Analysis of Climate Change Effects on Food Security in Egypt Using IMPACT Model

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Abstract:

There is an international consensus that climate change poses an imminent threat to development around the world. Egypt is not an exception; without a doubt, global warming has put Egypt among the countries that climate change is affected. Therefore, it has become necessary for Egypt to integrate plans of adaptation into its development strategies to overcome or cope with or limit the unavoidable impacts of climate change. Consequently, this study analyses the potential economic and social impacts induced by the deterioration of weather conditions on economic growth and food security in Egypt. Accordingly, the study was based on The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT); the IMPACT model system is a network of linked models. The main components include climate models, crop models, and water models.

The results show that climate change will reduce aggregate food production between -3% (2030) -3.8% (2050). Furthermore, it will lead to a rise in the general level of prices, which leads to a decrease in per capita food consumption (KCAL per capita per day) by around -1.7% and -3.8% during 2030 and 2050, respectively. In conclusion, this increases hunger (millions of people at risk) by 0.017% on average 2030-2050. Finally, the study recommends that Egyptian policymakers need to develop adaptive measures to address the potential impacts of climate change that induced agricultural productivity losses; such as providing climate-smart crop varieties (i.e., those that are resistant to heat and drought) to farmers, improving agricultural practices and educating farmers to shift from crops that are profoundly impacted by climate change to those that are not. Also, the agricultural sector needs more investment to improve productivity.

Keywords: Climate change; Food security; Agricultural productivity; IMPACT Model.

1. Introduction

The Climate warming system is unequivocal (Pachauri et al., 2014). During the 21st century, it was predicted by Intergovernmental Panel on Climate Change (IPCC) that there will be an increase in the average global surface temperatures by 2.8ºC, with best-guess estimates of the rise ranging from 1.8 to 4.0 ºC (IPCC 2007), brought about by a rise in the atmospheric concentration of greenhouse gases.

In this regard, the environmental system will face two types of climate change impacts. First, the direct effect of climate change incorporates the changes in temperature, the quantities of rains, and the harsh weather conditions. Second, the indirect effects of climate change involve the prevalence of insects and diseases

(Schmidhuber & Tubiello 2007; Fadina & Barjolle 2018). Furthermore, the time and spatial variation effect and uncertainty over the past few decades make studying climate change more challenging.

Meanwhile, some recent studies showed that the direct effect is the long-term change of temperature and rain within the agricultural sector (Rosegrant et al. 2014), using crop-simulation models. The study showed that this direct effect could decrease the global yield of wheat, rice, and maize by 11%- 25% in 2050, compared to 2010, regardless of technological change and a market influence (Hachigonta et al. 2013; Shaltout & Omstedt 2014).

From a national perspective, some studies examined the anticipated effect of climate change in Egypt was projected that the average temperature level would increase by approximately 1.4 and 2.5 °C by 2050 and 2100, respectively (Agrawala et al. 2004). Additionally, greenhouse gases significantly increase in CO2, which results in rain pattern changes. Furthermore, as a result of Egypt's presence among the countries directly or indirectly affected by climate change severely, which affects Egyptian agriculture, an overview of the literature in this regard is summarized below: Several studies have illustrated the potential effects of climate change on some field crops such as Jones et al., (1998); Jackson et al. (1988); El-Shaer et al. (1997) and Marsafawy (2007). Moreover, these studies highlighted the effect of climate change on crop yields by 2050 compared to status-quo; it is projected that rice yield would fall by 11%, soybean by 28%, maize by 19%, barley by 20%, and sunflower by 27%, however, the cotton yield would increase by 10%. Simultaneously, it is also projected that water consumption would increase by 8%, 16%, 12% for maize, rice, and sunflower, respectively, by the year 2050 (El-Marsafawy & El-Samanody 2009). The irrigation water demand increases; this increase is due to the high evaporation rates associated with higher temperatures (Agrawala et al. 2004). Moreover, a large share of agricultural land may become unusable due to immersion or saltwater intrusion landfall from the Nile Delta (Alkire & Santos 2010).

As a result of the preceding, achieving and maintaining food security will be a challenge due to climate change and several other global factors in general, such as the increasing population and income (Yang & Shumway 2015), specifically in developing countries. This poses a new challenge to the agricultural sector due to the demand growth, as well as the increasing competition among the uses of resources for production (Rosenzweig & Parry 1994). Given these challenges, global climate change has various repercussions on food security (Nelson et al. 2010). Egypt is not an exception; according to Bruinsma (2017), it is a low-income country (LIFDC) that faced economic deterioration resulting in high poverty, unemployment, and food insecurity. The agriculture sector accounted for 11.5% of the gross domestic product (GDP) in 2017[1], while simultaneously providing livelihoods for up to 30% of the population, and the agricultural cropland occupied 3.4 million hectares (a small strip along the banks of the Nile River). The agriculture sector in Egypt is irrigated agriculture-based (around 90% of Egypt's agricultural production is irrigated), and the

[1] **World Bank Database; https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=EG&view=chart**

Nile provides about 95% of the total Egyptian water uses (Agrawala et al. 2004). Moreover, agricultural production and imports have enabled the country to feed its population of One hundred million people, of whom Fifty-six million live in rural areas. Egypt produced only 60% of its food and 40% of its crop consumption (Abutaleb et al. 2018).

There are minimal studies that look at the economy-wide impacts of climate change in Egypt, e.g., Fahim et al. (2013), little is known about the roles of the adaptation strategy like Elshennawy et al. (2016). Even though crop cultivation and livestock production dominate Egyptian agriculture, all climate change studies have focused on crop cultivation but ignored the impact on livestock (Yates & Strzepek 1998), which accounts for 40% of agricultural value-added (FAO 2015). There appear to be essential linkages between crop and livestock subsystems within the agricultural household system, which in itself is a new dimension of interest in climate change studies in Egypt. Moreover, instinctively, the impact of climate change on livestock production is expected to be different. Thus, neglecting the livestock sector would underestimate the impact of climate change, which needs further investigation to cover this research gap.

As a result of what has been mentioned previously about the impacts of climate change, it poses potentially substantial threats to Egypt's economic growth, food security[2], and poverty reduction prospects due to high exposure to the biophysical effects and limited adaptive capacity. Therefore, the main objective of this study is to analyze the potential economic and social impacts induced by the deterioration of weather conditions on economic growth and food security in Egypt.

The other sections of the paper are organized as follows. Section 2 provides a methodology and model specification; section 3 explains the future climate prediction and its impact on the agricultural sector in Egypt. Section 4 explains Simulations outcomes—finally, section 5 summary and conclusion.

2. Methodology and model specification

The study was based on The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT); IMPACT model is a partial equilibrium model, which uses a system of supply and demand equations to analyze food demand, food production, prices, income, trade, and the population at the national and regional level. At the beginning of the 1990s the first version has been developed. This paper uses IMPACT 3, which is the latest updated in 2015. It consists of 159 countries, 154 basins, and 62 agricultural commodities markets.

The IMPACT model system is a network of linked models. The main components include climate models, crop models, and water models. Several of these modules are integrated into the IMPACT multimarket model, and others are coded as separate modules linked through information flows to others. Figure 1, a detailed schematic of the IMPACT model, summarizes the links between main component modules and the core multimarket model, with arrows indicating information flows. The climate models provide climate data (i, e. temperature and precipitation) as

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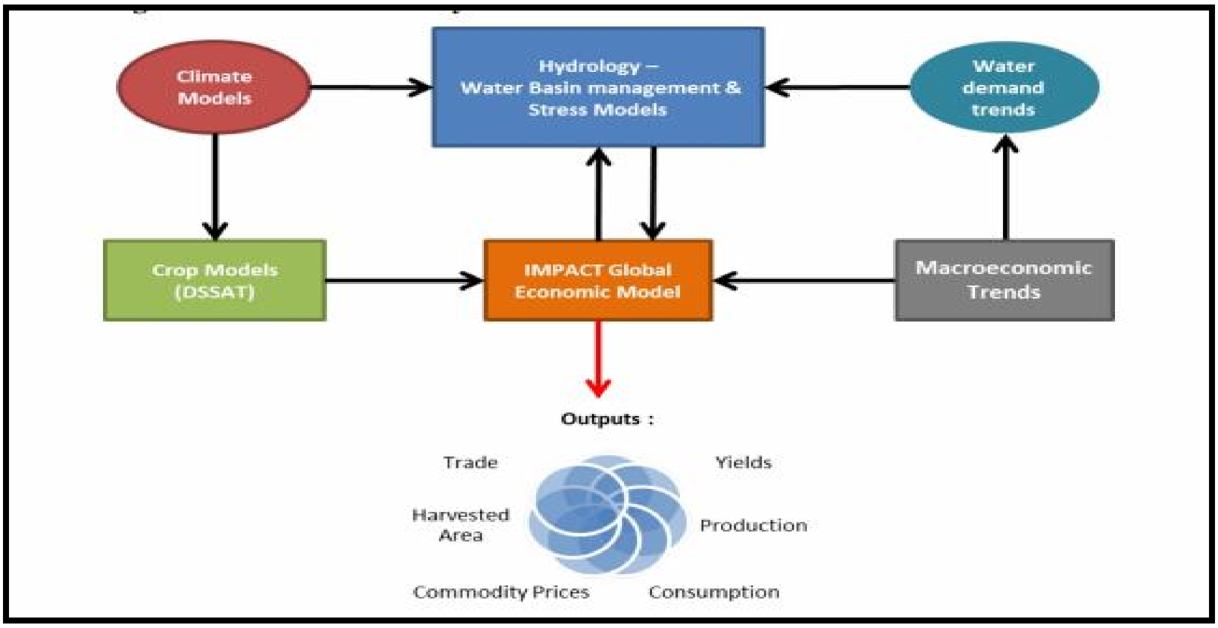
[2] **food security dimensions: Indicator is classified along the first dimension of the four food security dimensions namely food availability (i.e., production and trade). (van Heerden et al. 2019)**

inputs to the crop and water simulation models. Macroeconomic trends reflect projections from demographic (population growth rate) and economic growth models. These links are one way, from these models to the multimarket and water models. The water models are dynamically linked to the multimarket model, with two-way flows of information over time. More detail about some of the modules is provided in (Robinson, et al., 2015).

Figure 1. The IMPACT system of models: Climate, crops, and water models.



Source: Robinson et al., 2015.

3. Scenarios description

In analyzing the impact of climate change, the paper identifies two scenarios that represent different perspectives of the economic situation of Egypt and the world economy. First, a scenario without climate change is named a baseline scenario. The baseline (business-as-usual) scenario assumes that the historical trends in agricultural productivity growth, including its determinants such as agricultural inputs, outputs, and investments, would continue from the base year 2010 through 2030 and 2050. The baseline scenario depicts the socio-economic indicators' trend, assuming a stable climate. Therefore, Shared Socioeconomic Pathway assuming a stable climate from 2010 (SSP2-NoCC) projections were used. Shared Socioeconomic Pathways display different possible changes in the global economy, society, and demography in the future. The SSP2, called the 'middle of the road' scenario, depicts a future world where global indicators will differ significantly from historical trends.

The baseline scenario results are compared with the climate change scenario. Generally, climate change impacts are estimated using Global Climate Models (GCM) and biophysical models. First, Global Climate Models (GCM) are used to simulate the impact of physical climate change (according to the SSP2_GFDL Climate change scenario estimated under GCM_GFDL). Second, biophysical models are used to translate these physical effects into economic shocks. The challenge, however, is that different general circulation models produce distinct projections of climate change impacts.

3.1 Baseline scenario experiment

The baseline scenario explains the socio-economic indicators during 2010-2050, assuming a stable climate. Therefore, to develop this scenario, we use projections throughout 2050 for GDP, population, arable land, capital stock, and labor. Population, GDP growth, and arable land are obtained with the IMPACT model. Most of these variables have an increasing trend during 2010-2050 in all the regions. The global population will reach 9.2 billion in 2050, and average incomes will reach USD 25,000 per person. In Egypt, the population will increase by 131.5% in 2030 and around 153.9 by 2050. This high population growth rate is explained by the country's annual population growth rate, estimated at 2.45%, compared to the base year. The GDP will increase by more than 600% and precisely by 622% in 2050, relative to its level in 2010.

3.2 Climate change scenario experiment (Effect of climate change on agricultural yield)

The results of the climate change analysis were incorporated into an integrated biophysical and economic model to understand better 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 1. 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 1. Changes in productivity due to biophysical and economic effects of climate change in Egypt by 2050.

Commodity	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	-6.92	-12.08	-6.69
Pulses	-5.46	0.04	-1.57	0.47	-9.98	0.01
Roots & tubers	2.61	-0.29	-1.79	-11.96	3.56	-4.58
Sugar crops	-6.66	-4.19	-1.56		-13.28	-10.39

Source: **IMPACT results**

4. Simulations outcomes

This section presents the simulation results on the effect of climate change on households' consumption in Egypt. We present the impact of climate change on Per capita food consumption, Aggregate food production, Hunger, and household demand in addition to production and net trade of agricultural commodities.

Indeed, the median effect of climate change is negative in all economic indicators. The results show that climate change will lead to a decrease of Aggregate food production between -3% (2030) -3.8% (2050), as shown in Table 2; this is due to the decrease in the productivity of the unit area of the most important crops as a result of climate changes, As shown in Table 1. Furthermore, a decrease in Aggregate food production will lead to a rise in the general level of prices, which leads to a decrease in Per capita food consumption (KCAL per capita per day) by around -1.7% and -3.8% during 2030 and 2050, respectively. In conclusion, this increases Hunger (millions of people at risk) by 0.017% on average 2030-2050.

Table 2. Changes in Economic indicators due to effects of climate change in Egypt.

Indicators	Base year	Without climate change		With climate change		%	
	2010	2030	2050	2030	2050	2030	2050
Per capita food consumption (KCAL per capita per day)	3395	3580.0	3782.7	3517.9	3640.8	-1.7	-3.8
Aggregate food production (index, 2010 = 1.00)	1.00	1.5	2.0	1.4	1.9	-3.0	-3.8
Hunger (millions of people at risk)	1.6430	2.1604	2.5285	2.1608	2.5289	0.017	0.017

Source: IMPACT results

Table 3 shows the impact of climate changes on agricultural production, as the negative impact of climate change on the production of all commodities (The Pulses is the most affected crops by about -22.21% in 2050), except for roots and tubers, total production of roots and tubers will increase by 20% (2030) and 35% (2050) as a result of increased productivity (Table 1).

Table 3. Changes in total production due to effects of climate change in Egypt.

Commodity	Total production (million metric tons)						
		Without climate change		With climate change		%	
	2010	2030	2050	2030	2050	2030	2050
Cereals	19.76	23.69	25.99	22.21	22.98	-6.24	-11.61
Meats	1.60	3.20	5.63	3.19	5.61	-0.17	-0.38
Fruits & Vegetables	29.24	46.45	66.07	44.44	63.31	-4.33	-4.18
Oilseeds	0.79	1.20	1.41	1.19	1.37	-0.65	-2.59
Pulses	0.41	0.63	0.81	0.56	0.63	-11.69	-22.21
Roots & Tubers	3.40	5.91	8.38	7.11	11.33	20.35	35.30

Source: IMPACT results

The variation in crop productivity caused by climate change will impact production for agricultural products. Table 4 presents the variation in the households' demands for agricultural products in Egypt. On average, climate change will decline household demand for agricultural products for all commodities by a rate of -9.638% (Cereals, 2050); except Pulses, the demand for it will rise at a low rate.

Climate changes will lead to an increase in the trade deficit (Table 5) of all the commodities understudy, as the trade deficit of cereals will rise from about 39.7% to 40.4% by 2050, and the reason is due to the decrease in production at rates higher than the increase in the demand for cereals referred to in Table 3- 4, leads to an increase in imports to compensate for the decrease in domestic production, and I hope that this will increase the trade deficit of cereals. On the other hand, the crops that have a surplus, such as vegetables and fruits will decrease from 20.5% to 18.9% by 2050.

Table 4. Impact of climate change on households demand for agricultural products in Egypt

Commodity	Total Demand (million metric tonnes)						
		Without climate change		With climate change		%	
	2010	2030	2050	2030	2050	2030	2050
Cereals	31.118	46.593	65.285	44.681	58.993	-4.104	-9.638
Meats	1.886	3.462	5.262	3.445	5.211	-0.515	-0.975
Fruits & Vegetables	27.557	37.997	45.606	37.501	44.416	-1.306	-2.610
Oilseeds	1.461	1.987	2.385	1.907	2.191	-4.022	-8.122
Pulses	0.997	1.643	2.330	1.649	2.347	0.357	0.728
Roots & Tubers	3.177	5.001	7.262	4.641	6.453	-7.196	-11.143

Source: IMPACT results

Table 5. Impact of climate change on net trade for agricultural products in Egypt

Commodity	Net trade (million metric tons)			
	Without climate change		With climate change	
	2030	2050	2030	2050
Cereals	-23.3	-39.7	-23.9	-40.4
Meats	-0.3	0.4	-0.3	0.4
Fruits & Vegetables	8.5	20.5	6.9	18.9
Oilseeds	-0.8	-1.0	-0.7	-0.8
Pulses	-1.0	-1.5	-1.1	-1.7
Roots & Tubers	0.9	1.1	2.5	4.9

Source: IMPACT results

5. Summary and conclusion

The Climate warming system is unequivocal. During the 21st century, it was predicted by Intergovernmental Panel on Climate Change that there will be an increase in the average global surface temperatures by 2.8ºC, with best guess estimates of the rise ranging from 1.8 to 4.0 ºC, brought about by a rise in the atmospheric concentration of greenhouse gases. In this regard, the environmental system will face two types of climate change impacts. First, the direct effect of climate change incorporates the changes in temperature, the quantities of rains, and the harsh weather conditions. Second, the indirect effects of climate change involve the prevalence of insects and diseases. Furthermore, the time and spatial variation effect and uncertainty over the past few decades make studying climate change more challenging.

There is a consensus that climate change poses an imminent threat to development in countries around the world, especially in developing countries. Egypt is not an exception, and global warming has put Egypt among the countries predicted to be affected by climate change. Consequently, this study aimed to analyze the potential economic and social impacts induced by a deterioration of weather conditions on economic growth and food security. The study was based on The International Model for Policy Analysis of Agricultural Commodities and Trade

(IMPACT); IMPACT model is a partial equilibrium model, which uses a system of supply and demand equations to analyze food demand, food production, prices, income, trade, and the population at the national and regional level. It consists of 159 countries, 154 basins, and 62 agricultural commodities markets. The IMPACT model system is a network of linked models. The main components include climate models, crop models, and water models.

Actually, the results show that climate change will lead to a decrease of Aggregate food production between -3% (2030) -3.8% (2050) due to the decrease in the productivity of the unit area of the most important crops as a result of climate changes. Furthermore, a decrease in Aggregate food production will lead to a rise in the general level of prices, which leads to a decrease in Per capita food consumption (KCAL per capita per day) by around -1.7% and -3.8% during 2030 and 2050, respectively. In conclusion, this increases Hunger (millions of people at risk) by 0.017% on average 2030-2050, in addition to the decline in production and household demand for agricultural commodities and an increase in the trade deficit. Finally, the study recommends that Egyptian policymakers need to develop adaptive measures to address the potential impacts of climate change that induced agricultural productivity losses; such as providing climate-smart crop varieties (i.e., those that are resistant to heat and drought) to farmers, improving agricultural practices and educating farmers to shift from crops that are profoundly impacted by climate change to those that are not. Also, the agricultural sector needs more investment to improve productivity.

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تحليل آثار تغيرات المناخ على الأمن الغذائي في مصر باستخدام النموذج الدولي لتحليل سياسات السلع الزراعية والتجارة

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قسم الاقتصاد الزراعي، المركز القومي للبحوث ، القاهرة

الملخص:

هناك إجماع دولي على أن تغير المناخ يشكل تهديدًا وشيكًا للتنمية في جميع أنحاء العالم. ومصر ليست استثناء. لا شك أن الاحتباس الحراري وضع مصر بين الدول التي تتأثر بتغير المناخ. لذلك ، أصبح من الضروري لمصر أن تدمج خطط التكيف في استراتيجياتها التنموية للتغلب على الآثار الحتمية لتغير المناخ أو التعامل معها أو الحد منها. وتستهدف هذه الدراسة تحليل الآثار الاقتصادية والاجتماعية المحتملة الناجمة عن التغيرات المناخية على النمو الاقتصادي والأمن الغذائي في مصر. واستندت الدراسة في هذا التحليل إلى النموذج الدولي لتحليل سياسات السلع الزراعية والتجارة(IMPACT) ؛ وهذا النموذج عبارة عن شبكة من النماذج المرتبطة. ، حيث تتمثل المكونات الرئيسية فى النماذج المناخية ونماذج المحاصيل ونماذج المياه، فضلا عن نموذج توازن جزئي متعدد السلع ومتعدد الدول.

وتظهر النتائج أن التغيرات المناخية سوف تقلل من إنتاج الغذاء بما يتراوح بين -٣٪ (٢٠٣٠) و -٣,٨٪ (٢٠٥٠). وسيؤدي ذلك إلى ارتفاع المستوى العام للأسعار ، مما يؤدي بالتالي إلى انخفاض نصيب الفرد من استهلاك الغذاء (كيلو كالوري للفرد في اليوم) بحوالي -١,٧٪ و -٣,٨٪ خلال عامي ٢٠٣٠ و ٢٠٥٠ على التوالي. أخيرًا. وتوصي الدراسة بضرورة تطوير تدابير للتكيف مع التغيرات المناخية لمعالجة الآثار المحتملة من هذه التغيرات والتي تتمثل أساسا في خسائر في الإنتاجية الزراعية . ومن أهم هذه التدابير توفير أصناف محاصيل ذكية مناخيًا (أي الأصناف المقاومة للحرارة والجفاف) للمزارعين ، وتحسين الممارسات الزراعية وتوعية وإرشاد المزارعين فيما يتعلق بالتحول من المحاصيل التي تتأثر بشدة بتغير المناخ إلى تلك المقامة للضغوط المناخية. كما يتطلب القطاع الزراعي مزيدا من الاستثمارات لتحسين الإنتاجية.

الكلمات المفتاحية: تغيرات المناخ؛ الأمن غذائي؛ الإنتاجية الزراعية؛ نموذجIMPACT