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Economic impacts of climate change on livestock and crop returns in the coastal region of Kenya

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Abstract. *Wachira PW, Ndunda E, Sitati N. 2021. Economic impacts of climate change on livestock and crop returns in the coastal region of Kenya. Indo Pac J Ocean Life 5: 74-82.* The objectives were to assess which impact climate change has on crop net revenue, to evaluate the impact of climate change on livestock net revenue, and to estimate the impact of climate change on combined net revenue. The study was conducted in all six counties in coastal area of Kenya, i.e.: Kwale, Lamu, Tana River, Mombasa, Kilifi, and Taita Taveta. A sum of 631 respondents was interviewed to obtain the cross-sectional survey data. The secondary data on precipitation, temperature, and evaporation for 40 years was obtained from Kenya Meteorological Department. The data was analyzed using the Ricardian model; the linear and quadratic effects of climate change on crops, livestock net revenue, and the combination were calculated. The study shows that climate change significantly ($p<0.05$) affects net revenues from livestock, crops, and a combination of livestock and crops. Other socio-economic variables that were found to also significantly ($p<0.05$) affect net revenue from crops, livestock, and a combination of crops and livestock were access to media, credit services access, farmer-to-farmer extension services, size of land owned, climate change awareness, education level, age, and gender of the household head. The results show a non-linear relationship between climate variables and net revenues from crops, livestock, and agriculture. This study concludes that a unit increase in precipitation increases crop revenues; at the same time, a unit increase in mean annual temperature significantly reduces crop and total farm income. The marginal effect of increasing a unit in precipitation is a reduction of livestock net revenue. An increase in livestock production revenue from a unit temperature increase (linear) can be attributed to the livestock breeds in the coastal region inherent to dry weather. However, results show that increasing quadratic temperature would reduce net livestock revenue. This study recommends enhancing awareness of climate change, crop, livestock, and combined agriculture adaptation strategies. Also important is access to credit facilities that help farmers greatly to acquire the necessary inputs for crop production in time. Further, training groups of farmers would be appropriate in the study area since the trained farmers preferably transfer the learned technologies to others through farmer-to-farmer extension services. Media access should be enhanced whereby information on appropriate livestock and crop production technologies may be communicated to farmers.

Keywords: Climate change, crop, economic, livestock

INTRODUCTION

Agriculture is the backbone of Kenya's economy, which contributes 27% and 24% indirectly and directly, respectively. In addition, this sector accounts for 65% of all informal employment in rural areas. However, Kenya faces notable challenges as far as food security is concerned, mainly resulting from overdependence on rain-fed agriculture (Government of Kenya 2013; Wawira and Thenya 2017).

The number of people who rose to approximately 3.8 million in 2009/2010 from 650,000 in 2007 who required food assistance (Government of Kenya 2013). Nowadays, approximately 18 million people are starving without immediate assistance from the state (Ngwiri 2016). Agricultural areas, which are pastoral and marginal, are highly vulnerable to impacts arising from climate change. Livelihood opportunities and the resilience ability of communities have been eroded, as a result giving rise to undesirable coping strategies.

This background expresses the need to assess and estimate the impacts on agriculture from climate change incorporating crops and livestock production. The results will broaden and extend the understanding of Kenya's agricultural productivity and climate change. That will give rise to informed levels of decision-making, thus significantly reducing poverty and promoting sustainability in development. As far as vision 2030 in Kenya is concerned, the agricultural sector has been identified as could deliver 10% of the entire annual budget under the economic pillar. However, there is an urgent need to transform the smallholder sector to innovate, thus operating optimally for improved production (Government of Kenya 2010; Abraham and Pingali 2020; Fan and Rue 2020).

Kenya's agriculture is mainly fed through rain and thus depends fully on rainfall in almost the country. Only 1.7 percent of the total agricultural land is under irrigation (Agricultural Sector Development Strategy 2009). However, fluctuating agricultural productivity is a major concern considering Kenya's fast-growing population. In addition, marginal and pastoral agricultural areas are susceptible to the effects of changing climatic patterns. Nevertheless, agriculture remains the sole food source in Kenya, thus a notable basis of the national economy. Moreover, the food policy should serve humanity by the advancement of human goals, thus eradicating poverty and hunger. Even though emerging forces, including climate change, recently challenged these goals.

A common consensus among environmental and agricultural economists is that climate change seriously threatens sustainable agriculture. The United Nations Development Programme (UNDP) estimates that one of the hardest hit continents by changes in climatic patterns in Africa, as it faces severe effects in comparison to other parts globally. Because the African economy is climate-dependent in most sectors, the capability to adjust and subsist to changing climate is highly limited (Ayinde et al. 2011; Dell et al. 2012; Iheoma 2014; Abidoyea and Odusola 2015; Fant et al. 2016; Apollo and Mbah 2021). For instance, small-scale farms account for 75% of all agricultural production and 70% of livestock production, and the entire marketed crop (Agricultural Sector Development Strategy 2009).

Poverty has been a hard hit in the Kenyan coastal region for many decades. Land tenure, yearly drought and floods, and undeveloped agricultural markets as major challenges alongside increasing poverty levels to non-performing agriculture in the country (Agricultural Sector Development Support Programme 2009). It is clear that climate change may interrupt the progress already made regarding eradicating hunger globally. That is based on the fact that the stability of the entire food production system may be risked by changes in climate owing to short-term supply variability (Wheeler and Braun 2013). However, fewer studies have been done on agriculture to explain the results of variations in climate, especially in the coastal region. Therefore, this study aims to investigate climate change's impacts by analyzing trends in rainfall patterns and temperature variations over time in livestock and crop production.

The objective of this study was to assess the economic impacts of climate change on agriculture in Kenya's coastal region. Specific objectives were used to achieve this: to assess which impact climate change has on crop net revenue, to evaluate the impact of climate change on livestock net revenue, and to estimate the impact of climate change on combined net revenue.

MATERIALS AND METHODS

Study area

Location: Coastal region of Kenya, formerly the coastal province, comprises six counties, namely Tana River, Lamu, Kilifi, Kwale, Taita Taveta, and Mombasa County (Figure 1, Table 1). Taita Taveta covers an area of 17,083 Km^2, its capital town is Voi. Area coverage of Kwale County is 8,270 Km^2 and its capital town is Ukunda. Mombasa County lies between longitudes 39°34' and 39°46' and latitudes 3°56' and 4°10' south of the equator. The county has the smallest area in the region and covers an area of 229.7 km^2. It is headquartered in Mombasa city. Kilifi County has an area of 12,245 km^2 with 109 km of ocean line stretch. It is headquartered in Kilifi town. Lamu County is located in the northern part of the Kenyan coastal region. It lies 1° 40' and 2° 30' South and longitude 40° 15' and 40° 38' East. The county covers an area of 6,273 km^2 and a beach coastline of 130 km. The sixth county is Tana River, covering an area of 38,437 km^2.

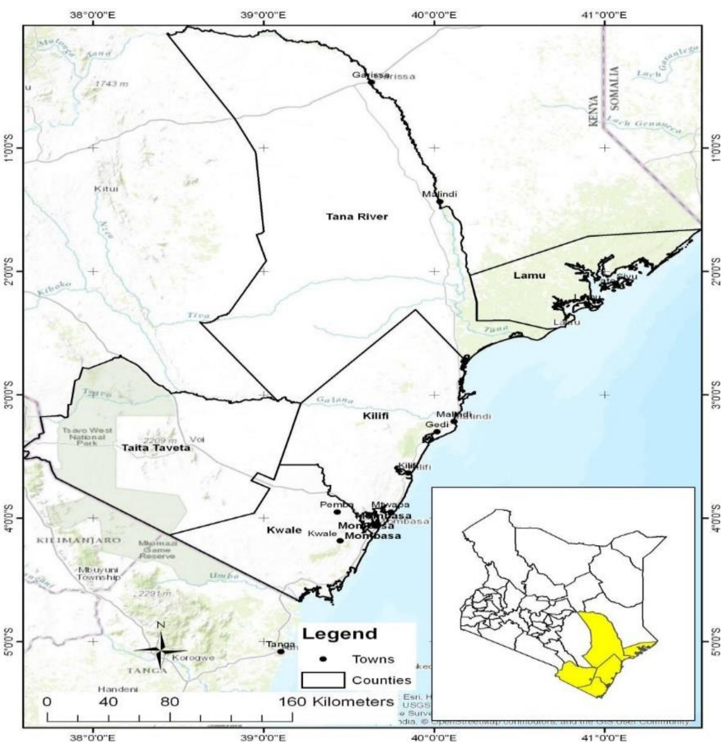

Figure 1. Map showing the study area in Coastal region of Kenya

Table 1. Coastal region population summary

County	Population (Census 2009)	% Total	The population of households practicing mixed farming	Sample size
Kilifi	1,109,735	33.37	93	92
Kwale	649,931	19.54	117	116
Lamu	101,539	3.06	137	135
Mombasa	939,370	28.24	67	67
Tana River	240,075	7.22	92	91
Taita Taveta	284,657	8.56	141	139
Totals	**3,325,307**	**100**		**640**

Drainage: The region has both perennial and seasonal rivers. Sabaki and Tana Rivers are the main perennial rivers. Tana River, 850 km in length, with 95,000 km^2. in the catchment area, enters the ocean halfway of Malindi in Kilifi County and Lamu County near Kipini. Sabaki River, 650 km long, discharges two million tons of sediments and 2,000 $million^3$ of fresh water into the Indian Ocean on the northern side of Malindi via the Sabaki estuary. Other seasonal and semi-perennial rivers in the coastal region include Ramisi, Tsalu, Nzovuni, Voi, Kombeni, Umba, and Mwachema (FAO 2015).

Population: In 2009 census, Kilifi County clearly leads in size among the six counties, with 33.37% of the population within the region. It is important to consider that, within the six counties, one of the Mijikenda people, Giriama, forms 57% of the total population living in Kilifi County. Mombasa County is a metropolitan area with the entire Mijikenda group equally represented. On the contrary, another subgroup within Mijikenda, Digo, constitutes 49% of the total population in Kwale County. Other tribes, such as Luhya, Kisii, Kamba, and Arabs, are also present within the six counties.

Social economic: The household source income, income level, and employment status in the coastal region are well documented. The main sources of income are self-employment in businesses at 39%, followed by agriculture at the household level at 15%, and finally, the public sectors employments. Tana River County has the highest number of households that depend on livestock and agriculture, which clearly indicates its population is mainly nomadic pastoralists.

Study design

This study used a dedicated survey research design. Cross-sectional data on farmland on actual observations within the different Counties of farm performance in areas where agriculture is practiced. The target group was farmers who practiced mixed farming.

Sample size and sampling procedure

Random and proportional sampling was employed in selecting households during this study. Proportional sampling reduces bias and ensures that particular parts of the population are not over-represented. A random selection method was done to identify the households. A total of 640 households sample size (Table 2) was derived based on the formula (Israel 2009) indicated below:

$$n = \frac{N}{1 + N(e)^2}$$

Where: a 95% confidence level and P = 0.05 in the sample size are used to assume for the equation, N is the population size, and e is the precision level that is 0.01. Based on the above figure, the response rate was 98.4%, with 631 questionnaires.

The household list was obtained from Nyumba Kumi village older adults at the location level through local National Administration (NA) officers (Chiefs). Ten questionnaires were administered in each of the six counties. Moreover, the questionnaire was pretested before to get a better actual data collection exercise, which helped to perfect the tool for quality and relevant data collection. Then the questionnaires were administered with the assistance of trained enumerators. Section C of the questionnaire was an in-depth interview with the respondents.

Data collection methods

Primary data

Primary data for this study was achieved by administering semi-structured questionnaires to household heads. Enumerators were trained in the administration of the questionnaires before data collection. That was to minimize mistakes, standardize the data collection procedure and ensure data quality. The questionnaires contained information on socioeconomics and adaptation to climate change, which captured 2015 production data incomes as the output. In addition, enumerators interviewed farmers practicing mixed farming as earlier identified that practicing agriculture within the counties in every tenth household.

Table 2. Study sample size summary

County	Population of households practicing mixed farming	Sample size
Tana River	92	91
Mombasa	67	67
Taita Taveta	141	139
Kilifi	93	92
Kwale	117	116
Lamu	137	135
Total		640

Secondary sources of data

Secondary data used for the study were obtained from Kenya Meteorological Department (KMD) and Kenya Agricultural Research and Livestock Organization (KARLO) Mtwapa. Other major sources of information included Government of Kenya publications, coastal counties websites, dissertations, peer-reviewed journals, Institutional websites, and textbooks. Climate data employed for the study covered 40 years (1972-2012). Secondary data collected included average temperature, precipitation, and evaporation every month within the 40 periods analyzed by this study.

Data analysis techniques

Theory and model

The Ricardian model is a linear regression model relating to cross-sectional data. The net revenue was a function of three regressors; The climate variables covering temperature and precipitation, characteristics of soil covering fertility and erosivity, and social and economic variables, including education level, age, gender, and distance to the market and land ownership. In addition, the annual mean average of the quadratic and linear terms of climatic variables (temperature, precipitation, and evaporation) were considered for 40 years. Therefore, the study analyzed three modified Ricardian models for livestock net revenue, crop net revenue, and combined net revenue of the entire farm. The Ricardian-modified models were analyzed using STATA 2014 software, which was used to calculate livestock net revenue, net crop revenue, and the combined farm revenue for livestock and crops as dependent variables. It is worth considering that climate change affects all variables across the three modified Ricardian models (Gebreegziabher et al. 2013). The results obtained were shown in graphs and table format.

The study used the Ricardian model to measure welfare change. According to Mendelsohn et al. (1994), this research employed Ricardian analysis to determine the impacts of climate change on Kenyan coastal region agriculture, generally mixed farming. This study tried to analyze the effect of climate change on crop farming, livestock farming, and the combined agriculture of crops and livestock. The principle captured in the equation indicates that the land net productivity is equivalent to their total farmland net revenue, as follows;

$$V_{rt} = P_t Q_{rt}\ ß_{rt}\ Z_t - M_t X_{rt}\ e^{-\partial t}\, dt \quad \text{[eq.1]}$$

Where: Pt is the market price at location t of every crop, Qrt is a crop at farm r output at location t, ßrtis a vector of inputs at farm r for each crop (other than land), Zt is an exogenous vector variable at location t, Mt is a vector of input prices at location t, ∂ is the interest rate, and t is period. Also, note that the $^{-}\partial$t term is for discounting. The farmer wants to select X to raise net revenues for crop net given market prices and farm characteristics. Therefore, the Land value Vrt can only be expressed as a function of exogenous variables by solving equation (1) above. Those site-specific exogenous environmental factors include climate variables (temperature (T) and precipitation (P)), socio-economic variables (H), soil variables (S), and geographical variables (G). An assumption was made to capture returns from livestock production: the farmer maximizes net revenue by selecting which livestock to buy and the inputs to apply.

$$\text{Max}\ (ß\square = P_{qx} Q_x (G_L, \infty, L, \mu, C, \Omega\ \square ø,)\ \square\ P_F \infty\ \square\ P_W L\ \square\ P_M \mu \quad \text{[eq.2]}$$

Where: ß is the revenue obtained from livestock (animal) x, GL is grazing land, Pqx is the market price of animal x, Qx is a production function for animal x, ∞ is feeds, L is a labor inputs vectors, µ is a vector of capital such as milking cans, C is a vector of climate variables, Ω is available water, ø is a vector of soil characteristics of grazing land vector, PF a vector of prices for each type of feed, PW is prices vector for every variety of labor, and PM capital (rental price). When a farmer rears the species (animal) x and the number of animals maximizing benefits, then the representative problem affecting the farmer's condition to maximizing profits can be specified as:

$$ß^* = ß\ (Pq, C, W, ø, PF, PW, PM) \quad \text{[eq.3]}$$

Equation (3) is the Ricardian equivalent of livestock production. Finally, Seo and Mendelsohn (2006) tell how profits vary across all the exogenous variables a farmer faces.

Empirical model and data

Empirical model

This study uses Log Linear Ricardian analysis, Massetti and Mendelsohn (2011), as land values are log-normally distributed. As earlier mentioned, the Ricardian model uses actual observations of farm performance (Mendelsohn et al. 1994). The analysis comes from several explanatory variables from geography, climate, and social-economic variables that directly affect farm revenue. The Ricardian technique's main aim is to assess agricultural land changes regarding net revenue across climate gradients (Wood and Mendelsohn 2014).

This study also used a quadratic model of climate indicating the non-linear relationship between climate, net crop, and livestock, including the following empirical model:

$$VL = R0 + R1\partial + R2\partial^2 + R3\infty + R4ß + \mu \quad \text{[eq.4]}$$

Where VL is the net revenue per hectare, ∂ the climate variables vector, ∂^2 squire vector of climate variables, ∞ set of soil variables, ß set of social-economic variables, µ is the error term, R's are requiring estimation parameters, and R0 is the constant term, and the rest are coefficients. Then, ∂^2 and ∂ captures linear and quadratic terms for precipitation and temperature, respectively. Moreover, when the quadratic term is negative, the function has a hill shape; when the quadratic term is positive, the net revenue function is U-shaped (Mendelsohn et al. 1994).

The equation below describes the marginal impact of climate variables on the value of land per hectare (direct crop revenue);

E {dV/d∂i}= E {R1i +2R2i *∂i} =R1i+2R2i*E (∂i) [eq.5]

The equation mentioned above established the net economic welfare change. The environmental changes bring about changes in welfare from x to y, which consequently causes changes in the farm inputs from ßa to ßb. Impacts of non-marginal changes in climate on land per hectare value in specific farms were expressed as the comparison between the approximated value of land with the new climate variables (precipitation (P) and temperature (T)) T1P1 and the approximated land value at the current climate variables T0P0.

ΔW=W (ßb) –W (ßa) [eq.6]

Where: Δ W represents welfare change, W (ßb) is the welfare after the change, and W (ßa) is welfare before the change.

$\Delta W = \sum_{i=1}^{n}$ (PLb Qbi-PLa Qai) [eq.7]

PLb Q bi =PiQi-Ci (ßi Mi, Zi) [eq.8]

Where: PLb Qbi are at ßb and PLa Qai are at ßa.

The data analysis

In this study, to obtain dependent variables, a cross-sectional survey of 640 households farms was carried out in the coastal region of Kenya that included livestock net revenue, net crop revenue, and net revenue from the whole farm as indicators of potential effects of climate change and variability in climate on household level farm production.

As independent variables, samples were used from different counties to capture the temperature, precipitation, and evaporation variability within Kenya's coastal region. The systematic sampling method selected 640 household samples supporting livestock and crop farming. Specifically, Kwale, Tana River, and partly Taita Taveta largely support livestock rearing on a large scale, while Kilifi, Lamu, and partly Mombasa and Taita Taveta counties largely support crop production. The main crops grown were maize, bananas, peas, beans, green grams, mangoes, cashew nuts, and coconuts. The main data captured in this study were the farms' production in terms of climate, net revenue, and social demographic aspects. In addition, net revenues were obtained for livestock and crop production data, which were obtained from respective district records.

Mean precipitation, temperature, and evaporation data for 40 periods (1972-2012) were obtained from Kenya Meteorological Department (KMD), and the soil characteristics were obtained from KARI regional offices, respectively. Net revenue, in this study, was obtained as overall revenue minus costs/expenses entailing outlay in cash. The Ricardian model on the analysis of land values or net revenue per hectare for crop agriculture (Gebreegziabher et al. 2013). The crops' net revenue was calculated as total returns less the cost of seeds, all chemical inputs, manure, and market costs. The livestock revenues were calculated as the total returns less the cost of feeds, veterinary services, and medicine. The significant challenge in measuring the amount of land used for livestock by farmers is the reliability of public, open, and communal land. Moreover, there was also the challenge of quantifying own household labor; thus, it was not factored as part of the cost. Therefore, the study needs to use the Ricardian model to analyze data.

RESULTS AND DISCUSSION

Data presentation

Descriptive statistics of variables used in the regression models

Table 3 shows the summary statistics of variables used for regression analysis for both secondary and primary data from the 631 respondents and climate data. According to the results, the annual minimum crops net revenue was Kshs.-36,000, while the maximum return per hectare was Kshs. 560,800. In Livestock production, the minimum net revenue was Kshs. -32,000; conversely, the maximum annual returns were Kshs. 977,500, with the combined agriculture minimum annual net revenue was Kshs. -36,000 and a maximum of Kshs. 973,000. In the studied area, the mean total revenue was Kshs. 99,168, contributed largely by livestock production at 53% (Kshs. 52,754) and crop production at 47% (Kshs. 46,414).

The maximum and minimum precipitation of the area was 95.0 and 38.9 mm, respectively. Mean precipitation during the 40 periods was found to be 76.59 mm. The minimum temperature was 29.88°C, and the maximum was 30.90°C. The mean temperature and evaporation were 30.62°C and 6.38 mm, respectively.

Adaptation to precipitation and temperature was 52%, and farmer-to-farmer information sharing was 46%. About 62% of the interviewed respondents stated that they had access to climate information, while 81% had access to media. However, only 20% of those who responded could access credit services. Most farmers in the study area used cattle to cultivate, and most were hired. The use of hired labor was 76% attributed to the preference for using cattle for cultivation.

The Ricardian model was used in this study, as described in the methodology chapter, to assess the effect of climate change on agriculture in Kenya's coastal region. The dependent variables in the regression models are; net livestock income, net crop income, and combined net income. According to the Student t-test for the significance of every estimated coefficient, climate variables were significant parameters ($p < 0.05$) to determine the net incomes from livestock, crops, and the net combined income. This study used three models of the Fisher-Snedecor tests (Snedecor and Cochran 1989), which were validated since their regressions were all significant ($p < 0.05$). The coefficients of determination livestock, crop, and combined models were 48%, 37%, and 42%, respectively.

Table 3. 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 the 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 the coastal region (Table 4), thus change in climate has a non-linear impact on overall crop revenue in the study area (Mendelsohn et al. 1994; Kurukulasuriya et al. 2006). According to linear terms, an increase in precipitation raises net crop income. However, the increase in both temperature and evaporation lowered crop income in the study area. That depicted that prolonged high temperatures are detrimental to crop productivity, indicating that global warming is probable to pose a damaging impact on agricultural activities unless government and farmers enhance measures to adapt 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 and outputs to the market. Awareness of climate change was found to raise net crop income significantly, which is attributable to the ability of the farmer to seek varieties of crops that can yield optimally in various climatic conditions.

A positive effect of adaptation to changes in climate on net income from crop farming could be attributed to the production of resilient crops and hence able to yield well under harsh climate conditions. In addition, 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, lowering revenue from crops. The increased revenue from hired labor may be explained by timely farm operations such as planting, weeding, harvesting, and postharvest processes.

Ricardian regression analysis for net livestock revenue

Results from the model for livestock production (Table 5) showed that climate change significantly ($p < 0.05$) affects net revenue for both the linear and quadratic terms. It implied that climate change has effects that are non-linear on net livestock revenue in the coastal region of Kenya. The linear term of precipitation significantly positively affected net revenue from livestock production. Similarly, the coefficient of the linear term of temperature was positive.

In addition to the climate change factors, several socio-economic variables were also found to influence the net revenue from livestock production significantly. Similar to the net crop revenue model, distance to the market significantly affected livestock net revenue. That may be readily explained by the costs incurred as farms transport livestock production inputs to the farms. Additional costs may be incurred when farmers transport their livestock to the market. Consequently, these costs lower the net revenue earned from livestock production.

Table 4. 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		

Note: *** $p < 0.05$

Table 5. 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		

Note: *** $p < 0.05$

Access to media turned out positive and significant, suggesting that providing information through local media outlets to farmers can influence their decisions greatly. Change in climate awareness had a notable and positive outcome on net livestock revenue, which implied that farmers who know the existing climatic conditions are likely to choose breeds of livestock that can suit their areas well. 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 the household head's age had a positive and significant coefficient, which may be partly attributable to experience gained in livestock production that can help make appropriate decisions and thus increase the net revenue (Gebreegziabher et al. 2013).

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 climate change have a significant ($p < 0.05$) consequence on the combined net revenue in the coastal region (Table 6). Therefore, there was a non-linear impact of change in climate on net combined revenue in the study area. Furthermore, 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 the market negatively affected the total farm net revenue. That compared well with the findings from the two separate models (crop and livestock), whereby costs incurred in transporting farm inputs and outputs can lower the enterprise's profitability. On the other hand, the farmer-to-farmer extension was a significantly positive determinant of the combined net revenue, which explained the importance of using farmers to reach out to others to disseminate farming technologies. Also, a farmer's land size significantly affects the combined net revenue. That 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 a 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, which is attributable to women's role in providing farm labor in Kenya's coastal region. Farmers' awareness of climate change was established to significantly influence the combined net revenue. That 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 the change in the climate.

The coefficient of adaptation to changes in climate was found to be positive and significant. That underscores the relevance of appropriate adaptation strategies in order to realize an increase in combined net revenue.

Table 6. 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		

Note: *** $p < 0.05$

Climate variables and their marginal effects

Table 7 indicates the marginal effects of the climate variables (precipitation, temperature, and evaporation) on agriculture. According to the results, the analysis of marginal impact showed that a 1mm increase in annual precipitation would increase to Kshs. 374.02 and 201.31 from net crop 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 an annual rise of 1°C in temperature would have a significantly positive effect on livestock net revenue but a 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 1°C. However, net losses of Kshs 4,893.35 and Kshs 374.88 resulted from a 1°C increase in temperature. These results compare with the ones obtained in similar studies by other researchers (e.g., Seo and Mendelsohn 2006; Gebreegziabher et al. 2013).

In analysis, the marginal result of evaporation on the crop, livestock, and farm net revenues showed that an increase in mean annual evaporation by 1mm significantly reduces net crop revenue by Kshs 10,312.92. However, the marginal impacts of evaporation on livestock and farms were insignificant.

Overview of adaptation to climate change in the coastal region of Kenya

Previous studies on adaptation to climate change show that it significantly reduces the susceptibility to expected imminent effects of climate change (Kabubo-Mariara and Karanja 2006). These studies show that the potential of adaptation strategies in lessening the extreme effects of global warming is huge. The adaptations addressed in this study were on livestock and crop production. In this study, the considered climate change adaptations in the coastal region of Kenya included: improved livestock and crop varieties, optimal water management approaches, increased use of organic fertilizer, conservation tillage farming, and adoption of agro-forestry techniques.

Figure 2 showed that there is awareness among farmers of the variability of climate and have started to adapt to varying precipitation and temperature. According to the figure, 78% of farmers adapt by focusing on improved varieties, diversifying crops, and breeding selection and enhancement through artificial insemination. Over 73% of farmers practice water management by harvesting runoff into small water pans for watering both crops and animals, especially after the rains. In soil management, over 60% of the farmers managed water and soil practices of conservations like terraces. The use of organic fertilizer was found at 58%. As indicated, practicing agro-forestry techniques and conservation tillage was relatively above average across the region.

Table 7. 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

Note: *** $p < 0.05$

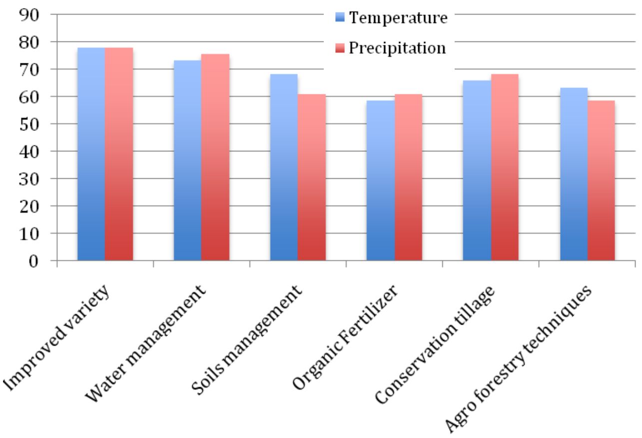

Figure 2. Adaptation to climate change in the coastal region of Kenya

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