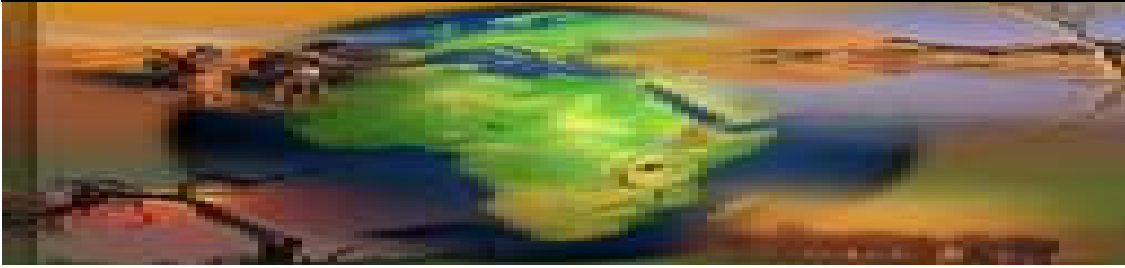


CLIMATE CHANGE AND AFRICAN AGRICULTURE

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Impacts of climate change on crop farming in Ethiopia¹

Agriculture remains by far the most important sector in the Ethiopian economy. The sector directly supports about 85% of the population in terms of employment and livelihood; contributes about 50% of the country's gross domestic product (GDP); generates about 88% of the export earnings; and supplies around 73% of the raw material requirement of agro-based domestic industries. It is also the major source of food for the population and hence the prime contributing sector to food security. In addition, agriculture is expected to play a key role in generating surplus capital to speed up the country's overall socio-economic development.

Small-scale farmers who are dependent on low input and low output rainfed mixed farming with traditional technologies dominate the agricultural sector. The present government of

Ethiopia has given top priority to this sector and has taken steps to increase its productivity. However, various problems are holding this back. One major cause of underproduction is drought, which often causes famine, and floods. These climate related disasters make the nation dependent on food aid.

The trends in the contribution of agriculture to the country's total GDP clearly explain the relationship between the performance of agriculture, climate and the total economy. Years of drought and famine (1984/1985, 1994/1995, 2000/2001) are associated with very low contributions, whereas years of good climate (1982/83, 1990/91) are associated with better contributions.

Climate change could be particularly damaging to countries in Africa, and Ethiopia, being dependent on rainfed agriculture and under heavy pressure from food insecurity and often famine caused by natural disasters such as drought, is even more likely to be affected

Studies to address the economic impact of climate change on Ethiopian agriculture and the farm level adaptations that farmers make to mitigate the potential impacts of climate change are lacking. Accordingly, little is known about how climate change may affect the country's agriculture. This seriously limits policy formulation and

¹ This Policy Note is prepared by R Hassan based on Deressa (2006), Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach, *CEEPA Discussion Paper No. 21, CEEPA, University of Pretoria*.

decision making in terms of adaptation and mitigation strategies.

The objective of this study was to assess the economic impact of climate change on Ethiopian farmers, using the Ricardian approach, and to inform policy makers on proper adaptation options to counteract the harmful effects of such change. Using selected climate scenarios, the study also made attempts to predict the extent to which projected climate changes will affect net revenue from crop farming in Ethiopia.

The Ricardian model

The Ricardian method is a cross-sectional approach to measuring determinants of land value. The principle follows Ricardo's original observation that land rents would reflect the present value of future net productivity of farmland (Ricardo 1817). The model uses actual observations of farm performance in various climatic regions to measure how long-term farm profitability varies with local climate while controlling for other factors. By regressing farm values on climate and other control variables we are able to measure the marginal contribution of each variable to land value.

The data and variables included

The household data for this study was based on a sample of 1000 farmers randomly selected from different agro-ecological regions of the country, believed to be representatives of the whole nation. A total of 50 districts (20 farmers from each) were purposely selected, from the extreme highlands of the southeastern regions of the Oromia Regional State to the lowlands of the Afar Regional States. The interviews

with the farmers took place during the 2003/2004 production seasons. Almost all were small-scale farmers with rainfed farms, as more than 95% of Ethiopian farmers are of this type.

The study relied on monthly temperature data collected from US Department of Defense satellites. The monthly precipitation data came from the Africa Rainfall and Temperature Evaluation System (ARTES) (World Bank 2003).

Soil data was obtained from FAO (2003). Hydrological data was predicted from a hydrological model for Africa (Strzepek & McCluskey 2006) which calculated the water flow through each district in the surveyed countries.

The dependent variable was measured as crop net revenue per hectare of cropland calculated as gross revenue from crops less total variable cost of production. The cost of household labor was not deducted but its effect was controlled for by including household size as a proxy for household labor as a regressor in the model.

Sensitivity of farm revenue to climate

The net revenue model for Ethiopia was estimated using seasonal climate means for summer, fall, winter and spring. The independent variables included the linear and quadratic temperature and precipitation terms for the four seasons: winter (the average for December, January and February), summer (the average for June, July and August) spring (the average for March, April and May) and fall (the average for September, October and November).

The independent variables also included household attributes and soil types. The

household variables in the model included livestock ownership, level of education of the head of the household, distance to input markets and household size. The soil types included nitosols and lithosols.

Table 1: Average net revenue per hectare (US\$) of the sample agro-ecological zones

Agro-ecological zones	Net revenue per hectare
Tepid to cool humid midlands	1270.7
Cold to very cold moist Afro-alpine	896.92
Tepid to cool pre-humid mid-highlands	998.04
Tepid to cool moist mid-highlands	1832.97
Tepid to cool sub-moist mid-highlands	927.75
Tepid to cool sub-moist mid-highlands	655.36
Hot to warm humid lowlands	522.6
Hot to warm sub-moist lowlands	963.17
Hot to warm pre-humid lowlands	192.55
Hot to warm arid lowland plains	2918.6
Hot to warm sub-humid lowlands	1168.92
Total	1213.56

The regression results indicate that most of the climatic, household and soil variables have significant impacts on the net revenue per hectare. While the coefficients of spring and summer temperature are both negative, those of winter and fall are positive. The coefficients of winter and fall

precipitation are negative, whereas for spring and summer they are positive. The interpretations of the signs and magnitudes of impacts are further explained under the marginal analysis.

As expected, the education level of the head of the household and the livestock ownership are positively related to the net revenue per hectare. The distance to input market place is negative, as farmers incur more cost in terms of money and time as the market place becomes further from their farm plots. The household size is negatively related to the net revenue per hectare because there are many dependent and unproductive people in rural Ethiopia (such as children, and the elderly and sick).

The marginal impact analysis was undertaken to observe the effect of an infinitesimal change in temperature and rainfall on Ethiopian farming. Table 2 shows the marginal impacts of temperature and precipitation. Increasing temperature during winter and summer seasons significantly reduces the net revenue per hectare. Increasing temperature marginally during the winter and summer seasons reduces the net revenue per hectare by US\$997.7 and US\$177.6 respectively. Increasing temperature marginally during the spring and fall seasons increases the net revenue per hectare by US\$337.8 and US\$1879.7 respectively. During spring, a slightly higher temperature with the available level of precipitation enhances germination, as this is the planting season. During fall, a higher temperature is beneficial for harvesting. It is important that crops have finished their growth processes by fall, and a higher temperature quickly dries up the crops and facilitates harvesting.

Increasing precipitation during the spring season increases net revenue per hectare by US\$225.1. As explained earlier, with slightly higher temperature and available precipitation (soil moisture level), crop germination is enhanced. Increasing precipitation levels during the winter significantly reduces the net revenue per hectare by US\$464.7. Winter is a dry season, so increasing precipitation slightly with the already dry season may encourage diseases and insect pests. Marginally increasing precipitation during the summer and fall also reduces net revenue per hectare, by US\$18.9 and US\$64.2 respectively, even though the level of reduction is not significant.

Table 2: Marginal impacts of climate on net revenue per hectare (US\$)

Season	Winter	Spring	Summer	Fall
Temp.	-997**	338	-178*	1880**
Precip.	-464**	225**	-18.9	-64

* significant at 5% ** significant at 1%

The reduction in net revenue per hectare during the summer is due to the already high level of rainfall in the country during this season, as increasing precipitation any further results in flooding and damage to field crops. The

reduction in net revenue per hectare with increasing precipitation during the fall is due to the crops' reduced water requirement during the harvesting season. More precipitation damages crops and may reinitiate growth during this season.

Impacts of future climate projections

The impact of climate change on the net revenue per ha was analyzed using uniformly changed temperature and precipitation levels. These uniform scenarios assume that only one aspect of climate changes and that the change is uniform across the country. These scenarios increase temperature by 2.5° C and 5° C and reduce precipitation by 7% and 14%.

Increasing temperature by 2.5°C and 5°C affects net revenue per hectare marginally (Table 3). Moreover, reducing precipitation by 7% and 14% also reduces net revenue per hectare, even though the level of damage is very small. These results are in line with the expectations that increasing temperature and reducing precipitation is damaging to agriculture in Africa, indicating a need for policy intervention targeting adaptation through technology such as irrigation, and the use of drought tolerant and early maturing crop varieties.

Table 3: Average net revenue per hectare impacts of uniform climate scenarios (US\$)

Impacts	2.5°C warming	5° C warming	7% decreased precipitation	14% decreased precipitation
Change in net revenue per hectare (US\$)	-0.00016 (-1.31902E-05 %)	-0.0003646 (-3E-05 %)	-0.3941333 (-0.03249 %)	-0.393894 (-0.03247)

Predicted values of temperature and rainfall from three climate change

models (CGM2, HaDCM3 and PCM) were also applied to help understand the likely impact of climate change on

Ethiopian agriculture. The predicted values for the scenario analysis were taken from the hydrological component of the project from Colorado University (Strzepek & McCluskey 2006). Table 4 shows the predicted values of temperature and precipitation from the three models for the years 2050 and 2100. As can be observed from this table, all the models forecasted increasing temperature levels for the years 2050 and 2100. With respect to precipitation, while the CGM2 predicted decreasing precipitation for the years 2050 and 2100, both HaDCM3 and PCM predicted increasing precipitation over these years.

The results of the predicted impacts from the SRES models are presented in Table 5. As can be seen from this table, using climate forecasts from all the models, this study revealed that by 2050 net revenue per hectare would increase, whereas by 2100 it would decrease. Even though the effects in both cases are marginal, this analysis further shows that climate change is damaging in the long run. The fact that all the models show similar results in the long run indicates a need for policy intervention before damage is done.

Table 4: Climate predictions of SRES models for 2050 and 2100

Model	Temperature			Precipitation		
	Current	2050	2100	Current	2050	2100
CGM2	21.25	24.51	29.26	76.77	64.75	50.27
HADCM3	21.25	25.07	30.66	76.77	83.53	93.46
PCM	21.25	23.50	26.69	76.77	80.83	85.67

Table 5: Forecasted average net revenue per hectare impacts from SRES climate scenario (US\$)

Impacts	CGM2		HADCM3		PCM	
	2050	2100	2050	2100	2050	2100
Change in net revenue per hectare (US\$)	0.0000342	-0.0003328	0.0004001	-0.0005612	0.0001707	-0.0003668
	(2.81946E-06 %)	(-2.74361E-05 %)	(3.29843E-05 %)	(-4.62655E-05 %)	(1.40725E-05 %)	(-3.02391E-05 %)

Conclusions and policy implications

The above analysis shows the magnitude and direction of climate change impact on Ethiopian agriculture. Most of the results show that climate change, especially increasing temperature, is

damaging. This has a policy implication worth thinking about and planning before damage occurs. The Ethiopian government must consider designing and implementing adaptation policies to counteract the harmful impacts of climate change. Adaptation options include investment in technologies such

as irrigation, planting drought tolerant and early maturing crop varieties, strengthening institutional set-ups working in research, and educating farmers and encouraging ownership of

livestock, as owning livestock may buffer them against the effects of crop failure or low yields during harsh climatic conditions.

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The agricultural sector in sub-Saharan Africa is predicted to be especially vulnerable to climate change because this region already endures high heat and low precipitation, provides the livelihoods of large segments of the population, and relies on relatively basic technologies, which limit its capacity to adapt. This series of Policy Notes reports on the methods and results of the first continent-wide study of this kind assessing how the economic well-being of African farming communities is currently affected by climate, predicts how future climate change effects may unfold under various possible global warming scenarios, and evaluates the roles adaptation to climate change could play. The study is based on collaborative research efforts conducted in 11 countries: Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe. The sampled districts used as the unit of analysis cover all key agro-climatic zones and farming systems in Africa. This is the first analysis of climate impacts and adaptation in Africa on such a scale and the first in the world to combine cross-country, spatially referenced survey and climatic data for conducting an analysis that uses economic impact assessment methods, river-basin hydrological modeling and crop growth simulation techniques.

All the reports produced under this GEF/WB/CEEPA funded project, *Regional Climate, Water and Agriculture: Impacts on and Adaptation of Agro-ecological Systems in Africa*, are found on CEEPA e-Library at its website link (www.ceepa.co.za/discussionp2006.html) and can also be accessed directly through the project link (www.ceepa.co.za/Climange_Change/project.html)

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