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CLIMATE CHANGE AND MAIZE PRODUCTION: A CASE OF KIAMBU COUNTY, KENYA

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ABSTRACT

Purpose of the Study: The overall objective of this study was to assess the impact of climate change on maize production in Kiambu County, Kenya.

Methodology: The study employed a mixed research methodology that combined qualitative as well as quantitative techniques, and production theory was applied to establish a theoretical framework. The study analyzed temperature and precipitation variations in Kiambu County in the period 2012 to 2020, and their subsequent impact on maize yields in the same period. Primary data was collected from 42 small-scale maize farmers in Juja, Gatundu North, Lari and Limuru sub-counties. Secondary data on precipitation and temperature levels in Kiambu County for the period 2012 to 2020 was sourced from the Weather and Climate global database. Secondary data on maize yields in Kiambu County from 2012 to 2020 was obtained from the Kenya National Bureau of Statistics.

Result: The study found that maize yields were influenced by both temperature and precipitation levels. However, only temperature was statistically significant in the model. Responses to the questionnaires distributed to forty-two small-scale maize farmers in Juja, Gatundu North, Lari and Limuru sub-counties indicated that the farmers have implemented a number of mitigation techniques, such as using more organic manure and fertilizers, spraying plants to ward off pests, watering manually when feasible, and planting trees in the surrounding areas. Some farmers, on the other hand, have adopted a more laid-back stance and did not implement any mitigation techniques since they felt they had no control over climate change.

Recommendation: The study recommends regular provision of capacity-building to small-scale maize farmers to increase awareness on climate change and possible mitigation techniques, equitable distribution of quality inputs such as seeds and fertilizers to the farmers, as well as enforcement of the law against destructive practices such as deforestation.

Keywords: *Climate Change*, *Maize Production*, *Kiambu County*, *Kenya*

INTRODUCTION

Agriculture plays a dominant role in Africa's economy, employing 60% of the workforce and generating 23% of GDP in sub-Saharan Africa, with particularly high employment rates in East and Central Africa. However, the sector faces significant challenges from climate change, as most crops are already growing at their maximum heat tolerance levels. Research has shown that maize productivity in Africa decreases by 1% for every degree above 30°C, with an additional 0.7% decrease during droughts. The agricultural workforce in Africa's major economies grew from 197 million in 2011 to 226 million by 2021, though North Africa shows lower agricultural employment due to its focus on industrial and service sectors.

Kenya's agricultural sector is particularly vulnerable to climate changes due to its heavy reliance on rain-fed farming, with only 2% of cultivable land being irrigated compared to 6% in Sub-Saharan Africa and 37% in Asia. The sector is crucial to Kenya's economy, contributing directly to 22% of GDP and indirectly to another 27% through linkages with other sectors. Agriculture employs over 40% of Kenya's workforce and 70% of rural residents, while providing 65% of export revenues. In 2021, the sector contributed approximately 2,713 billion Kenyan shillings to GDP, though the World Bank noted a decrease in actual value-added compared to 2006 due to weather shocks, pest outbreaks, and reduced information distribution methods. At the county level, Kiambu County exemplifies the importance of agriculture, with 17.4% of its population deriving their livelihood from the sector, employing approximately 304,449 people in various agricultural activities including tea, coffee, and food crop production.

Maize Production

Maize is the world's third most important basic food after wheat and rice, belonging to the Poaceae family as a highly adaptable C4 plant. Originally from Mesoamerica, it now grows globally between 58°N and 40°S latitudes, thriving in conditions with 600-1,200mm annual rainfall, altitudes of 900-2,500 meters above sea level, and temperatures between 20-30 degrees Celsius. Maize represents 30% of cereal-growing land worldwide and provides over 30% of calories and protein consumed in Africa, with 67% of developing world production coming from low and lower-middle-income countries. It serves multiple purposes beyond food, including the production of oil, alcoholic beverages, textiles, and paper.

In Kenya, maize plays a crucial role in food security, accounting for approximately 65% of household caloric intake and serving as the primary food staple for 85% of the population.

However, the country faces significant challenges in meeting its maize demand, with production consistently falling short of consumption since 2008 (except in 2010 and 2020). Recent years have seen declining yields, exemplified by a 12.8% drop in production from 42.1 to 36.7 million bags between 2020 and 2021, primarily due to climate-related factors such as unpredictable rainfall, rising temperatures, and drought. This situation is further complicated by Kenya's rapidly growing population, which increased from 8.12 million in 1960 to 54.03 million in 2022, putting additional pressure on maize production and necessitating imports to meet the deficit.

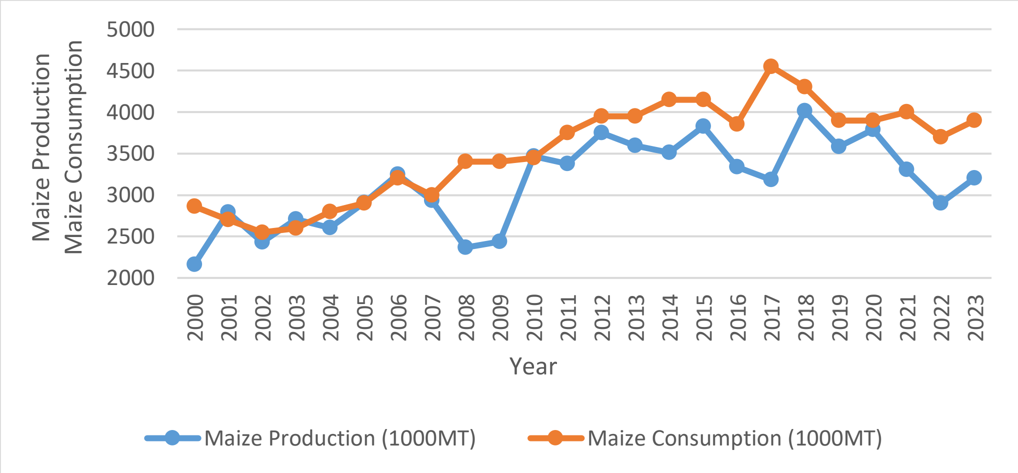

Figure 1: Maize production and consumption in Kenya (2000 - 2023)

Maize Production in Kiambu County

About 17% of the income of Kiambu County's population comes from agriculture, which is the county's primary economic sector. In terms of land, around 74 percent of the County—or 1880 hectares—is used for agriculture (Bioversity International & International Center for Tropical Agriculture, n.d.). Kiambu County has added to the economy's food basket and supplemented the maize production of large-scale producing counties. Four out of the seven agro-ecological zones in Kenya are found in Kiambu. The county also has three soil types with varying fertility, and four major topographical zones. Specific regions within these agroecological zones, topographical zones, and of varying soil types facilitate the cultivation of maize. The main food crop in Kiambu County is maize (45,980 ha), which is grown on small farms by about 144,130 households. Other crops that are grown there include beans (17,430 ha), bananas (3,520 ha), cabbages (1,100 ha) and Irish potatoes (9,200 ha) (Bioversity International & International Center for Tropical Agriculture, n.d.). However, Kiambu's maize yield has fluctuated over the past few years.

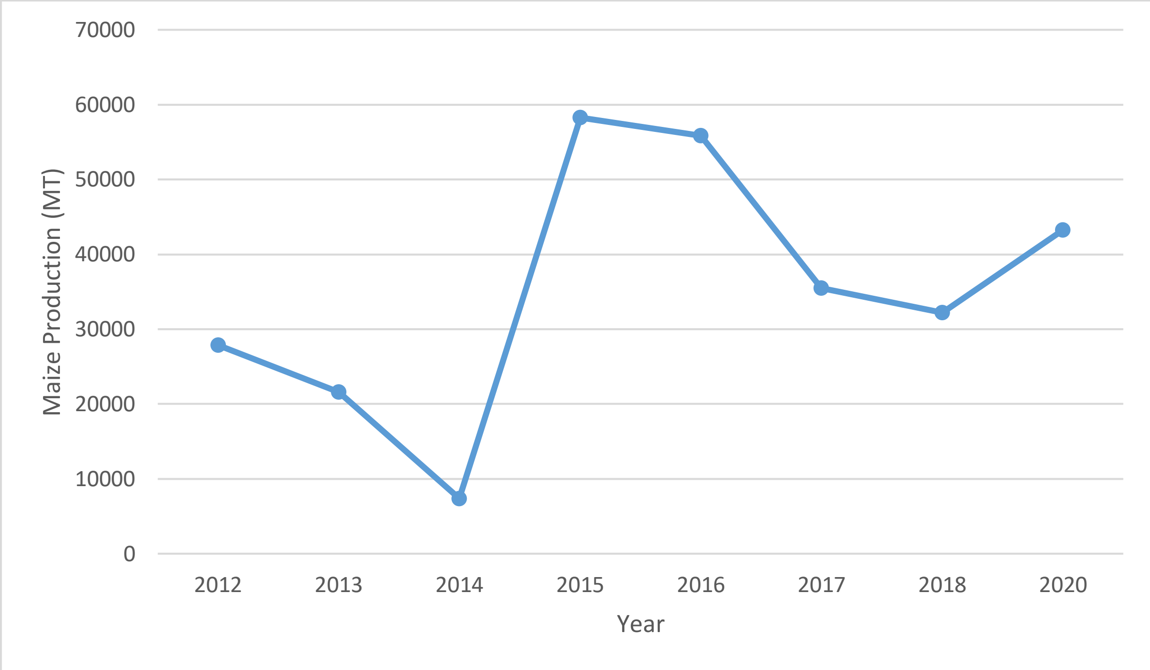

Figure 2: Maize production in Kiambu County (2012 - 2020)

Climate Change

Climate change, defined by the United Nations Framework Convention on Climate Change as any alteration in the earth's climate linked to human activities, poses a significant threat to the Sustainable Development Goals' aim of ending extreme poverty by 2030. The earth's temperature has risen dramatically, with an increase of 0.18 degrees Celsius per decade since 1981, more than double the rate observed since 1880. This global phenomenon is expected to require $580 billion for loss and damage mitigation, adaptation, and compensation by 2030, with costs projected to rise to $1.8 trillion by 2050. Major indicators of climate change include rising sea levels, increased greenhouse gas concentrations, altered weather patterns, ocean acidification, and increased ocean heat.

Africa, despite contributing less than 4% of global greenhouse gas emissions, is experiencing severe climate crisis impacts, including intense heatwaves, unpredictable rainfall, species extinction, and severe droughts. The continent has faced devastating natural disasters, exemplified by the sequence of tropical storms that hit Mozambique and neighboring countries between 2019 and 2021, affecting over 2.2 million people. Kenya, in particular, has been severely impacted by climate change despite not being a major contributor to carbon emissions. The country has experienced significant environmental challenges, including a devastating locust swarm in 2020 (the worst in 70 years), triggered by tropical cyclones across the Arabian

Peninsula. Additionally, the Lewis Glacier on Mt. Kenya has shrunk by 90% since the 1930s due to rising temperatures.

In Kiambu County, the local impacts of climate change have been particularly severe on agricultural communities. Farmers have observed significant environmental changes, including soil degradation, drying rivers, and increased pest and disease occurrence. The region experienced devastating floods between October 2019 and May 2020, causing substantial crop losses, particularly affecting Irish potato farmers in Bibirioni Ward and the neighboring Lari sub-county. The impact of these climate-related changes has had significant gender-specific consequences, with women being particularly vulnerable due to their predominant role in labor-intensive farming tasks. Men have also been affected through reduced agricultural yields, limiting their ability to support their families and implement necessary climate change mitigation measures.

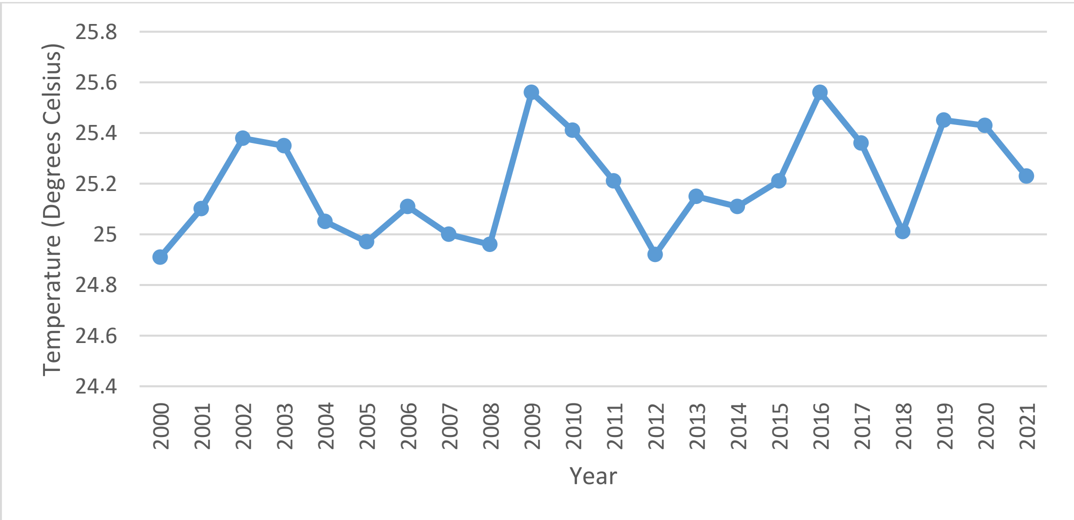

Figure 3: Observed Average Annual Mean Temperature in Kenya (2000-2021)

PROBLEM STATEMENT

A sufficient amount of maize is a sign of security in food, and is a way to create jobs and revenue in Kenya. Nonetheless, maize output levels in Kenya have varied over time, resulting in a production that typically falls short of consumption. In 2023, Kenya produced 47.6 million bags of maize, an increase of 38.8% from the previous year. Despite this rise, the country still had to import 507,900 metric tonnes of maize to make up for the shortfall between supply and demand (Kenya National Bureau of Statistics, 2024). Additionally, the government has set a target of zero maize imports by 2025, and Kenya must produce at least 60 million bags of maize annually to reach this goal (Milling Middle East and Africa, 2024). This means that in order to keep sustaining the livelihoods of Kenya's expanding populace, maize output needs to rise sustainably and keep up with the population growth. Weather patterns are a key contributor to the deficit in maize output. 98% or more of agricultural activities are rain-fed. Therefore, changes in climatic circumstances have a noteworthy impact on the output of maize.

In addition, the frequency of extreme weather events like floods and droughts has increased because of rising temperatures as well as shifting trends in rainfall (Wandaka, 2016). There has been research on how climate change affects maize productivity in Kenya. Nevertheless, many of these studies have adopted a broad approach and have mostly focused on large-scale maize production. Maize production in Kiambu County is undertaken on small-scale, and the county has distinct variations in topography zones, agro-ecological zones, soil types and water sources. Thus, it is crucial to conduct a study specifically focused on Kiambu County, to examine how climate change is influencing production of maize in the region. This will help in recommending the best measures to be implemented in the region to lessen the harmful consequences of climate change. This study thus aims to investigate the impacts of variations in temperature and precipitation on maize yields in Kiambu County, Kenya.

RESEARCH OBJECTIVES

The overall objective of this study was to assess the impact of climate change on maize production in Kiambu County, Kenya.

Specific Objectives

i. To assess the impact of temperature and precipitation on maize production in Kiambu County, Kenya
ii. To explore possible mitigation and adaptation strategies/policies to control the adverse impacts of climate change on maize production in Kiambu County, Kenya

LITERATURE REVIEW

The section presents the theoretical literature and empirical review.

THEORETICAL LITERATURE

The Production Function Approach offers an empirical evaluation of the relationship between environmental factors and crop yield through carefully controlled studies where plants are grown under various climate conditions. This method uses experimental production functions to assess environmental consequences and predict climate change impacts by varying inputs such as temperature, carbon dioxide, and precipitation. The approach allows for measurements without interference from external elements like soil quality and can provide clear gauges of climate impacts. However, it has significant limitations: it ignores farmers' adaptive responses to climate change, such as technology adoption, fertilizer use, land use changes, and the introduction of new crops, thereby overemphasizing negative effects while overlooking positive adjustments. Additionally, the high costs associated with controlled trials have restricted its application to only a few crops, primarily grains, and limited global regions.

The Ricardian Approach, based on David Ricardo's research showing how land values correspond to net productivity, provides a cross-sectional model examining how farmers perform across different climate zones (Mendelsohn et al., 1994; Mendelsohn & Dinar, 2003). This approach uses land rent as an indicator of farmland's long-term net production, expressed through the equation;

$V = \sum PiQi(X,C,S,G,H) - \sum PxX$……………………………………….(2.1).

The model employs a quadratic term to demonstrate the nonlinear structure of the net revenue climate response function, represented as;

$V = \beta 0 + \beta 1C + \beta 2C2 + \beta 3S + \beta 4G + \beta 5H + \mu i$…………………………………. (2.2),

where β and μ are the coefficient of the variables and error term respectively, and the variables S, G, H, and V represent soil, socioeconomic household characteristics, water flow and land value, respectively. The Ricardian model was specifically designed to illustrate changes in land value per hectare of agriculture between climate zones (Seo & Mendelsohn, 2007; Mendelsohn et al., 1994). Unlike the Production Function Approach, the Ricardian method is more economical as it allows for secondary data use and considers farmers' adaptation strategies to maintain or increase profit. However, its main drawback lies in the lack of a controlled environment, making it challenging to determine the precise contribution of specific inputs to variations in farmers' income and crop output. Despite this limitation, the approach remains valuable for investigating how farmers use various interventions, such as fertilizers, to positively affect their produce across different soil types and sub-counties.

EMPIRICAL LITERATURE

Recent studies across Africa have demonstrated the significant impact of climate change on maize production, with various methodological approaches yielding consistent concerns about future yields. In Malawi, Msowoya et al. (2016) used General Circulation Models to project decreased maize yields by mid and end-century, recommending adaptation techniques such as rainwater harvesting and crop diversification. In Kenya, Wandaka et al. (2016) employed Marginal Impact Analysis to show that temperature has a greater effect on maize yield than precipitation, projecting a 20% decrease in yield by 2100. This finding was further supported by Wanyama (2017), whose spatial analysis revealed temperature and precipitation as primary factors affecting Kenyan maize yields. Similarly, Kariuki et al. (2018) found that climate changes negatively impact maize yield, with temperature increases showing consistently adverse effects, while rainfall displayed a concave relationship with yield during both long and short rain seasons.

Studies from other regions have provided valuable insights into the relationship between climate variables and maize production. In Pakistan, Shakoor et al. (2018) used Vector Auto Regression models to demonstrate that average lowest temperature and increased rainfall positively impact maize output. Murray-Tortarolo et al. (2018) found a linear association between annual precipitation and rainfed maize yield in Mexico, while Siahi et al. (2018) applied the Production Function and Vector Error Correction Model in Kenya to show how temperature, carbon dioxide concentration, and precipitation explain maize yield variability. In Ghana, Fosu-Mensah et al. (2019) used the APSIM crop simulation model to predict a 19% and 14% decrease in maize yield under A1B and B1 scenarios respectively by 2050, highlighting the impact of delayed rainy seasons on planting schedules.

More recent studies have focused on specific regional impacts and adaptation strategies. In Tanzania, Nzaro (2020) found a correlation between favorable rainfall levels and maize production, while Guntukula (2020) used the Just-Pope production function in India to show positive correlations between maize output, rainfall, and maximum temperature. Makokha et al. (2021) and SOUMAERO (2021) both found positive associations between rainfall and maize output in Kenya and Mali respectively. Recent comprehensive studies by Zhang et al. (2022) and Kabara et al. (2022, 2023) have emphasized the importance of adaptation strategies, with Kabara's research particularly highlighting how conservation agriculture and irrigation emerged as the most successful adaptation strategies for maintaining maize yields in Kenya's semi-arid regions. These studies collectively emphasize the need for region-specific adaptation strategies and policy interventions to address the challenges posed by climate change to maize production.

RESEARCH METHODOLOGY

The study employed a mixed research design, combining qualitative and quantitative methods through triangulation, and was grounded in production theory using the Cobb-Douglas production function to examine the impacts of climate change on maize yield in Kiambu County, Kenya. The research targeted small-scale maize farmers across four strategically selected sub-counties (Juja, Gatundu North, Lari, and Limuru) and specifically focused on four wards (Murera, Mang'u, Lari/Kirenga, and Bibirioni), with these locations chosen based on their varying topographical zones, soil types, agro-ecological zones, and water sources, as well as established stakeholder linkages that facilitated efficient research completion. Using a combination of snowball and convenience sampling techniques, 42 farmers were selected as study participants. Data collection involved both primary and secondary sources: primary data was gathered through questionnaires containing both closed and open-ended questions focusing on farmers' perceptions of climatic variations' effects on maize yield and their adopted mitigation strategies, while secondary data included yearly weather variables (2012-2020) from the Weather and Climate global database, maize yield data from the Kenya National Bureau of Statistics, and additional information from government publications and literature sources. The data analysis utilized multiple linear regression analysis through both Microsoft Excel and STATA software, with weather variables analyzed to obtain trends and the coefficient of determinant (R^2), while the Cobb-Douglas function was employed in the following form:

$$\ln Y = \beta 0 + \beta 1 \ln L + \beta 2 \ln N + \beta 2 \ln T + \beta 4 \ln F + \mu jt \ldots\ldots (3.1)$$

where Y represents total maize yield, and L, N, T, and F represent labor, land, temperature, and rainfall respectively.

FINDINGS AND DISCUSSION

The study conducted a comprehensive analysis of climate change impacts on maize yield in Kiambu County using multiple linear regression analysis with Newey-West standard errors. The analysis examined the relationship between maize yield and various factors including land, temperature, and precipitation, while also incorporating farmers' perceptions and adaptation strategies. The regression model revealed significant insights into the dynamics of maize production in the region, with an overall model significance at 95% confidence level (Prob > F = 0.0137) and a robust R-squared value of 0.8364.

Model Specification and Results: The regression analysis yielded the following equation:

$$\ln Yield = -117.1965 + 1.3667 \ln N + 36.1977 \ln T + 0.5911 \ln F \ldots\ldots (4.1),$$

(-3.66)* (1.94)* (4.65)* (1.11)*

Where: * represents the t-values corresponding to the constant, Land (N), Temperature (T) and Precipitation (F) respectively.

The model demonstrated strong explanatory power, with approximately 83.64% of variations in maize production attributable to the included variables. The adjusted R^2 value of 0.6727 indicates that 67.27% of yield variations can be explained by the independent variables after adjusting for the number of predictors.

Environmental Variable Impacts and Farmer Perceptions: Temperature emerged as the most significant factor, with a coefficient of 36.1977 (p-value 0.019), indicating that a 1% increase in temperature leads to a 36.2% increase in maize yields. This relationship was particularly notable as the county's temperature remained within the optimal range of 20-30 degrees Celsius for maize production (Farm Link Kenya, 2017). The farmers' perceptions aligned with these findings, as shown in the following tables:

Table 1: Perceived Changes in Average Rainfall Over the Past Few Years

Change	**Frequency**	**Percentage**
Increase in rainfall	2	4.76
Decrease in rainfall	39	92.86
No changes	1	2.38
Total	42	100

Table 2: Perceived Changes in Average Annual Temperature Over the Past Few Years

Change	**Frequency**	**Percentage**
Increase in temperature	38	90.48
Decrease in temperature	0	0
No changes	4	9.52
Total	42	100

Adaptation Strategies and Support Needs: Survey results from 42 small-scale farmers across four sub-counties revealed diverse adaptation strategies to climate change impacts. Farmers implemented various mitigation measures including organic manure application, pest control measures, manual watering, and tree planting. However, the study identified a critical gap in climate change training, with only one farmer reporting receiving formal training in the past year. Key support areas identified by farmers included access to high-quality seeds and fertilizers, soil testing facilities (particularly in Limuru sub-county), and improved government accountability in resource distribution. The need for water catchment development, protection against deforestation, and pest control support were also highlighted as crucial areas requiring attention.

CONCLUSIONS

This study's investigation into climate change impacts on maize production in Kiambu County (2012-2020) yielded several significant findings through analysis of both primary data from 42 small-scale farmers across four sub-counties and secondary data from the Weather and Climate global database and Kenya National Bureau of Statistics. The research revealed a complex relationship between climatic variables and maize yield, with temperature showing a statistically significant positive correlation (coefficient 36.1977, p-value 0.019), while precipitation demonstrated a positive but statistically insignificant relationship (coefficient 0.5911, p-value 0.347). This dynamic can be attributed to Kiambu County's favorable agro-ecological conditions, including adequate annual rainfall (600-1300mm) and supplementary water sources. The study also identified diverse farmer adaptation strategies, ranging from proactive measures such as organic manure application, pest control, manual watering, and tree planting, to more passive approaches based on the perception of climate change as an uncontrollable natural phenomenon.

RECOMMENDATIONS

Based on the study's findings, several critical recommendations emerge for improving maize production resilience to climate change in Kiambu County. Priority should be given to implementing regular capacity-building programs for small-scale farmers, addressing the significant training gap revealed by only one farmer out of 42 receiving climate change training in the past year. This should be complemented by equitable distribution of high-quality agricultural inputs (seeds and fertilizers) through well-defined policy frameworks and quality control measures. Additionally, environmental protection measures should be strengthened through strict enforcement against deforestation and water catchment interference, potentially including incentives for tree planting initiatives. For future research, two key areas warrant investigation: an analysis of the 2020-2024 period to evaluate more recent climate impacts, particularly given the observed trend of rising temperatures beyond optimal ranges, and a more comprehensive qualitative study encompassing all sub-counties in Kiambu to better understand variations in farmer perceptions and adaptation strategies across different geographical and socio-economic contexts.

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