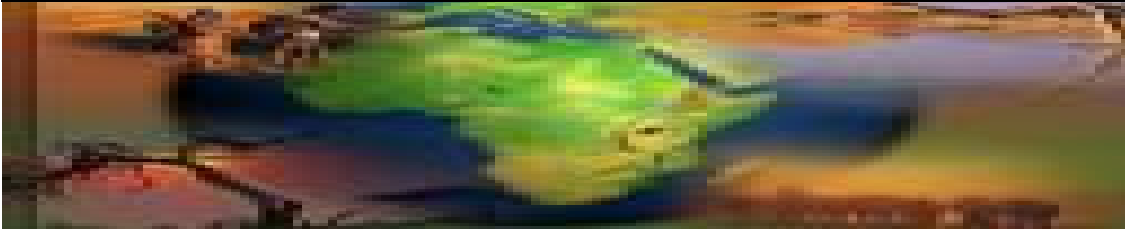


CLIMATE CHANGE AND AFRICAN AGRICULTURE

Policy Note No. 36, August 2006, CEEPA



Climate change and crop water use and productivity in Burkina Faso¹

This study examined soil water balance, crop water use and crop production in six provinces of Burkina Faso. The research also draws conclusions regarding overall climatic trends and possible ways of adapting to climate change.

The research implemented by a national team under the FAO leadership developed a unified approach in crop simulation modeling of the relationship between yield and evapotranspiration as the measure of water use by crop agriculture. The country team adapted the FAO's CROPWAT program to assess potential and actual crop water use of selected crops in six provinces of Burkina Faso. The simulation of yield reduction and estimation of crop use was based on climatic data provided by the National Meteorological Service. These are monthly averages for the minimum and maximum temperature, relative humidity (minimum and maximum),

¹ This Policy Note is prepared by S Perret based on Some, Dembele, Ouedraogo, Kambire & Sangare (2006), Analysis of crop water use and soil water balance in Burkina Faso using CROPWAT, *CEEPA Discussion Paper No. 36, CEEPA, University of Pretoria.*

sunshine, wind speed, rainfall and geographic coordinates (altitude, latitude, longitude) for the period 1963–2003.

Climatic conditions and agriculture in Burkina Faso

Located in the semi-arid tropical zone in West Africa, Burkina Faso stretches from the ninth to the fifteenth parallel in the northern latitudes. The country is subject to a high degree of both climate variability and population growth (2.3% per annum). Its main climatic features are a low level of rainfall that is also spatially and temporally variable, and high temperatures and a high level of evapotranspiration, particularly during the dry season. On the whole, the temperatures and temperature ranges increase from the south to the north. There is latitudinal sliding of all isohyets towards the south, translating to a reduction of 100mm in average rainfall. During the last few decades, the 400mm isohyets rose up to the northern border of the country and the 1100mm isohyets reappeared in the south. This rainfall dynamic has implications for crop production and food security in Burkina Faso. Beyond the Sahelian zone, the dryland Sudanian savanna, which registers an average annual rainfall greater than 600mm, has also experienced serious climate shocks, particularly droughts, since the early

1980s. These climate shocks, and growing demands for natural resources by an expanding population, compromise the sustainability of the current systems of land use and seriously threaten food security among rural populations. Massive degradation of soil chemical and physical status constitute another threat to agricultural production, and excessive runoff and low infiltration reduce the effectiveness of rainfall and increase water stress.

Case study areas, farming systems and crops studied

Smallholder, family-based, rainfed agriculture forms the backbone of Burkina Faso's economy. Livestock production supplements crop production for livelihood and social returns. In most provinces, millet and sorghum (in sandy uplands and drier areas), maize, and occasionally rice (in low and wet lands) are the main food crops. Other food and cash crops include groundnut, cowpea, sesame, soybean, yam, sweet potato, and a variety of marketable vegetables, tubers and starch crops when water availability allows. Cotton is the typical cash commodity crop in Burkina Faso, while tobacco is occasional.

One study area was chosen per agro-ecological zone, as shown in Figure 1. The provinces (and sites) studied were Houet (Bobo-Dioulasso) and Poni (Gaoua), which represent the most favourable agricultural conditions, Gourma (Fada N'Gourma), Kadiogo (Ouagadougou) and Yatenga (Ouahigouya), which represent the Sudano-Sahelian conditions, and Seno (Dori), which represents the typical harsh Sahelian conditions. The average annual rainfall of these sites is 1042mm,

1069mm, 818mm, 756mm, 617mm, and 480mm, respectively.

Besides low averages in annual rainfall, inter-annual variability in precipitation and temperature is marked, especially in Yatenga (Ouahigouya). A declining trend in rainfall that started with repeated droughts in the 1980s is even more worrying. The Sahelian conditions endured at Seno (Dori) are markedly the driest.

To reflect the reality of cropping systems in the selected provinces, a limited number of crops were selected: cotton, groundnut, maize and sorghum in Bobo-Dioulasso, Gaoua, and Fada N'Gourma; cowpeas, maize and sorghum in Ouahigouya and Ouagadougou; and cowpeas, sorghum and millet in Dori.

Simulating crop yield response to evapotranspiration

The program used for simulating crop yield response to water (CROPWAT) is a decision support system developed by the Land and Water Development Division of the FAO. Its main functions are to calculate reference evapotranspiration, crop water requirements and crop irrigation requirements in order to develop irrigation schedules under various management conditions and scheme water supply and to evaluate rainfed production, drought effects and efficiency of irrigation practices. It uses procedures for predicting yields when all the climate, soil and crop parameters are known. This approach allows estimation of actual evapotranspiration (ET_a or actual crop water use), after having estimated the stress factor K_s from the ratio of actual to potential yield.

In Burkina Faso, the input data for the model are monthly climatic parameters including minimum and maximum temperature, humidity, sunshine and wind speed. CROPWAT calculates reference evaporation E_{To} and maximum crop evapotranspiration E_{Tm} from crop coefficient K_c . The water stress coefficient K_s further lowers E_{Tm} to actual evapotranspiration E_{Ta} owing to lack of water. K_s is determined via a comparison between actual yields Y_a and maximum yields Y_m , using a yield response factor K_y .

Crop water use and productivity in Burkina Faso

Table 1 sums up the results of CROPWAT simulations for selected crops in the study sites. As expected, calculated crop water use in these sites reflects the differences in rainfall conditions and in evaporative demand.

First, optimum crop water demand increases according to climatic patterns, i.e. E_{Tm} increases (and rainfall decreases) from southwestern areas towards northeastern Sahelian conditions. For example, E_{Tm} for sorghum is 413mm and 405mm for Bobo–Dioulasso and Gaoua respectively; it increases to 422mm and 467mm for Fada N’Gourma and Ouagadougou respectively; and finally reaches 529mm and 556mm at Ouahiyouya and Dori respectively. Actual water consumptions (E_{Ta}) follow similar patterns for all crops, with even more marked relative differences.

Interestingly, crop water productivity and actual consumption figures also follows the same pattern, with striking repeatability: in the southwestern sites of Bobo-Dioulasso and Gaoua, a cubic meter of water allows for the production

of about 1.77kg of dry sorghum grain; in the Sudano-Sahelian central sites (Ouagadougou and Fada N’Gourma), it allows for the production of 0.9kg; in northeastern Sahelian conditions (Ouahiyouya and Dori), it allows for the production of 0.32kg. In such dry conditions, millet naturally competes with sorghum as staple food crop, as its water productivity remains relatively much higher (at 1.27kg/m³), for similar yields. This reflects a much better adaptation to drought.

Although grown in the relatively better conditions of the southwestern areas, cotton exhibits the lowest water productivity of all crops tested. Cowpea is also very sensitive to poor precipitation, with very low yields and poor water productivity in all stations.

Conclusions and implications

Agricultural production in Burkina Faso faces two climate-related issues.

On the one hand, low, unreliable (high inter-annual variability) and declining rainfall threatens crop production and forces smallholder farmers to adopt alternative crops and varieties. Efforts should be intensified to support water resource and small-scale irrigation development wherever possible and to promote drought-resistant crops and varieties.

In the southern part of the country, represented by the weather stations in Bobo and Gaoua, water requirements (E_{Tm}) for cereal crops and groundnut are more easily met by the rainfall. In the Sudano-Sahelian and Sahelian regions, water deficits are experienced towards the end of the rainy season. Supplementary irrigation is needed to

Table 1: Summary of water use by selected crops in the studied regions

Province	Crops	ET _o (mm)	ET _m (mm)	Y _a (t/ha)	Y _m (t/ha)	ET _a (mm)	CWP at ET _m (kg/m ³)	CWP at ET _a (kg/m ³)
Houet	Sorghum	412.84	412.80	1.00	4.50	56.55	1.09	1.77
	Cotton	822.35	797.20	1.04	2.50	375.26	0.31	0.28
	Maize	494.35	494.40	1.66	7.50	186.49	1.52	0.89
	Groundnut	515.12	513.00	0.87	2.00	100.04	0.39	0.87
Poni	Sorghum	406.31	404.70	1.03	4.50	58.01	1.11	1.78
	Cotton	747.40	745.50	0.78	2.50	280.31	0.34	0.28
	Maize	476.78	475.30	0.82	7.50	136.39	1.58	0.60
	Groundnut	515.49	513.50	0.96	2.00	130.67	0.39	0.73
Gourma	Sorghum	424.04	422.40	1.03	3.00	114.61	0.71	0.90
	Cotton	790.85	788.80	0.89	1.50	497.18	0.19	0.18
	Maize	506.48	504.80	1.21	3.50	240.61	0.69	0.50
	Groundnut	547.84	545.60	0.98	1.20	402.11	0.22	0.24
Seno	Sorghum	558.52	555.90	0.59	1.50	182.10	0.27	0.32
	Millet	592.75	592.80	0.60	3.50	47.42	0.59	1.27
	Cowpea	552.00	549.10	0.45	1.50	182.85	0.27	0.25
Kadiogo	Sorghum	478.84	467.20	0.84	3.00	92.84	0.64	0.90
	Maize	575.60	573.00	0.78	3.50	217.03	0.61	0.36
	Cowpea	486.21	483.30	0.55	1.50	161.10	0.31	0.34
Yatenga	Sorghum	531.43	529.40	0.67	1.50	202.47	0.28	0.33
	Maize	621.65	619.20	0.67	3.50	218.67	0.57	0.31
	Cowpea	542.11	539.30	0.45	1.5	179.77	0.28	0.25

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)

Centre for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria, Room 2-7, Agricultural Annex, 0002 PRETORIA, South Africa. Tel: +27 (0)12 420 4105, Fax: +27 (0)12 420 4958, Web address: www.ceepa.co.za

Core funding from the GEF and supplementary funding from TFESSD, Finnish TF, NOAA-OPG, and CEEPA in support of this project's activities are all gratefully acknowledged. The project was coordinated by CEEPA and managed in the World Bank by the Agricultural and Rural Development Department and World Bank Institute.



THE WORLD BANK

The findings, interpretations, and conclusions expressed herein are those of the author(s) and do not necessarily reflect the views of the Board of Executive Directors of the World Bank or the governments they represent. The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of the World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.