CLIMATE CHANGE AND AFRICAN AGRICULTURE

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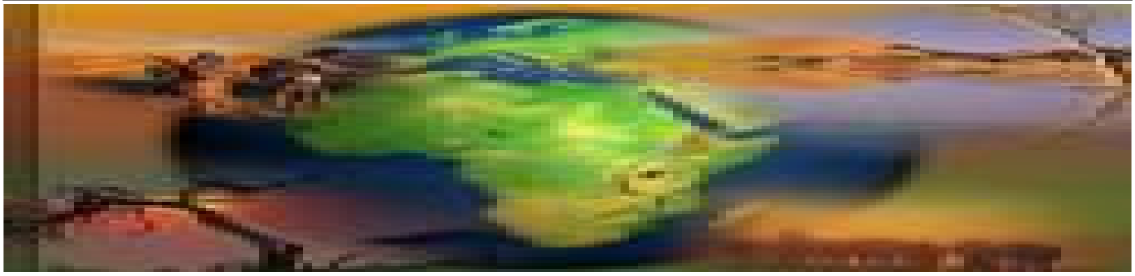

Climate change and crop water use and productivity in Cameroon[1]

The impact of climate variation on crop water use efficiency and yield has recently gained prominence. This study compares the differences between regions and between crops in terms of yield response to water use and attempts to assess the way these relate to climate variables such as rainfall, temperature, humidity and sunshine. Cameroon's range of intertropical climates offers immense opportunity for agronomic studies that examine climate effects on crops, using weather station and satellite data. Given that crop water requirements and water productivity in rainfed and irrigated agriculture are essential indicators for assessing the effect of climate on crop production, the goal of this study is thus threefold: to evaluate water use efficiency and crop water productivity under prevailing rainfall patterns and traditional farm practices; to assess the impact of rainfall variability and climatic change on yield and production; and to define options for farm improvements and appropriate strategies related to crop choice, planting time, soil cultivation and crop cultivating practices, in order to optimize yields and reduce the risk of crop failure.

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 CROPWAT program of the FAO to assess potential and actual crop water use of maize, groundnuts and soybean in three key agro-ecological zones.

Case study areas and crops studied

The study was conducted in three districts representing three key zones of Cameroon's eight agro-ecological zones: Ambam, Bamenda and Garoua (Table 1). These study zones offer diverse temperature, rainfall, sunshine and wind speed data that make them suitable for examining the influence of these variables on cropping patterns and crop specific water requirements, and are important because they contribute a significant share of 25% to Cameroon's agricultural GDP. Three crops were selected for the study: maize, soybean and groundnuts.

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[1] This Policy Note is prepared by R Hassan based on Molua & Lambi (2006), Assessing the impact of climate on crop water use and crop water productivity: The CROPWAT analysis of three districts in Cameroon, *CEEPA Discussion Paper No. 37, CEEPA, University of Pretoria.*

The model and data

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 evapo-transpiration, 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 (ETa or actual crop water use), after having estimated the stress factor Ks from the ratio of actual to potential yield.

Table 1: Geographic description of study districts

Farming district	Location			Ecology	Soil type	Av. rainfall (mm)	Av. temperature
	Long.	Lat.	Alt.				
Ambam	11.27°E	2.34°N	602m	Humid moist forest	Vertisols	3500	25°C
Bamenda	10.15°E	5.97°N	1609m	High savanna	Ferralsols	2500	19.4°C
Garoua	13.38°E	9.33°N	244m	Sahel savanna	Ferruginous fluvisols	900	28°C

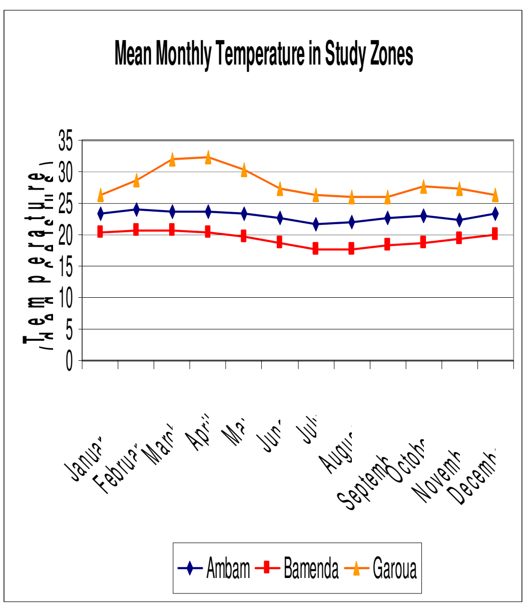

Figure 3: Mean monthly temperature distribution in the study zones

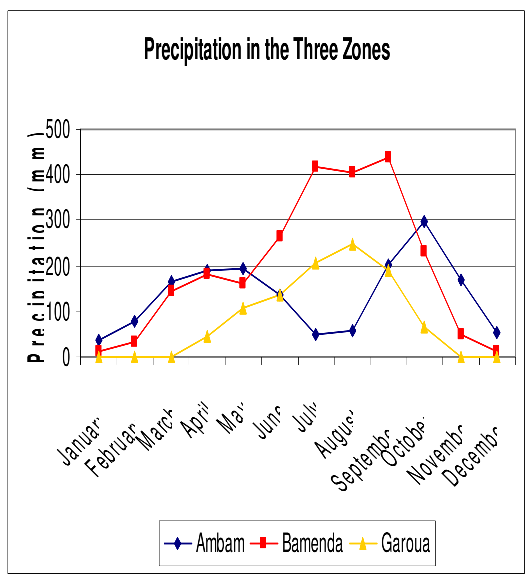

Figure 4: Mean monthly precipitation distribution in the study zones

The input data for the model are monthly climatic parameters including maximum and minimum temperature, humidity, sunshine and wind speed. CROPWAT calculates reference evaporation ETo and maximum crop evapotranspiration ETm from crop coefficient Kc. The water stress coefficient Ks further diminishes ETm to actual evapotranspiration ETa owing to lack of water. Ks is determined via a comparison between actual yields Ya and maximum yields Ym, using a yield response factor Ky.

Climatic and crop data for the CROPWAT model was obtained from multiple sources for the essential factors of mean maximum and mean minimum temperature (^oC); relative humidity (%/month), wind speed (km/day) and daily sunshine (hrs). Other data such as latitude, longitude, and altitude were incorporated into the model. Crop data variables such as cropping pattern, planted area and crop calendar were obtained from household field survey and from the Provincial Offices of the Ministry of Agriculture.

Simulating crop yield response to evapotranspiration

The study examined the crop water use and irrigation needs for the three crops in the three zones. Other interesting information obtained is the crop water requirements (CWR), the field water supply (FWS) and irrigation water requirements (IWR). The CWR, FWS and IWR for all crops are particularly high for Garoua. The high uptake of soil water by all crops to meet evaporative demand in Garoua implies that there is a high potential for crop water deficits in Garoua, which could reduce crop growth, thus affecting crop development and yields. This indicates the particularly high demand for soil moisture and need for irrigation scheduling for optimum water supply in the Garoua region.

Impacts of predicted climate change trends

The maize crop was selected to study the impact of climate change on crop water use. Outputs of three General Circulation Models (GCMs) were used to evaluate the impact on maize. The Genesis (GEN), HadCM2 and CSM models were employed. The modified climate data were entered into the CROPWAT model, and the reference evapotranspiration (ETo) figures, evapotranspiration of the maize crop (ETc) and moisture stress factor (Ks) obtained differed across the selected farming districts for the various climate scenarios.

The findings presented in Table 3 generally reveal that changes in temperature and CO_2 concentration lead to increased water requirements and uptake by the maize plant. However, the effects vary considerably from region to region. In a projected scenario of reduced rainfall and higher temperatures, such as in the Garoua District, these findings have profound implications for agriculture and food security.

Conclusions and policy implications

The findings of this study have some important messages for farmers, extension services and future studies. The study established that in the humid forest zones of Cameroon, with more than adequate rainfall, moisture stress is less significant. However, in the drier Sudano-Sahelian zone moisture stress is significant, particularly at the onset of the farming season. The heat stress brought on by higher temperatures compounds water stress. Water stress is brought on by increased crop needs for water (or high atmospheric demands for water because of high temperatures). So, since higher temperature increases the demand for water, crops in Garoua and across the northern region could be responding to water stress rather than to high temperature stress.

Table 2: Crop water use for maize, groundnuts and soybean in the study districts

Farming district	ETo (mm)	Kc	ETc (mm)	Ky	Ya (t)	Ym (t)	Ks	CWR (mm)	ETa (mm)	FWS (l/s/ha)	IWR
Maize											
Ambam	413.28	0.67	276.89	1.25	0.6	2	0.14	335.61	38.76	0.01	15.68
Bamenda	570.11	0.67	381.97	1.25	0.5	2	0.15	460.25	57.29	0.01	17.39
Garoua	890.12	0.67	596.38	1.25	0.7	2	0.13	723.79	77.53	0.37	432.95
Groundnuts											
Ambam	427.31	0.72	307.66	0.70	1.3	4	0.29	361.36	89.22	0.01	9.24
Bamenda	588.77	0.72	429.91	0.70	1.5	4	0.18	495.64	77.38	0.01	12.35
Garoua	919.89	0.72	662.32	0.70	0.9	4	0.33	778.77	218.56	0.38	464.25
Soybean											
Ambam	413.28	0.68	281.03	0.85	1.2	2.5	0.09	367.23	25.29	0.01	11.14
Bamenda	570.11	0.68	387.67	0.85	1.5	2.0	0.04	504.69	15.51	0.02	20.31
Garoua	890.12	0.68	605.28	0.85	0.8	1.5	0.08	792.05	48.42	0.43	501.05

Notes: ETo (reference crop evapotranspiration), ETc (evapotranspiration of the maize crop), Ky (yield reduction factor), Ya (actual yield of maize crop), Ym (maximum yield of maize crop), Ks (stress factor), CWR (crop water requirement), ETa (actual evapotranspiration), FWS (field water supply), IWR (irrigation water requirement).

Across Cameroon, there is variability in the amount of water typically available to the crop. In mid dry season in the south, Ambam for instance typically has 0.2m of plant-available water in the top 1.0m of soil. This assumes that crops have a 1.0m rooting depth and the water in the top 1.0m of soil is the water available to the crop. Some years, of course, both maize and soybeans may root deeper than 1.0m and on occasion the roots may not reach the 1.0m depth. But basically that is the rooting depth. About 0.2m of plant-available water typically available to the crop provides about one-third of the total requirement for the growing season. Across the region there is some variability in plant-available water. The water-holding field capacity of the soil is about 0.25m. ‘Water at the beginning of the farming year is somewhat of a crop insurance plan. The bank of water that is built up in the soils can carry a crop through a brief period of heat stress, or water stress, by providing moisture to the roots' (Weather Risk Management Association www.wrma.org/wrma/library/file775.pdf Accessed 14 August 2006).

In sum, therefore, water stress affects crop growth and productivity in many ways. Most of the responses have a negative effect on production, but crops have different and often complex mechanisms for reacting to shortages of water. Several crops and genotypes have developed different degrees of drought tolerance, drought resistance or compensatory growth to deal with periods of stress. Highest crop productivity is achieved for high yielding varieties with optimal water supply and high soil fertility levels. However, the same varieties are often highly sensitive to water stress and will give low yields or fail under conditions of even mild water stress during sensitive growth periods.

The results of this study therefore have important implications for Cameroon's current agrarian policy and for managers of Cameroon's agricultural sector. As discussed by the FAO (1995, section on defining the government's role and actions), these findings raise a number of generic policy questions particularly relevant to the introduction of new techniques for soil and crop water conservation. These are: (i) What should be the role of technical assistance in creating local awareness of opportunities for improved soil and crop water management? (ii) If it is important for farmers to have better weather forecasts, in what ways should meteorological services be strengthened? (iii) If new types of equipment or materials are needed for specific intervention, where would they come from, and at what cost? (iv) Might farmers require special once-off incentives or subsidies to allow them to initiate new practices for soil and crop moisture management? How would these be financed? How would continued dependence on subsidies be removed? (v) What would be the optimum means of providing land husbandry advice to farmers?

National policy can therefore have important positive effects on soil and crop water conservation. An appropriate policy environment and the provision of adequate support services will help farmers adopt appropriate soil and crop water conservation strategies. 'Incentives and support services must be stable and sustained. Arbitrary alterations by governments of policy or the support framework may inadvertently provoke altered farm level decisions, which in turn can encourage soil degrading practices that are antagonistic to optimal capture and use of rainfall' (FAO 1995, section on defining the government's role and actions).

Based on the findings of the research, the following recommendations are thus made:

1. To ease water constraints and enhance productivity, there is need to consider improving crop patterns and cultivate crops with lower water requirements.

2. There is need to improve irrigation efficiency by changing the traditional irrigation system to more efficient

systems such as drip irrigation and pipe irrigation.

3. There is need to mount an effort to integrate small farms into large units to increase the irrigation efficiency.

4. Various aspects of water resource management should be considered, such as supply, demand and construction management.

References

FAO (Food and Agriculture Organization), 1995. FAO Corporate Document Repository. Agricultural investment to promote improved capture and use of rainfall in dryland farming. FAO Investment Centre, Technical Paper No. 10. Technical Cooperation Department, FAO. http://www.fao.org/docrep/007/v9895e/v9895e00.htm Accessed 14 August 2006.

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*

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CEEPA
The Centre for Environmental Economics and Policy in Africa
University of Pretoria

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