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Determinants of Agricultural Production in Kenya under Climate Change

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Abstract

Climate change has been described as the most significant environmental threat of the 21st century with vast impact mostly on agriculture, altering food production processes. As an important sector in the Kenyan economy, agriculture continues to dominate other sectors despite its declining contribution to real GDP. Given that the performance of the agricultural sector is determined by a large number of factors, the need to articulate this study has become imperative in view of the climate phenomenon. Therefore, the study examined the determinants of agricultural production in Kenya under climate change with specific interests in assessing the trend of climate variables and growth rate of agricultural production within 1970-2012 periods; estimating factors influencing agricultural production and deducing policy implications from the findings. Data used were secondary and include value of agricultural production, livestock, machines, fertilizer, agricultural land, labour, annual precipitation and temperature over the study period. These were obtained from databases hosted by the Food and Agriculture Organization (FAOSTAT), the World Bank and United Nations Development Programme (UNDP). Data analysis was done using trend analysis, log quadratic trend equation and multiple regression model. The trend results show that precipitation pattern traced out high amplitude decadal variability with the forecast showing off a slightly upward trend. In temperature, the inter-annual variability observed was wide with a forecast of a slight increase up to 2020. In terms of growth analysis, the log quadratic equation indicates that agricultural production posted a compound growth rate of 3.252% during the period while production was determined by the quantum of labour, livestock, agricultural land, precipitation and its squared term. The implication is that precipitation both on the short and long run affected agricultural production. It is recommended that ecosystem based and technologically driven adaptation measures be taken to address climate change effects on agricultural production.

Subject Areas

Environmental Sciences, Natural Geography

Keywords

Agricultural Production, Climate Change, Kenya

1. Background to the Study

Agriculture is considered the most important sector in sub-Sahara Africa (SSA) and is set to be hit the hardest by climate change. As the most significant environmental threat of the 21st century, climate change has been predicted to decrease agricultural productivity by as much 20% in Africa, Asia and Latin America [1] [2] [3]. In most countries where agricultural productivity is already low and the means of coping with adverse events are limited, climate change is expected to reduce productivity to even lower levels and make production more erratic. Long term changes in the patterns of temperature and precipitation, that are part of climate change, are expected to shift production seasons, pest and disease patterns, and modify the set of feasible crops affecting production, prices, incomes and ultimately, livelihoods and lives [4].

In Kenya, agriculture as an income-generating sector contributed 21.4% and 24% of the country's GDP in 2010 and 2011 respectively with smallholder farmers providing 75% of the labour force and 75% of the market output produce [5] [6]. The agriculture sector, including crops and livestock, is a priority in *Vision* 2030 because it plays a critical role in improving livelihoods, enhancing food security and increasing GDP and employment [6]. *Vision* 2030 aims to achieve an innovative, commercially oriented, modern agricultural sector through institutional reforms, increased productivity, landuse transformation, increased access to markets and development of arid and semiarid lands (ASALs). The *Agricultural Sector Development Strategy* 2010-2020 sets out a detailed plan to "position the agricultural sector as a key driver for delivering the 10 per cent annual economic growth rate envisaged under the economic pillar of *Vision* 2030". The vision of the document is "a food secure and prosperous nation" and the strategy aims to increase productivity, commercialization and competitiveness of agricultural commodities and enterprises; and develop and manage key factors of production. Also important is government's goal of 10 percent farm forest cover on all agricultural land holding [7].

However, the agricultural sector is particularly vulnerable to adversities of weather, not only because farmers depend on rainfed agriculture, but also on small farm sizes that are not economically viable. These smallholder farmers thus already operate under pressure from food insecurity, increased poverty and water scarcity [8] [9]. This scenario constitutes a real challenge for a government with a population of over 40 million to feed. More worrisome is the fact that increase in the gap between population growth and agricultural capacity is exacerbating the already declining food security, and increasing vulnerability and rural poverty, which amplify the impacts of climate change that appear to have become more severe in the recent years [10] [11]. Even with the launch of the National Climate Change Response Strategy (NCCRS) [12], it is however unclear the extent of influence of the strategy on addressing food production issues. More so, with the newly adopted global Sustainable Development Goals (SDGs) replacing the MDGs and the recently concluded COP21 aimed at reaching a deal to avert dangerous climate change, the need to undertake this study has become imperative. In the light of the foregoing, the study sought to examine the determinants of agricultural production in Kenya under climate change with specific interests in assessing the trend of climate variables and growth rate of agricultural production for the period 1970-2012 periods; estimate factors influencing agricultural production and deduce policy implications of the findings.

2. Theoretical and Conceptual Literature

The first step in any attempt to evolve a meaningful perspective on the process of agricultural development is to perceive the view of agriculture in pre-modern or traditional societies as essentially static. Viewed in a historical context, the problem of agricultural development is not that of transforming a static agricultural sector into a modern dynamic sector, but of accelerating the rate of growth of agricultural output and productivity consistent with the growth of other sectors of a modernizing economy. Modern economy (for example, green economy) will require development resources to be stretched to meet the growing demands under changing climate [13] [14]. The Boserupian theory averred that the primary stimulus to agricultural development and productivity is population growth. This implies in other words that population growth or pressure triggered efforts towards increasing agricultural production. Over time, her postulation began to be reframed as a more generalized theory and had continued to mature in relation to population and environmental studies [15] [16]. Similarly, the Malthusian theory of population growth which examined the relationship between population growth and resources posts an interesting relation to this study. It avers that population growth occurs exponentially while food production increases arithmetically, implying that population can outgrow their resources if unchecked. With this rising ugly trend in the face of changing climate, the world is likely to encounter a higher magnitude of Malthusian catastrophe—a situation of forced return of a population to basic survival.

3. Methodology

Greenhouse gases emissions from human activities are responsible for climate change [17] [18]. Moreover, climate change triggers increased temperatures, changing rainfall, patterns and amounts, and a higher frequency and intensity of extreme climate events such as floods, cyclone, droughts and heat wave [17] [18]. However, temperature increases and erratic rainfall patterns affect crop agriculture mostly directly cum adversely [19] [20] [21], and by extension, food security. Changes in climate generally involve changes in two major climate variables: temperature and precipitation. In this study, the crop modeling or production function approach was employed. Based on the climate-yield relationship, the crop modeling approach estimates the effects of climate change on agricultural production [22] [23]. This model is suitable for the study due to its capability in reflecting the climate-yield relationship and data availability on aggregate basis for the inputs. In the bid to identify the determinants of agricultural production under climate change, we modeled a production function in which value of agricultural production is considered a function of some economic inputs and climate factors.

This is specified thus:

$$\begin{aligned} Y_t = \beta_0 + \alpha_1 L_n F_t + \alpha_2 L_n K_t + \alpha_3 L_n V_t + \alpha_3 L_n M_t + \alpha_4 L_n L_t \\ + \alpha_5 P_t + \alpha_4 T_t + \alpha_5 P^2 t + \alpha_6 T^2 t + \alpha_7 \tau_t + \omega_t \end{aligned} \quad (1)$$

The production function specified in Equation (1) is similar to those of [24] [25] and [26]. To permit inter-comparisons, the units employed include Y is value of agricultural production in "international dollars" rather than production quantity or local currency; V represents the livestock production index (2004-2006 = 100); L is the agricultural land expressed in hectares; M represents the number of agricultural tractors; K represents the total number of the population that is economically active in agriculture; and F represents the total agricultural consumption of fertilizers in 1000 tons. Climate variables are precipitation and temperature. P represents average precipitation in depth (mm per year), and T represents mean annual temperature (˚C per year). The squared terms are also integrated in the model to take into account the non-linear relationship between agricultural production and climate factors.

For assessing the changes in major climate variables, trend analysis was applied while log quadratic trend equation was fitted in determining the growth rate of production and stated thus:

$$L_n Q_t = a + b_t + C_t^2 + U_t \quad (2)$$

The compound growth rate equation is given as follows:

$$r = \left(e^b - 1\right) * 100 \quad (3)$$

where e is Euler's exponential constant (2.71828). This is in line with [27] [28].

Q_t = Value of agricultural production,

a = the constant in the regression line,

b_t = the estimate of the absolute increase of agricultural production,

U_t = the error term.

A positive significant value of c indicates acceleration while a negative significant value implies a deceleration. A non-significant value shows stagnation in the growth process. This is in line with [27] [28]. The study period was 1970-2012 while data of interest were secondary and were obtained from databases hosted by the Food and Agriculture Organization (FAOSTAT), the World Bank and United Nations Development Programme (UNDP).

4. Results and Discussion

4.1. Trend of Precipitation and Temperature (1970-2012)

4.1.1. Precipitation

Figure 1 shows the trend of mean annual precipitation pattern in Kenya for 43 years between 1970 and 2012. The trend has been unstable with precipitation level at the highest in 1997 and the lowest in 2000. The inter-annual sequence turned out a high amplitude decadal variability with visible absence of order. By implication, the estimated variability indicated that the amount of rainfall and the corresponding number of wet days varied appreciably from year to year. This consolidates the finding of [29] who observed that Kenya's annual rainfall genuinely follows a strong seasonal pattern. The trend forecast indicated that the precipitation in Kenya will experience very marginal increase in the next ten years. The mean absolute percent error (MAPE) (5.3605) produces a measure of relative overall fit and assesses the rate of accuracy of the fitted time series. In consolidation [30]. Government of Kenya (2013) reported that annual rainfall shows either neutral or slightly decreasing trends due to a general decline in the long raining season.

4.1.2. Temperature

The mean annual temperature of Kenya in Figure 2 showed an unsteady rise over the period. The inter-annual gaps are relatively wide and also traced at a general increase in temperature. The least temperature was observed in 2006 and the highest in 2010 within the study period. Since 2006, the annual temperature seemed to have been on the increase. The forecast trend also indicates a steep rise up to 2020.

4.2. Growth Rate of Agricultural Production

To determine the agricultural production growth rate in Kenya, a long-quadratic trend equation was fitted to the data with the intent to establish whether production experienced stagnation, acceleration or deceleration within the study period.

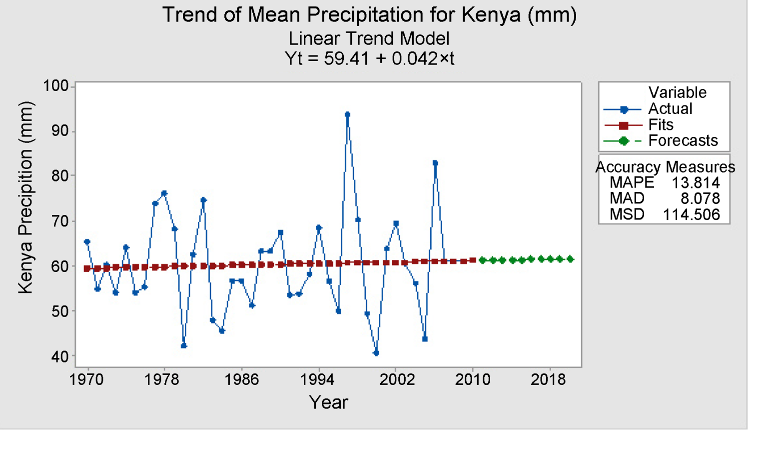

Figure 1. Precipitation trend in Kenya (Source: Authors analysis from study data).

The results of the analysis are presented in Table 1. The results of growth rate analysis in Table 1 revealed that agricultural production posted positive and non-significant coefficient during the study period. With a compound growth rate of 3.252%, it implies that the supply capacity to national and regional markets is relatively low. According to [31], Kenya has been experiencing decline per capita agricultural production with total annual on farm production of food crops lagging behind consumption. This has resulted in food deficits and the consequential food insecurity being witnessed in the country. Over time, agricultural commodities in Kenya concentrated on improvement of production of major food crops such as maize, wheat, rice, beans and Irish potatoes and as such, cassava enjoyed little or no attention. They tended to be grown by older farmers [32]. Given that the decision rule stipulates that agricultural production posted a non-significant coefficient, it could be inferred that the production experienced stagnation during the study period.

4.3. Factors Influencing Agricultural Production under Climate Change

The regression analysis on the factors influencing agricultural production under climate change is presented in Table 2. The *R* squared (coefficient of multiple determination) values of 0.989 respectively shows reasonable goodness-of-fit for the data sets. By implication, the total variations in agricultural production were accounted for by the regressors included in the model to the tune of 98.9%. The *F*-ratio is statistically significant and confirms the overall explanatory power of the model. With these diagnostic statistics, the result of the analysis is therefore

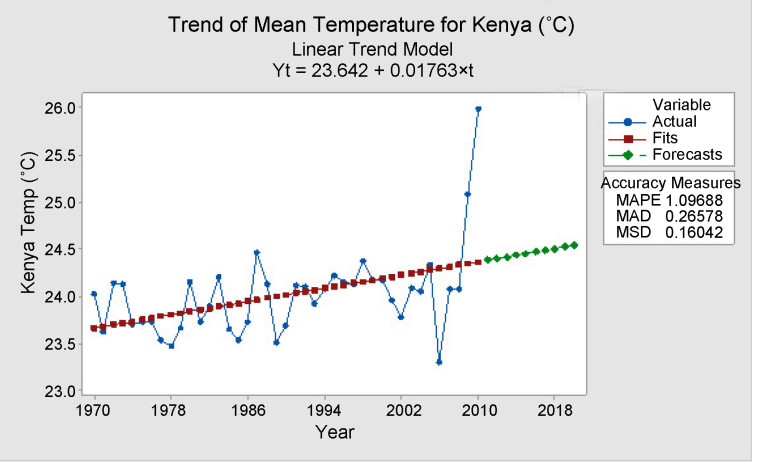

Figure 2. Temperature trend in Kenya (Source: Authors analysis from study data).

Table 1. Estimated growth rate of agricultural production in Kenya.

Variable/crop	a_t	b_t	C_t^2	R^2	F	R
Agric Prod	7.507*** (0.031)	0.032*** (0.003)	1.360E−6 (7.046E−5)	0.977	861.734	3.252%

t-test values in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Source: Authors analysis from study data.

Table 2. OLS estimates of factors influencing agricultural production under climate change.

Variables	Coefficients	Standard Error	*t*-Value
Constant	−24.974**	7.887	−3.166
Fertilizer	0.025	0.027	−0.896
Labour	0.641***	0.142	4.522
Livestock	0.345**	0.096	3.582
Machinery	−0.099	0.114	−0.872
Agric land	2.292*	0.833	2.752
Precipitation	0.010*	0.066	1.797
Temperature	−0.005	0.020	−0.245
Precipitation^2	−8.194E−5*	0.000	−1.814
Temperature^2	0.039	0.035	1.144
R^2	0.989		
F-Ratio	335.795***		

***, ** and * represent significance at 1%, 5% and 10% probability levels, respectively. Source: Authors analysis from study data.

reliable and can be used for drawing inferences. Agricultural labour posted a positive coefficient and statistically significant at one percent level of probability. This implies that increase in the population of people economically active in agriculture could lead to increase in agricultural production. Also, the coefficients of livestock, land and precipitation recorded positive signs and statistically significant at varying probability levels. Considering the magnitude of the elasticities of the significant coefficients, land has the most effect in determining agricultural production under climate change, followed by labour and livestock. Precipitation with its squared term is sparingly significant (10 percent probability), implying that precipitation influences production positively in the short run but negatively in the long run.

5. Conclusion and Policy Implications

The study analyzed the determinants of agricultural production under climate change in Kenya and specific interest in a number of important issues. Topical among the interest were to assess the trend of climate variables and growth rate of agricultural production within 1970-2012 periods; estimated factors influencing agricultural production. By applying a number of analytical tools in the bid to realize the objectives, the findings have huge theoretical and policy implications for the future of the country. The poor and uneven distribution of precipitation in Kenya had already taken a heavy toll on the capacity of the country to feed her ever teeming population. With the prediction of marginal increase in precipitation, agricultural production in the coming years may be adversely affected in Kenya. The effect may likely trigger reduced agricultural productivity and/or increase in the price while consumers may be faced with the option of resorting to substitutes. Temperature was observed to have been on the increase with some degree of variability. This is an indication that Kenya has been getting warmer. In the event of continued scenario of this, the use of alternative coping strategies such as irrigation should be explored. Agricultural production was observed to have stagnated over the period. In order to meet the rising need for food, the farmers are expected to adopt productivity enhancing technologies such as use of improved varieties which are not only high yielding but resistant to adverse climatic conditions. More so, agricultural production was found to be determined by labour, livestock, land and precipitation. Labour which represents the population of economically viable people in agriculture has some theoretical implications. Agricultural labour stands out as both producers and consumers of agricultural produce and thus negate the possible occurrence of Malthusian trap. However, the engagement of the youth in agriculture by exploring the quantum of opportunities that exist along the value chain will help in addressing the anomaly. Land tenure system needs to be addressed more efficiently to assist in making available land to prospective and existing farmers. To deal with the menace of climate change, efficient and proactive climate risk management portfolios should be developed at both local and national levels to address the emerging climate exigencies and impacts. Monitoring of the implementation of the national response strategies is also necessary while ecosystem based and technologically driven adaptation measures be integrated in farming system programmes. This is a veritable means of driving the nation towards achieving a low-carbon, climate-resilient economy.

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