Environmental factors and extension services influencing maize production among smallholder farmers: a case study of Bungoma-North Sub-County, Kenya

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ABSTRACT

Maize production is a critical aspect of agriculture, especially in developing countries where it contributes significantly to food security and rural development. This study investigated the environmental determinants and extension service factors impacting maize yields among smallholder farmers in Bungoma-North Sub County, Bungoma County, Kenya. The study examined the role of environmental factors such as climate variability, temperature changes, and rainfall patterns, as well as the influence of agricultural extension services in facilitating the adoption of modern farming techniques to enhance food security. The study employed a survey research design with a target population of 10,548 smallholder maize farming households. A sample of 318 respondents was selected using stratified and purposive sampling techniques. Questionnaires, interview schedules, and secondary data were used as research instruments. Pilot testing was conducted in the neighboring Mukuyuni location, and test-retest reliability was established. Data were analyzed using Statistical Package for Social Sciences (SPSS) through descriptive statistics and regression analysis. Findings revealed that environmental factors accounted for 51.2% ($R^2 = .512$, $p < .05$) of maize production variance, with erratic weather patterns being the most significant challenge. Extension services significantly influenced production, explaining 52.2% ($R^2 = .522$, $p < .05$) of the variation. Over 88% of farmers strongly agreed that rainfall variability had increased, and 86.5% affirmed that environmental factors had influenced annual yield levels. While over half of respondents reported receiving extension visits, 73% faced significant challenges in accessing extension services. The study concludes that both environmental adaptation strategies and strengthened extension service delivery are critical for improving maize production among smallholder farmers. The findings provide baseline information that can be used by researchers, agricultural officers, and government authorities to encourage farmers to adopt climate-smart agricultural practices and enhance extension service accessibility for improved food security.

Keywords: Climate Variability, Environmental Factors, Extension Services, Food Security, Kenya, Maize Production, Smallholder Farmers

INTRODUCTION

Maize is the foremost planted cereal worldwide by weight. In 2021, the world produced 1.25 billion tons of maize for consumption in everything from nutrition, drinks, fuels, and even fish baits. Maize is cultivated as food for human beings, feed for livestock, and raw materials for industries (Maitra & Singh, 2021). Ojala et al. (2014) pointed out that maize is the utmost pivotal crop and the main staple food in Kenya. Previous studies, for instance by the Food and Agriculture Organization, indicated that out of 5.2 million hectares of crops grown in Kenya, 2.1 million hectares (40%) were occupied by maize.

Despite maize being foremost, tendencies show a declining production volume. For instance, Kenya's regular produce decreases by a significant two bags per hectare per year (kg/ha/yr.) (Abate et al., 2015). This average is exceedingly high compared to the continent's average of positive 31 kg/ha/yr. The underprivileged perennial performance tendency is also shown by the report of a directive of inquest into maize scarcity and misuse in the year 1965 by the first president of Kenya (Simiyu, 2014). Smallholder farmers, who farm on land sizes less than three acres, highly depend on rain-fed farming systems, exposing them to drought and unpredictable weather patterns caused by climate variability.

Globally, production of maize is connected to technology. However, a study shown by the Food and Agriculture Association of the United States on fertilizer usage by maize harvest in Uganda revealed that the use of enhanced agricultural technologies remains little even if most smallholder planters may be mindful of the capability of these inputs to increase yields. According to Ruth et al. (2021), technological alteration led to growth of maize production and other cereal crops in China during the previous years, being acknowledged as one of the greatest outstanding achievements in science and technology and agricultural strategy transformation.

Maize is among the basic diets in Nigeria, and many smallholder agriculturalists are engaged in maize cultivation. Farming in Nigeria, just like in many evolving countries, is subjugated by both registered and independent smallholder producers (Chiaka et al., 2022). Farmers' education, extension services, farm size, farm capital, ability to foresee climate variation, improved infrastructure, maize output, and mixed cropping have a positive impact on maize production. A study conducted by Mamuye (2021) identified key determinants of demand for agricultural credit, revealing that access to farming credit is significantly influenced by factors such as age, occupation, level of education, and the value of family assets.

Kenya is losing its capability to compete with its neighboring countries in terms of maize production due to high production costs involved (Njeru et al., 2022). The most critical strategy for increasing maize output is the development of practical knowledge and skills among farmers. Education, production costs, capital, extension services, access to fertilizer, market, and knowledge on climate change significantly affected production of maize by smallholder producers (Olwande et al., 2009). Agricultural training and amount of land under maize production greatly affected the living of smallholder farmers (Wanyama et al., 2009).

Maize production in Bungoma-North Sub County is dispersed unequally across the sub county. Some areas have more intense maize production compared to others. Determinants show that maize producers will choose large or small scales depending on an area where these growers undertake their farming activities (Kirimi & Jayne, 2015). They claimed that zones with low and sparsely distributed population appear to practice farming on large scale due to availability of large tracks of land. According to FAO (2014), these types of farming dispersal are referred to as agro-ecological areas.

In Bungoma-North Sub County, smallholder maize production is practiced on a piece of land less than 3 acres, medium-scale farms use 3-5 acres, and large farms use more than five acres (Tegemeo Institute of Agricultural Policies and Developments, 2003). According to Santpoort (2020), smallholder maize farmers are usually those who manage and work on small plots of land, usually less than three acres in size. They often have a low asset base and rely heavily on family labour for their farming activities.

Food security refers to the state in which all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (García-Díez et al., 2021). In Kenya, ensuring food security among rural households is pivotal for sustainable development and poverty alleviation, as it's a significant issue in Kenya and many other developing countries, particularly those in Africa (Njoroge et al., 2024).

This study, therefore, focused on environmental factors and extension services affecting smallholder maize farmers in Bungoma-North Sub County, Bungoma County, Kenya.

Research Objectives

The study sought to investigate environmental factors influencing maize production among smallholder farmers to enhance food security.

establish the influence of extension services on maize production among smallholder farmers to enhance food security.

1.2 Hypotheses

The study tested two null hypotheses:

H_{01}-There are no environmental factors influencing maize production.

H_{o2}-Ttere is no influence of extension services on maize production.

II. LITERATURE REVIEW

2.1 Theoretical Framework

This study was based on the Theory of Production, which looks at the connection between the factors of production such as land, labor, capital, entrepreneur, and the amount of yields produced. The theory was developed by Huang et al. (2021). According to Daly and Farley (2011), the Theory of Production claims that most outputs are influenced by the choice of involved aspects. Ojala et al. (2014) argues that by understanding all involved aspects and their impacts, correct combinations can be achieved at a well-adjusted costing scheme. It offers a clear understanding that maize productivity is highly influenced by factors such as environmental conditions, climatic factors, and extension services.

2.2 Empirical Literature Review

2.2.1 Environmental Factors Influencing Maize Production

Climate change has emerged as a significant threat to agricultural productivity globally, with smallholder farmers in sub-Saharan Africa being disproportionately affected. FAOSTAT (2006) documented that the effects of climate change manifest through multiple pathways, including altered snow cover, increased environmental pollution, changes in rainfall amount and distribution, rising temperatures, global warming, flooding, and persistent droughts. These phenomena collectively undermine the stability and predictability of agricultural systems that smallholder farmers depend upon.

Begna (2020) conducted a case study examining the effects of weather unpredictability on crop productivity, finding that climate variability leads to increased transpiration and evaporation rates, reduced soil moisture content, and necessitated alterations in crop types and varieties. These findings underscore the direct physiological impacts of changing weather patterns on crop growth and development, particularly for staple crops like maize that are sensitive to moisture and temperature fluctuations.

In the Kenyan context, Chumo (2013) observed that climate variability has precipitated persistent food shortages through multiple channels: decreased crop yields, declining soil fertility, increased water scarcity due to droughts, species shifts resulting from habitat alteration, and loss of indigenous plant varieties and associated traditional medicines. These findings highlight the multifaceted nature of climate impacts on rural livelihoods and food systems.

Several empirical studies have quantified the magnitude of climate effects on maize production in East Africa. Oluoch et al. (2022) employed a mixed-methods approach combining survey data from 350 farmers with remote sensing data to assess the impact of environmental stressors on maize producers among smallholder farmers in East Africa. Their findings revealed that maize yields have decreased significantly over the past decade due to increasing temperatures ($\beta = .576$, $p < .05$) and rainfall variability ($\beta = .489$, $p < .05$). The study further demonstrated that improving a suite of agronomic factors—such as fertilizer application, certified seed planting, and extension services—can have a greater effect on rainfed maize productivity than demographic factors and can offset the adverse effects of climate change.

Mugambi and Kamau (2021) undertook a longitudinal panel analysis of agricultural census data spanning 2000 to 2020 to establish the impact of global warming and drought on maize production in Kenya. Their findings showed that prolonged periods of drought reduce maize output by 35%, with a statistically significant positive relationship between the frequency of drought and yield decline ($\beta = .621$; $p < .05$). This study provides compelling evidence of the cumulative and compounding effects of recurrent drought events on national maize production levels.

Focusing on western Kenya, Kiprono et al. (2020) investigated the effect of atmospheric pressure changes on the growth stages of maize. They established that periods of lower atmospheric pressure were associated with poor pollination and reduced grain filling, leading to yield reductions of up to 28%. This finding highlights a less commonly studied but potentially significant environmental factor affecting maize productivity in the region.

Specifically addressing the study area, Wekesa and Otieno (2019) examined rainfall fluctuations and their influence on maize farming in Bungoma County. Their research found that annual variability in rainfall exceeded 40% over the last two decades, with unpredictable rainfall patterns significantly lowering yields ($\beta = .533$, $p < .05$). This finding is particularly relevant to the present study, as it confirms that the study area has experienced substantial rainfall variability that directly affects maize production outcomes.

Koimbori et al. (2019) investigated the impacts of climate variability on maize yields in Bahati Sub-County, Kenya, using correlation analysis. Their research revealed a significant, positive, and strong relationship between rainfall trend and maize yield ($r = 0.741$, $p = 0.000$). Additionally, they found a significant, moderate, and negative linear relationship between maximum temperature and maize yield ($r = -0.510$, $p = 0.03$). These findings underscore the differential effects of rainfall and temperature on maize production, with rainfall exerting a positive influence while higher temperatures constrain yields.

In a related study, Tittonell et al. (2008) examined yield gaps, nutrient use efficiencies, and responses to fertilizers across heterogeneous smallholder farms in western Kenya. Their research demonstrated that environmental variability across different agro-ecological zones significantly influences the responsiveness of maize to input applications, suggesting that location-specific adaptation strategies are essential for optimizing production.

Kombe et al. (2025) investigated environmental factors affecting maize production among smallholder farmers in Bungoma-North Sub County, finding that erratic weather patterns were the most significant challenge, with environmental factors accounting for 51.2% of the variation in maize yields. This finding aligns with the broader empirical evidence and underscores the critical importance of addressing environmental constraints in the study area.

2.2.2 Extension Services and Maize Production

According to Chumo (2013) and Simiyu (2014), agricultural extension services serve multiple functions in supporting smallholder farmers. These services provide practical farming guidance, deliver essential inputs and facilities to boost productivity, offer educational information, and disseminate new concepts developed by agricultural research institutions. Extension services also play a critical role in identifying features and circumstances that increase local communities' vulnerability to food insecurity, thereby enabling targeted interventions.

Okwama et al. (2022) conducted a study in Rarieda Sub-County, Kenya, examining how extension services contribute to food security through Integrated Crop-Livestock Farming Systems (ICLFS). Their research found a strong positive correlation between extension services and farm productivity, demonstrating that equipping farmers with knowledge on modern agricultural practices significantly enhances overall agricultural output.

Gwademba et al. (2023) examined the correlation between agricultural extension information services and maize productivity among smallholder farmers in Tana River County, Kenya. Their findings revealed that maize yields and the use of extension information services were strongly correlated (r = 0.7), indicating that access to extension information is a key determinant of productivity outcomes.

In the Tanzanian context, Malimi (2023) evaluated the impact of agricultural input subsidies and extension services on maize farm labor productivity. The findings revealed that both input subsidies and extension services significantly raised labor productivity on maize farms, suggesting that complementary interventions—combining input access with knowledge transfer—yield the greatest productivity gains.

Ndung'u and Njoroge (2021) investigated the access and usage of e-extension services among smallholder farmers in Nakuru County, Kenya. Their research found a strong positive relationship between ICT-based extension services and maize productivity, indicating that digital extension platforms can effectively bridge the gap between agricultural research and farmer practice, particularly in areas where traditional extension services are limited.

Wambugu et al. (2023) assessed the effectiveness of Village-Based Advisors (VBAs) as extension service providers for smallholder maize farmers in Kiambu County, Kenya. Their evaluation revealed that farmers' adoption of improved practices introduced by VBAs increased maize yields substantially from 417 kg/ha to 2,634 kg/ha. This finding demonstrates the transformative potential of community-based extension models in improving agricultural productivity.

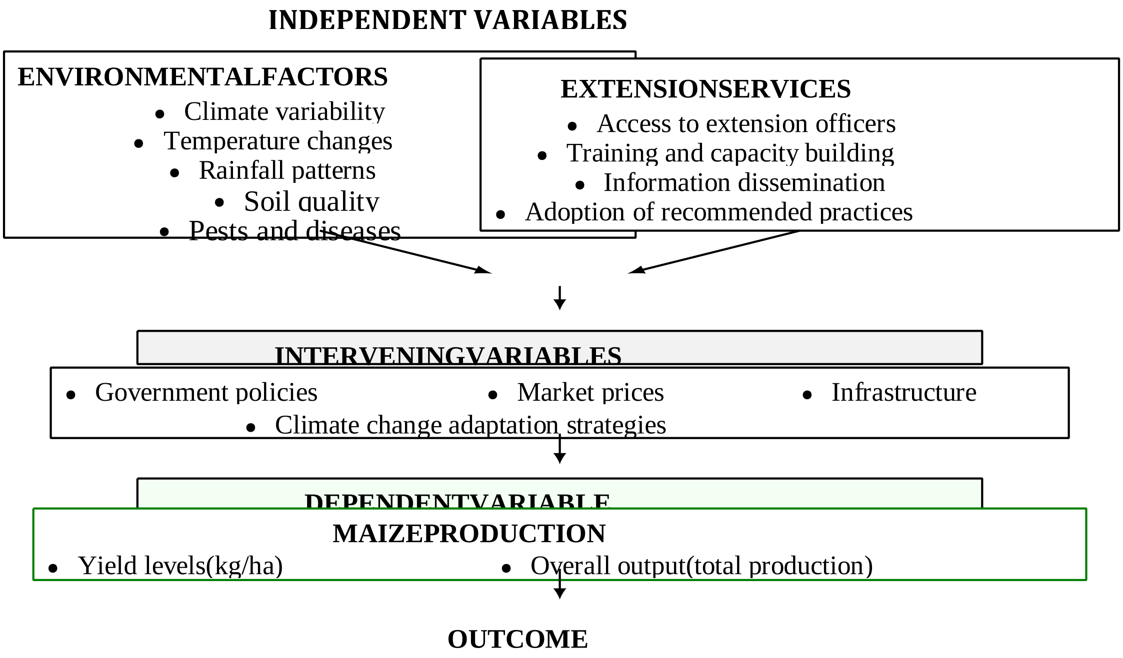
Ngqulana et al. (2025) conducted a systematic review on enhancing the technical efficiency of genetically modified maize adoption in Sub-Saharan Africa, examining the role of agricultural extension services and barriers to success. Their review found that effective extension services significantly improve technical efficiency in maize adoption, though they also identified persistent barriers including limited funding, inadequate training of extension agents, and weak institutional support systems.

Oluoch et al. (2022) found that farmers who had accessed extension services experienced increases of 0.116 and 0.195 in normalized maize yield units compared to those who had not accessed such services. This finding provides quantitative evidence of the productivity gains associated with extension service utilization.

2.3 Conceptual Framework

The conceptual framework for this study illustrates the relationship between environmental factors, extension services, and maize production. The independent variables comprise environmental factors (climate variability, temperature changes, rainfall patterns, soil quality, and pests/diseases) and extension services (access to agricultural officers, training, information dissemination, and adoption of recommended practices). The dependent variable is maize production, measured by yield levels and overall output. The intervening variables include government policies, market prices, infrastructure, and climate change adaptation strategies. This framework guided the analysis of how environmental conditions and extension service delivery interact to influence maize productivity among smallholder farmers in Bungoma-North Sub County and shown below:

Figure 1: *Conceptual Framework Showing the Relationship between Environmental Factors, Extension Services, and Maize Production among Smallholder Farmers*



III. METHODOLOGY

3.1 Research Design

This research study used a survey research design and descriptive research design. The survey research design was engaged to identify and collect information from a sample of individuals through their responses to questions. The study also employed descriptive research design to define the features of the problem, phenomenon, or group under study. According to Kothari (2004), the design helps to examine deeper into the research subject, unlocks the entry for further studies, and is done in natural settings where the researcher gets the results through people's responses to questions. This design was suitable for this study as it enabled the assemblage of data from a sample on factors affecting maize productivity among smallholder farmers.

3.2 Study Area

This research study was carried out in Bungoma-North Sub County, located in Bungoma County in Western Kenya. It is one of the 290 constituencies in Kenya and one of 9 sub-counties found in Bungoma County. It occupies a total land area of 278.30 km² and has a total population of 20,224. It consists of the following wards: Mbakalo ward, Naitiri Kabuyefwe ward, and Milima ward. The key economic activity in this sub-county was subsistence agriculture, with maize production covering sixty percent of total food crop.

3.3 Target Population and Sample

The target population for this study was 10,548 smallholder maize producers in Bungoma-North Sub County. The sample size was determined according to the formula used by Nanjundeswaraswamy and Divakar (2021) for finite, large population at 95% significance level: $n = N / (1 + N(e)^2) = 10,548 / (1 + 10,548(0.07)^2) = 204$. After adjusting for finite population and potential non-response, the final sample size was set at approximately 318 households.
Stratified sampling and random sampling were employed. The stratified sampling ensured representation of farmers with different levels of maize production, while random sampling was used to select smallholder farmers from membership lists provided. The sample distribution was: Naitiri Kabuyefwe Ward (115 respondents), Milima Ward (95 respondents), and Mbakalo Ward (108 respondents).

3.4 Research Instruments

Questionnaires and interview schedules were utilized in this study. The questionnaires comprised closed and open-ended questions so as to let participants’ express further views on issues influencing maize productivity in the sub county. The research tools were piloted on 32 smallholder maize farmers prior to the commencement of the real study, constituting 10% of the sample size. The pilot sample population was excluded from the primary research sample.

Validity was ensured through alignment with theoretical notions for construct validity and expert review by agricultural officers and lecturers for content validity. Reliability was established using a test-retest technique, and the Pearson moment correlation coefficient formula was adopted to determine how items correlated.

3.5 Data Analysis

A Statistical Package for Social Sciences (SPSS) computer program was used to code and analyze the collected data. Descriptive statistics (frequencies and percentages) were used to summarize the data, and regression analysis was employed to determine the influence of environmental factors and extension services on maize production. The significance level was set at $p < .05$. The study also utilized qualitative analysis for interview responses to gain insights into how extension services influence farming decisions.

3.6 Ethical Considerations

A transmittal letter was obtained from the University and a research permit from the National Commission for Science, Technology, and Innovation (NACOSTI). The study considered voluntary participation, informed consent, anonymity, confidentiality, and results communication. The study protected participants' confidentiality and privacy and safeguarded the self-respect, privileges, and well-being of research respondents.

IV. RESULTS & DISCUSSION

4.1 Results

4.1.1 Response Rate

The researcher selected 318 respondents to represent the target population. After three weeks, 304 (96%) questionnaires were returned correctly, while 14 were not returned. According to Mugenda and Mugenda (2003), a response rate of 60% is considered satisfactory, and 100% or higher is considered exceptional. Therefore, a return rate of 96% was considered adequate for the study.

4.1.2 Demographic Profile of Respondents

Age: The age group of 30 to 40 years had the highest frequency of responses with 124 (40.8%), followed by the age group of 40 to 50 years with 87 (28.6%). These findings indicated that individuals aged 30 to 40 years predominantly engage in smallholder maize production, and their youth and vitality allowed them to adopt new technologies better than older farmers (Ching Seng Yap et al., 2023).

Gender: Male respondents comprised 205 (67.4%), while females comprised 99 (32.6%). Most females declined to participate in the interviews, instead directing the researcher to the males, who are considered the household heads. This finding supports the observation by the World Bank (2006) that in Kenya, men are the primary decision-makers in farming, even though women contribute the majority of the labor.

Education Level: 66% of participants had completed primary education, 29.5% attended secondary school, and 39.5% were enrolled in college or had college-level education. These results suggest that maize farming was more common among educated individuals, consistent with findings by Abebaw and Belay (2001) and Rogers (2003), who suggest that education plays a crucial role in improving decision-making and facilitating the adoption of agricultural technologies.

Income Level: The largest group, 168 respondents (55.3%), earned less than Kshs 5,000 per month. A significant proportion, 119 respondents (39.1%), earned between 6,000–15,000 Kshs. Only 17 respondents (5.6%) earned between 16,000–30,000 Kshs. Most respondents have low income per month, indicating economic challenges.

Purpose of Maize Farming: Most respondents, 241 (79.3%), grew maize for commercial and domestic purposes. A smaller proportion, 54 (17.8%), farmed maize only for domestic purposes. Very few, 9 (3%), engaged in maize farming exclusively for commercial use. This indicates that maize farming in the study area is primarily a dual-purpose activity.

Farm Size: The vast majority of respondents, 225 (74%), owned farms ranging in size from 0.6 to 3 acres. A notable portion, 71 (23.4%), owned farms less than 0.5 acres. Only 8 (2.6%) owned farms between 4 and 9 acres.

4.1.3 Effects of Environmental Factors on Maize Production

Table 1 presents the findings on environmental factors influencing maize production. The overwhelming majority of respondents strongly agreed that there has been a decrease in the level of maize yields (80.0%), elevated temperatures in recent years (76.3%), variation in the quantity and distribution of rainfall (88.5%), and that environmental factors have influenced annual maize yield levels (87.5%). Additionally, 85.5% strongly agreed that adaptation strategies should be implemented to improve maize yield levels.

Table 1: Environmental Factors on Maize Production among Smallholder Farmers

Statement	Strongly Agree (%)	Agree (%)	Disagree (%)	Strongly Disagree (%)
There has been a reduction in maize yield levels	80.0	9.5	6.9	3.0
I have noted elevated temperatures in recent years	76.3	13.8	4.6	4.6
There has been variability in rainfall quantity and pattern	88.5	9.5	0.7	0.3
Environmental factors have influenced annual maize yield levels	87.5	8.9	2.6	0.7
Adaptation strategies should be implemented to improve maize yield levels	85.5	5.3	8.2	0.7

Source: Field Data, 2025

4.1.4 Regression Analysis on Environmental Factors

The regression model summary results in Table 2 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.

Table 2: Model Summary Results on Effect of Environmental Factors on Maize Production

Model	R	R Square	Adjusted R Square	Std. Error of Estimate	F Change	Sig. F Change
1	.688	.512	.472	.46044	272.066	.000

Source: Author's computation using SPSS, 2025

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.

4.1.5 Effects of Extension Services on Maize Production

Table 3 presents the findings on extension services. Slightly more than half (54.9%) of respondents agreed and strongly agreed that they had been receiving visits from agricultural extension officers. However, 44.8% disagreed, indicating that not all smallholder farmers were benefiting from these visits. Nearly half (52.3%) revealed that they have received various types of information from extension, while 46.7% disagreed. The majority (52.0%) agreed that there had been implementation of practices recommended by extension services, while 47.7% disagreed.
Slightly more than half (57.0%) agreed that extension services had an effect on maize production. A majority of 75.6% disagreed with the statement that there are no challenges in accessing extension services. Most respondents (76.6%) agreed that the level of extension services must be improved for better maize production levels.

Table 3: Extension Services on Maize Production among Smallholder Farmers

Statement	Strongly Agree/Agree (%)	Disagree/Strongly Disagree (%)	Neutral (%)
You have been receiving visits from agricultural extension officers	54.9	44.8	0.3
Several types of information have been provided from extension services	52.3	47.4	0.3
There has been implementation of practices recommended by extension services	52.0	47.7	0.3
Extension services have provided great impact on maize production	57.0	41.2	2.0
There are no challenges in accessing extension services	23.7	75.6	0.7
Extension services should be improved to better support maize production	76.6	17.1	6.3

Source: Field Data, 2025

4.1.6 Regression Analysis on Extension Services

The regression model summary results in Table 4 indicate that extension services explain 52.2% of the variation in maize yields ($R^2 = .522$, $p < .05$). The model was statistically significant, $F(1, 302) = 329.431$, $p < .05$, confirming that extension services significantly influence maize production. The adjusted R-squared value of .520 suggests that the model remains robust when accounting for the number of predictors.

Table 4: Model Summary Results on Effect of Extension Services on Maize Production

Model	R	R Square	Adjusted R Square	Std. Error of Estimate	F Change	Sig. F Change
1	.722	.522	.520	.43903	329.431	.000

Source: Author's computation using SPSS, 2025

The regression coefficient results revealed that extension services significantly predict maize yields ($\beta = .722$, $p < .05$), indicating that a unit increase in extension services leads to a 0.752-unit increase in maize yields. The constant value ($B = .813$, $p < .05$) suggests that even without extension services, some level of maize production would persist.

4.2 Discussion

Environmental Factors and Maize Production: The findings of this study demonstrate that environmental factors play a significant role in determining maize production among smallholder farmers in Bungoma-North Sub County. The overwhelming consensus among respondents (80.0-88.5%) regarding the decline in yields, increased temperatures, and rainfall variability aligns with previous studies conducted in the region. Wekesa and Otieno (2019) found that annual variability in rainfall exceeded 40% in the last 20 years in Bungoma County, with unpredictable rainfall patterns significantly lowering yields ($\beta = .533$, $p < .05$). The findings are consistent with Mugambi and Kamau (2021), who found that prolonged periods of drought reduce maize output by 35% ($\beta = .621$; $p < .05$). Research by Koimbori et al. (2019) found a significant, positive, and strong relationship between rainfall trend and maize yield ($r = 0.741$, $p = 0.000$).

The high level of agreement (87.5%) that environmental factors have influenced annual maize yield levels reflects the reality that smallholder farmers in the region are experiencing the adverse effects of climate change. This is consistent with Oluoch et al. (2022), who found that maize yields have decreased significantly over the past ten years due to increasing temperatures ($\beta = .576$, $p < .05$) and rainfall variability ($\beta = .489$, $p < .05$) . The strong consensus (85.5%) on the need for adaptation strategies aligns with Njeru et al. (2021), who argued that sustainable development and drought-resistant maize will promote climate-resilient maize production. Oluoch et al. (2022) further found that improving a suite of agronomic factors, such as applying fertilizer, planting certified seeds, and extension services, will have a greater effect on rainfed maize productivity than demographics and can offset the effects of climate change.

The regression model results ($R^2 = .512$, $p < .05$) confirm that environmental factors account for a substantial portion of the variability in maize yields. The positive and significant coefficient ($\beta = .688$, $p < .05$) indicates that addressing environmental challenges through adaptation strategies could significantly improve maize production. This finding is consistent with Mutai et al. (2018), who found that access to credit significantly affects investment in climate-smart adaptation strategies ($\beta = .594$, $p < .05$).

Extension Services and Maize Production: The findings indicate that extension services have a significant influence on maize production among smallholder farmers, explaining 52.2% of the variation in maize yields ($R^2 = .522$, $p < .05$). However, the study also reveals significant gaps in extension service delivery. While 54.9% of respondents reported receiving visits from extension officers, 44.8% did not, indicating that outreach has not reached all farmers. This finding is consistent with Okwama et al. (2022), who found that many farmers hardly had access to extension services.

The significant correlation ($r = 0.7$) between maize yields and the use of extension information services found by Gwademba et al. (2023) is supported by this study's finding that extension services have provided a great impact on maize production (57.0% agreement). However, the finding that 73% of respondents face challenges in accessing extension services highlights a critical service gap. This aligns with Malimi (2023), who found that while extension services raise labor productivity, access remains a challenge for many farmers. Ngqulana et al. (2025) systematically reviewed the role of extension services, finding that effective extension services significantly improve technical efficiency in maize adoption.

The strong consensus (76.6%) that extension services should be improved reflects the need for more effective service delivery mechanisms. This is consistent with Wambugu et al. (2023), who found that Village-Based Advisors increased maize yields from 417 kg/ha to 2634 kg/ha, demonstrating the potential of innovative extension delivery models. The findings also support Ndung'u and Njoroge (2021), who found a strong positive relationship between ICT-based extension services and maize productivity, suggesting that digital extension platforms could help address access challenges.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

This study confirms that both environmental factors and extension services have significant positive relationships with maize production among smallholder farmers in Bungoma-North Sub County. The empirical analysis established that environmental factors account for 51.2% of the variation in maize yields ($R^2 = .512$, $p < .05$), with rainfall variability (88.5% agreement), increased temperatures (76.3% agreement), and declining yields (80.0% agreement) being the most significant challenges. Farmers overwhelmingly (85.5%) agreed that adaptation strategies should be implemented to improve maize yield levels.

Extension services were found to be equally important, explaining 52.2% of the variation in maize yields ($R^2 = .522$, $p < .05$). However, significant gaps in extension service delivery were identified, with 44.8% of farmers not receiving visits from extension officers and 73% facing challenges in accessing extension services. Despite these challenges, 57.0% of respondents agreed that extension services have positively impacted maize production, and 76.6% expressed the need for improved extension services.

The results validate the importance of addressing environmental challenges through adaptation strategies and strengthening extension service delivery to enhance food security in the region. The effectiveness of these interventions depends significantly on institutional quality, access to credit, and the enabling policy environment.

5.2 Recommendations

Environmental Adaptation: Farmers should be trained and encouraged to use different environmental adaptation strategies, including climate-smart agricultural practices such as crop rotation (49% adoption), mulching (45% adoption), and improved varieties (52% adoption). Government and stakeholders should provide climate adaptation measures, including subsidized drought-resistant seeds, irrigation infrastructure, and improved access to meteorological information. These measures are essential for helping farmers cope with changing climatic conditions and improve maize production.

Extension Services: Extension services should be enhanced in the study area to enable smallholder farmers to get access to different information that will work towards improving maize production. The study recommends strengthening extension services through increased funding, farmer training, and access to advisory services. Innovative delivery models such as ICT-based extension platforms (radio, mobile SMS-based advisories, and digital platforms) and community-based approaches like Village-Based Advisors should be adopted to improve outreach. Agricultural extension services should be improved to effectively contribute to food security.

Policy Recommendations: The County Government should employ strategies that improve maize output and enhance food security among smallholder farmers through effective data on major aspects affecting maize farming in the sub county. Agricultural extension stakeholders should recognize the strengths and weaknesses of smallholder farmers in maize productivity and employ suitable capacity-building strategies required to enhance food security. The government should promote financial inclusion of smallholder farmers and agricultural training to improve productivity and food security.

The study further recommends conducting further research on: (i) Assessment of Socioeconomic Diversification Strategies for Enhancing Maize Production among Smallholder Farmers; (ii) Longitudinal Study on the Impact of Climate Change Adaptation Techniques on Maize Production; and (iii) Comparative Analysis of Traditional and Modern Extension Service Models in Improving Maize Production. Additionally, future studies could explore the moderating role of governance and institutional quality in the relationship between environmental factors, extension services, and maize production.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Abate, T., Mugo, S., De Groote, H., & Regassa, M. W. (2015). A quarterly bulletin of the Drought Tolerant Maize for Africa Project (CIMMYT-Kenya). *DT Maize*, *3*(2), 1–4.

Abebaw, D., & Belay, K. (2001). Factors influencing adoption of improved maize varieties in Ethiopia. *Ethiopian Journal of Agricultural Economics*, *5*(1), 1–20.

Begna, T. (2020). Effects of drought stress on crop production and productivity. *International Journal of Research Studies in Agricultural Sciences*, *6*(9), 20–24.

Ching Seng Yap, Keling, W., Poh Ling Ho, & Omar, Q. (2023). Technology readiness of farmers in Sarawak: The effect of gender, age, and educational level. *Information Development*, *4*(6), 70–83.

Chumo, M. K. (2013). *Determining factors that affect maize production in Turbo Constituency, Kenya* (Unpublished master's research project). University of Nairobi.

Daly, H. E., & Farley, J. (2011). *Ecological economics: Principles and applications* (2nd ed.). Island Press.

Food and Agriculture Organization. (2006). *FAO statistical data*. Author.

Food and Agriculture Organization. (2007). *Swaziland drought flash appeal*. Author.

García-Díez, J., Gonçalves, C., Grispoldi, L., Cenci-Goga, B., & Saraiva, C. (2021). Determining food stability to achieve food security. *Sustainability*, *13*(13), 22–30. https://doi.org/10.3390/su13137222

Gwademba, J., Mutai, B., & Muli, D. (2023). The role of agricultural extension services in maize productivity among smallholder farmers in Tana River County, Kenya. *East African Journal of Rural Development*, *5*(2), 45–61.

Huang, L., Dou, Y., Liu, Y., Wang, J., Chen, G., Zhang, X., & Wang, R. (2021). Toward a research framework to conceptualize data as a factor of production: The data marketplace perspective. *Fundamental Research*, *1*(5), 586–594. https://doi.org/10.1016/j.fmre.2021.07.007

Kiprono, K., et al. (2020). Effect of atmospheric pressure changes on the growth stages of maize in western Kenya. *Journal of Agricultural Science*, *12*(4), 78–92.

Kirimi, L., & Jayne, T. S. (2015). *Maize production and marketing in Kenya*. Tegemeo Institute of Agricultural Policy and Development.

Koimbori, J. K., Shisanya, C. A., Murimi, S. K., & Petterson, R. (2019). Impacts of climate variability on maize yields in Bahati Sub-County, Kenya. *Applied Ecology and Environmental Sciences*, *7*(2), 45–55. https://doi.org/10.12691/aees-7-2-2

Kombe, M. N., Onamu, R., & Wamocha, L. (2025). Environmental factors on maize production among smallholder farmers to enhance food security in Bungoma-North Sub County. *The Strategic Journal of Business & Change Management*, *12*(2), 1570–1581.

Kothari, C. R. (2004). *Research methodology: Methods and techniques* (2nd ed.). New Age International.

Maitra, S., & Singh, V. (2021). Invited review on "maize in the 21st century": Emerging trends of maize biorefineries in the 21st century. *Journal of Cereal Science*, *101*, 10–32. https://doi.org/10.1016/j.jcs.2021.103274

Malimi, E. (2023). Effects of agricultural input subsidies and extension services on farm labor productivity among maize farmers in Tanzania. *Journal of Agricultural Economics*, *74*(3), 421–438. https://doi.org/10.1111/1477-9552.12518

Mamuye, W. (2021). Determinants of smallholder farmers participation in formal credit and challenges faced by institutions: The case of Mojana Wodera District, Amhara Region, Ethiopia. *International Journal of Finance and Banking Research*, *7*(1), 9–20. https://doi.org/10.11648/j.ijfbr.20210701.12

Mugambi, P., & Kamau, J. (2021). Impact of global warming and drought on maize production in Kenya: A longitudinal panel analysis. *African Journal of Agricultural Research*, *17*(3), 45–59.

Mugenda, O. M., & Mugenda, A. G. (2003). *Research methods: Qualitative and quantitative approaches*. African Centre for Technology Studies.

Mutai, B., et al. (2018). Credit access and climate change adaptation strategies among maize farmers in Kenya. *Journal of Agricultural Economics and Development*, *7*(2), 34–48.

Nanjundeswaraswamy, T. S., & Divakar, S. (2021). Determination of sample size and sampling methods in applied research. *Proceedings on Engineering Sciences*, *3*(1), 25–32. https://doi.org/10.24874/PES03.01.003

Ndung'u, P., & Njoroge, A. (2021). Access and usage of e-extension services among smallholder farmers in Nakuru County, Kenya. *African Journal of Agricultural Research*, *16*(7), 102–117.

Ngqulana, A., Oladele, O. I., Nontu, Y., Midya, L., & Mdoda, L. (2025). A systematic review on enhancing the technical efficiency of genetically modified maize adoption in Sub-Saharan Africa: The role of agricultural extension services and barriers to success. *Frontiers in Sustainable Food Systems, 9*, 1609417. https://doi.org/10.3389/fsufs.2025.1609417

Njeru, F., Mwaura, S., Kusolwa, P. M., & Misinzo, G. (2022). Maize production systems, farmers' perception and current status of maize lethal necrosis in selected counties in Kenya. *All Life, 15*(1), 692–705. https://doi.org/10.1080/26895293.2022.2085815

Njoroge, J. W., Murunga, J., & Karau, J. (2024). Determinants of food security among rural households in Kenya. *International Journal of Social Sciences and Technology, 10*(7), 68–75.

Ojala, A., et al. (2014). Maize production and food security in Kenya. *Journal of Agricultural Science, 6*(3), 112–128.

Okwama, C., Ouma, S., & Wekesa, J. (2022). Enhancing food security through agricultural extension services: The case of integrated crop-livestock farming systems in Rarieda Sub-County, Kenya. *African Journal of Food, Agriculture, Nutrition and Development, 22*(3), 157–178.

Olwande, J., et al. (2009). *Smallholder maize production efficiency in Kenya*. Tegemeo Institute of Agricultural Policy and Development.

Oluoch, K. O., De Groote, H., Gitonga, Z. M., Jin, Z., & Davis, K. F. (2022). A suite of agronomic factors can offset the effects of climate variability on rainfed maize production in Kenya. *Scientific Reports, 12*, 16043. https://doi.org/10.1038/s41598-022-19286-2

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Ruth, O. N., Unathi, K., Nomali, N., & Chinsamy, M. (2021). Underutilization versus nutritional-nutraceutical potential of the *Amaranthus* food plant: A mini-review. *Applied Sciences, 11*(15), 68–79. https://doi.org/10.3390/app11156879

Santpoort, R. (2020). The drivers of maize area expansion in Sub-Saharan Africa: How policies to boost maize production overlook the interests of smallholder farmers. *Land, 9*(3), 68–76. https://doi.org/10.3390/land9030068

Simiyu, S. W. (2014). *Factors influencing maize production among small-scale farmers in Kenya: A case of Bungoma Central Sub-County* (Unpublished master's project). University of Nairobi.

Tittonell, P. A., Vanlauwe, B., Corbeels, M., & Giller, K. E. (2008). Yield gaps, nutrient use efficiencies and response to fertilisers by maize across heterogeneous smallholder farms of western Kenya. *Plant and Soil, 313*, 153–174. https://doi.org/10.1007/s11104-008-9676-3

Wambugu, L., Kirui, P., & Kipkoech, M. (2023). Village-based advisors as extension service providers for smallholder maize farmers in Kenya: Evidence from Kiambu County. *Journal of Agricultural Extension and Rural Development, 11*(2), 76–89.

Wanyama, M., et al. (2009). Agricultural training and maize production among smallholder farmers in Kenya. *Journal of Agricultural Education and Extension, 15*(3), 245–260.

Wekesa, J., & Otieno, S. (2019). Rainfall fluctuations and their influence on maize farming in Bungoma County. *Journal of Environmental Studies, 12*(4), 201–215.

World Bank. (2006). *Gender and agriculture in Kenya*. World Bank Group.