CLIMATE CHANGE AND AFRICAN AGRICULTURE
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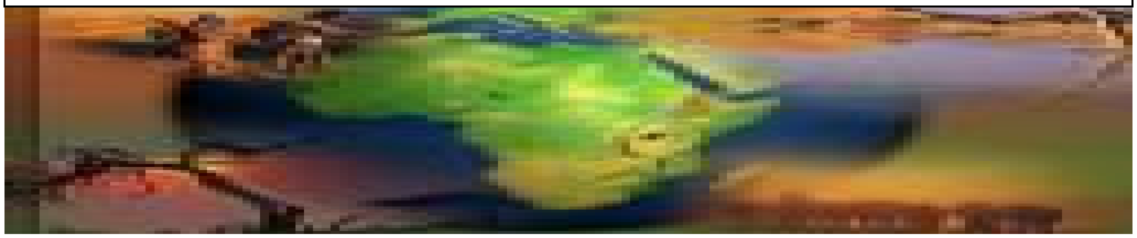

Climate change and crop water use and productivity in Ethiopia[1]

This study examined the impact of climate change on crop production in two districts in Ethiopia and also assessed adaptation measures in these districts. The research was implemented by a national team under the FAO leadership. It developed a unified approach to crop simulation modeling of the relationship between yield and evapotranspiration as the measure of water use by crops. The country team adapted the FAO's CROPWAT program to assess potential and actual crop water use by maize and sorghum in the Adama and Miesso districts. The simulation of yield reduction and estimation of crop use was based on ten-year crops and meteorological data using the model.

Case study areas, farming systems and crops studied

In Ethiopia rainfed agriculture is the backbone of the country's economy and rural livelihoods. Irrigation is currently applied to only 3% (160,000 hectares) of irrigable land. The dependency of most of the farmers on rainfed agriculture has made the country's agricultural economy extremely vulnerable to the adversities of weather and climate. Agriculture in the country is exposed to the effect of failure of rains or occurrence of successive dry spells during the growing season, which could lead to food shortage. Though food shortages resulting from adverse weather conditions are not new in this country, they have increased in severity and there have been shortages every two years since 1950. It is therefore important to have a good understanding of the potential impacts of predicted future climate trends to improve agricultural planning and productivity.

The selected study areas are representative of typical conditions in Ethiopia. Both districts reach 1300 to 1700m in altitude and have a semi-arid climate, with relatively lower altitude and drier conditions in Miesso. They display bimodal rainfall patterns with a mean annual rainfall of 740mm in Adama and 520mm in Miesso. Adama and Miesso are predominantly

[1] This Policy Note is prepared by S Perret based on Giorgis, Tadege & Tibebe (2006), Estimating crop water use and simulating yield reduction for maize and sorghum in Adama and Miesso districts using the CROPWAT model, *CEEPA Discussion Paper No. 31, CEEPA, University of Pretoria.*

categorized as 'sub-moist mountain and plateau, tepid and cool' and 'hot and warm sub-moist plain' agro-ecological zones, respectively (see Figure 1). Both districts are located in the central Oromiya Region.

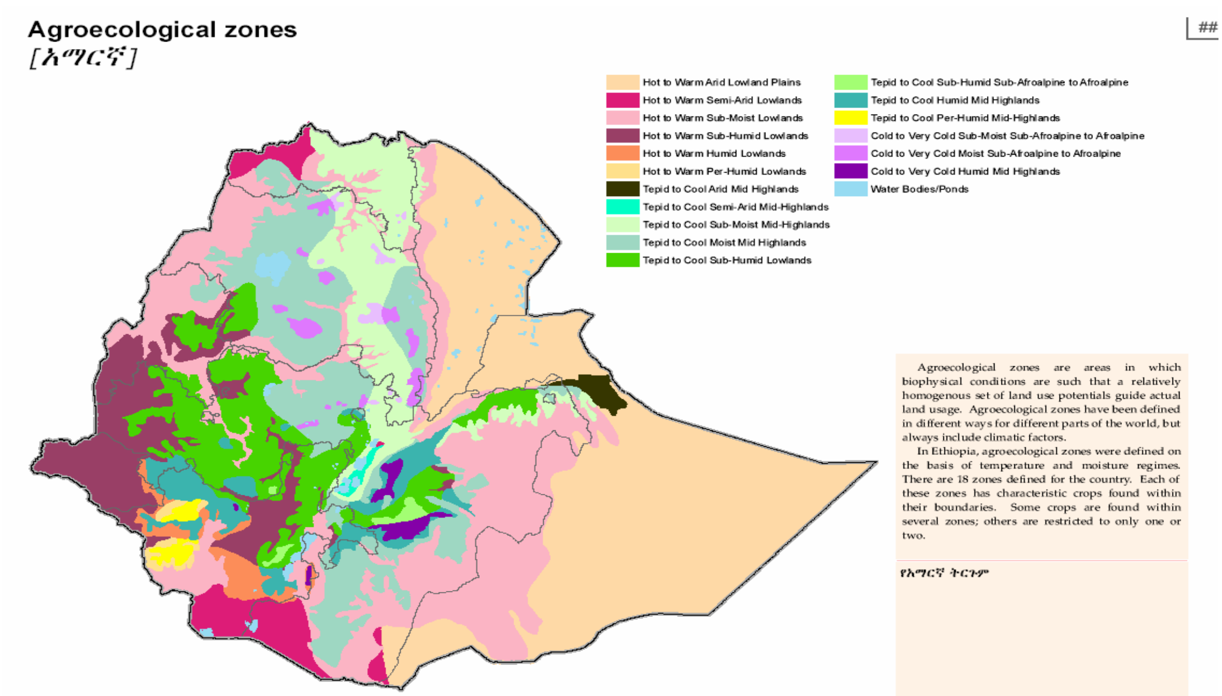

Figure 1: The agro-ecozones of Ethiopia

Crop production is the dominant agricultural practice in Adama and Miesso, where maize accounts for 30% and 24% of cultivable land, respectively. Sorghum is also an important crop and accounts for up to 66% of cultivable land in Miesso, being both a staple and a cash crop. Beans, teff, potatoes, wheat lentils and peas feature as other important crops in Adama, while sesame and chat are also grown in Miesso. In both districts there are two agricultural seasons, matching the two rainfall seasons, i.e. a short spring one, the *belg*, from March to May, and a longer summer one, the *kirmet*, from June to September. Depending on varieties, maize is planted between the end of April and the end of June in Adama, and during the second half of June in Miesso. Sorghum is planted early in June in Adama, and later in June in Miesso. Harvesting takes place between the end of September and early October.

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 the efficiency of irrigation practices. It uses procedures for predicting yields when all the climate, soil and crop parameters are known. This approach makes it possible to estimate the actual evapotranspiration (ETa or actual crop water use), after having estimated the stress factor Ks from the ratio of actual to potential yield.

In Ethiopia, 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 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 and productivity in Ethiopia

As shown in Tables 1 and 2, the water used in both these districts for maize and sorghum production is far less than actually needed, with a pronounced negative effects on yields, especially in the drier district of Miesso. Actual yields reach only 40% and 33% of maximum yields for maize and sorghum respectively in Miesso. Actual yields reach 64% and 60% of maximum yields for maize and sorghum respectively in Adama.

Table 1: Estimated values of crop water use (ET) and production (Y) in Adama district

Crop	ETm	ETa	Ym	Ya
Maize	532	383	3500	2257
Sorghum	469	257	4500	2671

Ya is actual yield and Ym is maximum yield in kg/ha

ETm is maximum & ETa is actual evapotranspiration in mm

Table 2: Estimated values of crop water use (ET) and production (Y) in Miesso district

Crop	ETm	ETa	Ym	Ya
Maize	375	199	3500	1422
Sorghum	353	92	4500	1500

Ya is actual yield and Ym is maximum yield in kg/ha

ETm is maximum & ETa is actual evapotranspiration in mm

As shown in Table 3, crop water productivity values for sorghum and maize in the selected districts are in line with the ranges published by the FAO and elsewhere. These values are slightly high for maize, especially in Adama. Although the actual reasons for these high figures are not known, they are not necessarily due to water use, and may be due to the varieties used. CWP is markedly lower in Miesso, owing to drier conditions and lower crop water use, which ultimately affect yields, especially for sorghum.

Table 3: Crop water productivity (CWP) of the maize and sorghum in selected districts

Crop	CWP	CWP range published in FAO and other
Sorghum (Miesso)	1.63	0.6 – 1.0
Sorghum (Adama)	1.04	0.6 – 1.0
Maize (Miesso)	0.71	0.8 – 1.6
Maize (Adama)	0.59	0.8 – 1.6

All figures in kg/m^3

Conclusions and implications

The study results give realistic values for maize and sorghum evapotranspiration and actual yield. The crop water response analyses show markedly different results between the two districts. They also show that the gap remains wide between actual and potential yield and actual and maximum evapotranspiration, especially in drier conditions for rainfed crops. However, rainfed maize and sorghum seem to be performing better in terms of crop water use in the sub-humid climate of Adama than in the semi-arid climatic conditions of Miesso, since Adama has better rainfall. This corroborates the well-known fact that water is among the main limiting factors in most African farming systems and therefore irrigation could play an important role in agricultural development.

The average values for crop water productivity (CWP) for these crops do not exactly match the commonly published ranges. As expected, sorghum appears to be the most water efficient crop grown in the selected districts and performs especially well in the dry conditions of Miesso, with very low actual evapotranspiration and still reasonable actual yields. Maize is a more water demanding and stress sensitive crop. From the results observed from Adama and Miesso, maize water productivity appears to be even poorer than usual standards. This might well be due to a varietal problem, or to crop management issues. In any case, maize should be grown only where good availability of water can be guaranteed. It should therefore be grown under irrigation or in rainfed areas where rainfall is reliable and the crop needs can be adequately satisfied.

In response to this situation, various adaptive measures have been undertaken in the selected districts as well as all over the country. Use of supplementary irrigation (small scale irrigation with tanks, water harvesting), mulching and the application of soil water conservation techniques, alternative crop management features (adapted planting densities, timing of operations, conservation tillage, intercropping) are being applied and should be further encouraged.

Although Ethiopia has 3.5 million hectares of potentially irrigable land, yet actual irrigated land covers only 160,000 hectares. The government is currently responding to the need for a shift away from mere rainfed production. For example, many small water tanks are being constructed in the study districts. Besides this, efforts are made to rationalize and increase the viability of current irrigation schemes. However, climate change effects and the current low performance of the prevailing rainfed agriculture necessitate accelerated measures and efforts, especially in view of the ever-present concern about rain failure and dry spells resulting in food shortages.

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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