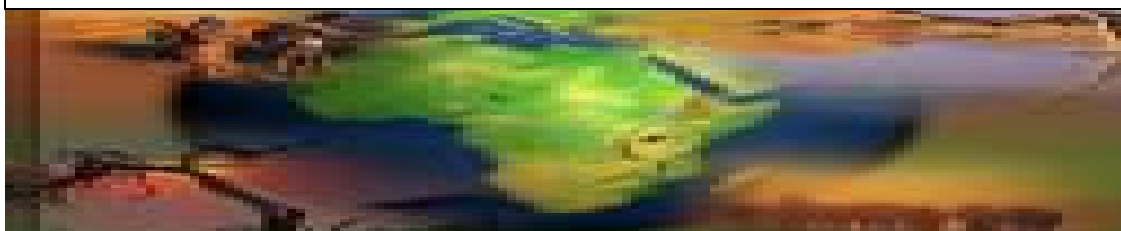


## CLIMATE CHANGE AND AFRICAN AGRICULTURE

*Policy Note No. 35, August 2006, CEEPA*



### **Climate change and crop water use and productivity in Kenya<sup>1</sup>**

This study examined the impact of climate change on water use and productivity of selected crops in six districts in Kenya. It also analyzed and evaluated strategies for adapting to climate change so as to mitigate its negative effects on agriculture in Kenya.

### **Agriculture and water availability in Kenya**

Agriculture is very important in Kenya, as 75% of its population depends on it for food and income and the sector contributes 26% to the Gross Domestic Product and 60% to foreign exchange earnings. However, only about one-third of the total land area of Kenya is agriculturally productive, including the highlands, coastal plains and the lake region. The other two-thirds have low, unreliable and poorly distributed rainfall.

83% of the land in Kenya is actually classified as arid to semi-arid, with the rest having a medium to high productive potential. The country has climatic and ecological extremes, with altitudes varying from sea level to over 5000m in the highlands. The mean annual rainfall ranges from less than 250mm in semi-arid and arid areas to more than 2000mm in high potential areas. Even though certain areas of Kenya endure arid and semi-arid conditions, most cropping systems are rainfed, and irrigation development remains all the more limited.

### **Case study areas, farming systems and crops**

Such diversity in conditions justified a wide selection of crops for assessment, including banana, beans, maize, potatoes, cowpeas, pigeon peas, sweet potatoes, groundnuts, sorghum, sugar cane, millet and wheat. These crops are of utmost importance in Kenya, in economic and food-security terms. They represent different agro-ecological zones, growing seasons and water needs.

The evaluation was carried out in six agricultural districts, Kiambu, Makueni, Kwale, Laikipia, Vihiga and Migori, which are distributed across six provinces of Kenya: Central, Eastern, Coast, Rift Valley, Western and Nyanza respectively. These districts were

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<sup>1</sup> This Policy Note is prepared by S Perret based on FKK Karanja (2006), CROPWAT model analysis of crop water use in six districts in Kenya, *CEEPA Discussion Paper No. 35*, CEEPA, University of Pretoria.

selected to reflect the diversity of the country's agro-ecological zones (see Figure 1). Owing to that diversity, not all selected crops are grown in one given selected district. This study assessed five main crops within each district.

Owing to great variations in altitude within any given district, rainfall patterns also vary immensely. In Kiambu, Makueni, Kwale, Laikipia, Vihiga and Migori, mean annual rainfall range between 850 and 2400mm, 200 and 1200mm, 450 and 1400mm, 400 and 750mm, 1800 and 2000mm, and 700 and 1800mm respectively. Such wide ranges and sometimes high figures at the district level obscure the fact that low rainfall remains common, and most districts (except Vihiga) include dry areas. Makueni especially, and to a lesser extent Kwale and Laikipia, include arid to semi-arid areas.

In all these districts, subsistence agriculture and food crops prevail, although surpluses may be marketed and even exported, and cash crops and commodity crops such as tea, coffee, horticultural crops, tobacco, cotton, sugar cane and the like may be grown wherever conditions allow.

### **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

rained 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 allows estimation of actual evapotranspiration (ET<sub>a</sub> or actual crop water use), after having estimated the water stress factor K<sub>s</sub> from the ratio of actual to potential yield.

The input data for the model are monthly climatic parameters, including maximum and minimum temperature, humidity, sunshine and wind speed. Crop parameters include K<sub>s</sub>, length of the growing season, critical depletion level and yield response factor K<sub>y</sub>. CROPWAT calculates reference evaporation ET<sub>o</sub> and maximum crop evapotranspiration ET<sub>m</sub> from crop coefficient K<sub>c</sub>. The water stress coefficient K<sub>s</sub> further lowers ET<sub>m</sub> to actual evapo-transpiration ET<sub>a</sub> owing to lack of water. K<sub>s</sub> is determined via a comparison between actual yields Y<sub>a</sub> and maximum yields Y<sub>m</sub>, using a yield response factor K<sub>y</sub>.

Climate change scenarios for each site were created by combining the output of two equilibrium 2xCO<sub>2</sub> General Circulation Models (GCMs) with the daily climate data for each site.

The outputs of these two GCMs (CCCM and GFDL3 models) were used to evaluate the impact of climate change on the main Kenyan crops. The modified climate data were incorporated into the CROPWAT model and used to evaluate the potential impact of climate change on water needs in Kenya.

### **Assessment of the impact of climate change on crop water use and productivity in Kenya**

The results obtained for beans and maize crops are discussed here since these are two major crops in Kenya, both being grown in all the six selected districts (see Table 1 with maize as an example).

Under current climate conditions, the reference evapotranspiration (ET<sub>o</sub>) for maize varies greatly across the districts covered, from 476mm in Laikipia to 663mm in Kwale. It also varies for beans, from 494mm in Migori to 365mm in Laikipia.

The crop water requirement (ET<sub>m</sub>) also varies a lot. For maize it ranges from 109mm in Makueni to 211mm in Migori, and for beans from 79mm in Makueni to 218mm in Migori. All these data spot Makueni as a problematic district for satisfying crop water needs. This also applies to Kwale to a lesser extent. Even though climatic water demand ET<sub>m</sub> remains reasonable in these areas, the ET<sub>a</sub> is far less than the ET<sub>m</sub> because of erratic and low water supply, resulting in high water stress, and lower yields.

Other crops were also assessed. Overall, the study shows that perennial crops (banana, mango, sugar cane) have much higher amounts of evapotranspiration, hence more sensitivity to lower water supply.

The results of the CROPWAT analysis under different climate change scenarios for the six districts and for three selected key crops are extremely rich and informative. Table 2 presents some findings for a selection of crops based on their regional importance, namely beans, maize and banana.

The findings show that the values of reference crop evapotranspiration (ET<sub>o</sub>),

crop evapotranspiration (ET<sub>m</sub>), and actual crop evapotranspiration (ET<sub>a</sub>) increased for all the three crops under the climate change scenarios that were assessed on the basis of temperature. It is readily seen that the higher the projected temperature rise, the higher the increase in the above parameters. Subsequently, irrigation water requirements also markedly increase. Since the difference between ET<sub>m</sub> and ET<sub>a</sub> increases, it can be readily deduced that yields would decrease in the absence of complementary supply under climate change conditions.

Rainfall scenarios did not show any impact on these parameters within each temperature scenario considered. This fact is clearly demonstrated for all the crops.

Overall, the results show that climate change (increasing temperatures) increases the ET<sub>m</sub> of all crops selected, by about 10 to 11% in all districts, except for Vihiga (about 8 to 9%) and Migori (about 5%). The changes in crop water use from the output of the CCCM scenario were lower than those from the GFDL3 for all the districts studied.

## **Conclusions and policy implications**

The CROPWAT analysis for Kenya yielded very interesting results for the patterns of crop water requirements for the dominant crop types across six districts of Kenya. From this investigation, it can be seen that, for a given crop type, crop water requirements are location specific owing to the marked variability in the agro-ecological characteristics of the study district. However, in spite of seemingly plentiful rainfall, reliable water supply remains

the exception, and all districts (except Vihiga) include dry areas.

Perennial crops (banana, mango and sugar cane) had higher amounts of crop evapotranspiration than the annual crops. Of the annual crops, beans had the lowest amount, probably because of this crop's relatively short growing period.

Agriculture is still a key sector in the economy of Kenya. The sector's contribution to real GDP, although it has seen some decline over the years, is still relatively higher than other sectors and remain the driving force for economic growth, employment generation and foreign exchange earnings.

Since 1996, agricultural production has been declining, except for the horticultural sector, which requires large quantities of irrigation water, and which has expanded by 48.8%.

Maize, mostly rainfed, the staple food for most Kenyans, fell from 27.3 million bags in 1998 to 25.0 million bags in 1999 and 73.5 thousand tons had to be imported. In the same period, wheat fell from 177.1 to 55.2 thousand tons.

In view of potential further decrease in yields due to climate change, such trends are all the more disturbing. In a context of relative scarcity of good arable land in Kenya, and underdeveloped irrigation, intensification and increased productivity of production factors, including land and water, are required.

Structural and policy-related reasons for the current plight of agricultural production in Kenya should be further investigated, in order to prompt

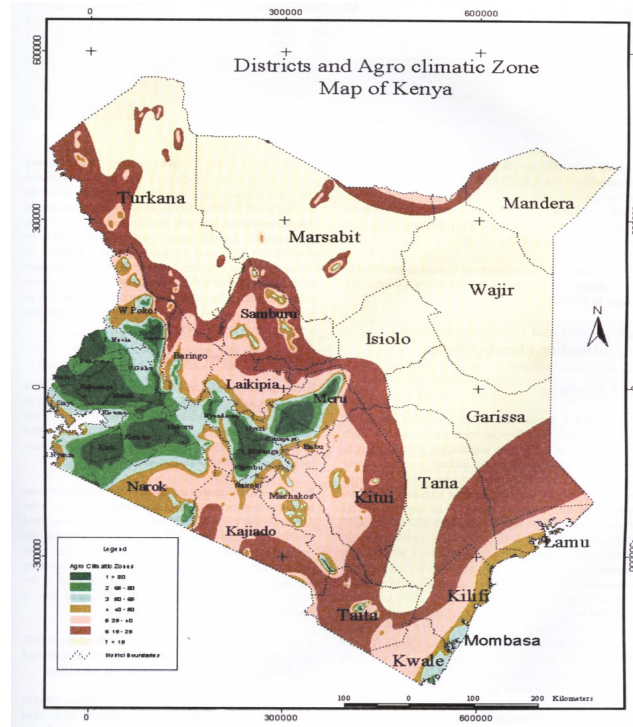
integrated policy responses that should probably include important irrigation development wherever possible.

Certain areas of Kenya are still well supplied with water. Such assets call for integrated water management at national level in order to overcome shortages in certain areas, and to support agricultural uses, especially in view of climate change threats.

The information obtained from this research enhances understanding of crop water requirements, which will consequently help improve the productivity of both food and cash crops. The much longed-for attainment of stability in food security, reduction in poverty and general enhancement of agro-ecosystem productivity which are all Kenya's concern, may be achieved through policies based on these findings.

These findings may also help achieve the potential for increased agricultural production in the arid and semi-arid areas of the country. There has been a growing need to quantify water use by various consumers with a view to apportioning the available water resources for use by the competing socio-economic sectors of the country: agricultural, industrial and domestic. This calls for the formulation of appropriate policies to guide the use of the available water resources.

**Figure 1: Map of agro-ecological zones and provinces in Kenya**



**Table 1: Crop water use for maize in selected study districts of Kenya**

District	ET <sub>o</sub> (mm)	ET <sub>m</sub> (mm)	Ya	Y <sub>m</sub>	K <sub>s</sub>	ET <sub>a</sub> (mm)
Kiambu	492.4	329.9	2270	9000	0.402	132.6
Makueni	565.0	378.6	978	9000	0.287	108.6
Vihiga	495.0	331.7	2407	9000	0.414	137.3
Kwale	662.8	444.0	1137	9000	0.301	133.7
Migori	588.3	394.1	3781	9000	0.536	211.3
Laikipia	476.2	319.0	2281	9000	0.403	128.5

**Table 2: Impact of climate change on crop water use in Kwale district**

Crop	Climate change scenario	ET <sub>o</sub> (mm)	ET <sub>m</sub> (mm)	Y <sub>a</sub>	Y <sub>m</sub>	ET <sub>a</sub> (mm)	% change in crop water use	IWR
Beans	Original	509	321	471	2500	94.4		19
	CCCM_LR	559	352	471	2500	103.7	9.8	29.3
	CCCM_HR	559	352	471	2500	103.7	9.8	21.5
	GFDL3_LR	566	357	471	2500	105.1	11.3	30.1
	GFDL3_HR	566	357	471	2500	105.1	11.3	22.1
Maize	Original	663	444	1137	9000	133.7		61.3
	CCCM_LR	727	487	1137	9000	146.6	9.7	93.1
	CCCM_HR	727	487	1137	9000	146.6	9.7	72.8
	GFDL3_LR	735	493	1137	9000	148.3	10.9	95.1
	GFDL3_HR	735	493	1137	9000	148.3	10.9	74.7
Banana	Original	1309	1139	20000	60000	576.6		61.3
	CCCM_LR	1423	1234	20000	60000	626.5	8.7	57.7
	CCCM_HR	1423	1238	20000	60000	626.5	8.7	45.5
	GFDL3_LR	1440	1252	20000	60000	633.7	9.9	91.6
	GFDL3_HR	1440	1251.9	20000	60000	633.7	9.9	46.4

*Notes:* ET<sub>o</sub> (reference crop evapotranspiration), ET<sub>m</sub> (maximum crop ET), K<sub>y</sub> (yield reduction factor), Y<sub>a</sub> (actual yield), Y<sub>m</sub> (maximum yield), K<sub>s</sub> (water stress coefficient), ET<sub>a</sub> (ET<sub>crop</sub>actual, calculated as K<sub>s</sub>\*ET<sub>c</sub>). IWR: Irrigation water requirements  
 CCCM (Canadian Climate Change Model), GFD3 (Geophysical Fluid Dynamics Laboratory, GFDL R-30).

*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](http://www.ceepa.co.za/discussionp2006.html)) and can also be accessed directly through the project link ([www.ceepa.co.za/Climange\\_Change/project.html](http://www.ceepa.co.za/Climange_Change/project.html))

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