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ECONOMIC IMPACT OF CLIMATE CHANGE ON MAIZE PRODUCTION IN KENYA

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Abstract

Purpose: The purpose of the study was to investigate the economic impact of climate change on maize production in Kenya.

Methodology: The study used climate, soil and household data for 1357 households. The climate data was from ARTES (African Rainfall and Evaluation System) and Satellite climate data while the Soil data was from Kenya Soil Survey conducted by Kenya Agricultural Research Institute. The household data was obtained from Tegemeo Research Institute.

Results: The regressions results suggest that climate has a significant impact on maize production. The study found that temperature has a bigger impact on maize production compared to precipitation as evidenced by the elasticity of temperature and precipitation.

Unique contribution to theory, practice and policy: The study recommends that policy efforts should be directed at addressing the impact of climate change on maize production. Through research and development, the government should encourage the development of maize varieties that can adapt to the future expected hot conditions.

Keywords: *Economic impact, climate change, maize production.*

1.0 INTRODUCTION

1.1 Background of the Study

The Kenyan economy is heavily reliant on agriculture. In the period 1975-1979, the agricultural sector contributed an average of 36% to the Kenyan Gross Domestic Product (GDP), 31.66% between 1980-1984 and 1985-1989 and 27.22% between 1990 and 1994. In the periods 1995-1999 and 2000-2004, the sector contributed an average of 27.18% and 26.33% respectively. Between 2005 and 2009, the sector contributed an average of 22.94% while between 2009 and 2011, the contribution averaged of 22.7%. In the same periods the manufacturing sector, a crucial sector of the Kenyan economy, contributed an average of 13.24%, 12.64%, 11.80%, 11.26%, 10.61%, 11.61%, 10.10% and 9.65% respectively (Economic surveys, 1975-2012*)*.The country has therefore witnessed a decline in the agricultural sector's contribution to the Kenyan Economy as the manufacturing sector has more or less remained constant.

According to the Ministry of Agriculture (2010), the agricultural sector can be divided into six sub-sectors namely industrial crops, food crops, horticulture, fisheries and forestry. In terms of their contribution to agricultural output, food crops such as maize, wheat and bean among others contribute the highest while livestock and fisheries contribute the least. Industrial crops such as tea, coffee and sunflower among others make the highest contribution to agricultural exports followed by horticulture. Fisheries and forestry contribute an insignificant amount to agricultural sector exports (Table 1.1).

Food security and maize supply in Kenya are closely linked. Given that maize is the country's most important staple crop. Kenya's food security depends on the availability of domestically grown maize. This is also true at the household level more so in the rural areas. The availability of maize in the household stores may determine the food security of the household (World Bank, 2010). In addition, maize is an important source of income for farmers especially in maize surplus regions such as the North Rift. Nationally, maize accounts for about 14% of farm household incomes although in maize surplus areas this is higher (Nyoro et al, 2004).

1.2 Problem Statement

The Kenyan economy is highly reliant on agriculture. Agriculture contributes a significant share to the Country's GDP, total employment and export earnings and provides a source of livelihood for a large part of the population especially in the rural areas. Maize is a key sub- sector in the agricultural sector. Maize is the most widely grown in the country in terms of area under cultivation. It provides the Kenyan population with a third of their calorie intake and a key source of farm incomes especially in the maize surplus areas. Food security in Kenya and maize production are closely interlinked. At the country level, the availability of maize determines whether the country is food secure or not (Nyoro et al., 2007). This is also true at the households level, more so in the rural areas.

However, despite the importance of maize to the country, production especially in the last decade has been poor. The reasons for this include the high cost and increased adulteration of inputs, low and declining soil fertility, decreasing land sizes, limited access to affordable capital and low absorption of modern technology (Ministry of Agriculture, 2010). Besides the above factors, policymakers have begun to recognize the increasingly adverse role being played by climate change on maize production. Erratic weather conditions have been blamed for a succession of maize crop failures forcing the Kenyan government to import maize to feed its population.

Most studies[1] conducted on the impact of climate change on agricultural sector in Kenya have analyzed the impact of climate on general agriculture. Mati (2002) and Karanja (2006) attempted to analyze the impact of climate change on individual crops. However, results by Mati (2002) were inadequate as they only addressed two ecological zones, yet maize is grown in nearly all seven agro-ecological zones while the study by Karanja (2006) mainly focused on the impact of temperature on production but failed to include the precipitation component. It is important to analyze the impact of climate change at individual crop or animal level so as to be able to get a better understanding of how climate change will affect agriculture production in Kenya.

This study sought to address this gap in knowledge by providing insights on how climate change affects maize production.

1.3 Research Objective

The objective of the study was to investigate the economic impact of climate change on maize production in Kenya.

2.0 LITERATURE REVIEW

2.1 Theoretical Review

2.2.1. The Production Function Approach

The production function approach was the pioneering approach used to analyze the impact of climate change on agriculture. The approach is based upon experimental or empirical production functions where environmental variables such as precipitation or temperature are inputs. These environmental variables in the production function are varied so as to estimate the impacts of climate change on yields These changes in yields are then incorporated in economic models so as to predicate the changes in welfare as a result of climate change (Mendelsohn et al., 1994).

Production function approach has the advantage of providing estimates of impact of climate that are free of bias as a result of the determinants of agricultural production that are beyond a farmer's control such as soil quality (Deschenes & Greenstone, 2006). In addition, the approach provides better predictions of the impact of climate change on agricultural yields because of its use of controlled experiments (Mendelsohn et al., 1994; Deschenes and Greenstone, 2006).

Despite this, the approach suffers from some limitations. First, the approach doesn't incorporate adaptation measures adopted by farmers in the face of climate change. This is unlikely since farmers will respond to the changing climate conditions. They may introduce new crops or replace crops with livestock. The lack of incorporation of adaptation measures results in an overestimation of damages as a result of climate change (Mendelsohn et al., 1994). Secondly, Deressa (2007) notes that the approach is very expensive because of the controlled experimentation required. This may explains why the approach has been used in few sites around the world and for a few crops mainly grains. Hence, the approach may be of little value for generalizing results.

2.2 Empirical Review

Rosenzweig et al., (1994) investigated the potential impact of global climate change on world food supply. The study used data drawn from other individual studies so as to obtain the world picture of the simulated change in crop yield associated with different climate change scenarios. To simulate the economic consequences associated with the different changes in yield associated with different climate scenarios, the study used a world food trade model. The study found out that developing countries were more vulnerable to climate change than the developed countries. The study also found out adaptation options taken up at the farm level in developing countries didn't reduce this gap in vulnerability.

The findings by Rosenzweig et al., (1994) were supported by findings of another study by Parry et al., (1999). The study by Parry et al., (1999) investigated the potential impact of climate change on world food security using crop growth models for wheat, rice, maize and soybeans and simulated the changes of crop yields to climate change. The study by Parry et al., (1999) found out that climate change will affect agriculture more in developing countries than in developed countries particularly those located in Africa. It further noted that, agricultural production in mid and high latitudes will benefit from climate change while agricultural production in low latitudes will suffer.

Chang (2002) used the production function approach to analyze the impact of climate change on Taiwan agricultural sector. The study by Chang (2002) used yield regression models and factored in farmer's adaptation responses. The study focused on 60 crops including rice, corn, wheat, sorghum, soybeans, carrots, tea and sesame among others. Chang (2002) noted that temperature and precipitation have significant impact of crop yields in Taiwan. Chang (2002) also found that climate change will have an overall positive impact on Taiwan society welfare.

The current study differs from the studies by Rosenzweig et al., (1994), Parry et al., (1999) and Chang (2002) in terms of approach used to analyze the impact of climate change. The above studies used the production function approach while the current study used the Ricardian approach. In addition, the current study differs from the studies by Rosenzweig et al., (1994) and Parry et al., (1999) in terms of area of focus. The studies by Rosenzweig et al., (1994) and Parry et al., (1999) looked at the impact of climate change on global agriculture and global food supply while the current study looked at the impact of climate change on maize production in Kenya.

3.0 RESEARCH METHODOLOGY

The study used climate, soil and household data for 1357 households. The climate data was from ARTES (African Rainfall and Evaluation System) and Satellite climate data while the Soil data was from Kenya Soil Survey conducted by Kenya Agricultural Research Institute. The household data was obtained from Tegemeo Research Institute.

4.0 RESULTS AND DISCUSSIONS

4.1. Normality of Data

The year 2000 household data set from Tegemeo Institute had 1446 households of which 1357 grew maize. Therefore, 1357 households represented the sample size. The data that is of most importance to this study is net maize revenue. 69 households bearing negative net farm revenues are eliminated because they would be a source of data loss once the data was converted into log form. The dependent variable (net farm revenue per hectare) is converted into its log form in order to satisfy the normality assumptions. This also ensured that the loss of households due to outliers is minimized.

Normality tests are then undertaken to inspect if the variables were normally distributed. As shown in Table 1, some of the variables are normally distributed. The rule of the thumb about normal distribution of data is that the variables should have a kurtosis of below three and a skewness of zero. However, the most important basis for testing the normality assumption is through checking the distribution of the residuals. For OLS estimation to be used, the residuals must be normally distributed (Gujarati, 1995). Results in appendix I indicate that the residuals are normally distributed which implies that OLS may be used.

Table 1: Normality Test Results

Variable name	Mean	Std. deviation	Skewness	kurtosis
Net farm revenue per hectare	4.27	0.58	(0.29)	4.27
Average years of education	5.86	2.64	0.27	2.63*
Size of the household	6.67	2.90	0.42	3.57
Distance to the extension service	5.25	5.36	3.39	24.56
Gender of the house head	0.88	0.33	(2.28)	6.19
Soil type	0.10	0.30	2.71	8.33
Farm size	5.08	8.94	14.48	289.97
March –May average precipitation	123.69	33.34	0.12	1.39*
March-May average temperature	18.10	2.40	1.74	5.73
June-August Average precipitation	72.35	41.39	(0.44)	1.81*
June-August average temperature	17.67	2.15	1.26	3.93

*indicates that the variable is normally distributed

4.2 Descriptive Statistics

Descriptive statistics are presented in table 2. The results indicate that the average net farm revenue per hectare[2] is Kshs.46, 030.49. The largest amount of net farm revenue per hectare is about Kshs 2,972,958 while the least is about Kshs. 64.97. The average years of education per household are 5.86 years. The descriptive results indicates that 88% of the households were male headed. The results also indicated the average size of the households is about 6.67 persons per household.

The results also show that the average farm size per household is 5.082 acres with largest recorded acreage being 204 acres and the least being 0.095 acres. The results also indicate that the average distance to extension services provider is about 5.39 kilometers with the largest distance reported being 62 kilometers while the least being zero kilometers.

Only 9% of the households are found in districts where Ferrasols is the dominant soil type. The results also show that the average summer and winter temperatures are about 18.096^{0}C and 17.672 ^{0}C respectively. The average summer and winter precipitation are about123.686 mm and 72.354 mm respectively.

Table 2: Descriptive Statistics

Variables	**Mean**	**Standard deviation**	**Min**	**Max**
Net Maize farm revenue per hectare (Ksh/Ha)	46,030.49	126,700.00	64.94	2,972,958.00
Size of the household (units)	6.67	2.90	1	21
Average years of education of household members (years)	5.86	2.37	0.17	15.50
Gender of the household Head (Male=1, Female=0)	0.88	. .32	-	1
Distance to the extension services (KM)	5.39	5.67	0	62.00
Soil type (Ferrasols=1,	0.10	0.30	0	1
Farm size (Acres)	5.08	8.94	0.10	204.27
Summer Temperature (March-May temperature average)-Degree Celsius	18.10	2.40	15.72	25.81
Winter temperature (June-August temperature average)-Degree Celsius	17.67	2.15	15.38	23.68
Summer Precipitation (March-May precipitation averages)-mm	123.69	33.34	78.53	166.49
Winter Precipitation (June-August precipitation averages)-mm	72.35	41.39	3.09	116.31
N	1288			

Source: Tegemeo Institute (2000)

4.3 Model Results

Estimation Issues

The study considered the following estimation issues that may affect the regressions results.

4.3.1 Heteroscedasticity

This is dealt with by estimating White heteroscedasticity–consistent variances and standard errors. It is the most recommended ways of dealing with heteroscedasticity (Gujarati, 1995).

4.3.2 Multicollinearity

Due to the quadratic nature of the climate variables a certain degree of, Multicollinearity is expected. It is expected that the squared climate values are highly correlated to the non squared values which introduces an element of Multicollinearity. Another element of Multicollinearity may exist between climatic values of different s seasons. However, this study ensures that the extent of this problem is reduced as far as possible by dropping some of the troublesome variables as evidenced by their high correlations and demeaning the climatic data (subtracting the mean from the data). According to Amiraslany (2010), demeaning reduces Multicollinearity among independent variables.

Results in a Table 3 indicate that winter temperatures are highly correlated with summer temperature ($r = 0.9786$, $p<0.01$). The rule of the thumb is that a correlation of above 0.8 implies high Multicollinearity among a set of independent variables. It may therefore be wise to drop one of the variables. Consequently, the study drops winter temperature from the analysis.

Table 3: Pair wise correlation matrix for climate data

	Summer temp	Winter temp	Summer Precipitation	Winter precipitation
Summer temp	1.0000			
Winter temp	0.9786*	1.0000		
Summer precipitation	-0.5973*	0.6514*	1.0000	
Winter precipitation	-0.5703	-0.5994*	0.7962*	1.0000

i) *Significant at 1%

Source: ARTES and Satellite

The model results are presented in Table 4. Model 1 consists of climate variables only. Model 2 consists of climate variables and soil variables. Model 3 includes household characteristics in addition to climate and soil variables.

The results presented in Table 4 indicate that there exists a significant non-linear relationship between climate variables and net farm revenue per hectare as shown in the three models. According to the results, high summer temperatures and high winter precipitation have an adverse effect on net farm revenue while high summer precipitation has a positive impact. The negative effect of high summer temperatures may be due to it disruptive role on the formative growth of maize crop (formative growth of the maize plant takes place during summer) while high winter precipitation would disrupt the ripening and harvesting of the maize plant (Kabubo-Mariara& Karanja, 2007).

According to the results, summer temperature and winter precipitation have an inverted U shaped relationship with net maize revenue per hectare while summer precipitation has a “U” shaped relationship with the same. The positive squared term for summer temperature indicates that there is minimum levels of summer temperature required for maize production and that more or less summer temperature will increase net farm revenue per hectare. This also applies to winter precipitation. The negative coefficient for summer precipitation indicates that there is an optimal level of summer precipitation from which the net farm revenue per hectare will decrease if it increases or decreases (Mendelsohn et al., 1994). The findings with regard to summer precipitation and summer temperature agree with those in Kabubo-Mariara and Karanja (2007), Deressa (2007), Mendelsohn et al.,(1994) . However, the findings contrast with those in Kurukulasuriya, Mendelsohn (2007), Seo, Mendelsohn (2007), and Maluo (2007) who found a negative and significant linear relationship between summer temperature and summer precipitation and net farm revenue per hectare.

Introducing the Soil variable (Ferrasols) in model two reduces the F statistic from 13.83 to 12.95 but marginally increases the R squared statistic from 0.0521 to 0.0580. The soil variable (Ferrasols) has a positive and significant relationship with net maize revenue and this is in line with the author a priori expectations that Ferrasols have a positive effect on maize production.

Results in model three indicate that, all household characteristics with the exception of distance to the extension services have a positive relationship with net farm revenue per hectare. However, only sizes of the household and average years of education have a significant relationship with net maize revenue. Distance to the extension services has a negative relationship implying that the further the farmer is from the extension service the lower the net farm revenue per hectare. However, the relationship is insignificant. The significant relationship of size of the household and average years of education implies the higher household sizes and education levels are associated with high productivity. The introduction of the household variables further reduces the F statistic to 10.30 but improves the R squared to 0.0837.

Table 4: Cross-section Regression Results

VARIABLES	MODEL ONE	MODEL TWO	MODEL THREE
Constant	4.27	4.26	3.93
Summer temperatures	-.53*(0.000)	-.55 *(0.000)	-.48* (0.001)
Summer temperatures squared	.011 *(0.001)	.011* (0.001)	.010 * (0.005)
Summer Precipitation	.083 *(0.005)	.078* (0.000)	.083 * (0.006)
Summer precipitation squared	-.0003 *(0.002)	-.0003 *(0.000)	-.00032*(0.004)
Winter precipitation	-.022*(0.001)	-.0215495*(0.001)	-.0216402* (0.000)
Winter precipitation squared	.0001145*(0.000)	.000121*(0.000)	.0001168*(0.000)
Soil type (Ferrasols)		.1631419 *(0.000)	.1575361 * (0.002)
Gender of the household Head			.0989008 (0.256)
Size of the household			.0146533 * (0.012)
Average years of education of the household squared			.0228201 *(0.000)
farm size			0046945 (0.208)
Distance to the Extension services			-.0028952 (0.425)
Number of Observations	1288	1288	1288
R squared	0.0521	0.0580	0.0892
F statistic	13.83 * (0.000)	12.95 * (0.000)	10.30 *(0.000)

* Significant at 1%,

( ) parenthesis represents the P values

4.4 Marginal Climate Impacts and Elasticity

The impact of climate change on net maize revenue per hectare is investigated by using marginal impact and elasticity analysis and. Marginal impact analysis is necessary because of the quadratic relationship between climate and net farm revenue per hectare (Mendelssohn et al., 1994). The marginal impacts indicate the change in mean net maize revenue per hectare as a result of a unit change in temperature and precipitation. The regression results in Table 4.4 are used to calculate the marginal impacts.

Elasticities are calculated so as to assess the relative change in net farm revenue per hectare associated with a unit change in temperature and precipitation. Elasticities are computed as follows;

$elasticity = \frac{C}{R}(\beta_1 + \beta_2 C)$ where

Where R is the net farm revenue per hectare and C is the climate variable. β_1 and β_2 represent the coefficient for the linear and squared term of the climate variables.

Results on marginal impacts and elasticities are presented in Table 5. The elasticity of net maize revenue to summer temperature falls in absolute terms from the "all climate model" to the "all variable model". However, the elasticity of net maize revenue to summer and winter precipitation increases. The summer temperature elasticity confirms that high summer temperatures have an adverse effect on maize production. According to the results on elasticities, net farm revenue is inelastic to both precipitation and temperature in both models.

Results from the "all variable model", reveal that an increase in temperature by 1^0C would result in a 47.7% decrease in net farm revenue while an increase in precipitation by 1 mm would increase net farm revenues by 45%.

Table 5: Marginal Impacts and Elasticities

	Climate model	All variables model
Summer temperature	-0.12	-0.11
Summer precipitation	0.0029	0.0043
Winter precipitation	-0.0047	-0.00473
Temperature elasticity	-0.53	-0.48
Precipitation elasticity	0.47	0.45

4.6 Predicting the Future Impacts

In this section, the study simulates the future impact of climate change on maize production using two climate change scenarios namely Uniform Change Scenario where the study assumes that temperature and precipitation levels shall change uniformly across the country and climate change scenarios produced by the Atmosphere–Ocean Global circulation models (AOGCM). Regression results in column four of table 4 are used to analyze the future impact of climate change. To get the impact of future climate change, temperature and precipitation are adjusted to the different climate scenarios. The difference between the old and the new climate variables is then plugged in the regression result from column 4 of table 4 so as to calculate the change in net farm revenue. Future Climate change impacts are calculated at the average net farm revenue.

4.6.1 Uniform Change Scenario

Results for impact of climate change under uniform change scenario are presented in table 6. Uniform change assumes that only one climate variable changes and such change is uniform across the region. According to results, a 2^0c increase in temperature would result in 21.5% decrease in net farm revenue per hectare while 5^0c would result in a fall of net farm revenue per hectare by half (50%). This implies that increase in temperature has a significant adverse impact on maize production. Similarly, decrease in precipitation has also an adverse effect on maize production. Overall, an increase in temperature has a larger negative impact than decrease in precipitation.

Table 6: Uniform Scenario Impacts

	% Change in mean net maize revenue	**Change in mean net maize revenue (in units)**
2^0C Increase in temperature	(21.45)	(0.92)
5 ^{0}C increase in temperature	(50.07)	(2.14)
10% decrease summer in precipitation	*(21.35)*	(0.92)
20% decrease winter precipitation	*(45.14)*	(1.93)

Global Circulation Models Scenarios

The results of the simulated impacts on maize production using climate scenarios derived from Ocean Global circulation models (AOGCM) are presented in table 7. According to the results, net farm revenue per hectare will decline in all climate model scenarios with exception of ECHAM-b2 climate scenario which reports a small gain of 1% by 2100. CSIRO2 climate scenario indicates the most adverse future for maize production in Kenya while ECHAM paints the least. Overall, climate change will have a negative impact on maize production in future. These results are consistent with other results by Rosenzweig et al., (1994), Parry et al., (1999) Mendelsohn et al., (1994), Seo and Mendelsohn (2007), Molua and Lambi (2007), Gbetibouo and Hassan (2005), Maddison et al. (2007) and Kabubo-Mariara and Karanja (2007) that climate change will have an adverse impact on agricultural production.

Table 7: Forecasted Impacts for the year 2100

	CGCM2	CSIRO2	ECHAM	HADCM3	PCM
A2- Scenarios (%)	-39.8827	-34.3595	-10.6634	-36.3914267	-25.2732
Change in net maize revenue	-1.69527	-1.45759	-0.445	-1.544234506	-1.07153
B2- Scenarios (%) change	-29.8855	-43.6355	1.464581	-32.85858092	-19.7729
Change in net maize revenue	-1.27114	-1.8585	0.073284	-1.395560856	-0.83866

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The results indicate that overall climate change will have an adverse effect on maize production in Kenya and hence may also have an adverse effect on food security. This is noted because of the close relationship between maize availability and food security as maize is the country principal food crop. Simulations from the climate scenarios indicate that maize production could fall by more than 20% by the year 2100. CSIRO2-B2 scenario paints the bleakest picture predicting that maize production could fall by 43.6% by the year 2100. ECHAM-B2 scenario however, paints a rosy picture of 1% gain in production. Overall the scenarios point out a decrease in maize production.

5.2 Recommendations

The study recommends that policy efforts should be directed at addressing the impact of climate change on maize production. Through research and development, the government should encourage the development of maize varieties that can adapt to the future expected hot conditions.

Finally, effective dissemination of climate related information to maize farmers should be urgently undertaken. Farmers should be informed on climate change and its likely impacts on maize production. This requires that government sets up effective extension service programs (Gbetibouo and Hassan, 2005).

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