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Climate Change and Egypt's Agriculture

Nicostrato Perez, Yumna Kassim, Claudia Ringler, Timothy S. Thomas, and Hagar ElDidi

With climate change, Egypt's already arid climate will face even higher temperatures and lower rainfall over key agricultural areas, requiring further urgent adaptation investments. Data from three general circulation models of climate were used to better understand the likely effects of climate changes on Egypt's agricultural sector.

The findings show largely adverse biophysical effects of climate change by 2050. Compared to a no-climate change scenario, yields for food crops are projected to decline by over 10 percent by 2050 due to higher temperatures and water stress as well as increased salinity of irrigation water. The highest biophysical yield declines are estimated for maize, sugar crops, and fruits and vegetables. Moreover, due to the country's dependence on food imports, Egypt is not only affected by climate change impacts at home, but also by impacts in other food producing countries.

Climate change-induced increases in food prices will reduce Egypt's food import demand, while also dampening demand for Egypt's exports. The implications for Egypt are tighter food markets with both reduced domestic production and increased difficulties to import food making it more difficult to augment domestic food supplies. This situation suggests the need for investments in climate change adaptation in the agriculture sector. Global cooperation to mitigate greenhouse gas emissions is also warranted given the high cost to Egypt's society from adverse climate change impacts worldwide.

Egypt has a hot desert climate with extremely limited precipitation. Annual rainfall ranges from 60 to 190 mm along the Mediterranean coast, but is less than 25 mm in Upper Egypt. The mean daily maximum and minimum temperatures are 28 and 14 degrees Celsius, respectively, over the country's agricultural areas (Table 1). Despite this desert climate, Egypt has developed a highly dynamic and diversified agricultural sector, chiefly due to the Nile River that has supported irrigated food production in the country over thousands of years. Egypt has combined irrigation and drainage development with investments in agricultural research and development, including mechanization, to produce some of the highest crop yields in Africa. In addition to the 'old' lands, located in the Nile Valley and Delta, which constitute around 85 percent of the country's cultivated areas, Egypt also has developed 'new' agricultural lands in the non-fertile desert zone to the east and west of the Nile Valley and Delta. Crop production there relies on pumping of non-renewable groundwater for use with drip and sprinkler irrigation technologies, due the high permeability of the soils in the new lands.

Table 1. Climate characteristics for agricultural areas of Egypt, 1970-2000, and estimated changes through 2040-2070 based on three global circulation models

Season	1970-2000 Baseline	Change from baseline, 1970-2000 to 2040-2070 GFDL	HGEM	IPSL
Mean daily maximum temperature, °C				
Annual	27.9	2.1	3.1	3.0
JFM	21.2	1.7	2.8	3.2
AMJ	31.2	1.9	3.2	2.8
JAS	33.7	2.2	3.7	2.9
OND	25.4	2.5	2.8	3.2
Mean daily minimum temperature, °C				
Annual	14.4	2.1	3.4	2.6
JFM	7.8	1.8	2.7	2.6
AMJ	16.3	1.8	3.3	2.3
JAS	20.5	2.3	4.1	2.9
OND	12.9	2.5	3.4	2.6
Rainfall, millimeters				
Annual	42	-6	-12	-15
JFM	21	0	-7	-8
AMJ	2	0	-1	1
JAS	0	0	0	0
OND	19	-5	-4	-8
Potential evapotranspiration, millimeters				
Annual	1,750	89	117	160
JFM	288	14	26	38
AMJ	604	31	45	52
JAS	572	25	36	38
OND	286	19	11	32

Source: Authors' analysis of global circulation models from Coupled Model Intercomparison Project – Phase 5 (CMIP5). Simulations are based on Representative Concentration Pathway 8.5.
Notes: GFDL = Geophysical Fluid Dynamics Laboratory model; HGEM = Hadley Centre Global Environmental Model; IPSL = L'Institut Pierre-Simon Laplace model. JFM = January, February, March; AMJ = April, May, June; etc.

Climate and water are intrinsically linked, and climate change is already affecting Egypt's water resources for food production and many other uses. Even without climate change, Egypt's water scarcity has been growing due to rapid population growth and increasing wealth, which have increased demand for food production. In the early 1990s, Egypt's water availability fell below the international water scarcity threshold of 1,000 cubic meters per capita per year. By 2007, Egypt approached the water poverty threshold, with annual per capita availability of less than 700 cubic meters.

A Hotter and Dryer Climate Future

Agriculture is the sector of Egypt's economy that has been and will continue to be most affected by climate change. Crop productivity is affected by these changes through increased evapotranspiration demand and direct heat stress. Fisheries and livestock are also subject to heat stress and climate change-induced changes in water quality and feed availability. Since Egypt's agriculture depends almost entirely on irrigation, climate change also indirectly affects crop production through changes in the availability and quality of irrigation water as well as in the availability of water for food processing and related uses.

Data from three general circulation models of climate from the Coupled Model Intercomparison Project – Phase 5 (CMIP5)[1] were used to calculate future climate conditions for Egypt's agricultural areas (Table 1). Annual temperature increases for Egypt may be over 3.0°C (HGEM model) in the next 20 to 50 years, with increases projected to be highest during the summer growing season between June and September. This will result in higher potential evapotranspiration levels, which, in turn, increase irrigation water demand. The additional heat will affect all crops grown, but particularly those grown in summer, such as maize, which is sensitive to heat above 29°C. At the same time, annual rainfall is projected to decline by up to 15 mm, which is a substantial amount given that annual rainfall levels average only 42 mm over the country's agricultural areas.

Lower Agricultural Productivity and Food Production

The results of the climate change analysis were incorporated into an integrated biophysical and economic model to better understand the likely consequences of changes in temperature and rainfall on Egypt's agricultural sector. The biophysical and economic effects of climate change are presented in Table 2. Largely adverse biophysical effects result from changes in temperature, rainfall, potential evapotranspiration, and increased salinity levels by 2050. Compared to a no-climate change scenario, on average, yields for food crops are projected to decline by 10 percent by 2050 as a result of heat stress (4.9 percent), water stress (4.1 percent), and salinity (1.6 percent). By commodity, the highest biophysical yield declines are estimated for maize (-16.2 percent), sugar crops (-12.0 percent), and fruits and vegetables (-11.7 percent). Among the three biophysical yield stressors, increased temperature contributes the most at -12.9 percent for maize, -7.0 percent for oilseeds, and -6.7 percent for sugar crops. The yield decline is lower for wheat (-2.8 percent), while the model suggests small yield increases for roots and tubers.

Table 2. Changes in productivity due to biophysical and economic effects of climate change, Egypt, projected by 2050

	Biophysical effects, Egypt				Combined Biophysical and Economic Effects	
Commodities	Heat Stress	Water Stress	Salinity	Cumulative Effects	Egypt	Rest of World
% change from a no climate change scenario						
All food crops	-4.94	-4.14	-1.55	-10.29	-6.17	-5.24
All cereals	-4.66	-2.57	-1.59	-8.59	-10.36	-7.74
Maize	-12.86	-2.46	-1.36	-16.16	-19.54	-17.66
Rice	-5.81	-1.59	-1.58	-8.78	-8.53	-5.61
Wheat	2.27	-3.25	-1.78	-2.81	-0.56	0.82
Fruits & vegetables	-4.73	-5.88	-1.48	-11.66	-8.28	-1.95
Oilseeds	-6.98	-3.18	-1.53	-11.31	-12.08	-6.69
Pulses	-5.46	0.04	-1.57	-6.92	-9.98	0.01
Roots & tubers	2.61	-0.29	-1.79	0.47	3.56	-4.58
Sugar crops	-6.66	-4.19	-1.56	-11.96	-13.28	-10.39

Source: Authors' estimates from IMPACT results.
Note: Values are averages of three general circulation models: GFDL = General Fluid Dynamics Laboratory model; HGEM = Hadley Centre Global Environmental Model; IPSL = Institut Pierre-Simon Laplace model; All are based on RCP 8.5 and SSP2.

The economic effects of the biophysical impacts of climate change on Egypt's food systems are mediated via producer and consumer responses to climate change-induced reduction in productivity

[1] The Intergovernmental Panel for Climate Change comprehensive scientific Assessment Report 5 includes the GFDL (Geophysical Fluid Dynamics Laboratory of Princeton University, USA), HGEM (Global Environmental Model of Met Office Hadley Centre in the U.K.) and IPSL (Institute Pierre-Simon Laplace in France) general circulation models as part of the Coupled Model Intercomparison Project Phase 5 (CMIP5). All simulations were done under the representative concentration pathways (RCP)/shared socio-economic pathways (SSP) framework, applying RCP 8.5 emissions and SSP2 population and Gross Domestic Product (GDP) assumptions. RCP 8.5 represents high levels of emissions across all of the RCPs, but is also reflective of recent emissions levels.

and food supply, resulting in higher food prices and associated lower food demand. As Egypt is connected with the rest of the world through trade, the economic impacts from climate change in Egypt, moreover, also need to consider the biophysical climate change impacts and associated producer and consumer responses in the rest of the world. The combined biophysical and economic effects from climate change in Egypt are generally lower than those from biophysical impacts alone. This is because for the commodities for which supply is most affected by climate change, higher prices will result in reduced demand while producers are incentivized to be more productive. Moreover, combined biophysical and economic impacts in the rest of the world are also below those in Egypt as trade between regions that are most affected by climate change impacts and those that are less affected dampens the adverse impacts on food systems.

For Egypt, the combined biophysical and economic climate change impacts on crop productivity across all food crops average 6.2 percent by 2050, a substantial reduction from the 10.3 percent decline from biophysical impacts alone. Maize, oilseed, and sugar crops are hardest hit, while wheat and potatoes are barely affected.

The largely negative impacts of climate change on crop yields translate into national food production declines for Egypt, with production by 2050 falling by 5.7 percent. In the rest of the world, food production is expected to decline by 4.4 percent. The largest overall production declines are projected for maize (Egypt, -21.8 percent; rest of the world, -22.1 percent). However, the spread in anticipated production declines between Egypt and elsewhere is widest for pulses (Egypt, -23.9 percent; rest of the world, -0.2 percent).

Higher Prices and Tighter Food Markets

Global declines in yields and production due to climate change are projected to push world prices of food up by as much as 22.8 percent for maize and by 18.7 percent for rice by 2050. Prices of oilseeds, roots and tubers, and poultry are projected to also increase significantly due to higher prices for animal feed. Higher climate change-induced food prices will pose a significant threat to food security, limiting access to food by poorer segments of society.

Higher food prices will also result in an overall decline in Egypt's food import demand by 1.3 million mt (4.5 percent). Demand for Egypt's exports will also be adversely affected – for example, exports of fruits and vegetables from Egypt are projected to decline by 4.6 million mt. The implication for Egypt of global declines in yields and food production are tighter food markets that will make it more difficult for the country to rely on food imports to augment domestic food supplies.

The threat of climate change for food security in Egypt is further reinforced by declines in per capita food and calorie availability. Egypt's per capita consumption of food crops is projected to decline by 2.1 percent by 2050 and calorie availability by 1.7 percent. These declines will primarily be driven by reduced consumption of roots and tubers (-8 percent), oilseed crops (-7 percent) and rice (-5 percent) due to higher prices for those foods as a result of climate change.

Climate Change Exerts a High Economic Cost

Climate change impacts both agricultural production levels (yield) and food security (world prices, net trade, and consumption). By doing so, climate change can perpetuate the already slowing productivity growth of Egypt's agricultural sector. Understanding the economic effects of climate change can enable the government and Egyptian society, in general, to weigh the costs of reacting to adverse impacts from climate change against those of anticipatory adaptation and prevention. The economic surplus framework for cost-benefit analysis, which measures the costs and benefits that accrue from shifts in supply and demand over time, can be used to estimate the impact of climate change on agricultural producers and consumers, and, hence, on society as a whole. Within this framework, positive values indicate net benefits, while negative values indicate net costs.

On this basis, the average economic costs of climate change to Egyptian society are estimated at US$ 55.3 billion for the 30-year period from 2020 to 2050, or US$ 1.8 billion per year. Egyptian consumers will bear most of these costs (US$ 66.2 billion from 2020 to 2050 or US$ 2.2 billion per year). In contrast, producers will see a net gain of US$ 2.0 billion overall or US$ 0.4 billion per year, implying that higher food prices more than compensate food producers for the productivity losses they experience due to climate change, on average. However, most farmers – and especially smallholder farmers – are net consumers of food, and, thus, are expected overall to suffer economic losses from the combined producer and consumer effects. Moreover, farmers will likely incur higher costs to retain even lower productivity levels, for example, through increased need for investments in advanced irrigation technologies or in pesticides to deal with increased pest and disease incidence.

Policy Conclusions

Climate change will increase temperatures across Egypt while also increasing demand for water for food production. Biophysical stresses from climate change will lower yields of some crops, particularly maize, fruits and vegetables, and oilseeds, while other crops, like wheat and roots and tubers, will be less affected. Climate change-induced increases in food prices will reduce both Egypt's food import demand and demand from the rest of the world for Egypt's exports. The implications for Egypt are tighter food markets that will make it more difficult for Egypt to rely on food imports to augment domestic food supplies.

This situation suggests the need for investments in breeding heat- and salinity-stress tolerant varieties of the crops most negatively affected by climate change as well as improved water management. Global cooperation to mitigate greenhouse gas emissions is also warranted given the high cost to Egypt's society from the adverse impacts of climate change worldwide.

The government of Egypt acknowledges the need for the country to adapt to climate change. It proposes adopting heat, salt, and pest tolerant crop cultivars, modifying crop planting dates, improving water use efficiency, and using improved livestock feeding practices and species as adaptation strategies within agriculture.[2] Given that the economic costs to the Egyptian society from climate change induced impacts on agriculture are estimated at US$ 55.3 billion for the 2020 to 2050 period, or US$ 1.8 billion per year, adaptation investments are likely to be cost-effective in reducing both the country's net import bill and the risk of growing food insecurity.

[2] United Nations Framework Convention on Climate Change. 2014. *The Arab Republic of Egypt: Intended Nationally Determined Contributions as per United Nation Framework Convention on Climate Change*. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Egypt%20First/Egyptian%20INDC.pdf

ABOUT THE AUTHORS

Nicostrato Perez is a Research Fellow in the Environment & Production Technology Division (EPTD) of the International Food Policy Research Institute (IFPRI), based in Washington, DC. **Yumna Kassim** is a Research Associate with IFPRI's Egypt Strategy Support Program (ESSP), based in Cairo. **Claudia Ringler** is Deputy Division Director of EPTD of IFPRI, based in Canada. **Timothy S. Thomas** is a Research Fellow in EPTD of IFPRI, based in Washington, DC. **Hagar ElDidi** is a Research Analyst in EPTD of IFPRI, based in Washington, DC.

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
1201 Eye St, NW | Washington, DC 20005 USA
T. +1-202-862-5600 | F. +1-202-862-5606
Email: ifpri@cgiar.org | www.ifpri.org | www.ifpri.info

IFPRI-EGYPT
2 Port Said Street, Victoria Square, Maadi, Cairo, Egypt
T: +202-23591144 | F: +202-23591143
Email: ifpri-egypt@cgiar.org | www.egyptssp.ifpri.info

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