THE ROLE OF CLIMATE VARIABILITY ON MAIZE PRODUCTION. EVIDENCE FROM KENYA

BY

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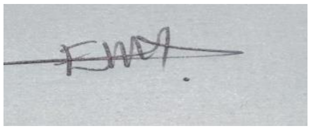
DECLARATION

This research paper is my original work and has not been presented for a degree award in any other university.



05/12/2023

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Emily Gacheri Date

This research paper has been submitted with my approval as University supervisor.

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Dr. Peter Muriu Date

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This work is a product of a plenary discussion with friends at the University of Nairobi that attended the African Climate Summit, 2023. After mulling over delegates deliberations, it was apparent that food insecurity remains a pressing issue across the region. That is why when Professor Muriu was willing to guide and supervise me in this scholarly journey, I was immensely thrilled, knowing I am contributing to solving one of the pressing problems that humanity has had to contend with.

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DEDICATION

To Judah Karemu M'Araja and Agnes Nduru, the best parents any daughter could be proud of.

ABSTRACT

The harsh climate effects continue to adversely affect Kenya's agricultural sector. Motivated by this development, this study examined the role of climate variability on maize production in the country. Secondary time series data spanning 43 years from 1980-2022 obtained from the Kenya National Bureau of Statistics for maize output, maize output prices and the Gross Domestic Per capita variates and the from the World Bank Climate Change Knowledge Portal for climatic variates of rainfall and mean temperature was run on a Nerlovian partial adjustment model. This model takes stock of the slow adjustment process. OLS regression show that rainfall and maize out price have a significant effect on maize yield. Temperature and GDP per capita income had no significant influence on maize yield. This study recommends climate sensitive measures for mitigating and adopting climate change effects be put into place for motivating farmers to increase their production. Using the, which accommodates the,

ACRONYMS AND ABBREVIATIONS

ADF	Augmented Dickey-Fuller test
FAO	Food Agriculture Organization
FAW	Fall Army Worm
IPCC	Intergovernmental Panel on Climate Change
KFSSG	Kenya Food Security Steering Group
KNBS	Kenya National Bureau of Statistics
OLS	Ordinary Least square test
RCM	Regional Climate Models
UNDESA	United Nations Department of Economic and Social Affairs

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CHAPTER ONE: INTRODUCTION

1.1 Background

The world has continued to experience multiplicity of unprecedented global events. Prevalence of these adverse events mainly in maize-crop agriculture has been associated with climate change (Bwambale & Mourad, 2021; Msowoya et al., 2016). In Kenya, like much of the developing world – mainly in Africa, maize yield has been on the decline. This has been attributed to countries' overreliance on rainfed agriculture.

The Kenya National Bureau of Statistics (KNBS) Economic Survey (2020) indicates that 98 per cent of the country's agricultural activities are rainfed. This is because farmers for far too long believed predictability of seasons; considering majority of them are small scale farmers, they cannot afford astronomical cost of mechanizing farms through irrigation (Msowoya et al., 2016).

As weather uncertainty looms, agricultural activities directly and indirectly continue to suffer quite disproportionately, a development that is complicated by reduction in maize yield, which is a staple food. Some studies suggest the crop is rich in B vitamins, folic acid and Vitamin C. It is also rich in vitamin phosphorus, magnesium, manganese, zinc, copper, iron and selenium, potassium and calcium. It is because of this rich nutritional value that maize is the country's mainstay crop. Its reliance as a crop that can fight hunger is being tested by extreme weather events – drought and floods.

Maize has been given more attention in Kenya as staple food for reasons that range from a combination of historical, cultural, economic and agronomic factors. The crop is suited to diversity of agro-climatic zones in Kenya making it flexible crop that can be cultivated throughout the country. The crop has deep cultural roots in Kenya and can be consumed in different forms such as ugali thus it's widespread consumed. Maize crop is cost friendly compared to other cereals making it more accessible food source for the majority of the population. The crop has multiple ways that it can be used such production of animal feed, production of industrial products and cooking oil. There is high demand for the crop both locally and internationally which creates incentives to the farmers to prioritize the crop over other crops.

Inadequate irrigation schemes dedicated for the large-scale production while for the small-scale farmers production accounts to 78% of the total food intake (Mutiso & Kimtai, 2022). These shifts are caused by three forces, as much as broadly speaking, they are either internally triggered by human or natural processes through events such volcanic activity, seabed movement, the orbital shifts, solar fluctuations and internal variability. But since the 1800s, climate change was majorly contributed by human activities through combustion of fossil fuels. Through these changes the normal operations of the people have been affected.

The earths landscape temperature for the first two decades in 21st century recorded a 0.99°C higher than the one observed in 1850-1900. The projected total human induced landscape temperature is from 1850-1900 to 2010-2019 is from 0.8% to 1.3% which so far is the best estimate of 1.07% degrees Celsius (IPCC IR6 SYR, 2023). The adverse effects of climate change are noted in the social, economic and human welfare across the world since the countries depend on each other through trade and capital flows, (IPCC 2023).

Combating climate change is a measure which is necessary to ensure that its adverse effects are mitigated. Climate change is an externality that is affecting the globe therefore teamwork is necessary to ensure sustained safe environment for the human beings. The United Nations climate change conference for 2022 held in Egypt (cop 27) is one of the steps which has been taken for combating the negative effect of climate change. Recently Africa climate change summit held in Kenya at KICC and a national holiday which was dedicated towards national tree planting by the citizens are some of that have been recently taken place in an effort to reduce the climate change impact together with preventing where possible.

Kenya as a country is largely exposed to climate-related challenges and therefore quantifying the effects is important in making informed decision and effective adaptation decisions. Quantifying the effects of climate change adaptability in Kenya involves a multidisciplinary approach, combining scientific research, local knowledge, and policy analysis. This information can inform evidence-based decision-making and support the development of robust adaptation strategies that address the specific challenges faced by the country. These strategies include but are not limited to diversification of crops, improved water management such the construction of water dams, use of climate resilient variety of maize, and early warnings for planting and harvesting times for the farmers. These measures will help the country manage the challenges that come with climate change.

Maize is a cereal that is highly valued in Kenya. Unfavorable weather events of unpredictable precipitation and increase in the temperature are the key causes of the declining maize yield. The country consequently has been faced by food insecurity since maize crop is the staple food. The 2021 report from the KFSSG imply that decline in the maize yield led to extreme levels of hunger where 3.1 million of Kenyans in marginal areas and pastoral are mostly affected. Climate change also has created an enabling environment for pest breeding such as army worm which affected maize yield in 2017 as it was reported by Fall Army Worm (FAW). In 2022, a maize yield decline of 34.3 million from 36.7 million bags in 2021 was noted. This drop was mainly contributed by unconducive weather conditions, (Natalie 2023).

Maize (Zea Mays L) productivity is the quantitative measure of maize yield in a given measured area of yield. Maize productivity is key to food security, economic growth and international trade stability (P. Kitiem el. 2022). Figure 1 illustrates the decline of maize yield from the tear 2015 to 2022. This shows that the unreliable weather patterns have had negative effect in the maize production in the country.

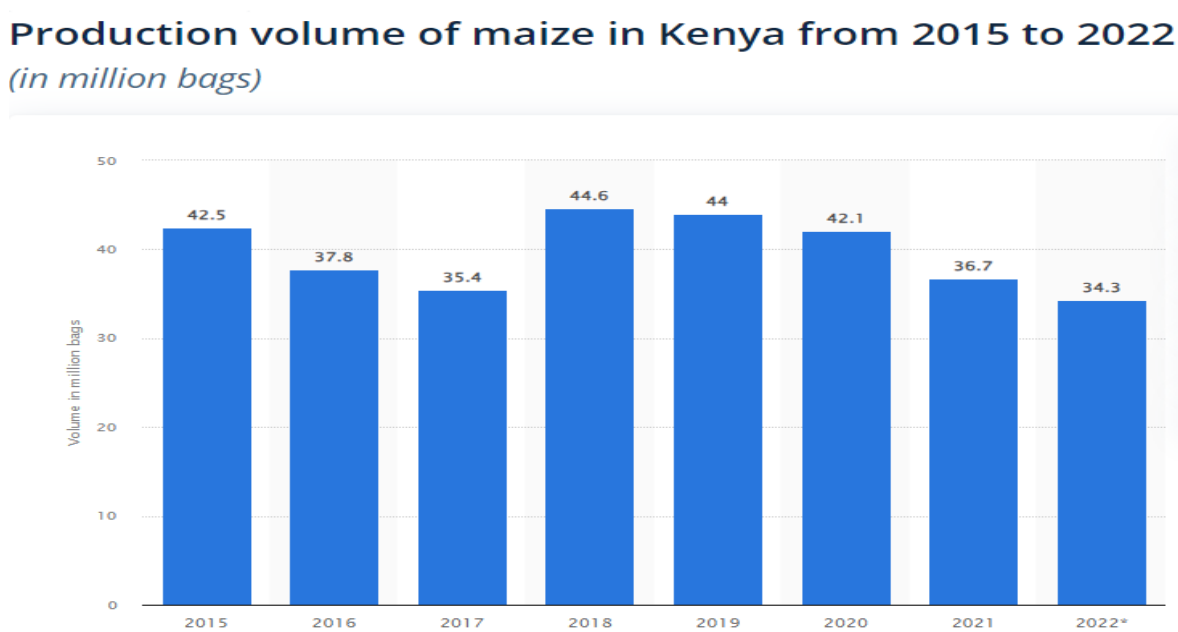

Figure 1: Trends in maize yields – 2015 to 2022

1.2 Climate Change and Maize Production

Climate change has led to rising sea level, rising temperatures and abnormalities in the rainfall have become prevalent. The normal planting, harvesting and land preparation seasonal patterns guiding the farmers have been altered by the climate changes. Some regions are experiencing short or no rain at all while others are facing floods which affects their crops and livestock. The North Eastern part of the country during rainy seasons have been experiencing floods while the key areas where maize crop is mainly grown have experienced less or no rainfall. The arid and semi-arid areas experience low rainfall i.e., from less than 250mm on average while the high lands rainfall of more than 2000mm has been noted. The vast amount of land in Kenyan territory has a small share that is used for agricultural activities i.e., Out of the 580,367 square kilometers land size only 12 % is suitable for farming and 6 % for animal husbandry, Government of Kenya (2016).

The country has in the recent devised measures such as increased campaigns on tree planting, banning of tree cutting which is not monitored and the use of clean energy. These measures have proven to be effective though they require more time for their fruits realized. Some have led to restructuring of the institutions such has the Kenya Forest service to ensure better forest coverage of the country.

This study focuses on the supply response on maize in Kenya whose consumption in the recent past has been exceeding its production due to factors majorly contributed by the effects of climate change. Kenya's burgeoning population requires a stable agricultural productive sector specifically maize productivity since it's the staple food. The rise in population complicates food security amid climate change.

1.3 Statement of Problem

Climate change has posed a serious problem to the economic growth of Kenya majorly due to the effect it has on the agricultural sector. Agriculture indirectly contributes about 30 % of Kenyan's GDP. As an agricultural product, maize has faced negative effect in its production due to the climate change. The country is also forced to increase its import of the maize which is the main staple food for the majority of Kenyans. According to Nyoro et al., 2007, the supply of maize informs the country's food security level. The government has continuously planned and implemented policies such as input subsidy, infrastructure development, institutional changes, agricultural innovation and management practices that are aimed at increasing the maize output. These measures all have been focused on curving the adverse effect that the climate change has had on the output of maize.

Whereas previous studies have associated climate change and agriculture, they have mainly addressed the demand side and ignored the supply side. This study focuses on the supply of the maize rather than the demand, where the cost of producing maize is given full focus. Mati (2002) and Karanja (2006) conducted a study focusing on two ecological zones but this study focuses on all the ecological zones in Kenya in different time periods. This study is based in the time series data so as to show how climate change has gradually but significantly impacted the supply of maize in the country.

1.4 Study Objectives

This study is focused at determining the role of climate change on maize supply response of farmers in Kenya. The specific objective is to:

a. Examine the supply response of maize production due to changes in climate.

1.5 Research Questions

The main research question is to explore:

a. What impacts does climate change have on maize supply?

1.6 Significance of the Study

In Kenya, majority of studies have been based on low agricultural productivity by focusing on the causative factors such as low soil fertility. For example, Kenya and other countries within Sub-Sahan Africa have experienced declining soil fertility leading to more research being centered on it. By the same token, association of climate parameters and maize is an important aspect that remains overly negated within literature.

Maize supply decline in the recent past has posed a serious problem to the Kenyans since it is the main staple food. Majority of previous studies were based on the general crops. For example, Justus et al., 2016 studied the effect of climate change on tea, general crops and maize. However, this study investigates how supply of maize is affected by climate change. The study uses the most recent data, giving evidence-based insights. Certainly, the study can influence policy today especially when the rainfall and temperature trends have taken general upward trajectories.

CHAPTER TWO: LITERATURE REVIEW

2.1 Theoretical Literature

Climate is a broad topic which is common to all human beings on planet Earth. A climate system refers to the complex interplay of various components and processes in the Earth's atmosphere, oceans, land surface, and ice cover, working together to determine the prevailing weather patterns and long-term climatic conditions of a region (IPCC, 2007a). The climate system is dynamic and influenced by a range of factors, both natural and human-induced. The transfer and transformation of energy in the atmosphere is a result of the global climate components. The global climate has been stable from the beginning mainly because the balance between energy received and the one lost. The World Meteorological Organization 2012 confirmed that sunlight rays hitting the surface of the earth were on an average of 1370 watts per square meter.

Sunlight rays radiate energy, of which one-third of the radiated energy is reflected back to the atmosphere after hitting the landscape and two-third of the energy is absorbed by the surface (IPCC, 2007a). Part of the emission of the Earth reaches the cosmos, and the other part of it is cast back to the landscape by the atmosphere, resulting to a global average of around 14°C, well above -19 ° C. This temperature is palpable, so that it is noticeable even without the natural greenhouse effect. This is called the greenhouse effect, which enables the existence and survival of living things on the surface of the Earth. Weather describes short-term atmospheric conditions, while climate is the long-term average of these conditions over a more extended period. Weather is what we experience day to day, whereas climate represents the more enduring patterns for a period of more than 30 years that shape our environment. The changes in weather are noticeable on a daily basis, which is contrary to the climatic changes. (IPCC, 2007).

Theories on climate change effects on maize productivity or supply focus on theories such as theories on market theories and development theories to improve the understandability of the study. Theories documented from the Washington Consensus of the early 1990s on growth and development advocated laissez-faire where in the market, the forces of demand and supply should be left alone to operate. Growth experts have put forward an emphasis through theories for the need to integrate climate change into growth models. This will aid in stabilising the macroeconomic, fostering innovation and inventiveness, and improve on the world economy and political stability (Brown, Cochrane and Frankhauser 2012).

Robert Solow and Trevor Swan (1956) came up with an economic theory on Neoclassical growth theory that aids in stabilising the economic growth rate while combining labour, capital, and technology. The exogenous population increases initially was used in the model to set the growth rate, but Robert Solow (1957) integrated technology change in determining economic growth rate in the model. Capital continuously endowed within an economy, combined with efficient use of the capital by the labour, stimulates economic growth which is evidenced by the increased output supply in the market. Marginal productivity of labor is enhanced by incorporation of advanced technology. The model takes into consideration endogenous factors; labour, capital, and technology. However, the model that it analyses did not factor in the effects of climate variability on productivity.

The neoclassical growth models that factored effects of climate variability on productivity in which growth is a function of investment, savings, and capital accumulation were those studied in Ramsey, Cass, and Koopmans model (Akram, 2012). Change in the size of some the country's GDP has been due to the effect of climate variability due to difference in productivity of some the sectors (Akram, 2012). The outcome of this increase negatively impacts on economic development since it will impact on population health, water safety and agricultural output. It is forecasted that there will be a decline of 5% of world GDP per annum due to these impacts.

Extremely high temperatures lead to the loss of crops yield, Mendelsohn and Dinar (1999). Food systems will be altered by climate change in numerous ways with changing levels of rainfall and temperature. Rainfall changes leads to drought of floods while change in temperature leads to prolonged growing seasons of crops. The result of these climate-induced changes will lead to changes in food prices and the entire supply chain of crop yields. Maize yield and supply have a direct relationship with moderate amount of rainfall but for the temperature the relationship is indirect, i.e. the higher the temperatures, the lower the productivity (Godwin p. 2021).

Kenya population has been on the rise putting pressure on the demand for maize which is a staple crop. The country needs to come up with strategies that will cater for the increasing demand through implementing policies in the agricultural sector that will ensure a sustainable growth and development. The country is endowed with resources that will help to achieve this goal.

Farmers response to price changes will inform the outcome of deregulation on the growth of agriculture, Rao (2003). Farmers' flexibility in accepting price changes determines the outcome of the effect of price changes on the amount of maize supplied. However, this changes with time, where in the long run other factors influence the farmers decision. A positive response from farmers to price will lead to increased production in an instance where prices are expected to increase. This evidence has no documented evidence support its argument. The study key objective is to analyse the effect of climate variability on the supply of maize. The study incorporates the consequences of non-price incentives i.e rainfall and temperature which influences the agricultural production.

2.2 Empirical Literature

Joash and Khaldoon (2021) conducted a study in Uganda on the impact of climate change on maize production in the Victoria Nile subbasin. According to them, the rainfed form of farming informed the minimal levels of agricultural productivity. The production of the presence per hectare is expected to reduce in the presence of climate change. The study was based on the Victoria Nile Sub-basin and utilized the Aqua Crop model. The results postulate that the decline in the decline in maize yield will range from 1 to 10% in the short term, 2 to 42% in the medium term and 1 to 39% in the long term depending on the agroclimatic zone. Food security will be adversely affected when productivity levels continue to trend downward.

The maize crop is the staple food for the country, and thus the decline in its productivity worsens the food security of the country. The efforts made to improve soil fertility do not help to improve maize production levels in the presence of climate change. The recommendations made were that farmers combine good irrigation practice with planting dates that would result in more crop productivity. This measure will lead to security in food at large result to socio-economic development. The study findings indicate that adaption measures combined with mitigation measures are necessary for the country to reduce decline in maize yield. This study confirms that climate change has a negative impact in the crop productivity.

Feleke, Savage, Fantaye, and Rettie (2022) conducted a study on role of Crop Management Practices and Adaptation Options on maize to reduce climate variability impacts in Ethiopia. The study recommended for change of planting periods, increased use of nitrogen fertilizer and a choice of maize cultivar. They used sites with different agro-climatic conditions. This included Ambo, Bako, and Melkassa. The projected average monthly maximum air temperature in the 2030s from the study results could increase in these places. The maize yield would decline in Ambo and Melkassa but increase in Bako in 2030 if existing maize cultivars management practice didn't change with climate varying. Higher altitudes were advised to plant early to improve productivity. The study recommended for the farmers should combine early planting and increased fertilizer usage so as to achieve improved crop productivity.

Erica and David conducted a study in Malawi on the projections of climate variability effects on maize yield. The maize crop in Malawi is crucial as it accounts for 14% of the calorie consumption of maize, it is a major contributor of local income and contributes significantly to the country's GDP. The study projected temperature rice but precipitation conditions were uncertain. The study majored on effect of warming and three rainfall incidents on maize planted on three separate dates warm season. The study recommended early planting to help increase maize crop productivity.

2.3 Overview of the Literature

Theories of climate change shows that climate change has affected several areas of the world. These effects have directly affected crop productivity, leading to severe problems of food security. These effects have led farmers to face droughts, shorter rains or floods, and extreme temperatures that negatively impact the crop growth process. Erica and David in 2020 recommended planting to help increase maize crop productivity. Feleke, et al (2022) study recommended for the farmers should combine early planting and increased fertilizer usage so as to achieve improved crop productivity. The study by Joash and Khaldoon (2021) recommended that farmers combine good irrigation practice with planting target dates that would result in greater crop productivity.

The results of the recommendations made are early planting time depending on the agroclimatic region combined with increased fertiliser input use that has increased productivity. The theories focus was based on food security, economic growth,, and GDP increase,, but the response to the response to maize yield supply by farmers due to both economic and noneconomic factors was not factored, and that is what this study is based on.

CHAPTER THREE: METHODOLOGY

3.1 Theoretical Framework

The model developed by Dell, Jones and Olken (2008) in which they integrated the climatic variables in the production function of their model is what this study used. In this model climate change was factored in the growth equations and the step by step illustration for analyzing the impacts of climate change on economic growth. Consider the production function:

$$Yit = e\alpha Tit\ Ait\ Lit\ Kit \quad (1)$$

$$\Delta\ Ait\ /Ait = gi + \beta Tit \quad (2)$$

Where:

Y is Maize Yield (dependent variable)

L is labour force (independent)

A is technology (representing labour productivity)

T are the impacts of climate

g is GDP growth rate and

K is human capital.

The model explains the effects climate change has on productivity, which are both direct and indirect. The direct effects of climate change such as labour productivity are illustrated in Equation 1. The indirect effect of climate change is seen on its impact on variables that inform the GDP such as the decrease in consumption levels. The equation 3 below is as a result of log linearizing equation 1 and taking difference with respect to time.

$$git = gi + (\alpha + \beta)\ Tit - \alpha Tit\text{-}1 \quad (3)$$

Where:

git = the growth rate of output,

α = direct effects of climate change on economic growth

β= indirect effects

gi= fixed effects.

Equation 3 explains both the direct and indirect effects of climate change on economic growth. These effects at the beginning affect GDP but when climate change reverses to its initial state the direct effects return to their initial state. This is witnessed where extreme temperatures affect crop growth, but when they reverse, the crop growth is restored. The indirect effects on the contrary persist even in normal conditions after climate change disturbance. For example, restoration of human health after deterioration might be permanent.

3.2 Model specification

In this section, the model adopted by the study in analysing the response of farmers' supply to changes in the variable' GDP per capita, rainfall, temperature and output prices is presented. This study uses the Nerlovian model to analyze the variables. The empirical model that the study adopted is as follows:

$$Y_t = \beta_0 + \beta_1 P_{t-1} + \beta_2 AR_{t-1} + \beta_3 AT_{t-1} + \beta_4 (GDP\ per\ capita\ income_{t-1} + \beta_5 Y_{t-1} + \epsilon_t$$

(1)

Where:

Yt is the maize yield in the current period

$P_{t-1}, AR_{t-1}, AT_{t-1}\ and\ GDP - Per\ capita\ income_{t-1}$ are the lagged values of maize output price, annual rainfall, average temperature and GDP per capita income, respectively.

Y_{t-1} is the lagged value of maize yield from the previous period.

β_0 is the intercept.

$\beta_1, \beta_2\ , \beta_3, \beta_4\ and\ \beta_5$ are the coefficients representing the impact of lagged values on maize yield.

ϵ_t is the error term.

This model is useful since it allows the examination of whether the values of maize output prices, GDP per capita income, annual rainfall and average temperature in the previous time period have an impact on the current maize yield. The lagged terms Pt-1, Art-1, ATt-1 and GDP per capita income (t-1) capture the delayed effects of these variables.

The inclusion of lagged effects adds a temporal dimension to the model, to capture potential time-dependent relationships between maize yield and independent variables. The coefficients $\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$ and $\beta 5$ indicate the partial adjustment coefficients, representing the speed at which maize yield adjusts to changes in the lagged effects of rainfall temperature, maize output prices and GDP per capita. The coefficients will therefore be interpreted with lagged effects in mind.

3.3 Definition and Measurement of Variables

3.3.1 Maize Yield

Maize yield is defined as the amount of maize harvested per unit of cultivated land, usually expressed in bushels or metric tons per acre or hectare. It is a measure of the productivity and efficiency of maize cultivation in a given area during a specific growing season. Maize yield is associated with a specific growing season or time period. Annual yield data provide insights into yearly variations in productivity and are essential for assessing the impact of factors such as climate, technology, and agricultural practice.

In this study maize yield data focused on maize yield measured in kilograms per hectare depending on regional conventions. Maize yield amount depends on rainfall and temperature levels. Maize being a warm temperature growing crop, it is affected by extreme temperatures (either too hot or too cold) negatively. Warm temperatures improve the productivity levels of maize crop. Maize is grown mostly in regions having annual rainfall between 50−100cm.

3.3.2 Temperature

The temperature variable typically refers to the measure of atmospheric temperature, which is a key climatic factor influencing various natural processes, including agricultural activities. It is defined as the degree or intensity of heat present in the atmosphere, usually measured in degrees Celsius (°C) or Fahrenheit (°F). In the context of agriculture, temperature is a crucial climatic variable that affects crop growth, development, and various physiological processes. Temperature is commonly measured in degrees Celsius (°C) or Fahrenheit (°F). Both scales provide a numerical representation of the intensity of heat.

Temperature variations is critical for maize planting planning, as it directly influences plant growth, crop phenology, and various developmental stages. Farmers, researchers, and policymakers use temperature data to make informed decisions about planting times, crop selection, and managing agricultural risks related to temperature extremes. The sign will be based on change of temperature therefore it will be a negative sign. According to Mounir (2014), temperature influences largely crop growth and productivity. Low or high extreme temperature affects crop productivity negatively leading to low yield. Maize is a warm season crop and thus its growth is highly sensitive to the temperature. Optimal temperature ranges are essential during maize growth seasons in order to achieve maximum yields.

3.3.3 Maize Output prices

The maize output price variable represents the price at which maize is sold in the market. It is an essential component in agricultural economics and is used to measure the monetary value of maize production. It is defined as the price at which maize is sold per kilogram, typically measured in this study in Kenyan shilling per kilogram. It reflects the market value of maize produced by farmers.

The maize output price and maize yield amount have a positive relationship as stated by the law of supply i.e., the higher the prices the more the maize is produced and thus the higher the output. Maize output prices is crucial for farmers, policymakers, and other stakeholders in the agricultural supply chain. It helps in assessing the economic viability of maize production, making informed planting decisions, and formulating agricultural policies. The sign for maize output price is expected to be positive. Changes in crop prices can significantly impact farmer's production decisions (Assouto et al. 2019). Farmers will allocate more resources for maize cultivation when the output prices are higher leading to increased yield.

3.3.4 Rainfall

Rainfall is the amount of precipitation, typically in the form of rain, that falls within a specific area and time period. Rainfall is a critical climatic variable affecting agriculture, ecosystems, and water resources. Rainfall is commonly measured in terms of the depth of water accumulated over a specific area. This measurement is expressed in millimeters (mm) or inches. An increase in rainfall is associated with increased maize yield therefore it is expected to have a positive sign. Rainfall plays a key role in the optimal growth of maize crop. Areas where irrigation is not prevalent rainfall can significantly affect maize yields. Varying climatic indicators such as precipitation and temperature, impact negatively on agricultural productivity (Mounir 2014).

3.3.5 GDP per capita

GDP per capita explains economic output per person in the country and it is obtained by dividing the total value of services and goods generated in a country by its population. This metric, details a per person mean measure of economic contribution, giving insight into the standard of living and prosperity of the residents of a particular country. GDP per capita is calculated using the formula below:

$$\text{GDP per capita} = \frac{Gross\ Domestic\ Product}{Population} \qquad (2)$$

Higher GDP per capita might imply better resource allocation and investment in the agricultural sector, (Culas 2006). This could lead to improved farming practices, access to technology, and the adoption of more efficient agricultural techniques. GDP per capita reflects the average income of individuals in a country. Higher income levels may positively correlate with increased purchasing power, potentially enabling farmers to invest in better seeds, fertilizers, and equipment, which can impact maize yield.

Table 1. Model Variables Summary

Variable	Notation	Definition	Expected Sign	Data source
Maize Yield	y	The amount of maize harvested per hectare, expressed in hectare	Dependent	KNBS
Rainfall	AR	The amount of precipitation, typically in the form of rain, that falls within a specific area and time	Positive	WB climate change

		period.		Portal
Temperature	AT	The degree or intensity of heat present in the atmosphere, usually measured in degrees Celsius (°C) or Fahrenheit (°F).	Negative	WB climate change Portal
Maize output price	P	The price at which maize is sold per kilogram, typically measured in this study in Kenyan shilling per kilogram.		KNBS
GDP per capita income	(GDP per capita income)	GDP per capita explains economic output per person in the country	Positive	KNBS

3.4 Econometric approach

Analysing how changes in economic and noneconomic factors impact the quantity of maize supplied by producers is achieved through econometric estimation of the maize supply response. The log transformation stabilizes the variance of the data series (Lutkepohl and Xu, 2009). This study used the OLS regression method to estimate the coefficients (β0, β1, β2, β3, β4) in the empirical model of the study in equation (5).

For estimating a Nerlovian model using time series data with lagged effects, where maize yield is the dependent variable and rainfall and temperature are the independent variables, OLS regression method will be adopted. Pre and post-estimation tests are important to assess the validity, reliability, and robustness of Nerlovian model with lagged effects for maize yield.

3.5. Diagnostic tests

3.5.1. Normality test

Normality tests assess whether the errors from a regression model, in this case, time series data, follow a normal distribution. It's important to ensure that the normality assumption holds for valid inference based on statistical tests. The Shapiro-Wilk test was used to test for normality. The Shapiro-Wilk test checks whether a sample originates from a normally distributed population.

3.5.2. Stationarity Test

A stationary time series is one whose statistical properties do not change over time. In the context of OLS estimation, the stationarity of the variables is crucial for reliable parameter estimates. In an instance where time series data exhibits non-stationarity, it can lead to spurious regression results. The Augmented Dickey-Fuller (ADF) test will be used for testing for stationarity.

A time series dataset is said to be stationary if:

$$\in (x_t) = constant \forall t \epsilon X \quad (3)$$

$$Var(x_t) = constant \forall t \epsilon X \quad (4)$$

$$Cov(x_t, X_{t+j}) = constant \forall t \epsilon X \neq 0 \quad (5)$$

A time series (dataset) is non-stationary if it processes the above properties. Non stationary data is transformed to stationary through differencing method (Thomas, 1997).

3.5.3.Autocorrelation test

Autocorrelation occurs when the residuals from a regression model are correlated over time. This can violate the independence assumption of Ordinary Least Squares (OLS) regression. To test for autocorrelation, the Durbin-Watson test was used. The Durbin-Watson statistic ranges from 0 to 4, with values near 2 indicating no autocorrelation, values significantly less than 2 suggesting positive autocorrelation, and values significantly greater than 2 suggesting negative autocorrelation.

3.5.4.Heteroscedasticity Test

Heteroscedasticity it’s an econometric problem noted when the residuals in regression model aren’t constant in all levels of independent variable(s). If heteroskedasticity is present, it can affect the efficiency of parameter estimates and lead to biased standard errors.

The test used for checking heteroskedasticity is the White test which involves regressing the squared residuals on the independent variables and additional lagged squared residuals. The test statistic is then used to assess the presence of heteroskedasticity.

3.5.5.Data Type and Sources

Secondary time series dataset for the period 1980 to 2022 for was utilized in this study. The WB climate change portal where meteorological datasets for temperature and rainfall were assembled, computations were made to come up with changes in temperature. The data sets on GDP per capita too will be obtained from the WB portal. The Maize yield and maize output prices datasets are obtained from the Kenya National Bureau of statistics (KNBS). This is obtained from the reports that are annually published. The KNBS has an elaborate structure for collecting data that on maize yield and maize output prices that are used for analyzes.

CHAPTER FOUR: FINDINGS

4.1 Descriptive Statistics

Economic data, like any other type of data, possesses certain properties that characterize its nature and behavior. The summary statistics data show that data was obtained from a dataset of a sample size of 43 years ranging from 1980 to 2022. The data was transformed into log form. The 7.55 maize yield standard deviation values in the dataset indicate that on average, data deviates on average approximately 7.55 units from the mean value. A higher standard deviation suggests a greater spread of maize yield values around the mean. The mean which is 29.87 is the central measure of the dataset. The mean of 29.87 and median of 28 for maize yield imply that the data is approximately symmetrical.

The range which provides the spread of data is calculated mathematically as follows:

$$\text{Range} = \text{Max} - \text{Min}$$

The range is a straightforward measure of variability and is sensitive to outliers or extreme values. While it provides a quick sense of the spread in the data, it doesn't capture the entire distribution and can be influenced by extreme values. For a more robust understanding of variability, additional measures such as the interquartile range or standard deviation may be considered.

Table 2. Summary statistics

Statistic.	Maize Yield (In tons)	GDP per capita income	Price of Maize Yield (per kg)	Mean Temperature (In degree Celsius)	Rainfall (In mm)
N	43	43	43	43	43
Standard Deviation	7.55	71540.96	19.07	0.83	148.84
Mean	29.87	64747.25	21.28	23.6	775.77
Median	28	31585.68	15.2	23.24	752.92

Min	15.8	3330.43	1.78	22.58	517.64
Max	44.6	247435.91	67.72	25.27	1210.33
Skewness	0.27	1.15	0.79	0.74	0.71
Kurtosis	2.26	3.03	2.4	2.06	3.42

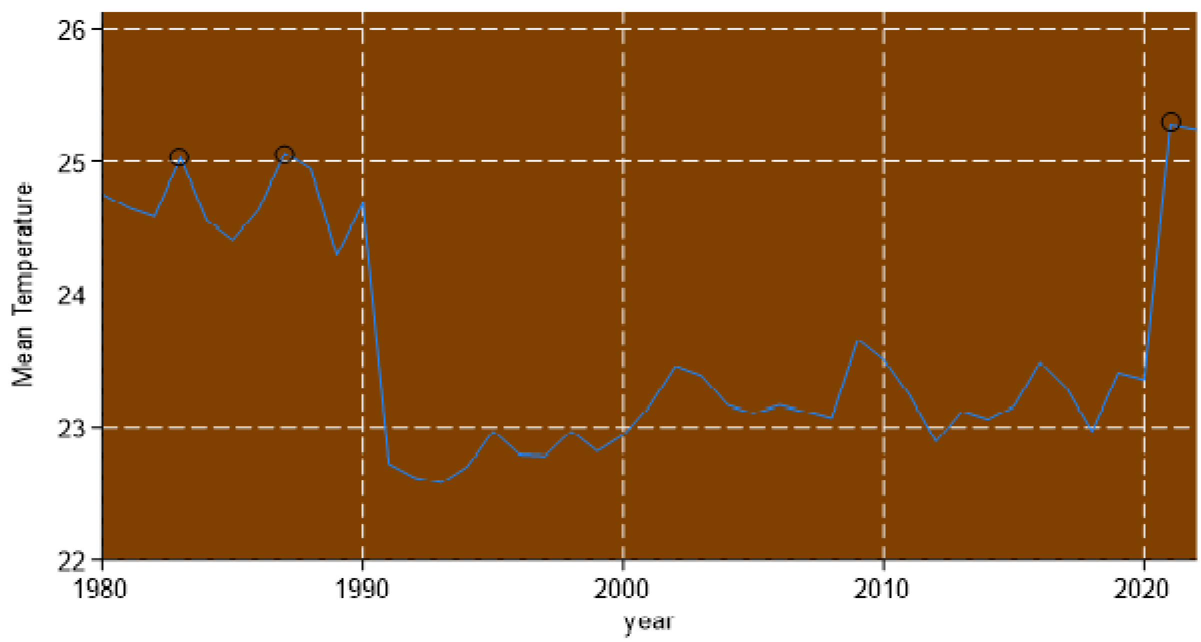

Figure 2: Trends in mean temperature

It is revealed that years where temperature has a sharp fluctuation such 1983, 1995/6, 1998, 2006/7 and 2019 are followed by an almost equal fluctuation in the rainfall. Synchronized fluctuations in temperature and rainfall may contribute to the occurrence of extreme weather events, such as heavy rainfall followed by high temperatures. This can lead to floods, landslides, and other weather-related disasters. The increase in temperature noted especially in between 2018 to 2022 is an implication that the greenhouse gases have been on the rise. The precipitation level also is seen to peak at this period. This follows the IPCC (2007) conclusion that climate change will lead to increased temperature and changing trends in rainfall.

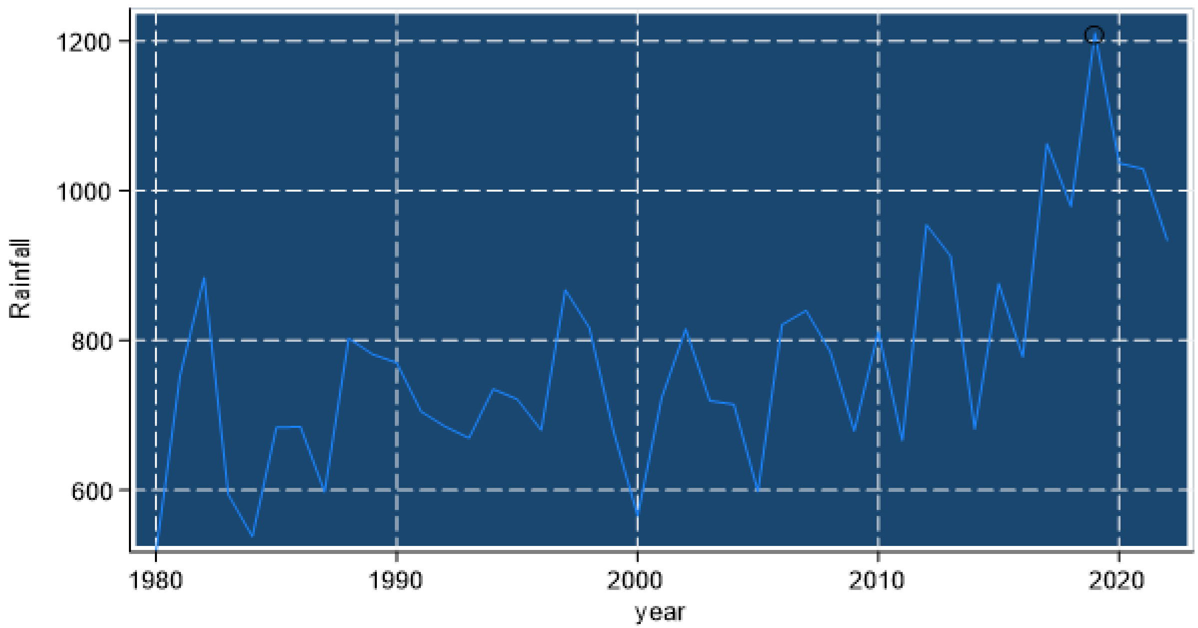

Figure 3: Trends in rainfall

4.2 Correlation Analysis

Correlations provide information about the strength and direction of linear relationships between variables, but they do not imply causation.

Table 4.3. is a correlation matrix for the variables Maize yield, GDP per capita, Maize output Price, Temperature, and Rainfall. Each cell in the matrix represents the correlation coefficient or covariance between two variables.

The maize yield: diagonal elements (top left to bottom right) are 1 because a variable is perfectly correlated with itself. Maize yield and GDP per capita income have a small negative correlation (-0.112). Maize yield and maize output price have a moderate negative correlation (-0.436). Yield and Temperature have a small negative correlation (-0.062). Maize yield and rainfall have a moderate negative correlation (-0.398). The small and moderate negative correlation shows that the variable is almost independent from the other. Therefore, the variables will have little or no problem of multicollinearity in the analysis.

GDP per capita income: GDP per capita income and maize yield have a small negative correlation (-0.112). The correlation between GDP per capita and Price is positive (0.432). The correlations between GDP per capita and Temperature, as well as GDP per capita and rainfall, are close to zero (-0.009 and -0.030, respectively). The GDP per capita income variable is almost independent to maize yield and price. There is independency of GDP per capita to temperature and rainfall. Therefore, GDP per capita has negligible or no multicollinearity problem with other variables.

Maize output price: maize output Price and Maize yield have a moderate negative correlation (-0.436). Maize yield price and GDP per capita have a positive correlation (0.432). The correlations between maize output price and Temperature, as well as maize output price and rainfall, are positive but relatively small (0.011 and 0.278, respectively). The maize output price, has negligible or no multicollinearity problem with other variables.

Temperature: Temperature and maize yield have a small negative correlation (-0.062). The correlations between Temperature and GDP per capita income, maize output price, and rainfall are very close to zero (-0.009, 0.011, and 0.034, respectively). Therefore, temperature has negligible or no multicollinearity problem with other variables.

Rainfall: rainfall and maize yield have a moderate negative correlation (-0.398). Rainfall and GDP per capita income, as well as rainfall and maize output price, have small negative correlations (-0.030 and 0.278, respectively). Rainfall and Temperature have a small positive correlation (0.034). Therefore, rainfall has negligible or no multicollinearity problem with other variables.

Table 3: Matrix of correlations

Variables	Maize yield	GDP per capita income	(3)	(4)	(5)
Maize yield	1.000				
GDP per capita income	0.786* (0.000)	1.000			
Maize output price	0.751* (0.000)	0.969* (0.000)	1.000		
Mean Temperature	-0.104 (0.506)	-0.016 (0.921)	-0.144 (0.357)	1.000	
Precipitation	0.698* (0.000)	0.729* (0.000)	0.661* (0.000)	-0.061 (0.696)	1.000

** shows significance at p<.05*

4.3 Stationarity Test

Table 4.2 details the result output from Augmented Dickey-Fuller (ADF) test, for with a constant, with a trend and intercept, and with a suppressed trend and different variables. The results typically include statistics for different specifications of the model, such as intercept. The results for maize yield indicate that test statistics(1%: -7.051 < Critical Value, 5%: -6.955 < Critical Value and 10%: -7.065 < Critical Value) are more negative than the critical values at all significance levels 1%, 5%, and 10%. Therefore we reject reject the null hypothesis of a unit root for the maize yield variable. This suggests that the Yield variable is stationary.

Similar to maize yield, the test statistics for GDP per capita are more negative than the critical values at all significance levels(1%: -5.024 < Critical Value, 5%: -5.000 < Critical Value and 10%: -2.264 < Critical Value). The null hypothesis is rejected indicating that GDP per capita is stationary. From the table, all the other variables test statistics is more negative indicating that we reject the null hypothesis and accept that they are stationary.

Table 4: Test for Stationarity using the Augmented Dickey Fuller Model

Variable	No. of lags	Order of Integration	Typology of model		
			Constant	Trend and intercept	trend and intercept
Yield	1	1	-7.051	-6.955	-7.065
GDP	0	1	-5.024	-5.000	-2.264
Price	0	1	-6.854	-6.765	-6.416
Temperature	0	1	-7.068	-7.482	-7.152
Precipitation	0	1	-8.910	-8.791	-9.012

4.4 Estimation Results

Table 5 shows the results for OLS test. The results for variables with their respective results on coefficient values, standard error, t-value and p-value are detailed. The coefficient of correction i.e R and F tests also are detailed.

Table 5. OLS Estimation Results

Maize	Coef.	St.Err.	t-value	p-value
GDP per capita	3.01	12.215	0.25	0.807
Maize output price	-6.423 **	2.836	-2.27	0.029
Temperature	-0.473	1.397	-0.34	0.737
Rainfall	-422.86 *	214.232	-1.97	0.056
Constant	0.512	1.349	0.38	0.706
Mean dependent var		0.398	SD dependent var	5.005
R-squared		0.276	Number of obs	168
F-test		3.534	Prob > F	0.015
Akaike crit. (AIC)		249.869	Bayesian crit. (BIC)	258.558

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

The R-squared value is 0.276, indicating that approximately 27.6% of the variability in Maize output is explained by the independent variables in the model. The F-test assesses the overall significance of the model. The p-value (0.015) is less than the conventional 0.05 significance level, suggesting that the model is statistically significant as a whole.

The temperature coefficient is -0.473. However, it is not statistically significant (p-value = 0.737). This suggests that there is no significant linear relationship between Temperature and Maize output in the model. The rainfall coefficient is -422.856. It is marginally significant at the 0.1 significance level (p-value = 0.056). The negative sign suggests that there is a negative linear relationship between Rainfall and Maize output. As Rainfall increases, Maize output is expected to decrease (Mounir 2014). The constant term is 0.512. It represents the estimated Maize output when all other independent variables are zero. However, it is not statistically significant (p-value = 0.706).

Coefficient for GDP per capita income is 3.01. However, it is not statistically significant (p-value = 0.807). This suggests that there is no significant linear relationship between GDP per capita and Maize output in the model. The maize output price coefficient is -6.423. It is statistically significant at the 0.05 significance level (p-value = 0.029). The negative sign suggests that there is a significant negative linear relationship between Maize output price and Maize output. As the price increases, the Maize output is expected to decrease. According to Assort et al. (2019) changes in crop prices can significantly impact farmer's production decisions.

In summary, the model suggests that Maize output is significantly influenced by the Maize output price and Rainfall, while GDP per capita, Temperature, and the Constant do not appear to have a significant impact in this analysis. The overall model is statistically significant according to the F-test.

4.5 Diagnostic Test Results

4.5.1. Heteroskedasticity

Heteroskedasticity occurs when residuals vary in a regression model. The study conducted the White's test then the Cook-Weisberg test for heteroskedasticity. The null hypothesis shows that there is no relationship between the independent variables and error term.

Hettest
Breusch–Pagan/Cook–Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of dzea
H0: Constant variance
chi2(1) = 0.81
Prob > chi2 = 0.3669

Therefore, the study failed to reject the null hypothesis. There is not enough evidence to conclude that there is heteroskedasticity in the residuals based on this test. The assumption of constant variance is not violated at the 0.05 significance level.

4.5.2. Normality test

Validity and applicability of OLS estimates demands that the data be normally distributed (Gujarati, 1995). Behaviour of data that is characterized by fluctuations, spikes, dips and stagnations may not always guarantee normal distribution for purposes of estimation. As a result, it is not uncommon for economic data to be skewed – right of left along the base, have spikey peakedeness or deflated dstributions imparing a normal distribution.

Since skewness and Kurtosis have limits, in this study, it was established that the conventional limits were not exceeded. GDP per capita income and precipitation had the highest level of skewness and kurtosis, in that order at 1.146 and 3.416. Details for all variates are as provided in Table . 6.

Table 6: Normality test results

Variable	**N**	**SD**	**Mean**	**Skewness**	**Kurtosis**
Maize	43	7.545	29.871	.269	2.262
GDP per capita income	43	71540.958	64747.249	1.146	3.027
Maize output price	43	19.066	21.283	.786	2.399
Mean temperature	43	.834	23.601	.741	2.058
Precipitation	43	148.839	775.769	.71	3.416

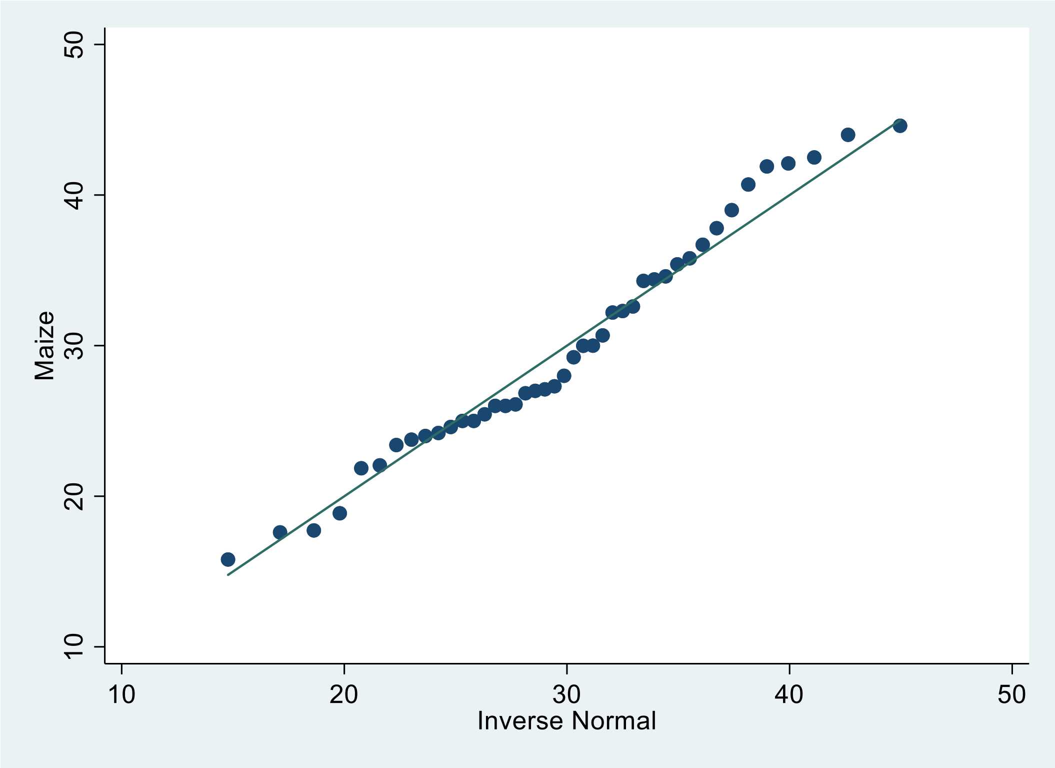

Fig 4. Graph for Maize normality test.

The Graph shows that the log linearized data for maize fits the normal line curve. This gives confidence on the estimation results.

4.5.3. Autocorrelation Test.

Table 7: Durbin-Watson Test result

Test	Results

Durbin Watson d	statistic(5, 42) = 2.444619

Durbin-Watson test was carried out to check the autocorrelation. The presence of autocorrelation makes the OLS assumption of independence of residuals to be violated. A value close to 2 suggests that there is little evidence of autocorrelation in the residuals. The results of 2.444619 then imply that there is weak negative autocorrelation. The estimates therefore have no error of correlation.

CHAPTER FIVE: CONCLUSION

5.1 Summary of the key findings

The effects that are associated with extreme climatic change such as drought, floods, heat stress etc., has claimed the decline of agricultural productivity. The developing nations such as Kenya lack sufficient capital for implementing measures that will curve for the climate change. Food security has proven to affect the bigger part of the country. This study main objective of determining the impact of climate change on supply response of farmers to maize production shows that Agricultural productivity has been on the decline mainly due to the climate change. Increased amount of investment on the amount of inputs for production is necessary to offset this trend.

5.2 Conclusion

The study findings have given a clear indication that the varying climatic conditions have negative impact to the maize productivity. Farmer's needs are made from unformed state leading to the decline in the productivity. The uncertainty of weather trends has made most the production either not happening or if it does the expected productivity is under achieved. The output prices have not been fruitful in achieving the intended aim of motivating the farmers. This is because the cost of production too has been erratic. The lack of clear information especially to the small-scale farmers also has contributed to the declining output levels.

5.3 Policy Recommendations

The study findings recommended measures that can help increase the supply of maize while mitigating for adverse effect of climate change. These measures are: Invest in irrigation systems to mitigate the dependency on unpredictable rainfall, Promote the adoption of modern irrigation techniques among farmers, Collaborate with agricultural research institutions to develop and introduce new varieties that can withstand varying rainfall patterns, Implement mechanisms to stabilize maize prices, preventing drastic fluctuations, Establish a minimum support price to ensure farmers receive a fair income for their produce, Develop and maintain robust market information systems to keep farmers informed about current market prices and trends.

5.4 Areas for Further research

The study recommends research to be conducted in areas on the impact of changing precipitation patterns on water availability for maize cultivation, investigate the influence of extreme weather events (e.g., storms, hurricanes, heatwaves) on maize yield and assess the cost-effectiveness of different adaptation measures and technologies.

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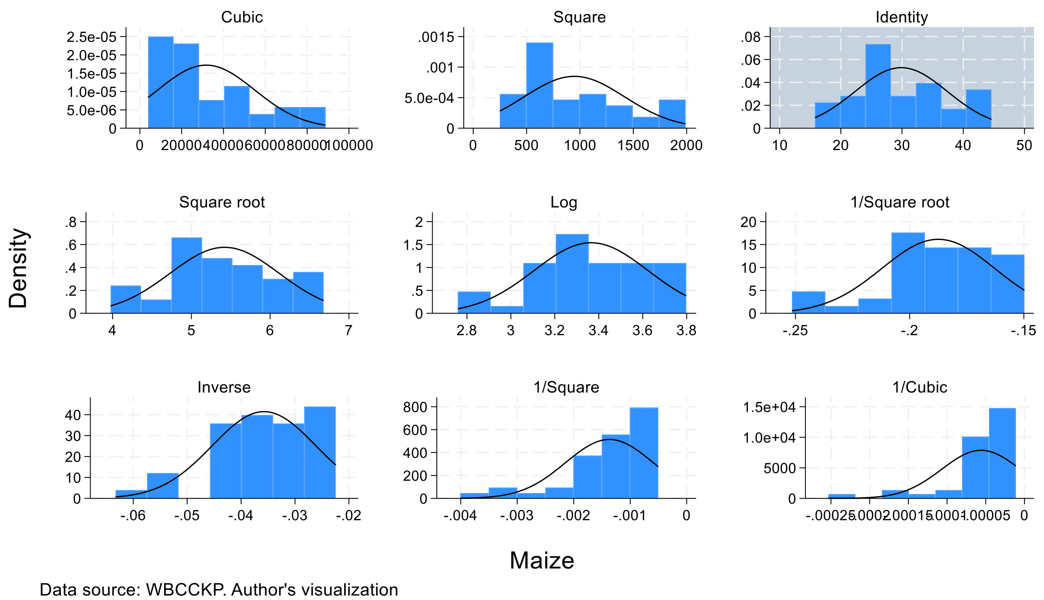
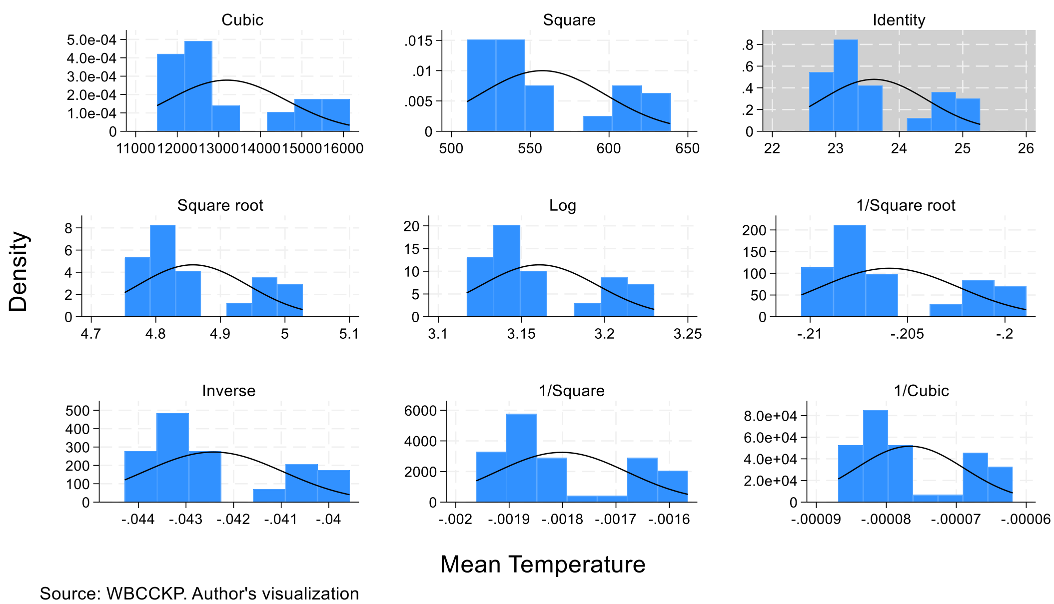
APPENDIX

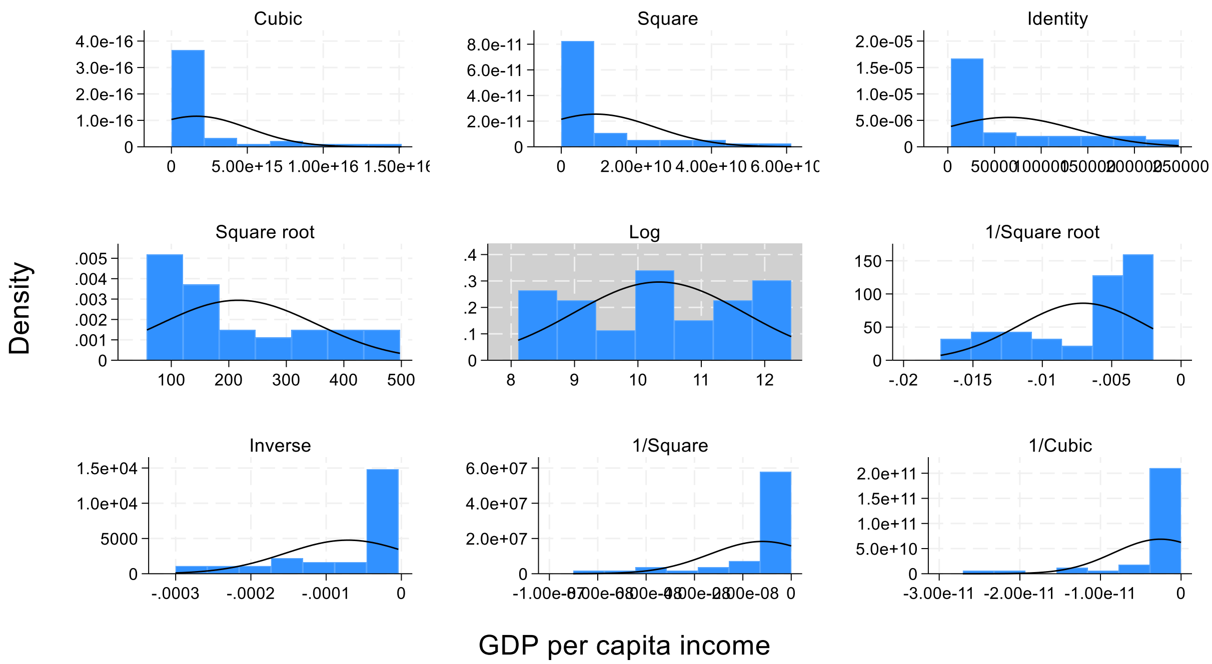
Appendix 1: Graph 1



Appendix 2: Graph 2

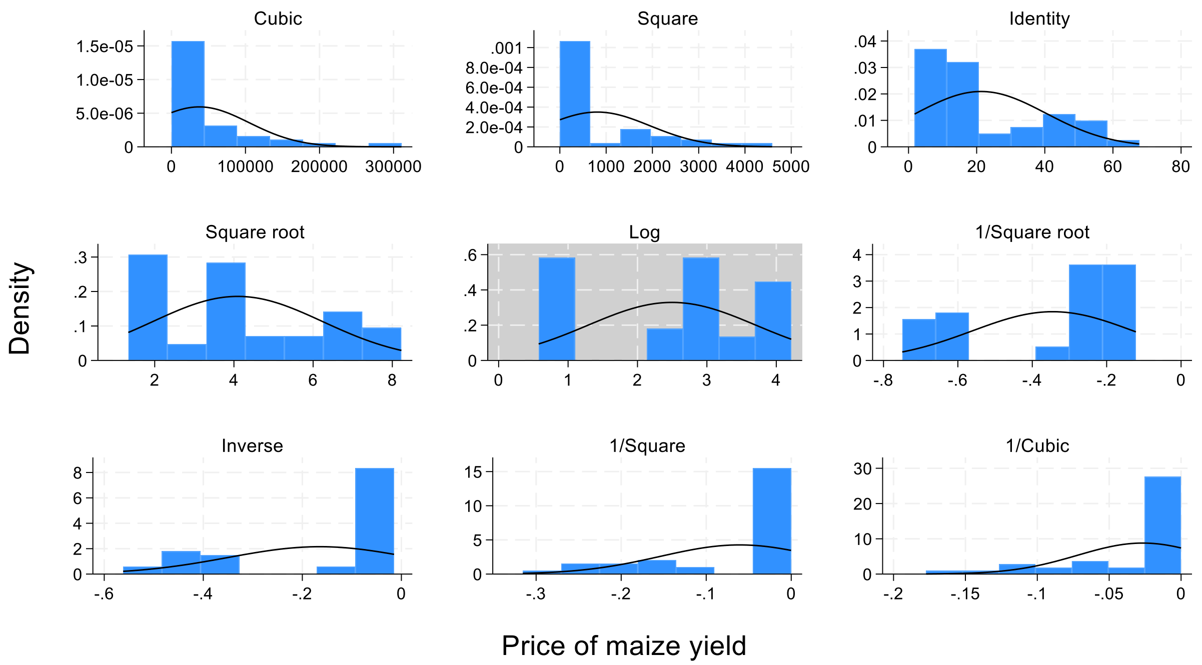


Appendix 3: Graph 3



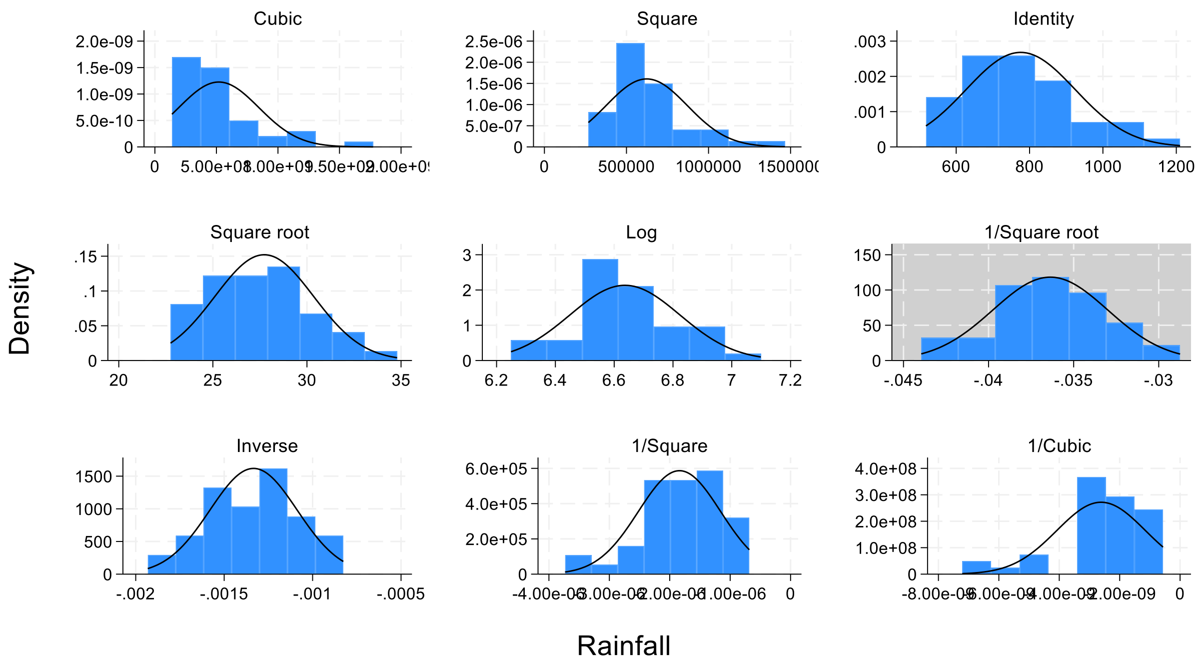
Source: WBCCKP. Author's visualization

Appendix 4: Graph 4



Source: WBCCKP. Author's visualization

Appendix 5: Graph 5



Source: WBCCKP. Author's visualization