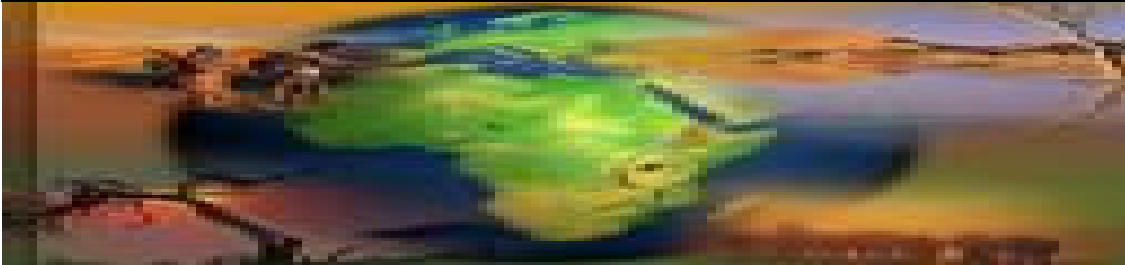


CLIMATE CHANGE AND AFRICAN AGRICULTURE

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Impacts of climate change on crop farming in Senegal¹

Located in West Africa, Senegal is one of the Sahelian countries whose geographical position provides many opportunities for trading agricultural products with the rest of the world. The Senegalese economy is heavily dependent on agriculture. From 1960 to 2003, on average 59% of the population was primarily employed in agriculture, which accounted for 10% of GDP and generated 35% of all exports. The agricultural sector now contributes only 8% of the GDP and employs 59% of the working population (DPS 2004). Although it increased at an annual average rate of 1.62%, total food production did not keep up with the population growth until the early 1970s. This situation led to uncertainty in food availability and an overall poor economic performance.

The decline in the farming sector's contribution is mainly due to the consecutive years of drought. Senegal has essentially rainfed farming that represents 98% of the farmlands (Figure

1). Rainfed agriculture depends heavily on climatic conditions: the duration of the season and the distribution and abundance of rains. Yields are directly subject to the climatic risk. The risk of drought is particularly high in the northern half of the country.

The dependence of agriculture on climatic conditions to a large extent explains the accelerating rural exodus: people leave their villages for the cities, searching for better living conditions.

This study attempted to measure how climate affects net farm revenues in Senegal. It adopted the cross-sectional (Ricardian) approach to measure climate change damages and examine the implications of future climate scenarios.

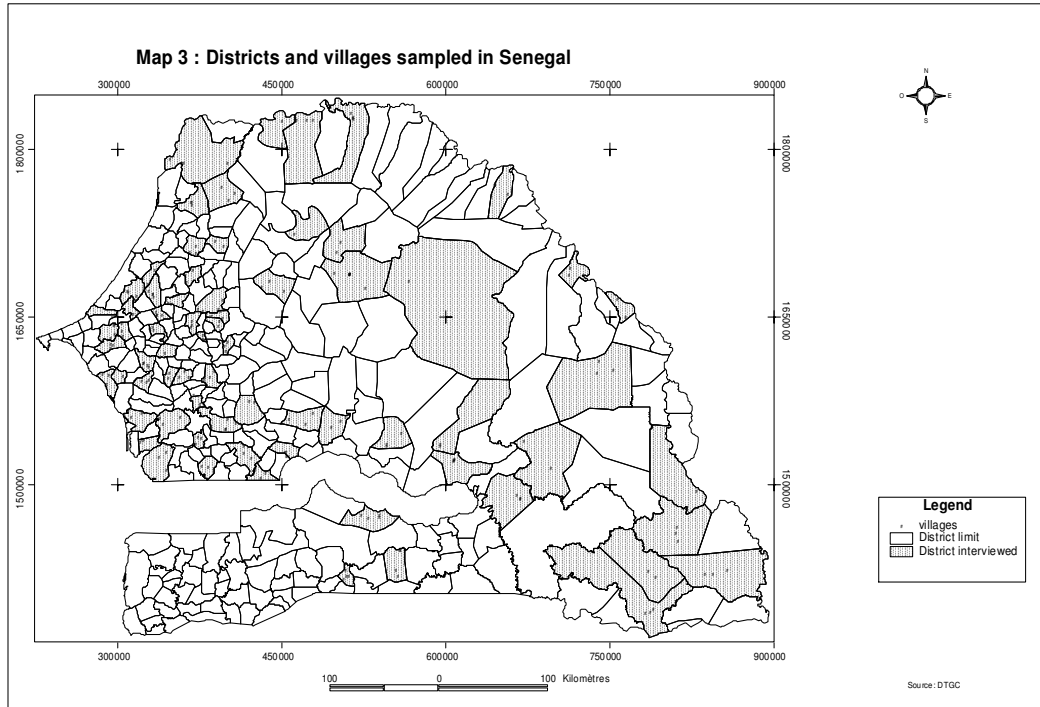
The Ricardian model

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

¹ This Policy Note is prepared by R Hassan based on Sene, Diop & Dieng (2006), Impacts of climate change on the revenues and adaptation of farmers in Senegal, *CEEPA Discussion Paper No. 20*, CEEPA, University of Pretoria.

measure the marginal contribution of each variable to land value.

Figure 1: Sampled districts of Senegal



The data and variables included

Because land markets are imperfect and agricultural farm values in the developing world are weakly documented, net farm revenue per hectare is commonly used as the response variable instead of land values. In this study the focus is on crop net revenues.

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. The population under study comprised all farming households in the administrative regions of Saint-Louis, Thies, Diourbel, Louga, Kaolack, Fatick, Tamba, Matam

and Kolda, from which a sample was selected. The National Agricultural Census of 1998/1999 was used as the sampling frame for selecting sample units. The selection was conducted in two stages: villages were selected in the first stage and agricultural households in the second. The sample size was equivalent to 0.3% of the national census. The size of the selected sample was 1200, giving a representative sample with a 93% level of confidence.

The survey covered all the agro-ecological zones in the country, as well as the major and minor crops, rainfed and irrigated agriculture, small- and large-scale production, and traditional and improved technology-based agriculture.

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). The model 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.

Table 1 shows the variability in net farm revenue across the sampled regions. The differences in climatic conditions and the level of technology can explain the variability. The use of irrigation and advanced technologies explains why net revenues are higher in some districts than in others.

Sensitivity of farm revenue to climate

The results of estimating Senegal’s net farm revenue response function show the Senegalese realities, with two main seasons: dry and rainy. In the rainy season, an increase in precipitation increases net revenue and an increase in temperature decreases it.

Table 1: Average net farm revenue (US\$/ha) across sample districts

| Regions | Net farm revenue |
|----------------|-------------------------|
| Diourbel | 26.5 |
| Fatick | 156.9 |
| Kaolack | 91.0 |
| Kolda | 260.7 |
| Louga | 194.4 |
| Matam | 133.5 |
| Saint-Louis | 249.1 |
| Tambacounda | 139.2 |
| Thies | 151.8 |
| Senegal | 142.8 |

The soil variables that were included in the model were generally significant in explaining the variability of net revenues. The size of the household and the presence of male workers have a positive effect on net revenue. Keeping livestock has a positive impact on net revenue. This implies that farmers should keep livestock so as to reduce the variability of crop production, which is strongly dependent on climate variations. The results also confirm the quadratic relationship between net farm revenues and climate variables. Temperature and precipitation have a quadratic relationship with farm net revenues. In addition, annual temperatures and seasonal and annual precipitation variables show a positive relationship with farm net revenues, implying that minimal increases in each of these climate variables yield positive benefits to farm net revenues. No significant linear relationship was found between runoff and net revenue. However, the irrigation variable has a positive sign in this model.

The analysis of marginal effects of changes in climate attributes indicates that annual high temperature affects farm net revenues positively such that a 1°C increase will be accompanied by an increase of US\$15 in net revenue (Table 2). On the other hand, a 1mm increase in precipitation gives an increase of US\$16 in net revenue.

The results indicate that seasonal temperature and precipitation also affect farm net revenues. High temperature during the rainy season reduces net revenue whereas precipitation is increases it. The implication of these results is that further increases in temperature in the rainy season are detrimental to agricultural activities, as indicated by the negative marginal effect. During the dry season, an increase in precipitation is beneficial to crop production.

Table 2: Marginal effect of annual temperature and precipitation on net revenue

| | Change in net revenue | Std err | t |
|----------------------|-----------------------|---------|-------|
| Annual temp | -1.175 | 4.99 | -0.24 |
| Annual precipitation | 6.337 | 5.21 | 1.22 |

Impacts of future climate projections

To assess the impact of different climate scenarios, three General Circulation Models (GCMs) scenarios are used:

- The CCEQ reported in Boer & al. (1992) is developed by using the Canadian Climate Center GCM with high spatial resolution coupled with

an oceanic model. The model's climate sensitivity is 3.5°C for temperature and 4% for precipitation.

- In the UKTR experiment natural and slow climate evolution is taken into account. In this experiment, the concentration of greenhouse gases increases in a proportion of 15% per year during a period of 75 years.
- The third experiment, HadCM2, was carried out during the winter of 1994–1995 in the Hadley Center by using the UK Meteorological Office Model. Spatial representations of temperature and precipitation changes in Senegal are for the year 2050.

We also used the climate projections from the GIEC (2002). The climate change scenarios predict a further increase in temperature and a simultaneous decrease in rainfall. The resulting changes in net farm revenues were simulated using the climate scenarios defined above.

Based on these models, we simulated two different scenarios. For the first one, we simulated the impact of an increase in temperature of 1.5°C combined with 8.5% decrease in rainfall, and for the second one, the same increase in temperature but a 17% decrease in rainfall.

The simultaneous changes in temperature and rainfall variables shown in Table 3 indicate that net farm revenues are negatively affected by further increases in temperature as well as by further decreases in rainfall. The implication of these results is that high

temperature and low rainfall are bad for Senegal's agriculture.

Conclusions

This study uses the Ricardian method to measure how climate affects net revenues. Using empirical data about current farmers, the study attempts to predict how climate change is likely to affect future farmers in Senegal. An inquiry into 1200 sampled households, distributed across many different climate

zones so that there would be a great deal of climate variation, shows that farmers in Senegal have a low net revenue and suggests that small rainfed farms are highly vulnerable to climate change. The study also reveals that farmers have several ways of adapting to climatic constraints: diversifying crops, choosing crops with a short growing cycle, weeding early in the north and late in the south, and praying.

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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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