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Crop substitution behavior among food crop farmers in Ghana: an efficient adaptation to climate change or costly stagnation in traditional agricultural production system?

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Abstract

This study analyzes impact of climate change on yield, planting decisions and output of five major food crops (cassava, maize, sorghum, rice and yam) in Ghana. Results of Multivariate Tobit Model show that yield, planting decisions and output of cassava, maize, sorghum and rice will increase as a result of climate change. This is in clear contrast to the hypothesis that warming and drying will reduce crop yields in countries located within the tropics. Climate change impact on yields, planting decisions and output of yam is projected to be negative. Analysis of planting decisions indicates that climate change will stimulate farmers to allocate more land for cassava, maize, sorghum and rice cultivation. It is observed that farmers respond to positive impact of climate on yields of cassava, maize, sorghum and rice by reallocating more land for the cultivation of these crops, which is in line with neoclassical understanding of producer behavior. In contrast, farmers' response to price rise does not display a consistent pattern. By and large, farmers respond weakly to price increases. This peculiar trait of food crop farmers can stifle the future development of the food crop subsector in Ghana.

Keywords: Multivariate Tobit Model; Climate change; Major food crops; Crop yield; Farm size; Ghana

Background

Climate is one of the most important inputs in agricultural production system. The hard truth that the world is getting hotter and drier is of a major concern to many a developing country dependent on agriculture as their main livelihood source. Low precipitation and increased frequency of extreme events such as floods and droughts can reduce crop yields and increase risks in agricultural production in many countries located in the lower latitudes. In Ghana, agriculture is largely rain-fed, and the vagaries of the weather determine agricultural productivity. Farmers usually respond to reduction in crop yield by putting more land into cultivation. It is therefore no wonder that yield levels of major food crops are significantly lower than their potential levels, indicating a potential of raising outputs of major food crops through crop productivity growth. Cassava, maize, sorghum, rice and yam have yield gaps of 57.5%, 40%, 33.33%, 40% and

38%, respectively (MOFA 2007). Increasing agricultural growth by land expansion may not be sustainable because farmers are not only limited by plot size in their possession but also difficulties associated with managing large tracts of land under cultivation including labor availability and loss of forest cover. Increasing production of major staple crops can be enhanced by utilizing the land more intensively thereby closing these crop yield gaps (Breisinger et al. 2009).

Crop intensification is an option mainly for commercial farmers, since they are more likely to be linked to national markets and international agribusinesses and be able to invest in agricultural technologies. Smallholders in developing countries do not have much access to agricultural inputs such as fertilizers, pesticides and improved seeds. Besides crop intensification, agriculture production growth could also be reached using sustainable agriculture technologies which are extensively promoted by international development agencies and research centers (Branca et al. 2013; Garrity et al. 2010). It is imperative to note that adopting intensive farming and other farm practices is not free from the adverse effects of changing climate. More recent literature points to the adverse impact of changing climate on crop productivity. A review of climate impact literature on various crops by Knox et al. (2012) indicates that yields of cassava, sorghum, millet and maize will decrease in West Africa through adverse effects of climate change. Warming and drying exacerbate stresses in crop plants, potentially leading to catastrophic yield reductions: It reduces water availability for irrigation; it also reduces soil fertility through increased oxidation of soil organic carbon; and it also increases incidence of pests, diseases and weeds. Sagoe (2006) used crop simulation model to analyze climate change impact on root crops in Ghana and the results indicate reductions in yields of cassava and cocoyam under all projected climate scenarios. Analysis of projected climate change impact in Ghana's initial communication to Inter-governmental Panel on Climate Change (IPCC) also indicates reductions in yields of maize in the transition zone, located between the forest and the savanna ecological zones in Ghana (GEPA 2001). The afore-mentioned analyses and other similar studies are based on crop simulation models which show relationship between environmental variables including climate and the growth of crop plants. The effect of climate on crop yield may be more complex than just mere climate-crop plant growth relationship. Other factors can reverse an otherwise positive or negative effect of climate on crop yield. The failure to take into account the role of non-environmental variables denoting farm or farmer characteristics and/or management practices by farmers may undermine the use of crop simulation models in climate research. Further, research on the impact of climate change on agricultural production has mainly focused on the effect of climate and its variability on individual crops, while the potential for adapting to climate change through crop substitution has received less attention. Crop switching has not generally been captured by the climate change.

Based on national survey data, this paper intends to extend this line of analysis by using the production function approach, which considers and incorporates some socioeconomic variables in analyzing climate impact not only on crop yield, but also on farmers' planting decisions. Analysis of this nature is intuitive because food farmers especially in developing countries may not respond to price/profit incentive but rather higher yield or output. This therefore makes necessary it to investigate the alignment of yield-maximizing behavior of food crop farmers with planting decisions. In the next section, a review of some adaptive responses to adverse on-farm conditions by farmers is carried out. Econometric methods used to assess the effect of various factors including climate variables on crop production are explained in detail in section Methods using appropriate mathematical equations. In addition, the data and summary statistics of all variables used in this study are also presented and explained. In section Results and discussion, model results are presented and discussed. In section Climate change impact on food crop production in Ghana, regression coefficients together with trend of climate variables are used to simulate the impact of changing climate on crop yield and planted area in future years. The last section presents the discussion and summary of the research findings and proceeds to make recommendations for consideration of policymakers.

Review of farm-level adaptation measures

Climate change is predicted to have negative impact on farm outcomes in most developing countries. The potential yield- or welfare-reducing effect of climate change can be ameliorated by autonomous adaptation by farmers. Climate change impact studies which ignore farmers' adaptive responses are likely to overstate damages or understate benefits of climate change (Mendelsohn et al. 1994).

Broadly speaking, farmers adapt to varying climate either through the modification of the set of crops they choose to plant or improved cultural/management operations. Although many studies assume that no change in future in the set of crops cultivated, the importance of adopting crops or varieties which are tolerant to projected warmer and drier climate in the future cannot be glossed over. Adaptation options accessible by farmers include crop diversification, varying crop varieties, changing planting and harvesting dates, irrigation, use of water and soil conservation techniques and diversifying away from farming (Nhemachena and Hassan 2007). A study by Corobov (2002) in Moldova shows that the adoption of late-maturing maize hybrids as an adaptation measure engenders considerable yield enhancement. The adoption of heat tolerant varieties of sorghum, millet, cotton, cowpeas and rice in Mali also attest to the yield- and welfare-enhancing effects of this adaptation measure (Butt et al. 2005). Additionally, farmers can response to climate change in a more radical manner by changing the mix of crops grown. Kurukulasuriya and Mendelsohn (2006) and Seo and Mendelsohn (2008a) climate change adaptation studies for Africa and South America, respectively, have demonstrated how farmers change their planting decisions in response to warmer and drier climate. In dry and warm locations of Africa, farmers tend to choose millet and groundnut while maize and beans are chosen in wet but warm locations. Similarly, in warm locations of South America, farmers grow squash, fruits and vegetables while potatoes and maize are grown in cooler locations. Varying set of crops cultivated induces spatial shift of production pattern to places with mild climate. An assessment of global impact of climate change by Darwin et al. (1995) indicates that expansion of cultivable land will increase global food production. Butt et al. (2005) reports that the shift in crop production patterns southwards in Mali has helped to mitigate welfare losses.

The use of crop switching as adaptation measure is hindered by the fact that production decisions by farmers may not be motivated by yield- or profit-optimizing behavior. Farmers as consumers may have certain preferences for some crops over others. They are therefore likely to choose these crops although they may not be the ideal crop in terms of yield or welfare maximization (Chipanshi et al. 2003). The disposition of farmers to risk may also stifle crop-switching efforts. Small-scale farmers are usually risk-averse and they are more likely to settle for crops with low yield variance rather than riskier but high yielding crops (Kaiser et al. 1993). Finally, spatial shift in cropping patterns may result in degradation of tropical rainforest with its attendant effects on the ecosystem and loss of some economic benefits from utilization of forest resources (Darwin et al. 1995).

Methods

Empirical model

This study is based on the notion that climate is one of the important determinants of crop productivity. Most climate impact studies tend to focus on crop yield with the assumption that farmers hardly vary their cropping decisions, implying that a crop yield change proportionately translates to crop output change. Since crop output is a product of crop yield and harvested or planted area, this study evaluates the impact of climate on both yield and planted area of major food crops in Ghana in order that the combined effect on crop output can be determined.

The first step in assessing potential costs and climate change adaptation strategies is to determine the effect of climate on crop yields (Cabas et al. 2010). One of the methods to measure the sensitivity of crop yields to changing climate is to analyze how actual crop yields vary across different locations with different climatic conditions (Mendelsohn and Dinar 2009). Regression models have the potential flexibility to integrate both physiological determinants of yield including climate and socioeconomic factors. With this approach, an appropriate production function is specified in order to isolate the effect of climate from the effects of other confounding variables including modern inputs and socioeconomic variables. Formally, a production function developed by Just and Pope (1978) to analyze effect of production inputs on crop yields is specified as in equation (1).

$$Y^* = f\,(X,\ \beta)\ + \mu \tag{1}$$

$$Y = \begin{cases} Y^* \text{ if } Y^* > 0 \\ 0 \text{ if } Y^* \leq 0 \end{cases} \tag{2}$$

Y^* is a latent variable for observed crop yield, Y; X is vector of independent variables; μ is stochastic error term for crop yield model which is assumed to be multivariate normally distributed. The symbol β represents vector of parameters for the model.

Equation (1) can be estimated for each crop individually or jointly for all crops in question. In Ghana, farmers usually cultivate more than more than one crop on a plot of land. It is therefore difficult to isolate the effect of production inputs on each crop as crops are produced jointly. In this instance, a system of single production functions can be estimated jointly for all mixed crops. Estimating production functions jointly is appropriate when the vector of explanatory variables is same across crops, and cross-equation correlations are relevant (Zellner 1962). As a result, the production functions in this study are estimated jointly for cassava, maize, sorghum, rice and yam at the farm level using Multivariate Tobit (MVT) specification as in equations (1).

The second strand of analysis of the impact of climate variables on crop production is its impact on planted area. Amount of land allocated to each crop has a substantial influence on the level of production. Acreage of planted area allocated will only be positive for those crops an individual farmer decides to plant. That is, there is a selection bias as a result of the decision by a reasonable number of farmers not to cultivate some of the crops considered under this study, otherwise known as corner solution in econometric parlance. More formally, this type of data can be fitted using Tobit model specification as in equations (3) and (4).

$$A^* = f\,(Z, \gamma) + \varepsilon \tag{3}$$

A^* is the latent planted farm area; Z is the vector of explanatory variables; γ is the vector of regression coefficients; and ε is the error term for the planted area allocation model with multivariate normal distribution. The observed planted farm area for crops (A) is related to the latent planted area as in equation (4).

$$A = \begin{cases} A^* \text{ if } A^* > 0 \\ 0 \quad \text{if } A^* \leq 0 \end{cases} \tag{4}$$

Equation (3) is estimated for the five major food crops in question simultaneously with the notion that unobserved factors that influence crop planted area allocation are correlated. That is, a MVT model also is employed as it provides efficient statistical estimation of parameter estimates under the conditions stated above. Since there are five crop choices involved, it will therefore mean that evaluation of the five-dimensional multivariate normal integral will be a difficult exercise. To improve estimation time and accuracy, the maximum simulated likelihood (MSL) is employed using Geweke-Hajivassiliou-Keane (GHK) simulator in estimating the model in equations (1) and (3) (Roodman 2011; Hajivassiliou et al. 1996).

The impact of future climate on crop yield, planted area and crop output is simulated using equations (5), (6) and (7), respectively.

$$\Delta Y\% = \frac{\left(Y_{\text{future}} - Y_{\text{present}}\right)}{Y_{\text{present}}} \times 100 \tag{5}$$

$$\Delta A\% = \frac{\left(A_{\text{future}} - A_{\text{present}}\right)}{A_{\text{present}}} \times 100 \tag{6}$$

$$\Delta Q\% = \Delta Y\% + \Delta A\% \tag{7}$$

ΔY% is percentage change in crop yield; Y_{futute} is the future prediction of crop yield; Y_{present} is the predicted crop yield in the current period; ΔA% is change in planted area; A_{futute} is the future prediction of planted area; A_{present} is the predicted planted area in the current period; and ΔQ% is the percentage change in crop output.

Data and descriptive statistics

This study analyzes the effects of climate variables on crop production using data from fifth round of Ghana Living Standards Survey (GLSS V) compiled by Ghana Statistical Service (GSS) in 2005/2006 as well as climate (temperature and rainfall) data sourced from Ghana Meteorological Service Agency for ten weather stations across the length and breadth of the country. The GLSS V data contains information on socioeconomic characteristics of 8,687 households. For the purpose of this study, 2,577 farming households which cultivate at least one of the five major crops of cassava, maize, sorghum, rice and yam are considered.

Five different crop yields expressed in kg/ha are used as the dependent variables: cassava, maize, sorghum, rice and yam. Crop yield is calculated by dividing total crop output by hectares of harvested farm area. Yields of the major food crops are generally low. The mean crop yields range from a low of about 346.33 kg/ha for sorghum to a high of about 5,342.36 kg/ha for cassava as shown in Table 1. Additionally, farm sizes for the five crops are also used as dependent variables. The mean farm size ranges from 1.65 hectares for cassava to 3.22 hectares for sorghum. The independent variables used in the study include climate variables (minimum and maximum temperature, and rainfall), household labor, age, gender and education of household head, crop prices and farm input (Table 1).

Table 1 Description and summary statistics of model variables

Variables	N	Mean	Standard deviation	Minimum	Maximum
Crop yield (kg/ha)					
Cassava	1513	5342.36	8437.83	45.59	85097.14
Maize	2017	661.26	1429.954	0.59	32592.59
Sorghum	560	346.33	503.37	2.70	4325.26
Rice	333	637.65	1154.79	2.06	12722.65
Yam	682	3150.98	5935.54	61.31	72598.55
Farm size (ha)					
Cassava	1508	1.65	3.27	0.02	97.10
Maize	2012	1.97	4.07	0.02	97.10
Sorghum	555	3.22	10.69	0.09	194.21
Rice	328	2.13	4.07	0.05	42.48
Yam	677	2.01	4.14	0.04	82.94
Output price (GHS/kg)					
Cassava	2577	0.12	0.07	0.02	1.07
Maize	2577	0.55	0.84	0.01	6.00
Sorghum	2577	0.38	0.40	0.12	4.00
Rice	2577	0.41	0.59	0.03	9.00
Yam	2577	0.46	0.32	0.07	5.47
Climate					
Minimum temperature (°C)	2577	22.29	0.63	21.18	23.48
Maximum temperature (°C)	2577	31.88	1.66	29.6	34.94
Rainfall (mm)	2577	1179.79	145.95	807.69	1377.49
Socioeconomic					
Household labor (number)	2577	2.58	1.64	0	16
Age-head (years)	2577	45.57	14.62	18	95
Gender-head (=1 if female)	2577	0.17	0.38	0	1
Education-head (years)	2577	3.13	4.60	0	16
Farm input (GHS/ha)	2577	35.79	84.81	0	1200

Notes GHS: Ghana cedi; 1 US$ = 0.92 GHS as of December 2005.
Source: calculated from 2005 Ghana Living Standard Survey and Ghana Meteorological Agency data.

The climate variables used in this study are normal minimum and maximum temperature and normal annual rainfall for the crops in question. The climate data covers fifty years (1961-2010), a long enough period to be used to construct normal climate variables. The climate data is, in turn, matched with locations of farming households as identified in the GLSS V. Ghana is generally a warm country with high temperature all year round. Normal temperature during the effective growing season of crops is about 26 °C. It is hypothesized that high temperature will impact negatively on yields of the crops in question. Normal monthly rainfall during effective growing season for crops is about 1179.79 mm per month. Since all crops need wet conditions up to a certain threshold, it is hypothesized that rainfall will have positive effect on all crops. The non-climate variables including household labor, age and education of household head and farm inputs have hypothesized positive effect on crop yield while gender has hypothesized negative effect on crop yield. The average household labor force, defined as the number of household members aged 15-60, is about 3 indicating the contribution of family labor to on-farm production. Average age of family heads is about 46 years who are mostly males with about three years of formal education. Although majority of Ghanaian food crop farmers cultivate cassava and maize, they do so on a plot size of about 2 hectares.

Farm inputs, which is the sum of household expenditure of hired labor, fertilizer, pesticide, seeds, irrigation and machinery are also hypothesized to have positive effect on all crop yields since their enhanced use are likely to increase crop yield. Generally speaking, farmers do not adequately use farm inputs in Ghana for various reasons including weak financial position. The average expenditure on farm inputs is about GHS 35.79. The meager expenditure on farm inputs reflects the fact that a significant number of farmers do not purchase these input at all.

Results and discussion

Climate effects on crop yield

This section presents and discusses the results of the MVT model from equation (1). Before the estimation was carried out, some validity checks of model data were undertaken to ensure that no outliers skew expected model results. Diagnostic tests indicate that model has no multicollinearity problems. Breusch-Pagan/Cook-Weisberg test, however, revealed presence of heteroskedasticity, implying that analyzing this data without addressing this problem would result inefficient parameter estimates, although the estimates would still be unbiased. This model is therefore estimated using as a robust regression, which helps to resolve the problem of heteroskedasticity. Ramsey RESET test for omitted variables bias in the MVT regression reveals no problems of misspecification for all regressions. The results of running MVT regression for crop yields on the set of the independent variables selected for this study as in equation (1) is displayed in Table 2. Wald chi^2 is statistically significant at 1% indicating the independent variables used in this model jointly provide plausible explanation for crop yield trends.

Household labor has statistically significant positive effect on yields of sorghum and yam. Its effects on yields of maize and rice have correct hypothesized signs but they are not statistically significant. Family members are engaged in on-farm activities including clearing, sowing, weeding and harvesting of these crops during the growing season when demand for alternative labor sources are high in farming communities. Age of household

Table 2 Results of crop yield Multivariate Tobit regression

Variables	Cassava	Maize	Sorghum	Rice	Yam
Intercept	−22085.7*** (6979.3)	−1164.1** (1294.1)	−326.04*** (274.58)	−1627.0*** (466.52)	6394.3 (3353.6)
Minimum temperature (°C)	1343.5*** (161.98)	37.157 (23.640)	−33.917*** (8.2782)	−14.726 (20.900)	−598.40*** (144.27)
Maximum temperature (°C)	−422.27*** (76.506)	9.4009 (10.171)	44.748*** (4.8346)	65.896*** (9.8528)	255.50*** (47.226)
Rainfall (mm)	6.7402*** (0.8432)	0.4223*** (0.1081)	−0.2217*** (0.0387)	−0.0365 (0.0932)	−0.6704 (0.4607)
Household labor	−0.3968 (63.653)	9.2969 (6.2705)	3.6002** (1.7373)	4.2471 (5.2064)	84.960*** (26.098)
Age of household head	12.709** (6.4873)	−0.4100 (1.4013)	−0.0065 (0.1929)	−0.5743 (0.6322)	6.8758** (3.3654)
Female household head	−47.711 (213.04)	−21.759 (35.012)	−19.482* (11.810)	−82.135** (31.884)	−370.89*** (140.82)
Education of household head	2.6794 (20.073)	2.0806 (3.5869)	−1.7510* (0.9272)	−1.1015 (2.4904)	−15.585 (10.595)
Farm input	5.6789** (2.6433)	1.3230*** (0.4452)	−0.2184*** (0.0834)	0.3579*** (0.1118)	0.1537 (0.5131)

Notes: *** means significant at 1%, ** means significant at 5% and * means significant at 10%; the total number of observations = 2577; Wald chi^2 (8) =111.34***; Log pseudo-likelihood = -31604170; the dependent variable is crop yield; and Figures in parenthesis are standard errors of regression estimates.

head has statistically significant positive effect on yields of cassava and yam. This means that older farmers who are engaged in cassava and yam cultivation achieve higher yields as compared to younger farmers. The coefficient of gender is negative and significant in the sorghum, rice and yam regressions but not statistically significant for other crops, implying that male headed homes gain higher yields from the cultivation of these crops but there is no statistical significant difference in yields of other food crop between male and female farmers. By and large, education of the household head has no significant effect on yields of all food crops. Researches in experimental plant physiology show that the soil fertility can be enhanced by adding several soil nutrient supplements to the soil (Ramteke and Shirgave 2012). Farm input has significant positive effect on yields of cassava, maize, sorghum and rice but its effect on yield of yam is not statistically significant.

Climate variables tend to have mixed effects on yields of food crops. Minimum temperature has significant positive on cassava yield but statistically negative effect on yields of sorghum and yam. Maximum temperature has significant negative effect on yields of cassava but positive effect on yields of sorghum, rice and yam. Both minimum and maximum temperatures have no statistically significant effect on yield of maize. Rainfall has significant positive effect on yields of cassava and maize but negative effect on sorghum yield. Positive effect of additional rains on yields of cassava and maize confirms the fact that cassava and maize are rain-loving crops which benefit from reasonably wet climatic conditions. Sorghum requires a reasonable amount of water from germination up till heading. Additional rains after heading can, however, be harmful. Although rainfall has no significant impact on rice yield, it may be true in rice growing areas in Ghana. Rice is mostly cultivated in the valley bottoms of the drier savanna ecological zone with waterlogged soils. As a result, additional rains may not bring about significant increase in yield of rice.

Impact of climate variables on planting decisions

This section analyzes the impact of climate variables on planting decisions of food crop farmers in Ghana using a Multivariate Tobit model, with farm size of each crop being used as dependent variable and, climate variables and crop prices as independent variables. These independent variables fit the model well as evidenced by significant values of Wald chi^2 (Table 3).

Prices of food crops do not display any consistent pattern in terms of its effect on land allocation (Table 3). Farmers who cultivate sorghum and rice respond positively to increases in the prices of these crops by putting more land into cultivation. Maize farmers, however, respond negatively to increase in the price of maize. Crop prices especially for cassava, maize and sorghum prices, however, have significant indirect effect on planting decisions. Increase in cassava price prompts farmers to allocate more land for maize and less land for sorghum and yam cultivation. Increase in maize price is associated with increased land allocated for cassava. . While sorghum price signal farmers to increase planted area allocated for yam cultivation, it, however, decreases the amount of land put into rice cultivation. Rice and cassava prices do not have significant cross-price effects.

Climate variables have statistically significant influence on farmers' planting decision. Minimum temperature has significant positive coefficients for cassava and significant

Table 3 Results of farm size Multivariate Tobit regressions

Variables	Cassava	Maize	Sorghum	Rice	Yam
Intercept	−3.6388** (2.6345)	−1.635921 (3.686328)	−7.7645** (5.1367)	−2.9370** (1.6151)	2.058012 (1.6034)
Minimum temperature (°C)	0.4814*** (0.0934)	0.0620 (0.0736)	−0.3945** (0.1789)	−0.2093*** (0.0734)	−0.2440*** (0.0764)
Maximum temperature (°C)	−0.2900 (0.0344)	0.0479* (0.0265)	0.6878*** (0.2135)	0.2567*** (0.0421)	0.1332*** (0.0361)
Rainfall (cm)	0.0026*** (0.0005)	0.0003 (0.0003)	−0.0032*** (0.0011)	−0.0003 (0.0003)	−0.0002 (0.0003)
Cassava price	0.1497 (0.1701)	0.4618* (0.2478)	−4.7550* (2.6651)	0.5283 (0.3677)	−1.1822* (0.6329)
Maize price	0.0607*** (0.0191)	−0.0681*** (0.0216)	−0.7577 (0.3776)	−0.0871** (0.0403)	−0.0578 (0.0426)
Sorghum price	0.0143 (0.0888)	−0.0868 (0.0788)	0.8904** (0.4143)	−0.1247* (0.0687)	0.2969*** (0.0641)
Rice price	0.0516 (0.0456)	−0.0479 (0.0381)	−0.3624 (0.3054)	0.1058*** (0.0357)	−0.0329 (0.0501)
Yam price	−0.0763 (0.0813)	−0.0834 (0.1046)	−0.3765 (0.3321)	0.1140 (0.0715)	−0.1982 (0.2084)

Notes: *** means significant at 1%, ** means significant at 5% and * means significant at 10%; the total number of observations = 2572; Wald chi^2 (8) = 97.98***; Log pseudo-likelihood = -10301403; the dependent variable is farm size; and Figures in parenthesis are standard errors of regression estimates.

negative coefficients for sorghum, rice and yam. This means that an increase in minimum temperature provokes reallocation of land away from sorghum, rice and yam towards cassava. Similarly, maximum temperature has significant positive coefficients for maize, sorghum, rice and yam. This means that an increase in maximum temperature increases land allocated for these crops. Rainfall has significant positive coefficients for cassava and negative for sorghum. This implies that reduced levels of rainfall will impact negatively on land allocated for the cultivation of sorghum while cassava benefits from additional rains through increased land allocation.

Climate change impact on food crop production in Ghana

This section simulates future change in climate using historical trend of climate variables (minimum and maximum temperature, and Rainfall) in order to analyze the impact of climate change on food crop production in Ghana. Trend analysis of climate variables over the period 1961-2010 show that both minimum and maximum temperatures are projected to increase while rainfall is projected to decline. Table 4 presents the future changes in temperature and rainfall generated using climate trends coefficients across the ten regions of Ghana. With the exception of Brong Ahafo region, rainfall is projected to reduce in all regions. Both minimum and maximum temperatures are projected to increase in all regions.

Using the change in climate variables as reported in Table 4 together with coefficients from the estimation of yield and farm size equations (Tables 2 and 3), we can simulate the future impact of climate change on food crop production.

It can be seen from Table 5 that climate change will raise the yields of cassava, maize, sorghum and rice but it will impact negatively on yields of yam. Cassava yield is expected to increase by 1.25%, 3.02% and 3.76% for 2015, 2020 and 2025, respectively. Maize yield is projected to go up by 0.33%, 0.86% and 0.99% for 2015, 2020 and 2025, respectively. Similarly, sorghum yield is projected to increase by 5.32%, 9.75% and 15.63% for 2015, 2020 and 2025, respectively. The yields of rice will increase by 8.79%, 17.50% and 26.30% 2015, 2020 and 2025, respectively. The yield of rice, however, will reduce by 3.57%, 7.32% and 10.74% for 2015, 2020 and 2025, respectively.

Table 4 Change in climate variables vis-à-vis 2010 values

	Rainfall (mm)			Minimum temperature (°C)			Maximum temperature (°C)		
	2015	2020	2025	2015	2020	2025	2015	2020	2025
Upper west region	−3.249	−6.498	−9.747	0.1095	0.219	0.329	0.102	0.203	0.305
Uppereast region	−0.583	−1.166	−1.749	0.1175	0.235	0.353	0.124	0.247	0.371
Northern region	−4.196	−8.391	−12.587	0.1065	0.213	0.320	0.136	0.271	0.407
Brong-Ahafo region	7.920	15.84	23.76	0.0615	0.123	0.185	0.126	0.251	0.377
Volta region	−16.269	−32.538	−48.807	0.1595	0.319	0.479	0.148	0.295	0.443
Ashanti region	−20.717	−41.433	−62.150	0.137	0.274	0.411	0.181	0.367	0.542
Eastern region	−12.887	−25.774	−38.661	0.101	0.202	0.303	0.148	0.295	0.443
Greater Accra region	−20.183	−40.365	−60.548	0.2165	0.433	0.650	0.095	0.189	0.284
Central region	−26.072	−52.143	−78.215	0.104	0.208	0.312	0.033	0.066	0.099
Western region	5.794	10.429	17.382	0.137	0.274	0.411	0.130	0.260	0.390

Table 5 Impact of climate change on food crop production (in percentage point change)

	2015	2020	2025
Crop yield			
Cassava	1.247	3.023	3.764
Maize	0.329	0.860	0.987
Sorghum	5.321	9.748	15.631
Rice	8.791	17.495	26.303
Yam	−3.565	−7.320	−10.739
Farm size			
Cassava	1.840	3.672	5.559
Maize	0.702	1.451	2.103
Sorghum	10.432	19.777	31.199
Rice	4.477	8.697	11.254
Yam	−1.781	−3.623	−5.378
Crop output			
Cassava	3.087	6.695	9.323
Maize	1.031	2.311	3.091
Sorghum	15.718	29.625	46.997
Rice	13.274	26.202	37.567
Yam	−5.351	−10.956	−16.132

Notes: all figures represent changes from the base year of 2010.

Climate change will prompt farmers to increase the cultivation of cassava, maize, sorghum and rice, as evidenced by the increased levels of land allocated for cassava, maize, sorghum and rice (Table 5). By 2015, climate change is projected to raise farm size for cassava, maize, sorghum and rice by 1.84%, 0.70%, 10.43% and 4.48%, respectively while farm size for yam will decrease by 1.78%. By 2025, land allocated for cassava, maize, sorghum and rice cultivation will increase by 5.56%, 2.10%, 31.20% and 11.25%, respectively, while decreasing farm size for yam by 5.38%.

Overall, climate change will increase output of cassava, maize, sorghum and rice by 3.09%, 1.03%, 15.72% and 13.27% by 2015. By 2020, climate change is projected to raise output of cassava, maize, sorghum and rice by 6.70%, 2.31%, 29.63% and 26.20%, respectively. By 2025, output of cassava, maize, sorghum and rice cultivation will increase by 9.32%, 3.09%, 47.00% and 37.57%, respectively %. Output of yam will, however, decline by 5.35%, 10.96% and 16.13% for 2015, 2020 and 2025, respectively.

Conclusions and discussion

This study uses national household survey data to analyze impact of climate change on food crop production in Ghana. Multivariate Tobit Model is used to assess the impact of climate variables on crop yields and planting decisions of farmers. It is found that climate change will have positive impact on yields, farm size and output of cassava, maize, sorghum and rice. This is in clear contrast to the hypothesis that climate change will reduce crop yields in countries located within the tropics. Yam, however, proved to be more susceptible to climate change. The use of farm inputs significantly improves yields of food crops. But, the effects of these inputs are economically smaller as compared to climate variables. Apart from climate variables and farm inputs, some socioeconomic variables, especially household labor and gender of household heads also have significant influence on crop yields.

Further, climate change has significant influence on crop planting decisions. Additional warming and drying will prompt farmers to increase the cultivation of cassava, maize, sorghum and rice, but it decreases the cultivation of yam. It is observed that farmers respond to positive impact of climate on yields of cassava, maize, sorghum and rice by reallocating more land towards the cultivation of these crops. This is the overriding consideration in crop planting decisions in many developing economies. Sale of food stuffs to supplement family income is considered a secondary issue. It is therefore no wonder that food crop farmers respond weakly to price incentives, as they do not increase the size of farms for most of the crops in question in respond to positive change in output prices. Growers of cassava, maize and sorghum, however, react to changes in prices of related crops by putting more land into cultivation. This peculiar trait of food crop farmers can stifle the future development of the food crop subsector in Ghana.

The interpretation of the findings is conducted with the assumption that the only variables which will change in the future are climate variables. All other independent variables and even variables not considered in this study including population and technology are assumed constant over the projection period. The study also assumes that farmers can adapt fully to warming and dying by switching from one crop to another. However, this may not be the case because adaptation requires specific investments before it can be accessed.

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References

Branca G, McCarthy N, Lipper L, Jolejole MC (2013) Food security, climate change and sustainable land management: A review. Agronomy for sustainable development 33:635–650, doi: 10.1007/s13593-013-0133-1

Breisinger B, Diao X, Thurlow J (2009) Modeling growth options and structural change to reach middle income country Status: The Case of Ghana. Economic Modeling 26:514–525

Butt TA, McCarl BA, Angerer JA, Dyke PA, Stuth JW (2005) The Economic and food security implications of climate change in Mali. Climatic change 68(3):355–378

Cabas J, Weersink A, Olale E (2010) Crop yield response to economic, site and climate variables. Climate Change 101:599–616

Chipanshi AC, Chanda R, Totolo O (2003) Vulnerability assessment of the maize and sorghum crops to climate change in Botswana. Climatic change 61(3):339–360

Corobov R (2002) Estimations of climate change impacts on crop production in the Republic of Moldova. Geo journal 57:195–202

Darwin R, Tsigas M, Lewandrowski J, Raneses A (1995) World agriculture and climate change: Economic Adaptations, Agricultural economic report, Natural Resources and Environment Division, Economic Research Service, U.S. Department of Agriculture Agricultural Economic Report No. 703.

Garrity D, Akinnifesi F, Ajayi O, Weldesemayat S, Mowo J, Kalinganire A, Larwanou M, Bayala J (2010) Evergreen agriculture: a robust approach to sustainable food security in Africa. Food Security 2:197–214

GEPA (Ghana Environmental Protection Agency) (2001) Ghana's initial national communications report. United Nations Framework Convention on Climate Change, Accra

Hajivassiliou VA, McFadden D, Ruud P (1996) Simulation of multivariate normal rectangle probabilities and their derivatives: theoretical and computational results. Journal of Econometrics 72(1–2):85–134

Just R, Pope R (1978) Stochastic specification of production functions and economic applications. Journal of Econometrics 7:67–86

Kaiser HM, Riha SJ, Wilks DS, Rossiter DG, Sampath R (1993) A farm-level analysis of economic and agronomic impacts of gradual climate warming. American journal of agricultural economics 75(2):387–398

Knox JW, Hess TM, Daccache A, Wheeler T (2012) Climate change impact on food crop productivity in Africa and South Asia, Environmental Research Letters 7 034032

Kurukulasuriya P, Mendelsohn R (2006) Crop selection: adapting to climate change in Africa, CEEPA Discussion paper No. 18, Center for Environmental Economics and Policy in Africa, University of Pretoria.
Mendelsohn R, Dinar A (2009) Climate change and agriculture: An economic analysis of global impacts, adaptation and distributional effects. Edward Elgar Publishing Ltd., Cheltenham, UK and Northampton, MA, USA
Mendelsohn R, Nordhaus WD, Shaw D (1994) The impact of global warming on agriculture: a ricardian analysis. The American economic review 84(4):753–771
MOFA (Ministry of Agriculture) (2007) District level agricultural production and price data. Statistics Research and Information Directorate, Accra
Nhemachena C, Hassan RM (2007) Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion paper 00714. International Food Policy Research Institute, Washington, IFPRI Discussion paper 00714
Ramteke AA, Shirgave PD (2012) Study the effect of common fertilizers on plant growth parameters of some vegetable plants. Journal of Plant Product and Natural Resources 2(2):328–333
Roodman D (2011) Estimating fully observed recursive mixed-process models with cmp. Stata Journal 11(2):159–206
Sagoe R (2006) Climate change and root crop production in Ghana. Retrieved June 8, 2012, from http://www.nlcap.net/fileadmin/NCAP/Countries/Ghana/ROOT_TUBERS_DRAFT_FINAL_REPORT.pdf
Seo SN, Mendelsohn R (2008) An analysis of crop choice: adapting to climate change in South American Farms. Ecological economics 67(1):109–116
Zellner A (1962) An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. Journal of American Statistical Association 57(298):348–368

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