extension visits (number)	0.011	0.081	0.893	0.016	0.008	0.044*
Membership to a farmer group (0=No,1=Yes)	-0.239	0.613	0.697	-0.066	0.062	0.286
Distance to market (Km)	-0.002	0.028	0.945	-0.001	0.003	0.899
Year 2015/2016✓						
Year 2018/2019	-0.962	0.583	0.037*	-0.449	0.059	0.000*
Year 2019/2020	-0.843	0.412	0.041*	0.018	0.041	0.667
Constant	2.629	0.790	0.001*	1.115	0.081	0.000*
Chi-square	680.780			158.800		
Number of observations	4161			4161		
Prob > chi2	0.000			0.000		
Significance: *p < 0.05						
✓Reference categories adopted in the analysis						
^a Coefficients						
^b Standard Errors of Coefficients						

4.3.1 Time Effects on the Intensity of Input Use

The time dummy coefficients indicate significant changes in input-use intensity relative to the 2015/16 base year. The intensity of inorganic fertilizer use declined significantly in both 2018/19 (Coefficient = -0.962 , $p = 0.037$) and 2019/20 (Coefficient = -0.843 , $p = 0.041$). Similarly, the intensity of improved maize seed use declined significantly in 2018/19 (Coefficient = -0.449 , $p < 0.001$), although the 2019/20 coefficient was not statistically significant ($p > 0.05$). Thus, compared with 2015/16, fertilizer use intensity remained significantly lower in both subsequent survey periods, whereas the decline in improved seed-use intensity observed in 2018/19 did not persist into 2019/20.

The decline in input-use intensity may reflect changes in the economic and production environment faced by smallholder farmers over the study period. In particular, increases in the cost of agricultural inputs, liquidity and credit constraints, changes in expected returns to input use, and production risks may have reduced farmers' willingness or ability to apply inorganic fertilizer at higher rates. These factors may be particularly important for fertilizer because it requires relatively substantial cash expenditure and its economic returns depend on soil conditions, rainfall, crop prices, and other complementary inputs. The relatively smaller and temporary decline in improved seed-use intensity suggests that farmers may have been willing to maintain improved seed use than fertilizer use, possibly because improved seed generally requires a lower absolute financial outlay per unit of land than fertilizer.

These findings have important implications for the study. First, the significant time effects demonstrate that input-use intensity changed over the study period even after controlling for the observed farmer, farm, and institutional characteristics included in the model. This indicates that changes in the broader production environment should be considered when interpreting determinants of fertilizer and improved seed use. Second, the persistent decline in fertilizer use intensity suggests that policies aimed at increasing agricultural productivity should not focus only on farmers' characteristics or access to extension services, but should also address the affordability and accessibility of inorganic fertilizer. Finally, the absence of a significant decline in improved seed use intensity by 2019/20 suggests relatively greater stability in improved seed use, highlighting the importance of examining fertilizer and improved seed use separately rather than assuming that farmers respond to both inputs in the same way.

4.3.2 Differences and Similarities in the Determinants of Inorganic Fertilizer and Improved Seed Adoption

In both models, male farmers used technologies more intensively than female farmers, though the effect was more substantial for fertilizer (Coefficient = 0.587, $p = 0.043$) than for improved seed (Coefficient = 0.053, $p = 0.040$). This gender disparity highlights persistent structural barriers facing women, including access to resources and decision making autonomy. Similarly, the application rate of organic fertilizer positively influenced the intensity of both fertilizer use (Coefficient = 0.922, $p = 0.000$) and improved seed use (Coefficient = 0.013, $p = 0.003$), suggesting complementarities between organic practices and the use of modern inputs.

However, key differences also stand out. Larger crop area reduced the intensity of fertilizer use (Coefficient = -0.204, $p = 0.036$), but increased the intensity of improved seed use (Coefficient = 0.144, $p = 0.000$). This contrast may reflect economies of scale in seed use, where farmers with larger plots invest more in improved seeds, while fertilizer use is constrained by cost, making it less feasible to apply uniformly on larger areas. Pesticide use was another significant factor for inorganic fertilizer application rate (Coefficient = 1.111, $p = 0.001$) but not for the rate of use of improved seed, underscoring the role of integrated pest and soil fertility management practices in shaping fertilizer demand.

Regional differences also played a role, but only in the inorganic fertilizer application rate. Farmers in the Eastern (Coefficient = -1.349, $p = 0.001$) and Northern regions (Coefficient = -1.818, $p = 0.000$) applied inorganic fertilizers less intensively than their counterparts in the Central region, while no regional differences were observed in the rate of use of improved seed.

This suggests that inorganic fertilizer use is more sensitive to regional disparities in market access, extension services, and agroecological conditions, while improved seed use may be more evenly spread across regions.

These results suggest that while some determinants, such as gender and complementarities with organic inputs, affect both technologies similarly, the application rate of inorganic fertilizer and the rate of use of improved seed is also driven by distinct dynamics. Inorganic fertilizer use is shaped more by structural constraints such as region and land size, while improved seed use is more closely linked to the expansion of cultivated area.

4.3.3 Factors influencing the intensity of use of inorganic fertilizer

Sex of the farmer

The results in Table 4.4 show that sex of the farmer was positively and significantly associated with the intensity of use of inorganic fertilizer (Coefficient = 0.587, $p = 0.043$). Male farmers applied fertilizers more intensively than female farmers, suggesting that being male is positively associated with adoption intensity. This finding aligns with Aseete et al. (2023) who observed that male-headed households in Uganda were more likely to use fertilizers because men typically have greater control over productive resources such as land and income. Similarly, Nchanji et al. (2021) in Tanzania reported that female farmers faced constraints in accessing inputs, which reduced their adoption intensity of maize technologies. In the context of this study, the significance of sex likely reflects men's stronger decision-making power in agricultural investment, better access to markets and extension services, and larger cultivated areas. By contrast, female farmers often depend on low-input practices due to limited financial capacity and cultural norms that restrict their access to land and credit. These structural disparities help explain why male farmers in the sample applied fertilizers more intensively than women.

Crop Area

Crop area was negatively and significantly associated with the intensity of use of inorganic fertilizer (Coefficient = -0.204, $p = 0.036$). For every one percent increase in land allocated to maize, fertilizer application declined by 0.204 kg/acre. This indicates that farmers with larger plots applied lower rates of fertilizer per acre compared to those with smaller plots. This finding contrasts with Nchanji et al. (2021) in Tanzania and Katuuramu et al. (2020) in Uganda, who found that larger farms were associated with higher input adoption due to economies of scale and stronger incentives to invest in yield-enhancing technologies. The divergence observed here may be due to financial constraints faced by Ugandan smallholders. Farmers with larger plots may be unable to afford sufficient fertilizer for the entire farm, leading to under-application, while those with smaller plots concentrate inputs more intensively to maximize output from limited land.

Organic fertilizers application rate

The results also revealed a significant positive association between organic fertilizer use and the intensity of use of inorganic fertilizer (Coefficient = 0.922, $p = 0.000$). A unit increase in organic fertilizer application (kg/acre) was associated with a 0.922 kg/acre increase in

inorganic fertilizer use. This finding is consistent with Kyebogola et al. (2021) in Uganda and Rurangwa et al. (2020) in Rwanda, who demonstrated that combining organic and inorganic fertilizers boosted yields by 22% and 18%, respectively, due to improved soil structure and nutrient availability. In the context of this study, farmers who applied organic fertilizers were more likely to supplement them with inorganic fertilizers, reflecting complementary rather than substitutive use. The joint application helps mitigate soil fertility challenges common in Ugandan smallholder systems. Moreover, as noted by MAAIF (2019), most farmers apply less than the recommended rates of inorganic fertilizer. Thus, the positive effect of organic fertilizer suggests that farmers are using integrated soil fertility management strategies to move closer toward the recommended levels.

Pesticides application rate

Pesticide use was also positively and significantly associated with fertilizer use intensity (Coefficient = 1.111, $p = 0.001$). Farmers who applied more pesticides also applied more fertilizer per acre. This aligns with Tukahirwa (2019), who observed that pesticide use reduced pest-related losses and enabled farmers to maximize returns from other inputs. Similarly, Andaregie et al. (2021) in Ethiopia found that farmers who invested in pest control were also more likely to adopt complementary technologies such as fertilizers and improved seed. In this study, the relationship suggests that pesticide and fertilizer use are used as part of a package of technologies. Farmers aware of pest risks may intensify fertilizer use only when they can also protect crops from losses, ensuring greater returns from input investments.

Region

Finally, regional location was significantly associated with fertilizer use intensity ($p < 0.05$). Compared to farmers from the Central region, those from both the Eastern (Coefficient = -1.349, $p = 0.001$) and Northern (Coefficient = -1.818, $p = 0.000$) regions had significantly lower levels of fertilizer use, while those from Western region did not differ significantly from Central. This finding is consistent with Katuuramu et al. (2020), who highlighted regional disparities in technology use in Uganda, and with Nkhata et al. (2021), who reported that adoption is often shaped by location-specific factors such as infrastructure, soil conditions, and access to markets and extension services. The lower intensity in Eastern and Northern Uganda could be due to weaker market linkages, lower access to agricultural extension, and higher poverty levels compared to Central and Western regions. Central Uganda benefits from better

infrastructure, input distribution systems, and proximity to markets, while Northern and parts of Eastern regions are still recovering from historical conflicts and structural disadvantages that limit input adoption.

4.3.4 Factors influencing the intensity of improved seed use

Sex of the farmer

The results in Table 4.4 show that sex of the farmer was positively and significantly associated with the intensity of improved maize seed use (Coefficient = 0.053, $p = 0.040$). Male farmers used improved maize seed more intensively than female farmers, suggesting that gender plays an important role in seed technology adoption. This finding is consistent with Nchanji et al. (2021) in Tanzania, who found that female farmers faced systemic constraints in accessing inputs, thereby reducing their intensity of maize technology adoption. Similarly, Aseete et al. (2023) reported that male-headed households in Uganda used more fertilizers, largely due to their greater control over household resources. Martey et al. (2020) also confirmed in Ghana that male-headed households were more likely to adopt improved maize varieties, partly because they had better access to extension services. In the context of this study, the significant role of gender can be attributed to disparities in resource access and decision-making in Uganda. Men often have greater access to land, credit, and extension services, which facilitates their use of improved seeds at higher rates compared to women, who may face barriers such as limited land rights and restricted access to financial capital.

Crop Area

Crop area was positively and strongly associated with the rate of use of improved seed (Coefficient = 0.144, $p = 0.000$). Farmers cultivating larger plots used improved maize seed more intensively compared to those with smaller plots. This finding is consistent with Nchanji et al. (2021) in Tanzania and Katuuramu et al. (2020) in Uganda, both of whom showed that larger crop areas correlated with greater input adoption. Arslan et al. (2020) similarly observed in Ethiopia that farmers with more than 1 hectare of maize had a 17% higher adoption rate of improved maize seeds due to economies of scale. In this study, the positive association suggests that larger farms face greater production risks and therefore have stronger incentives to invest in yield-enhancing technologies. Larger landholders may also benefit from economies of scale, which reduce per-unit adoption costs, making intensive use of improved seed more feasible.

Organic fertilizers application rate

The intensity of improved seed use was also positively influenced by organic fertilizer use ($p < 0.05$). A unit increase in the application rate of organic fertilizer (kg/acre) was associated with a 0.013 kg/acre increase in improved maize seed use (Coefficient = 0.013, $p = 0.003$). This finding supports evidence from Kyebogola et al. (2021) in Uganda and Rurangwa et al. (2020) in Rwanda, both of whom found that combining organic and inorganic fertilizers improved soil fertility and crop yields. Similarly, Arslan et al. (2020) in Ethiopia noted that farmers applying organic fertilizers, such as chicken manure, achieved higher grain yields and were more likely to adopt improved seeds. In the Ugandan context, where most farmers apply less than the recommended 8–10 kg/acre of improved maize seed (FAO, 2017; MAAIF, 2018a), the complementary use of organic fertilizers appears to encourage improved seed use by improving soil health and nutrient availability. This complementary relationship helps farmers realize greater benefits from improved seed, thereby motivating more intensive use.

Agriculture extension visits

Extension visits were positively and significantly related to the rate of use of improved seed (Coefficient = 0.016, $p = 0.044$). Farmers who interacted more frequently with extension agents used improved seed at higher rates. This aligns with Maertens et al., (2021), who found in Malawi that frequent extension visits increased adoption of fertilizers by up to 88% through improved farmer knowledge on application practices, leading to higher maize productivity. Atukunda et al. (2022) also reported that agricultural extension enhanced productivity in Uganda by facilitating farmer awareness and adoption of improved inputs. The significance of extension visits can be explained by their role in bridging the information gap that often limits smallholder adoption. Farmers who receive extension support are better informed about the benefits, planting techniques, and management practices associated with improved seed, which motivates them to use more intensively. The positive effect of extension therefore highlights the importance of strengthening Uganda's extension services to scale up the use of improved seed technologies.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.0. Introduction

This Chapter presents the summary of the findings, conclusion, and recommendations from the study.

5.1. Summary of results

This study examined the determinants of the intensity of inorganic fertilizer and improved seed use among smallholder maize farmers in Uganda, focusing on household, farm-related, institutional, and time-related factors. The findings showed that the average intensity of improved maize seed use (6.07 kg/acre; 95% CI: 5.78–6.36) was higher than that of inorganic fertilizer use (4.51 kg/acre; 95% CI: 4.09–4.82). This indicates greater use of improved seed relative to inorganic fertilizer among the sampled maize farmers, highlighting differences in the intensity with which these two production inputs were used.

The analysis also revealed significant changes in input-use intensity across the survey periods. Relative to the 2015/16 base year, the intensity of inorganic fertilizer use declined significantly in both 2018/19 and 2019/20. For improved maize seed, intensity of use also declined significantly in 2018/19 relative to 2015/16, but the difference in 2019/20 was not statistically significant ($p > 0.05$). These results indicate that the decline in fertilizer use intensity persisted through 2019/20, whereas the decline in improved seed use intensity observed in 2018/19 was not statistically evident in 2019/20. The time effects therefore suggest that changes in the broader agricultural and economic environment over the study period affected the use of the two inputs differently.

At the bivariate level, the intensity of inorganic fertilizer use was significantly associated with farmer education, crop area, organic fertilizer application rate, and region ($p < 0.05$). Other factors, including age, sex, household size, pesticide use, access to credit, extension training, extension visits, farmer group membership, and distance to market, were not statistically significant ($p > 0.05$). For improved seed use intensity, crop area, organic fertilizer application rate, and extension visits were significant ($p < 0.05$), while the other variables were not statistically significant.

At the multivariable level, a Seemingly Unrelated Regression (SURE) model was estimated to jointly examine the determinants of inorganic fertilizer use intensity and improved maize seed use intensity. For inorganic fertilizer use, sex of the farmer, crop area, organic fertilizer application rate, and pesticide use were significant household and farm-related predictors ($p < 0.05$), while region was the only institutional factor that remained significant. For improved maize seed use, sex of the farmer, crop area, and organic fertilizer application rate were significant household and farm-related predictors, while agricultural extension visits emerged as the only significant institutional determinant ($p < 0.05$).

Overall, the findings reveal both common and distinct determinants of the intensity of inorganic fertilizer and improved seed use. Sex of the farmer, crop area, and organic fertilizer use consistently influenced the intensity of both inputs. In contrast, region was uniquely important for inorganic fertilizer use, while extension visits were particularly important for improved seed use. The significant time effects further demonstrate that input-use intensity changed over the study period, with a persistent decline in inorganic fertilizer use relative to 2015/16 and a more temporary decline in improved seed use. These findings underscore the importance of considering both farmer- and farm-level characteristics and changes over time when designing interventions to promote sustained and appropriate use of improved agricultural inputs among smallholder maize farmers in Uganda.

5.2. Conclusion

This study set out to examine the determinants of the intensity of inorganic fertilizer and improved seed use among smallholder maize farmers in Uganda. The findings demonstrate that while the rate of use of improved maize seed was relatively higher, farmers continue to underutilize inorganic fertilizers, falling well below recommended application rates. The analysis further showed that household and farm-related factors particularly sex of the farmer, crop area, and organic fertilizer use consistently influenced the intensity of both inorganic fertilizer and improved seed use. Institutional factors, however, varied: region significantly shaped inorganic fertilizer application rate, while extension visits were central to improved maize seed use.

These results underscore that technology use among smallholder farmers is multifaceted and input-specific. Whereas the rate of use of improved seed is more responsive to extension support, inorganic fertilizer use is strongly shaped by regional disparities and complementary

input practices such as organic manure application. Addressing these differences is critical for achieving balanced and sustainable productivity gains.

In sum, the study highlights the need for targeted interventions that go beyond simply promoting input use, focusing instead on reducing structural and institutional barriers that limit farmers' ability to intensively use both inorganic fertilizers and improved maize seed.

5.3. Recommendations

Based on the study findings, several interventions are necessary to enhance the intensity of inorganic fertilizer and improved seed use among smallholder maize farmers in Uganda. These recommendations address key structural barriers and leverage opportunities to promote wider intensity use:

Sex of the farmer

Since male farmers were more likely to intensively use both fertilizers and improved seeds, interventions should focus on empowering women farmers, who often face barriers in accessing inputs, credit, and extension services. Policies promoting gender-sensitive input distribution, targeted training programs, and women's participation in farmer groups could reduce these disparities and improve adoption rates among female-headed households.

Crop Area

The negative association between crop area and inorganic fertilizer application rate, alongside the positive effect on improved maize seed use, suggests that farmers with larger landholdings may under apply inorganic fertilizers due to cost constraints but invest in improved seeds for efficiency. Programs should promote input packages tailored to farm size, such as subsidies or bulk purchase schemes for fertilizers, while also encouraging efficient land use and intensification strategies for sustainable productivity.

Organic fertilizers application rate

The strong positive association between organic and inorganic inputs indicates that promoting Integrated Soil Fertility Management (ISFM) can boost intensity of use. Extension services should emphasize the complementarities of organic and inorganic fertilizers, training farmers on composting, manure management, and balanced nutrient application. Support for

community level organic fertilizer production and distribution could also make this approach more accessible.

Pesticides application rate

The positive link between pesticide application and inorganic fertilizer application rate suggests that farmers investing in crop protection are also more likely to use fertilizers. This underscores the need for integrated pest and soil fertility management programs. Policies should ensure that training on fertilizer use includes guidance on pest management, promoting a holistic approach to improving yields.

Region

Significant regional differences in inorganic fertilizer application rate highlight disparities in infrastructure, agro-ecological conditions, and market access. Policymakers should prioritize region-specific strategies, such as improving transport and market infrastructure in the Eastern and Northern regions, and providing location-tailored input distribution and extension services. Regional equity in service delivery is critical for closing intensity of use gaps.

Agriculture extension visits

The positive effect of extension visits on the rate of use of improved seed emphasizes the role of knowledge transfer. Strengthening extension systems through increased staffing, digital platforms, and farmer-to-farmer learning networks can expand access to reliable information. Sustained investment in extension services will enhance farmers' capacity to adopt and manage improved seeds effectively.

Finally, further research should investigate the causal mechanisms behind changes in input-use intensity over time. The study found that inorganic fertilizer use intensity declined significantly in 2018/19 and 2019/20 relative to 2015/16, while improved seed use intensity declined in 2018/19 but was not significantly different from the base year in 2019/20. Further research could investigate why these changes occurred, particularly the roles of input prices, access to credit, rainfall and production risks, output prices, and farmers' expected returns. A future study could use more recent panel data and time varying economic and climatic variables to identify the factors driving changes in input use intensity over time.

References

- Abdulaleem, M. A., Oluwatusin, F. M., & Ojo, O. S. (2019). Efficiency of Maize Production among Smallholder Farmers in Southwest, Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology*, 30(1), 1–10. <https://doi.org/10.9734/ajaees/2019/v30i430120>
- Abebe, T., Sintayehu, H., Endeshaw, H., Yared, D., & Berhanu, A. (2020). Factors affecting the profitability of smallholder common bean producers in central rift valley of Ethiopia. *Ethiopian Journal of Agricultural Sciences*, 30(3), 99–118.
- Akwango, A. D., Lukwago, G., Ariong, R. M., Kiyangi, I., Obongo, I., Adur, S., Angundupo, S., Ndhokero, J., Luzinda, H., Akongo, T., Magala, D., Mutonyi, S., Bwanika, G., Ambrose, A., Yona, B., & Bua, A. (2022). Impact of NARO Bean and Maize Technologies on Farmer Livelihoods and Contribution to Uganda's Economy.
- Anang, B. T., & Asante, B. O. (2020). Farm household access to agricultural services in northern Ghana. *Heliyon*, 6(11). <https://doi.org/10.1016/j.heliyon.2020.e05517>
- Andaregie, A., Astatkie, T., & Teshome, F. (2021). Determinants of market participation decision by smallholder haricot bean (*phaseolus vulgaris* l.) farmers in Northwest Ethiopia. *Cogent Food and Agriculture*, 7(1). <https://doi.org/10.1080/23311932.2021.1879715>
- Arslan, A., Floress, K., Lamanna, C., Lipper, L., Asfaw, S., & Rosenstock, T. (2020). The Adoption of Improved Agricultural Technologies - a Meta-Analysis for Africa. In SSRN Electronic Journal. <https://doi.org/10.2139/ssrn.3681375>
- Aseete, P., Barkley, A., Katungi, E., Ugen, M. A., & Birachi, E. (2023). Public-private partnership generates economic benefits to smallholder bean growers in Uganda. *Food Security*, 15(1), 201–218. <https://doi.org/10.1007/s12571-022-01309-5>
- Atukunda, G., Atekyereza, P., Walakira, J., & State, A. E. (2022). Increasing Farmers' Access to Aquaculture Extension Services: Lessons from Central and Northern Uganda. *Uganda Journal of Agricultural Sciences*, 20(2), 49–68. <https://doi.org/10.4314/ujas.v20i2.5>
- Chemura, A., Arumugum, P., Murken, L., Romanovska, P., Awori, E., Loeben, S. Von, & Gornott, C. (2025). Contribution of improved varieties to maize productivity under climate change in Uganda. *Food Security*. <https://doi.org/10.1007/s12571-025-01564-2>
- Cholo, M., Marisennayya, S., Bojago, E., Leja, D., & Divya, R. K. (2023). Determinants of adoption and intensity of improved haricot bean (*Phaseolus vulgaris* L.) varieties: A Socio-agronomic study from southern Ethiopia. *Journal of Agriculture and Food*

- Research, 13(April). <https://doi.org/10.1016/j.jafr.2023.100656>
- Erenstein, O., Jaleta, M., Sonder, K., & Mottaleb, K. (2022). Global maize production , consumption and trade : trends and R & D implications. *Food Security*, 14, 1295–1319. <https://doi.org/10.1007/s12571-022-01288-7>
- FAO. (2017). Drought-tolerant maize varieties in Uganda.
- FAO. (2022). The State of Food and Agriculture 2022. Leveraging automation in agriculture for transforming agrifood systems.
- FAO. (2023). Crop Prospects and Food Situation Report (Issue 3). <https://www.fao.org/giews/reports/crop-prospects/en/>
- Guye, A., Tefera, T., Sileshi, M., & Khalil, A. (2024). Determinants of multiple maize technology package adoption in Ethiopia : evidence from the Sidama region. *Discover Food*. <https://doi.org/10.1007/s44187-024-00166-9>
- Juarez, R. T., Fowler, M., & Kobusingye, C. M. (2025). UNDERSTANDING FARMERS' USE OF IMPROVED MAIZE SEEDS IN UGANDA. *Research Journal of Agricultural Economics and Development*, 4(1), 1–23. <https://doi.org/10.52589/RJAED-EVFXZTRN>
- Katuuramu, D. N., Luyima, G. B., Nkalubo, S. T., Wiesinger, J. A., Kelly, J. D., & Cichy, K. A. (2020). On-farm multi-location evaluation of genotype by environment interactions for seed yield and cooking time in common bean. <https://doi.org/10.1038/s41598-020-60087-2>
- Katuuramu, D. N., Luyima, G. B., Nkalubo, S. T., Wiesinger, J. A., Kelly, J. D., & Cichy, K. A. (2020). On-farm multi-location evaluation of genotype by environment interactions for seed yield and cooking time in common bean. 1–12. <https://doi.org/10.1038/s41598-020-60087-2>
- Katya, K. E., Agole, D., Obia, A., Okello, D. M., & Odongo, W. (2025). Adoption of sustainable agricultural intensification practices: assessing the role of institutional and socio-economic factors amongst smallholder farmers. *Cogent Social Sciences*, 11(1). <https://doi.org/10.1080/23311886.2025.2470373>
- Kelil, A., Girma, Y., & Hiruy, M. (2020). Access and Use of Agricultural Information in Africa: Conceptual Review. *Information and Knowledge Management*, 10(7), 1–5. <https://doi.org/10.7176/ikm/10-7-01>
- KilimoTrust. (2022). The Maize Value Chain in Uganda. <https://kilimotrust.org.ug>
- Kipkogei, S., Han, J., Mwalupaso, G., Tanui, J., & Brenya, R. (2025). The synergistic effects of microcredit access and agricultural technology adoption on maize farmer ' s income in Kenya. *PLoS ONE*, 20(1), e0316014. <https://doi.org/10.1371/journal.pone.0316014>

- Kyebogola, S., Semalulu, O., Lenssen, A. W., Yost, R. S., Kyomuhendo, P., Tenywa, M. M., & Mazur, R. E. (2021). Exploring on-farm additive common bean yield potential to organic and mineral fertilizers on contrasting soils of Buganda Catena , Central Uganda. *African Journal of Agricultural Research*, 17(3), 463–471. <https://doi.org/10.5897/AJAR2020>.
- Lance, H. G., Andrew, W. L., Russell, S. Y., Ebby, S. L., Onesmus, S., Moses, T., & Robert, E. M. (2016). Improved production systems for common bean on Phaeozem soil in South-Central Uganda. *African Journal of Agricultural Research*, 11(46), 4796–4809. <https://doi.org/10.5897/ajar2016.11760>
- MAAIF. (2018a). Maize Training Manual for Extension workers in Uganda.
- MAAIF. (2018b). National Seed Policy (Issue April).
- MAAIF. (2019). Maize Training Manual for Extension workers in Uganda Partners. Maize Training Manual for Extension Workers in Uganda Partners, 81.
- Macauley, H. (2015). Cereal Crops: Rice, Maize, Millet, Sorghum, Wheat.
- Manda, J., Feleke, S., Mutungi, C., Tufa, A. H., Mateete, B., Abdoulaye, T., & Alene, A. D. (2024). Technological Forecasting & Social Change Assessing the speed of improved postharvest technology adoption in Tanzania : The role of social learning and agricultural extension services. *Technological Forecasting & Social Change*, 202(March), 123306. <https://doi.org/10.1016/j.techfore.2024.123306>
- Manyanga, M., Pedzisa, T., & Hanyani-Mlambo, B. (2023). Adoption of agroecological intensification practices in Southern Africa: A scientific review. *Cogent Food and Agriculture*, 9(1). <https://doi.org/10.1080/23311932.2023.2261838>
- Martey, E., Etwire, P. M., & Kuwornu, J. K. M. (2020). Economic impacts of smallholder farmers’ adoption of drought-tolerant maize varieties. *Land Use Policy*, 94(March 2018), 104524. <https://doi.org/10.1016/j.landusepol.2020.104524>
- Midamba, D. C., Agbolosoo, J. A., Ouya, F. O., Kwesiga, M. (2025). The contribution of Socio-Economic factors to adoption of inorganic fertilizers among maize farmers in Western Uganda. *Discover Sustainability*, 6(1), 1–16. <https://doi.org/10.1007/s43621-025-01610-1>
- Midamba, D. C., Agbolosoo, J. A., Ouya, F. O., & Kwesiga, M. (2025). The contribution of Socio-Economic factors to adoption of inorganic fertilizers among maize farmers in Western Uganda. *Discover Sustainability*, 6:683. <https://doi.org/10.1007/s43621-025-01610-1>
- Miehe, C., Sparrow, R., Spielman, D., & Nabwire, L. (2025). How misinformation and

- mismatched expectations reduce adoption of improved seeds. 2(2).
- Namirembe, S. K., & Kisaame, E. K. (2023). © 2023 by the International Fund for Agricultural Development (IFAD) The opinions expressed in this publication are those of the authors and do not necessarily represent those of IFAD.
- Nchanji, E. B., Lutomia, C. K., & Ageyo, O. C., Karanja, D., & Kamau, E. (2021). Gender-responsive participatory variety selection in kenya: Implications for common bean (*phaseolus vulgaris* l.) breeding in kenya. *Sustainability* (Switzerland), 13(23), 1–17. <https://doi.org/10.3390/su132313164>
- Ndeko, A. B., Chuma, G. B., Mondo, J. M., Kazamwali, L. M., Civava, R., Bisimwa, E. B., & Mushagalusa, G. N. (2025). Farmers’ preferred traits, production constraints, and adoption factors of improved maize varieties under South-Kivu rainfed agro-ecologies, eastern D.R. Congo: implications for maize breeding. *International Journal of Agricultural Sustainability*, 23(1), 1–26. <https://doi.org/10.1080/14735903.2025.2464524>
- Nkhata, W., Shimelis, H., & Chirwa, R. (2021). Productivity of Newly Released Common Bean (*Phaseolus vulgaris* L.) Varieties Under Sole Cropping and Intercropping With Maize (*Zea mays* L.). *Frontiers in Sustainable Food Systems*, 5(October), 1–10. <https://doi.org/10.3389/fsufs.2021.741177>
- NPA. (2020). Third National Development Plan (NDPIII) 2020/21-2024/25. In National Planning Authority (Issue January). <http://envalert.org/wp-content/uploads/2020/06/NDP-3-Finale.pdf>
- Osewe, M., Aijun, L., & Jiqin, H. (2023). Sustainable intensification and food security : A panel data assessment of the smallholder maize farmers in Uganda. *Global Food Security* V, 39, 100724. <https://doi.org/10.1016/j.gfs.2023.100724>
- Rurangwa, E., Vanlauwe, B., & Giller, K. E. (2020). The response of climbing bean to fertilizer and organic manure in the Northern Province of Rwanda. *Experimental Agriculture*, 56(5), 722–737. <https://doi.org/10.1017/S0014479720000277>
- Ruzzante, S., Labarta, R., & Bilton, A. (2021). Adoption of agricultural technology in the developing world : A meta-analysis of the empirical literature. *World Development*, 146, 105599. <https://doi.org/10.1016/j.worlddev.2021.105599>
- Selejio, O., & Lasway, J. A. (2018). Economic analysis of the adoption of inorganic fertilisers and improved maize seeds in Tanzania. 14(4), 310–330.
- Tafesse, A., Gechere, G., Asale, A., Belay, A., Recha, W., Aynekulu, E., Berhane, Z., Osano, P. M., Teferi, D., & Solomon, D. (2023). Determinants of maize farmers market participation in Southern Ethiopia : Emphasis on demographic , socioeconomic and

- institutional factors Determinants of maize farmers market participation in Southern Ethiopia : Emphasis on demographic , socioeconomic a. *Cogent Food & Agriculture*, 9(1). <https://doi.org/10.1080/23311932.2023.2191850>
- Tambo, J. A., & Mockshell, J. (2018). Differential Impacts of Conservation Agriculture Technology Options on Household Income in Sub-Saharan Africa. *Ecological Economics*, 151(May), 95–105. <https://doi.org/10.1016/j.ecolecon.2018.05.005>
- Tudi, M., Ruan, H. D., Wang, L., Lyu, J., Sadler, R., Connell, D., Chu, C., & Phung, D. T. (2021). Agriculture Development, Pesticide Application and its Impact on the Environment. *International Journal of Environmental Research and Public Health*, 18(3), 1–24. <https://doi.org/10.3390/ijerph18031112>
- Tukahirwa, E. M. (2019). Trends In Pesticide Usage In Uganda. In *Management of Pests and Pesticides* (pp. 182–190). <https://doi.org/10.1201/9780429038587-22>
- UBOS. (2019). Annual Agricultural Survey.
- UBOS. (2023a). Statistical Abstract 2022. <http://www.ubos.org/onlinefiles/uploads/ubos/pdf documents/abstracts/Statistical Abstract 2013.pdf>
- UBOS. (2023b). Uganda Bureau of Statistics Evidence Based: Annual Agricultural Survey 2020 (Issue December).
- Wongnaa, C. A., Awunyo-Vitor, D., & Bakang, A. J. E. (2018). Factors affecting Adoption of Maize Production Technologies: A study in Ghana. In *The Journal of Agricultural Science* (Vol. 13, Issue 1, pp. 81–99).
- World Bank. (2018). Agriculture and rural development in Uganda.

APPENDICES

Appendix I: Results of the Variance Inflation Factor for the Inorganic fertilizer model

Variable	VIF	1/VIF
Age of the farmer	4.83	0.21
Sex of the farmer (0=Female, 1=Male)	1.90	0.53
Education Level		
1=No education (0=No,1=Yes)✓		
2=Primary (0=No,1=Yes)	3.27	0.31
3=Secondary (0=No,1=Yes)	2.20	0.45
4=Higher (0=No,1=Yes)	1.40	0.71
Household size (number)	4.05	0.25
Crop Area (acres)	3.04	0.33
Organic fertilizers application rate (kgs/acre)	1.40	0.71
Pesticides application rate (liters/acre)	6.58	0.15
Region		
1=Central (0=No,1=Yes)✓		
2=Eastern (0=No,1=Yes)	1.66	0.60
3=Northern (0=No,1=Yes)	1.52	0.66
4= Western (0=No,1=Yes)	1.47	0.68
Access to credit (0=No,1=Yes)	1.11	0.90
Access to Agriculture extension trainings (0=No,1=Yes)	1.79	0.56
Agriculture extension visits (number)	2.48	0.40
Membership to a farmer group (0=No,1=Yes)	1.68	0.60
Distance to market (Km)	1.11	0.90
Year 2018/2019	4.94	0.20
Year 2019/2020	2.10	0.48
Mean VIF	2.55	

Appendix II: Results of the Variance Inflation Factor for the Improved seeds model

Variable	VIF	1/VIF
Age of the farmer	4.88	0.20
Sex of the farmer (0=Female, 1=Male)	1.90	0.53
Education Level		
1=No education (0=No,1=Yes)✓		
2=Primary (0=No,1=Yes)	3.32	0.30
3=Secondary (0=No,1=Yes)	2.22	0.45
4=Higher (0=No,1=Yes)	1.41	0.71
Household size (number)	5.16	0.19
Crop Area (acres)	3.04	0.33
Organic fertilizers application rate (kgs/acre)	1.40	0.71
Pesticides application rate (liters/acre)	6.70	0.15
Region		
1=Central (0=No,1=Yes)✓		
2=Eastern (0=No,1=Yes)	1.66	0.60
3=Northern (0=No,1=Yes)	1.52	0.66
4= Western (0=No,1=Yes)	1.47	0.68
Access to credit (0=No,1=Yes)	1.11	0.90
Access to Agriculture extension trainings (0=No,1=Yes)	1.79	0.56
Agriculture extension visits (number)	2.49	0.40
Membership to a farmer group (0=No,1=Yes)	1.68	0.60
Distance to market (Km)	1.12	0.89
Year 2018/2019	4.94	0.20
Year 2019/2020	2.10	0.48
Mean VIF	2.63	