The impact of climate change on food security dimensions in Egypt by 2070

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Abstract

Egypt is one of the countries expected to suffer from climate change in the next 50 years. This study analyses the impacts of climate change on food security dimensions in Egypt during the period 2022-2070 by using statistical analysis methods (ARIMA and MLR). The study found that there is a negative and significant impact of climate change on food availability, food access, food utilization, and food stability. In terms of food availability, increases in temperature will reduce yields of wheat from 8.1% up to 24.5%, maize from 9.7% up to 29.1%, and rice from 2.1% up to 6.1% by 2070. In terms of food access, food prices are expected to rise from 13.5% to 18.9% by 2070. In terms of food utilization, it is expected that there will be an increase in the percentage of children under 5 years of age who are overweight from 17.8% to 21.2% and an increase in the prevalence of obesity in the adult population (18 years and older) from 40.0% to 53.1% by 2070. In terms of food stability, the food security level in Egypt will decrease from 76.1% to 73.9%. This study recommends some adaptation options to reduce the impact of climate change on food security dimensions in Egypt, including designing and applying a national adaptation strategy.

Keywords: *Climate change, Egypt, Food security, ARIMA, National adaptation strategy.*

1. Introduction and objectives

According to the Food and Agriculture Organization of the United Nations (FAO) report in 2015, despite the global efforts made on the issue of hunger during the last several decades, almost 800 million people do not have enough food to meet their basic nutritional needs. It is estimated that 160 million children under the age of five are suffering from malnutrition and stunting. On the other hand, about 500 million people are obese. There are more than two billion people who lack the essential micronutrients they need to lead healthy lives, especially in rural areas.

According to the United Nations report from 2015, there are more than 800 million people in the world living in extreme poverty (about USD 1.25 per day), and more than 65 percent of the very poor live in rural areas, most of them depending on agriculture for their livelihoods. It is estimated that 500 million smallholder farms in the developing world are supporting more than 1.8 billion people, especially in Asia and sub-Saharan Africa, where these small farms produce about 80 percent of the food consumed.

On other hand, climate change threatens the progress of the fight against hunger and malnutrition. According to the latest report of the

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Intergovernmental Panel on Climate Change (IPCC), climate change increases risks to food security for the most vulnerable countries and populations. There are four key risks induced by climate change identified by IPCC that have direct consequences for food security: (1) Loss of rural livelihoods and income; (2) Loss of marine and coastal ecosystems, and livelihoods; (3) Loss of terrestrial and inland water ecosystems, and livelihoods; (4) Breakdown of food systems. Moreover, there are also broader impacts through effects on trade flows, food markets, and price stability. So, expanded international efforts to respond to climate change are needed immediately to safeguard the capacity of food systems and achieve global security for the present and future generations. Additionally, in order to satisfy the growing demand driven by population growth and other changes, food production will have to increase by 60 percent by 2050, according to FAO estimates from 2015.

The main problem of this study is that climate change has a negative effect on food security and agriculture in Egypt. The average temperature has risen by 0.9 degree Celsius in Egypt since 1902, leading to a decrease in crop yields, especially the most important three strategic crops, which are wheat, maize, and rice. In addition, rising temperatures and decreasing annual precipitation in Egypt due to climate change effects are not only reducing food availability but also food affordability (rising food prices due to a decrease in food production). Moreover, climate change affects child health outcomes in Egypt by reducing food availability, quality, and safety levels as a result of the spread of diseases and changing the nutritional content of some crops due to the high level of CO_2 in the atmosphere. According to Global Hunger Index in 2019, the malnutrition rates in Egypt are high, with a 21 percent stunting rate, a 16 percent obesity rate, and a 6 percent underweight rate for children under 5 years of age.

As a result of the current situation, the Egyptian government has launched the National Climate Change Strategy (NCCS). This strategy is designed to unify all climate change aspects in a single document to serve as a reference that supports the move to climate-resilient economy. NCCS contains five main goals, which are: (1) Achieving sustainable economic growth and low-emission development in various sectors, (2) Enhancing adaptive capacity and resilience to climate change and alleviating the associated negative impacts, (3) Enhancing climate change action governance, (4) Enhancing climate financing infra-structure, and (5) Enhancing scientific research, technology transfer, knowledge management and awareness to combat climate change. Additionally, in Sustainable Development Strategy (SDS): Egypt Vision 2030, Egypt pledged to integrate climate change into national development policies and to gradually green its budget across sectors.

This study serves two main objectives. First, to highlight the impact of climate change on food security dimensions in Egypt and raise awareness that, if action is not immediately taken, climate change will increasingly threaten the achievement of the sustainable development goals, including the food security goal. Second, determining the pathways or possible scenarios by which climate change ultimately impacts the Egyptian economy and people to implement a range of actions required through technical and social protection to strengthen international cooperation.

In order to achieve the study objectives, this study follows the statistical analysis methods to examine the potential impact of climate change on food security dimensions in Egypt during the period (2022-2070) by using the ARIMA model to predict future trends of climate change variables (i.e. temperature, precipitation, relative humidity, and carbon dioxide emissions) during the period (2022-2070) based on past values of these variables during the period (1973-2021). Moreover, this study uses multiple linear regression analysis to identify the variables and then measure the impact of explanatory variables on a response variable (i.e., crop yield versus climate change variables, malnutrition and obesity versus elevated CO_2 during the period (2022-2070) based on past values of these variables during the period (1973-2021). This study also examined scenarios for climate change impacts on food security dimensions in Egypt under different circumstances (i.e., changes in levels of temperature, precipitation, carbon dioxide emissions, and population growth rates) during the period (2022-2070) through Minitap Software Version 16.

The main contribution of this study is that previous and recent studies have acknowledged the risks expected to face Egypt due to climate change, and these studies mainly focused on the impact of climate change on the yield and price of specific crops (they mainly focused on food availability and food access dimensions only). Less attention has been given to studying the impact of climate change on food utilization and food stability dimensions. So, this study will contribute to filling this research gap by conducting a comprehensive study on the potential impact of climate change on food availability, food access, food utilization, and food stability (food security dimensions) in Egypt by 2070.

2. Theoretical framework and literature review

According to World Food Summit (WFS) in 1996, "food security" exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. This widely accepted definition includes the following four dimensions of food security: (1) Availability: the availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports; (2) Access: access by individuals to adequate resources for acquiring appropriate foods for a nutritious diet; (3) Utilization: the utilization of food through an adequate diet, clean water, sanitation, and healthcare to reach a state of nutritional well-being where all physiological needs are met; and (4) Stability: to be food secure, a population, household, or individual must have access to adequate food at all times.

Based on the United Nations Framework Convention on Climate Change (UNFCCC, 1992), climate change is a change in climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to the natural climate variability observed over comparable periods of time. This definition differs from that in the IPCC (2012), where climate change is defined as a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.

There is a strong linkage between climate change and food security, in which climate change impacts food security in its four dimensions (availability, access, utilization, and stability). According to (Porter *et al.*, 2014), increasing global temperatures by 4 degrees or more along with increased food demand would lead to large risks to food availability globally. According to (Nelson *et al.*, 2014), climate change has an impact on the production capacity of food security, especially through increases in food prices and their volatility, which affect food accessibility globally. Studies (Nelson *et al.*, 2009; Porter *et al.*, 2014; Tirado *et al.*, 2010) point to the potential impacts of climate change on food utilization through a reduction in the production and consumption of some foods, a reduction in the nutritional quality of foods, and a reduction in food safety due to elevated CO_2. According to FAO in 2008 and the Global Food Security Programme in 2015, climate changes can affect the stability of food availability, access, and utilization, leading to global production shocks through increased supply risks combined with reduced supply predictability, affecting both supply chain costs and retail prices.

The impact of climate change on food security in Egypt has been pointed out in many previous studies. Joel Smith *et al.* (UNDP, 2013), in a study titled "Potential Impacts of Climate Change on the Egyptian Economy", focus on the potential impacts of climate change on Egypt's agriculture economy during the period of 2030 to 2060 by using a sea level rise scenario (SLR) to estimate the water supplies and crop yield changes. The results showed that by 2060, there will be a decline in agricultural production from 8% to 47%, increases in food prices from 16 to 68%, reductions in agriculture-related employment by 39%, and agriculture welfare losses expected to be from 40 to 234 billion Egyptian pounds (EGP). The author recommends that

Egypt needs to develop a national adaptation plan to reduce the potential negative impact of climate change on the Egyptian economy, and this adaptation should target different sectors including water resources, agriculture, tourism, health, and coastal resources.

Fahim *et al.* (2014), in a research paper titled "Climate Change Adaptation Needs for Food Security in Egypt", focus on the impacts of climate change on food security based on field study results and recent project activity outputs in Egypt by using different general circulation models based on climate projections for 2030 in food-insecure regions to conduct an analysis of climate risks for selected agriculture crops. The study also focuses on the impacts of climate change on the agriculture sector in Egypt, particularly biophysical and socio-economical parameters. The study found that Egypt will suffer from adverse climate change impacts on several crops without sufficient adaptation measures. So, the author recommends designing and applying a national adaptation strategy for the agriculture sector to overcome a group of barriers and limitations such as poor financial support, poor adaptive capacity of the rural community, and a poor institutional framework.

"Climate Change and Food Security in Egypt," Laila Yassin's 2016 thesis, examines the impact of climate change on food security, with a particular emphasis on Egypt's agricultural sector and food production system. It focuses on examining the current policies in place to mitigate the effects of climate change on food security in Egypt by conducting in-depth interviews with climate change experts. The study found that the current policies are not enough and not effective because of the weakness of a relevant legal framework, low awareness, and lack of cooperation among stakeholders at all levels. So, the study recommends adopting a new comprehensive legal framework to help the government increase cooperation among stakeholders, raise awareness of the effect of climate change on food security through cooperation between the Egyptian government and non-governmental organizations, and train stake-holders on using new technologies.

Eman Ahmed Hashem (2020), in a study titled "The Impacts of Climate Change on Food Security - Case Study: Egypt", the author focuses on analyzing the effects of climate change on food security in Egypt by using the Auto Regressive Distributed Lag Model (ARDL) to examine the relationship between the climate change and food security dimensions in Egypt. The results showed that there is an adverse and significant impact of temperature on domestic food supply and prices, as an increased temperature will lead to a decrease in some crop production (negative relationship) and a rise in food prices (positive relationship), which will result in a high production shock. Therefore, the study recommends activating a sufficient, comprehensive adaptation system to lower the potential negative impacts of climate change on food security in Egypt.

Nicostrato D. Perez *et al.* (2021), in their project paper, "Climate Change Adaptation Strategies for Egypt's Agricultural Sector: A Suite of Technologies Approach", focus on the negative impact of climate change on Egypt's agriculture sector by investigating a range of climate change adaptation approaches through the use of a suite of technologies rather than simulating a single one. The results showed that crops such as maize, oilseeds, pulses, and sugar will be more negatively affected by climate change while crops such as wheat, rice, potatoes, fruits, and vegetables will be less affected. So, the study recommends increased investments in enhancing crop traits, improving soil fertility, managing water, providing crop protection, establishing strong cooperation with the rest of the world on climate change adaptation, and adopting new technologies that can decrease the negative impacts of climate change on agricultural productivity in Egypt.

The impact of climate change on food security in Africa has also been pointed out in many previous studies. Houcine Jeder *et al.* (2021), in a research paper titled "Smallholder farmers' perceptions and adaptation strategies to mitigate the effect of climate change in the oases of South-Eastern Tunisia", focus on the impact of climate change on arid regions in Tunisia by conducting an econometric analysis and using the technique of ordered and binary probit models. The results showed that the majority of oasis farms were exposed to an increase in temperature and drought frequency and a decrease in rainfall with changes in the timing of rains due to climate change. Moreover, it noted that variables such as education level, agricultural area, residence on the farm, land owner, and farmer membership in the agricultural development group are critical factors in encouraging oasis farmers to understand climate change impacts. So, this research suggests developing climate change adaptation strategies by focusing on the reinforcement of the adoption of the bottom-up approach in scientific and participatory ways with the actors involved.

Houcine Jeder *et al.* (2020), in a research paper titled "An econometric analysis for food security in Tunisia", focus on the food security issue in Tunisia, especially after the 2011 revolution. The econometric analysis of food security was conducted using the Vector Error Correction Model approach (VECM). The result showed the existence of a short-term causal relationship between food security and independent variables such as land, inflation, and food imports. Moreover, the results showed the existence of a long-term causal relationship between the dependent variables and the explanatory variables. So, this research recommended improving food security levels in Tunisia by controlling inflation, decreasing food importation, maintaining the land and improving its fertility, and enhancing adaptation strategies to climate change.

Luca Mulazzani *et al.* (2020), in a research paper titled "Food security and migration in Africa: a validation of theoretical links using case studies from literature", focus on the relationship between food security and migration. The purpose of the research is to put a general framework of this relationship for validation using the empirical literature on Africa. The author noted that a few common points can be confirmed for the continent according to its structural and familiar characteristics: different strategies based on opportunity costs or minimization of risk, including food security aspects, may emerge; individuals often migrate following household strategies; multi-nodal households are emerging; land grabbing and land tenure security represent important drivers to be considered; emergencies or critical situations often cause the erosion of women's rights. In many situations, the poverty trap prevents most food-insecure households from leaving marginal lands.

3. Data and methods

3.1. *Data sources*

The data was collected from different sources, like the Food and Agriculture Organization of the United Nations (FAO), the World Bank (WB) the Climate Change Knowledge Portal (CCKP), the Population Pyramid, Country Economics, and the Intergovernmental Panel on Climate Change (IPCC). The main limitation of this study is that only secondary data has been used. Conducting a survey across governorates could have strengthened the study, but it was avoided due to the high financial cost required to gather accurate primary data.

3.2. *Data variables*

Climate change and food security variables used in this research are as follows:

- *Maximum temperature*: is the highest temperature at a place in a given time period.
- *Minimum temperatures*: is the lowest temperature at that place in a given time period.
- *Precipitation*: is any liquid/frozen water that forms in the atmosphere and falls back to the Earth.
- *Relative humidity*: is a ratio, expressed in percent, of the amount of atmospheric moisture present relative to the amount that would be present if the air were saturated.
- *Food inflation*: is the rate at which the prices of food items increase or a general increase in the prices of goods and services in a country.
- *Crop yield*: is a measurement of the amount of agricultural production harvested/unit of land area.
- *Population growth*: refers to the increase in the number of individuals in a population in a particular year.
- *Youth female literacy rate*: is the females ages 15–24 who can both read and write with an understanding of a short simple statement about their everyday life.
- *Unmanaged sanitation and unsafe water*: are people using unimproved sanitation facilities that are not shared with other households and where excreta are unsafely disposed of *in situ*.

- *Poverty rate*: is the mean shortfall in income or consumption from the poverty line $3.65 a day.
- *Child malnutrition*: is a pathological state resulting from inadequate nutrition, including undernutrition (protein-energy malnutrition) due to insufficient intake of energy and other nutrients; overnutrition (overweight and obesity) due to excessive consumption of energy and other nutrients; and deficiency diseases due to insufficient intake of one or more specific nutrients such as vitamins or minerals or etc.

3.3. *Descriptive statistics (adding table)*

Descriptive statistics were conducted to describe or summarize the characteristics of the data for all variables mentioned earlier (see Table 1). It includes three main categories of measures:

- *Measures of central tendency*: summarize the center of the data set, like mean, median, and etc.
- *Measures of variability*: summarize the dispersion of the data set with terms like variance, standard deviation, minimum, maximum, kurtosis, and skewness.
- *Measures of frequency distribution*: the occurrence of data within the data set as count.

3.4. *ARIMA model*

The Box-Jenkins or Autoregressive Integrated Moving Average (ARIMA) method is considered one of the most essential methods that are used for forecasting in time series because it differs from other forecasting methods in that it does not assume the existence of any specific pattern for the historical data of the time series that it predicts, and the appropriate model is chosen by comparing the distributions of correlation coefficients. In the case of differences between the estimated values and the historical data, where they are small, have a normal distribution, and are independent of each other.

The ARIMA model was introduced by George Box and Gwilym Jenkins in the 1970s to describe changes in the time series using a mathematical approach. ARIMA models are based on the assumption that past values have some residual effect on current or future values. In addition, the model is based on an adjustment of observed values to reduce the difference between the values produced by ARIMA model and the observed ones as close as possible to zero. In addition, it can describe the behaviors of stationary and non-stationary series (dynamic model).

The following are the ARIMA model components:

- Autoregression (AR): refers to a model that shows a changing variable that regresses on its own lagged, or prior, values.
- Integrated (I): represents the differencing of raw observations to allow for the time series to become stationary (i.e., data values are replaced by the difference between the data values and the previous values).
- Moving average (MA): incorporates the dependency between an observation and a residual error from a moving average model applied to lagged observations.

A prediction model is built using the Box-Jenkins (ARIMA) method in four stages, as follows:

- *Stage one is "knowing the model"*: a specific mathematical model (ARIMA) is selected based on some statistical measures that distinguish one model from another and on the experience derived from studies and research.
- *Stage two is "model estimation"*: after nominating one or more suitable models to describe the observed time series, we estimate the parameters of this model from the observed data using statistical estimation methods for time series.
- *Stage three is "diagnosing and testing the model"*: check tests are conducted on the differences to see the extent to which the observations correspond to the values calculated from the candidate model and the validity of the hypotheses of the model.
- *Stage four is "forecasting"*: graphical model – Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) – is used to generate future forecasts and then calculate prediction errors as new values are observed from the time series and monitor those errors.

The ARIMA equation for predicting y takes the following form:

$$\hat{y}_t = \mu + \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} - \theta_1 e_{t-1} - \ldots - \theta_q e_{t-q}$$

Where, ($\hat{y}_t$) is the year to be forecast, (μ) is the constant, φ_k is the AR coefficient at lag k, θ_k is the MA coefficient at lag k, and $e_{t-k} = y_{t-k} - \hat{y}_{t-k}$ is the forecast error that was made at period $_{t-k}$. Notice that the MA terms in the model (the lags of the errors) are conventionally written with a negative sign rather than a positive sign (this is the convention that was established by Box and Jenkins).

Non-seasonal ARIMA model parameters are (p, d, and q). Where, p is the number of autoregressive terms, d is the number of non-seasonal differences needed for stationarity, and q is the number of lagged forecast errors in the prediction equation. Y denote the dth difference of Y, which means: If d=0: yt = Yt, If d=1: yt = Yt − Yt−1, and If d=2: yt = (Yt − Yt-1) - (Yt−1 − Yt−2) = Yt – 2Yt−1 + Yt−2.

The forecasting equation in ARIMA (1,0,0) case is as following: $\hat{y}_t = \mu + \phi_1 y_{t-1}$, in ARIMA (0,1,0) case $\hat{y}_t = \mu + y_{t-1}$, in ARIMA (1,1,0) case $\hat{y}_t = \mu + y_{t-1} + \phi_1 (y_{t-1} - y_{t-2})$, in ARIMA (0,1,1) case $\hat{y}_t = \mu + y_{t-1} - \theta_1 e_{t-1}$, in ARIMA (0,2,1) or (0,2,2) case $\hat{y}_t = 2y_{t-1} - y_{t-2} - \phi_1 e_{t-1} - \phi_2 e_{t-2}$, and etc.

4. Results and discussion

This study will estimate the impact of climate change on food security in Egypt by examining the relationship between climate change and food security dimensions; in which food availability is affected by food production, food access is affected by food price inflation, food utilization is affected by elevated CO_2, and food stability is affected by food availability, food access, food utilization, and population growth.

4.1. *The impact of climate change on food availability in Egypt*

Crops are sensitive and vulnerable to climate change, in which increases in temperature and changes in precipitation have a negative impact on crop yields. According to the results obtained from the ARIMA model for climate change variables, in Egypt, it is expected to see an increase in maximum temperature by 0.8 degree Celsius, minimum temperature by 0.7 degree Celsius, precipitation by 3.7 millimeters, and almost constant relative humidity by 2070. Moreover, the impact of climate change on crop yields was estimated by using multiple linear regression analysis for three strategic crops, which are wheat, maize, and rice, based on the changes in temperature and precipitation by 2070. The results showed that increasing temperatures by 0.8 degree Celsius and precipitation by 3.7 millimeters will reduce the yields of wheat by 8.1%, maize by 9.7%, and rice by 2.1%.

The author combines those obtained results with Scenarios of Shared Socio-Economic Pathways (SSPs): SSPs are scenarios of projected socio-economic global changes up to 2100 that are used to generate greenhouse gas emissions scenarios with various climate policies. Since the climate change pathways cannot be predicted, there will be a reduction in yields of wheat from 16.4% up to 24.5%, maize from 19.4% up to 29.1%, and rice from 4.1% up to 6.1% by 2070. As a result, rising temperatures combined with changes in precipitation over the next 50 years would pose significant risks to Egypt's agricultural production (food availability will be negatively impacted by climate change).

4.2. *The impact of climate change on food access in Egypt*

Climate change has a negative impact on food availability because it reduces agricultural food production, resulting in higher food prices. Additionally, the rapid population growth rate causes more pressure on food demand, leading to more inflation in food prices in Egypt. According to the results of the ARIMA model for Egypt food indices, food prices in Egypt are expected to rise by 13.5% by 2070 (this increase in food prices is due solely to the impact of climate change). Because the population growth rate cannot be predicted, the author combines this obtained result with various population growth rate scenarios; based on the increase in population growth rate by 2070, food prices will rise by 15.7% to 18.9%. Therefore, increasing the food prices in Egypt during the next 50 years would lead to an increase in the number of people undernourished and a decrease in the average per capita food intake (food access will be negatively affected by climate change).

4.3. *The impact of climate change on food utilization in Egypt*

The problem is not only decreasing access to food due to the impact of climate change (reduction in food production), but also decreasing the nutritional quality of foods available due to elevated CO_2 (the main factor contributing to climate change). Climate change affects food utilization by increasing child malnutrition (Nelson *et al.*, 2009) and increasing obesity and diabetes (Alexander R. Zheutlin *et al.*, 2014). According to the results obtained from the ARIMA model for CO_2 emissions (2021-2070) and multiple linear regression for child malnutrition and adult obesity, it is expected that the percentage of children under the age of 5 who are overweight in Egypt will increase from 17.8% in 2020 to 21.2% in 2070. Moreover, it also expected an increase in the prevalence of obesity in the adult population (18 years and older) in Egypt from 40.0% in 2020 to 53.1% in 2070. Therefore, climate changes have a negative impact on food utilization by affecting the quality of air, water, and foods (which in turn are consumed by humans), leading to dangerous consequences for human health.

4.4. *The impact of climate change on food stability in Egypt*

Since climate changes have a negative impact on food availability by reducing agricultural productivity, access to food through rising food prices, and food utilization by lowering the nutritional quality of foods, food stability will be insecure and unstable (Hashem, 2020). Even in the case of stability on food availability, food access, and food utilization, there is another factor that can negatively affect the food stability dimension in the long run, which is the rapidly increasing population growth in Egypt, leading to a decrease in food security level (Kousar *et al.*, 2021).

According to the Population Pyramid database, Egypt's population is expected to grow from 104.2 million in 2021 to 193.2 million in 2070. The results obtained from a simple linear regression equation between population growth and food security show a negative relationship between population growth and food security level in Egypt, in which an increase in population growth tends to decrease food security levels, which means there is a negative relationship between population growth and food security. The study also showed that the prevalence of food security among the populations in Egypt will increase from 24.1 million in 2020 (food security level = 76.1%) to 51.7 million in 2070 (food security level = 73.9%). Therefore, climate changes have a negative impact on the food stability dimension by causing instability in food availability, access, and utilization, leading to a reduction in the level of food security in Egypt.

Table 1 - Descriptive statistics of the variables.

Descriptive statistics	*Max. temp.*	*Min. temp.*	*Rainfall (Prec.)*	*Relative humidity*	*Food inflation*	*Wheat yield*	*Maize yield*	*Rice yield*	*Child malnutrition*	*literacy rate*	*Poverty rate*
Mean	30	16	21	39	164	52927	60939	78185	11963182	41882591	60214542
Stand. Error	0	0	1	0	12	1866	2321	2487	546255	613289	1330934
Median	30	16	21	39	221	55994	61346	84152	11741500	42644500	60051713
Kurtosis	0	0	0	0	-1	-1	-2	-2	-1	-1	1
Range	3	3	24	4	212	37422	47913	50073	8288000	8381000	24798736
Minimum	29	14	11	36	21	31175	35792	50677	7752000	37961000	48182093
Maximum	32	17	35	41	233	68597	83705	100750	16040000	46342000	72980829
Sum	1478	746	1025	1905	8012	2593404	2986023	3831053	263190000	921417000	1324719916
Count	49	49	49	49	49	49	49	49	22	22	22

Source: Author.

Table 2 - ARIMA model results based on climate change variables.

Variable	*Estimates*	*Differencing, Number of observations, and Residuals*	*Ljung-Box (P-Value)*
Maximum Temperature*	*Type* *Coef* *SE Coef* *T* *P* AR 1 -0.7535 0.1377 -5.47 0.000 AR 2 -0.3229 0.1377 -2.34 0.023	Differencing: 1 regular difference, No. of observations: 52, Residuals: SS = 8.1, MS = 0.16, DF = 49	0.59
Minimum Temperature*	*Type* *Coef* *SE Coef* *T* *P* AR 1 -0.7535 0.1377 -5.47 0.000 AR 2 -0.3229 0.1377 -2.34 0.023	Differencing: 1 regular difference, No. of observations: 52, Residuals: SS = 7.9, MS = 0.16, DF = 49	0.64
Precipitation*	*Type* *Coef* *SE Coef* *T* *P* AR 1 -0.8862 0.1083 -8.18 0.000 AR 2 -0.6548 0.1084 -6.04 0.000	Differencing: 1 regular difference, No. of observations: 52, Residuals: SS = 1136.7, MS = 23.2, DF = 49	0.97
Food Inflation**	*Type* *Coef* *SE Coef* *T* *P* AR 1 0.4723 0.0607 7.78 0.000 AR 2 -0.2478 0.0608 -4.08 0.000 MA1 0.9829 0.0007 1385 0.000	Differencing: 2 regular differences, No. of observations: 264, Residuals: SS = 903.2, MS = 3.501, DF = 258	0.06

** Source: Data collected from CCKP database and analyzed using Minitab Software, Version 16.*
*** Source: Data collected from FAO database and analyzed using Minitab Software, Version 16.*

Table 3 - MLR Analysis results based on variables affected by climate change variables.

Variable	*Regression Equation*	*R^2*	*R^2 (adj.)*
Wheat Yield	- 405688 + 206 Maximum Temperature + 17689 Minimum Temperature - 348 Precipitation + 4732 Relative Humidity	69.1%	66.4%
Maize Yield	- 277075 - 13626 Maximum Temperature + 32413 Minimum Temperature - 941 Precipitation + 6789 Relative Humidity	67.8%	65.0%
Rice Yield	- 373304 - 6732 Maximum Temperature + 29235 Minimum Temperature - 724 Precipitation + 5518 Relative Humidity	71.9%	69.6%
Child Malnutrition	- 8114872 - 0.298 Female literacy rate + 0.085 Unsafe water + 0.134 Poverty + 16.6 CO_2	92.4%	90.6%

Source: Data collected from FAO database and analyzed using Minitab Software, Version 16.

Table 4 - Impact of climate change on food security dimensions in Egypt under different scenarios.

Dimension	*Variable (2020)*	*Scenario (2070)*	*Impact/Effect (%)*
Food Availability	Wheat (hg/ha) = 65682 Maize (hg/ha) = 71409 Rice (hg/ha) = 88298	Wheat (hg/ha) in 2070 = 60305 Maize (hg/ha) in 2070 = 64473 Rice (hg/ha) in 2070 = 86490	Wheat = 8.19% to 24.5%* Maize = 9.71% to 29.1%* Rice = 2.05% to 6.1%*
Food Access	Population growth rate = 1.3%	Population Increases by 1.67% Population Increases by 1.94% Population Increases by 2.35%	Food Inflation 13.5% Food Inflation 15.7% Food Inflation 18.9%
Food Utilization	Children overweight = 17.8% Obesity in the adult = 40.0%	Increase in CO_2 Concentration Level (2.5% ~ 4%) by 2070	Ch. overweight = 21.2% Ob. in the adult = 53.1%
Food Stability	Food security level = 76.1%	Increase in population growth from 104 to 193 million	Food security level = 73.9%

Source: Data collected from FAO database and analyzed using Minitab Software, Version 16

5 Recommendations and conclusions

Depending on the results obtained by this study, there is no doubt that climate change has a negative impact on food security dimensions in Egypt, and without paying more attention to this issue, the economic, social, and environmental costs will be destructive and cannot be irreversible. Therefore, the study recommends designing and applying a national adaptation strategy for the sectors with the highest potential to be negatively affected by climate change, particularly the agriculture sector, water resources, and health, and then developing this adaptation strategy based on different climate change pathways to adopt a range of actions needed based on each scenario to reduce the potential negative impact of climate change on food security dimensions. The study also recommends establishing and activating a new comprehensive legal framework to increase cooperation between the government, non-governmental organizations, and stakeholders, raise awareness of the climate change phenomenon, and reduce the impact of severe climate change on the dimensions of food security. Moreover, significant attention needs to be given to investment in adaptation options such as clean technologies and training stakeholders on using them to reduce polluting emissions that cause climate change. It is also recommended to invest in agriculture sector adaptation options such as improving crop traits, improving soil fertility, managing water, and providing crop protection. Finally, Egypt must establish strong cooperation with the rest of the world on climate change adaptation.

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