CLIMATE CHANGE AND AFRICAN AGRICULTURE
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Assessing the economic impacts of climate change on agriculture in Egypt[1]

This study uses a cross-sectional approach to measure the relationship between net revenue from growing crops and climate in Egypt by correlating variations in key climate attributes and corresponding variations in net revenue observed across a wide spatial spread. In total 900 households were interviewed. Besides climate attributes, this method also controls for the effects of variations in other determinants of crop productivity such as water flows, soils and socio-economic factors on net revenue. Cross-sectional observations across various climates can reveal the climate sensitivity of farms. The advantage of this empirical approach is that it does not only capture the direct effect of climate on productivity but also reflects farmers' adaptation to local climate. This farmer behavior is important as it mitigates problems associated with deviations from optimal environmental conditions. Analyses that do not include adaptation (such as the early agronomic studies) overestimate the damages associated with any deviation from the optimum. However, while the Ricardian model takes into account the costs associated with various adaptation alternatives, it suffers some limitations.

Net farm revenue in Egypt

In Egypt, 99.8% of cropland is irrigated. The largest consumers of irrigation water are rice and sugar cane because they have high water requirements and occupy a considerable area. Major crops in Egypt include wheat (used as a staple food crop), maize (used primarily as coarse grain for animal feed), clover, cotton, rice (which grows only in the Delta and the Fayoum Governorate in Middle Egypt), sugar cane (which grows in Upper and Middle Egypt), fava beans, sorghum and soybeans. Crop production contributes about 68% of the total value of agricultural GDP. Field crops are estimated at about 66% of the total crop production value, and vegetables and fruit at 17% and 15% respectively.

There are three livestock production systems in Egypt: traditional extensive, semi-extensive and extensive. The traditional extensive system is characterized by low production inputs and outputs. It is practiced for sheep, goats, cattle, buffalo and poultry in the agricultural sector. The semi-extensive system depends on improved local breeds and husbandry techniques. It is practiced for lamb and calf fattening and producing locally improved chickens. The extensive production system has

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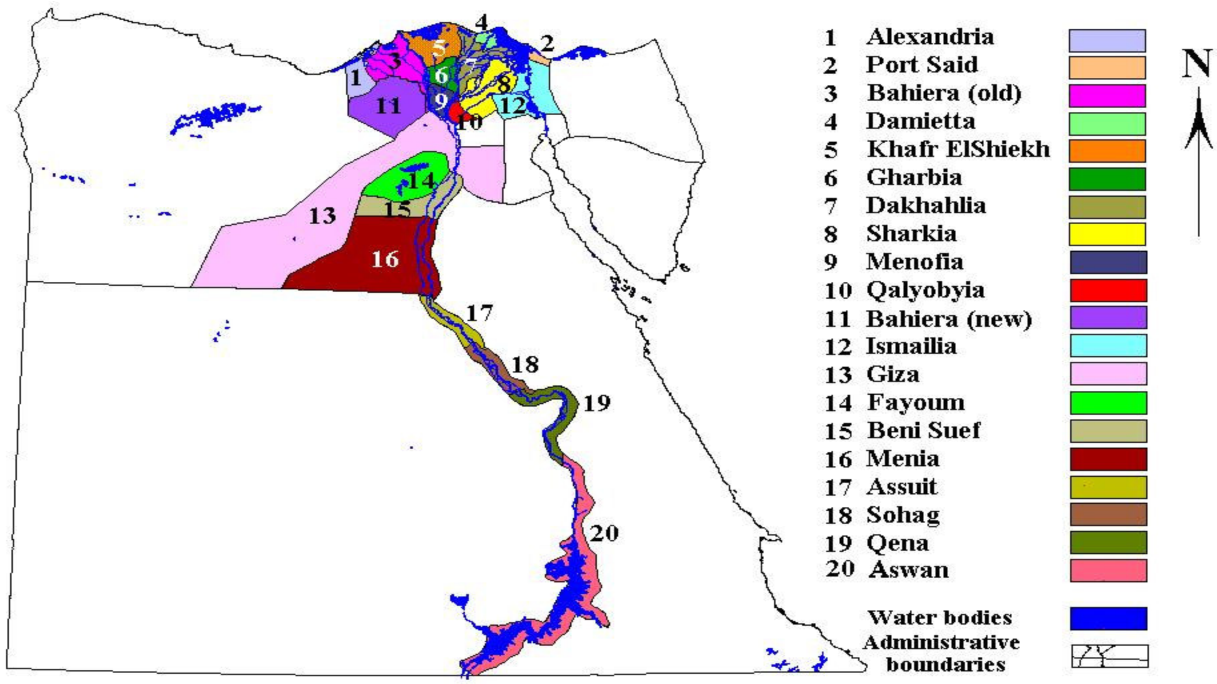
high inputs and output and is practiced for the production of exotic poultry and cattle.

Figure 1: Map of governorates in the agro-ecological zones in Egypt



Farm net revenue is defined in the model as household crop gross revenue less fertilizers and pesticide costs per hectare of total cropped area. Four models were developed to assess the impact of increased temperature on farm net revenue, each representing an adaptation option to be used to reduce the harmful effects of temperature stress. The first one is nr1_3, which is gross revenue less the cost of fertilizer and pesticides per hectare of cropped area. The second is nr2_3, where hired labor cost per hectare was deducted from nr1_3. The third is nr3_3, where total machinery cost per hectare was also deducted from nr2_3. Other crop farming costs were deducted from nr3_3 to obtain the values of nr4_3. Table 1 summarizes the statistics for these four variables. The mean value of nr1_3 ($1395 per household) was the highest compared with the other definition of net revenue.

Table 1: Estimated crop net revenues in Egypt (US$, 2001/2)

Variable	Mean	Minimum	Maximum
nr1_3	1394.65	-118.61	5231.67
nr2_3	1233.80	-227.29	4890.69
nr3_3	1142.14	-1393.57	4889.09
nr4_3	1073.51	-1393.57	4654.94

Source: GEF Farm Household Survey Data (2001/2002)

Sensitivity to warming and precipitation

An increase in temperature of 1°C would reduce net revenue by $968.94 per hectare without livestock and by $1044.28 per hectare when livestock is included (Model 1). When irrigation is included in the analysis, it reduces the harmful effect of increased temperature and increases net revenue by $26.17 per hectare without livestock and reduces it by $1680.14 per hectare when livestock is included (Model 2). When including for linear and quadratic term flow sums, the harmful effect of increased temperature is reduced and net revenue increases by $150.96 per hectare without livestock and decreases by $1412.41 per hectare when livestock is included (Model 3). Including the quantity of heavy machinery per hectare in the analysis reduces the harmful effect of increased temperature by $77.78 per hectare without livestock and by $1837.17 per hectare when livestock is included (Model 4).

Agriculture and climate change

Two climate change scenarios were used in the analysis to predict the reduction in farm net revenue by the year 2050. These two scenarios were MAGICC/SCENGEN results, which predict a 1.5°C rise in temperature, and GCM results, which predict a 3.6°C rise by the year 2050.

Table 2: Impact of climate change on net farm revenue (without livestock)

Net revenue	Mod 1	Mod 2	Mod 3	Mod 4
Under current temperature	-968.9	+26.2	+151	-77.78
Under current temperature +1.5°C	-1453.4	+39.3	+226	-116.67
Under current temperature +3.6°C	-3488	+94.2	+544	-280.01

The reductions in net revenue are $1453.41 and 3488.18 per hectare for increases of 1.5°C and 3.6°C respectively, if no adaptation options are taken into consideration (Model 1). Reductions in net revenue could be less severe if farmers used more heavy machinery on their farms (Model 4), showing that expenditure on farm machinery could reduce the harmful effect of temperature increase. The results for Model 2 show that irrigation could increase farm net revenues by $39.26 and $94.21 per hectare for 1.5°C and 3.6°C increases respectively, and for Model 3 by $226.44 and $543.46 per hectare for 1.5°C and 3.6°C increases respectively. Large losses in farm net revenue would occur when including livestock on farms.

Farmers' adaptation strategies to cope with climate change

Several adaptation options were chosen by these farmers to overcome the harmful effects of climate change. The most common adaptation to increased temperatures is irrigation, either by increasing the frequency of irrigation (short irrigation duration) or by increasing the quantity. Another procedure is to irrigate early in the morning or late in the evening and avoid irrigating in the afternoon, when the temperature is at its highest. Some farmers change their crop sowing dates to avoid the expected high temperatures, and some farmers said they use heat tolerant varieties. Other management practices they mentioned were managing pesticide and fertilizer applications, planting trees as fences around the farm, using intercropping between crop plants of different heights, and fruit mulching for vegetables. To adjust to changes in rainfall, farmers said that using varieties with high water use efficiency and/or early maturing varieties could help in coping with rainfall shortage, and some said that using underground or drainage water for irrigation and improved drainage could also be important.

Conclusions and policy implications

The empirical results suggest that irrigation is one of the most important adaptation options used to overcome heat stress, with expenditure on heavy machinery being another alternative. However, warming may also affect water resources and that would pose another problem for agricultural production. Adaptation policies should therefore be developed to cope with the adverse impacts of climate change and should address three areas: crop management, water management and land management.

First, there should be careful selection and/or breeding for heat tolerant, salinity tolerant, and water conserving cultivars. Crop rotation should be practiced so as to use high revenue crops with low water needs, such as all-season vegetables and fruits. Another alternative is to plant tomatoes, onions or potatoes as winter crops before cotton in the rotation instead of wheat, which could conserve irrigation water and increase cash return. In addition, efforts should be made to promote the preferential adoption of high-return and water conserving crops, such as sugar beet, instead of the presently grown water-profligate crops such as rice.

Second, water resources should be appropriately managed. This could be done by improving both technical water application efficiency and agronomic water use efficiency. This would involve revamping the entire system of water delivery and control and ensuring effective monitoring and regulation to avoid water losses.

Third, a further set of measures should be taken into consideration involving the management of low-lying lands at the northern fringe of the Delta, where the consequences of sea-level rise are causing submergence and increasing the salinity of these soils. Some of these lands must be retired from agriculture, and the water that was assigned to them should be made available for irrigating new lands outside the New Valley and the Delta.

It is important that future research consider micro-level analysis of adaptation strategies, using behavioral models to capture farmer behavior in choosing among various adaptation options.

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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