CLIMATE CHANGE AND AFRICAN AGRICULTURE

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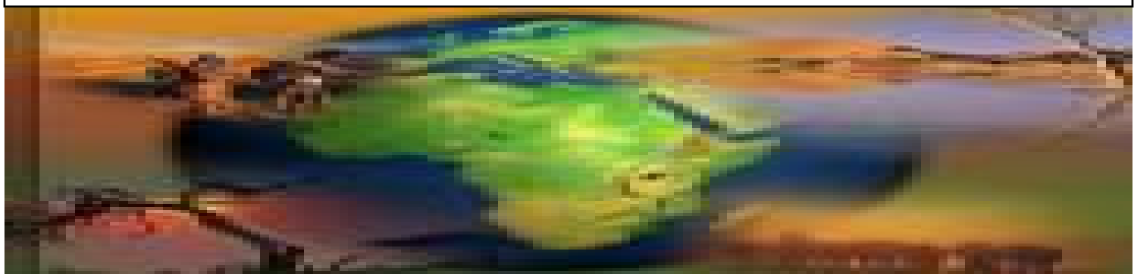

Impacts of climate change on crop farming in Burkina Faso[1]

In Burkina Faso agriculture dominates the economy. It employs 86% of the total population (estimated at 12.1 million in 2003). About 40% of GDP comes from agriculture (crops 25%, livestock 12% and forestry and fishing 3%), which are the main sources of the county's economic growth. Burkinabe agriculture is a subsistence agriculture based on cereal growing (sorghum, millet, maize, fonio and rice) which takes up 88% of the cultivated area and constitutes the staple diet of the majority of the population. Cotton is the main export crop and provides on average 50% of export income. Burkinabe agriculture is almost exclusively extensive and hence its development is hampered by major natural constraints (climatic factors and soil degradation).

The country lies in the Sudano-Sahelian zone, where the climate and natural environment are harsh. The rainfall is low and characterized by strong inter-annual and space-time variability. This directly affects agro-pastoral production. At present aridity in the north is increasing, causing a decrease in the crop growing period of 20 to 30 days. A succession of droughts has modified the natural environment and caused desertification.

The soils are generally not very deep, with low water retention capacity and low organic matter content. Natural resources are becoming further degraded from year to year because of traditional farming methods and population growth, notably near the urban centers.

These physical and climatic constraints make Burkinabe agriculture vulnerable to climate hazards. As crops are essentially rainfed, vulnerability due to climatic hazards, inadequate growth of productivity and poor diversification of incomes are the reasons why economic and food insecurity persist in the rural households. The fragility of the economy will be exacerbated by global climate change because Burkina Faso's economic performance closely depends on the agricultural sector's performance.

This study attempts to measure how climate affects net farm revenues in Burkina Faso. It adopts the cross-sectional (Ricardian) approach to

[1] This Policy Note is prepared by R Hassan based on Ouedraogo, Some & Dembele (2006), Economic impact assessment of climate change on agriculture in Burkina Faso: A Ricardian approach, *CEEPA Discussion Paper No. 24, CEEPA, University of Pretoria.*

measure climate change damages and examines the implications of future climate scenarios.

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 different 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 analysis uses cross-sectional data at the household and district levels on farm activities, climate, soils and hydrology. Data from the survey sample was used to implement the Ricardian approach. Farm household data was obtained from a survey conducted in 51 districts across the country. The survey covered all of the country's provinces, except Kadiogo, which is the province of the capital city of the country. The surveyed districts were selected based on agro-climatic zones in order to capture the spatial distribution of the climatic variability across the country. Figure 1 presents the distribution of the study sites. A sample of 1530 households was chosen from the typology of farms described in Table 1. The data collected at household level was for the year 2002–2003, in particular the rainy season from May to October 2002 and the dry season from November 2002 to April 2003.

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 the 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 is 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 is not deducted but its effect is 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 results of the estimation of Burkina Faso's net farm revenue response function show that the relationship between revenue and temperature or precipitation is non-linear. This means that temperature or precipitation affects the net revenue positively up to a certain level, above which it causes damage to the crops. The effect of the hydrologic variable on net revenue is also non-linear.

Figure 1: Sampled districts of Burkina Faso

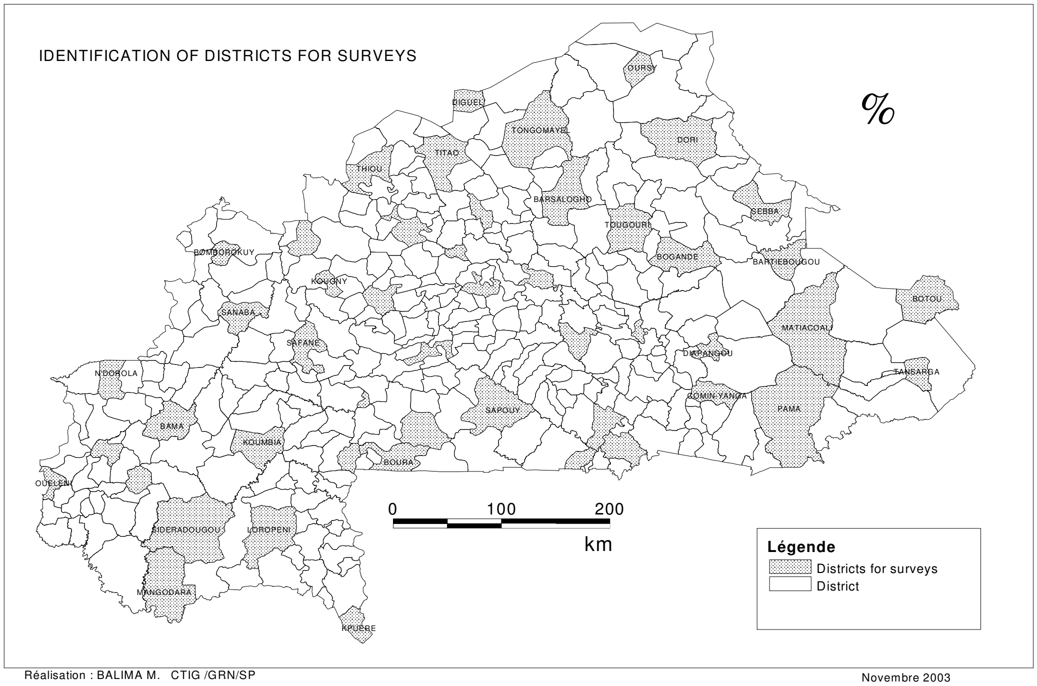

Table 1: Distribution of agricultural household and farm typology in Burkina Faso

Criteria	Typologies	No. of households	% of farms
Inputs + equipment	Without fertilizer, without equipment	539 336	60.96
	With fertilizer, without equipment	85 580	9.67
	Without fertilizer, with equipment	172 288	19.47
	With fertilizer, with equipment	87 481	9.89
Surface	Small farms (<3ha)	441 577	49.91
	Average size farms (3 to 5ha)	209 560	23.69
	Large farms (>5ha)	233 551	26.39
Population	Small size (<5 persons)	253 689	28.67
	Average size (5 to 9 persons	295 631	33.41
	Big size (>10 persons)	335 369	37.90

Precipitation and runoff are significant in the model with zone dummy variables, but temperature effects are not very significant in this model. This means that water is the main factor that explains the spatial variation of revenue in Burkina Faso. The effects of the soils are negative, which may be attributed to the low fertility level and low water retention capacity of the soils in Burkina Faso.

Household size affects revenue positively. Because agriculture is extensive, the size of the household is important for supplying sufficient labor. As expected, extension service helps improve net revenue.

Irrigation has a positive effect on revenue. As a way of adapting to climate change, it is practiced during the dry season and provides farmers with some additional income. During the rainy season it helps to alleviate the hazards of irregular rainfall and ensure stable production.

The marginal effect of temperature is calculated on the basis of the average temperature of the sample, which is 26°C in the rainy season and 26.6 °C in the dry season. The marginal effect of precipitation is calculated similarly at the average annual precipitation of 717mm in the rainy season and 80mm in the dry season. No significant difference is observed between the average temperatures for rainfed and irrigated crops. However, precipitation figures for rainfed farms are slightly higher than for irrigated ones for any season. This difference suggests that irrigation is practiced where it is necessary because of lower rainfall, but we see that its development depends on the hydrological potential of the region. Therefore most of the drier areas which have water resources develop irrigation.

The marginal effect of precipitation is significant at 1% while the marginal effect of temperature is significant at 10% for the model with adaptation (Table 2). This model shows that if the average annual precipitation increases by 1mm, agricultural incomes will increase by US$2.70/ha on average for all the farms in the sample. The increase will be US$2.56/ha for rainfed farms, and will reach US$3.51/ha for farms which have not adapted to drier conditions. This means that the farmers' current practices mitigate the effects of climatic variability.

Table 2: Marginal impact of climate on net revenue (US$/ha) in Burkina Faso

	Without adaptation		**Model with adaptation**		**Model with zone dummy**	
	All farms	**Dryland**	**All farms**	**Dryland**	**All farms**	**Dryland**
Temperature	-11,5	-12,2	-19,9*	-15,62	-27,07**	-21,51*
Elasticity	(-2,08)	(-2,39)	(-3,60)	(-3,07)	(-4,89)	(-4,23)
Precipitation	3,51***	3,43***	2,7***	2,56***	3,86***	3,52***
Elasticity	(19,21)	(20,39)	(14,75)	(15,23)	(21,12)	(20,92)

* Significant at 10% level, ** Significant at 5% level *** Significant at 1% level
Numbers in bracket represents the elasticity of climate variable.

On the other hand, if the average temperatures increase by 1°C net agricultural incomes will drop by US$19.90/ha for the model with adaptation. The drop in income is less for the model without adaptation (US$11.5/ha) but remains non-significant. The effects of climate on income are slightly mitigated in strictly rainfed zones. This means that the rainfed farms are less vulnerable to the effects of climatic changes, maybe because they have already adapted to marginal climates by taking sufficient precautions to protect their incomes. As the model is based on responses from farmers, we can say that the rainfed farms have already adopted other strategies of adaptation to climate change.

Impacts of future climate trends

To predict the impact of climate change on agricultural income in the future, the study ran simulations based on uniform climate scenarios and predicted scenarios specific to Burkina Faso.

Uniform scenarios. The uniform scenarios are based on the projections made by the IPCC (2001). On the basis of this information we examined the effect of climatic changes for the following scenarios: an increase in the temperatures of 2.5°C and 5°C and a reduction in the average rainfall of 7% and 14%.

As expected, the increase in temperature and reduction in precipitation inevitably involve a reduction in incomes according to the estimated marginal effects (Table 3). The simulations show that a rise in temperature of 5°C on average will reduce incomes by 93% for all farms. A fall in the annual average precipitation of 7% will mean a total loss of income for all the farms (ceteris paribus). But adaptation is part of human nature, so these alarming forecasts will certainly be mitigated.

Burkina specific climate scenarios. This section examines the impact of the climate scenarios specific to Burkina Faso, based on Strzepek and McCluskey's (2006) climate evolution models for the period between 2050 and 2100. These models are based on the A2 and B2 scenarios of SRES. They all forecast a rise in temperatures for Burkina Faso that ranges from 2.4°C to 3.9°C in 2050 and from 5.7°C to 9.7°C in 2100 for the A2 scenario. The B2 scenario envisages increases of between 2.4°C and 3.8°C in 2050 and between 4°C and 7.1°C in 2100. This latter scenario looks less alarming.

Four of the five models predict an increase in precipitation of from 1% to 12% in 2050 and from 3% to 30% in 2100. Only one model foresees a decrease in precipitation of about 4% in 2050 and 9% in 2100.

We examined a few of these models with varying predictions. The results of simulations show that the models cs-a2 and cs-b2 are the most alarming for Burkina Faso (Table 4). According to the cs-a2 model, farmers will lose 72% of their income in 2050 and 177% in 2100 following the increase in temperatures. The decrease in precipitation predicted by this model will result in a reduction in farm households' income of from 84% in 2050 to 190% in 2100. The cumulative effect of the two factors will be dramatic for the farmers who will experience the total erosion of their incomes by the 2050s.

Table 3: Impacts from Uniform Climate Scenarios on net crop revenue in Burkina Faso

Scenarios	All farms		Dryland farms	
	ΔNet revenue (US$/ha)	ΔNet revenue (%)	ΔNet revenue (US$/ha)	ΔNet revenue (%)
Temperature warming (2.5°C)	-68	-46%	-54	-40%
Temperature warming (5°C)	-135	-93%	-108	-80%
Precipitation decreasing (7%)	-215	-148%	-196	-146%
Precipitation decreasing (14%)	-431	-296%	-392	-293%

With regard to the other models (ec-a2, ec-b2, ha-a2 and ha-b2) the increases in the temperature certainly lead to a reduction in incomes but at the same time the increases in precipitation lead to a rise in incomes. The loss of income is thus compensated for by the profits generated by the increase in rains. The combined effect will be positive for incomes. If things evolve this way, rainfed agriculture will adapt better than irrigated agriculture in Burkina Faso.

Table 10: Impacts of specific scenarios on net revenue in Burkina Faso

Models	Year	Temperature effect				Precipitation effect			
		All farms		Dryland		All farms		Dryland farms	
		ΔNR (US$/ha)	ΔNR (%)	ΔNR (US$/ha)	ΔNR (%)	ΔNR (US$/ha)	ΔNR (%)	ΔNR (US$/ha)	ΔNR (%)
A2- Scenarios									
cs-a2	2050	-106	-72%	-84	-63%	-123	-84%	-112	-84%
	2100	-257	-177%	-204	-153%	-277	-190%	-252	-188%
ec-a2	2050	-89	-61%	-71	-53%	369	253%	336	251%
	2100	-225	-154%	-179	-133%	923	634%	840	628%
ha-a2	2050	-106	-72%	-84	-63%	185	127%	168	126%
	2100	-263	-180%	-209	-156%	461	317%	420	314%
B-2 – Scenarios									
cs-b2	2050	-108	-74%	-86	-64%	-123	-84%	-112	-84%
	2100	-192	-132%	-153	-114%	-277	-190%	-252	-188%
ec-b2	2050	-89	-61%	-71	-53%	369	253%	336	251%
	2100	-157	-108%	-125	-93%	923	634%	840	628%
ha-b2	2050	-103	-71%	-82	-61%	185	127%	168	126%
	2100	-181	-125%	-144	-108%	461	317%	420	314%

Indeed, irrigation is practiced only for specific crops such as rice and for truck farming in small areas in the dry season. If the increase in precipitation relates only to the rainy season (which will undoubtedly be the case), it will be useful for the irrigated system only through the filling of dams and the resupplying of ground waters. However, rising temperatures, especially during the dry season, will increase the crops' demand for water.

Conclusions and implications

This study uses the Ricardian approach to measure the relationship between the net crop revenue and climate variables (temperature and precipitation) and other relevant soil, hydrology and socio-economic variables The results of the study show that climate affects crop net revenue in Burkina Faso. Marginal impact analyses indicate that for a temperature increase of 1°C, net crop revenue falls by US$19.9/ha. On the other hand, if precipitation increases by 1 mm, net revenue will increase by US$2.7/ha.

The elasticity shows that agriculture in Burkina Faso is more sensitive to precipitation changes (14.7) than to temperature changes (3.6). Dryland farms are more sensitive to precipitation and less sensitive to temperature than all farms, including irrigated ones.

The analysis of the climate change scenarios shows that scenarios of decreasing precipitation with rising temperatures will cause more damage to agriculture in Burkina Faso. On the other hand, scenarios of increasing precipitation and rising temperature will be tolerable because the positive impact of increased precipitation will compensate for the negative effect of the warming. As the climate in Burkina Faso is already hot and dry, the scenarios of decreasing precipitation and rising temperature will be very harmful for crop production.

According to the model cs-a2 (specific to Burkina Faso), all farms will lose 72% of their net revenue as a result of the increase in temperature and 84% as a result of the decrease in precipitation in 2050. The cumulative effect of these temperature and precipitation changes will be dramatic for the farms, which could lose all their net revenue by 2050.

The analysis of farmers' perceptions indicates that 26% of the surveyed farmers noticed a long-term increase in temperature. The surveyed farmers developed strategies for adapting, including water and soil management, agro-forestry techniques, crop management techniques, use of improved varieties, use of organic fertilizer (compost, mulching and placing animals in the fields); planting trees, extending land, diversification of crops and activities, and so on.

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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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