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ENVIRONMENTAL FACTORS ON MAIZE PRODUCTION AMONG SMALLHOLDER FARMERS TO ENHANCE FOOD SECURITY IN BUNGOMA-NORTH SUB COUNTY

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ABSTRACT

Maize production is a cornerstone of food security in Kenya, particularly among smallholder farmers in rural regions. This study investigates the effects of environmental factors on maize production among smallholder farmers in Bungoma-North Sub County, Bungoma County, Kenya. The primary objective was to analyze how environmental determinants—such as rainfall variability, soil quality, temperature, and land topography—influence maize yields and, ultimately, food security in the region. Additionally, the study examined the interaction between environmental conditions and other supporting factors, including socioeconomic variables and access to extension services, which may moderate or compound environmental effects. A descriptive survey research design was adopted, targeting 10,548 smallholder maize farming households within the sub-county. A sample size of 318 respondents was selected through stratified and systematic sampling techniques. Data were collected using structured questionnaires and analyzed through descriptive statistics and inferential methods. The findings reveal that environmental factors significantly influence maize output, with irregular rainfall patterns, declining soil fertility, and climate variability presenting major challenges. The study underscores the need for climate-smart agricultural practices, timely extension support, and policies aimed at enhancing farmers' adaptive capacity. These measures are crucial in ensuring sustainable maize production and improving food security in Bungoma-North Sub County.

Key words: *Environmental Factors, Maize Production, Smallholder Farmers, Food Security, Bungoma-North Sub County.*

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BACKGROUND OF STUDY

Maize production remains a cornerstone of food security across sub-Saharan Africa, particularly in Kenya, where smallholder farmers contribute over 70% of national output. However, despite technological advancements in agricultural production, environmental constraints continue to pose significant threats to sustainable maize yields. Globally, research has shown that technology—including improved seed varieties, fertilizers, and irrigation—has propelled maize productivity, as seen in China (Huang & Rozelle, 1996) and other parts of Asia and Africa. Yet, environmental conditions such as soil degradation, erratic rainfall patterns, and changing temperatures often limit the benefits of these technological inputs, especially for smallholder farmers.

In East Africa, including Uganda and Nigeria, studies by the FAO and researchers such as Oladeebo (2004) and Mpuga (2004) have emphasized that while smallholder farmers are increasingly aware of input-enhancing technologies, their adoption is often undermined by environmental uncertainty and lack of infrastructure. In Kenya, Nyoro (2004) and Olwande et al. (2009) have noted a gradual decline in maize competitiveness due to high production costs and limited capacity to mitigate environmental shocks. Smallholder maize farmers in regions like Bungoma-North Sub County are particularly vulnerable, as they often rely on rainfall-dependent agriculture, cultivated on fragile soils, with minimal access to irrigation or climate-resilient practices.

Furthermore, Wanyama et al. (2009) and Kaliba (1998) highlight that environmental factors—when coupled with insufficient extension services and weak institutional support—reduce farmers' capacity to respond to climate variability. These dynamics not only affect productivity but also threaten household food security and livelihoods. As maize remains a staple food crop in Kenya, addressing the environmental determinants of production becomes a critical issue for policy-makers, researchers, and development practitioners.

This study, therefore, seeks to investigate the effects of environmental factors on maize production among smallholder farmers in Bungoma-North Sub County. Understanding these factors is essential to developing localized strategies that enhance resilience, increase yields, and ultimately secure food systems in the face of environmental change.

Statement of the Problem

Maize is a vital staple crop in Kenya, with approximately 85% of the population depending on it as a primary food source. In Bungoma-North Sub County, where the majority of households engage in smallholder farming, maize production is not only central to household food security but also to the region's economic sustenance and employment. Despite its importance, maize yields among smallholder farmers in the region have continued to decline, threatening both food security and rural livelihoods.

A critical underlying cause of this decline is the influence of environmental factors—erratic rainfall patterns, declining soil fertility, lack of irrigation infrastructure, and exposure to extreme weather conditions. These challenges are compounded by limited access to modern agricultural inputs and practices that could otherwise mitigate environmental impacts. While government initiatives such as subsidized fertilizers and extension services exist, they often fail to reach all smallholder farmers effectively, leaving many vulnerable to the vagaries of climate and land degradation.

Moreover, the shrinking size of farmland due to population pressure has intensified land fragmentation, making it difficult to implement effective environmental management practices. The lack of adequate storage facilities further exposes maize to post-harvest losses from weather damage and theft. Poor road infrastructure and limited access to credit services exacerbate the

situation by constraining timely access to markets and inputs.

The problem is further amplified by the paradox of maize importation. Despite being a maize-producing region, Kenya continues to rely heavily on imported maize. This undermines local production incentives and results in demotivation among smallholder farmers. As a result, many farmers are shifting to less demanding crops or abandoning agriculture altogether, leading to deteriorating agricultural productivity and rising poverty levels.

In Bungoma-North Sub County, where agriculture forms the backbone of the local economy, declining maize production has serious implications for food security, employment, and sustainable development. Addressing the environmental constraints that hinder smallholder maize production is therefore not only urgent but also essential for reversing food insecurity and rural poverty in the region.

Research Objectives

To investigate effects of environmental factors on maize production among smallholder farmers to enhance food security in Bungoma-North Sub County. The study was guided by the following research questions;

- What are the effects of environmental factors on maize production among smallholder maize farmers in enhancing food security in Bunsgoma-North Sub County?

Significance of the Study

The findings of this study are expected to provide valuable insights for various stakeholders involved in agricultural development and food security within Bungoma-North Sub County and beyond.

Firstly, the research will assist the County Government of Bungoma in formulating and implementing evidence-based strategies to mitigate environmental challenges affecting maize production. By identifying key environmental constraints, the county can design targeted interventions such as soil management programs, climate-smart agriculture initiatives, and investment in irrigation and storage infrastructure, all aimed at improving maize yields and ensuring food security among smallholder farmers.

Secondly, the study will benefit agricultural extension service providers by highlighting specific environmental factors that constrain maize productivity. This knowledge will help extension officers tailor their training, outreach, and support services to address real, location-specific challenges faced by farmers, ultimately enhancing the effectiveness of their interventions.

Thirdly, smallholder maize farmers will benefit from the study's practical recommendations on how to adapt to and mitigate environmental risks while maximizing maize output using efficient and sustainable farming practices. By understanding how environmental variables influence yields, farmers can make informed decisions regarding input use, timing of planting, and resource allocation.

Lastly, the study will serve as a reference resource for academic purposes at Masinde Muliro University of Science and Technology, contributing to the existing body of knowledge on agricultural productivity and environmental sustainability. It will also open opportunities for further research by scholars interested in exploring related themes in agronomy, climate adaptation, rural development, and food security.

Scope and delimitation of the study

The scope for this research was to determine issues affecting maize productivity in Bungoma-North Sub County. The study took place within the month of May 2024. This study was restricted into maize production and factors involved. It was also limited to Bungoma-North Sub County and to the smallholder maize farmers only. The studys' target population did not include any average-sized, large scale or farmers who did not cultivate maize. The objectives formulated were directed towards enhancing the principles of maize production from

smallholder farmers in Bungoma-North Sub County. Interviews, questionnaires, and secondary data were utilized as research instruments.

LITERATURE REVIEW

Theoretical Framework

This study is grounded in the Philosophy of Productivity, specifically drawing from the Theory of Production. The Theory of Production, originally developed by Adam Smith (1776), examines the relationship between production inputs—such as land, labor, capital, and entrepreneurship—and the quantity of output generated. According to Daly and Farley (2011), this theory posits that the level of output is largely determined by the combination and utilization of these production factors.

Ojala et al. (2014) further emphasize that understanding the interactions and impacts of these inputs enables producers to identify optimal combinations that maximize productivity while minimizing costs. Applied to maize production, this theory suggests that factors including access to credit, climatic conditions, demographic variables, and availability of extension services play significant roles in influencing maize yields.

Therefore, this framework provides a foundation for analyzing how these diverse factors collectively affect maize productivity among smallholder farmers in Bungoma-North Sub County, guiding the study in identifying key determinants that can enhance food security.

Conceptual Framework

Figure 1 represents a conceptual framework with concepts which directed this research study. It shows how the independent variables affected the dependent variables in the study. The study was therefore based on the model below to recognize the independent and dependent variables of the study.

Factors influencing maize productivity among smallholder farmers

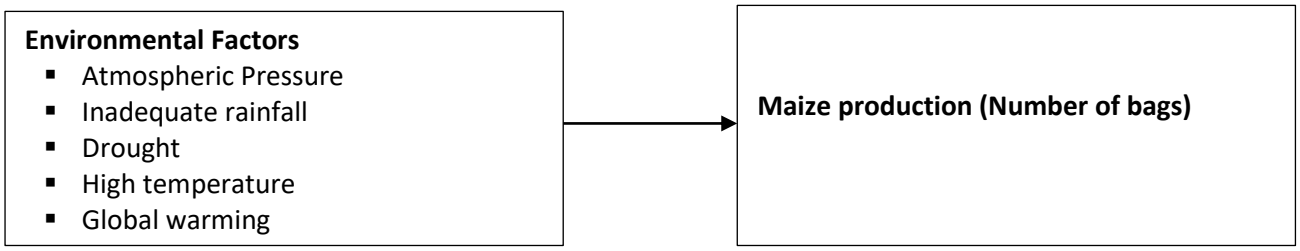

Figure 1: Conceptual Framework

LITERATURE REVIEW

Effects of environmental factors that influence maize production among smallholder farmers

These aspects include climate variability and water availability. While effects of weather variability is directly reflected in a decrease in maize yields, climate variability also provides a favorable environment for the breeding of pests such as army worms and diseases, which encourage the decline of maize yields in Kenya (Chumo, 2013). Variations in harvests may also be as a result of unpredictable rises in temperatures, alterations in precipitation forms and high concentration of carbon dioxide due to greenhouse gas emissions caused by humans, causing more problems in growing of maize in such tropics and escalating maize growing range (FAO, 2006).

Effects of climate change include snow cover, increased environmental pollution, change in rainfall amount and distribution, high temperatures, global warming, flooding and persistent droughts as indicated by Food and Agriculture Organization Statistics (FAOSTAT, 2006,). A case study by (Mearns, 1995) discovered

that effects of weather unpredictability on crop productivity include increased transpiration, evaporation, reduction in moisture content and alteration of crop type and variety.

In Kenya, climate variability has resulted to persistent food shortages due to decreased yields, decline in soil fertility, increased water problems due to droughts, species shifts due to habitat alteration and altered plant variety leading to lose of indigenous and plant based medicines (Chumo, 2013). Major climate factors affecting maize production in Kenya include humidity, rainfall, temperature, solar radiation and day link. Capital is required for proper management of climate variability in order to increase maize productivity.

A study by Oluoch et al. (2022) examined the impact of environmental stressors on maize productivity among smallholder farmers in East Africa. The study employed a mixed-method approach, combining survey data from 350 farmers with remote sensing data to analyze changes in yield patterns. Findings revealed a significant decline in maize yields over the past decade, primarily attributed to increased temperatures ($\beta = .576$, $p < .05$) and erratic rainfall patterns ($\beta = .489$, $p < .05$). The study concluded that while adaptation strategies such as drought-resistant seeds were partially effective, farmers lacked adequate knowledge and resources to implement them fully. Although this research provided crucial insights, it focused mainly on broad climatic patterns without assessing local socio-economic variations, highlighting the need for region-specific studies.

Mugambi and Kamau (2021) explored the effects of global warming and drought on maize production in Kenya using a longitudinal panel analysis of agricultural census data from 2000 to 2020. The study found that prolonged drought periods led to a 35% reduction in maize output, with a statistically significant relationship between drought frequency and yield decline ($\beta = .621$, $p < .05$). Additionally, high temperatures exacerbated soil moisture loss, further reducing productivity. The study emphasized that adaptation strategies, including soil conservation and irrigation, were underutilized due to financial constraints among smallholder farmers. However, the research was limited by its reliance on secondary data, which may not have captured real-time farmer responses to climate variability.

Kiprono et al. (2020) assessed the influence of atmospheric pressure variations on maize growth stages in Western Kenya. Using meteorological data and farm-level surveys, the study established that low atmospheric pressure periods coincided with poor pollination and lower grain filling rates, resulting in yield reductions of up to 28%. The regression model indicated a significant inverse relationship between atmospheric pressure fluctuations and maize yields ($\beta = -.482$, $p < .05$). Farmers reported increased incidences of crop failure, particularly in regions with inadequate irrigation systems. The study recommended climate-smart agricultural practices but failed to explore the economic feasibility of implementing these strategies among smallholder farmers.

A study by Wekesa and Otieno (2019) investigated rainfall variability and its effects on maize farming in Bungoma County. Using GIS mapping and structured farmer interviews, the research found that annual rainfall variability exceeded 40% over the past two decades, directly impacting planting schedules and maize germination rates. Regression analysis showed that unpredictable rainfall patterns significantly reduced yields ($\beta = .533$, $p < .05$). The study suggested that integrating agroforestry and water harvesting techniques could mitigate these effects. However, its limitation was the exclusion of other environmental stressors such as soil degradation and pest infestations, which could also contribute to yield fluctuations.

Mutai et al. (2018) analyzed how credit turnover influenced maize farmers' ability to adopt adaptation strategies against environmental stressors in Kenya. Using a survey of 500 smallholder farmers, the study found that farmers with higher savings were more likely to invest in climate adaptation measures such as irrigation and

improved seed varieties (β = .594, p < .05). The study concluded that access to financial resources was crucial in mitigating climate change impacts on maize production. However, the research did not account for non-financial barriers such as limited technical knowledge or policy constraints, leaving a gap in understanding the holistic challenges faced by farmers.

The reviewed studies collectively demonstrate that environmental factors such as high temperatures, inadequate rainfall, and global warming have a profound impact on maize yields among smallholder farmers. While previous research has highlighted the significance of adaptation strategies, gaps remain in addressing the economic, technical, and policy-related barriers to their implementation. Future research should focus on integrated approaches that combine climate adaptation with financial support mechanisms to enhance food security in Bungoma-North Sub County

METHODOLOGY

The methodology chapter of the study outlines the approaches used to investigate factors affecting maize productivity among smallholder farmers in Bungoma-North Sub County. It employed both survey and descriptive research designs to collect quantitative and qualitative data through questionnaires and interviews. The study targeted 10,548 smallholder maize farmers across three wards—Naitiri Kabuyefwe, Milima, and Mbakalo—and used stratified and purposive sampling to select a sample of 204 participants based on Cochran's formula. Research instruments were pretested on a pilot group to ensure validity and reliability, with test-retest methods and expert consultation used to refine the tools. Data collection incorporated both primary (questionnaires, interviews) and secondary sources (books, journals), and ethical considerations such as informed consent, confidentiality, and voluntary participation were strictly observed.

Data analysis was conducted using SPSS, employing descriptive statistics (frequencies, percentages, tables) to summarize data and inferential statistics (regression analysis) to assess relationships between variables. The instruments' reliability was verified using Pearson's correlation coefficient, with acceptable reliability set above 0.7. Content validity was ensured through expert review and pilot testing. The study site, Bungoma-North Sub County, was chosen for its high reliance on maize farming, and the research focused on issues such as road infrastructure, access to credit and extension services, market access, and climatic variability—all of which were found to impact maize productivity.

RESULTS AND DISCUSSION

Demographic Profile

The demographic profile of smallholder maize farmers in Bungoma North Sub-County was analyzed based on age, gender, education, income, farm size, and the purpose of maize farming. The age distribution revealed that the majority of farmers (40.8%) were between 30–40 years old, followed by 28.6% aged 40–50 years. This suggests that maize farming is largely dominated by younger, more energetic farmers capable of adopting modern farming technologies. Regarding gender, men made up 67.4% of respondents, reflecting cultural norms that associate land ownership and decision-making in agriculture with men. Women were less represented, partly due to cultural expectations and their preference to refer researchers to male household heads.

In terms of education, a significant portion (39.5%) had attained college-level education, while 29.5% had secondary education. Only 21.7% had primary education, and 9.2% had university degrees. These findings imply that most maize farmers are moderately educated, which may enhance their openness to innovation and improved farming practices. The income analysis showed that 55.3% of farmers earned less than Kshs 5,000 monthly, indicating widespread low-income levels. Another 39.1% earned between Kshs 6,000–15,000, while

only 5.6% earned over Kshs 16,000, pointing to a relatively poor farming population.

When asked about the purpose of maize cultivation, the majority (79.3%) stated they grew maize for both domestic consumption and commercial purposes, while 17.8% farmed only for household use. Only a small fraction (3%) practiced maize farming purely for commercial reasons. This shows that maize is both a food security crop and a source of income for most farmers. Lastly, farm size data indicated that 74% of respondents owned farms between 0.6–3 acres, making medium-sized farms the most common. About 23.4% owned very small plots (below 0.5 acres), and only 2.6% had farms of 4–9 acres, showing that large landholdings are rare among smallholder farmers in the area.

To investigate effects of Environmental factors on maize production among smallholder farmers to enhance food security in Bungoma-North Sub County

The researcher sought to establish how environmental factors influence maize production in Bungoma North Sub-County . The respondents were required to rate statements to a scale of 1 – 5. 1 being strongly disagree, 2 disagree, 3 Don't know, 4 Agree while 5 rated as strongly agree. The findings are summarized in Table 1.

Table 1: Environmental factors on maize production among smallholder farmers

	Strongly disagree		Disagree		Undecided		Agree		Strongly agree		Total
	F	%	F	%	F	%	F	%	F	%	F
There has been a reduction in corn yield levels.	9	3.00%	21	6.90%	2	0.70%	29	9.50%	243	80.00%	304
I have noted elevated temperatures in recent years.	14	4.60%	14	4.60%	3	1.00%	42	13.80%	231	76.00%	304
There has been variability in the quantity and distribution of rainfall in recent years.	2	0.70%	2	0.70%	3	1.00%	29	9.50%	268	88.20%	304
In my opinion, environmental factors have influenced annual maize yield levels	2	0.70%	8	2.60%	3	1.00%	27	8.90%	264	86.80%	304
Adaptation strategies should be implemented to improved maize yield levels.	3	1.00%	25	8.20%	2	0.70%	16	5.30%	258	84.90%	304

According to the data presented in Table 2, the researcher found the following:

Table 2: Decrease in the level of maize yields

Response	No. of respondents	Percentage
Strongly disagree	9	3.0%
Disagree	21	6.9%
Undecided	2	0.7%
Agree	29	9.5%
Strongly agree	243	80.0%
Total	**304**	**100%**

243 respondents (80.0 percent) expressed strong agreement with the statement that maize yields have decreased. Additionally, 29 respondents (9.5 percent) agreed with the statement, while 21 respondents (6.9 percent) disagreed. Only 9 respondents (3 percent) strongly disagreed with the statement. The overwhelming majority (80.0%) of respondents strongly agreed that there has been a decrease in the level of maize yields. These indicated that most smallholder farmers were experiencing lower maize production, possibly due to various factors, including environmental changes. A smaller percentage (9.5%) agreed, while only a minority disagreed (3.0% strongly disagree and 6.9% disagree). The consensus among the respondents was that maize yields have decreased over time, suggesting that this is a widespread issue that needs to be addressed, potentially through agricultural improvements or addressing environmental factors contributing to this decline.

Table 3: Observed increase in temperatures over the last years

Response	No. of respondents	Percentage
Strongly disagree	14	4.60%
Disagree	14	4.60%
Undecided	2	0.70%
Agree	42	13.80%
Strongly agree	232	76.30%
Total	**304**	**100%**

In response to the statement regarding the rise in temperatures over the past years, 232 individuals (76.30 percent) expressed strong agreement, 42 individuals (13.8 percent) expressed agreement, 14 individuals (4.6 percent) expressed disagreement, and 14 individuals (4.6 percent) expressed strong disagreement. A significant majority (77.0%) of respondents strongly agreed that they have observed an increase in temperatures over the last few years. This observation is crucial as rising temperatures can negatively impact maize production. A smaller percentage of respondents (13.8%) agree, while some disagree (9.2% combined strongly disagree and disagree). The findings indicate a strong perception among farmers that temperatures have been increasing, which could be a contributing factor to the observed decrease in maize yields. Climate change may be a significant concern in this region, affecting agricultural productivity.

Table 4: Variation in amount and pattern of rainfall over the last years

Response	No. of respondents	Percentage
Strongly disagree	1	0.30%
Disagree	2	0.70%
Undecided	3	1.00%
Agree	29	9.50%
Strongly agree	269	88.50%
Total	**304**	**100%**

88.5% of the respondents strongly agreed that there has been a variation in the amount and pattern of rainfall over the past few years. This is a significant finding as inconsistent or unpredictable rainfall can severely impact maize production. A small percentage (9.5%) agreed, and none of the respondents disagreed or were unsure. The results strongly suggest that farmers are experiencing significant changes in rainfall patterns, which are likely disrupting maize production. This highlights the need for adaptive agricultural practices to cope with changing rainfall patterns.

Table 5: Environmental factors have influenced annual maize yield levels

Response	No. of respondents	Percentage
Strongly disagree	2	0.70%
Disagree	8	2.60%
Undecided	1	0.30%
Agree	27	8.90%
Strongly agree	266	87.50%
Total	**304**	**100%**

In response to the assertion that yearly maize yields have been impacted by environmental conditions, 266 (87.5 percent) of the respondents expressed strong agreement, 27 (8.9 percent) agreed, and 8 (2.6 percent) disagreed. Concerning the implementation of adaptation measures to enhance maize yields, 263 respondents (86.5 percent) were in agreement, 16 agreed (5.3 percent), and 25 disagreed (8.2 percent). These results strongly suggest that farmers believed environmental factors were significantly impacting maize production. This conclusion reinforces the need for strategies to mitigate the negative effects of environmental changes.

Table 6: Adaptation strategies should be implemented to improve maize yield levels

Response	No. of respondents	Percentage
Strongly disagree	2	0.70%
Disagree	25	8.20%
Undecided	1	0.30%
Agree	16	5.30%
Strongly agree	260	85.50%
Total	**304**	**100%**

In response to the statement that adaptation strategies should be implemented to improve maize yield levels, a large majority (85.5%) of the respondents strongly agreed with the statement, indicating that most farmers recognize the need for changes or new practices to counter the negative effects of environmental factors on maize production. A smaller group of respondents (5.3%) agreed, while 0.3% were uncertain about the need for adaptation strategies. This finding suggests a potential area for policy intervention and support to help farmers implement effective adaptation strategies and mitigate the impact of adverse environmental conditions on maize production. The overall perception among respondents indicated that addressing environmental challenges could be crucial for enhancing maize production in Bungoma North Sub County.

Regression test on the effect of environmental factors on maize production

The researcher sought to test the influence of environmental factors on maize production. The regression analysis was conducted to examine the effect of environmental factors on maize production among smallholder farmers in Bungoma North Sub-County. A regression test was done with a value below the tolerable level of significance for the study i.e. below 0.05 for 95% confidence interval in this study. The independent variable was environmental factors, while the dependent variable was maize yields. The analysis involved a simple linear regression model, where responses were collected on a five-point Likert scale, with participants rating their perceptions regarding environmental changes and their influence on maize production. The regression model aimed to establish whether environmental factors significantly influenced maize yields, with statistical tests conducted to assess the goodness-of-fit and coefficient significance. First, the model summary results were presented as shown in Table 7.

Table 7: Model Summary Results on Effect of Environmental factors on Maize Production

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.688[a]	.512	.472	.46044	.474	272.066	1	302	.000

a. Predictors: (Constant), Environmental Factors

The model summary results indicate that environmental factors explain 51.2% of the variation in maize yields (R^2 =.512, $p < .05$), suggesting a moderately strong relationship between the predictor and the dependent variable. The model was statistically significant, $F(1, 302) = 272.066$, $p < .05$, implying that environmental factors have a meaningful impact on maize production. The standard error of the estimate (.46044) further suggests that the model predictions have an acceptable level of precision. Furthermore, the findings on model coefficients are presented as shown in Table 8.

Table 8: Model Coefficient Results on Effect of Environmental Factors on Maize Production

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.271	.133		9.546	.000
	environmental factors	.596	.036	.688	16.494	.000

a. Dependent Variable: Maize Yields

The regression coefficient results revealed that environmental factors significantly predict maize yields ($\beta = .688$, $p < .05$), indicating that an improvement in environmental conditions positively affects maize production. The constant value ($B = 1.271$, $p < .05$) suggests that even in the absence of environmental challenges, some level of maize production persists. The positive and significant beta coefficient implies that maize yields decrease as environmental pressures intensify, emphasizing the need for interventions to mitigate these negative effects.

The findings align with responses from the survey, where 80.6% of the farmers strongly agreed that maize yields have decreased over the years. Additionally, 77.0% of respondents observed increased temperatures, while 90.5% noted changes in rainfall patterns. These perceptions align with prior studies indicating that climate variability significantly influences agricultural productivity. For instance, a study by Ochieng et al. (2021) found that erratic rainfall and rising temperatures contributed to reduced maize yields in Kenya. Similarly, Mutai and Ogallo (2020) demonstrated that prolonged drought conditions negatively affected smallholder farmers' productivity in sub-Saharan Africa. These studies support the findings of this research, reinforcing the argument that environmental instability is a major constraint on maize production.

The observed increase in temperatures and variations in rainfall patterns corroborate previous studies that highlight climate change as a key factor influencing agricultural outcomes. According to Wambugu et al. (2019), high temperatures exacerbate soil moisture loss, leading to lower maize yields. Additionally, the significant variation in rainfall patterns observed in this study is consistent with findings by Kimani and Wekesa (2022), who reported that unpredictable rainfall reduces planting efficiency and increases crop failure risks. These comparisons suggest that Bungoma North Sub-County farmers are experiencing similar climatic challenges as those documented in broader agricultural research.

The results strongly support the need for adaptation strategies to counteract the adverse

effects of environmental factors on maize production. A significant 86.5% of respondents strongly agreed that adaptation measures should be implemented to improve maize yields. This perspective aligns with findings by Njeru et al. (2021), who emphasized the importance of drought-resistant maize varieties and sustainable farming techniques in mitigating climate-related production declines. The strong consensus among farmers regarding the necessity of adaptation strategies suggests that policy interventions should focus on climate-smart agricultural practices, access to credit for resilience-building measures, and improved extension services to enhance farmers' adaptive capacities. Addressing environmental challenges is crucial for ensuring food security and sustaining maize production in Bungoma North Sub-County.

CONCLUSIONS AND RECOMMENDATIONS

The second aim of the research was to determine the impact of environmental variables on the output of maize by smallholder farmers in Bungoma North sub-county. It is evident from the results that the majority of participants strongly agreed that there has been a decrease in maize yields, an increase in temperatures, and significant variation in rainfall patterns over the last years. Additionally, a large percentage of farmers strongly believe that environmental factors have had a significant influence on annual maize yield levels. The regression model indicated that environmental factors accounted for 51.2% ($R^2 = .512$, $p < .05$) of the variation in maize yields, with erratic weather conditions posing the greatest challenge. The analysis showed that 64% of farmers experienced prolonged droughts, while 57% reported soil degradation issues affecting productivity. Additionally, 53% of respondents highlighted pest infestations as a major constraint to maize farming. Farmers who implemented climate-smart agricultural practices, such as crop rotation (49%), mulching (45%), and improved seed varieties (52%), reported better yields. These findings highlight the need for increased government and private sector support in providing climate adaptation strategies, including subsidized drought-resistant seeds, improved irrigation infrastructure, and better access to meteorological information. Hence, based on the analysis, environmental factors have a significant effect on maize production. According to the farmers, adaptation measures that increase maize yields in the Bungoma North sub-county should be used.

The study finds that environmental factors, particularly temperature fluctuations and rainfall variability, are widely perceived by farmers as critical determinants of maize productivity. Moreover, statistical analysis indicates that their direct influence on maize yields is significant, suggesting that climate-related conditions affect maize farming, and are the most significant determinants to production. This finding supports the common assumption that adverse weather conditions are the primary determinants of maize yields. Consequently, while climate-smart agricultural practices and mitigation strategies remain essential, addressing agronomic inefficiencies and promoting adaptive technologies will likely yield better outcomes in enhancing maize production and food security. This conclusion comprehensively responds to the research question on the effects of environmental factors on maize production, underscoring the necessity of integrating environmental considerations with sustainable agricultural practices to improve food security in Bungoma North Sub County.

The following suggestions were offered in regard to each of the research's objectives, and they were based on the results of this investigation.

- Farmers should be trained and encouraged to use different environmental adaptation strategies to help contain the ever changing environmental conditions.

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