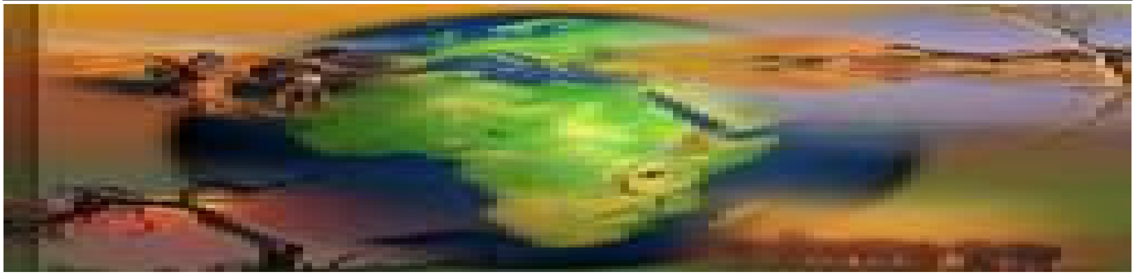
CLIMATE CHANGE AND AFRICAN AGRICULTURE
Policy Note No. 29, August 2006, CEEPA



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

The core research activity of this GEF/World Bank project adopts the cross-section (Ricardian) approach to assess the economic impacts of climate change on African agriculture. The cross-sectional approach uses statistical analyses of data across geographic areas to separate the effect of climate factors from that of other factors explaining production differences across regions, and uses the estimated statistical relationships to predict future impacts of climate change. To further increase the understanding of climate effects on crop agriculture, a parallel analysis of crop yield response and water use employing crop growth simulation models and climate scenario analyses was undertaken. The FAO CROPWAT model was used for this purpose.

This study examined the impact of climate change on selected crop water use and production in three districts (governorates) in Egypt. It also analyzed and evaluated strategies for adapting to climate change so as to mitigate its negative effects on agriculture in Egypt.

The research implemented by a national team under the FAO leadership 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 the potential and actual crop water use of wheat, maize and cotton, since these crops represent different growing seasons and water needs. The evaluation was carried out in the three main agricultural regions of Egypt: the Delta (Lower Egypt), represented by the Kafr El-Sheikh Governorate; Middle Egypt, represented by the Giza Governorate; and Upper Egypt, represented by the Sohag Governorate.

Case study areas, farming systems and crops studied

Egypt is virtually rainless. The inhabited area does not exceed 3.5% of the total area and is confined to the narrow strip which borders the main course of the River Nile from Aswan in the South to

[1] This Policy Note is prepared by S Perret based on Eid, El Marsafawy & Ouda (2006), Assessing the impact of climate on crop water needs in Egypt: The CROPWAT analysis of three districts in Egypt, *CEEPA Discussion Paper No. 29, CEEPA, University of Pretoria.*

Cairo in the North, plus the Nile Delta area. Agricultural land in Egypt is determined by climate and water availability and follows the same spatial pattern, with irrigation being predominant. The country's per capita share of water is now below 1000 cubic meters per year, and is expected to fall to less than 500 before 2030 when the population reaches 100 million. Such a state of affairs requires solutions and puts tremendous pressure on irrigated agriculture, as the main water-using sector (85% of all extractions).

The major crops in Egypt are wheat (used as a staple food crop), maize (used primarily as coarse grain for animal feed), clover, cotton, rice (grown only in the Delta and the Fayoum Governorate in Middle Egypt), sugar cane (grown in Upper and Middle Egypt), fava beans, sorghum and soybeans. The national wheat and maize production do not meet the current demand for these crops, and each year additional amounts have to be imported – up to 50% of total consumption in the case of wheat.

The study sites were Sakha (in Kafr El-Sheikh, in the north of the Delta); Giza (in Giza, near Cairo, Middle Egypt); and Shandaweel (in Sohag, Upper Egypt). These were selected to represent the main agro-ecological zones and the old lands in Egypt (Nile Valley and Delta) (see Figure 1). The total average annual precipitation for the sites are 62mm, 17mm, and 0mm respectively. Reference evapo-transpiration can be as high as 8mm per day in summer in Shandaweel.

In Kafr El-Sheikh the main winter crops are wheat and sugar beet, which occupy about 33% and 18% respectively of the total area in winter. Of the summer crops, maize occupies the largest area (about 11%). Cotton occupied about 93% of the total area of perennial crops in 2001.

In Giza wheat and tomatoes occupy the largest area of winter crops, about 21% and 9% respectively. In summer, maize and tomatoes occupy about 47% and 9% respectively. Citrus, mango, grapes and date are the main perennial crops in Giza, at about 20%, 14%, 13% and 11% respectively.

In Sohag in winter about 66% of the area is occupied by wheat. In summer, sorghum and maize occupy about 46% and 45% respectively. Sugar cane and cotton are the main perennial crops, occupying about 56% and 24% respectively.

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 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.

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.

The normal data for the study sites (average of 30 years) were used in calculating ETo and ETcrop. Data of actual yield and maximum yield were obtained from Agricultural Economic Research Institute Bulletins to obtain the water stress coefficient (Ks).

Climate change scenarios for each site were created by combining the output of three equilibrium 2xCO_2 General Circulation Models (GCMs) with the daily climate data for each site. The three GCMs used in this study to create the climate change scenarios are at the high end of the IPCC range (1.5^{o}C to 3.5^{o}C).

Outputs of three GCMs were used to evaluate the impact of climate change on the main Egyptian 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 Egypt. Wheat, maize and cotton were selected for the study since they represent different growing seasons and water needs.

Assessing the impact of climate change on crop water use and productivity in Egypt

Table 1 provides the complete results of the analyses done for wheat. Under current climate conditions, the reference evapotranspiration (ETo) is 426mm, 547mm and 632mm for Sakha, Giza and Shandaweel respectively. Shandaweel's ETo is 48% more than Sakha's and 16% more than Giza's. The crop water requirements (ETm) for wheat are 351mm, 453mm and 519mm for the three regions respectively. ETc equals ETm because the water supply is sufficient. ETa is 288mm, 365mm and 426mm, respectively.

Under climate change conditions, the findings recorded in Table 1 indicate that the smallest decrease in ET was found under the GFD3 scenario. In general, the three GCMs were found to have approximately the same efficiency in predicting wheat ET. Increasing temperature would increase the wheat ET by 10.8%, 11.4% and 10.3% for Sakha, Giza and Shandaweel respectively, in comparison with current climate conditions. Few yield reductions were obtained under increasing temperature at Shandaweel region only.

The same approach was applied to the maize crop. ETo under current climate conditions is 746mm, 900mm and 1009mm for Sakha, Giza and Shandaweel respectively. Shandaweel's ETo is 35% higher than Sakha's and 12% higher than Giza's. The maize crop water requirement (ETm) is 611mm, 730mm and 817mm for the three regions respectively. The ETc is less than the ETm because the water supply is insufficient as a result of the long intervals between irrigations. The actual crop evapotranspiration (ETa) at Sakha, Giza and Shandaweel is 521mm, 620mm and 731 mm respectively. The total yield reduction for the three regions under current climate conditions is 1.9%, 2.1% and 0.7% respectively as a result of increasing the intervals between irrigations.

Increasing the temperature increases the maize ET by 7.9%, 7.8% and 8% for Sakha, Giza and Shandaweel respectively compared with maize ET under current climate conditions. Increasing temperature reduces the yields further, particularly at the third growth stage. Generally, the effect of climate change on the maize crop is to further increase ET and further decrease yields.

Cotton is not grown in the Giza region. ETo under current climate conditions is 1009mm and 1383 mm for Sakha and Shandaweel, respectively. Cotton crop water requirements (ETm) at Sakha and Shandaweel regions are 931mm and 1260 mm respectively. The ETc is less than the ETm because the water supply is insufficient as a result of long intervals between irrigations. ETa is 532mm for Sakha and 1040mm for Shandaweel. Few reductions in yield were obtained under current conditions as a result of increasing the intervals between.

Climate change could increase the crop evapotranspiration by about 8.4% for Sakha and 7.6% for Shandaweel compared with the cotton ET under current climate conditions. Increasing the temperature leads to further reductions in yields in the two regions, particularly at the third growth stage Generally, the effect on the cotton crop is to increase the ET and reduce the yields.

Conclusions and policy implications

Previous research on the potential impact of climate change on ET and the yields of some field crops in Egypt suggests that climate change could decrease national production of many crops (ranging from -11% for rice to -28% for soybean) by the year 2050 compared with their production under current conditions. Yield of cotton would be increased in comparison with current climate conditions. At the same time, water needs for summer crops will be increased up to 8% for maize and up to 16% for rice by the year 2050 compared to their current water needs.

With the population increasing, serious water shortages are developing and dependence on this limited resource has become a critical constraint on further agricultural progress, which threatens to slow down development, endanger food supplies and aggravate rural poverty. The cultivated and cropped areas in Egypt have been increasing over the past few years and will continue increasing because of the government policy of adding more agricultural lands. The great challenge for the coming decades will therefore be the task of increasing water productivity, i.e. increasing food production while using less water, especially in arid and semi-arid regions.

Future strategies for adapting to climate change may involve the development of new, more heat-tolerant cultivars, and new crops (more cotton cultivation as an alternative to some maize and more winter legumes instead of some wheat). Changing the cotton crop practices (optimum sowing date, cultivars, water amount and plant density) could allow farmers to benefit from climate change, increasing cotton productivity by about 29%.

Suitable adaptations are modifying the cropping pattern (i.e. partly growing cotton after wheat in the same year and on the same land); reducing or retaining the current area under cultivation for some high water consumer crops (i.e. sugar cane and rice); and changing practices (using optimum sowing dates, more water, more nitrogen, and suitable cultivars for the particular agro-climatological region).

It can be concluded that a strategy that includes transition to more cotton appears to be well supported on the basis of economics, but some caution should be exercised. All our information indicates that under climate change growing incrementally more cotton could have the following strong economic benefits.

First, cotton productivity may not only increase relative to other major crops, but it may increase absolutely too. Second, cotton prices are very strong and it appears possible that they will remain strong in a hotter future climate, since cotton is one of the best textiles for use in hot environments. Finally, cotton production also provides more jobs, both in the agricultural sector and in the textiles industry that can expand with cotton growth.

In this case, Egypt may be paying very heavily for food security, given that it appears to be holding back on cotton production so that more wheat can be grown domestically. Apparently some have been arguing in favor of more cotton even today. Looking into a hotter future, the arguments for more cotton may be enhanced: wheat prices may decline on a global basis, whereas income from cotton may increase.

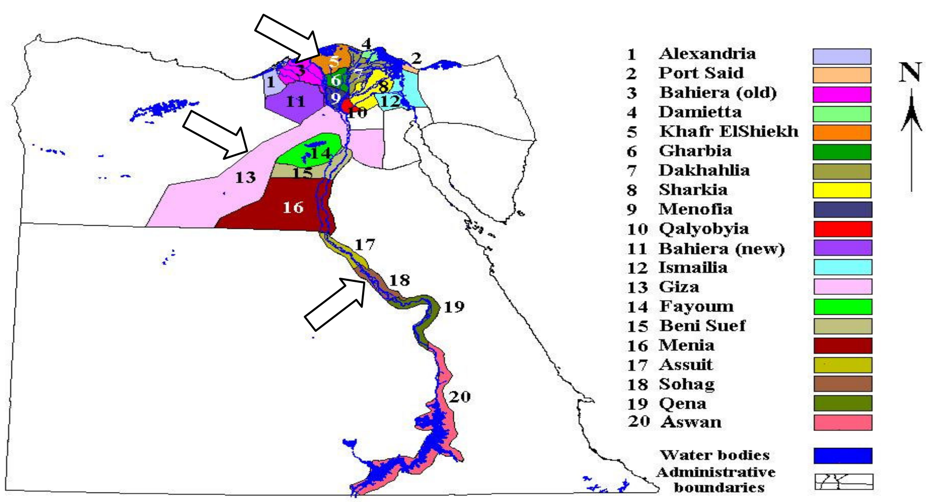


Figure 1: Map of governorates in the agro-ecological zones in Egypt: Location of selected study areas

Table 1: Simulated wheat ET under baseline climate (current climate) and GCM climate change scenarios in Sakha, Giza and Shandaweel regions

Site		ETo mm	ETm mm	ETc mm	Ya t/ fed	Ym t/ fed	ETa mm	Yield reduction (%) Stage # 1	Stage # 2	Stage # 3	Stage # 4	Total yield reduction (%)	Change % of wheat ET due to climate change
Sakha	Current climate	426	351	351	2.3	2.8	288	0.0	0.0	0.0	0.0	0.0	…
Giza	Current climate	547	453	453	2.5	3.1	365	0.0	0.0	0.0	0.0	0.0	…
Shandaweel	Current climate	632	519	519	2.3	2.8	426	0.0	0.0	0.0	0.0	0.0	…
Sakha	CCCM	473	390	390	2.3	2.8	320	0.0	0.0	0.0	0.0	0.0	10.8
	GFD3	470	387	387	2.3	2.8	318	0.0	0.0	0.0	0.0	0.0	
	GF01	474	390	390	2.3	2.8	320	0.0	0.0	0.0	0.0	0.0	
Average		472	389	389	2.3	2.8	320	0.0	0.0	0.0	0.0	0.0	
Giza	CCCM	615	509	509	2.5	3.1	410	0.0	0.0	0.0	0.0	0.0	11.4
	GFD3	606	501	501	2.5	3.1	404	0.0	0.0	0.0	0.0	0.0	
	GF01	609	504	504	2.5	3.1	406	0.0	0.0	0.0	0.0	0.0	
Average		610	505	505	2.5	3.1	407	0.0	0.0	0.0	0.0	0.0	
Shandaweel	CCCM	716	589	584	2.3	2.8	480	0.0	0.0	0.4	0.8	0.5	10.3
	GFD3	689	567	564	2.3	2.8	463	0.0	0.0	0.3	0.5	0.4	
	GF01	697	572	569	2.3	2.8	467	0.0	0.0	0.3	0.6	0.4	
Average		701	576	572	2.3	2.8	470	0.0	0.0	0.3	0.6	0.4	

Notes: ETo (reference crop evapotranspiration), ETm (maximum crop ET), ETc (crop evapotranspiration), Ky (yield reduction factor), Ya (actual yield),
Ym (maximum yield), Ks (water stress coefficient), ETactual (ETcropactual, calculated as Ks*ETc).
CCCM (Canadian Climate Change Model), GFD3 (Geophysical Fluid Dynamics Laboratory, GFDL R-30) and GF01 (GFDL 1%/yr transient).

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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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.

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