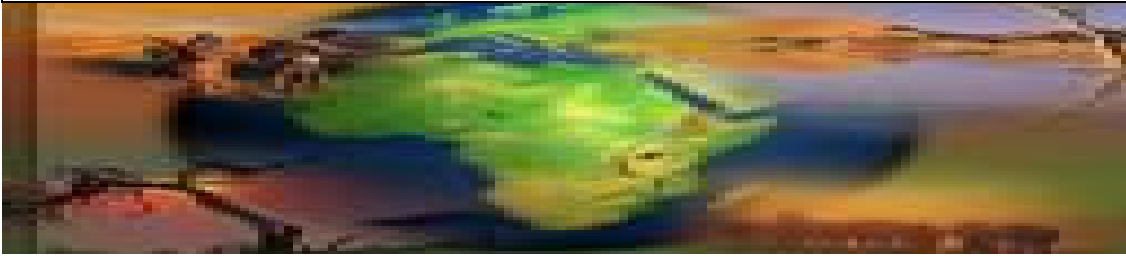


CLIMATE CHANGE AND AFRICAN AGRICULTURE

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Agriculture, climate and water resources in Zambia

Climate change and crop water use and productivity in Zambia¹

This study examined crop water use in two districts of Zambia.

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 selected cropping patterns. Cropping patterns included maize, groundnut and cotton in the Chipata district, and maize, sunflower and groundnut in the Chongwe district. Input data were obtained from FAO CLIMWAT, from the Ministry of Agriculture headquarters in Lusaka and from the Central Statistics Office in Lusaka, and from the district officials where feasible.

Zambia is a landlocked country occupying a near central position on the southern African subcontinent and covering an area of 752,620km². Although Zambia is tropical, the relatively high altitude of most parts of the country (between 900 and 1500m above sea level) permits the production of temperate crops and exotic breeds of livestock.

The country is also endowed with ample water resources comprising seven big lakes and four major rivers. The Zambian climate is favorable for agriculture production, with abundant arable land receiving about 650mm annually in the southern part of the country and 1800mm in the north. Groundwater resources are also abundant in the Congo/Zaire and Zambezi river basins. The combined irrigation potential is 523,000ha, of which only 46,400ha (9%) is currently being irrigated, mostly by commercial farmers cultivating sugar, wheat and plantation crops. The majority of agricultural production remains rainfed and based on small-scale, subsistence family farming systems (about 80% of all farmers), combined with extensive livestock production, with farm holdings of less than nine hectares. Production varies according to inter-annual

¹ This Policy Note is prepared by S Perret based on Kambikambi (2006), CropWat exercise report for Zambia, *CEEPA Discussion Paper No. 39*, CEEPA, University of Pretoria.

variations in rainfall. Land degradation further aggravates the situation.

Case study areas, farming systems and crops studied

Two out of Zambia's total of 72 districts were purposely selected as experimental units for this study. Chongwe (1280m above sea level) and Chipata (1032m) represent agro-ecozones I and II respectively. Both are important agricultural districts (see Figure 1).

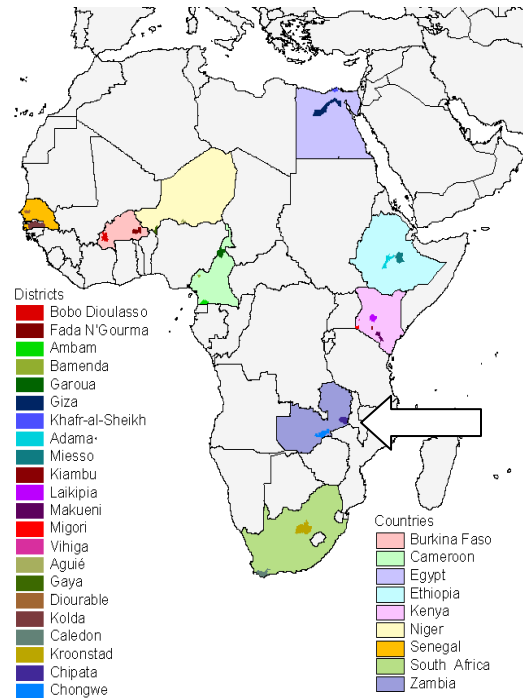
Zone I includes flood prone valleys and vast western semi-arid plains, and covers 42% of the country. It is dominated by subsistence food crop production of small grain (sorghum and pearl millet). Major constraints on agricultural production include low and unpredictable rainfall (mean annual precipitation of less than 800mm), recurrent floods, periodic droughts, and a lack of updated technical packages. High temperatures during the growing season limit crop options. These factors expose Zone I to a high risk of food insecurity.

Zone II includes most central and eastern provinces and covers 12% of the country. The area receives between 800 and 1000mm of rainfall annually. Most commercial and emerging farmers of Zambia are found in this zone, which has maize as the prevailing cash crop, and mechanization. Other cash crops include cotton, irrigated wheat and soybeans. High value cash crops include spices, flowers and horticultural products.

Zone III, although representing nearly half of the country, is not represented here. It features high rainfall (above 1200mm), and has leached and acidic soils with poor production potential.

Small-scale family farming prevails, combining maize, finger millet and cassava as food crops.

Figure 1: Selected districts for CROPWAT analysis in the project countries: Zambia



From the early 1990s onwards there has been a general decline in agricultural production in Zambia, mostly resulting from a decline in the total cultivated hectareage. Such decline can be ascribed to repeated droughts that have made farming unpredictable and risky and resulted in a loss of animals, including work oxen. Besides this, the total removal of all subsidies on agricultural inputs has forced smallholder farmers to give up on fertilization.

To provide a fairly representative model of cropping systems in both selected study areas, typical cropping patterns were selected for water use assessment, as suggested by district agricultural officials.

In Chongwe, a cropping pattern of 85% maize, 15% sunflower and 5% groundnuts was used. Planting dates of 15 December, 15 January and 1 December were used for the three crops respectively. For Chipata, the cropping pattern used was 80% maize, 15% groundnuts and 5% cotton. Planting dates for these crops were 15 November, 1 November and 15 October respectively. For both combinations, a medium soil was factored into the model.

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

For the study in Zambia, the input data for the model were monthly climatic parameters, including minimum and maximum temperature, humidity, sunshine and wind speed. Calculations of crop evapotranspiration were carried out with additional inputs of crop and

soil data. These datasets were obtained from FAO CLIMWAT. Monthly rainfall data was divided into a number of rainstorms each month, and cropping patterns consisted of the planting date, crop coefficient data (including Kc values, stage days, root depth, depletion fraction) and the area planted (0–100% of the total area). CROPWAT calculates reference evaporation ETo and maximum crop evapotranspiration ETm (or crop water requirement – CWR) from crop coefficient Kc. The water stress coefficient Ks further lowers 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.

Crop water use in Zambia

Table 1 shows the results obtained in both case study sites. It must be noted that in this study potential and actual yields and the impact of climate change scenarios thereon have not been investigated.

Table 1: Estimated crop water use as per typical cropping patterns in two selected zones of Zambia

	Chipata	Chongwe
ETo	850	950
ETm	474	450
Effective rainfall	603	547
Cumulated water deficit	3	111

Table 1 shows cumulated data that actually spread throughout the cropping calendar of the two selected cropping patterns, i.e. from early October to early May in Chipata, and from early October

to the end of May in Chongwe. Initial data resulted from calculations done on a 10-day basis.

In Zone I, represented by the Chipata site, cumulated optimal crop water requirements (represented by ET_m) remain well below the effective rainfall over the same period. This results in virtually no need for complementary water supply in the form of irrigation.

In Zone II, represented by the Chongwe site, although cumulated ET_m remains below the effective rainfall for the cropping season, detailed information reveals a cumulated deficit of 111mm, spreading throughout March and April, and peaking at 28mm during the first 10 days of April. This means that at best ET_a represents 75% of ET_m for that selected cropping pattern on average, resulting in decreased yields. The analysis as per 10-day periods indicates even more disturbing results since it reveals that, in spite of soil water stock, ET_a is virtually nil for the whole of April. For crops whose critical stages in terms of water use fall into that period (the maize flowering period for instance), such a deficit may result in a severe loss in yield.

Conclusions and policy implications

The results, although limited to two case study sites, and incomplete in terms of crop productivity, reveal contrasted situations. Zone II shows severe water deficit, hence stress, at certain periods of cropping calendars. Such a deficit may result in severe yield decrease for crops such as maize. Zone II hosts most of Zambia's commercial farming systems, and includes most of its irrigation. Since irrigation is still very limited in Zambia, further water resource and irrigation developments should be implemented in order to overcome water stress and risks.

Zone I is relatively well endowed with rainfall as compared to the needs of typical cropping sequences and patterns. However, observations show that land degradation is a widespread problem, owing to floods and extreme rainfall events which cause erosion in slope cultivation.

To determine the ultimate effects of climate change, further research should be done on the likely future extent and effects of land degradation, the quantification of rainfall variability, and the consequences of improved cultivation practices (anti-erosion measures).

Overall, the pattern of declining maize production in Zambia, especially among smallholder farmers, indicates that maize is no longer a suitable crop for this country's bio-climatic and socio-economic conditions. There is a trend towards cultivating the more profitable, drought resistant food crops such as sorghum, cassava, millet and tubers that require less chemical fertilizer. There have been considerable increases in the production of cassava, groundnuts and millet in the last decade. However, over 70% of poor households still grow maize as the major staple crop. Increasing use of fertilizer does lead to improved productivity for smallholders, but usage is still less than 15% nationally, with increasing prices making it difficult to afford on a commercial basis.

The results of this first phase of study may be used as an initial picture, to which climate change scenarios can be applied. For this purpose, the FAO has developed under this project a draft methodology that would allow CROPWAT to be used to analyze the effect of climate change on crop water requirements.

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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