EFFECTS OF AGRICULTURAL INPUTS AND CLIMATE SMART TECHNOLOGIES AND PRACTICES ON MAIZE YIELD IN RWANDA (from 2017 to 2022)

BY

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DECLARATION

I, Fidele NTAWUMENYUMUNSI hereby declare that this thesis entitled ‘’Impact of agricultural inputs and climate-smart technologies and practices on maize yield in Rwanda’’ is my original research work and it had not been presented to any other university for any award.

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Signature……………………….

Date……………………………………

APPROVAL PAGE

This research which is entitled ‘’Impact of agricultural inputs and climate-smart technologies and practices on maize yield in Rwanda’’ has been carried out under my guidance and supervision.

Date……………………

Signature………………

Dr. Gisanabagabo Sebuhuzu

DEDICATION

To

My wife and entire family

To my friends and relatives

ACKNOWLEDGEMENT

I am grateful to the Almighty for blessing me with good health and the strength to successfully complete this study.

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May God bless you.

LIST OF ABBREVIATION AND ACRONYMS

APHRC: African Population and Health Research Center

CIP: Crop Intensification Program

FAO: Food and Agriculture Organization of the United Nations

IAASTD: International Assessment of Agricultural Knowledge, Science and Technology for Development

IFAD: International Fund for Agricultural Development

MINAGRI: Ministry of Agriculture and Animal Resources

NISR: National Institute of Statistics of Rwanda

NFS: National Fertilizer Strategy

NST1: National Strategy for Transformation

PSTA4: The fourth Sector Strategic Plan for Agriculture

SDFDS: Strategy for Developing Fertilizer Distribution Systems

SSA: Sub-Saharan Africa

UN: United Nations

UNDP: United Nations Development Programme

UNICEF: United Nations Children’s Fund

VECM: Vector Error Correction Model

WHO: World Health Organization

WMO: World Meteorological Organization

WFP: World Food Programme

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ABSTRACT

The rapid global population growth, projected to exceed 9.8 billion by 2050, necessitates a corresponding surge in agricultural production to meet increased food demand. Maize, identified by FAO as a globally vital food crop, plays a crucial role in food security due to its nutritional richness, providing energy, dietary fiber, vitamins, and minerals. It also serves as a vital raw material in various industries. In Rwanda, maize stands as the second major crop, with 56% of household farmers engaged in its cultivation. Despite Rwanda's commitment to agricultural transformation and global recognition, a notable gap persists in maize yield and production, leading to a deficit. This study's purpose was to evaluate the impact of agricultural inputs and climate-smart technologies on maize yield in Rwanda, utilizing six years of SAS data from NISR (2017-2022). Cross-sectional analysis was done by using STATA. The results showed that maize cultivation predominates in season A, with its area being three times that of season B. The Eastern Province consistently maintains a substantial share (ranging from 47% to 64%) of the total maize cultivation area nationwide. Remarkably, the Northern Province emerges as the top performer in maize yield, and the 5 districts that stand out for their exceptional yield are Burera, Gisagara, Nyaruguru, Nyagatate and Ngoma with a yield ranging from 1.6 to 2.16MT/ha. The study revealed that the adoption of organic and inorganic fertilizers, along with improved seeds, pesticides, effective irrigation, erosion control, and pure cropping systems have shown a positive impact on maize yield. Conversely, the presence of drought and heavy rainfall exerts detrimental effects on yield. In conclusion, the formulation of strategic interventions to optimize agricultural practices is imperative for sustaining maize production in Rwanda and meeting the growing demand for this essential crop.

Key words; maize yield, agriculture inputs and climate-smart technologies and practices

CHAPTER 1: GENERAL INTRODUCTION

The General Introduction in the opening chapter establishes a comprehensive foundation for exploring maize yield. It covers key elements including background, problem statement, objectives, research questions, scope, justification, and thesis structure. This comprehensive overview provides readers with a roadmap for understanding the factors impacting maize agricultural production and yield.

1.1 Background of the study

Globally, population growth is advancing at a rapid pace, with projections indicating that by the year 2050, the world's population is expected to surpass 9.8 billion individuals. This demographic surge has given rise to a parallel escalation in the demand for agricultural products to feed them (UN, 2017). The drive towards food security in the 21st century has seen the global rise of commissions of inquiry in various agricultural sub-sectors. In under-developed and developing countries, this tendency is highly experienced to the extent that food security forms part of most government's top agenda (FAO, 2014). Although from a global perspective indicating that food security is meant to outline the sustainability position of all consumables and in respect to health productions (Blanca, 2017)

Rwanda has formulated Vision 2050 to outline the long-term strategic direction for "**The Rwanda we want**". This vision sets new pathway that will lead the country to the living standards of upper middle income by 2035 and high-income countries by 2050. Agriculture for wealth creation is one of the pillars of Vision 2050, agriculture has and will continue to play a prominent role in both economic growth and poverty reduction as it has important implications for food security, nutrition and exports.

In agriculture, the aim is to increase productivity and develop professional agriculture services including but not limited to equitable production and distribution of fertilizers, quality seeds, irrigation technology and others (Vision, 2050).

One of the world’s foremost food crops is maize, plays a pivotal role in addressing food security and providing sustenance to populations across various regions. The nutritional value of maize also plays a significant role in its prominence, and it serves as a rich source of carbohydrates, providing essential energy for human consumption. Moreover, maize is a source of dietary fiber, vitamins, and minerals contributing to balanced nutrition. In addition to its direct consumption, maize serves as a crucial raw material for various food products and industrial applications (FAO, 1992).

1.1.1 Maize production globally

In the global viewpoint maize production stands intricately linked with technological advancements. As a crucial cereal crop, maize plays a pivotal role in agricultural economies, serving as sustenance for humans, fodder for animals, and a fundamental source of raw materials for various industries. Cultivated across approximately 142 million hectares worldwide, maize boasts an impressive production figure of 637 million tons of grain. In Nepal, maize cultivation spans an area of 979,777 hectares, yielding a production of 2,997,733 metric tons and achieving a productivity rate of 2.96 metric tons per hectare, with a maize yield averaging 3.06 metric tons per hectare (MOAD, 2022).

The projections indicated an anticipated rise in maize demand over the next two decades, expected to escalate by 4% to 8% annually, driven primarily by increased food requirements. Addressing this surge in demand necessitates augmenting maize productivity per unit of land (Paudyal, et al., 2001; Pingali, 2001). However, agricultural productivity, including maize cultivation, has either stagnated or improved at a very slow rate (Kaini, 2004).

Successful maize cultivation hinges on prudent utilization of production inputs and adherence to sound farming practices that sustain the environment. Essential facets include employing superior seed varieties, judicious application of fertilizers, implementing effective weed and pest management strategies, adopting advanced mechanization for tillage, ensuring proper harvesting techniques, addressing raw material marketing challenges, and ensuring access to financial resources.

Most of the maize produced and consumed in Africa comes from smallholder rural farms. Production takes place under difficult conditions characterized inter alia, by poor soils; low-yielding varieties; inadequate access to yield-enhancing inputs such as fertilizers and improved seeds; inadequate access to finance by producers, suppliers and buyers; and variable climatic and environmental conditions. According to (FAOSTAT, 2021), Africa produces 7.3% of the total world maize production, most of which is used for human consumption Governments in East and Southern Africa have given top priority to maize production, because maize in this sub region is as important as rice and wheat in Asia. Maize is an essential crop for food security of Ethiopian households and is a source of calorie available at the lowest cost compared to all other major cereals (Bealu, 2021). On average Ethiopia consumes a total of 1,858kilocalories daily of which four major cereals (maize, teff, wheat, and sorghum) account for more than 60percent, with maize and wheat representing 20 percent each (Rashid, 2010). It has also continued to be an important cereal crop as a source of both food and cash income.

Maize cultivation spans globally, with a substantial weight of maize produced annually, surpassing other grains. The Americas dominate production with 51.9%, followed by Asia at 29.5%, Europe at 11.2%, and smaller shares in Africa and Oceania. Top-producing nations encompass the United States of America, China, Brazil, Mexico, Indonesia, India, France, and Argentina. Notably, the USA, China, and Brazil account for over 60% of total maize output in the developing world, with the USA leading with over 30% (FAOSTAT, 2021).

1.1.2 Maize production in Africa

Maize was introduced in Africa by the Portuguese in the 16th to 18th century, maize has become Africa's most staple food and feed system (Miracle, 1965). Back in 2005, the leading maize exporting nations within sub-Saharan Africa comprised South Africa, Tanzania, Uganda, Zambia, and Swaziland. Interestingly, Zimbabwe, once a significant maize exporter until the late 1990s, transitioned to become one of the primary maize importers. Alongside Zimbabwe, other notable maize-importing countries during that period included Angola, Ghana, Kenya, and Mozambique. Facing a growing population, several studies (Pingali, 2001) (World Bank, 2007) but in 2022, Zambia, South Africa and Tanzania are the major maize producers and exporters in the region. However, Kenya, Zimbabwe, Botswana, and Mozambique are often the importers (Sihlobo, 2022) note that it is critical for Kenya and other African countries to increase maize production in order to feed their people.

According to the FAO/WFP 2004/2005 crop and food provision evaluation, the production of maize was on a long-term decline due to non-cultivation of the arable lands due to delayed rainfall and the high risk of making loss from agriculture as well as shortage of seeds for alternative crops among others. The African rain-fed agriculture is viewed by many observers to be the most vulnerable sector to climate variability and the potential effects of climate change on agriculture are highly uncertain (Holleman, Rembold, Crespo, & Conti, 2020).

According to reports of (IPCC, 2007), factors such as widespread poverty, bureaucracy, lack of physical and financial capital, frequent conflicts and ecosystem degradation make Africa vulnerable to change. Despite the progress made in national and international policies since the first international conference on women in 1975, the International Agriculture Knowledge, Science and Technology Development (IAASTD, 2009) reported that urgent action was still needed in both policy and practice about gender and social issues. Good justice can better address gender issues, particularly maize, as part of the development process.

Most of the maize produced and used in Africa comes from smallholder rural farms. Production used in difficult conditions characterized by poor soil; inadequate access to supporting inputs such as fertilizer and improved seeds; lack of access to finance for producers, sellers and buyers; and poor air quality and environment.

1.1.3 Maize production in Rwanda

In 2011, maize was the third largest crop and is largely produced by smallholder farmers (WFP,2011) in Rwanda, often grown in both hills and marshlands where it is usually associated with other food crops which are especially legumes such as beans (MINAGRI, 2011). According to the Rwanda National Institute of Statistics of Rwanda, Maize has become the second major crop in Rwanda, with 56% of households farmers cultivated the maize crop (NISR, 2023).

The productivity of maize holds paramount significance due to its status as a staple food crop and its pivotal role as a direct indicator of income, particularly for rural smallholders. Maize production not only serves as a vital source of sustenance for the population but also significantly impacts the economic well-being of farming communities.

In 2016, the total area under maize cultivation in Rwanda was reported to be 237,658 hectares, with a corresponding maize production of 340,326 metric tons with productivity rate of 1.43 metric tons per hectare (MT/ha) as the baseline of maize productivity levels of maize during that period. Furthermore, the strategic plan projected a noteworthy transformation in maize production within the same cultivation area. The plan aimed to significantly boost maize production, with a target of reaching a total production of 689,208 metric tons in 2018. What makes this projection particularly significant is the accompanying increase in productivity, which was estimated to rise to 2.85 metric tons per hectare (MT/ha). This ambitious target reflects the nation's commitment to improving maize production efficiency and, by extension, the livelihoods of its rural smallholders (PST4).
For the exploitation of wetlands, priority is given by the district to the farmers 'cooperatives and associations that can occur over large areas especially crops recommended by MINAGRI, including maize crops. These cooperatives generally work with agricultural support and supervision of various specialized organizations. Maize cultivation in swamps is developed mainly in areas of medium and low altitudes (IPAR, 2009).

However, according to SAS report of 2022 revealed that the progress in the adoption of improved seeds among farmers, the utilization rates remain relatively low. In the context of seasonal planting of 2022, only 33.1% of farmers opted for improved seeds in season A, contrasting 8.7% in season B, and 26.1% in season C. Specifically focusing on maize cultivation, 58.2% of farmers chose improved seeds in season A, while 41.8% adhered to traditional seeds. In season B, 48.7% favored improved seeds, while 51.3% relied on traditional varieties (NISR 2022). These statistics underscore the continued need for initiatives and interventions aimed at promoting the widespread adoption of improved seeds for enhanced agricultural productivity.

1.2 Problem statement

From 2016, the world began implementation of the 2030 Agenda for Sustainable Development Goals, emphasizing the goal to end hunger, achieve food security, and promote sustainable agriculture by recognizing the interlinkages among supporting sustainable agriculture, all empowering all farmers and tackling climate change. FAO data shows growing concern about people around the world not getting enough food. Specifically, nearly one in three people experienced food insecurity in 2020, with 11.9% of severe and 18.5% of moderate food insecurity percentages rising from 8.3% and 15.3% in 2016 (FAO, 2021). Approximately 820 million people (11% of the current world population) do not have enough food based on energy consumption (FAO, IFAD, UNICEF, & WFP and WHO, 2019).

Rwanda has demonstrated a strong commitment to agricultural reform goals and has gained international recognition for its progress including developed strategies and policies (e.g., NST1, PSTA 4, National Environment and Climate Change Policy) that are geared towards it (APHRC, et al., 2021).

However, recent data from Seasonal Agriculture Surveys and PST4 shows a significant gap between projected and actual maize yield and production in Rwanda that led to a maize deficit of 132,576 Metric tons (maize imports exceeded the exports) in 2022 from 70,719 MT in 2020, this highlights the need for improved crop management and policies to enhance productivity.

As, the demand for maize is projected to double by 2050 this study sets to evaluate the course of efforts in place to increase maize yield using selected agriculture inputs and climate smart technologies and practices.

1.3 General Objective

The general objective of this study is to evaluate the impact of agricultural inputs and climate smart technologies and practices to the maize yield in Rwanda.

1.4 Specific objectives

The specific objectives of this study are:

i. To examine the trend of maize yield with its determinants
ii. To analyze effects of agricultural inputs to the maize yield in Rwanda
iii. To examine the effects of climate smart technologies and practices to the maize yield in Rwanda
iv. To assess the relationship between environmental factors and maize yield in Rwanda

1.5 Research questions

This study is intended to investigate the responsible factors that influence maize yield in Rwanda. The following are the questions of the study.

i. What are the effects of climate smart technologies and practices on maize yield in Rwanda?
ii. To what extent does agricultural inputs affect the maize yield in Rwanda?

1.6 Scope of the study.

1.6.1 Geographical scope

This study took place in Rwanda where the data used were obtained from National Institute of Statistics of Rwanda through Seasonal Agricultural Survey covering the period from 2017 to 2022.

1.6.2 Content scope

The study is in the field of economics and is focused on the modules learnt in Master of Science in economics like Economic development, Microeconomics, Econometrics among others.

1.7 Justification of the study

This This study is important in investigating the impact of agricultural inputs and climate-smart technologies on maize yield in Rwanda, offering crucial insights for targeted interventions to enhance agricultural productivity and food security. Understanding these factors' interplay is vital for evidence-based strategies, mitigating climate change effects, optimizing resource use, and promoting sustainable agriculture. The research holds potential to inform policymaking, benefiting stakeholders, farmers, and decision-makers in advancing Rwanda's agricultural sector. Furthermore, the study provides a clear insight into the relationship between maize yield as well as production and agriculture inputs and climate smart technologies and practices.

1.8 Structure of the thesis

This study is structured across five comprehensive chapters. The initial chapter introduces the study's foundation, encompassing the background, problem statement, research objectives, research questions, study scope. Moving forward, the theory and empirical findings on agricultural inputs, climate-smart technologies and environmental factors have been discussed in the second chapter titled literature review. The methodology, model specification, data, sources and test of variables significance have been displayed in the third chapter. The results are discussed in the fourth chapter in accordance with the study's objectives. The main findings, conclusion and possible recommendations were given in the final chapter. This study involves five chapters with an introduction and conclusion.

CHAPTER 2: LITERATURE REVIEW

The literature review commences by providing a comprehensive overview of the current state of knowledge regarding the interplay between agricultural inputs, climate smart technologies and practices on maize yield in Rwanda. This section aims to synthesize existing research findings, identifying key variables, methodologies, and trends that have been observed in similar studies. By establishing this foundation, the review will pave the way for a deeper exploration of the specific factors influencing maize yield in Rwanda, ultimately contributing to a more understanding of the subject matter.

2.1 Conceptual review

This part of conceptual review section serves as a critical foundation for this study, encompassing key terminologies pivotal to our investigation. It provides a clear and concise understanding of the fundamental concepts underpinning the research, offering a framework for the subsequent analysis and discussion.

2.1.1 Maize yield

Maize yield refers to the quantity of maize harvested from a specific area of land, typically measured in metric tons per hectare (MT/ha) or any other appropriate unit of measurement. It serves as a crucial agricultural metric, representing the productivity of maize cultivation within a defined agricultural area (FAO, 1998) Maize yield is influenced by various factors including agricultural inputs, agronomic practices and environmental conditions.

2.1.2 Agricultural inputs

Agricultural inputs refer to the various resources, materials, and factors utilized in the production process of crops and livestock. These encompass a wide range of elements, including but not limited to seeds, fertilizers, pesticides, water, machinery, labor and knowledge or technical expertise. These inputs are crucial in enhancing agricultural productivity and play a pivotal role in achieving optimal yields and overall farm profitability.

2.1.3 Climate Smart technologies and practices

Climate-smart technologies and practices in agriculture refer to a set of innovative and sustainable approaches, techniques, and tools designed to address the challenges posed by climate change while simultaneously enhancing agricultural productivity, resilience, and environmental sustainability. These strategies aim to mitigate greenhouse gas emissions, adapt to changing climatic conditions, and optimize resource use within the agricultural sector. Climate-smart agriculture integrates the principles of adaptation, mitigation, and improved resource efficiency, fostering a holistic approach to agricultural development in the context of a changing climate (FAO, 2016). It also contributes to resource use efficiency and environmental conservation in the context of low and erratic rainfall and offers alternatives to mitigate greenhouse gases (FAO, 2013).

2.1.3.1 Agronomic practices

Agronomic practices refer to the set of techniques and methods employed in agriculture to optimize crop production and overall farm efficiency.

This encompasses a range of activities including soil preparation, planting density, irrigation, fertilization, pest and disease management practices. These practices are designed to maximize the use of available resources while minimizing negative environmental impacts (Gliessman, 2014)

2.1.3.2 Climate change

Climate change refers to long-term changes in temperature, rainfall patterns and other climatic changes that have a significant impact agricultural. Especially when it comes to maize yields, climate change can lead to changes in the growing season, changes in water availability, and the increased frequency of extreme weather events such as droughts, floods, and heat waves. These changes can have a positive impact on corn growth, development and ultimately yield potential (Porter et al., 2014; Lobell et al., 2014).

There are four seasons in Rwanda; among these, the long rainy season (March-April-May) and the short rainy (September-October-November) seasons alternate with the long dry season (June-July-August) and short dry season (Mid-December-January-February) throughout the year (REMA, 2018). Rwanda has seen an increase in the frequency and severity of extreme weather events such as heavy rainfall, floods, and droughts. Climate change poses a significant threat to Rwanda's agricultural sector, which is predominantly rainfed. Changes in rainfall patterns and increased temperatures can lead to reduced crop yields and livestock productivity (NISR, 2018).

(Ujeneza, et al., 2020), projected climate change in Rwanda is expected to adversely affect crop yields, particularly maize, which may see a reduction of 10% to 15%. To mitigate these impacts, farmers can implement adaptive measures such as adjusting planting schedules, utilizing new technologies, and considering alternative crop choices.

2.2 Theoretical review

This chapter serves the primary purpose of examining the theoretical foundations and empirical research that explain the impact of agricultural inputs, agronomic practices and climate change on maize production. Additionally, it elucidates the Malthusian theory and theory of production, aiming to highlight influential factors and underscore the significance attributed to maize cultivation.

2.2.1 Malthusian Theory

Malthusian Theory (MT) was developed by (Malthus, 1798) in the first essay on *An Essay on the Principle of Population*. The second essay version combining of four editions ranging from 1806, 1817, 1826 and 1830 refined the first edition to produce what is today known as Malthusianism philosophy. The theory argues that the power of population growth is higher than the one responsible for food production. The theory further adds that food insecurity will always be an issue as long as population growth rate exceeds the rate of food production and technology.

Although the theory is relevant to many situations related to the population and distribution, as shown in (Quamrul & Oded, 2008) and (Weisdorf, 2007), MT's originality is based on food security and population factor. The Malthusian theory spanned two centuries from 1798 to the present day, but is still current and still applicable in today's thought, as shown in (Khalil and Amjad, 2016). In the first edition of the second edition, created in 1806, Malthus argued that population increases geometrically and food production increases by means of arithmetic progression. (Leufstedt, 2012) defines the geometric progression as a sequence in which each term is established by multiplying the previous one by a constant number that is not zero and called a common ratio. Meaning, if the current population is 50 units and the common ratio is 5, then the second and third population generation will be 250 and 1250 respectively. On the hand, (Agarwal, 2022) defines the arithmetic progression as a sequence of numbers such that difference between the consecutive terms is constant. This means that if the current produce is 2 and the common difference is 3, the series will be 2,5,8,11,14,17. He derived this conclusion due to the law of Diminishing returns.

From this, we can conclude that populations will grow faster than the supply of food. This exponential population growth will lead to a shortage of food.

Malthus insists in the third edition of 1817 that there exists no immediate solution to this growth gaps and further predicts that the principle will finally spread to every useful resource to human. (Ehrlich & Ehrlich, 2009) supports Malthus' assertion, adding that the battle against hunger is bound to fail.

In the subsequent editions of *An Essay on the Principle of Population,* Malthus refines the population control aspect as a control measure. His argument is that the situation will get better after attaining the apex of its worse. The Malthusian catastrophe, as he calls it, which includes feminine, wars and natural disasters will express natural and positive checks on the gap. Most importantly, MT suggests the use of preventive measure which include population growth controls and relooking on means and technology to enhance crop and general food production. Quinn (1997) argued against MT, suggesting that the increasing world population is instigated by food production and supply. This argument against MT is also supported by (Hopfenberg, 2003) who demonstrates that through measuring future agricultural and food dynamics, the world's population can be projected and estimated correctly.

This kind of measure indicator is used by FAO in estimating population. Odds against MT include the Western Europe population that grows much slower than food production.

However, the situation in SSA, including Rwanda directly aligns to Malthusianism. The Malthusian theory underscores the fundamental connection between population growth and the demand for food including maize. As the population expands, the demand for maize and other staple crops intensifies. This dynamic aligns with Malthus's assertion that food production must keep pace with population growth to avert scarcity. Consequently, efforts to enhance maize yield are rooted in the Malthusian understanding that sustainable agricultural inputs and practices are essential for meeting the nutritional needs of a growing population.

2.2.2 Production Theory

The Theory of Production originates from the classical work of (Smith, 1776). The first classical illustrative writing depicting the theory was developed in the article *The Wealth of Nations*.

The classical approach of the theory looks at the physical resources that are directly involved in production and on which value and cost can then be appropriated. The contemporary approach goes beyond physical resources to include technological progress, and intellectual and social capital (Daly & Farley, 2011).

The theory of production argues that all outcomes depend on a choice of involved factors, their perceived and exhibited optimal combination. According to (Ojala, et al., 2014), the theory drives the profit notion in terms of maximum production levels. They argue that with complete understanding of all involved factors and their individual contribution and group dynamics, correct combinations can be executed at a balanced costing system. The decision making is aided by modelling factor behavior under a production function approach as $Y = (X1, X2, X3 \ldots, Xn)$. From the model, Y represents the outcome or output while X1 to Xn represents the individual inputs.

Sometimes, depending on the objectives behind the modelling, X1 to Xn may include all involved factor; whether direct or indirect and whether controllable or not. In maize production, the output of the model represents high or low maize production which is denoted by 'Y' (Ojala, et al., 2014) while the factors include access to land (X1), seeds (X2) and fertilizer (X3), use of extension services (X4), use of machines (X5) and use of chemicals (X6). Use of machines and chemicals are grouped under use of technology.

The choice on the best and optimal scenario option varies from region to region. Njogu (2019), because some things will be developed in certain areas called regions, so the focus should be on important things that need to be produced, not just developed. To obtain a high harvest, it is necessary to choose the most competitive combination of the use of all advantages and focus on it. In this study, production theory shows the basis of corn production.

It provides an understanding that high production/yields are realized at the expense of many factors which include seedlings and fertilizer; climatic changes; irrigation and mechanization. The theory of production guides farmers and policymakers in making decisions related to the allocations of resources in determining the most efficient use of inputs to achieve the highest possible maize yield and provides an understanding of the relationship between maize production and the involved factors.

2.2.3 Modernization Theory

Modernization theory in agriculture refers to the process of transitioning from traditional, subsistence-based farming practices to more technologically advanced and commercially oriented agricultural systems. It is characterized by the adoption of modern technologies, such as improved seeds, fertilizers, machinery, and irrigation methods, along with changes in farm management practices.

Modernization theory casts development as a uniform evolutionary route that all societies follow, from agricultural, rural, and traditional to postindustrial, urban, and modern forms (Bradshaw, 1987; Escobar, 1995; Chirot and Hall, 1982; Shrum, 2000). In other words, all societies, once engaged in the modernization process, follow a predetermined sequence of developmental stages: traditional economies, transition to takeoff, takeoff itself, drive to maturity, age of high consumption, and postindustrial society (Chirot and Hall, 1982: 82).

Modernization theory emphasizes internal forces and sources of socioeconomic development such as formal education, market-based economy, and democratic and secular political structures. Although modernization theory does not rule out external forces and sources of social change and economic development, it focuses less on foreign influences (Jenkins and Scanlan, 2001; Shrum, 2000).

The literature on technological change in agriculture documents that countries tend to adopt the technology that can raise the productivity of the scarce factor or the factor with the lowest quality. Countries with scarce labor but abundant land and capital tend to adopt labor-saving technologies such as tractors and machinery. Countries with scarce land but abundant labor tend to adopt land-saving types of technologies such as chemical and biological high-yield technologies. (Hayami and Ruttan,1985) provide a theoretical framework of this type of biased technological change based on the induced innovation hypothesis.

According to this theory, innovation is induced as a response to changes in relative prices, which push firms to innovate to use less of the resource that has become more expensive. However, the hypothesis of biased technical change as hypothesized by Hayami and Ruttan may not hold in low income and sub-Saharan countries (Cuffaro,1997). In most of these countries, land and labor are abundant, but capital is scarce, and land inequality is high so that most of the farmers are smallholders. Thus, the theory of induced innovation cannot hold for the following reasons: (1) demand for innovation for small- and large-scale farms is different; (2) small- and large-scale farms have different influence on public research; (3) imported technology is absent in induced innovation theory. The agricultural modernization includes mechanization strategy as part of technological change and the modernization of agriculture behavior, structure and institutions. The choice of the technology, which depends on the factor price and public policies, must be centered on the technological need of small-scale farmers.

The process of agriculture modernization includes mechanization and chemicalization. Mechanization comes with higher capital intensity whereas chemicalization implies that farmers adopt practices that increase the efficiency in the use of fertilizer and chemicals required to produce a certain level of outputs. This scheme includes also organic farming that maintains soil fertility to avoid the overuse of chemicals. Given the actual price and subsidies level, this technological path enables farmers to make effective and efficient use of the limited amount of fertilizer.

These practices include crop rotation or integrated livestock crop rotation, intercropping, cover cropping or green manure, and composting waste materials. Finally, it is worth noting that achieving agricultural mechanization requires institutional changes that increase trust and encourage the private sector to adapt progressively proven technologies to local practices and production modes (Thirtle et al.,1998). In the case of Rwanda, the public interventions are required to improve access to agricultural inputs including organic and inorganic fertilizers, improved seeds and adoption of climate-smart technologies and practices.

In the context of maize yield, the modernization theory posits that adopting modern agricultural technologies and practices can lead to significant improvements in maize production. This includes the use of high-yielding varieties, precision farming techniques, mechanized cultivation, and the application of fertilizers and other inputs. These technologies are intended to enhance the efficiency of resource use, increase yields, and ultimately improve the livelihoods of farmers (Evenson & Gollin, 2003).

The Green Revolution is a prominent example of the application of modernization theory in agriculture. It involved the widespread adoption of high-yielding crop varieties, along with modern agricultural technologies, in the mid-20th century. This revolutionized agricultural productivity, particularly in countries like India and Mexico, leading to substantial increases in crop yields, including maize.

It's important to note that while modernization theory has led to significant gains in agricultural productivity, it also raises concerns about sustainability, environmental impacts, and socio-economic equity. Balancing the benefits of modernization with these potential drawbacks is a crucial consideration for sustainable agricultural development.

2.3 Review of related literature

The key to reducing hunger and poverty in developing countries is believed by many to lie in increasing productivity in smallholder agriculture (Zhou, 2010). However, smallholder farmers face multiple constraints related to their socio-economic and environmental conditions. In sub-Saharan Africa, smallholder farms are characterized by low land areas of less than 5 ha although this is usually not the primary factor limiting crop production (Giller et al., 2009). The majority of smallholder farmers often fail to meet their subsistence food requirements due to limited access to financial capital and farming implements, dependence on manual labor and lack of information on appropriate technologies (Wall, 2007; Mudhara et al., undated). The inherently infertile soils and lack of resources to purchase inputs such as fertilizer have resulted in low yields under smallholder farms of less than 1 t ha-1 for cereals including the staple maize crop (Twomlow et al., 2006).

A number of technologies have been promoted to smallholder farmers to address the problem of low crop productivity. The promotion of hybrid maize was one of the successful technologies with the majority of smallholder farmers buying and planting improved maize seed each year. Rohrbach (1988) attributes the high adoption rate of maize hybrid to increased yields, drought tolerance and good yield stability under adverse conditions. However, less than 5% of smallholder farmers in semi-arid areas use fertilizers at the recommended rates (Rusike et al., 2003) with farmers citing the high risk of crop failure due to dry spells and droughts in semi-arid areas (Twomlow et al., 2009). Therefore, smallholder farmers will only invest their limited resources in a technology if the expected returns are higher than those obtained from current practices and the risk of failure is low. Smallholder agriculture in southern Africa is based on cropping systems combined with livestock production on communal rangelands and fallow land (Masikati, 2010). Livestock complement cropping through the provision of manure for fertility management, draught power for ploughing and cultivation, and as a source of cash for the purchase of inputs. Other benefits obtained from livestock include their use as an important investment, insurance against risk, source of milk production and for transportation (Bossio, 2009). On the other hand, crop residues that are a by-product of the cropping system provide feed for livestock during the dry season when fodder is limited in smallholder agriculture (Nyathi et al., 2011). In particular maize residues are an important livestock feed during the dry season when they are either grazed in situ or harvested and transported to cattle pens (Masikati, 2010). Consequently, any innovation on crop production should also consider the livestock component as smallholder farms are commonly managed as mixed crop/livestock systems if it is to be widely adopted by smallholder farmers.

Allan Masese(2021) conducted a comprehensive investigation into the determinants of maize production and its supply response in Kenya. This study aims to assess the collective impact of key variables, namely, maize area harvested, expenditure on fertilizers, the number of tractors used, and maize seed quantity to national maize production in Kenya. To gather data for this study, Secondary data sources were utilized, including FAOSTAT, Economic surveys of Kenya and records pertaining to maize production in Kenya.

Annual time-series data were collected and analyzed using the Vector Error Correction Model (VECM). The findings indicated that both areas harvested, and the quantity of maize seed are significant factors in determining maize production in Kenya. At the same time, expenditure on fertilizers and the number of tractors were statistically insignificant.

Interestingly, the study also revealed a negative association between maize production and maize area harvested, expenditure on fertilizers and number of tractors used, whereas a positive relationship was observed between maize production and the quantity of maize seed.

Based on findings, the research recommended that the government should provide an adequate quantity of maize seeds to boost maize production and educational initiatives aimed at farmers to promote the proper utilization of fertilizers and the optimal utilization of tractors and land resources.

Dickson Utonga(2022) conducted a cross-sectional study to analyze the determinants of maize yields among small-scale farmers in Tanzania. The findings revealed that farm size, seed quantity, fertilizer application, and labor input are significant determinants of maize yield among small-scale in the district.

Based on the results, the study recommended that; the government should ensure access to quality and affordable inputs to farmers by employing effective price control mechanisms on fertilizers and improved seeds which are imperative in improving the yield and the farmers should be exposed to better farming techniques such as the national application of inputs through effective provision extension services.

Agosson et al(2020)'s research in northern Togo assessed the impact of full and limited irrigation on maize biomass and yield during the dry season. The results indicated that optimizing irrigation practices especially during critical growth stages, could significantly enhance grain yield and water use efficiently, proving valuable insights for dry season maize cultivation in the region. On other hand, Janos Nagy (2003) examined maize hybrid reactions to the fertilizer and irrigation at Látókép experimental station reveals that year significantly impacts yield with fertilization exerting a notable influence, often surpassing the impact of irrigation.

Huang Cheng-dong (2019)'s research assessed the impact of intercropping on maize grain yield, revealing a 3.1 tons per hectare decrease in maize grain yield in intercropping due to lower ear density. that intercropping significantly reduces yield due to lower ear density. The study emphasized the importance of optimizing plant interactions, suggesting strategies like adjusting sowing dates to enhance intercropping yields and promote sustainable agricultural development.

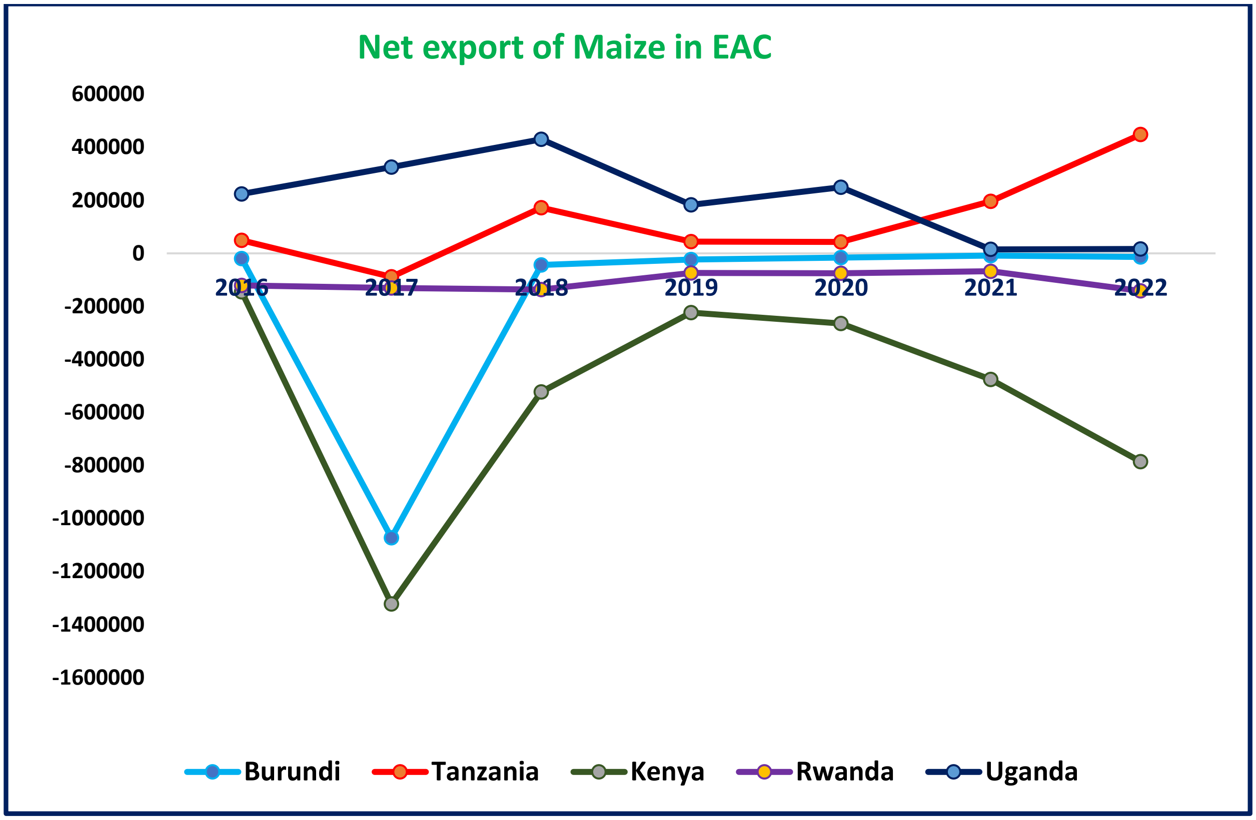
Chumo(2013)'s study investigated the determining factors influencing maize production in Turbo Constituency, Kenya. The research aimed to understand the impact of climatic changes, market demand, available inputs, quantity of production, and other activities in the area. The study, benefiting farmers, traders, future researchers, and the local donor community, utilized a simple random sampling design with 103 participants from a population of 140 farmers. Findings revealed that factors such as age, gender, education, labor, land, market conditions, inputs, transportation, infrastructure, and economic activities significantly affected maize production. Although climatic data collection posed challenges, ANOVA analysis was applied. Recommendations included improving access to credit and timely delivery of farm inputs, enhancing infrastructure, strengthening agricultural institutions, and formulating policies to mitigate market risks. Furthermore, advancements in technologies, particularly in quality hybrid seeds and soil conservation, were advised. The study provides valuable insights for policymakers to plan irrigation methods in arid regions and devise drought mitigation strategies in the agricultural sector.

Kenate(2020) conducted a research study aimed at identifying the factors influencing maize production and market participation among smallholder farmers in Dedo District, Ethiopia. The study employed a random sampling design to select a sample of 192 farmers from a total population of 3,500, from whom primary data was collected through semi-structured questionnaires. Kenate utilized Ordinary Least Squares and Henchman analysis to identify the factors affecting maize production and market participation, respectively. The results of the linear regression models indicated that factors such as age, education level, total land ownership, farming system, farming experience, family size, extension contacts, and crop rotation had a positive and significant impact on maize production. Conversely, factors like plot distance, soil quality, and engagement in off-farm activities negatively and significantly affected maize production.

In Mrutu (2022)'s research, the primary objective was to transform agriculture practices with modern practices in order to improve the productivity for smallholder farmers. Employing secondary data, the study revealed that agricultural modernization has left smallholder farmers under a marginalized, leading to issues such as land grabbing, challenges in the availability, accessibility, affordability, and quality of agricultural inputs, as well as market-related problems. To address these concerns and uplift the agriculture sector, it is imperative for the government to increase investment in agricultural inputs by facilitating the establishment of industries dedicated to the production of essential resources like fertilizer.

The study of Mwongera, et.al (2020) highlights the significance of Climate-smart agriculture Technologies (CSA) in addressing productivity, climate adaptation, and mitigation to achieve resilient food production systems and ensure food and income security. The study employs a mixed-method approach, utilizing the Climate-Smart Agriculture Rapid Appraisal (CSA-RA) tool, to assess farmers' preferred CSA technologies and their alignment with the Sustainable Development Goals (SDGs). The research demonstrates that prioritized CSA options not only meet the food security and livelihood needs of smallholder farmers but also contribute to multiple SDGs, including SDG1 (poverty reduction), SDG2 (sustainable agriculture and ending hunger), SDG13 (climate change mitigation), and SDG15 (life on land).

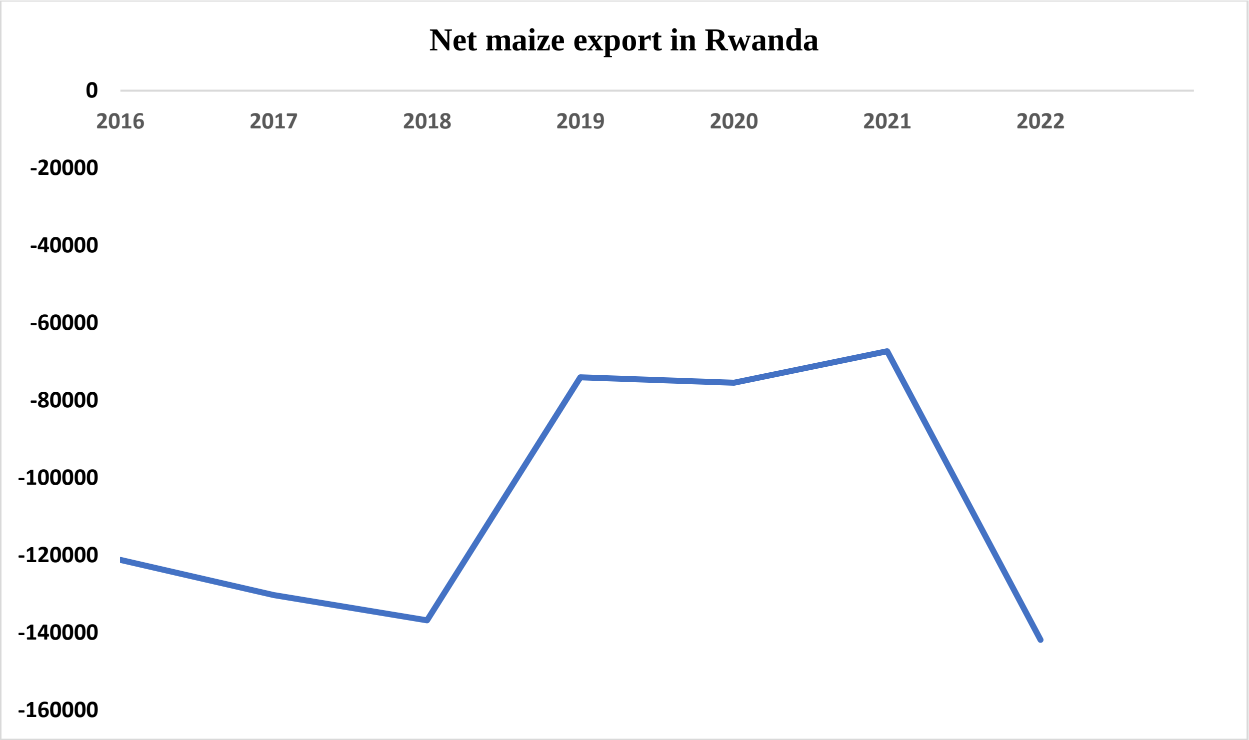
However, challenges related to limited awareness of agricultural technologies and diverse stakeholder objectives pose trade-offs in achieving the SDGs.



Source: EAC STATISTICS 2023

Figure 2. 1: The net export of maize in EAC countries

According to trade statistics sourced from the East African Community, the data reveals an interesting pattern in maize trade within the region. Kenya and Rwanda emerge as the primary importers of maize, indicating a substantial demand for this staple crop in these nations. In contrast, Tanzania and Uganda are the leading exporter countries in the East African Community, showcasing their capacity to produce surplus maize that can be traded within the EAC and beyond. This trade dynamic not only reflects the diverse agricultural landscapes and production capacities of these countries but also underscores the importance of maize as a vital commodity in the food trade within the EAC.



Source: EAC STATISTICS 2023

Figure 2. 2: The net export of maize in Rwanda from 2016 to 2022

Figure 2.2 illustrates the trajectory of maize net exports in Rwanda over the period from 2016 to 2022. The figure notably highlights a consistent maize deficit, which is quantified in metric tons, varying from 73,975 to 141,798 metric tons. The most significant deficit is particularly evident in the year 2022, with a staggering figure of -141,798 metric tons.

This persistent shortfall in maize exports underscores an ongoing challenge in meeting the demand for maize within the country. It signifies that the rate of increase in maize productivity is insufficient when compared to the rising demand for maize within Rwanda. The data highlights the need for strategic interventions to enhance maize production and address the demand-supply gap effectively.

2.4 Factors influencing maize production.

The comprehensive agricultural support policies by government or donors such as fertilizer subsidies, credit subsidies, fixed prices, floor prices and public irrigation schemes, were the main features of the Asian Green Revolution of the 1970s (Bahiigwa, Mdoe, & Ellis, 2005), further indicated that it was challenging to replicate the Asian Green Revolution in Africa because the Structural Adjustment Program (SAP) of the 1980s and 1990s eliminated the agricultural support policies enjoyed by Asian countries.

The Structural Adjustment Program, with the emergence of neo-liberal conservative ideologies, reduced the government sponsored agricultural support (Markelova, Meinzen-Dick, Hellin, & Dohrn, 2009). One of the aims of the program is for governments to reduce external and internal deficits by restricting money and credit growth (Weissman, 1990). As a result, it became difficult for many farmers to get access to services.

The major reforms in the Structural Adjustment Program were, firstly, to encourage the involvement of the private sector in agricultural marketing activities, to reduce or eliminate government agricultural input and product marketing subsidies, enhance the diversification of agricultural exports and encourage the government to motivate NGOs and cooperatives to perform their roles (Bingen, Serrano, & Howard, 2003).

Similarly, the structural adjustment program and the policies of Washington Consensus rejected sectoral policies that focused on the macro fundamentals and promoted the significant role of market forces. Conversely, in the case of Africa, agriculture has suffered from major market failures and there was a need for government intervention to ensure growth and development which was ignored by the Washington Consensus (de Janvry, 2010)

There are views that the Green Revolution in Africa should be designed differently from that of Asia because African in general and Sub-Saharan Africa in particular, has mainly a rain-fed agriculture and varying agro-ecological conditions (de Janvry, 2010).In addition, irrigation facilitated the adoption of Green Revolution technologies such as varieties of rice and wheat in Asia and it had an impact on income, prices, food security and growth (Hussain & Hanjra, 2004). o fulfills the Millennium Development Goals of eradicating hunger and poverty, it is imperative to prioritize agricultural sector growth, specifically by augmenting maize production as a fundamental staple food source. (Rockström, et al., 2009)

To achieve high productivity in maize production, the amount or quantity of agricultural inputs used is paramount. The required amount of input and quality of farm inputs are an essential prerequisite for high maize yields. Land, water, chemicals such as fertilizers, pesticides and herbicides and high-quality seed are among key inputs for maize production (IPBO, 2017).

Among the needed farm inputs, seed is recognized and considered having the highest ability of boosting on-farm productivity potential of all other agricultural inputs. Improved Yields or output and the productivity since seed determines the actual amount of crop Varieties of seed are essential agricultural inputs that supports farms to obtain improved Agricultural yields. The genetic manipulation of selective breeding improved the productivity and value of crops obtained. Chemical fertilizer is another important input to increase smallholder farm production.

This is because the use of organic and inorganic Fertilizer helps to improve the soil fertility status if soil fertility is not improved the use of other Technologies such as high-yielding varieties will not have a significant impact (Bihon Kassa, 2015).

2.4.1 Household characteristics of farm operators

The household characteristics consisting of variables such as age, gender, education level, family size and landholding size, exert significant influence on the agricultural production of maize by farm operators, as reviewed below.

2.4.1.1 Education and agricultural production

Research findings have indicated the importance of education in agricultural production of maize and income. For example, (Asfaw & Admassie, 2004) reported that the conventional factor of production such as growth of stock, of capital and labour were unable to explain fully the growth in national income.

The contribution of education to the growth of national income was recognized in the 1960s.To achieve agricultural development, the investment in production techniques and technology should be supported by a comparable investment in human capital (Bingen, Serrano, & Howard, 2003). This is because information and knowledge are prerequisites for farmers to adopt technology, access input, change ways of doing things and market their produce (Chowa, Garforth, & Cardey, 2013)

Formal education enhances farmers' engagement in environmental programs and methods for the sustainability of agriculture (Burton, 2014). Education is also believed to stimulate economic growth by enhancing the productive capability of farmers as well as eliminating the customs that are contrary to growth such as traditional word-of-mouth communication methods (Asfaw &

Admassie, 2004). If there is inequality in educational endowments, the returns from irrigation are likely to remain low for poor farmers, thereby supporting the notion that “knowledge poor will remain income poor” (Hussain & Hanjra, 2004). There is agreement that the accumulation of knowledge through education is an important factor for economic development (Asfaw & Admassie, 2004).

2.4.1.2 Gender and agricultural production

Gender refers to socially constructed roles and relationships of women and men in a given culture or location (Adeoti, Cofie, & Oladele, 2012). In enhancing agricultural production and income, the full participation of men and women is very important. Women tend to be the major players in the farm labour force engaged in production, harvesting and processing activities (Jafry & Sulaiman, 2013). It is also known that the majority of food is produced by women farmers and they are responsible for fulfilling the basic needs of the family (Camara, Diakite, Gerson, & Wang, 2011). Studies have also indicated that women farmers are more environmentally conscious compared to men farmers. Nevertheless, there are research findings that indicate the existence of gender inequalities in the agricultural sector. For instance, there is categorization of some crops to be “men’s crops” and others as “women’s crops” (Mohammed & Abdulquadri, 2011).

A study conducted in Ghana by (Adeoti, Cofie, & Oladele, 2012) indicated that vegetable production demanded more physical strength and was dominated by men. On the other hand, (de Brauw, Li, Liu, Rozelle, & & Zhang, 2008) revealed that, in China, the contribution of women to livestock production was 64 per cent while 59 per cent of the marketing work was dominated by men.

They noted that this is labour feminization and that the earnings are controlled by their male counterparts.

Women farmers are also challenged by the absence of capital, information and access to markets which prevents them from producing enough to fulfil the basic necessities (Jafry & Sulaiman, 2013). The scarcity of knowledge related to women's rights exposes them to land grabbing and the loss of their heritage (Camara, Diakite, Gerson, & Wang, 2011). Historically, there were other issues that hindered women's participation and influence in the agricultural sector. One of the hindrances was the tradition of passing farms from father to son, while daughters were denied farm ownership (Alston, 2003). Furthermore, the mind-set that land rights belonged to men only made women voiceless in the ownership of land. Consequently, as the contribution of women in the agricultural sector is vital, there is a need to clarify which obstacles are unique to them (de Brauw, Li, Liu, Rozelle, & & Zhang, 2008). Researchers are also interested in investigating the productivity differences between male and female headed households. In this respect, researchers found mixed results. In the study conducted in China, (de Brauw, Huang, Zhang, & Rozelle, 2012) showed that female headed households achieved the same crop yield as their male counter parts.

They further stated that it is the differences in access to quality extension services, access to inputs and the quality of the plot that created differences in productivity. If women get equal access to the application of inputs, information and technologies, there is no sound reason for them to be less productive than men (de Brauw, Li, Liu, Rozelle, & & Zhang, 2008).

In Rwanda, there was an insignificant involvement of women in decision–making about political issues or other high level, however this has changed, and women are now given a chance to participate in decision-making activities, both political and economic issues (Mutamba & Izabiliza, 2005). Gender equality is enhanced, and women are recognized, in management of both natural and agricultural resources in order to allow equal access to those resources and to decrease poverty especially in rural areas (Feldman, 2018).

For example, Rwanda through its commitment towards gender equality has ranked fourth behind Iceland, Finland and Norway in addressing gender gaps in 2017 and this has led to economic, social and political success. Women are involved in decision and policy making, and in 2018, the proportion of women in Rwanda Parliament was at 62% and participation of women’s labor force is at the rate of 86% (UNDP RWanda, 2019-2022).

2.4.1.3 Age, family size, landholding size and agricultural production

Agricultural production is influenced by other household characteristics such as the farm operator’s age, family size and landholding size. The age of the household head is a proxy variable for the farming experience of farm operators. Farmers are highly dependent on their previous knowledge of farm practices in cultivating different crops. Hence, experienced farmers are expected to enhance the productivity of their holdings. However, it is not without limit as older farmers lack the required physical strength on the farm and lower the probability of technology adoption (Moussa, Otoo, Fulton, & Lowenberg-DeBoe, 2011; Burton, 2014).

After its people, land is Rwanda’s most important asset and a cornerstone of the economy. Rwandan social and cultural traditions are closely tied to the land (UNDP, 2008). The historical resonance of land in Rwanda is profound, with a legacy of communal ownership and intricate land use systems dating back centuries. This deep connection between the Rwandan people and their land is woven into the very fabric of the nation's identity, underpinning social structures, agricultural practices, and even legal frameworks.

The implementation of forward-thinking policies and innovative approaches, such as terracing and agroforestry have not only safeguarded the environment but have also moved the agricultural sector to new heights.

Farm operators with larger landholding sizes would have a better farm income if sufficient family labour was available. This leads to an increased demand for children who can work on the land (Hedican, 2006). It is not possible to expand the landholding size without matching it with an increase in the size of the household. Hence, households with larger families face a challenge to feed each of the family members and this will have its own negative effect on the nutritional status of the family (Olayemi, 2012).

2.4.2 Agricultural production technologies

Agricultural production technologies include biological and chemical technologies. Specifically, these technologies include chemical fertilizers, selected seeds or High Yielding Varieties, irrigation and soil quality enhancing technologies. Farmers use these technologies in order to enhance the production and productivity of the land. It is also indicated that, for poor farmers, adoption of technology places new demands on their limited resource base (Kamruzzaman & Takeya, 2008).

2.4.2.1 Chemical fertilizer

African governments have promoted the increasing use of agricultural inputs in their own countries inspired by the Asian Green Revolution which was brought about by using high-yielding seed and fertilizer technologies (Crawford, Kelly, Jayne, & Howard, 2003). In a similar vein, (Aune & Bationo, 2008) argued that the entry point for intensification is the use of organic and inorganic fertilizer in the Sahel because, if soil fertility is not improved, the use of other technologies such as high-yielding varieties will not have a significant impact.

(Crawford, Kelly, Jayne, & Howard, 2003) further indicated that the objectives of input promotion strategies have many features such as financial, economic, social and political objectives. The financial aspect of the input promotion strategy is to increase the net income of farmers, traders or other participants in the agricultural economy. The economic feature of input promotion strategy is also to increase the real income of the society. The social aspect of the input program is the improvement of welfare indicators that are difficult to measure in terms of monetary values. Some of the social objectives are to improve nutrition intake and national food self-sufficiency. The political objective of the input program arises because of the government intervention for the sake of equalization of benefits. Some programs may be designed intentionally to build political support; consequently, they may benefit one or more groups at the expense of others.

Documents indicated that the application of inorganic fertilizers in Sub-Saharan Africa is minimal (de Janvry, 2010). According to (Mohammed and Nuno, 2021) Agriculture needs improvement through increasing production and productivity of cereal crops and maize productivity of smallholder farmers is fundamental in securing households' food security and reduce poverty, which in turn can ensure the wellbeing of farmer households. The results showed that the use of fertilizers have a positive influence on the higher maize yield.

In Rwanda, MINAGRI developed the National Fertilizer Strategy (NFS) for the Africa Fertilizer Summit and embodied in the Abuja Declaration on Fertilizer for the African Green Revolution. The aim was to achieve timely delivery of quality fertilizer to farmers in a cost-effective manner and address the constraints limiting the use of inorganic and organic fertilizer.

In 2007, the NFS was replaced with the Strategy for Developing Fertilizer Distribution Systems (SDFDS) with the objective of establishing market-based mechanisms to improve fertilizer distribution systems that enable the right product to be delivered at the right time in sufficient quantities and at the most cost-effective manner by a competitive and profitable private sector. Its overall goal was to increase fertilizer use to achieve the SPAT target of 7 percent agricultural growth and significantly reduce poverty in rural areas. This includes improving fertilizer distribution systems to increase the availability, accessibility and affordability of fertilizer to farmers; developing enabling policy, regulatory and investment environments for fertilizer market development; strengthening the capacity of the private sector to supply quality fertilizer at affordable prices and in a timely manner.

The Crop Intensification Program (CIP), which was launched in 2007 to increase agricultural productivity of high-potential food crops by creating incentives for producers to adopt new production technologies, especially fertilizer, seed, and irrigation to improve soil fertility. Before the CIP was launched in 2007, fertilizer application averaged 4.2 kilograms per hectare (kg/ha) per year which is below sub-Saharan Africa's average of 16 kg/ha (World Bank, 2011).

The estimates of 2012 indicated that fertilizer application rates in Rwanda reached an average of 29 kg/ha (MINAGRI, 2013); the main types of used are Urea at 61%, diammonium phosphate (DAP) at 62% and NPK at 25% and consumed and demanded at 61%, 62% and 25% respectively for the maize crop specifically. (IFDC, 2014).

The study conducted by in southern Province showed that Soil fertility management had a significant influence on the productivity of maize and bean crops (Bucagu, Mbonigaba, & Uwumukiza, 2013), In other words, combining liquid fertilizer containing fulvic acid and humic acid with granular fertilizer can significantly increase maize yields (Hatungimana, Srinivasan,, & Vetukuri, 2021).

2.4.2.2 Improved seeds

In combination with chemical fertilizers, improved varieties of seeds are critical agricultural inputs that help farmers to obtain improved agricultural yields. The productivity and value of crops is improved through the genetic manipulation of selective breeding (Sassenrath, Heilman, Luschei, Bennett, Fitzgerald, Klesius, Tracy, Williford, & Zimba, 2008, p. 287).

Moreover, formal sector supplied improved seeds should fulfil certain quality standards set by the national regulations (Bishaw, Struik, & Van Gastel, 2012, p. 657). Seeds that fulfil the quality requirements have a positive impact on the productivity of land. For instance, Li, Liu and Deng (2010, p. 457) found that 30 per cent of the growth rate of agricultural production was due to new seed varieties. A study conducted in Afghanistan by Kugbei (2011, p. 198) confirmed that the yield from the improved wheat seeds was 33 per cent higher than the local seed varieties.

Furthermore, Alemu, Mwangi, Nigussie & Spielman (2008, p. 305) stated that improved seeds can cause a remarkable improvement in agricultural productivity and production for small-scale farmers in Ethiopia if they are combined with modern science and modest changes in farmers' cultivation practices. As the improved seeds are small, farmers are more concerned about the characteristics of the seeds rather than the price (Li et al., 2010, p. 468).The farmers may reduce costs by saving and using the seed varieties for the following production year (Rohrbach, Minde, &Howard, 2003, p. 319).

In a study conducted in Nigeria, Awotide, Awoyemi, & Diagne (2012, p. 576) showed that poverty reduction should be combined with the provision of improved rice seeds to farm operators at the appropriate time.

2.4.2.3 Irrigation facilities

The poorest people who mainly depended on rain-fed agriculture for their livelihoods reside in Sub-Saharan Africa (Burney, &Naylor, 2011, p. 110). Burney and Naylor stated that crop yields in Sub-Saharan Africa were low and influenced by the variability of weather conditions in the area.

The cropland which is irrigated accounted for only 3 per cent compared to 39 per cent in South Asia and China (de Janvry, 2010, p. 22). One of the lessons of the Asian Green Revolution was that repeated cultivation during a year and improved yield could be possible with the application of irrigation combined with fertilizer and improved crop varieties (Burney, &Naylor, 2011, p. 111). Water, as one of the major instruments of poverty alleviation, plays a significant role in food production, food security, hygiene, sanitation and environment (Hussain, & Hanjra, 2004, p. 3). The proper utilization and the reduction of wastage of water resources is critical. This is because the level of water consumption in agriculture is influenced by the efficiency of irrigation systems and cultivation methods used by farmers (Castro, & Heerink, 2010, p. 168). For instance, introducing a system of trading water can be a powerful incentive to reduce the amount of water used in agriculture once it has a value and can be sold by the rightful owners (de Janvry, 2010, p. 30).

Irrigation is one of the critical inputs in agriculture which benefits the socio-economic status as it leads to poverty reduction. However, irrigation can also trigger socio-economic upheavals when it causes problems such as disease, land degradation, water pollution and destruction of living beings and natural ecosystems (Hussain, & Hanjra, 2004, p. 4). Hussain & Hanjra (2004, p. 4) further stated that poor populations are most affected by the potential negative effects of irrigation.

Access to good irrigation allows the poor to increase production, gives them opportunities to diversify their income base and reduce their vulnerability to the seasonality of agricultural production and external shocks (Hussain, & Hanjra, 2004, p. 4).

As the first beneficiaries from irrigation infrastructure are often landowners, poor landless farmers are not direct beneficiaries in the short run (Hussain, &Hanjra, 2004, p. 6) but may, in the long run, receive an indirect benefit in the form of increased employment opportunities, higher stable wages and lower food prices (Hussain, &Hanjra, 2004, p. 6; Berg, &Ruben, 2006, p. 872). While irrigation is believed to provide advantages for net food buyers, it may have disadvantages for those who are net food sellers (Berg, &Ruben, 2006, p. 872).

Farmers incur costs to utilize productivity enhancing technologies. On the one hand, there are complementary technologies that could be utilized with little or no financial costs to the farmers. Aune & Bationo (2008, p. 121) explain that mulching and seed priming are among the technologies that boost crop production without cost implications for farmers. Seed priming is carried out by soaking seeds in water to stimulate germination and reduce germination time. They also found that a crop residue application rate of 500kg per hectare increased crop yield. On the other hand, the competing uses of crop residues such as for fodder, building materials and fuel, have limited the benefits obtained from mulching (Moges, & Holden, 2007, p. 551).

2.4.2.4 Intercropping

Intercropping is another practice of cultivation used by farmers to improve soil quality and productivity. The aim of intercropping is to enhance the yield of farm land by using resources that cannot be used by a single crop (Kamruzzaman, & Takeya, 2008, p. 220). Intercropping is practiced by a large proportion of farmers in developing countries (Guvenc, & Yildirim, 2006, p. 30). While in western Kenya, intercropping with leguminous plants and fallow rotation has been applied to increase the fertility of the soil (Waithaka et al., 2007, p. 213),in developed countries monoculture has increased crop yield with a huge energy cost of production and operation of machinery, fertilizers and pesticides (Karlidag, &Yildirim, 2009, p. 107). This is because in developed countries intercropping was not suitable for mechanized farming and was abandoned (Guvenc, & Yildirim, 2006, p. 30).

Intercropping is becoming crucial for increasing crop productivity and fulfilling the food requirements of the world’s growing population (Karlidag, & Yildirim, 2009, p. 108). The intercropping method has also contributed to the sustainability of agriculture (Guvenc, & Yildirim, 2006, p. 30; Karlidag, & Yildirim, 2009, p. 108). In addition, to ensure yield and quality in intercropping, the varieties that are considered to be complementary in the utilization of resources should be identified (Guvenc, & Yildirim, 2006, p. 31).

Intercropping wheat and chickpea at 30cm spacing and weeding twice, increased wheat yield to 39.43 quintals per hectare (Banik, Midya, Sarkar, & Ghose, 2006, p. 330). Banik et al. (2006) further explained that the yield for mono-crop wheat at 30cm spacing and weeded twice was 26.71 quintals per hectare. In a study conducted in Turkey, Karlidag and Yildirim (2009, p. 114) showed that strawberries intercropped with early maturing vegetables were more productive and ensured efficient utilization of land and resources compared to the sole strawberry cropping system. Furthermore, intercropping legumes and maize led to the reduction of weeds (Flores-Sanchez, Pastor, Lantinga, Rossing, & Kropff, 2013, p. 756). Similarly, in Africa, the need for intensification and diversification led to the substitution of mono-cropping systems by a complex intercropping practice (Alene, Manyong, & Gockowski, 2006, p. 52). Farmers in the Southern region of Ethiopia have benefitted from the intercropping of annual and perennial crops.

As presented above, the agricultural production technologies such as chemical fertilizer, improved seeds and irrigation affect the productivity and income of farm operators. In addition to these factors, the productivity and income of farmers was influenced by access to credit in rural areas.

2.4.3 Environmental factors

Environmental factors influence agricultural production and therefore the income of farm operators. The environmental factors included in this review are rainfall, erosion, vegetation and soil type of the area. The extension and intensification of agriculture has contributed to climate change by accounting for between 25and 30 per cent of global greenhouse gas emissions (de Janvry, 2010, p. 25). Kintomo et al. (2008, p. 1262) stated that one of the causes of the reduction in productivity and environmental quality is the intensive land use of farm operators.

2.4.3.1 Rainfall

The extent of rainfall is one of the critical factors that influence the agricultural production of farmers. In rain fed agriculture, the percolated rainfall in the roots is the source of moisture and water consumption for the crops (Rockstrom et al., 2009, p. 544).The erratic nature of rainfall makes rain fed agriculture unreliable for farmers and it is for this reason that the agricultural productivity of rain fed areas is lower than irrigated areas (Rockstrom et al., 2009, p. 544). Ethiopia has a rain-fed agriculture therefore production is sensitive to variations in rainfall. The loss of life as a result of drought in 1973, 1974 and 1984 showed the existence of a strong link between climate and Ethiopia's economy (Conway, & Schipper, 2010, p. 227). As the level of productivity loss increases with the reduction in rainfall, adaptation in areas with more moisture stress becomes challenging (Di Falco, & Chavas, 2008, p. 91).

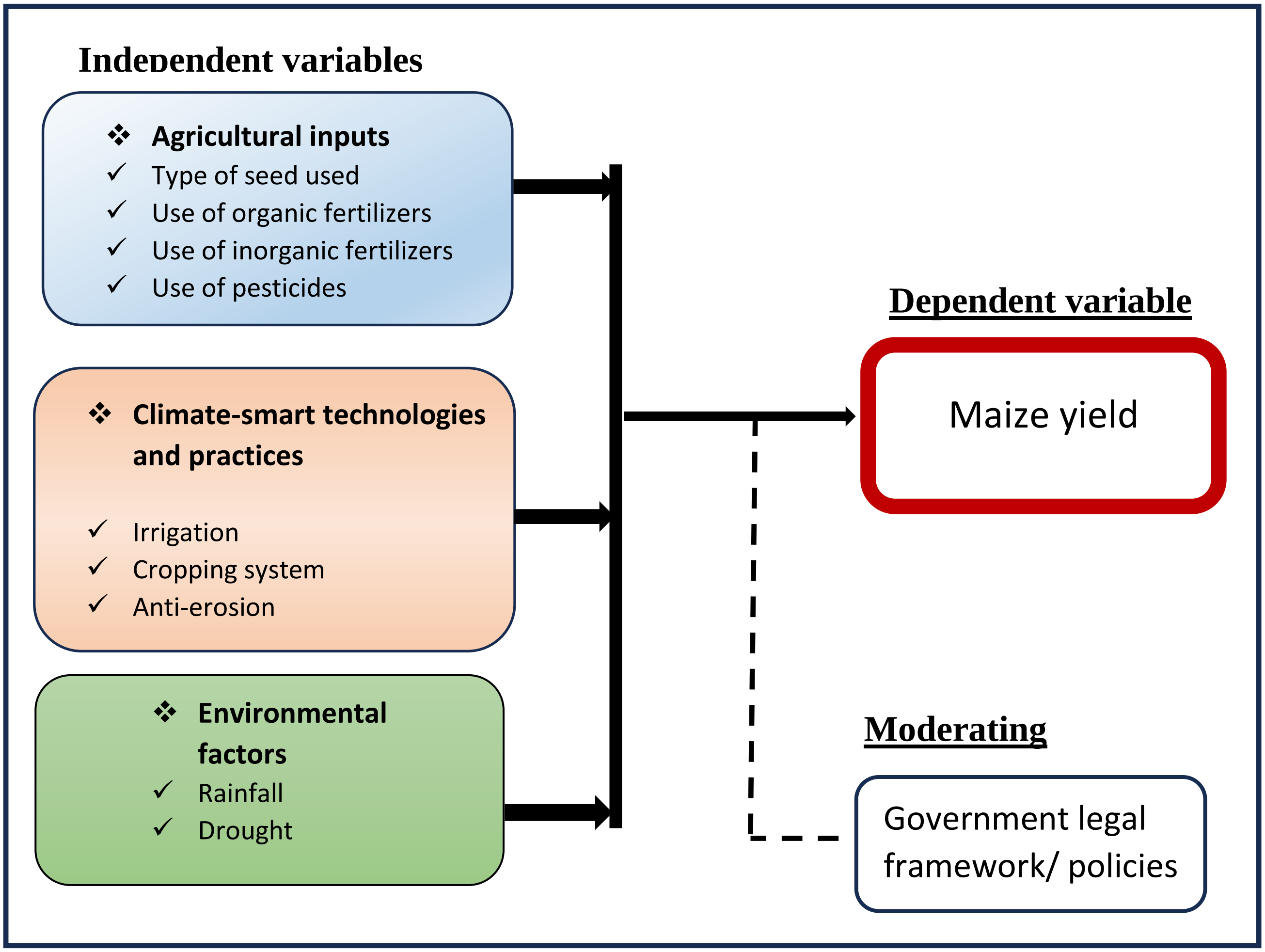
According to World Bank, in South Africa, as the number of cooler days was reduced,the number of warmer days increased (Maponya, & Mpandeli, 2012, p. 48). The Bank further indicated that South Africa's average rainfall was estimated to be 450mm per year which is below the average of 860mm. Thus, rainfall is the source of risk and uncertainty regarding the agricultural production outcomes of the harvest season (Rockstrom et al., 2009, p. 544).

2.4.3.2 Erosion and vegetation

Soil erosion is one of the challenges of agricultural productivity especially in areas where there is poor vegetation cover and the soils are not resilient (Powlson et al., 2011, p. 581). In Ethiopia, soil erosion has contributed to the existing problem of food insecurity and is becoming a real threat to the sustainability of the country’s dominantly subsistence agricultural system (Bewket, 2011, p. 54). The major causes of soil erosion are water, wind and tillage (Powlson et al., 2011, p. 581). In a study conducted in Laos, farmers identified that intense rainfall, repeated cultivation, cultivation on steep slopes and high elevation sites, and short fallow periods were the essential factors that caused severe soil erosion in the area (Lestrelin, Vigiak, Pelletreau, Keohavong, &Valentin, 2012, p. 69). According to Bakker, Govers, Kosmas, Vanacker, Van Oost & Rounsevell (2004, p. 468), the cultivation of steep land is a cause of soil erosion as well as the driver of land-use change because steep slopes are hard to cultivate. The extent of soil erosion is exacerbated by the clearing of permanent vegetation for repeated farming of crop land or reduced by the re-establishment of natural vegetation and the land becomes covered by plant biomass (Fen-Li, 2006, p. 420; Pimentel, 2006, p. 123).

2.5 Conceptual framework

Conceptual framework is an illustrative representation of variables in a study, their preparation depends on meaning and how they interrelate in the study. It shows how the independent variables influence the dependent variable of the study. The framework below is design of possible underlying factors influencing maize production and market participation among smallholder farmers. The independent variables are grouped together on one side but the dependent variable is placed on the right hand connected with an arrow as a sign of direct relationship.



Source: Researcher

Figure 2. 3: Conceptual framework

Based on the objectives of this study, figure 2.1 shows that the independent variables directly determine the outcome of the dependent variable. This means that if farmers can find a way of optimizing irrigation management and terracing and soil erosion control, access improved seeds and sustainable amount of fertilizer, align shifts in rainfall patterns and reasonable soil temperature, then high maize production and yield in terms of maximum number of bags will be realized. The figure shows that when both production and institutional factors are fully instituted and operationalized, maize production increases: more maize bags are realized.

2.6 Research gap

Basing on the existing literature contextually presented in this part, none of the research use the pure cropping system to evaluate its impact on maize yield in Rwanda, which is the gap between the existing studies that must be filled with this one.

2.7 Chapter Summary

Analyzing maize production and yield using Malthusian Theory and the Theory of Production and Modernization Theory reveals a diverse global perspective. Existing literature indicates a solid statistical foundation for achieving high maize production when factors are appropriately optimized. Moreover, it highlights significant disparities in production levels and factor considerations between Sub-Saharan Africa and America. The Government of Rwanda's backing through the Strategic Plan for Agriculture Transformation Phase 4 (PSTA 4) underscores the importance of tailoring strategies based on regional factors for optimal outcomes.

CHAPTER 3: RESEARCH METHODOLOGY

Methodology is a chapter in research that shows how the work is going to be done for reaching the settled objectives. In this chapter, we have to handle the following; the research design, the population of the study where you specify population of interest, the source of data you are going to use to a certain conclusion, sampling design procedure where you have to specify which sampling techniques to be used in the study, data collection techniques and tools where you clarify what kind of materials needed to collect data like questionnaire, documentary review, methods of data collection where we specify in which way your data will be collected, gathered , how will you process your data and methods of data analysis and finally tackle about limitations of our study. And in this study, all those points will be being explained in detail.

This chapter outlines and explains the research methodology used in the study to evaluate the relationship between independent variables and dependent variable. This chapter also identifies the data that are used from National Institute of Statistics Rwanda.

3.1 Research design

In this research, the researcher have used quantitative research design and the researcher gathered together data from NISR survey called Seasonal Agricultural Survey (SAS) and organized to align with the study's objectives, data have been analyzed in a way responding to our objective, that is, the researcher has made descriptive analyzes, we developed statistical model, and test for significance of our independent and dummy variables and come up with conclusions regarding determinants of maize yield in Rwanda.

3.2 The study population identification

The target population is the entire group a researcher is interested in; the group about which the researcher wishes to draw conclusions, the target population for a survey is the entire set of units for which the survey data are to be used to make inferences. Thus, the target population defines those units for which the findings of the survey are meant to generalize (Lavrakas, 2008). In this research our target population is the farmers (Large Scale Farmers (LSFs) and Small-Scale Farmers (SSFs) followed during Seasonal Agriculture Surveys from 2017 to 2022 that constituted our population, and we gathered them from NISR. These data of individuals followed during SAS will be our population of interest in this research.

3.3 Sampling

Since the research must use the secondary from SAS (Seasonal Agriculture Survey), it is imperative to include all farmers who have been followed in accordance with National Institute of Statistics of Rwanda (NISR). These farmers were instrumental in fulfilling our research objectives. Our focus was examining the dataset, specifically on those farmers who were part of the SAS, constituting our sample and outlined in the table below that provides a breakdown of the sample from 2017 to 2022 for both seasons A and B. Notably, the number of farmers sampled in Season A surpasses that of Season B, with the sample size for Season A ranging from 5,046 to 8,435, while for Season B, it ranges from 2,718 to 4,048 (Source; NISR,SAS 2017-2022, Re-analysis of raw datasets). This robust sampling approach ensures a comprehensive and representative dataset for our research objectives.

Table 3. 1: The number of farmers sampled by year by season.

SEASON	Freq.	Percent	Cum.
SeasonA 2017	6284	9.86	9.86
SeasonA 2018	5,046	7.92	17.79
SeasonA 2019	7,228	11.35	29.13
SeasonA 2020	8,145	12.79	41.92
SeasonA 2021	8,435	13.24	55.16
SeasonA 2022	7,731	12.14	67.3
SeasonB 2017	4,048	6.35	73.65
SeasonB 2018	2718	4.27	77.92
SeasonB 2019	3657	5.74	83.66
SeasonB 2020	3577	5.62	89.27
SeasonB 2021	3248	5.1	94.37
SeasonB 2022	3586	5.63	100
Total	**63703**	**100**	

Source: SAS,2017-2022

3.4 Data collection Techniques and Tools

As the researcher have to use secondary data, gathered them from the source (NISR, SAS, raw data, https://microdata.statistics.gov.rw/index.php/catalog. So here the data collection technique is documentary review to view collected data and organize them according to our study. We put together farmers interviewed and followed in SAS and base our analysis on them. Meaning that our main work here was to organizing data in a manner that helped us to make our analysis and respond to our study objectives. In this part, we cleaned the datasets, make them analyzable depending on variable of our interest from the main datasets.

3.5 Data processing

The researcher gathered data from NISR and organized them according to variables we want to use in our study. We cleaned them and remained with the variables we want in our study. After cleaning them, we have used STATA to analyze them where we did descriptive analysis, test significance of different variables, verified the hypothesis set and do regression analysis of maize yield and variables that depend on maize yield and then built econometric model.

3.6 Methods of data analysis

For the analysis of the seasonal agricultural data that were collected as secondary, both descriptive statistics and econometric methods were used by cross-sectional analysis by season. In our study, the researcher will make test of variables significance, building regression model and testing the hypothesis.

3.6.1 Descriptive analysis

Descriptive analysis helps you to make a glance of your data and we will make it to picture out how the farmers are, concerning maize yield and factors associated with it. In this part, we will make different description such farmers' gender disaggregated by district, use of organic and inorganic fertilizers, types of used seeds, types of erosion control have used by famers, irrigation management, cropping system, rainfall and drought and so on to relate them with maize yield.

3.6.2 Test of variables significance

As our conceptual framework is, we have different variable to test its significance and we will make it to see whether statistical significance is or not to be included in our analysis and model building as well.

3.6.3 Building Multiple linear regression Model

Based on research conducted by Bhattacharyya, Biswas, & Chiphang(2021), which studied the effects of weather variables on crop yield in Manipur state, and Badaruzaman & Tiong(2022), who employed multiple linear regression for crop yield prediction in Malaysia, a regression model was developed. This model aims to predict maize yield based on categorical independent variables.

Multiple regression analysis is the measure of the average relationship between two or more variables. If two variables are correlated, unknown value of one of the variables can be estimated by using the know the known value of other variables. The regression theory was first introduced by Sir Francis Galton in the field of genetics [Galton (1997)]. When data on two variables are known, by assuming one of the variables to be dependent on the other, we fit a linear equation to the data by the method of least squares. The linear equation is called regression equation.

Thus, the model specification will have the following equation form.

$$Yield_t = C + \beta_0 SED_t + \beta_1 ORG_t + \beta_2 INORG_t + \beta_3 PES_t + \beta_4 CRO_t + \beta_5 ERO_t + \beta_6 IRR_t + \beta_7 DRAIN_t + \beta_8 DIRR_t + \beta_9 CAL_t + \varepsilon_t \quad \text{(Eq 3.1)}$$

Where;

C =Constant

SED_t= Use of improved seeds at time t

ORG_t= Use of organic fertilizers at time t

$INORG_t$= Use of inorganic fertilizers at time t

PES_t= Use of pesticides at time t

CRO_t= Cropping system at time t

ERO_t= Anti-erosion at time t

IRR_t= Irrigation management at time t

$DRAIN_t$= Rainfall at time t

$DDRO_t$= Drought at time t

CAL_t= Calendar of sowing date at time t

ε_t=Error term

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8, \beta_9$ are the coefficients that are to be estimated, ε_t is an error term at time t.

The fit of the equation is typically measured using R^2 ("adjusted R squared"), which vary between 0 (no fit) and 1 (perfect fit). There is no hard and fast rule for determining whether an equation fits well, although with agricultural survey data one is often pleased to get an R^2 of 0.5 or more.

There is also a need to know how much confidence to place in the accuracy of the coefficients as guides to the truth; this is commonly done by reporting p-values, which give the confidence level directly; arbitrarily, it is standard to consider a coefficient to be statistically significant if the p-value is less than 0.05.

3.6.4 Testing the hypothesis.

As we have set them in our hypothesis part of this research, we will test the hypothesis set to take a decision accordingly.

3.7 Limitation of the study

In this study, the researcher aimed to investigate various factors, including the gender of the farmer and age, but found these factors were not available for certain years prior to 2020.

3.8 Ethical consideration

Ethical consideration means a lot of things, including but not limited to confidentiality, anonymity, respect for the dignity of research participants, the protection of the privacy of research participants, consent from the participants and so on (Bryman & Bell, 2007).

Since the researcher used the secondary data collected from respondents, the researcher kept a high ethical consideration by not using the data from primary source in unauthorized way, keeping anonymity of respondent who took part in SAS got from primary source, respecting confidentiality of research participants and ensured high level of integrity in our data analysis.

CHAPTER 4: PRESENTATION AND INTERPRETATION OF FINDINGS

4.1 Introduction

This chapter present the information obtained from National Institute of Statistics of Rwanda and was in line with the objective of the study. The researcher wanted to show the determinants of maize yield in Rwanda by analyzing Seasonal Agriculture Surveys' data and discuss about the findings. This part shows different empirical analysis done to show the contribution of both agricultural inputs, climate smart technologies and practices factors to maize yield.

4.2 Descriptive analysis

This section shows descriptive statistics with the aim to provide a detailed overview of the relationships and trends within dataset, offering valuable insights into the contributions of specific inputs and technologies to maize yield variations.

4.2.1 Agricultural characteristics of Maize in Rwanda by using SAS data.

The National Institute of Statistics of Rwanda conduct the Seasonal Agricultural Survey covering three seasons; Season A start in September and end with February of next year, Season B start in March and end with June while Season C stary in July and ends in September. Maize farming takes place in two distinct seasons, namely Season A and Season B. In 2017 Government of Rwanda developed Strategic plan for Agriculture Transformation (PST4) under Rwanda's National Strategy for Transformation (NST1) to guide public investment in agriculture during the period 2018-2024, it was planned to cultivate maize on constant area of 237,658ha for all years from 2017 to 2024. According to SAS data, since 2017, the cultivated area under maize was 207,964 ha, 218,179ha, 2015,158ha, 221,521ha, 236,642ha and 219,683ha in 2017,2018, 2019, 2020, 2021 and 2022 respectively for season A while 84,252ha, 78,151ha, 73,140ha, 72,918ha, 80,570ha and

81,339ha in 2017,2018, 2019, 2020, 2021 and 2022 respectively for season B. This section will also cover maize yield, total production in metric tons, as well as assess the presence of collinearity and multicollinearity among variables.

Table 4. 1: Description of cultivated area under maize crop

CULTIVATED AREA UNDER MAIZE IN HECTARE (ha)						
Province	**SEASON A**					
	2017A	**2018A**	**2019A**	**2020A**	**2021A**	**2022A**
KIGALI	5,192	5,145	6,647	4,585	4,960	5,216
SOUTHERN	28,232	26,829	27,796	35,638	36,786	37,286
WESTERN	30,078	31,288	43,697	37,408	38,288	35,841
NORTHERN	31,564	33,411	38,322	37,014	37,162	37,143
EASTERN	112,898	121,505	98,696	106,876	119,446	104,197
NATIONAL	**207,964**	**218,179**	**215,158**	**221,521**	**236,642**	**219,683**
Province	**SEASON B**					
	2017B	**2018B**	**2019B**	**2020B**	**2021B**	**2022B**
KIGALI	2,231	2,172	1,380	1,394	1,761	1,884
SOUTHERN	9,159	10,005	8,192	8,363	9,133	9,567
WESTERN	9,857	8,309	10,324	10,704	12,535	12,250
NORTHERN	8,984	8,703	9,000	8,991	9,831	9,298
EASTERN	54,019	48,963	44,244	43,466	47,310	48,339
NATIONAL	**84,252**	**78,151**	**73,140**	**72,918**	**80,570**	**81,339**

Source: Elaborated by the researcher, 2023

Table 4.1 provides an overview of the cultivated area dedicated to maize crop farming for the years 2017, 2018, 2019, 2020, 2021 and 2022, categorized by seasonal variations. Generally, maize cultivation exhibits its highest presence during season A when compared to season B. The data indicates that the Eastern Province consistently maintained a significant share, ranging from 46%(in 2019) to 54%(in 2017) of the total maize cultivation area nationwide in season A.

This trend continued in season B, with the Province accounting percentage share ranging from 58.7%(in 2021) to 64%(in 2017) of the total cultivated area under maize farming. On the other hand, Kigali city consistently recorded the lowest percentage of maize cultivation, at 2% for both season A and B. Notably, the data reveals a progressive increase in the cultivated area for maize at national level in both season A and B over the specified time.

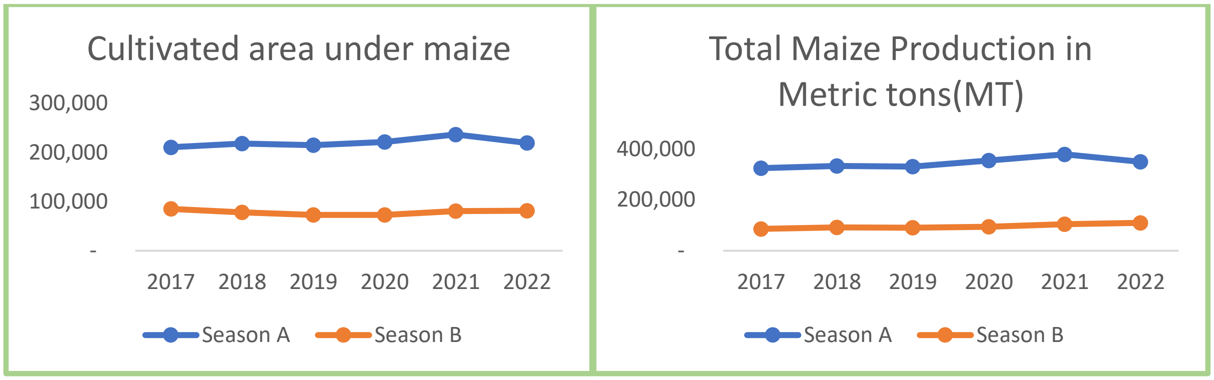


Figure 4. 1: Relationship between cultivated area and maize production over time

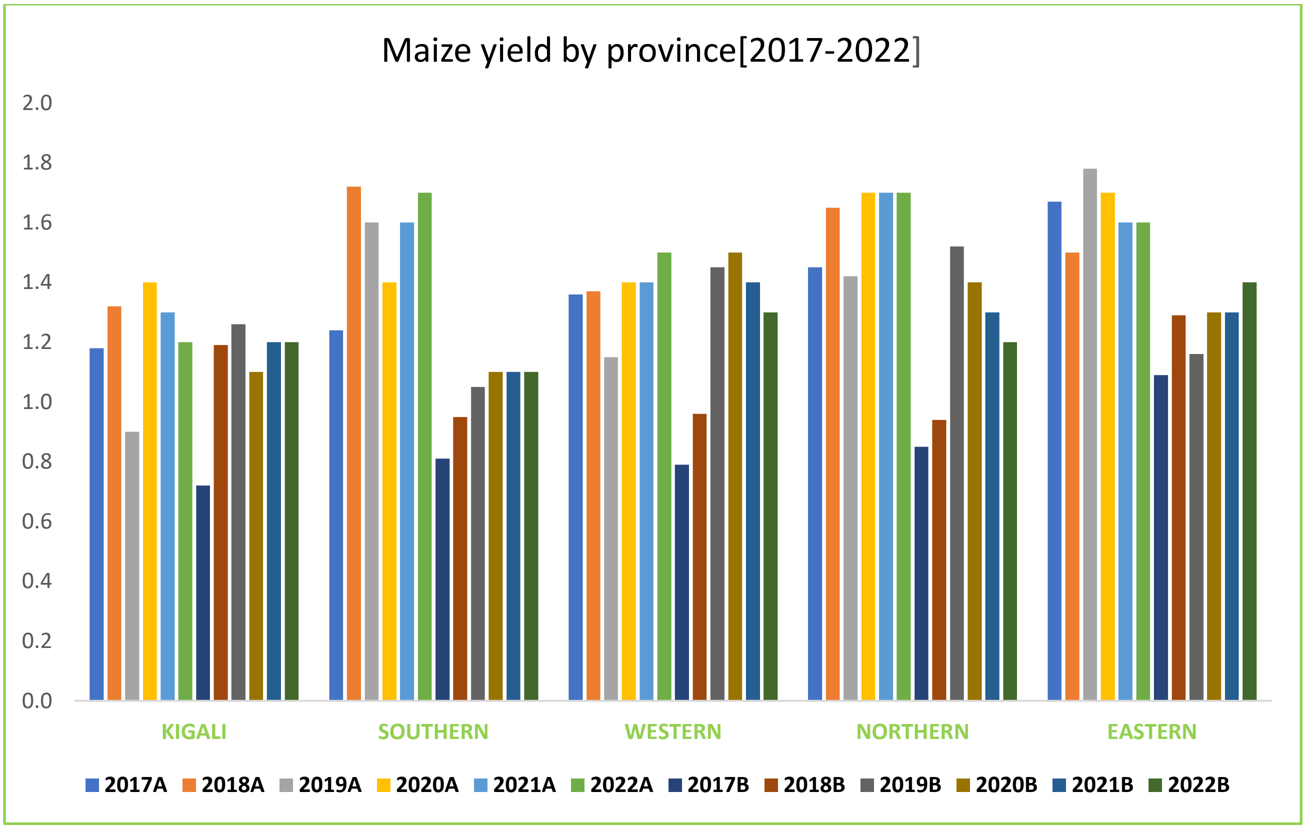
The above figure illustrates a clear relationship between changes in total maize production and alterations in the cultivated area. It is evident that total production is notably influenced by the extent of cultivated land dedicated to maize cultivation.

Table 4. 2: Description of total maize production across Provinces

TOTAL PRODUCTION OF MAIZE IN METRIC TONS(MT) BY PROVINCE						
	SEASON A					
Province	2017A	2018A	2019A	2020A	2021A	2022A
KIGALI	6,110	6,796	5,972	6,433	6,428	6,049
SOUTHERN	34,880	46,277	44,588	51,220	58,943	62,365
WESTERN	40,847	42,753	50,257	52,867	55,295	53,070
NORTHERN	45,801	55,108	54,364	63,044	63,856	63,183
EASTERN	188,840	181,736	175,913	180,435	194,119	164,240
NATIONAL	**316,477**	**332,670**	**331,094**	**353,999**	**378,641**	**348,907**
	SEASON B					
Province	2017B	2018B	2019B	2020B	2021B	2022B
KIGALI	1,605	2,577	1,742	1,541	2,036	2,172
SOUTHERN	7,378	9,534	8,620	9,047	10,219	10,595
WESTERN	7,767	7,974	14,960	16,342	17,317	16,307
NORTHERN	7,660	8,200	13,690	12,749	12,552	10,767
EASTERN	58,735	63,249	51,115	54,954	61,917	69,775
NATIONAL	**83,144**	**91,534**	**90,127**	**94,634**	**104,041**	**109,615**

Source: Elaborated by the researcher, 2023, 2023

Table 4.2 presents a detailed breakdown of the total maize production, measured in metric tons, categorized by Provinces. The data clearly illustrates a consistent trend: notably, the highest production levels are consistently observed during season A, as opposed to season B. Specifically, the production output during season A surpasses that of season B by a significant margin. In fact, the production during season A is approximately three to five times greater than that recorded in season B. This significant disparity emphasizes the substantial influence of seasonal factors on maize production across the regions.

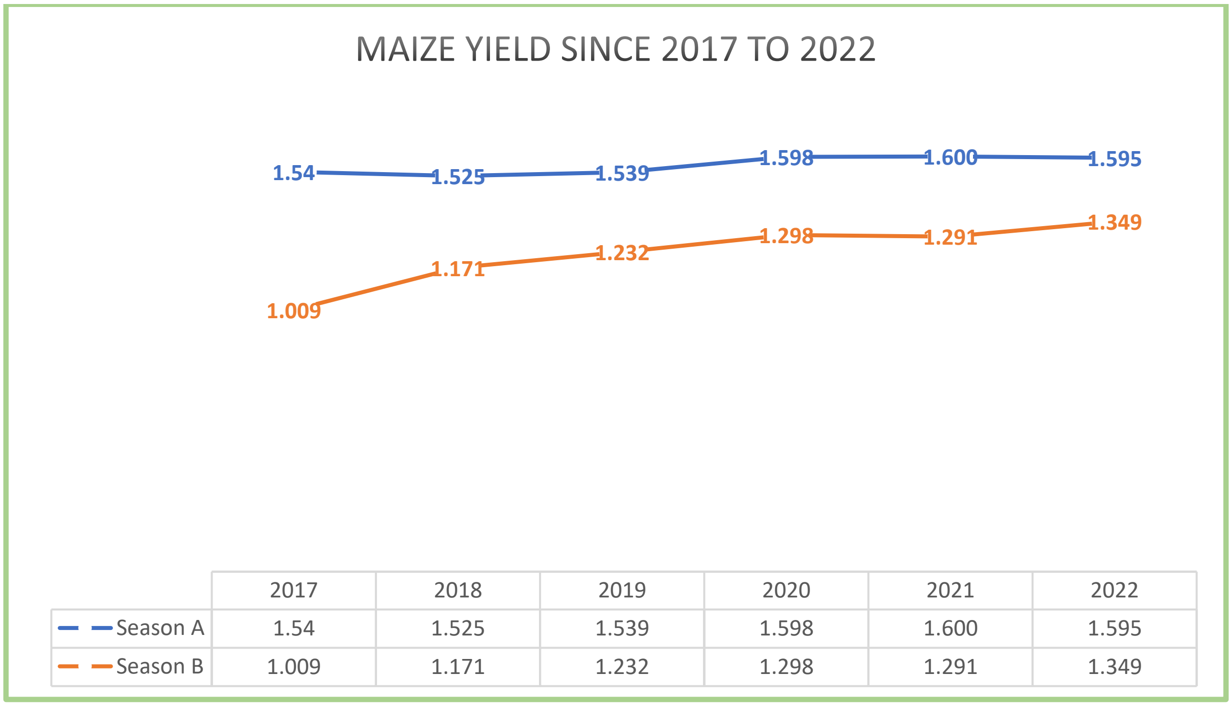


Source: Elaborated by the researcher, 2023

Figure 4. 2: Description of maize yield disaggregated by Province.

Figure 4.2 visually represents the maize yield across different Provinces, where yield is quantified in metric tons per hectare (MT/ha). According to the analysis conducted through SAS, the Northern Province emerges as the top-performing region, consistently achieving the highest maize yield. Following closely is the Eastern Province, which also demonstrates commendable yield levels. Conversely, Kigali City records the lowest maize yield among the five provinces, including Kigali itself.

In Season A, the five districts that stand out for their exceptional yield are Burera, Gisagara, Nyaruguru, Nyagatare, and Ngoma. These districts achieve yields ranging from 1.6 to 2.16 MT/ha. In Season B, the leading districts in maize yield are Kirehe, Rubavu, Nyaruguru, Musanze, and Nyabihu. These districts consistently achieve yields ranging from 1.43 MT/ha as the minimum to 2.14 MT/ha as the maximum.

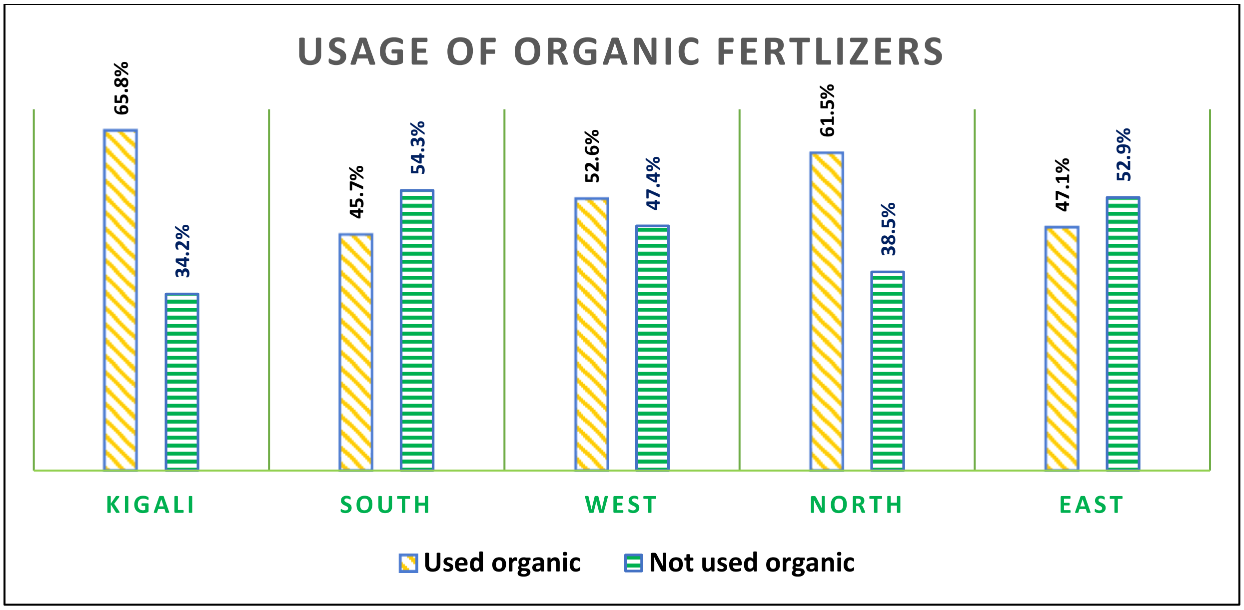


	2017	2018	2019	2020	2021	2022
Season A	1.54	1.525	1.539	1.598	1.600	1.595
Season B	1.009	1.171	1.232	1.298	1.291	1.349

Source: Elaborated by the researcher, 2023

Figure 4. 3: Trend of maize yield since 2017 to 2022 at National level

Figure shows the stagnant maize trend in season A against weak positive trend in season B since the implementation of PST4.



Source: Elaborated by the researcher, 2023

Figure 4. 4: Percentage of Farms Using Organic Fertilizers

Figure 4.4 shows the percentage of using or not using organic fertilizers for maize farming by Province. The results indicate that the highest percentage of using organic fertilizers observed in Kigali City at 65.8%, followed by Northern Province at 61.5% while Southern Province is the recorded with the highest percentage of not using organic fertilizers at 45.7% followed by Eastern Province at 47.1%.

Table 4. 3: The reasons of not using organic fertilizers by Province

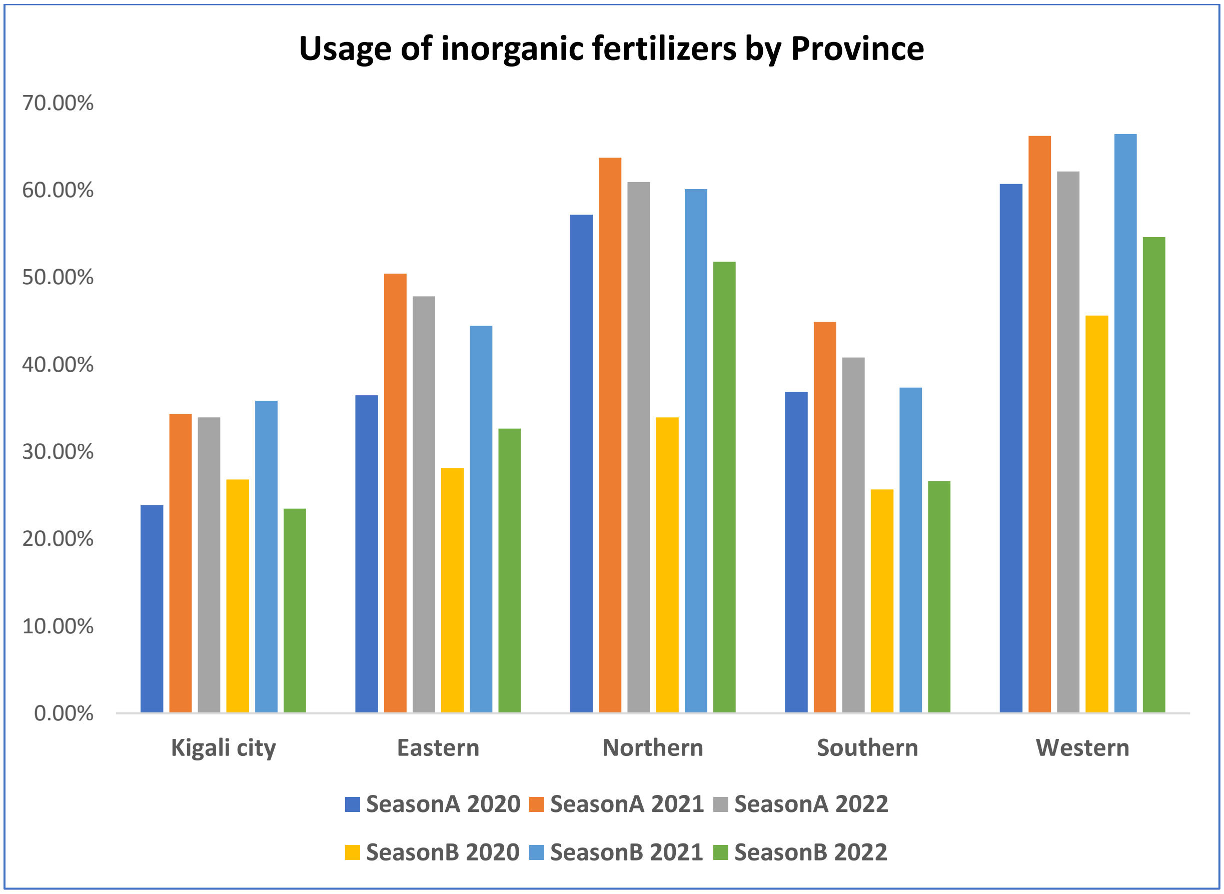
Main reasons of not using organic fertilizers							
Province	**No livestock at home**	**Few livestock at home**	**Not available on market**	**Lack of financial means**	**Lack of transport facilities**	**Other reason**	**Total**
Kigali	22.2	30.7	5.1	36.9	5.1	-	100
South	9.2	51.3	2.9	29.5	6.6	0.6	100
West	13.2	48.9	1.5	22.5	12.6	1.3	100
North	5.3	50.9	1.9	24.6	13.6	3.7	100
East	12	45.6	3.6	29.6	8.8	0.5	100
Total	10.9	47.8	2.9	28	9.4	1.1	100

Source: Researcher's computation, 2023

Table 4.3 provides a detailed breakdown of the primary reasons for the 48.4% of farmers who cultivated maize crops did not use organic fertilizers. These reasons include not having livestock at home, having a limited number of livestock that can provide the required organic fertilizers, unavailability of organic fertilizers in the market, lack of financial means to purchase them, and insufficient transport facilities to convey organic matter from the livestock's living area to the plots.

The most prevalent reason, accounting for 47.8% of cases, is having few livestock at home. This is followed by the lack of financial means, which constitutes 28% of cases. Conversely, the least common reason is the unavailability of organic fertilizers in the market.

Kigali City leads in the category of farmers who do not have livestock at home. This is attributed to the urban nature of the province, as indicated by the fifth Rwanda population and housing Census, which reported that the City of Kigali is the most urbanized Province, with 86.9% of its population residing in urban areas.

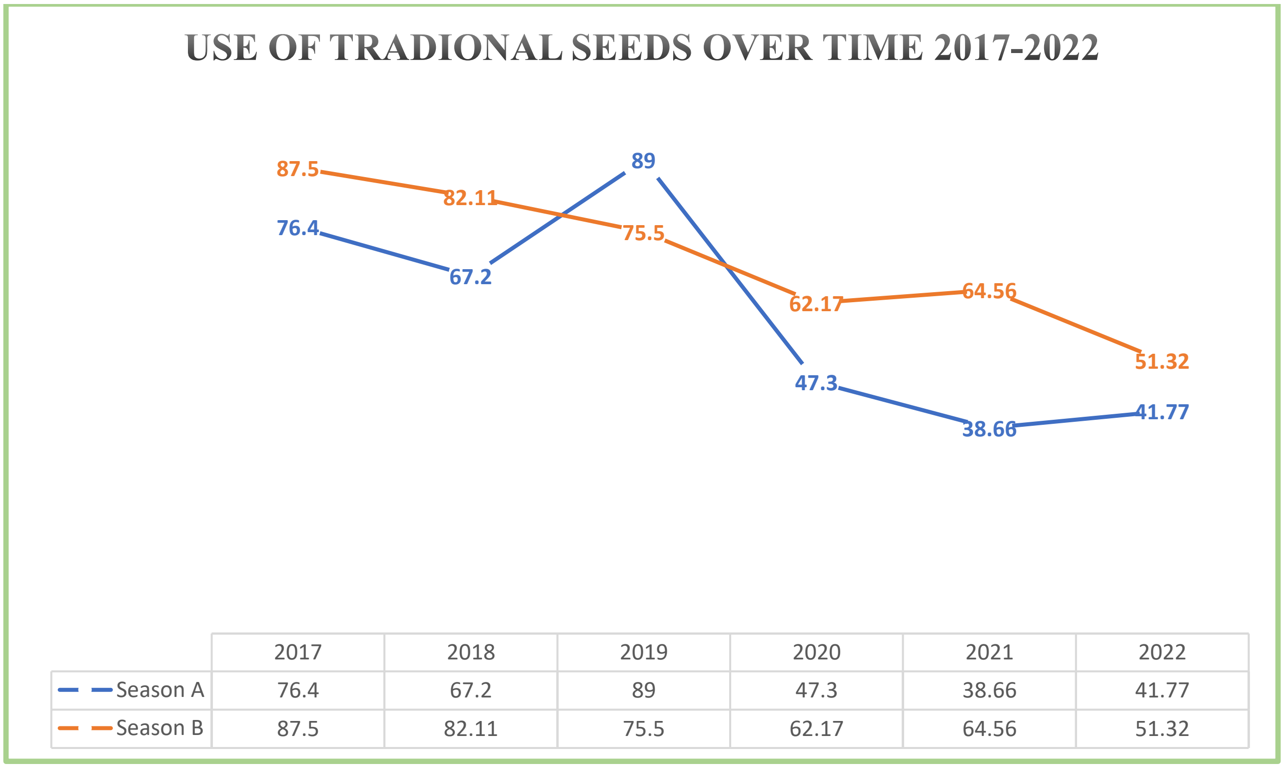


Source: Elaborated by the researcher, 2023

Figure 4. 5: Percentage of Farms Using inorganic Fertilizers by Province

Figure 4.5 shows the percentage of farmers used inorganic fertilizers for maize farming by Province across all seasons of 2020,2021 and 2022. The results indicate that the highest percentage of using inorganic fertilizers observed in Western and Northern Provinces particularly in season

A while Kigali city has the lowest percentage of using inorganic fertilizers which is below 40% in both season A and B of 2020, 2021 and 2022.



	2017	2018	2019	2020	2021	2022
Season A	76.4	67.2	89	47.3	38.66	41.77
Season B	87.5	82.11	75.5	62.17	64.56	51.32

Figure 4. 6: Use of improved and traditional seeds by Province

Figure 4.6 presents a comprehensive overview of the utilization of traditional seeds in maize farming. Notably, the findings reveal a consistent downward trajectory in the adoption of traditional seeds over a six-year period, encompassing both Season A and Season B within the Strategic Plan for Agricultural Transformation. Specifically, in Season A, the proportion of farmers employing traditional seeds decreased substantially from 76.4% in 2017 to 41.77% in 2022. Similarly, for Season B, there was a notable decline, with usage dropping from 87.5% in 2017 to 51.32% in 2022. This marked shift indicates a substantial increase in the adoption of improved maize seeds, which signifies a positive advancement within the agricultural landscape.

It is noteworthy that in 2019, there was a notable surge in farmers reverting to traditional seeds, with usage increased from67.2% in 2018 to 89% in 2019 for season A. This surge can be attributed to Rwanda's introduction of a seed hybridization program, aimed at reducing dependence on costly imported seeds, thus prompting farmers to turn to traditional seeds as a cost-effective alternative or viable alternative solution.

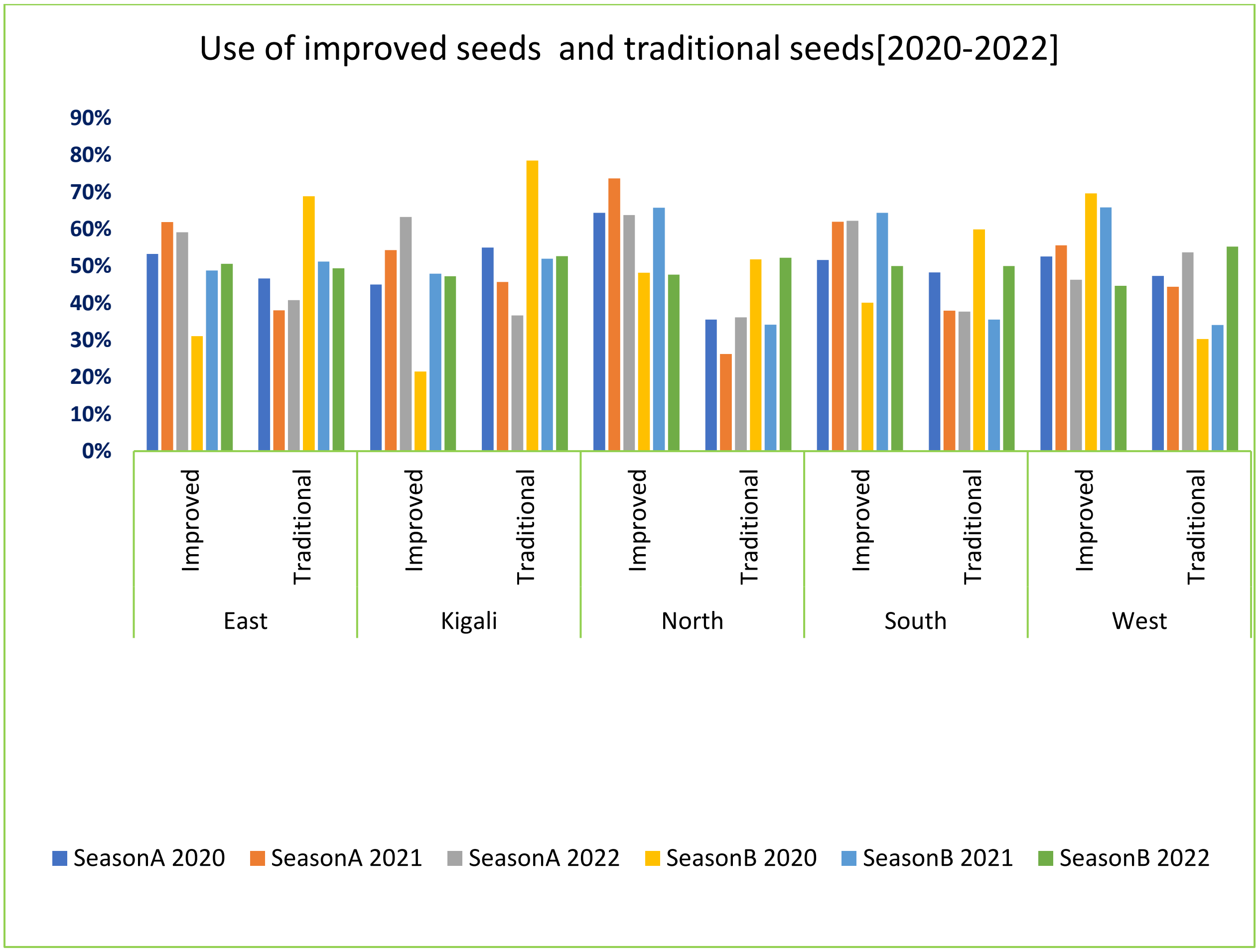


Figure 4. 7: Use of improved seeds and traditional seeds [2020-2022]

The above figure provides a comprehensive visual representation of the utilization patterns of improved and traditional seeds for maize cultivation across various Provinces during both Season A and Season B over a three-year span (2020, 2021, and 2022). The data demonstrates that both improved and traditional seed varieties hold significant prominence in agricultural practices of maize.

Specifically, in the Northern Province, there is a notable preference for the adoption of improved seeds over traditional counterparts. Conversely, in the Kigali City, traditional seeds exhibit higher prevalence in comparison to improved varieties.

Notably, the preference for traditional seeds tends to be more utilized during season B across the majority of Provinces. This shift in seed preference during this particular season has brought to light a significant concern raised by farmers regarding delays in the supply of modern seed varieties, which subsequently necessitates the reliance on traditional seeds as a viable alternative.

Table 4. 4: The percentage share of independent variable by Province for Season A 2022

Variable	Kigali	South	West	North	East
Organic fertilizer	69.2	82.0	83.0	87.5	65.3
Inorganic fertilizer	34.0	40.8	62.2	60.9	47.8
Improved Seed	63.3	62.3	46.3	63.8	59.2
Pesticide	22.9	31.3	18.3	39.5	17.3
Pure Cropping System	9.6	6.8	6.9	17.7	8.7
Anti-Erosion	80.1	89.3	88.1	95.0	81.5
Irrigation	65.9	25.5	17.9	45.7	31.5
Drought	34.5	7.4	13.7	2.1	27.3
Rainfall	65.3	45.6	21.4	30.0	53.7

Source: Elaborated by the researcher, 2023

Table 4.4 shows the percentages of all independent variables for maize yield. The survey includes 55.9% male farmers in Western province as the lowest and 61.0% male farmers in Eastern province as the highest. The Northern is the province with high percentage 87.7% of using of organic fertilizers versus inorganic fertilizes at 60.9%, the lowest percentage for inorganic and organic fertilizers is counted in Kigali city and Eastern province at 34.0% and 65.3% respectively.

Only less than 10% of the farmers cultivate with pure cropping systems while in Northern province's plots with maize have anti-erosion. The significant percentage optimize the crop calendars particularly in Kigali city, Eastern and Southern provinces.

Table 4. 5: The summary statistics for Season A (2022)

	N	Mean	SD	Min	Max
Yield fertilizer	7699	1409.263	1175.41	0	8496.835
Organic fertilizer	7731	0.757	0.429	0	1
Inorganic	7731	0.5	0.500	0	1
Improved Seed	7731	0.588	0.492	0	1
Pesticide	7731	0.245	0.430	0	1
Cropping System	7731	0.096	0.294	0	1
Anti-Erosion	7037	0.866	0.340	0	1
Drought	6517	0.172	0.377	0	1
Rainfall	6517	0.437	0.496	0	1

Source: Elaborated by the researcher, 2023

Table 4. 6: The summary statistics for Season B (2022)

	N	Mean	SD	Min	Max
Yield	3586	1232.04	1015.73	45.123	8020.86
Organic fertilizer	3586	0.578	0.494	0	1
Inorganic fertilizer	3586	0.358	0.48	0	1
Improved Seed	3586	0.491	0.5	0	1
Pesticide	3586	0.197	0.398	0	1
Cropping System	3586	0.073	0.26	0	1
Anti-Erosion	3136	0.845	0.362	0	1
Irrigation	3586	0.019	0.136	0	1
Drought	2947	0.097	0.297	0	1
Rainfall	2947	0.428	0.495	0	1

Source: Elaborated by the researcher, 2023

Table 4.5 and 4.6 displays summary statistics for both Seasons A and B in 2022, including the number of observations, mean, standard deviation (SD), minimum and maximum values. In season A, there are roughly twice as many observations compared to Season B. The mean yield in Season A is 1.41 metric tons per hectare, in contrast to 1.23 metric tons per hectare in season B. The maximum yield for Season A is 8.5 MT/ha while for season B is 8.0 MT/ha. For the other variables, the minimum value observed 0 indicates instances where certain measures (eg. Anti-erosion,) were not implemented while the maximum value 1 signifies full implementation of these measures.

Table 4. 7: The summary statistics for Season A (2021)

	N	Mean	SD	Min	Max
Yield	8435	658.015	804.97	10.104	7453.61
Organic fertilizer	8435	0.72	0.449	0	1
Inorganic fertilizer	8435	0.531	0.499	0	1
Improved Seed	8435	0.621	0.485	0	1
Pesticide	8435	0.271	0.444	0	1
Cropping System	8435	0.117	0.321	0	1
Anti-Erosion	8435	0.771	0.42	0	1
Irrigation	8435	0.024	0.154	0	1
Drought	8435	0.054	0.226	0	1
Rainfall	8435	0.291	0.454	0	1

Source: Elaborated by the researcher, 2023

Table 4. 8: The summary statistics for Season B (2021)

	N	Mean	SD	Min	Max
Yield	3248	488.403	621.516	15.421	7667.83
Organic fertilizer	3248	0.573	0.495	0	1
Inorganic fertilizer	3248	0.481	0.5	0	1
Improved Seed	3248	0.56	0.496	0	1
Pesticide	3248	0.267	0.443	0	1
Cropping System	3248	0.095	0.293	0	1
Anti-Erosion	3248	0.732	0.443	0	1
Irrigation	3248	0.019	0.136	0	1
Drought	3248	0.105	0.306	0	1
Rainfall	3248	0.454	0.498	0	1

Table 4.7 and 4.8 displays summary statistics for both Seasons A and B in 2021, including the number of observations, mean, standard deviation (SD), minimum and maximum values. In season A, there are nearly triple as many observations compared to Season B. The mean yield in Season A is .65 MT/ha, in contrast to 0.48 MT/ha in season B. The maximum yield for Season A is 7.5 MT/ha while for season B is 7.7 MT/ha. For the other variables, the minimum value observed 0

indicates instances where certain measures (eg. Pure cropping system,) were not implemented while the maximum value 1 signifies full implementation of these measures.

Table 4. 9: The summary statistics for Season A (2020)

	N	Mean	SD	Min	Max
Yield	8145	1500.17	1254.6	87.546	7983.17
Organic fertilizer	8145	0.68	0.466	0	1
Inorganic fertilizer	8145	0.431	0.495	0	1
Improved Seed	8145	0.54	0.498	0	1
Pesticide	8145	0.247	0.431	0	1
Cropping System	8145	0.129	0.336	0	1
Anti-Erosion	7078	0.854	0.354	0	1
Irrigation	8145	0.013	0.114	0	1
Drought	8145	0.017	0.129	0	1
Rainfall	8145	0.272	0.445	0	1

Source: Elaborated by the researcher, 2023

Table 4. 10: The summary statistics for Season B (2020)

	N	Mean	SD	Min	Max
Yield	3577	1222.81	959.238	16.79	7052.01
Organic fertilizer	3577	0.505	0.5	0	1
Inorganic fertilizer	3577	0.328	0.469	0	1
Improved Seed	3577	0.389	0.488	0	1
Pesticide	3577	0.204	0.403	0	1
Cropping System	3577	0.098	0.298	0	1
Anti-Erosion	2852	0.81	0.392	0	1
Irrigation	354	0.201	0.401	0	1
Drought	3577	0.084	0.278	0	1
Rainfall	3577	0.457	0.498	0	1

Table 4.9 and 4.10 displays summary statistics for both Seasons A and B in 2020, including the number of observations, mean, standard deviation (SD), minimum and maximum values. In season A, there are nearly triple as many observations compared to Season B. The mean yield in Season A is 1.5 MT/ha, in contrast to 1.2 MT/ha in season B. The maximum yield for Season A is 7.98 MT/ha while for season B is 7.05 MT/ha. For the other variables, the minimum value observed O

indicates instances where certain measures (eg. pesticides,) were not applied while the maximum value 1 signifies full application of these measures.

Table 4. 11: The summary statistics for Season A (2019)

	N	Mean	SD	Min	Max
Yield	7228	1050.36	840.698	78.094	4406.47
Organic fertilizer	7228	0.604	0.489	0	1
Inorganic fertilizer	7228	0.357	0.479	0	1
Improved Seed	7228	0.357	0.479	0	1
Pesticide	7228	0.222	0.416	0	1
Cropping System	7228	0.142	0.349	0	1
Anti-Erosion	7228	0.697	0.46	0	1
Irrigation	7228	0.016	0.125	0	1
Drought	7228	0.092	0.288	0	1
Rainfall	7228	0.389	0.488	0	1

Source: Elaborated by the researcher, 2023

Table 4. 12: The summary statistics for Season B (2019)

	N	Mean	SD	Min	Max
Yield	3657	1228.26	723.099	100.284	2636.97
Organic fertilizer	3657	0.414	0.493	0	1
Inorganic fertilizer	3657	0.233	0.423	0	1
Improved Seed	3657	0.251	0.434	0	1
Pesticide	3657	0.158	0.364	0	1
Cropping System	3657	0.062	0.242	0	1
Anti-Erosion	3657	0.6	0.49	0	1
Irrigation	3657	0.013	0.111	0	1
Drought	3657	0.075	0.263	0	1
Rainfall	3657	0.406	0.491	0	1

Source: Elaborated by the researcher, 2023

Table 4.11 and 4.12 displays summary statistics for both Seasons A and B in 2019, including the number of observations, mean, standard deviation (SD), minimum and maximum values. In season A, there are nearly triple as many observations compared to Season B. The mean yield in Season A is 1.05 MT/ha, in contrast to 1.23 MT/ha in season B. The maximum yield for Season A is 4.4 MT/ha while for season B is 2.6 MT/ha. For the other variables, the minimum value observed O indicates instances where certain measures (eg. irrigation,) were not applied while the maximum value 1 signifies full application of these measures.

Table 4. 13: The summary statistics for Season A (2018)

	N	Mean	SD	Min	Max
Yield	5046	1494.32	1107.72	100.362	8470.65
Organic fertilizer	5046	0.561	0.496	0	1
Inorganic fertilizer	5046	0.32	0.466	0	1
Improved Seed	5046	0.367	0.482	0	1
Pesticide	5046	0.263	0.44	0	1
Cropping system	5046	0.233	0.423	0	1
Anti-erosion	5046	0.636	0.481	0	1
Irrigation	5046	0.018	0.132	0	1
Drought	5046	0.13	0.336	0	1
Rainfall	5046	0.302	0.459	0	1

Source: Elaborated by the researcher, 2023

Table 4. 14: The summary statistics for Season B (2018)

	N	Mean	SD	Min	Max
yield	2718	1314.33	1086.14	21.697	8807.26
Organic	2718	0.369	0.483	0	1
Inorganic	2718	0.185	0.388	0	1
Improved Seed	2718	0.219	0.413	0	1
Pesticide	2718	0.157	0.364	0	1
Cropping System	2718	0.084	0.277	0	1
Anti-Erosion	2718	0.579	0.494	0	1
Irrigation	2718	0.013	0.111	0	1
Drought	2718	0.024	0.154	0	1
Rainfall	2718	0.223	0.416	0	1

Source: Elaborated by the researcher, 2023

Table 4.13 and 4.14 displays summary statistics for both Seasons A and B in 2018, including the number of observations, mean, standard deviation (SD), minimum and maximum values. In season A, there are nearly triple as many observations compared to Season B. The mean yield in Season A is 1.5 MT/ha, in contrast to 1.3 MT/ha in season B. The maximum yield for Season A is 8.5 MT/ha while for season B is 8.8 MT/ha. For the other variables, the minimum value observed 0 indicates instances where certain measures (eg. Inorganic fertilizers,) were not applied while the maximum value 1 signifies full application of these measures.

Table 4. 15: The summary statistics for Season A (2017)

	N	Mean	SD	Min	Max
Yield	6284	1534.1	814.419	14.056	8797.36
Organic	6284	0.552	0.509	0	1
Inorganic	6284	0.227	0.432	0	1
Improved Seed	6284	0.259	0.438	0	1
Pesticide	6283	0.103	0.304	0	1
Cropping System	6284	0.1	0.3	0	1
Anti-Erosion	6284	0.648	0.478	0	1
Irrigation	6284	0.015	0.162	0	1
Drought	6284	0.389	0.488	0	1
Rainfall	6284	0.323	0.468	0	1

Source: Elaborated by the researcher, 2023

Table 4. 16: The summary statistics for Season B (2017)

	N	Mean	SD	Min	Max
Yield	4048	1036.07	842.117	8.326	7782.69
Organic fertilizer	4048	0.316	0.465	0	1
Inorganic fertilizer	4048	0.126	0.332	0	1
Improved Seed	4048	0.146	0.353	0	1
Pesticide	4047	0.113	0.317	0	1
Cropping System	4048	0.049	0.217	0	1
Anti-Erosion	4048	0.558	0.497	0	1
Irrigation	4048	0.005	0.072	0	1
Drought	4048	0.145	0.352	0	1
Rainfall	4048	0.242	0.428	0	1

Source: Elaborated by the researcher, 2023

Table 4.15 and 4.16 displays summary statistics for both Seasons A and B in 2017, including the number of observations, mean, standard deviation (SD), minimum and maximum values. In season A, there are nearly triple as many observations compared to Season B. The mean yield in Season A is 1.53 MT/ha, in contrast to 1.04 MT/ha in season B. The maximum yield for Season A is 8.79 MT/ha while for season B is 7.78 MT/ha. For the other variables, the minimum value observed 0 indicates instances where certain measures (eg. drought,) were not happen while the maximum value 1 signifies the existence of the drought.

4.2.2 Checking for multicollinearity among the inputs and practices variables

If one variable is a perfect linear function of another in the model, standard errors become infinite and the solution to the model becomes indeterminate. To the extent that one independent is a near but not perfect linear function of another independent, the problem of multicollinearity will occur in multiple regression. As the independents increase in correlation with each other, the standard errors of the logit (effect) coefficients will become inflated. Multicollinearity does not change the estimates of the coefficients, only their reliability.

To avoid the misleading results, we have used the Variance Inflation Factor (VIF) to check for multicollinearity between the independent variables.

According to Kennedy (1992), a VIF greater than 10 indicates harmful collinearity. When the VIF reaches these threshold levels, researchers may feel compelled to reduce the collinearity by eliminating one or more variables from their analysis; combining two or more independent variables into a single index; resorting to a biased regression technique that can reduce the variance of the estimated regression coefficients; or, in rejecting a paper because VIF exceeds a threshold value. (Belsley et al., 1980)

The following tables show the results of the checking from STATA

Table 4. 17: Checking for multicollinearity by Variance Inflation Factor (VIF)

	VIF	1/VIF
inorganic	1.354	.738
pesticide	1.324	.755
Improved seed	1.140	.877
organic	1.088	.919

Cropping system	1.088	.919
calendar	1.059	.944
Anti-erosion	1.055	.948
rainfall	1.051	.952
drought	1.049	.953
irrigation	1.041	.961
Mean VIF	1.125	.

Source: Elaborated by the researcher, 2023

The findings presented in Tables 4.17 indicate that there is no issue of multicollinearity among the independent variables. This is evidenced by the fact that, in every instance, the Variance Inflation Factor (VIF) is less than 10.

As a result, the study can confidently proceed with the inclusion of all independent variables in order to construct the multiple linear regression model. This suggests that the selected variables are sufficiently independent and do not exhibit high correlations that could potentially distort the regression analysis.

4.2.3 Checking for non-linearity between the dependent variable and independent variables and for non-normality of errors

The multiple linear regression does not assume a linear relationship between the dependents and the independents normally distributed error terms are not assumed. The following table is the output of STATA on the linearity between the dependent variable (maize yield) and the independent variables: organic, inorganic fertilizers, improved seeds, use of pesticides, pure cropping system, anti-erosion, irrigation, male, drought, rainfall and optimization of crop calendars.

Table 4. 18: Checking the collinearity between variables.

	(1) yield	**(2)** organic	**(3)** inorganic	**(4)** improved seed	**(5)** pesticide	**(6)** Cropping	**(7)** anti-erosion	**(8)** irrigation	**(9)** drought	**(10)** rainfall
[**1**]	1									
[**2**]	0.0884	1								
[**3**]	0.2107	0.2572	1							
[**4**]	0.2075	0.1627	0.4103	1						
[**5**]	0.2229	0.2067	0.4024	0.2405	1					
[**6**]	0.2287	0.0669	0.1927	0.1561	0.1596	1				
[**7**]	0.0429	0.1948	0.0631	0.0362	0.0954	0.022	1			
[**8**]	0.0747	0.0437	0.0958	0.0533	0.1628	0.045	0.0286	1		
[**9**]	-0.0443	-0.0261	-0.0018	0.0069	-0.0299	-0.0077	-0.0255	0.0184	1	
[**10**]	-0.0724	-0.0216	0.0248	0.0139	-0.0084	-0.0184	-0.0441	0.029	-0.1028	1

From table 4.18, observed that the largest correlation coefficient is 0.41 which is recorded between use of improved seeds and inorganic fertilizers. This shows that there is no variable which exhibits any stronger linear association with the dependent variable.

The correlation coefficients are all different from zero, which implies that all independent variables have an association with maize yield. Thus, these variables are being used in the multiple linear regression.

4.3 Multiple Linear Regression Model fitting for independent variables on maize yield

4.3.1 The fitted model with all independent factors

This study had ten independent variables or factors which are use of organic fertilizers, use of inorganic fertilizers, use of pesticides, age of the farmers, status, improved seeds, irrigation, drought, rainfall, cropping system and soil erosion control. The dependent variable is maize yield. The results shows that the model was statistically significant, it showed by significance which is less than critical value of 10%.

Table 4. 19: The fitted model coefficients for determinants of maize yield in both seasons of 2022, 2021 and 2020

	Season A 2022		Season B 2022		Season A 2021		Season B 2021		Season A 2020		Season B 2020	
yield	**Coef.**	**p-value**	**Coef.**	**p-value**	**Coef.**	**p-value**	**Coef.**	**p-value**	**Coef.**	**p-value**	**Coef.**	**p-value**
organic	28.5	.044**	78.6	.072*	11.8	.477	12.1	.546	4.9	.020***	31.8	.411
inorganic	331.7	.019**	320.0	.000***	243.1	.000***	159.9	.000***	238.4	.000***	78.6	.056*
Improved seed	315.8	.031**	295.5	.000***	208.5	.000***	194.9	.000***	403.9	.000***	369.3	.000***
pesticide	482.7	.001***	242.9	.000***	270.2	.000***	228.3	.000***	481.4	.000***	331.2	.000***
Cropping system	445.2	.006***	318.9	.000***	1,039.0	.000***	723.0	.000***	299.5	.000***	223.5	.000***
Anti-erosion	286.4	.080*	71.8	.016***	35.0	.040**	75.8	.000***	160.8	.000***	72.4	.125
drought	- 618.7	.000***	- 94.8	.203	- 40.5	.092*	- 86.8	.006***	- 305.4	.006***	220.8	.002***
rainfall	- 724.9	.000***	- 52.6	.213	- 84.5	.000***	- 48.4	.013**	- 299.1	.000***	- 180.3	.000***
irrigation	586.8	.000***	527.2	.000***	365.6	.000***	532.2	.000***	421.4	.000***	- 180.3	.000***
Constant	1,766.4	.000***	980.6	.000***	119.7	.000***	257.8	.000***	1,201.6	.000***	1,078.9	.000***
Mean dependent var		1898		1176		658		480		1480		1186
R-squared		69.4%		59%		56.7%		28.3%		63.1%		50.8%
SD dependent var		1477		1083		805		625		1254		970
Number of obs		468		2574		8435		3243		7078		2613

**** p<.01, ** p<.05, * p<.1*

Table 4. 20: The fitted model coefficients for determinants of maize yield in both seasons of 2019, 2018 and 2017

	Season A 2019		Season B 2019		Season A 2018		Season B 2018		Season A 2017		Season B 2017	
Yield	**Coef.**	**p-value**	**Coef.**	**p-value**	**Coef.**	**p-value**	**Coef.**	**p-value**	**Coef.**	**p-value**	**Coef.**	**p-value**
Organic	35.7	.074*	38.0	.117	41.9	.176	53.1	.215	90.4	.000***	54.5	.053*
inorganic	252.8	.000***	146.0	.000***	155.7	.000***	2.7	.967	185.4	.000***	177.2	.000***
Improved seed	330.5	.000***	250.6	.000***	413.5	.000***	353.6	.000***	122.1	.000***	340.4	.000***
pesticide	233.2	.000***	296.5	.000***	322.0	.000***	393.3	.000***	192.0	.000***	338.0	.000***
Cropping system	285.3	.000***	206.5	.000***	222.0	.000***	517.4	.000***	76.3	.030**	135.0	.029**
Anti-erosion	86.5	.000***	76.1	.002***	68.7	.029**	220.8	.000***	123.8	.000***	100.8	.000***
drought	- 153.8	.000***	- 165.5	.000***	17.2	.704	- 424.3	.001***	- 176.2	.000***	- 141.4	.000***
Rainfall	- 160.5	.000***	- 127.5	.000***	- 184.3	.000***	- 86.6	.069*	- 119.6	.000***	- 21.6	.481
irrigation	49.4	.497	95.5	.356	255.7	.023**	716.9	.000***	219.0	.014**	944.4	.000***
Constant	907.1	.000***	1,205.8	.000***	1,135.8	.000***	1,260.5	.000***	1,665.8	.000***	969.2	.000***
Mean dependent var		1,050		1,228		1,494		1,314		1,534		1,036
R-squared		48.2%		53.1%		43.7%		12.1%		55.3%		69.1%
SD dependent var		841		723		1,108		1,086		814		842
Number of obs		7228		3657		5046		2718		6283		4047

**** p<.01, ** p<.05, * p<.1*

4.3.2 Discussion of the results

For the year 2022: the sampled farmers are 7,731 in season A and 2,574 in season B across the country. A small p-value (Prob>F= 0.000) suggests that the determinants of maize in 2022 are jointly statistically significant at all levels of significance.

The R-squared value (0.694) in season A and (0.590) in season B are a measure of how well the independent variables explain the variation in the dependent variable. It represents the proportion of the variance in the dependent variable that is explained by the independent variables. In this case, the R-squared value of 0.69 and 0.59 suggest a moderate level of explanatory power for the model.

The p-values for individual independent variables indicate the statistical significance of each independent variable. In this context, a lower p-value suggests greater statistical significance. The analysis for Season A 2022 shows that all determinants of yield were statistical contribute to the yield at 90% CI while for season B, drought and rainfall are not statistically significant at all levels. In addition, the location of some of the plots (hillside, marchland, etc) the farmer did not control for erosion due to its degree; the data shows that mostly the level of erosion is minimal except some segment in Northern Province.

Model is specified bellow:

$$\boldsymbol{Yield_{2022\,A}} = 1766.4 + 28.5\ Organic + 331.7\ Inorganic + 315.8\ Improved\ seeds + 482.7 Pesticide + 445.2\ cropping\ system + 286.4\ Anti\ erosion + 586.8\ irrigation - 618.7\ Drought - 724.8\ Rainfall$$

$$\boldsymbol{Yield_{2022\,B}} = 0.981 + 0.078\ Organic + 0.320\ Inorganic + 0.295\ Improved\ seeds + 0.243 Pesticide + 0.319\ cropping\ system + 0.072\ Anti\ erosion + 0.527\ irrigation - 0.094\ Drought - 0.053\ Rainfall$$

Use of organic and inorganic fertilizers, improved seeds, pesticides, cropping system, anti-erosion and irrigation have positive effect to the maize yield where using pesticides and irrigation management showed the highest positive effect on maize yield; irrigation management increase the maize yield by 586.8 kilogram or 0.59 MT per hectare in season A and 527.2 Kg or 0.53 MT/ha in season B, holding other factors constant. Conversely, the coefficients of drought and heavy rainfall have negative coefficient which suggests that a significant and negative relationship between them and maize yield. Specifically, it implies that an occurrence of drought, the maize yield is expected to decrease by 724.8 kilograms or 0.725 metric tons per hectare in season A.

Drought has a detrimental impact on maize yield by interrupting the normal physiological processes of the plant and creating unfavorable environmental conditions that persist throughout the entire life cycle of the maize crop. This disruption manifests at various stages of the plant's growth and development leading to stunted plant growth, reduced photosynthetic and diminished maize production.

Excessive rainfall, causing waterlogging, and insufficient rainfall, causing drought stress, harm maize yield. These extreme weather conditions disrupt the normal growth of maize plants, resulting in lower crop productivity.

For the year 2021; The sampled farmers are 8435 in season A and 3,243 in season B across the country. A small p-value (Prob> F=0.000) suggests that determinants of maize yield in both seasons A and B are jointly significant at all levels of significance.

The use organic and inorganic fertilizers, use of pesticide, improved seeds, cropping system, anti-erosion and irrigation management are positively associated with maize yield. Conversely, drought and heavy or insufficient rainfall show a negative association

Model is specified bellow:

$$\boldsymbol{Yield_{2021\,A}} = 119.7 + 11.7\ Organic + 243.1\ Inorganic + 208.5\ Improved\ seeds + 270.2\ Pesticide + 1.04\ cropping\ system + 34.9\ Anti\ erosion + 365.6\ irrigation - 40.5\ Drought - 84.5\ Rainfall$$

$$\boldsymbol{Yield_{2021\,B}} = 0.257 + 0.012\ Organic + 0.160\ Inorganic + 0.195\ Improved\ seeds + 0.228 Pesticide + 0.723\ cropping\ system + 0.075\ Anti\ erosion + 0.532\ irrigation - 0.087\ Drought - 0.048\ Rainfall$$

Holding other variables constant, employing organic, inorganic, improved seeds, pesticides, appropriate cropping system, anti-erosion and efficient irrigation management is projected to increase maize yield. Conversely, the presence of heavy rainfall and drought, the maize yield is expected to decrease.

All independent variables are statistically significant at 90% confidence level, except organic fertilizers which is not significant at any level of confidence for both seasons A and B.

For the year 2020; The sampled farmers are 7078 in season A and 2613 in season B across the country and a small p-value (Prob> F=0.000) suggests that determinants of maize yield in season A and B are jointly significant at all levels of significance.

Model is specified bellow:

$$\boldsymbol{Yield_{2020\,A}} = 1.202 + 0.005\ Organic + 0.238\ Inorganic + 0.404\ Improved\ seeds + 0.481\ Pesticide + 299\ cropping\ system + 0.161\ Anti\ erosion + 0.421\ irrigation - 0.305\ Drought - 0.299\ Rainfall$$

$$\boldsymbol{Yield_{2020\,B}} = 1.078 + 0.032\ Organic + 0.079\ Inorganic + 0.369\ Improved\ seeds + 0.331 Pesticide + 0.223\ cropping\ system + 0.072\ Anti\ erosion + 0.482\ irrigation - 0.221\ Drought - 0.180\ Rainfall$$

Holding other variables constant, employing organic, inorganic, improved seeds, pesticides, appropriate cropping system, anti-erosion and efficient irrigation management is projected to increase maize yield by 0.005, 0.238, 0.404, 0.481, 0.299, 0.161 and 0.421 metric tons per hectare in season A and 0.032, 0.079, 0.369, 0.331, 0.223, 0.072 and 0.482 metric tons per hectare in season B respectively.

Conversely, the presence of heavy rainfall and drought, the maize yield is expected to decrease by 0.299 and 0.305 metric tons per hectare in season A and 0.180 and 0.221 metric tons per hectare in season B respectively, holding other factors constant.

All independent variables are statistically significant at 90% confidence level except organic and anti-erosion which are not significant in season B.

For the year 2019: The sampled farmers are 7228 in season A and 3657 in season B across the country a small p-value (Prob> F=0.000) suggests that determinants of maize yield in 2019 are jointly significant at all levels of significance.

The use organic and inorganic fertilizers, use of pesticide, improved seeds, cropping system, anti-erosion and irrigation management are positively associated with maize yield. Conversely, drought and heavy or insufficient rainfall show a negative association.

Model is specified bellow:

$$\boldsymbol{Yield_{2019\,A}} = 0.907 + 0.035\,Organic + 0.252\,Inorganic + 0.330\,Improved\ seeds + 0.233\,Pesticide + 0.285\,cropping\ system + 0.086\,Anti\ erosion + 0.049\,irrigation - 0.153\,Drought - 0.160\,Rainfall$$

$$\boldsymbol{Yield_{2019\,B}} = 1.206 + 0.038\,Organic + 0.146\,Inorganic + 0.251\,Improved\ seeds + 0.297\,Pesticide + 0.207\,cropping\ system + 0.076\,Anti\ erosion + 0.096\,irrigation - 0.166\,Drought - 0.128\,Rainfall$$

Holding other variables constant, employing organic, inorganic, improved seeds, pesticides, appropriate cropping system, anti-erosion and efficient irrigation management is projected to increase maize yield by 0.035, 0.252, 0.330, 0.233, 0.285, 0.086 and 0.049 metric tons per hectare in season A and by 0.038, 0.146, 0.251, 0.297, 0.207,0.076 and 0.096 metric tons in season B respectively.

Conversely, the presence of heavy rainfall and drought, the maize yield is expected to decrease by 0.160 and 0.153 metric tons per hectare in season A and 0.128 and 0.166 MT/ha in season B respectively holding other factors constant.

All independent variables are statistically significant at 90% confidence level except irrigation in both seasons and organic fertilizer in season B which are not significant.

For the year 2018: The sampled farmers in season A are twice of season B and a small p-value (Prob> F=0.000) suggests that determinants of maize yield in 2018 are jointly significant at all levels of significance.

The use organic and inorganic fertilizers, use of pesticide, improved seeds, cropping system, anti-erosion and irrigation management are positively associated with maize yield. Conversely, drought and heavy or insufficient rainfall show a negative association.

Model is specified bellow:

$$\boldsymbol{Yield}_{\mathbf{2018}\,\boldsymbol{A}} = 1.135 + 0.041 Organic + 0.156\ Inorganic + 0.413\ Improved\ seeds + 0.322 Pesticide + 0.221\ cropping\ system + 0.068\ Anti\ erosion + 0.256\ irrigation - 0.017\ Drought - 0.184\ Rainfall$$

$$\boldsymbol{Yield}_{\mathbf{2018}\,\boldsymbol{B}} = 1.260 + 0.053 Organic + 0.003\ Inorganic + 0.354\ Improved\ seeds + 0.393 Pesticide + 0.517\ cropping\ system + 0.221\ Anti\ erosion + 0.716\ irrigation - 0.424\ Drought - 0.086\ Rainfall$$

The pure cropping system and appropriate irrigation system showed the significant/highest positive impact on maize yield in 2018 where maize yield expected to increase by 0.517 and 0.716 MT/ha in season B, holding other factors constant. Conversely, the presence of drought, the maize yield is expected to decrease by 0.424 metric tons per hectare holding other factors constant.

All independent variables are statistically significant at 90% confidence level, except organic fertilizers in both seasons and drought in season A which are not significant.

For the year 2017: The sampled farmers in season A constitute one and a half times the number of those in season B and a small p-value (Prob> F=0.000) suggests that determinants of maize yield in season A are jointly significant at all levels of significance.

The use organic and inorganic fertilizers, use of pesticide, improved seeds, cropping system, anti-erosion and irrigation management are positively associated with maize yield. Conversely, drought and heavy or insufficient rainfall show a negative association.

Model is specified bellow:

$$\boldsymbol{Yield_{2017\,A}} = 1.665 + 0.090 Organic + 0.185\ Inorganic + 0.122\ Improved\ seeds + 0.191 Pesticide + 0.076\ cropping\ system + 0.123\ Anti\ erosion + 0.218\ irrigation - 0.176\ Drought - 0.119\ Rainfall$$

$$\boldsymbol{Yield_{2017\,B}} = 0.969 + 0.055 Organic + 0.177\ Inorganic + 0.340\ Improved\ seeds + 0.338 Pesticide + 0.135\ cropping\ system + 0.100\ Anti\ erosion + 0.944\ irrigation - 0.141\ Drought - 0.021\ Rainfall$$

Holding other variables constant, employing organic, inorganic, improved seeds, pesticides, appropriate cropping system, anti-erosion and efficient irrigation management is projected to increase maize yield by 0.090, 0.185, 0.122, 0.191, 0.076, 0.123 and 0.218 metric tons per hectare in season A and 0.055, 0.177, 0.340, 0.338, 0.135, 0.100 and 0.944 metric tons in season respectively. Conversely, the presence of heavy rainfall and drought, the maize yield is expected to decrease by 0.119 and 0.176 metric tons per hectare in season A and by 0.141 and 0.021 metric tons in season B respectively holding other factors constant.

All independent variables are statistically significant at 90% confidence level.

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In this study, the cross-sectional analysis and multiple linear regression model were employed to analyze the impact of agricultural inputs and climate-smart technologies and practices to maize yield in Rwanda by using the Seasonal agriculture surveys data from National Institute of Statistics of Rwanda. This chapter summarizes the empirical findings in the following section: summary, conclusions and recommendations for further research.

5.2 Summary

In line with the study's objectives, tests for both multicollinearity and linearity were conducted. The results indicate the absence of multicollinearity issues between agricultural inputs and climate-smart technologies and practices, as evidenced by Variance Inflation Factor (VIF) values consistently below 10 for all factors. Additionally, the correlation matrix reveals the presence of linearity, with correlation coefficients deviating significantly from zero.

5.2.1 The agricultural characteristics of Maize yield in Rwanda

The findings showed that the maize cultivation exhibits its highest presence in season A when to compared to season B, with the area under maize cultivation in season A is being three times that of season B. The Eastern Province consistently maintained a significant share ranging from 46% to 64% of the total maize cultivation area nationwide. On other hand, Kigali consistently recorded the lowest percentage share of maize cultivation at 2% for both seasons A and B. The total maize production is also positively correlated to the magnitude area under cultivation where the production during season A is approximately three to five times greater than that recorded in season B. Again, the maize production from Eastern Province account 47-59% share of the national total production.

Interestingly, the Northern Province emerges as the top-performing region consistently achieving the highest maize yield and is closely followed by Eastern Province which also demonstrated commendable yield levels. Conversely, Kigali City records the lowest maize yield among five province including Kigali itself.

The five districts that stand out for their exceptional yield are Burera, Gisagara, Nyaruguru, Nyagatare and Ngoma with an average yield ranging from 1.6 to 2.16 MT/ha.

For the use organic fertilizers, the results indicated that the highest percentage observed in Kigali City at 65.8%, followed by Northern Province at 61.5% while southern Province is recorded with the highest percentage of not using organic fertilizers at 45.7% followed by Eastern Province at 47.1%. In other hand, the highest percentage of using inorganic fertilizers observed in Western and Northern Provinces particularly in season A while Kigali City has the lowest percentage of using inorganic fertilizers which is below 40% in both season A and B of specified period.

Some primary reasons for the 48.4% of farmers who cultivated maize crop did not use organic fertilizers are; not having livestock at home, having limited number of livestock that can't provide the required quantity, unavailability of organic fertilizers in the market, lack of financial means to purchase them and insufficient transport facilities to convey organic matter from the livestock's living area to the plots.

The data demonstrated that both improved and traditional seed varieties hold significant prominence in agricultural practices of maize. Specifically in the Northern Province, there is a notable preference for the adoption of improved seeds over traditional counterparts. Conversely, in the Kigali City, traditional seeds exhibit higher prevalence in comparison to improved varieties.

Notably, the preference for traditional seeds tends to be more utilized during season B across the majority of Provinces. This shift in seed preference during this particular season has brought to light a significant concern raised by farmers regarding delays in the supply of modern seed varieties, which subsequently necessitates the reliance on traditional seeds as a viable alternative.

Lastly, only less than 10% of the farmers cultivate with pure cropping systems while 95% in Northern Province’s plots with maize have anti-erosion. The significant percentage optimize the crop calendars particularly in Kigali city, Eastern and Southern Provinces.

5.2.2 To evaluate the impact of agricultural inputs to maize yield

The study had four independent variables of agricultural inputs or factors which are; use of organic fertilizers, use of inorganic fertilizers, use of improved seeds and use of pesticides. The study found the relationship between variables, whereby multiple linear regression model was used, and showed that use of inorganic fertilizers, use of improved seeds and use of pesticides are statistically significant at 10% except organic fertilizers which is not statistically significant in season A&B 2021, B 2020 and A 2018 at 10%.

In 2022, the high impact of employing the aforementioned variables is evident. The utilization of pesticides, improved seeds, and inorganic fertilizers is forecasted to lead to an increase in maize yield. Specifically, it is projected to raise maize yields by 0.482, 0.315, and 0.331 MT/ha during season A 2022, and by 0.232, 0.256, and 0.299 MT/ha during season B 2022, holding other factors constant.

5.2.3 To evaluate the impact of climate-smart technologies and practices to maize yield

The study had three independent variables of climate-smart technologies and practices or factors which are; irrigation, pure cropping system and anti-erosion. The study found the positive relationship between variables, whereby multiple linear regression model was used, and showed that predictors are statistically significant because the p-value is less than 0.1.

In 2022, once again, the substantial influence of employing climate-smart technologies and practices is evident when compared to previous years. Specifically, the application of irrigation systems, anti-erosion mechanisms, and pure cropping systems is anticipated to result in an increase of maize yield by 0.587 MT/ha, 0.286 MT/ha, and 0.445 MT/ha, respectively, during Season A 2022, with all other factors held constant.

5.2.4 To evaluate the impact of environmental factors to maize yield

The study had two independent variables of environmental factors notably drought and rainfall. The study found negative relationship between variables, whereby multiple linear regression model was used, and showed that are statistically significant at 10% except in season B of 2022 and 2017.

The presence of drought and heavy rainfall is projected to lead to a decrease in maize yield by 0.618 and 0.724 MT/ha in Season A 2022, holding other factors constant.

In others words, the positive impact of variables on maize yield is counteracted by those with a negative impact, resulting in a stagnation of maize yield over time.

5.3 The conclusion

This research has provided valuable insights into the significant impact of agricultural inputs and climate-smart technologies and practices in Rwanda. Through a comprehensive analysis of seasonal Agricultural surveys data from National Institute of Statistics of Rwanda, it is evident that the adoption of climate-smart technologies and practices and use of agricultural inputs have the potential to significantly enhance agricultural productivity, resilience and sustainability in Rwanda.

The findings showed that the utilization of organic and inorganic fertilizers, along with the adoption of improved seeds, pesticides, effective irrigation management, anti-erosion measures and appropriate cropping system have demonstrated a substantial positive impact on maize productivity.

Conversely, it was observed that the presence of drought and heavy rainfall exerted detrimental effects on maize yield. Recognizing these critical determinants enables policymakers to formulate significant strategic interventions in optimizing agricultural practices for sustainable and resilient maize production in Rwanda's dynamic agro-climate context.

5.4 Recommendation

The study highlights the pivotal role of specific agricultural inputs and climate-smart technologies in enhancing maize yield in Rwanda, based on the findings, the following are four vital recommendations:

1. Enhancing improved seed availability and timeliness: Agricultural inputs like organic and inorganic fertilizers, as well as improved seeds and pesticides, have demonstrated their positive impact on maize yield in Rwanda. However, the study reveals that many farmers still resort to traditional seeds due to supply delays of modern varieties. Consequently, it is recommended that the government, working through relevant agricultural agencies, ensures the timely availability of improved seeds to encourage their adoption, thereby increasing overall productivity.

2. Investment in Climate-Smart Technologies: Climate-smart technologies and practices, such as effective irrigation, anti-erosion measures, and suitable cropping systems, have a significant influence on maize yield. To harness their potential, it is advisable for the government, in collaboration with partners and stakeholders, to increase investments in these areas. This includes measures to ensure consistent water availability, particularly during irregular rainfall, implementing anti-erosion strategies to counter soil degradation, and optimizing cropping systems to boost maize productivity.

3. Mitigating the Impact of Drought and Heavy Rainfall: Recognizing the detrimental impact of both drought and heavy rainfall on maize production, it becomes crucial to implement necessary measures. These encompass advocating for drought-resistant crop varieties, the adoption of water conservation practices, and the application of improved water management techniques. To address the potential repercussions of excessive rain, it is vital to enact practical solutions like upgraded drainage systems and judicious selection of planting schedules.

4. Capacity Building for Farmers: Strengthening the capacity of farmers in maize cultivation practices is essential for increasing productivity. This includes providing training and resources to equip farmers with the knowledge and skills necessary to optimize their productivity for sustainable improvement of maize yields in Rwanda.

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Annex: Data.

The source of data: NISR, SAS, raw data, https://microdata.statistics.gov.rw/index.php/catalog.

Plot number	Province	yield	Improved seeds	organic fertilizer	inorganic fertilizer	pesticide	anti-erosion	pure cropping system	Irrigation	drought	rainfall	round
0001	Kigali	1071.3	No	Yes	No	No	Yes	No	Yes	No	Yes	SeasonA 2020
0002	Kigali	111.9713	No	Yes	No	No	Yes	No	Yes	No	No	SeasonA 2020
0003	Kigali	1593.181	Yes	No	Yes	No		No	No	No	No	SeasonA 2020
0004	Kigali	2798.223	No	No	No	No	Yes	No	No	No	No	SeasonA 2020
0005	Kigali	260.0163	Yes	Yes	No	No	Yes	No	No	No	No	SeasonA 2020
0006	Kigali	1431.447	No	Yes	No	No	Yes	No	Yes	No	Yes	SeasonA 2020
0007	Kigali	632.2454	No	Yes	No	No		No	Yes	No	No	SeasonA 2020
0008	Kigali	925.7585	Yes	Yes	No	No	Yes	No	No	No	No	SeasonA 2020
0009	Kigali	5273.862	No	Yes	No	Yes	Yes	No	No	No	No	SeasonA 2020
0010	Kigali	808.1742	No	Yes	No	No	Yes	No	No	No	No	SeasonA 2020
0011	Kigali	2079.545	No	Yes	No	Yes	No	No	No	No	No	SeasonA 2020
0012	Kigali	1424.467	Yes	No	No	Yes	Yes	No	Yes	No	No	SeasonA 2020
0013	Kigali	1250.613	Yes	Yes	No	No	No	No	Yes	No	No	SeasonA 2020
0014	Kigali	1742.229	No	No	No	No	Yes	No	No	No	No	SeasonA 2020
0015	Kigali	273.2831	No	Yes	No	No	Yes	No	Yes	No	No	SeasonA 2020
0016	Kigali	756.4833	Yes	Yes	No	No	No	No	Yes	No	Yes	SeasonA 2020
0017	Kigali	741.9005	Yes	Yes	No	No		No	Yes	No	No	SeasonA 2020
0018	Kigali	512.6611	No	No	No	No	Yes	No	No	No	No	SeasonA 2020
0019	Kigali	2622.008	Yes	Yes	No	No	Yes	No	No	No	No	SeasonA 2020
0020	Kigali	1509.535	Yes	Yes	No	No	No	Yes	No	No	No	SeasonA 2020
0021	Kigali	432.1358	No	No	No	No		No	No	No	No	SeasonA 2020
0022	Kigali	297.2096	No	No	No	No	Yes	No	Yes	No	No	SeasonA 2020
0023	Kigali	796.3286	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	SeasonA 2020
0024	Kigali	1081.717	No	Yes	No	Yes		No	Yes	No	No	SeasonA 2020
0025	Kigali	371.2708	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	SeasonA 2020

Plot number	Province	yield	Improved seeds	organic fertilizer	inorganic fertilizer	pesticide	anti-erosion	pure cropping system	Irrigation	drought	rainfall	round
31251	East	2567.837	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	SeasonA 2022
31252	East	690.6313	No	Yes	No	No	Yes	No	Yes			SeasonA 2022
31253	East	2250.155	Yes	Yes	Yes	No	Yes	No	No	No	Yes	SeasonA 2022
31254	East	555.2961	Yes	No	Yes	No	Yes	No	No	Yes	No	SeasonA 2022
31255	East	5528.519	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	SeasonA 2022
31256	East	4215.554	No	Yes	Yes	No	Yes	No	No	No	No	SeasonA 2022
31257	East	529.402	Yes	No	Yes	No		No	Yes	No	Yes	SeasonA 2022
31258	East	1554.122	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	SeasonA 2022
31259	East	5838.23	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	SeasonA 2022
31260	East	3605.623	Yes	Yes	Yes	Yes	Yes	No	No			SeasonA 2022
31261	East	772.0958	Yes	No	No	No	Yes	No	Yes			SeasonA 2022
31262	East	1107.111	No	Yes	No	No	Yes	No	No			SeasonA 2022
31263	East	2806.347	Yes	No	Yes	Yes	No	No		No	No	SeasonA 2022
31264	East	485.5734	No	Yes	No	No	Yes	No	Yes	No	Yes	SeasonA 2022
31265	East	454.5776	Yes	No	No	No	Yes	No	Yes	No	No	SeasonA 2022
31266	East	2546.97	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	SeasonA 2022
31267	East	1380.053	Yes	Yes	Yes	No	Yes	No	Yes			SeasonA 2022
31268	East	386.9688	Yes	Yes	No	No	Yes	No	No	No	Yes	SeasonA 2022
34847	East	0	No	No	No	No	No	No	No	No	Yes	SeasonB 2022
34848	East	233.0272	Yes	No	No	No	Yes	No	Yes	No	Yes	SeasonB 2022
34849	East	2308.553	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	SeasonB 2022
34850	East	2414.296	No	No	No	No	Yes	No	No	No	No	SeasonB 2022
34851	East	0	No	No	No	No	Yes	No	Yes	No	Yes	SeasonB 2022
34852	East	0	No	No	No	No	Yes	No	Yes	No	Yes	SeasonB 2022
34853	East	1711.033	Yes	No	Yes	No	Yes	Yes	Yes			SeasonB 2022
34854	East	276.4684	No	Yes	No	No	No	No	Yes	No	No	SeasonB 2022