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Research Article

Determinants of Maize Production and Its Supply Response in Kenya

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Maize (*Zea mays* L.) is an essential crop in Kenya and its production has a direct implication on food and economic security. However, in Kenya, there is a gap between what is being produced and what is being consumed. This gap is growing and, hence, remains a policy concern. Under this backdrop, this study aimed to estimate thecombined contribution of maize area harvested, expenditure on fertilizers,number of tractors used, and maize seed quantity to national maize productionin Kenya using the Vector Error Correction Model (VECM) and Nerlove Model. The findings indicate that maize production in Kenya is negatively associated with maize area harvested, expenditure on fertilizers, and the number of tractors used. However, there is a positive relationship between maize production and maize seed quantity. The response of maize production depicted that the price of maize in the previous period determined the production levels in the current period positively; however, as we move further away, the price level in the fourth period depicted a negative relationship. This study recommended that the government provide an adequate quantity of maize seeds to boost maize production. It also recommended that farmers be educated on the proper use of fertilizers and the optimum use of tractors and land. Furthermore, the government needs to ensure a favorable and stable price for farmers to contribute to increased maize production.

1. Introduction

The Kenyan government is committed to attaining a food secure, healthy, productive, and wealthy nation that assures its citizens the right to be free from hunger and to have adequate food of acceptable quality [1]. The maize subsector significantly contributes to Kenya's economy through foreign exchange earnings, a source of family income, employment creation, and food security. As a result, Kenya appears on the list of African countries with the highest consumption of maize. However, there is a negative relationship between maize production and consumption trends in Kenya. Over the years, maize production has revealed a declining trend, whereas consumption has increased. For instance, in 2017, 2016, and 2015, maize consumption was seen to be 4.55, 3.85, and 4.15 million tons, respectively, with a production of 3.186, 3.339, and 3.825 million tons, respectively [2]. Despite this increasing gap, empirical study to estimate the combined contribution of the factors of production to maize production is still missing.

In addition, farmers' responses to maize prices have not been on target, thus exhibiting reactionary behaviors. For instance, in 2014, when the price per 100 kg was at 3,318.49 Kenyan Shilling (Kshs.), the maize production was 39 million bags. In response to this high price compared to the 2013 price of Kshs. 3,133.16 per 100 kg, production jumped to 42.5 million bags in 2015 (an increase of 8.97% in one year), but the price dropped to Kshs. 2,870.08 per 100 kg in 2015. This, in turn, led to a decline in production in 2016 to 37.8 million bags, a reduction of 11.06% [3]. This demonstrates how farmers' responses to the price of maize are reactionary, irrational, and always delayed. This, therefore, presents a challenge to maize farmers, which needs to be evaluated and an answer sought.

This study, therefore, sought to evaluate the combined contribution of maize area harvested, expenditure on fertilizers, the number of tractors used, and maize seed quantity to national maize production in Kenya. It is important to note that recent studies that have been done on determinants of maize production have only researched factors that contribute to maize production [4–10]. In contrast, this study went a step further to analyze the combined contribution of the four inputs to maize production in Kenya. These inputs are considered vital in the Kenyan setup since most maize farmers widely employ them. In addition, this study also analyzed the supply response of maize production to the maize price.

2. Literature Review

Production theory provides principles that help an individual/firm decide how much output it will produce and how much of the inputs, that is, labor, fixed capital goods, etc., they will use to achieve optimal results [11]. It also aims to achieve maximum production by combining factors at the lowest possible cost.

The input-output relationship was extensively analyzed by the use of the Cobb–Douglas production function. Cobb and Douglas [12] did research to demonstrate America's economy in the years 1899 to 1922. In that study, they believed that production is a function of the aggregate labor used and the aggregate capital utilized, despite many more factors determining economic performance.

Besides, utility maximization theory has been extensively employed [13] to describe the choice of inputs used by farmers. A farmer would select an input if the satisfaction obtained from the input is greater than the utilization of other inputs.

Mohammed [14] found that farmers who had income from nonfarm sources used that income to invest in agricultural inputs for maize production, resulting in increased maize production. Similarly, the size of the cultivated land areas had a positive influence on the quantity of maize production. Naseem et al. [15] found that the number of improved maize varieties released and the share of area under improved varieties have no impact on maize yields. Ombuki [16] also found that the key factors influencing maize production are land tenure systems that are practiced, lack of use of high-yielding maize varieties, household income, number of extension visits, and acreage devoted to maize cultivation. Kirimi et al. [17] found that use of subsidized fertilizer in place of commercial fertilizer by small-scale farmers saved them Kshs. 178 per 90 kg bag. Further, large-scale farmers received higher prices, resulting in better revenues as compared to small-scale producers. Scheiterle and Birner [18] found that production systems with yields above the national average of 1.5 Mt/ha are profitable at a private level and contribute to the growth of the national economy. Farming systems producing below this threshold report negative social profits, implying that they do not use scarce resources efficiently in the production of maize and depend on government intervention. Wanjala [10] showed that a large proportion of farmers do not plant qualified seeds and apply organic fertilizers. In addition, many small-scale maize farmers do not examine acidity levels or check the nutrient levels of the soil they are cultivating. Urassa [19] found that education was an important factor in raising yields, suggesting that nonagriculture policies may also be important for improving productivity and the welfare of farmers. Simiyu [9] found that fertilizer is still the most expensive raw material in maize farming, followed by land preparation. Bunde et al. [5] found that costly operational and transport costs, actual supply prices, and a lack of a sufficient supply of raw materials were the most significant drawbacks encountered while doing agribusiness. Ojala [20] found that a farmer's age-a proxy for experience; resource base as captured by size of cattle herd; total cropped area; and competition from tobacco production influenced maize production. Onono et al. [21] found that the price of fertilizer and poor weather conditions negatively affected maize production. Kimeli [7] found that maize production was influenced by several factors: age, gender, academic status, labor, land, market, farm raw materials, transport and infrastructure, and other economic activities. Ali-Olubandwa et al. [4] showed that the household maize farmers in Western Province in Kenya lacked knowledge of modern farming practices and technology due to a substantially low ratio of extension staff to farmers. Kibaara and Kavoi [6] found that production was directly related to purchasing hybrid maize seed, land tilling by tractors, academic status, male-headed households, age, availability of credit facilities, and high probability area. Mignounaab et al. [8] found that Imazapyr-Resistant Maize (IRM) breeding considerably improved maize production; household size reduced ineffectiveness together with land acreage.

From the previous literature, it can be concluded that many studies on maize have been conducted in various parts of Kenya. However, no research has been done on the combined contribution of the factors to maize production and the supply response of maize. This research, therefore, bridges the gaps existing in the literature.

3. Methodology

3.1. Data. This study used annual time series data from 1976 to 2016 at the national level. The data for different variables are compiled from various sources. For example, data on maize production and areas harvested were collected from FAOSTAT [22], whereas information on values of expenditure on fertilizers and prices was gathered from multiple Economic Surveys of Kenya published between 1976 and 2017 [23–32]. In addition, data on agricultural machinery, precisely the number of tractors and quantity of maize seeds, was compiled from Africa Development Indicators [33].

3.2. Cobb–Douglas Production Function. The Cobb–Douglas production function is among the kinds of production functions that exist. It is used to show the technological relationship between the quantities of two or more inputs, that is, capital and labor, and the amount of output that can be yielded from those inputs. It was pioneered and empirically tested using statistical evidence by Charles W. Cobb and Paul H. Douglas during 1927–1947. The function takes a general form, as shown in Equation 1

$$Y = AL^{\alpha}K^{\beta}, \tag{1}$$

where Y = total output, L = labor input, K = capital input, that is, the actual value of all machinery, equipment, and buildings, A = total factor productivity, α and β are coefficients defining labor and capital responsiveness correspondingly. They depend on the existing technology.

This research paper estimated a production function employing the generalized Cobb–Douglas form (Equation (2)) so that the maize production was seen to relate to the inputs X_1, X_2, X_3, and X_4 by the function

$$Q = A \cdot X_1^{a1} X_2^{a2} X_3^{a3} X_4^{a4}, \tag{2}$$

where Q is the maize production (in tons), A is the total factor productivity, X_1 is the maize area harvested (in hectares), X_2 is the expenditure on fertilizers (in a million Kenyan Shilling, Kshs.), X_3 is the number of tractors, X_4 is the quantity of maize seeds (in tons), a_1, a_2, a_3, and a_4 were the output elasticities of the corresponding inputs.

The parameters to be estimated were A, a_1, a_2, a_3, and a_4 estimated through taking the logs of function (2). Hence, the following was obtained:

$$\text{LnQ} = \ln\ A + a_1 \ln\ X_1 + a_2 \ln\ X_2 + a_3 \ln\ X_3 + a_4 \ln\ X_4. \tag{3}$$

The estimated model was therefore expressed in a general form as

$$\text{Maize production} = f\,(\text{maize area harvested, expenditure on fertilizers, number of tractors, quantity of maize seeds}). \tag{4}$$

3.3. Empirical Model

3.3.1. Diagnostic Tests. Economic time series data may exhibit a trend or unit-roots over time. A time series is stationary if the mean and variance do not vary systematically over time [34]. A static stochastic process implies that the underlying stochastic process that generates the series is invariant with time. Nonstationary time series produce spurious regression where results may suggest a significant statistical relationship when no meaningful relationship exists between the variables.

In the presence of unit roots, detrend the series to remove its nonstationarity. The Augmented Dickey–Fuller (ADF) test investigates systematic and linear relationships between past and present values of variables. In addition, the ADF test adds lagged values of the variables to address the problem of correlation of the error term.

We test the following hypothesis when investigating stationarity:

H_0: $\alpha = 0$ (nonstationary) H_1: $\alpha \neq 0$ (stationary).

The null hypothesis is rejected when stationarity is established in the time-series data.

Multicollinearity is another diagnostic test to check for a close correlation between independent variables over time. The high correlation will lead to inflated coefficients, bringing about misleading results. Often, variables tend to be collinear in economic regression, but the degree of collinearity matters. This study tested for the existence of a multicollinearity problem using the Variance Inflation Factor (VIF). The VIF values of more than 10 would imply the existence of multicollinearity between variables. Thus, such variables will be dropped.

The error terms in a regression model are required to have the normal distribution for a model to have unbiased estimates. Therefore, the Skewness/Kurtosis test for normality was employed in this study to examine normality of the residual.

Autocorrelation means a relationship between a variable and itself over various time intervals. The autocorrelation may cause the underestimation of error variance and invalidate the significance test. The presence of autocorrelation was tested using the Breusch–Godfrey Linear Model test. Differencing a series helps solve the problem of autocorrelation. The interpretation of the results is that we do not accept the null hypothesis of no serial correlation if the p value of the test is less than 5%.

In a case where the present value of a dependent variable is explained by the current and the past value of an exogenous variable, lag selection is necessary. The Akaike Information Criterion, which imposes a penalty for adding regressors to the model, selects the maximum lag length.

Table 1: Summary statistics (number of observations 41 years, from 1976 to 2016).

Variable	Mean	Standard deviation	Minimum	Maximum
Maize production (million t)	2.62	0.57	1.42	3.83
Maize area harvested (million ha)	1.59	0.31	0.99	2.34
Expenditure on fertilizers (million Kshs)	3,080.172	3,633.89	193.28	13,930.7
Number of tractors used (number)	12,021.02	4,402.54	5,982	23,409
Maize seed quantity (t)	47,737.05	9,211.33	29,550	68,000
Prices (Kshs/100 kgs)	1,086.493	1,033.89	77	3,396

Cointegration means that the nonstationary series move simultaneously over time, and their difference is stable. A cointegration test is conducted when integration between variables is of the same order. This is to avoid spurious regression results. In addition, a cointegration test is carried out to ensure that the regression model is statistically sound for meaningful data analysis. The Johansen test for cointegration, which has gained more importance in economic applications, was used to test for cointegration. It is the most appropriate for multivariate models. The trace statistic and eigenvalues were used to determine if a linear combination of the variables reveals cointegration.

3.3.2. Vector Error Correction Model. The presence of cointegration meant that the variables were related by a Vector Error Correction Model (VECM). VECM measures the short-run dynamics. The parameters of interest in the VECM were the coefficients of the differenced variables. The short-run results readjusted themselves through the residual error, so there was no need to test for the long run.

4. Results and Discussion

4.1. Descriptive Statistics. In Table 1, The mean maize production in Kenya from 1976 to 2016 was 2.62 million tons (t), with a minimum production of 1.42 million t and a maximum of 3.83 t million (Table 1). The average area of land was 1.59 million hectares (ha), with a minimum of 0.99 million ha and a maximum of 2.34 million ha. The average value of fertilizers used in that period was Kshs. 3.08 billion, with a low of Kshs. 0.19328 billion and a high of Kshs. 13.93 billion. The average number of tractors purchased for use during that period was 12,021.02, with a minimum number of 5,982 and a maximum of 23,409. The average quantity of maize seed used in that period was 47,737.05 tons, with a low of 29,550 tons and a high of 68,000 tons. The average price of maize during the period was Kshs. 1,086.49 per 100 kg, with a low of Kshs. 77 and a high of Kshs. 3,396 per 100 kg.

4.2. Trend Analysis. The trend of maize production against the areas harvested, the expenditure on fertilizers, the number of tractors, and maize seed quantities are presented in Figures 1 and 2. The figures give a pictorial view of how maize production has varied over the years, with the production factors affecting total maize production.

Maize production significantly varies with changes in the areas harvested (Figure 1). For example, from 1976 to 1980, maize production declined considerably along with the decline in areas harvested. This is explained by the fact that harvested areas are directly related to the quantity of maize production since on a larger piece of land, more maize is planted, thus realizing more maize production and vice versa. This could also be explained by other factors like good soil fertility, optimal utilization of other inputs like fertilizers and pesticides, and good weather patterns, among many others. In 1984 and 2008, there was a sharp decline in maize production. In 1984, the drop was linked to the decrease in the land area under maize. This can be explained by the expectation that a decline in land area under maize will lead to a reduction in maize production. A different case is seen in 2008 in that there is a fall in maize production despite an increase in land area under maize as shown in Figure 1, as well as an increase in use of tractors and fertilizers (Figure 2). This can be attributed to poor weather conditions, suggesting that the variation in maize production depends not only on areas harvested. Other inputs are helpful too in determining maize production, like expenditure on fertilizers; use of agricultural machinery, i.e., tractors; and maize seed quantities. For example, in the periods between 1985 to 1993 and 2011 to 2015, growth in the area harvested has been negligible, yet production has been drastically changing. This could be explained by factors like increased fertilizer expenditure, which can also be understood as increased use of fertilizers, optimal use of tractors in tilling the land, and increased use of maize seed quantities.

4.3. The Combined Effect of Production Factors on Maize Production - Vector Error Correction Model. An Augmented Dickey–Fuller Unit Root Test shows the trend data to be nonstationary. This is because the observations were first differenced to make the series stationary. An Augmented Dickey–Fuller Unit Root Test of the first differenced observations shows a significant p value suggesting the observations of all five variables, namely, maize production, areas harvested, expenditure on fertilizers, number of tractors, and maize seed quantity, are stationary.

The mean-variance inflation factors of 1.29 with the range of 1.08–1.54, which in all cases are less than 10, suggest an absence of multicollinearity in the regression analysis in this study. Similarly, a nonsignificant p value obtained from the Skewness/Kurtosis test for normality and the Breusch/Godfrey LM test for autocorrelation suggests the data set to be normally distributed and the absence of serial correlation in the regression analysis.

The analysis for lag length selection criteria depicts constant results for lag selection. Akaike's Information Criterion, Hannan and Quinn Information Criterion, and

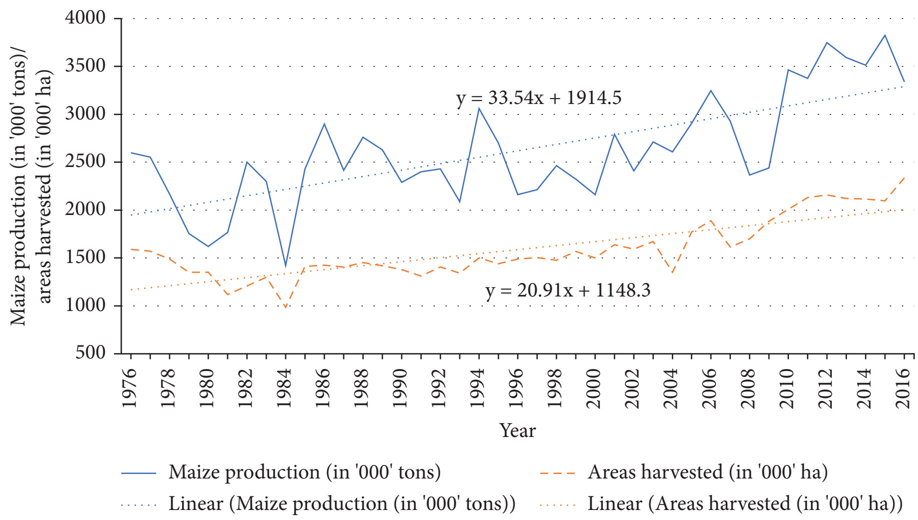

Figure 1: The trend of maize production and area harvested [22].

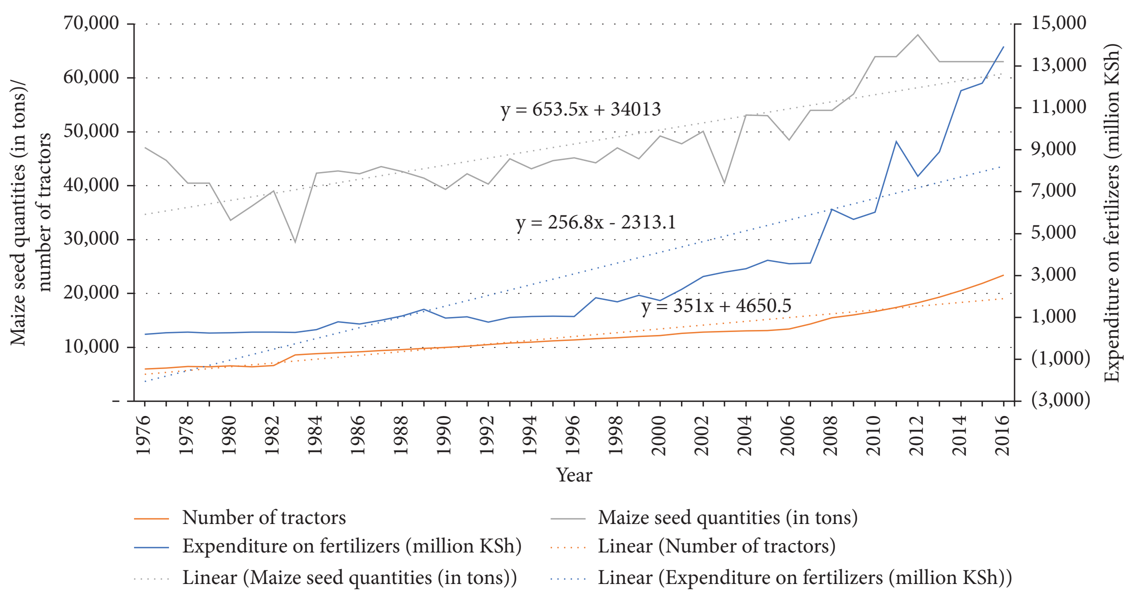

Figure 2: The trend of the number of tractors, expenditure on fertilizers, and maize seed quantities [23–33].

Schwarz/Bayesian Information Criterion were minimized at a lag of 1, and this study used a lag of 1.

The cointegration diagnostic test results of maize production, areas harvested, expenditure on fertilizers, number of tractors, and maize seed quantities indicate that the null hypothesis can be rejected. Thus, we can conclude that there is cointegration. Therefore, vector error correction model can be estimated.

4.4. Combined Effect Using Vector Error Correction Model. The output of the vector error correction model is presented in Table 2. From the output table, it can be deduced that the area harvested is a significant factor in determining maize production. A percent increase in maize area harvested leads to a decrease in maize production by 0.17 percent *ceteris paribus*. Similarly, there exists a negative relationship between expenditure on fertilizers and maize production. A one percent increase in the spending on fertilizers leads to a decrease in maize production by 0.06 percent holding all other factors constant. Finally, there exists a negative relationship between maize production and the number of tractors. A percent increase in tractors leads to a decrease in maize production by 0.01 percent *ceteris paribus*. The relation between expenditure on fertilizers and the number of tractors, however, is not statistically significant. In the case of maize seed quantities, the result depicts a positive and significant relationship; a one percent increase in maize seed quantity leads to a 0.13 percent increase in maize production, *ceteris paribus*. Hence, maize seed quantities prove to be a significant factor in contributing to increased maize production in Kenya.

The computed coefficient of the combined contribution of the variables was −0.12, which was obtained by summing all the individual coefficient values. This, therefore, meant

Table 2: Estimates of vector error correction model.

Variables	Coefficient	Standard error	z-value	p value
Areas harvested (ha)	−0.17	0.00573	−30.3	0.001
Expenditure on fertilizers (Kshs)	−0.06	0.05431	−1.16	0.246
Number of tractors	−0.01	0.00822	−1.33	0.183
Maize seed quantities (tons)	0.13	0.02064	6.17	0.001

Table 3: OLS regression of maize production against lagged prices of maize.

Variables	Coefficient	Standard error	T	$P > t$
Price of maize when lagged once	280.488	255.167	1.1	0.28
Price of maize when lagged twice	125.096	317.323	0.39	0.696
Price of maize when lagged thrice	71.1703	326.185	0.22	0.829
Price of maize when lagged four times	−35.94	286.182	−0.13	0.901
Constant	2152116	102571	20.98	0.001
Number of observations		37		
F (1, 38)		10.41		
Prob > F		0.001		
R-squared		0.5654		
Adj R-squared		0.511		
Root MSE		4.0e+0.5		

that the model exhibited decreasing returns to scale, that is, doubling the inputs leads to a reduction in the maize production by 0.12 percent *ceteris paribus*.

4.5. Results of Supply Response Using OLS Regression Analysis. The p value of 0.001 (Table 3), which is less than 0.01, suggests that the model was statistically significant at a one percent level of significance. Hence at a 99% confidence interval, the null hypothesis (R^2 equaled to zero) was rejected and concluded that the R^2 does not equal zero. Therefore, the regression model has explanatory power and is an excellent model to work with.

The study compared the p value with the significance levels. The hypothesis tested was

H_0: $R^2 = 0$ against H_A: $R^2 \neq 0$ for all$i = 1\&k$.

The R-squared of 0.5654 (Table 3), which is the coefficient of determination, implied that lagged prices of maize explained 56.54% of all the variations in maize production *ceteris paribus*. After adjustments were made, the adjusted R-squared of 0.5110 insinuated that lagged price explained 51.10% of all variations in maize production *ceteris paribus*.

From the analysis in Table 3, the regression equation to be interpreted took the form shown below

$$Q = b_0 + b_1 P_{1(t-1)} + b_2 P_{2(t-2)} + b_3 P_{3(t-3)} + b_4 P_{4(t-4)}. \quad (5)$$

The constant suggests that with a zero lagged price, the maize production will be 2.15 million tons, *ceteris paribus* (Table 3). However, a unit increase in the previous period's price leads to an increase in the maize production for the current period by 280.49 tons *ceteris paribus*. When the price is lagged twice, a unit increase in the price of maize leads to a rise in the maize production of 125.10 tons, *ceteris paribus*. Similarly, when the price is lagged thrice, a unit increase in the price of maize leads to a rise in the production of maize by 71.17 tons *ceteris paribus*; however, lagging the prices further by four portrays different results in that a unit increase in the price of maize leads to a decrease in the maize production by 35.94 tons *ceteris paribus*. The response of maize production depicts that the price of maize in the previous period determines the maize production levels in the current period positively; however, as we move further away, the price level at the fourth lag depicts a negative relationship with maize production.

5. Conclusion and Recommendations

The findings based on analysis using the VECM concluded that the area harvested and the quantity of maize seed are significant factors in determining maize production in Kenya. At the same time, expenditure on fertilizers and the number of tractors were insignificant. The value of the computed coefficient used to test for the combined contribution of the factors of production to maize production exhibited decreasing returns to scale whereby jointly doubling the four inputs would less than double maize production, *ceteris paribus*. From the findings based on the OLS regression analysis, maize prices in the previous periods were seen to have a positive influence on the current levels of maize production initially, but further lagging the fourth time the results depicted a negative relationship.

Based on the findings, this study recommends that the government, through the National Cereals and Produce Board, should make maize seeds available to farmers to boost their maize production. Despite maize area being a significant factor in determining maize production, this research found that increasing the area under maize led to a decrease in maize production. This certainly contradicts what is theoretically known to be true that increasing the area under maize production should improve maize production. However, this could mean that the increased land areas were underutilized, hence the need to educate farmers on the right mix and quantity of inputs used in maize production per hectare. Hence, farmers need to be sensitized on optimal utilization of land. The study also recommends that farmers be educated on the proper use of fertilizers. This form of education will educate the farmers on the correct type of fertilizers to be used, proper application, and reasonable timelines for applying these fertilizers. Furthermore, there is a need to educate farmers on optimizing the use of tractors. Lastly, the government needs to ensure that the prices offered to farmers are favorable and stable to encourage farmers to increase their production of maize and control the amount of maize supplied to the market.

This study creates a gap in the sense that other researchers can find out why increased area of maize and fertilizer use negatively affects maize production in Kenya.

Data Availability

Data for this study was obtained from the following sources and their websites: 1. FAOSTAT data-https://www.fao.org/faostat/en/#data/QC. 2. Economic Surveys of Kenya (1976–2016)-https://www.knbs.or.ke/publications/. 3. Africa Development Indicators-https://databank.worldbank.org/source/africa-development-indicators.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this manuscript.

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