ECONOMIC IMPACT OF CLIMATE CHANGE ON SMALLHOLDER AGRICULTURE IN COASTAL KENYA: A RICARDIAN APPROACH

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ABSTRACT

The effect of climate change on agriculture in Kenya is increasingly gaining attention among researchers and policy makers. However, there is scant econometric literature that looks into the relationship between agricultural productivity and climate change in the country. This study evaluates the effect of climate change on both livestock and crop production in the coastal region of Kenya. The specific objectives of this study are: to assess the impact of climate change on crop farming income, to evaluate the impact of climate change on livestock farming income and, to estimate the impact of climate change on combined income from both crop and livestock production. A Ricardian model was used in this study to estimate how mixed agriculture has been affected by the change in climate across the coastal region of Kenya. Results from the study show that climate change significantly ($p<0.05$) affects net revenues from crops, livestock and a combination of both livestock and crops. The other socioeconomic variable that were found to also significantly ($p<0.05$) affect net revenue from crops, livestock and a combination of crops and livestock.

Key Words: *Climate change, Linear regression, Net Crop Revenue, Net Livestock Revenue, Ricardian model, Smallholder agriculture*

INTRODUCTION

Climate change is projected to largely affect agriculture in many African countries (Challinor et al., 2007; Deressa et al., 2005; Gbetibouo & Hassan, 2005; Gebreegziabher et al., 2013). Numerous studies have shown a rising global concentration of greenhouse gases and consequently global warming (IPCC, 2007). There are several studies suggesting that warming would have extensively harmful agronomic effects in Africa. However, only a few economic studies have addressed the effect of climate change on agriculture in sub-Saharan Africa (Kurukulasuriya & Rosenthal, 2003). This article examines the effect of climate change on agriculture in Coastal Kenya.

Agriculture is the backbone of the Kenyan economy directly contributing 24% of the GDP and another 27% indirectly. This sector accounts for 65% of informal employment in rural areas. Kenya's Vision 2030 has identified agriculture as one of the key sectors to deliver the 10 per cent annual economic growth rate envisaged under the economic pillar. To achieve this growth, transforming smallholder agriculture from subsistence to an innovative, commercially oriented and modern agricultural sector is critical. However, the country faces major food security challenges due to the over dependence on rain-fed agriculture for food production (Government of Kenya, 2013). The number of Kenyans requiring food assistance rose from 650,000 in 2007 to almost 3.8 million in 2009/2010 (Government of Kenya, 2013). Currently, it is approximated that, more than 18 million people are starving with no immediate hope for assistance from the state.

Pastoral and marginal agricultural areas in Kenya are particularly vulnerable to the impacts of climate change. This is generally because agriculture is largely rainfed, which makes it dependent on weather conditions. This underlines the importance of climate change in Kenya. Extended periods of drought erode livelihood opportunities and community resilience in these areas; leading to undesirable coping strategies that damage the environment and impair household nutritional status, further undermining long-term food security. Against the background of limited arable land, predicted adverse climate conditions and declining agricultural productivity, the biggest challenge facing Kenya is intensified food crop production to feed the rapidly growing population. However, agricultural productivity continues to be undermined by unpredictable weather and climate conditions as well as declining soil fertility. While there is a growing body of literature on the impact of soils on productivity in Kenya, there is a dearth in literature on the impact of climate on agriculture. This paper addresses these research gaps.

This article uses the Ricardian approach to analyze the impact of climate on crop productivity in Kenya by simulating the impact of long-term climate change on agriculture. Understanding the impact of climate on agricultural productivity is crucial for future agricultural policies and interventions in Kenya, more so interventions to mitigate potential adverse impacts of climate change. Such interventions would have important implications for future food security and overall growth of the sector. The impact of this growth would in turn trickle down to the rest of the economy: increase employment and incomes in agriculture and related sectors and therefore boost overall economic growth.

The rest of the paper is organized as follows. The next section presents an analysis of the relationship between climate and agriculture in Kenya. Section three discusses the study site and data. Section four and five present the methods and research findings respectively. Section six concludes.

CLIMATE CHANGE, AGRICULTURE AND RICARDIAN MODEL

The use of Ricardian model to assess the impact of climate change on agriculture can be traced back to Mendelsohn et al. (1994). This model was named after David Ricardo (1772–1823) because of his original observation that land rents would reflect the net productivity of farmland (Mendelsohn and Dinar, 2003). Ricardian approach has been applied to value the contribution of environmental factors to farm income by regressing farm performance, with land values or net revenue taken as dependent variables, on a set of independent variables, including environmental factors, traditional inputs and support systems.

Several studies have employed this technique in analyzing the impact of climate change on agriculture (e.g., Ouedraogo et al., 2006; Molua & Lambi, 2006; Kabubo-Mariara & Karanja, 2006; Eid et al., 2006; Benhin, 2006; Sene et al., 2006; Jain, 2006; Mano & Nhemachena, 2006; Deressa, 2006; and Gebreegziabher et al., 2013). The use of Ricardian approach in the broader African context suggests that hot and dry climate scenarios would reduce net crop revenues in Africa (Seo & Mendelsohn, 2006, 2008a, b; Kurukulasuriya et al., 2006; Kurukulasuriya & Mendelsohn, 2008; and Seo et al. 2009). However, the magnitude and direction of the impact may differ from region to region.

STUDY SITE AND THE DATA

Sampling Procedures

The main data for this study were based on a sample of 631 households from Coastal Region of Kenya. This data was collected from all the six counties in Coastal Kenya between April and August 2017. These counties are: Tana River, Mombasa, Taita Taveta, Kilifi, Kwale, and Lamu. Using purposive sampling method, a representative sample of farmers practicing mixed farming (keeping livestock and growing crops) was randomly selected as follows: Tana River (89), Mombasa (66), Taita Taveta (136), Kilifi (91), Kwale (115), and Lamu (134).

The Data

The data used in this study included socio-economic, climate, farm, soils and information. There were three main sets of the modified Ricardian model that were used in this study: crop net revenue, livestock net revenue, and whole farm net revenue. These net revenues are the dependent variables in the model. In this article, net revenue (gross margin) is computed as total revenue minus total costs including cash expenditure. The livestock total cost comprises the cost of feed, tools, machinery and medicines. In the case of crop, total cost included cost of fertilizer, seed, manure and all other chemical inputs. Net revenues are a function of the following regressors: climate variables (temperature, precipitation and evaporation); soil types/characteristics, and socio-economic variables. The independent variables estimated in the models included the linear and quadratic temperature, precipitation and evaporation terms.

The study also made use of climate data (temperatures, precipitation, evaporation and soil). This secondary data used for the study were obtained from Kenya Meteorological Department (KMD) and Kenya Agricultural Research and Livestock Organization (KARLO) Mtwapa. The used climate data covered a period of 40 years (1972 - 2012).

CONCEPTUAL FRAMEWORK AND METHODOLOGY

The Ricardian model is a cross-sectional approach that is applied to agricultural production (Mendelsohn *et al.*,1994). It takes into account how variations in climate change affect net revenue or land value. This approach involves specifying a net productivity function of the form:

$$N = \sum p_i q_i (B, C, S, E) - \sum p_B B \quad (1)$$

where N is net income per hectare, p_i is the market price of crop i, q_i is output of crop i, B is a vector of purchased inputs (excluding land), C is a vector of climate variables, S is a set of soil variables, E is a set of economic variables such as market access and p_B is a vector of input prices. The farmer is assumed to choose B to maximize net revenues given the characteristics of the farm and market prices.

The Ricardian model is a reduced form model that examines how a set of exogenous variables C, S, and E affect farm value.

The standard Ricardian model relies on a quadratic formulation of climate:

$$N = \beta_0 + \beta_1 C + \beta_2 C^2 + \beta_3 S + \beta_4 E + \varepsilon \quad (2)$$

where ε is an error term, C are the levels of climate variables (temperature, precipitation and evaporation) and C^2 are the quadratic terms for climate variables.

These quadratic terms for temperature, precipitation and evaporation reflect nonlinear forms of the response function between net revenues and climate. A function of farm revenue is expected to be concave with respect to temperature. The net revenue function is U-shaped when the quadratic term is positive. However, the function is inverted U-shape when the quadratic term is negative.

RESULTS AND DISCUSSION

Descriptive statistics of variables used in the regression models

Table 1 presents the summary statistics of variables used for regression analysis in this study for both secondary and primary data from the 631respondents and climate data. According to the results, annual minimum crops net revenue was Kshs. -36,000 while the maximum returns per hectare was Kshs. 560,800. In Livestock production, minimum net revenue was Kshs. -32000, while maximum returns annually were Kshs. 977,500. Combined agriculture minimum annual net revenue was Kshs. -36,000 and a maximum of Kshs. 973,000. The mean total revenue of the studied area was Kshs. 99168, slightly largely contributed by livestock production with 53% (Kshs. 52,754) and crop production at 47% (Kshs. 46,414).

The minimum and maximum precipitation of the area was 38.9 and 95.0 mm respectively. Mean precipitation during the 40year period was found to be 76.59mm. Minimum temperature was 29.88 Celsius, and a maximum 30.9 Celsius. The mean temperature and Evaporation was 30.62 Celsius and 6.38 respectively. The closest farmer to a major market was 2kms of distance with the farthest being 22kms away. Adaptation to precipitation and temperature was 52 percent and farmer-to-farmer information sharing 46 percent. About 62 percent of the interviewed respondents stated that they had access to climate information, while 81 percent had access to media. Only 20% of those who responded were able to access credit services. Most farmers in the study area used cattle to cultivate most of which are hired. Use of hired labor was 76 percent attributed to the preference of using cattle for cultivation.

This study made use of Ricardian model as described in the methodology chapter to assess the effect of climate change on agriculture in the coastal region of Kenya. The dependent variables in the regression models are: net crop income, net livestock income and combined net income. According to the Student t test for the significance of every estimated coefficient, climate variables were found to be significant ($p < 0.05$) parameters in determining the net incomes from crops, livestock and the net combined income. Using the Fisher-Snedecor tests (Snedecor and Cochran, 1989) the three models used in this study were validated since their regressions were all significant ($p < 0.05$). The coefficients of determination crop, livestock and combined models were 37%, 48%, and 42%, respectively.

Table 1. Descriptive statistics of variables used in the regression models

Variable	Mean	Std. dev.	Min	Max
Crops Net Revenue (KSHS)	46414.55	59464.04	-36000	560,800
Livestock Net Revenue (KSHS)	52753.69	81769.79	-32000	977,500
Combined Net revenue (KSHS)	99168.24	104117.7	-36000	973,000
Precipitation (mm)	76.59	20.20	38.9	95
Temperature (^{0}C)	30.62	0.43	29.88	30.96
Evaporation (mm)	6.38	0.59	5.82	7.19
Market Distance (Km)	8.33	5.40	2	22
Adaptation (0/1)	0.52	0.49	0	1
Farmers to farmer information (0/1)	0.46	0.49	0	1
Climate change awareness (0/1)	0.32	0.48	0	1
Access media (0/1)	0.81	0.38	0	1
Access to Credit services (0/1)	0.20	0.40	0	1
Hired labor use (0/1)	0.76	0.42	0	1
Land owned (acres)	1.05	3.55	0	16
Climate change awareness (0/1)	0.68	0.46	0	1
Employment status (0/1)	0.19	0.38	0	1
Soil erosion severity (0/1)	0.11	0.31	0	1
Soil fertility status (0/1)	0.36	0.48	0	1
Education level of household head (years)	6.14	0.80	1	11
Age of household head (years)	40.99	17.15	0	77
Gender of household head (0/1)	0.70	0.56	0	1

Crop Net Revenue Analysis on Ricardian Regression

The Results from Ricardian regression model based on net crop revenue showed that both the linear and the squared terms of climate change significantly ($p < 0.05$) affect the net crop revenue in coastal region (Table 2), thus change in climate has non-linear impact on overall crop revenue in the study area (Mendelsohn et al 1994, 2003; Kurukulasuriya et al., 2006). According to the linear terms, an increase in precipitation raises net crop income. However, the increase of both temperature and evaporation lowered crop income in the study area. This depicted that prolonged high temperatures are detrimental to crop productivity indicating that global warming is probable to poses damaging impact on agricultural activities unless government and farmers enhances measures to adapt in order to counter the expected impacts of changes in climate (Kurukulasuriya et al., 2006)

Other factors that were found to significantly ($p < 0.05$) influence overall revenue from the crops are distance to market, severity of erosion, employment status of the household head, availability of climate change information from media outlets, access to credit services, extension services for farmer-to-farmer, land size owned, adaptation to changes in climate, as well as the use of hired labor in the farm. The inverse relationship between distance to the market and the net revenue from crop production may be attributed to costs incurred in transporting inputs to the farms as well as outputs to market. Awareness to climate change was found to significantly raise net crop income. This is attributable to ability of the farmer to seek varieties of crops that can yield optimally in various climatic conditions.

A positive effect of adaptation to change in climate on net income from crop farming could be attributed to production of crops that are resilient and hence able to yield well under harsh climate conditions. The access to credit facilities can enable farmers to acquire farm inputs and hence increase farm productivity. The coefficient of erosion severity in the farms was as anticipated. An increase in erosion lowers the ability of the farm to support optimal crop yields hence lowering revenue from crops. The increased revenue due to use of hired labor may be explained by timely farm operations such planting, weeding, harvesting and postharvest processes.

Table 2. Ricardian Regression Estimates for Crops Net Revenue

Variable	Coeff.	Std. Err.	t-test
Precipitation	981.53***	174.40	5.63
Precipitations_ SQ	6.62***	1.13	5.84
Temperature	-51272.92***	6084.46	-8.43
Temperature_ SQ	840.94***	99.12	8.48
Evaporation	-19809.23***	4383.86	-4.52
Evaporation_ SQ	-79.87	85.67	-0.93
Distance market	-8487.11***	1414.97	-6.00
Erosion severity	-16042.57***	5977.35	-2.68
Employment status	11642.41***	4074.02	2.86
Access to media	16035.65***	5321.58	3.01
Credit services access	20708.27***	4716.24	4.39
Farmer to farmer extension services	11079.11***	5058.67	2.19
Size of land owned	3428.97***	651.10	5.27
Climate change awareness	9244.50***	3868.37	2.39
Adaptation to climate change	22393.21***	3740.88	5.99
Hired labor use	10001.50***	4461.34	2.24
Education level of household head	4308.09	2366.97	1.82
Age of household head	36.53	111.14	0.33
Gender of household head	-5194.55	3811.60	1.36
Soil fertility	1024.12	2154.51	0.48
Constant	646372.90***	255509.00	2.53
F (20, 610)	20.58		
Prob > F	0.00		
R-SQ	0.37		
Root MSE	61078		
N	631		

*** $p < 0.05$

Ricardian Regression Analysis for Net Livestock Revenue

Results from the model for livestock production (Table 3) showed that climate change significantly ($p < 0.05$) affects net revenue for both the linear and quadratic terms. It implied that change in climate has effects that are non-linear on net livestock revenue in the coastal region of Kenya. The linear term of precipitation had a significantly positive effect on net revenue from livestock production. Similarly, the coefficient of the linear term of temperature was positive.

In addition to the climate change factors, several socioeconomic variables were also found to significantly influence the net revenue from livestock production. Similar to the net crop revenue model, distance to the market was found to significantly affect livestock net revenue. This may be readily explained by the costs that are incurred as farms transport livestock production inputs to the farms. Where farmers transport their livestock to the market, additional costs may also be incurred. Consequently, these costs lower the net revenue earned from livestock production.

Access to media turned out positive and significant, suggesting that provision of information through the local media outlets to farmers can influence their decisions greatly. Change in climate awareness had a notable and positive outcome on net livestock revenue. This implied that farmers who have knowledge about the existing climatic conditions are likely to choose breeds of livestock that can well suit their areas. Adaptation to climate change had the expected positively significant coefficient. Livestock farmers who have adapted to climate change have realized increased net revenue. The results showed that household head's age had positive and significant coefficient. This may be partly attributable to experience gained in livestock production that can help in making appropriate decisions and thus increasing the net revenue (Gebreegziabher *et al.*, 2013).

Table 3. Ricardian Regression Estimates for Livestock Net Revenue

Variable	Coeff.	Std. Err.	t-test
Precipitation	2089.73***	1090.01	2.11
Precipitations_ SQ	49.56	37.74	1.31
Temperature	229.10***	110.21	2.08
Temperature_ SQ	-531.42***	130.81	-4.06
Evaporation	-1052.91***	482.00	-2.18
Evaporation_ SQ	-75.27***	33.17	-2.27
Distance market	-3244.01***	914.97	-3.55
Erosion severity	-3982.57	3166.21	-1.26
Employment status	2842.41	2918.22	0.97
Access to media	1595.15***	729.81	2.19
Credit services access	4281.27***	1716.24	2.49
Farmer to farmer extension services	-1066.13	2188.02	-0.49
Size of land owned	2009.51***	998.01	2.01
Climate change awareness	2818.20***	1301.09	2.17
Adaptation to climate change	12921.34***	5192.99	2.49
Hired labor use	-10011.50	5193.17	-1.93
Education level of household head	6302.99	4116.92	1.53
Age of household head	909.19***	409.37	2.22
Gender of household head	4701.37	2704.99	1.74
Soil fertility	978.86	701.21	1.40
Constant	337624.50	270515.50	1.25
F (20, 610)	15.53		
Prob > F	0.00		
R-SQ	0.38		
Root MSE	60542		
N	631		

*** $p < 0.05$

Ricardian Regression Analysis for Net Combined (Crop & Livestock) Revenue

The regression model results based on net crop and livestock revenue (whole farm) showed that both the linear and the squared terms of change in climate have a significant ($p < 0.05$) consequence on the combined net revenue in coastal region (Table 4). Therefore, there was a non-linear impact change in climate on net combined revenue in the study area. The linear term for precipitation had a significant and positive coefficient whereas the coefficients for temperature and evaporation were negative.

Results of the model show the distance to market negatively affected the total farm net revenue. This compared well with the findings from the two separate models (crop and livestock), whereby costs incurred in transportation of farm inputs and outputs can lower the profitability of the enterprise. The farmer-to-farmer extension was a significantly positive determinant of the combined net revenue. This explained the importance of using farmers to reach out to others in dissemination of farming technologies. Also, the size of land owned by a farmer had a significantly positive effect on the combined net revenue. This is partly due to the requirement of a large parcel of land to practice mixed farming.

The level of education of a household head had a significant as well as positive coefficient. Education contributed to a farmer understanding complex aspects of climate change easily compared to illiterate farmers. The gender variable had a negatively significant coefficient. A female-headed household in the study area increased combined net revenue significantly. This is attributable to the role of women in provision of farm labor in the coastal region of Kenya. The farmers' awareness to climate change was established to be a significant factor that influences the combined net revenue. This compares well with the results from earlier regression models where crop and livestock net revenues were considered in isolation. Similar results were also observed for the farmers who had adapted to change in climate. The coefficient of adaptation to change in climate was found to be positive and significant. This underscores the relevance of appropriate adaptation strategies in order to realize an increase in combined net revenue.

Table 4. Ricardian Regression Estimates for Combined Net Revenue

Variable	Coeff.	Std. Err.	t-test
Precipitation	-481.53***	174.40	-2.76
Precipitations_ SQ	31.11***	4.06	7.66
Temperature	-329.26***	101.96	-3.23
Temperature_ SQ	1929.49***	364.40	5.30
Evaporation	-19809.23***	4383.86	-4.52
Evaporation_ SQ	-7700.24***	1912.34	-4.03
Distance market	-2143.27***	819.97	-2.61
Erosion severity	-921.30	3109.41	-0.30
Employment status	1108.41	7114.21	0.16
Access to media	2172.33***	818.53	2.65
Credit services access	10019.23***	3702.45	2.71
Farmer to farmer extension services	21179.71***	8793.10	2.41
Size of land owned	1008.29***	379.44	2.66
Climate change awareness	1819.37***	717.11	2.37
Adaptation to climate change	10401.92***	4393.41	2.37
Hired labor use	1770.18	3809.53	0.46
Education level of household head	3804.67***	1873.15	2.03
Age of household head	109.03	86.33	1.26
Gender of household head	-7099.01***	3299.00	-2.15
Soil fertility	602.93	499.07	1.21
Constant	1488413.00***	541470.10	2.75
F (20, 610)	5.85		
Prob > F	0.00		
R-SQ	0.42		
Root MSE	1.00E+05		
N	631		

*** $p < 0.05$

Climate Variables and their Marginal Effects

Table 5 indicates the marginal effects of the climate variables (precipitation, temperature as well as evaporation) on agriculture. According to the results, the analysis of marginal impact showed that a 1mm increase in annual precipitation would result in increase of Kshs. 374.02 and 201.31 from net crop revenue, and total net farm revenue respectively. However, the marginal impact of precipitation on livestock net revenue was significantly negative. A unit increase in annual mean precipitation reduced livestock net income by Kshs 119.04.

The marginal impacts of temperature on the overall revenues showed that annual rise of 10C of temperature would have a significantly positive effect on livestock net revenue, but negative impact on farm net income and crop net revenue. According to the results, an annual net gain of Kshs 229.65 is expected from livestock agriculture when the annual temperature increases by 10C. However, net losses of Kshs 4893.35 and 374.88 results from a 10C increase in temperature. These results compare with the ones obtained on similar studies by other researchers (e.g., Gebreegziabher et al., 2013; Seo and Mendelsohn, 2006). In analysis, the marginal result of evaporation on crop, livestock and farm net revenues showed that an increase in mean annual evaporation by 1mm significantly reduces crop net revenue by 10312.92. However, the marginal impacts of evaporation on livestock and farm were not significant.

Table 5. Climate Variables Marginal Effects

Climate Variables	Crop	Livestock	Agriculture (total)
Precipitation	374.02***	-119.04***	201.31***
Temperature	-4893.37***	229.65***	-374.88***
Evaporation	-10312.92***	-391.11	-1127.56

*** $p < 0.05$

CONCLUSIONS AND POLICY IMPLICATIONS

The results showed varied effects of different parameters across the Ricardian models. According to these, a nonlinear relationship exists between climate variables and net revenues from crop, livestock and agriculture as a whole.

The Ricardian model for net revenue from crop production showed mixed effect for precipitation, temperature and evaporation. Marginal effect of precipitation on crop revenues was found to be positive. However, the marginal effects of mean annual temperature and evaporation on crop revenues were negative. When the Ricardian model was used on livestock production data, the results showed that a unit increase in precipitation lowered livestock net revenue. Similar results were obtained for a unit increase in evaporation. However, marginal increase in temperature was found to increase livestock net revenue. The general effect of climate change on combined agriculture was also analyzed. The results showed that the unit increase in both temperature and evaporation negatively affected combined agriculture. However, a unit increase in precipitation was observed to positively affect the combined agriculture.

In crop agriculture, awareness about climate change should be enhanced among farmers. This can be achieved through increased access to media outlets that are accessible to most farmers. Farmers should be facilitated to access appropriate strategies of adaptation to climate change (e.g., seeds appropriate for the hot and dry climatic conditions). Access of credit facilities needs to be promoted. This can greatly help farmers to acquire the necessary inputs in time for crop production.

In livestock agriculture, access to media should be enhanced whereby information on appropriate livestock production technologies may be communicated to farmers. There is need for training of farmer groups since the trained farmers are likely to transfer the learned technologies to others through farmer-to-farmer extension services. Awareness creation about climate change together with providing information about adaptation strategies should be encouraged. This can help farmers in raising breeds that can excel in harsh hot and dry weather conditions.

In total agriculture, credit facilities should be made accessible for timely acquisition of inputs. Farmer to farmer extension services should be encouraged as a means of increasing awareness about adaptations to climate change and resilience. There is need for the County governments to improve local infrastructures such as upgrading the local feeder roads and construct more markets near the production areas to reduce farmers cost in obtaining inputs and venturing the far and old markets.

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