

Chapter 2

Climate Change Impact on Revenue of Major Food Crops in Ghana: Structural Ricardian Cross-Sectional Analysis

Zakaria Amidu Issahaku and Keshav Lall Maharjan

Abstract This chapter analyzes the impact of climate change on net revenues of five major food crops in Ghanaian using Structural Ricardian method. First, a multinomial logit regression is used to evaluate crop selection among food crop farmers. The results of this regression show that warming is likely to prompt farmers to switch from the cultivation of cassava and maize to the planting of sorghum, rice and yam. Reduced rainfall is expected to decrease the selection of maize among farmers, and increase the planting of other food crops (cassava, sorghum, rice and yam). Taking into account crop selection bias, warming increases revenues of cassava and sorghum while additional rainfall increases sorghum revenue and decreases revenues of cassava and maize. As a long-term phenomenon, climate change is projected to reduce expected revenue from cassava and maize, but the losses in revenue can be minimized through adaptation by switching among crops. Climate change is expected to have positive impact on revenues of sorghum and yam, which is expected to be maximized through crop switching (climate change adaptation). This study suggests public investment in research on high-yielding, heat-tolerant and flood-prone varieties of the above mentioned food crops in order to make crop switching a more beneficial exercise for farmers.

Keywords Climate change • Crop switching • Ghana • Major food crops • Structural Ricardian method

Parts of this chapter is also published in *International Development and Cooperation* 19(4):5–16.

Z.A. Issahaku (✉)

Graduate School of International Development and Cooperation, Hiroshima University,
Hiroshima, Japan

Ministry of Finance and Economic Planning, Accra, Ghana

e-mail: zakh2000us@gmail.com

K.L. Maharjan

Graduate School of International Development and Cooperation, Hiroshima University,
Hiroshima, Japan

2.1 Introduction

The importance of agriculture to the economies of most developing countries cannot be overemphasized. The agricultural sector has a high share in national output while at the same time employs the largest share of the labor force in many developing countries. Agriculture contributes at least 40 % of exports, 30 % of Gross Domestic Product (GDP), up to 30 % of foreign exchange earnings and 70–80 % of employment in the Sub-Saharan region as a whole (UNECA 2005). The agricultural sector remains the primary source of employment in sub-Saharan Africa, accounting for approximately 70 % of the total employment in the late 1990s (Delgado 1995). Evidence consistently shows that agricultural growth is highly effective in reducing poverty. Gallup et al. (1998) report from a cross-country study that every 1 % increase in per capita agricultural output led to a 1.61 % increase in the incomes of the poorest 20 % of the population.

Despite visible contribution of agriculture, it suffers from perennial neglect from governments of sub-Saharan countries. Less than 10 % of annual budgeted revenue of these countries is allocated to agricultural sector (NEPAD 2009). This problem of low investment will be exacerbated by threat of global warming and its associated effects on temperature and rainfall patterns and ultimately farming. It is, thus, predicted that African countries with low adaptive capacity will suffer the unfriendly brunt of climate change since a larger proportion of their economies are in climate sensitive sectors.

In Ghana, agricultural production is largely small-holder and rain-fed (GEPA 2007). Slight change in weather and climate is expected to pose major challenges to the growth and development of Ghana's agriculture (Nankani 2009). Prompted by threats of vagaries of weather and climate, some researchers have attempted to investigate its impacts on crop production in Ghana. Based on crop simulations model, Sagoe (2006) reports that climate change will reduce yields of cassava by 3 %, 13.5 % and 53 % in 2020, 2050 and 2080 respectively, but cocoyam yield is expected to decline by 11.8 %, 29.6 % and 68 % in 2020, 2050 and 2080 respectively. Ghana Environment Protection Agency (GEPA) concludes from analysis of climate change impact on cereals that it will reduce yield of maize by 6.9 % in 2020 but that of millet will remain unaffected because it is more drought-tolerant (GEPA 2001). International Center for Tropical Agriculture (CIAT) (2011) used crop prediction model, MAXNET, to analyze impact of climate on cocoa in Ghana and La Cote d'Ivoire for 2030 and 2050. This study concludes that climate change will reduce land suitability for cocoa in the Lagunes and Sud-Comoe in Côte d'Ivoire whereas an increase in land suitability for cocoa will be observed in Kwahu Plateau in Ghana. In other areas, land suitability will remain same with the right adaptive measures. Some areas which are not currently under cocoa cultivation can become suitable for cocoa production in the future (18 Montagne in La Côte d'Ivoire).

Previous climate impact studies on crop production in Ghana tend to be more reliant on crop simulation models, describing the relationship between climate and crop growth, and ignoring farmers' actions to moderate the adverse effects of

changing climate (dumb farmers scenario). Granted that food crop farmers, the poorest segment of Ghanaian society, depend on the weather for their livelihood, this chapter uses structural Ricardian model to assess the impact of climate on major food crops based on national survey data. This approach incorporates efficient adaptive responses by farmers (Mendelsohn and Dinar 1999). Findings of this study are expected to contribute to climate impact literature and provide useful information government may need in crafting appropriate adaptation policy for Ghana.

2.2 Climate and Crop Production in Ghana

Agriculture engages about 57 % of the economically active population in Ghana (GSS 2005) and contributes about 30 % to Gross Domestic Product (GDP). About 57 % of arable land in Ghana is put into cultivation. About 90 % of farms are less than 2 ha in size, although there are some large farms and plantations, particularly for rubber, oil palm and coconut and to a lesser extent, rice, maize and pineapples. Main system of farming is traditional with hoe and cutlass being the main farming implements. There is little mechanized farming, but bullock farming is practiced in some places, especially in the Northern part of the country.

Climate in Ghana varies by agro-ecological zones. Broadly speaking, there are three ecological zones: savanna, forest and coastal zones. The savanna zone covers large parts of northern, upper east and upper west regions, and relatively smaller portions of Brong Ahafo and Volta regions. The climate, soils and other physical conditions in this zone are more suitable for cultivation of cereals like maize, sorghum, millet and rice. Other crops such as cashew, cassava, yam, potato and vegetables can be grown. In fact, apart from maize, largest production of cereals comes from this part of the country. This zone is also characterized by unimodal rainfall pattern (April–October). The forest zone covers greater part of Brong Ahafo, Volta, Ashanti, eastern and western regions. This zone is noted for the cultivation of root and tuber and cash crops including cocoa, cassava, plantain and cocoyam. This zone has bi-modal rainfall pattern (March–July and August–November) where a crop like maize is cultivated twice a year. The coastal savanna covers Greater Accra and Central regions and crops like maize and vegetables can be grown in this zone (Fig. 2.1). In all ecological zones, mean annual temperature is generally high ranging from 24 °C to 30 °C. The wettest area is the extreme southwest in the forest zone where annual rainfall is about 2,000 mm. The driest area is wedge-like strip in the coastal savanna zone where the annual rainfall is about 750 mm.

This chapter focuses on five major food crops only of cassava, maize, sorghum, rice and yam. These crops are grown for home consumption and for sale in the domestic market to meet household financial needs. These crops were chosen because they contribute significantly to GDP. These crops constitute about 80 % of food crops contribution to agricultural GDP and feature prominently in the diet of most Ghanaians (Breisinger et al. 2007). Supply of rice has a high import component. Ghana is currently self-sufficient in the production of the above-mentioned crops except rice.

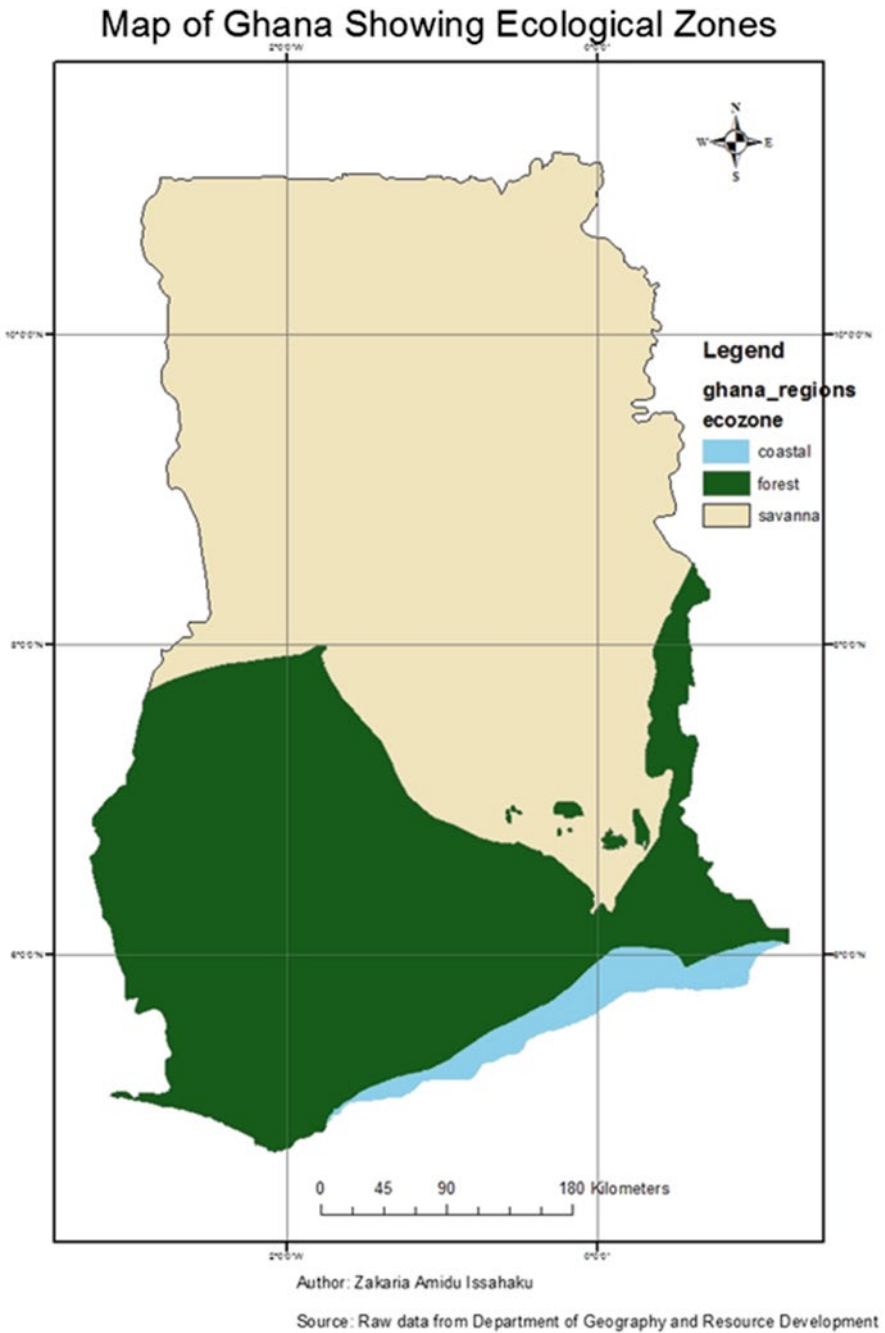


Fig. 2.1 Map of Ghana showing ecological zones

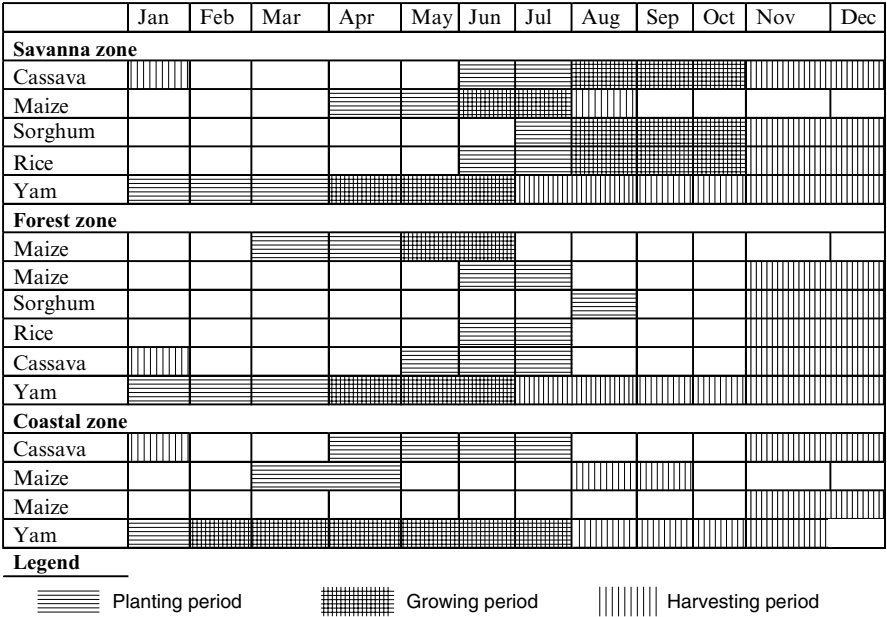


Fig. 2.2 Cropping calendar for major food crops in Ghana. *Source:* Food and Agriculture Organization (FAO) Retrieved 20 June 2012, from <http://www.fao.org/agriculture/seed/cropcalendar/searchbycountry.do>

2.3 Empirical Strategy

This study uses a Ricardian method to analyze the impact of climate variables on revenues from major food crops (cassava, maize, sorghum, rice and yam) in Ghana. It is so named because of the original observation of David Ricardo (1772–1823) that the value of land reflects its net productivity and, by extension, farm net revenue reflects its net productivity (Kurukulasuriya and Mendelsohn 2006). This approach captures not only the direct effect of climate on net revenue but also the adaptation response by farmers to mitigate damages associated with sub-optimal climatic conditions. This study adopts the Structural Ricardian technique whereby farmers respond to changing climate by switching crops. It is basically a micro-econometric model whereby a farmer chooses j among J crops in the first stage, and maximizes net revenues in the second stage conditional on those choices (Mendelsohn et al. 1994; Mendelsohn and Dinar 2009; Seo and Mendelsohn 2007). Based on utility theory, a crop is chosen if it gives the farmer highest net revenue as compared to other crops (Train 2003). Equations (2.1) and (2.2) are econometric specification of net revenue and crop choice equations, respectively.

$$\pi_j = X_j\beta_j + U_j \tag{2.1}$$

$$\pi_{ji} = Z_{ji}\gamma_j + \epsilon_{ji} \tag{2.2}$$

Where, Z is a vector of explanatory variables for crop choice equation; X is a vector of independent variables for the revenue equation; π is net revenue per hectare, β and γ vector of coefficients for revenue and crop choice equations respectively; U and ϵ are the error terms for revenue and crop choice equations respectively.

Efficient and consistent estimates of Eq. (2.1) cannot be obtained if U and ϵ are correlated resulting in what is often called selectivity bias. Heckman (1979) developed a two-step procedure to correct self-selection bias in cases of binary choices while Lee (1983) and Dubin and McFadden (1984) developed the approach to apply to multiple choice. Dubin and McFadden (1984) approach to polychotomous choice, which has been enhanced by Bourguignon et al. (2007), is more appealing in that the inclusion of multiple correction terms allow us not only to attribute a selection bias in the estimation of earnings to the allocation of individuals with better or worse unobserved characteristics in farming, but also to link the selection bias to the allocation of individuals to each other alternative (Zheren 2008). That is, it allows for identification of selection bias and its source. This study employs the Dubin and McFadden (1984) approach for correction of bias in a two-stage process as five crops are involved. With the assumption that ϵ is independently and identically Gumbel distributed, logistic specification of Eq. (2.2) as in Eq. (2.3), indicating the probability (P_{ji}) that a farmer chooses a particular crop, is estimated by multinomial logistic regression at the first stage.

$$P_{ji} = \frac{\exp(Z\gamma)}{\sum_{k=1}^K \exp(Z\gamma)} \quad (2.3)$$

At the second stage, Eq. (2.1) is estimated by including as additional explanatory variables the selection bias correction terms (calculated from the first stage) other than the chosen crop in each crop revenue regression (Dubin and McFadden 1984). Equation (2.4) below is the selection bias corrected (conditional) revenue regression based on Eq. (2.1):

$$\ln \pi_j = X_j \phi_j + \sigma \sum_{i \neq j}^J r_i \left(\frac{P_i \ln P_i}{1 - P_i} + \ln P_j \right) + w_j \quad (2.4)$$

$\ln \pi_j$ is the logarithm of net revenue per hectare; the second term on the right-hand side is the selection bias correction term; X_j is a vector of independent variables that including climate variables; ϕ_j is a vector of parameters; and w_j is the error term. $\ln P_i$ is logarithm of crop probability (P_i); σ stands for standard deviation of error term in Eq. (2.2); and r_i is the correlation coefficient between error terms in Eqs. (2.1) and (2.2). The above correction of selection bias provides fairly good estimation of net crop revenue even if crop choices are completely independent of each other (Bourguignon et al. 2007).

Having estimated Eqs. (2.3) and (2.4), expected revenue of a typical farm V is calculated as the sum of the probabilities of each crop choice times the conditional net revenue of that crop choice as follows:

$$V = \sum_{j=1}^J P_j(Z_{ji}) \pi_j(Z_{ji}) \quad (2.5)$$

Expected net revenue denotes long term average farm net revenue. Marginal effect of climate on expected net revenue comes from two sources: effect on the probability of crop choice and effect on conditional net revenue per hectare. To analyze the marginal impact of climate on expected net revenue, Eq. (2.5) is differentiated with respect to climate variables to obtain Eq. (2.6).

$$\frac{\partial V}{\partial Z_c} = \frac{\partial P_j}{\partial Z_c} \cdot \pi_j + \frac{\partial \pi_j}{\partial Z_c} \cdot P_j. \quad (2.6)$$

Marginal effect of climate variables on probability of crop selection, $\partial P_j / \partial Z_c$, is estimated by differentiating Eq. (2.5) as in Eq. (2.7).

$$\frac{\partial P_j}{\partial Z_c} = P_j \left[\gamma_j - \sum_{k=1}^J P_k \gamma_k \right] \quad (2.7)$$

The marginal effect of climate variables on conditional net revenue, $\partial \pi_j / \partial Z_c$, can also be estimated by differentiating Eq. (2.4) as shown in Eq. (2.8).

$$\frac{\partial \pi_j}{\partial Z_c} = \varphi_j \quad (2.8)$$

The above approach assumes profit maximization behavior subject to exogenous production conditions, no change in technology, no change in input and output prices and no carbon fertilization (Mendelsohn and Dinar 1999). More importantly, there is no full cost accounting in adapting to changing climate by switching crops. The cost of switching to new crops such as seeds and new equipment paid by farmers are correctly captured as adaptation cost. However, cost of crop failures resulting from trials of new crops and costs associated with retiring capital equipment is not captured (Kurukulasuriya and Mendelsohn 2006).

The approach was first applied in the United States and later used in other countries to predict the damages from changes in climate (Mendelsohn et al. 1994; Sanghi et al. 1998; Mendelsohn and Neumann 1999; Mendelsohn et al. 2001). Ricardian method was used to examine impact of climate change on cropland based on a survey of more than 9,000 farmers in 11 African countries including Ghana and the results show that net revenues fall with drying and warming (Kurukulasuriya and Mendelsohn 2006). Seo and Mendelsohn (2008) developed a Structural Ricardian model to analyze impact of climate on choice of farm type and farm revenue.

Results indicate that warming and drying prompts farmers to switch from crop-only or livestock-only or rain-fed farms to mixed farming or irrigated crops. Warming and drying also reduce incomes from crop-only or livestock-only or rain-fed farms whereas incomes from mixed farms and irrigated farms increase. Seo and Mendelsohn (2007) also used structural Ricardian model to assess climate impact on African livestock choices and number. The results indicate that warming enable farmers to switch from beef cattle to more heat-tolerant goats and sheep. Drying prompts farmers to switch from cattle and sheep to goats and chickens.

In general, studies using the Ricardian approaches point to the slight beneficial effects of warming and drying to U.S. and other countries in temperate zones but likely harmful effects to tropical and semi-tropical countries where most developing countries including Ghana are located.

2.4 Data and Summary Statistics

This study uses data mostly from the fifth round of the Ghana Living Standards Survey (GLSS V) conducted by Ghana Statistical Service (GSS) in 2005/2006. All non-climate variables used in this study are extracted from GLSS V. Data on climate variables were obtained from Ghana Meteorological Agency (GMET) covering ten weather stations (Wa, Navrongo, Tamale, Sunyani, Kumasi, Koforidua, Ho, Saltpond, Accra and Takoradi) across the length and breadth of the country. The climate data covers 50 years (1961–2010). Climate normal variables (temperature and rainfall) are constructed to synchronize crop-specific growing periods of all selected crops. The climate data is, then, matched with the farming households in the GLSS V.

Net revenue per hectare is calculated as the difference between gross crop revenue (sales of processed and unprocessed produce, in-kind receipts and the value of home consumed produce) and crop expenses (fertilizer, pesticide, seedlings, hired labor, irrigation and processing cost) divided by the number of hectares of farmland. The vector of independent variables X consists of climate variables and non-climate variables. The climate variables are monthly mean temperature (temperature) and monthly mean rainfall (rainfall) during growing season for respective crops. The non-climatic independent variables include household size, age, gender and years of education of the household head and farm size. The independent variables for the crop choice equation, Z , include all explanatory variables for the revenue equation in X above and the selling price of the crops in question (cassava, maize, sorghum, rice and yam).

The summary statistics of model variables is presented in Table 2.1. Net revenue per hectare is higher among the tuber crops (cassava and yam) as against the cereals. The unit price of crops ranges from 14 pesewas for yam to 42 pesewas for rice. That is, among the five food crops, rice attracts the highest output price. All growing areas have high temperature of about 26 °C. Levels of rainfall range from about 11 cm for rice to 160 cm for maize. A typical farmer who grows any of these crops is likely to be a male aged 46 years with at least a year of formal education, five household members and a farm size of about 2 ha.

Table 2.1 Description and summary statistics of model variables

Variables	Description	Cassava	Maize	Sorghum	Rice	Yam
Net revenue per hectare (GHS)	Gross crop revenue minus costs of inputs	306.40 (489.42)	200.97 (386.28)	166.25 (312.79)	135.06 (292.42)	327.62 (429.62)
Temperature (°C)	Monthly mean temperature (°C) for 1961–2010 in effective growing seasons	25.4875 (0.3717)	25.9912 (0.3689)	26.8790 (0.4362)	26.5583 (0.8245)	27.7326 (1.2230)
Rainfall (cm)	Monthly mean rainfall (cm) for 1961–2010 in the effective growing seasons	11.1582 (3.3234)	16.1399 (2.8539)	16.3079 (0.3332)	15.1723 (2.1574)	14.1799 (2.3635)
Household size	Number of individuals living in a household	4.4981 (2.6621)	5.2177 (3.2068)	5.9215 (2.8457)	5.9762 (3.3382)	5.8404 (3.5137)
Age of household head	Age in years of the head of household	48.2102 (14.8061)	45.0842 (14.9315)	48.2987 (14.9838)	46.5397 (14.7679)	47.5019 (15.7328)
Gender of household head	Dummy variable (0 = male; 1 = female)	0.3002 (0.4585)	0.1669 (0.3730)	0.1089 (0.3119)	0.1032 (0.3054)	0.1288 (0.3354)
Education of household head	Schooling years of household head	4.1547 (4.8565)	3.2112 (4.7925)	0.7823 (2.84956)	1.1984 (3.3443)	1.8096 (3.8363)
Farm size (ha)	Farm size in hectares (ha)	1.6428 (3.7547)	2.5761 (8.8999)	1.8091 (1.8371)	3.7735 (10.7838)	2.9981 (6.1471)
Crop price (GHS)	Price per kilogram of crop in 2005 (GHS)	0.3774 (0.2928)	0.3364 (0.8148)	0.3130 (0.2070)	0.4245 (0.5771)	0.1394 (0.0940)
N		1,299	1,378	395	126	520

Source: Calculated from 2005 Ghana Living Standard Survey and Ghana Meteorological Agency data

Notes: °C = Degree Celsius; GHS = Ghana Cedis; cm = centimeter; 1US\$ = 0.92 GHS; figures in parenthesis are standard deviations model variables

2.5 Results and Discussion

In this section, a trend analysis of climate variables is first carried out, and then followed by an estimation of an econometric model for farmers' cropping decisions under profit maximizing conditions. This model is estimated in a two stage process. At the first stage, Eq. (2.3) is estimated using multinomial logit method. At the second stage, Eq. (2.4) is estimated using Ordinary Least Squares (OLS) method. Crop price is included as an additional explanatory variable in crop choice equation but not in the revenue equation to ensure model identification. In the ensuing sections, climate trends and the results of the two equations are presented and discussed.

2.5.1 Trend Analysis of Climate Variables

Climate variables in this study are mean monthly temperature and rainfall for growing seasons of the five food crops considered under this study. Figures 2.3, 2.4, 2.5, 2.6, and 2.7 show the trends of temperature and rainfall for cassava, maize, sorghum, rice and yam, respectively. Temperature during growing seasons for all crops over the period 1961–2010 is on an increasing trend. The rate of temperature increase is about 0.02 °C for all crops. With the exception of sorghum, rainfall amounts tend to be decreasing for all other crops over the period. Monthly average rainfall during maize growing season has the highest rate of decline of 0.21 cm. Rainfall declines at the rate of 0.140 cm and 0.104 cm for yam and rice, respectively. The least rate of rainfall decline is 0.013 cm during the growing season for cassava. Rainfall, however, increases at a rate of 0.061 cm during the sorghum cropping season.

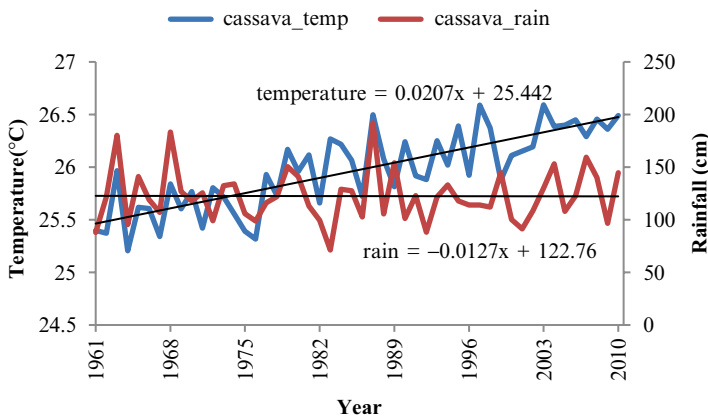


Fig. 2.3 Trends of cassava growing season temperature and rainfall

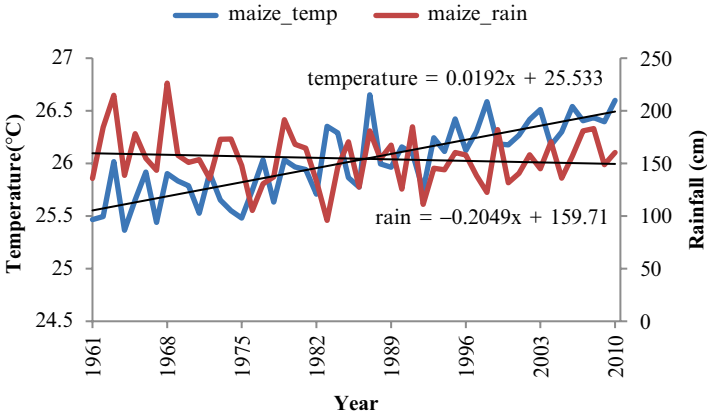


Fig. 2.4 Trends of maize growing season temperature and rainfall

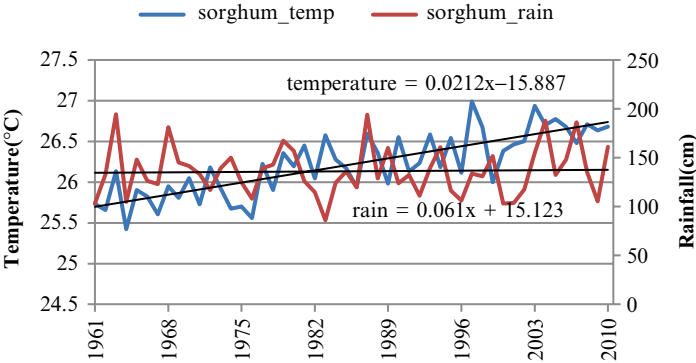


Fig. 2.5 Trends of sorghum growing season temperature and rainfall

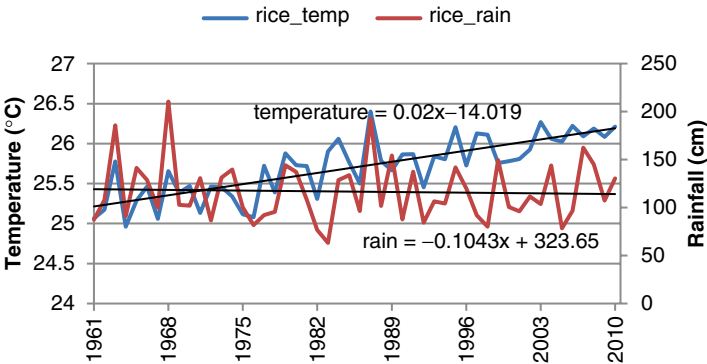


Fig. 2.6 Trends of rice growing season temperature and rainfall

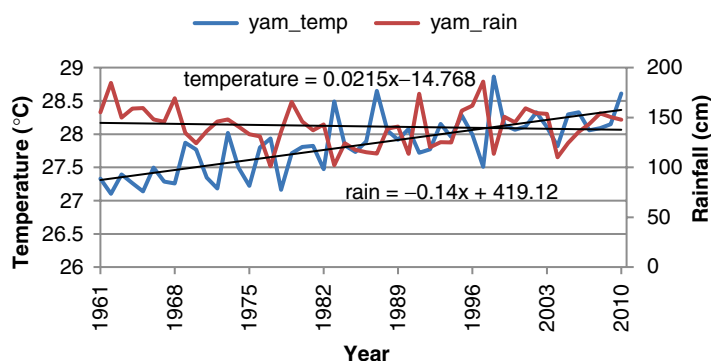


Fig. 2.7 Trends of yam growing season temperature and rainfall

2.5.2 Impact of Climate Variables on Crop Choices

This section assesses the impact of climate on farmers' probability of selecting crops using a multinomial crop choice regression. The dependent variable is crop choice variable, indicating five major food crops grown in Ghana (cassava, maize, sorghum, rice and yam). Mean monthly temperature and rainfall for growing seasons of selected crops are the main variables of interest. The other variables which are controlled for in this model are household size, age, gender and education of household head, farm size and output price variables for the selected crops.

Table 2.2 presents the regression results of the multinomial logit model. There are 3,718 observed plots in the regression. The coefficients on household size are significantly positive for all crops. This implies that cassava, sorghum, rice and yam are often chosen in larger households whereas the omitted choice, maize is selected in smaller families. The coefficients on age of heads household head have significant positive effect on cassava and yam but not on other crops, meaning that older household heads are more likely to select cassava and yam. Coefficients on female household head and education of household head are significantly positive for cassava, and negative for sorghum and rice. This implies that cassava is often chosen by female educated farmers while sorghum and rice are often grown by less educated male households. Coefficients on log of farm size are negative for cassava and positive for rice and yam, indicating that small scale farmers are more likely to select cassava while large scale farmers often grow rice and yam. Output prices tend to have positive effect on the probability of selecting cassava and rice, but negative effect on yam selection. That is, price per kilogram of yam reduces the likelihood of selecting yam. This may be due to the fact that higher prices are often as a result of higher input prices or production costs thereby negatively affecting crop selection.

Climate variables have statistically significant effect on the probability of selecting crops. The coefficients on temperature are negative for cassava but positive for sorghum, rice and yam. This means that higher temperature decreases the probability of selecting cassava but increases the selection of sorghum, rice and yam.

Table 2.2 Multinomial logit crop choice regressions in Ghana

Variables	Cassava	Sorghum	Rice	Yam
Constant term	43.0054*** (3.6262)	-167.9339*** (8.6774)	-137.7486*** (9.1929)	-180.8193*** (8.9667)
Temperature (°C)	-1.2411*** (0.1448)	6.6336*** (0.3409)	5.6329*** (0.3598)	7.3093*** (0.3491)
Rainfall (cm)	-0.8973*** (0.0438)	-0.5069*** (0.0401)	-0.7972*** (0.0537)	-0.7665*** (0.0478)
Household size	0.0485** (0.0216)	0.0764*** (0.0254)	0.0750** (0.0333)	0.0543* (0.0311)
Age of household head	0.0200*** (0.0038)	0.0074 (0.0051)	-0.0014 (0.0070)	0.0161*** (0.0059)
Female household head	0.3091** (0.1379)	-0.6420*** (0.2457)	-0.6281* (0.3363)	0.2037072 0.2449763
Education of household head	0.0270** (0.0117)	-0.1601*** (0.0244)	-0.1615*** (0.0315)	0.0192364 0.0211688
Log of farm size	-0.1193** (0.0543)	0.0187499 0.0784363	0.3525494*** 0.1034992	0.2155416** 0.0930771
Output price	0.1489* (0.0802)	-0.8334** (0.3761)	0.0814 (0.0966)	-9.9929*** (0.7047)

Source: Authors' calculations

Notes: ***means significant at 1 %, **means significant at 5 % and *means significant at 10 %; number of observations = 3,718; LR chi2 (32) = 5,375.93***, Pseudo R² = 0.5303 and Log likelihood = -2,380.7675; This model correctly predicts 89.30 % for cassava, 80.84 for maize, 50.63 % for sorghum, 71.71 % for rice and 89.80 % for yam; Figures in parenthesis are standard errors of regression coefficients; and cassava is the base outcome

Table 2.3 Marginal effects of climate variables on the probability of selecting crops

Crop	Base	Temperature (°C)	Rainfall (cm)
Cassava (%)	23.973	-59.24***	-12.55***
Maize (%)	52.16	-64.16***	19.49***
Sorghum (%)	10.45	56.46***	-1.39***
Rice (%)	8.71	38.36***	-3.69***
Yam (%)	4.70	28.58***	-1.85***

Source: Calculated using multinomial logit regression coefficients

Notes: The marginal change denotes 1 °C increase in temperature and 1 cm increase in rainfall, ***means significant at 1 %

The coefficients on rainfall are significantly negative for cassava, sorghum, rice and yam but indicating higher rains decreases the likelihood of selecting cassava, sorghum, rice and yam but increase the likelihood of selecting the omitted choice, maize.

Since coefficients in Table 2.2 are maximum likelihood estimates, they cannot be used to assess average impact of climate variables on crop choice. Average impact of climate variables on the probability of selecting crops in Ghana is presented in Table 2.3. The probability of selecting cassava, maize, sorghum, rice and yam are 23.97 %, 52.16 %, 10.45 %, 8.71 % and 4.70 %, respectively. Marginal increase in temperature is likely to prompt farmers to switch from cassava and maize to

cultivation of sorghum, rice and yam. The marginal increase in rainfall prompts farmers to switch from other crops to maize. That is, in warm and dry places, sorghum, rice and yam are more likely to be selected while in cooler and wet locations, maize will be more preferable. Cassava is grown in places relatively cooler and wet climate.

2.5.3 Climate Impact on Conditional Crop Revenue

The impact of climate variables on revenues from major food crops is assessed using selection bias corrected (conditional) revenue equation from Eq. (2.4). The dependent variable is the log of net revenue per hectare. The independent variables are mean monthly temperature, rainfall, household size, age, gender and educational attainment of the household head and log of farm size. Sample selection bias correction terms estimated at the first stage from the results of multinomial regressions are included as additional explanatory variables for each crop regression other than the crop for which the regression is run. This specification provides the best fit of the model.

Table 2.4 shows the results of conditional net revenue regressions of the five major crop species cultivated in Ghana. Many climate variables have statistically significant impact on net revenues of crops. Mean monthly temperature has significant positive effect on net revenues of cassava and sorghum but negative effect on revenue of other crops. Rainfall has positive influence on sorghum revenues and negative effect on cassava and maize revenues, but it has not significant effect on revenue of other crops. Household size has significant positive effect on net revenues of all crops with the exception of rice. Positive sign of household size coefficient for most crops is not surprising because family labor supports farmers during planting, weeding and harvesting periods especially in many developing countries including Ghana. Age and gender of the household head have no significant effect on revenues of all crops. That is, there is no significant difference in net revenue between older and younger farmers, and between male and female farmers. Educational attainment of the household head has significant influence on revenues of cassava and rice. Educated farmers tend to receive higher profits from rice cultivation while less educated farmers earn higher revenue from cultivation of cassava.

Apart from the factors explained earlier, farm size and crop selection terms also have statistically significant effect on some crops. Farm size has significant negative effect on earnings of all crops. Mendelsohn and Dinar (2009) attribute this to the omission in cost calculation of household labor which overstates net earnings of smaller farms. It is also explained by the higher management intensity on smaller farms as compared to larger ones. Statistical significance of the some crop selection terms indicates the presence of selection bias and this model would not produce efficient parameter estimates if this model were to be estimated using unadjusted OLS regression. The significant coefficients of sorghum and rice selection are positive and negative, respectively, in the cassava regression. This implies that farmers

Table 2.4 Conditional revenue regressions of major food crops in Ghana

Variables	Cassava	Maize	Sorghum	Rice	Yam
Intercept	-5.4124 (4.6270)	0.8559 (7.4926)	-101.2667*** (25.1420)	42.1662 (35.6907)	7.0730 (5.1679)
Temperature (°C)	0.4336** (0.1820)	0.1944 (0.2883)	3.4120*** (0.8705)	-1.4458 (1.3444)	-0.0254 (0.1547)
Rainfall (cm)	-0.0802*** (0.0451)	-0.0820** (0.0347)	0.7924*** (0.2044)	-0.0178 (0.2115)	-0.1132 (0.0879)
Household size	0.0681*** (0.0168)	0.0672*** (0.0140)	0.1323*** (0.0263)	0.0605 (0.0575)	0.0632*** (0.0175)
Age of household head	0.0008 (0.0034)	0.0008365 0.0029603	0.0032304 0.0050926	0.0039505 0.0119072	0.0007198 0.0039979
Female household head	-0.0715 (0.1002)	-0.0501 (0.1293)	0.0122 (0.2172)	0.6022** (0.6994)	0.1004 (0.2024)
Education of household head	-0.0202*** (0.0097)	-0.0022 (0.0123)	-0.0442 (0.0306)	0.1406** (0.0643)	-0.0051 (0.0208)
Log of farm size	-0.8244*** (0.0472)	-0.6615*** (0.0436)	-0.9544*** (0.1200)	-0.7951*** (0.2047)	-0.5340*** (0.0797)
Cassava selection		0.0531 (0.3416)	0.8490 (2.1969)	0.3129 (1.1517)	-1.8719 (1.7488)
Maize selection	-0.5460 (0.5358)		-3.0271*** (1.2440)	1.6670** (1.5785)	-0.0254 (0.7493)
Sorghum selection	3.6744*** (1.1360)	-0.5445 (0.9751)		-1.3788** (0.9565)	-1.4418 (0.9522)
Rice selection	-3.2123*** (1.2122)	-0.5843 (0.9061)	-0.2390 (1.5153)		2.9571** (1.3547)
Yam selection	0.0277 (0.4882)	1.0989** (0.5055)	2.0238*** (0.4327)	-0.5276 (0.9496)	
R ²	0.3078	0.2765	0.4159	0.3148	0.2329
F-statistic	37.52***	33.90***	20.00***	3.22***	12.39***
N	940	988	321	89	461

Source: From authors' calculations

Notes: The dependent variable is the log of net revenue per hectare; ***denotes significant at 1 %, **denotes significant at 5 % and *denotes significant at 10 %; figures in parenthesis are bootstrapped standard errors of regression coefficients

who the selection model predicts would select cassava will earn higher revenue if they actually select sorghum and lower net revenue if they actually grow rice. The coefficient of yam selection is positive in the maize regression indicating that farmers who the model predicts would select maize will actually earn higher if they actually select yam. The coefficients of maize and yam selection terms are negative and positive, respectively, in the sorghum regression indicating that farmers who the model predicts would select sorghum will actually earn lower revenue if they actually select maize and higher revenue if yam is actually selected. Farmers who actually select maize instead of rice as predicted by the model will earn higher revenue, while those who actually select sorghum will earn lower revenue. Similarly,

farmers who actually select rice instead of yam as predicted by the model will earn higher revenue.

Results of the crop revenue regressions in Table 2.4 are partly consistent with that of the crop selection equation in Table 2.3. For instance, coefficients of rainfall are negative for cassava and maize regressions, and this is matched by decreased probability of selecting these crops. Warming increases the likelihood of selecting sorghum and this is matched by increased probability of selecting sorghum. The direction of impact of climate variables on the probability of selecting some crops is not matched by that of net revenue. Temperature and rainfall reduce the likelihood of selecting cassava and sorghum, respectively, but this is matched by corresponding effect of these climate variables on net revenue. Although climate variables have no significant effect on revenues of rice and yam, temperature and rainfall have positive and negative effect, respectively, on the probability of selecting rice and yam. The above analysis implies that farmers' choice of the major food crops is not largely motivated by profit optimizing behavior. Cultural factors¹ which sanction the use of these crops in preparing traditional dishes and other rituals in Ghanaian society may explain the irrational choice of these crops and thus defy neoclassical understanding of producer behavior.

2.6 Simulating Climate Change Impact on Expected Net Revenue

This section assesses the impact of climate change on expected net revenue (long term net revenue) in Ghana. In line with the idea of permanent income hypothesis, farmers strategize to minimize fluctuations in farm revenues by switching from crops with lower earnings over time to stabilize earnings from crop production (Friedman 1957).

To analyze climate change impact on farm outcome, results of Eqs. (2.5) and (2.6) as representing in Tables 2.3 and 2.4 together with the trend analysis of climate variables in Sect. 2.5.1 can be used. Trend analysis of climate variables shows projected increase in temperature in growing seasons of all crops (Table 2.5). Rainfall is projected to decrease in growing seasons of all crops except sorghum, which will experience an increase. Using the climate projections in Table 2.5 together with regression coefficients for climate variables from Tables 2.3 and 2.4, we can estimate the future impact of climate change on expected net crop revenue.

It can be seen from Table 2.6 that expected revenue per hectare for the five major crops is about GHS 161.86. If there is no adaptation to climate change through switching crops, expected net revenue will decrease by 13.53 %, 27.07 % and 40.60 % for 2015, 2020 and 2025 respectively. At the crop level, expected cassava

¹There are yam festivals for many ethnic groups in Ghana. Most traditional Ghanaian dishes are prepared from cassava and maize in many locations. In the northern part of Ghana, sorghum is used in preparation of traditional dishes during funerals.

Table 2.5 Future trend of climate variables in Ghana

	Change in temperature (°C)			Change in rainfall (cm)		
	2015	2020	2025	2015	2020	2025
Cseason	0.1033	0.2067	0.3100	-0.0633	-0.1265	-0.1898
Mseason	0.0960	0.1921	0.2881	-1.0246	-2.0492	-3.0737
Sseason	0.1060	0.2121	0.3181	0.3049	0.6098	0.9147
Rseason	0.1000	0.2001	0.3001	-0.5213	-1.0426	-1.5639
Yseason	0.1073	0.2146	0.3219	-0.7002	-1.4004	-2.1007

Notes: Cseason=cassava growing season; Mseason=maize growing season; Sseason=sorghum growing season; Rseason=rice growing season; and Yseason=yam growing season

revenue will decrease by 5.03 % in 2015 to reach 15.08 % in 2025; expected maize revenue will also reduce by 14.16 % in 2015 to 28.32 % in 2025. The effect of climate change is, however, positive for sorghum, rice and yam, but it progressively worsens from 2015 to 2025. By 2015, 2020 and 2025, expected sorghum revenue will increase by 3.42 %, 6.85 % and 10.275, respectively; expected rice revenue will go up by 1.64 %, 3.29 % and 4.93 % for 2015, 2020 and 2025, respectively; and expected yam revenue is also projected to increase by 6.06 %, 12.11 % and 18.11 %, respectively. If farmers adapt to climate change by switching among the food crops in question, it will not only maximize expected net revenues of sorghum and yam alone, but also minimize the losses in cassava and maize. Sorghum revenue will increase by 21.67 % in 2015 and 65.00 % in 2025; yam revenue will also inch up by 13.14 % in 2015 and 41.99 % in 2025. It is observed that there is no much difference in expected rice revenue in terms of climate change impact with and without adaptation. With climate change adaptation, losses in expected cassava and maize revenues are projected to decline. In fact, the percentage decline in expected net revenue of cassava and maize will be less than 5 % up till 2025.

2.7 Conclusion and Recommendation

This study analyzes the impact of climate variables on the probability of selecting among five major food crops and on their net revenues in Ghana using a two-stage econometric process. At the first stage, a multinomial logit regression is used to analyze the effect of climate variables on crop choice while a selection bias corrected net revenue regression based on the multinomial logit regression is used to assess the impact of climate on revenues of farmers at the second stage. The results of the multinomial regression show that warming is likely to prompt farmers to switch from cassava and maize to the cultivation of sorghum, rice and yam while additional rainfall increases the likelihood of selecting maize instead of the other crops in question. Farmers’ choice of crops tends to be partly consistent with revenue predictions. Coefficients of rainfall are negative for cassava and maize regressions, and this is matched by decreased probability of selecting these crops. Warming

Table 2.6 Impact of climate change on expected net revenue of food crops in Ghana

	No climate change adaptation		Climate change adaptation			
	2015	2020	2025	2015	2020	2025
Cassava	-8.1345 (-5.0255)	-16.2689 (-10.0511)	-24.4034 (-15.0766)	-2.2579 (-1.5865)	-5.1357 (-3.1729)	-7.7036 (-4.7594)
Maize	-22.9165 (-14.1580)	-45.8331 (-28.3161)	-68.7496 (-42.4741)	-16.6184 (-10.2670)	-33.2368 (-20.5340)	-49.8552 (-30.8010)
Sorghum	5.5418 (3.4238)	11.0836 (6.8476)	16.6255 (10.2714)	35.0683 (21.6655)	70.1366 (43.3310)	105.2049 (64.9965)
Rice	2.6617 (1.6444)	5.3234 (3.2889)	7.9852 (4.9333)	2.2745 (1.4052)	4.5490 (2.8104)	6.8235 (4.2156)
Yam	9.8025 (6.0561)	19.6051 (12.1122)	29.4076 (18.1683)	22.6542 (13.1400)	45.3083 (27.9919)	67.9625 (41.9879)
Total	-21.9060 (-13.5337)	-43.8120 (-27.0675)	-65.8120 (-40.6012)	-5.3642 (-3.3141)	-10.7284 (-6.6281)	-16.0926 (-9.9422)

Notes: All figures are in Ghana Cedis (GHS), monetary currency of Ghana. As of 2005, 1 USD=0.92 GHS; Expected net revenue of base year (2010) is GHS161.82; figures in parenthesis are in percentage difference from base year expected revenue

increases the likelihood of selecting of sorghum and this is matched by increased probability of selecting sorghum. The direction of impact of climate variables on the probability of selecting some crops is not matched by that of net revenue. Temperature and rainfall reduce the likelihood of selecting cassava and sorghum, respectively, but this is matched by corresponding effect of these climate variables on net revenue. The above analysis implies that farmers' choice of maize and sorghum is not largely motivated by profit optimizing decisions. Cultural factors which sanction the use of these crops in preparing traditional dishes and other rituals in Ghanaian society may explain the irrational choice of these crops and thus defy neoclassical understanding of producer behavior.

Climate change impact will not have same effect across crops. Climate change is projected to raise expected revenues of sorghum, rice and yam. The positive climate change impact on sorghum and yam will be much enhanced if farmers adapt to climate change by switching among food crops. It is observed that there is no much difference in expected rice revenue in terms of climate change impact with and without adaptation. Climate change will impact negatively on expected revenues of cassava and maize, but these revenue losses will be minimized if farmers adapt by crop-switching.

From the foregoing discussions, it can be discerned that adaptation to changing climate through crop switching has beneficial outcomes in Ghana. Crop switching is an adaptation option but it is not without cost. Farmers who adopt crop switching can only use available crop varieties. In this regard, public investment in research on high-yielding, heat-tolerant and flood-prone varieties of the above mentioned food crops is suggested in order to make crop switching a beneficial exercise for farmers.

References

- Bourguignon F, Fournier M, Gurgand M (2007) Selection bias corrections based on the multinomial logit model: Monte Carlo comparisons. *J Econ Surv* 21:174–205
- Breisinger C, Thurlow J, Duncan M (2007) A 2005 social accounting matrix for Ghana. Ghana Statistical Services and International Food Policy Research Institute, Accra/Washington, <http://www.ifpri.org/data/ghana03.asp>. Retrieved 12 Jan 2011
- CIAT (International Center for Tropical Agriculture) (2011) Predicting the impact of climate change on the cocoa-growing regions in Ghana and Cote D'Ivoire. http://www.ciat.cgiar.org/Newsroom/Documents/ghana_ivory_coast_climate_change_and_cocoa.pdf. Accessed 18 Apr 2012
- Delgado CL (1995) Agricultural diversification and export promotion in Sub-Saharan Africa. *Food Policy* 20(3):225–243
- Dubin JA, McFadden DL (1984) An econometric analysis of residential appliance holdings and consumption. *Econometrica* 52:345–362
- Friedman M (1957) A theory of the consumption function. Princeton University Press, Princeton
- Gallup J, Radelet S, Warner A (1998) Economic growth and the income of the Poor. CAER II Discussion Paper 36, Harvard Institute for International Development, Boston
- GEPA (Ghana Environmental Protection Agency) (2001) Ghana's initial national communications report. United Nations Framework Convention on Climate Change, Accra

- Ghana Environmental Protection Agency (GEPA) (2007) Climate change and the Ghanaian economy. Policy Advice Series, vol 1. Ghana Government Policy Document, Accra
- Ghana Statistical Service (GSS) (2005) Ghana living standards survey V. Ghana Government, Accra
- Heckman JJ (1979) Sample selection bias as a specification error. *Econometrica* 47(1):153–162
- Kurukulasuriya P, Mendelsohn R (2006) A ricardian analysis of the impact of climate change on cropland. CEEPA Discussion Paper 8, CEEPA, University of Pretoria. <http://www.ceepa.co.za/docs/CDP8.pdf>. Accessed 15 June 2011
- Lee LF (1983) Generalized econometric models with selectivity. *Econometrica* 51:507–512
- Mendelsohn R, Dinar A (1999) Climate change, agriculture, and developing countries: does adaptation matter? *World Bank Res Obs* 14(2):277–293
- Mendelsohn R, Dinar A (2009) Climate change and agriculture: an economic analysis of global impacts, adaptation and distributional effects. Edward Elgar Publishing Ltd, Cheltenham/Northampton
- Mendelsohn R, Dinar A, Sanghi A (2001) The effect of development on the climate sensitivity of agriculture. *Enviro Devel Econ* 6:85–101
- Mendelsohn R, Neumann J (1999) The impacts of climate change on the US economy. Cambridge University Press, Cambridge
- Mendelsohn R, Nordhaus W, Shaw D (1994) The impact of global warming on agriculture: a ricardian analysis. *Am Econ Rev* 84:753–771, http://www.geofaculty.org:16080/figures/Rood_Climate_Change_AOSS480_Documents/Mendelsohn_Climate_Change_Agriculture_AmEconRev_1994.pdf. Accessed 15 June 2011
- Nankani G (2009) Challenges of the Ghanaian economy. <http://www.ghanabusinessnews.com/2009/02/25/the-challenge-of-agriculture-in-ghana-what-is-to-be-done/>. Accessed 12 July 2012
- NEPAD (2009) Comprehensive Africa Agricultural Development Programme (CAADP) Annual Report. http://www.nepad-caadp.net/pdf/CAADP_AR2010_WEB.pdf. Accessed 12 Aug 2012
- Sagoe R (2006) Climate change and root production in Ghana. http://www.nlcip.net/fileadmin/NCAP/Countries/Ghana/ROOT_TUBERS_DRAFT_FINAL_REPORT.pdf. Accessed 9 June 2012
- Sanghi A, Mendelsohn R, Dinar A (1998) The climate sensitivity of Indian agriculture. In: Dinar AR, Mendelsohn R, Evenson R, Parikh J, Sanghi A, Kumar K, McKinsey J, Loneragan S (eds) Measuring the impact of climate change on Indian agriculture. World Bank Technical Paper 402. World Bank, Washington
- Seo SN, Mendelsohn R (2007) Measuring impacts and adaptations to climate change: a structural ricardian model of African livestock management. *Agric Econ* 38:151–165, http://dev.thegnscs.org/sitefiles/file/Kenya_Adaptation_CRM_Livestock_Seo%20et%20al__2007.pdf. Accessed 15 June 2011
- Seo SN, Mendelsohn R (2008) A structural ricardian analysis of climate change impacts and adaptations in African agriculture. World Bank Policy Research Series Working Paper 4603, Washington. http://www-wds.worldbank.org/servlet/WDSPContentServer/WDSP/IB/2008/04/17/000158349_20080417151505/Rendered/PDF/WPS4603.pdf. Accessed 15 June 2011
- Train K (2003) Discrete choice methods with simulation. Cambridge University Press, Cambridge
- UNECA (2005) Economic report on Africa 2005: meeting the challenges of unemployment and poverty in Africa. Addis Ababa, Ethiopia
- Zheren W (2008) Self-selection and earnings of migrants: evidence from rural China. Discussion Paper 08–25. Graduate School of Economics and Osaka School of International Public Policy (OSIPP), Japan

Communities and Livelihood Strategies in Developing
Countries

Maharjan, K.L. (Ed.)

2014, XXV, 178 p. 54 illus., 50 illus. in color.,

ISBN: 978-4-431-54774-7