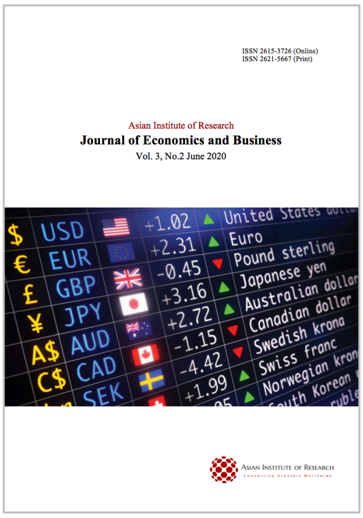

Journal of Economics and Business

Hashem, Eman Ahmed. (2020), The Impacts of Climate Change on Food Security - Case Study: Egypt. In: *Journal of Economics and Business*, Vol.3, No.2, 868-884.

ISSN 2615-3726

DOI: 10.31014/aior.1992.03.02.244

The online version of this article can be found at:
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The Asian Institute of Research
Journal of Economics and Business
Vol.3, No.2, 2020: 868-884
ISSN 2615-3726

DOI: 10.31014/aior.1992.03.02.244

The Impacts of Climate Change on Food Security – Case Study: Egypt

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Abstract
This study analyses the impacts of climate change on food security in Egypt. The study depends on using ARDL model (Auto regressive distributed lag model) in order to estimate the impacts of climate change on food security dimensions in Egypt. The study found that there is a negative and significant impact of temperature on food production as increasing temperature leads to decreasing some crops' production. Also, there is a positive and significant impact of temperature on food access as increasing temperature leads to increase food prices. These findings showed that unless sufficient adaptation, Egypt will suffer from negative effects on food production and food access and that will result in a high insecurity of food. This study reached a recommendation of enhancing a comprehensive adaptation system in order to lower the negative impacts of climate change on food security.

Keywords: Egypt, Food Security, Climate Change, Agro Biodiversity

Introduction

Food security is one of the most important challenges in all countries. The world food summit (1996) defines food security as "situation 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. "Food insecurity is a vital challenge that the Egyptian authority faces as 20% of Egyptian population have food insecurity.

According to Global Food security Index 2019, Egypt rank 55 out of 113 countries with overall score 64.5 that consists of food affordability 57.6, food availability 70.2 and quality & safety 65.9. Agricultural sector in Egypt represents about 17% of GDP of Egypt, employs 50% of the labor force and gives about 50% of the country's food. Therefore, any problems in the agricultural sector will have negative effects on food security that has a negative effect on national security and political stability. Climate change will lead to negative effects on the four dimensions of food security: food Availability, food access, food utilization and food stability.

This paper aims to investigate the impacts of climate change on food security. So, this study is organized as follows. Section 1 literature review to illustrate some of the previous studies that estimate the impact of climate change on food security. Section 2 discuss the impacts of climate change on the 4 dimensions of food security (food availability, food access, food utilization and food stability). Section 3 Illustrates the impacts of Agro biodiversity on food security. Section 4 illustrates different estimates of costs of adaptation to climate change. Section 5explainsn the situation of food security in Egypt and the impact of climate change on the 4 dimensions of food security. Section 6explainsn adaptation cost in Egypt and climate finance and section estimateste the impacts of climate change on food security in Egypt through ARDL model (Autoregressive distributed lag) model.

1. literature Review

(Laila Yassin, 2016), this study concentrates on the effect of climate change on food security by focusing on the agricultural sector and the food production system in Egypt. This study depends on deep interviews with people who are specialized in the agricultural field from governmental, local and international organizations.

This study investigates the agricultural system and the problems that the system faces because of climate change. In addition, this study also analyses management of adaptation policies in order to lower the negative impacts of climate change on food security in Egypt. This study reached that the current mechanisms are not efficient due to absent legal policy, no coordination among stakeholders and the low standard of awareness. The study did a recommendation of enhancing a clear comprehensive legal policy that may lead to enhancing cooperation among different stakeholders. There is also another study (Fahim M.Aet altal, 2013) which analysed effects of climate change by relying on findings in the field study and results of projects activity in Egypt.

Risks analysis of climate for crops in food insecurity areas in Egypt was done to know priorities of adaptation relying on statistical models of crops and projections of climate for 2030. The findings of the study show that unless good measures of adaptation, Egypt will suffer from negative effects on a lot of important crops for a lot of people who suffer from food insecurity. There is also a study of (Helmy M. Eid & et. al, 2007) which analyses the effects of climate change on net revenues of farms in Egypt. This study depended on a regression model of net revenues of farms in case of a lot of variables such : climate, soil. Socio economic and hydrological in order to know the variables that have effects on net revenues of farms. A survey was conducted by doing interviews for 900 households in 20 governorates.

The findings indicated that raising temperature will be a constraint on production of agriculture sector in Egypt. Technology and irrigation are recommendations for adaptation. Warming also has an impact on water resources and may be other obstacle for production of agriculture sector. Another study (Matto Bocci & et. al, 2019) examined the effects of climate change on agriculture sector in the Eastern countries (Egypt, Israel, Lebanon, Jordan and Palestine) and Western countries (Morocco, Algeria and Tunisia) of the Southern Mediterranean. The study reached that there are depressing effects of climate change on the agriculture sector and may increase in the future especially the negative effects on water resources & agricultural systems.

The study recommended that support of policies for adaptation is a solution in order to lower the negative effects of climate change on the agricultural sector, increasing the need for increasing national technical capacity for assessing and planning the needs of local systems of farming in plans and policies of development on the sectorial side. Finally, studies that analyses the impacts of climate change on food security in Egypt are limited, therefore this study tries to estimate the relationship between food security (food availability through food production and food access through food inflation) and climate change (temperature & CO_2 emissions). It also tries to analyses policies of adaptation of agriculture sector in order to lower the negative impacts of climate change on food security.

2. The Impacts of climate change on food security

The Food and Agriculture organization (FAO) defines food security as a “food security exists when all people at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (FAO, 1996). This definition consists of four components of food security: food availability, food access, food utilization and food stability.

2.1 Impacts of climate change on food Availability

Food availability means availability of sufficient food quantities on a stable way. It includes production, processing, packing, transport, storage of food and all necessary systems included in doing those procedures (USDA, 2015: 53). Variability of climate has a direct impact on production of agriculture sector, because of sensitivity of agriculture sector to conditions of climate and its vulnerability to risks and effects of global climate change (Greg E Edame & et al, 2011: 211). Climate change has an indirect impact on production of agriculture sector by having an effect on growth and income distribution and therefore affects the demand of agricultural products (Josef Schmidhuber & Francesco N. Tubiello, 2007: 19703).

Effects of climate change on food availability have been analyzed in several studies. RSIS policy brief[1] discuss potential consequences of disturbances of climate change on crops and global production by 2030, 2050 and 2080. This report showed that by 2030, stress of heat can lead to significant decreases in quantities of rice production in South and Southeast Asia. Temperatures of warmer nights affect rice yield in a greater negative way. +1ºC above critical temperature (>24 C) may cause 10 % decrease in grain yield and biomass.

By 2030, production of rice in North eastern Thailand can be decreased by up to 17.8% without adaptation. Increasing world temperature will have an effect on production of wheat in all countries that produce wheat. As an example, In India, heat by 2050 will lead to decrease of 50% of its growing area of wheat. A temperature rise of 20 c in India could lower yield of rice by about 0.75 tons per hectare in the areas that have high yielding.

This study explained that yield of wheat will be decreased by – 24.1 ± 7.1 percent between 2050 and 2080 in South East Australia. Warm temperatures can lead to depressing changes of yield from -25 to -29 percent. And by 2080, North East Thailand may have a depressing yield in changes of rice from 8.6 to – 32.2 percent. Nelson (2009) also shows findings that analyze the effects of climate change and evaluate the results for food security.

Increasing temperature and rainfall systems changes affect yields of crop directly and indirectly by changes of irrigation water. Climate change in developing countries will lead to decreases in yield for the most vital crops. Irrigated Wheat and rice are the most crops affected. On average, yields of developing countries are affected more than those in developed countries. 2050 availability of calorie is not only less than the no climate change. It lowers relative to 2000 levels throughout the whole world. In a developing country, the average consumer decrease is 10 percent relative to 2000. The decreases with fertilization of co2 are 3 percent to 7 percent less severe but are still high relative to scenario of no climate change. Study of (Ray D.K & et al, 2009) constructed linear regression relationships relying on data of weather and reported crop to estimate the expected effect of climate change on the yields of the top world crops.

The study found that yields of crops are expected to lower according to climate change scenario. They result that the effect of world climate change on yields of various crops from trends of climate was from -13.4% (oil palm) to 3.5% (soybean). For the top three world cereals, yields have lowered for rice (-0.3%) or -1.6 million tons yearly and wheat -0.9% or -5 million tons yearly and 0% for maize. This shows a yearly 0.4%, 0.5% and 0.7% decline in consumable calories of food available from rice, wheat and maize respectively.

2.2 Impacts of climate change on food Access

Food access is achieved when all people have enough resources to get food by sufficient amount, quality and varieties in order to reach nutritious diet. This relies on the quantity of people resources and prices (Ray D K, 2019: 1). Access to food is affected by climate change in a negative way because of a decrease of production of agricultural sector, increasing prices of food and lowering purchasing power. The impacts of climate change could cause a decrease in incomes and an increase in prices of food and that influences economic access of persons, especially poor persons, to food.

[1] Paul P.S. teng & et al (2015), Impact of climate change on food production: options for Importing countries, RSIS , policy brief.

Climate change could also affect rural incomes, as agriculture sector is highly sensitive to climate change, temperature and rainfall changes can lower rural incomes (Jobbins G. & Henley G., 2015: 8). Study of (Nelson, 2010) indicates that increasing prices is a sign of imbalances between demand and supply and increasing scarcity of resources because of factors of demand like increasing population and income, or factors of supply like decreased productivity because of climate change. The study estimated that real prices will raise by 87- 106 % for maize, 55-78% for rice and 54-58% for wheat by 2050 relative to the 2010 baseline because of the effects of climate change.

Another study by FAO[2] assesses the negative impact of climate change on food prices, with a lot of the raises from 5-25% in 2050. A study of (Hertel & et al, 2010) shows that price of a lot of staples increases by 10- 60% by 2030 and rises levels of poverty by 20-50% in many areas of Africa and Asia under these changes of prices. This paper shows three scenarios of effects of climate change on agricultural sector by 2030 (effects leading to low, medium or high productivity) and asses the changes in world prices of goods, national economic welfare and poverty in 15 developing countries. There is also a study of (Ivanic & Martin, 2008) that showed the relationship between increased world prices of food and poverty. By doing an approach of ten detailed surveys, the study evaluates the effect of increased prices of food on poverty in nine low income countries. The results show that raising of prices of food lead to an increase in poverty in low income countries. The average of the estimated impacts on national rates of poverty (US 1$/ day) in the sample is a rise of 4.5 percentage. It is translated to a rise in the poverty of 105 million people (out of 2.3 billion people in low income countries).

2.3 Impacts of climate change on food Utilization

Food utilization means that there is an access of persons to an enough diverse amount of food to meet their needs. Food utilization is the capability of persons of using the food they access well. This will be done by a sufficient diet, clean water, sanitation and health care which will lead to meet all their needs whether physiological or nutritional needs. Climate change will negatively affect food utilization through impacts on human health and illnesses spread in areas which did not have previous effects. Climate change will raise hunger and malnutrition because climate change will negatively affect farmers, forest dependent and fishers living conditions. Therefore, hunger and malnutrition will rise (Greg E. Edame, 2011: 214).

A study of (Nelson & et al, 2009) discussed that climate change increases child malnutrition and lower consumption of calorie. This study assessed that a decrease in availability of calorie will lead to a rise in malnutrition of children by 20 percent by 2050 comparative to the scenario that does not have climate change. Climate change will lead to a decrease in the improvement in child malnourishment levels that may happen in the case of not having a climate change. There is another study (Jobbins G. & Henley, 2015) which analysed problems that nutrition and food utilization face like illnesses from infections and poor quality of water. Diarrheal illness has a correlation with raising temperatures and poor quality of water can come from droughts & floods. This paper found that malnourished children under age of five years in MENA countries were estimated to decrease from 3 million to 1 million between 2000 and 2050. However, 2 million malnourished children could continue by 2050 as a result of climate change.

Another study (Simon J. Lioyed & et al, 2011) depended on data of current national availability of food and nutrition to estimate a world model, by relying on a way driven approach depended on approximation of the relationship between food lack and stunting. This study found that climate change will rise a moderate stunting of 1-29% in 2050 relative to scenario of future with no climate change. Climate change will lead to a higher effect on severe stunting rates, which are estimated will rise by 23% central SSA to 62% South Asia.

2.4 Impacts of climate change on food stability

Food stability indicated security of food as all persons must have access to sufficient food for all times. They should not have a risk of not getting access to food as a result of sudden shocks like economic or climatic crisis

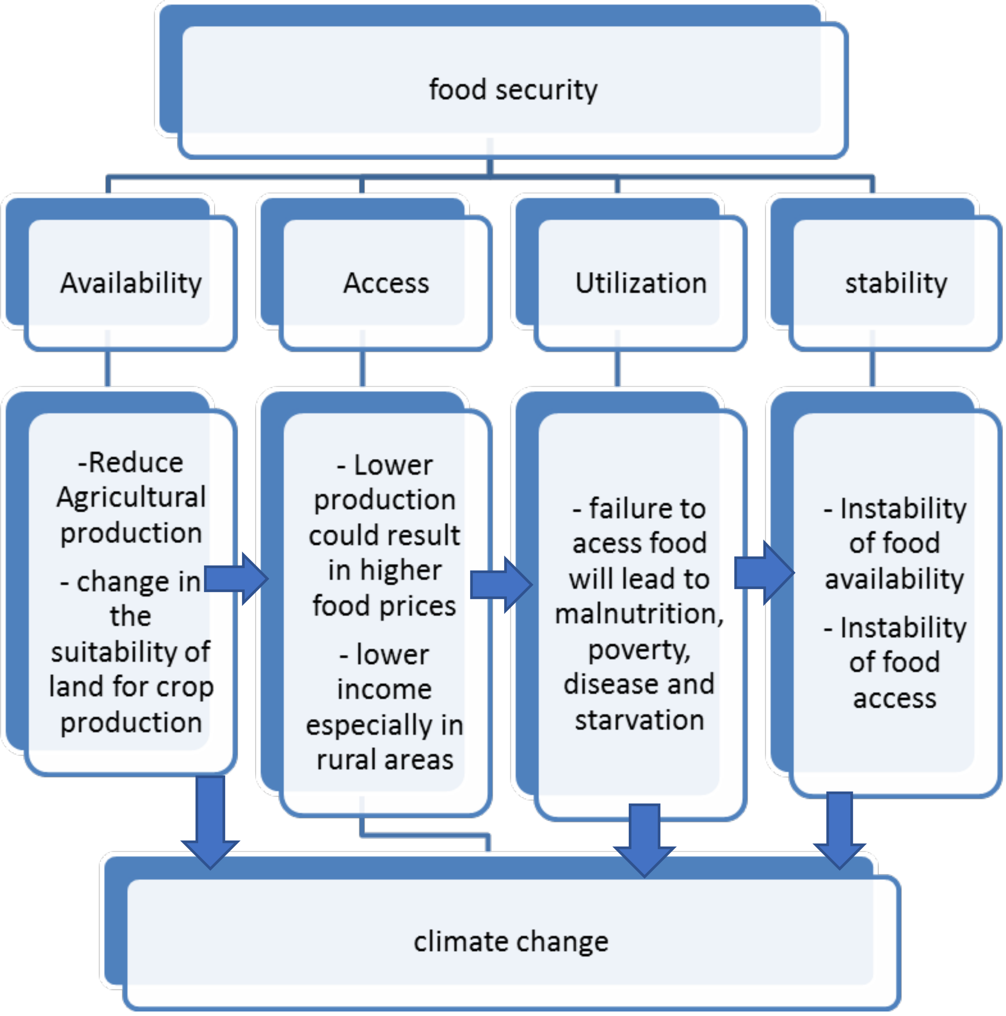
[2] FAO (2018), how climate change may affect global food demand and supply in the long term, FAO, Global perspective studies team

or cyclical problems like seasonal insecurity of food (FAO, 2006: 1). The term stability is concerned with the dimensions of food security: availability and access to food. Agriculture is having vulnerability to external shocks like economic crises, raises of prices of food and emergencies like droughts, floods, pests and outbreaks of illnesses.

Stability of food availability: several crops have yearly yields and cycles have fluctuations with climate change, especially rainfall and temperature. Droughts and floods are a special risk to stability of food and could lead to insecurity of food. They are estimated to be more frequent, more existed as a result of climate change. (Nathan Akila loks, 2015: 806)

Stability of food Access: world markets of food may have greater volatility of price. Which have an effect of returns' stability to farmers and access to buy food of poor persons who are farming and non farming. Climate change is related that availability and access to food can be more volatile in the future. So, achieving a stable availability and access of food can only by attained by suitable adaptation and mitigation of climate change.

Figure 1: The Impacts of climate change on food security



3. The Impacts of Agro biodiversity on food security

Biodiversity of agricultural sector, also. Named Agro- biodiversity, is a vital sub set of biodiversity. Agro biodiversity is component of biodiversity concerned with agricultural sector and food production and non food natural resources. FAO[3] defined Agro biodiversity as "the variety and variability of animals, plants and micro-

[3] FAO (2004), what is Agro biodiversity?, available at http://www.fao.org/tempref/docrep/fao/007/y5609e/y5609e00.pdf

organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries. It comprises of diversity of genetic resources (varieties, breeds) and species used for food, fodder, fibre, fuel and pharmaceuticals. It also includes the diversity of non harvested species that support production (soil micro- organisms, predators, pollinators) and those in the winder environment that support agro ecosystems (agricultural, pastoral , forest and aquatic) as well as the diversity of the agro- ecosystems."

3.1 Agro- Biodiversity and food availability

Biodiversity of the agricultural sector is a means for production and supply of food. Farmers utilize biodiversity for crops' adaptation to various and changing environments of production. Biodiversity of agricultural sector is related to a greater production of agricultural sector and decreases risk (Salvatore di falco, 2012: 208). Agro biodiversity (biodiversity of the agricultural sector) makes a possibility of utilizing infertile land in a productive way, hence sharing in security of food for persons who are vulnerable to poverty and hunger and therefore to improves world production of farms. Genetic diversity is important for agricultural sector for adaptation to climate change and changes in the environment. For instance, crops that can tolerate heat and drought (Federal Ministry for Economic cooperation and development, 2011: 5).

Food and agriculture biodiversity can enhance production system resilience by lowering vulnerability to shocks, lowering their effects and supporting adaptation. Biodiversity increases resilience of production systems and livelihoods to shocks, involving to the impacts of climate change. It is important in efforts to enhance production of food while decreasing negative effects on the environment. It contributes to a lot of persons' livelihoods, often lowering food need and producers of agricultural sector to depend on external inputs that are costly and environmentally harmful. Systems of production that are not diverse can have more vulnerability to negative effects from shocks like illness and outbreaks of pest than those that are more diverse (FAO, 2019 A: 23).

3.2 Agro- Biodiversity and food Access

Agro biodiversity enhances the access of persons to food in various ways:

First: Agro biodiversity leads to increase production of agricultural sector. Enhancing production of agricultural sector leads to enhancing access of people of farm to food, by subsistence production of food and giving higher cash incomes that can be utilized to purchase food.

Second: natural ecosystems agro biodiversity can be a direct food source for people, especially for those who live inside or on such ecosystems fringes.

Third: natural ecosystems agro biodiversity can be cash incomes source for people, which can lead to enhance their access to food (FAO,2019 B: 17).

3.3 Agro- biodiversity and food utilization

Persons need to eat diets that are balanced to become healthy. Diets give them all the nutrients they want. Biodiversity is a source for making dietary diversity, which in turn is a key of good nutrition and health. (FAO,2018:47). Agro biodiversity leads to a different and wide range of nutrient foods and dietary parts with vital health specifies (Biodiversity International, 2011: 33). Management of biodiversity plays an important role in enhancing practices of sustainable agricultural enhancing and policies against malnutrition (Alvaro Toledo & Barbara Burlingame, 2006: 12). Biodiversity of agricultural sector has played an important role in achieving security of food nutrition, health, and livelihood all over the world.

3.4 Agro biodiversity and food stability

Biodiversity is important for stability, at level of a person and at large scales, in that the existence of a variety of food producing spices, varieties and breeds that have different cycles of life and different adaptive properties lead to keep supplies of food during year's seasons and during variations inter year in challenges of rainfall, temperature and illness. Biodiversity leads to stability by lowering the effects of disruptive challenges and risks like floods, droughts, illness and pest out breaks that may have an impact on production of food. Biodiversity can also lead to keep income stability in the case of risks related to market (FAO, 2019 A: 53).

4. Costs of adaptation to climate change

4.1. Different estimates of costs of adaptation to climate change

Several of analysts have tried to estimate the adaptation costs for the world and for developing countries. Report of UNFCCC (2007) found that need of finance for adaptation could be to 49$- 171$ billion annually by 2030 for the world, of which 27$- 60 $ billion would be in developing countries.

Table 1: costs of adaptation to climate change- UNFCCC

sector	Global cost	Developed countries	Developing countries
Agriculture	14	7	7
water	11	2	9
Human health	5	Not estimated	5
Coastal zones	11	7	4
Infrastructure	8-130	6-88	2-41
Total	49-171	22-105	27-66

This study concentrated on sectors of agriculture, forestry and fishery, supply of water, human health, coastal and infrastructure. The largest cost sector is investment of infrastructure that accounts for three quarters of overall costs. Another study (stern, 2006) relied on estimate of World Bank 2006 which depended on an estimate of the current flows of finance development, merged with very rough estimates of the percentage of those investments that have sensitivity to risk of climate and the addition cost to lower that risk to account for climate change (5-20% was a very rough estimate)

Table 2: Estimate costs of adaptation- stern

Item	Amount per year	Estimated portion climate sensitive	Estimated costs of adaptation	Total per year (US$ 2000)
ODA and concessional finance	100 $ bn	20%	5-20%	1-4 $ bn
Foreign Direct investment	160 $ bn	10%	5-20%	1-3 $ bn
Gross domestic investment	1500 $ bn	2-10%	5-20%	2-3 $ bn
Total adaptation finance				**4-37 $ bn**

A study of (UNDP, 2007) analysed the requirements of funding in 2015 for adaptation to climate change as follows:-

a) Development investment of climate proofing: fulfilling detailed costing exercises for existing infrastructure protection. Building on the methodology of World Bank, climate proofing development investment and infrastructure costs are at least US $ 44 billion yearly by 2015.
b) Adapting programs of reducing poverty to climate change: the incremental risks made by climate change require a more extensive reaction involving public health support, development of rural and community relied on protection of environment. The aim of 2015 should be a commitment of at least US 40 $ billion annually that is around 0.5% of GDP for low income countries for enhancing programs of social protection and increasing aid in other key areas.

c) Enhancing the response system of disaster: provisions should be done for a rise in a disaster response related to climate of 2$ billion annually in bilateral and multilateral aid by 2015 to prevent development aid diversion.

Table 3: Investment in adaptation to climate change- US billion 2015

Climate proofing development investment	44
Adapting poverty reduction to climate change	40
Strengthening disaster response	2
Total	**86**

A study of (World Bank, 2010) found that the cost of adaptation between 2010 and 2050 to an about 2^{o} c warmer world is between 70$ billion to 100$ billion annually by 2050. This study has used the additional costs of public sector that will be wanted for countries for adaptation to climate change through 2 scenarios. The drier scenario (CSIRO) wants less total cost of adaptation than does the wetter scenario (NCAR), due to the less costs of infrastructure, that out weight the greater costs for management of water and flood. The paper included agriculture, forestry, fisheries, infrastructure, resources of water, health, coastal areas and extreme events of weather sectors.

Table 4: World Bank study scenarios

	NCAR (Wettest)	CSIRO (driest)
Infrastructure	27.5	13.0
Coastal zones	28.5	27.6
Water supply& flood protection	14.4	19.7
Agriculture, forestry, fisheries	2.5	3.0
Human health	2	1.5
Extreme weather events	6	6.4
Total	**81.5**	**71.2**

A report by (UNEP 2016) assessed that adaptation costs are two to three times greater than previous world estimates by 2030 and four to five times greater by 2050. This study showed that adaptation costs could be between US $ 140 billion and US $ 300 billion by 2030 and from US$ 280 billion to 500 $ US billion by 2050. However, overall bilateral and multilateral funding for a climate change adaptation achieved US$ 25 billion in 2014, of which US$ 22.5 billion related to developing countries. Most funding come from institutions of development funding (US $ 21 billion or 84 percent and 26 percent of the overall cost respectively). Developing countries in East Asia and the pacific have almost half of the finance (some 46 percent of the overall finance). Over half of the overall funding (55 percent) is related to management projects of water and wastewater.

4.2 Why cost Estimates differ?

There have been various estimates of adaptation costs to climate change.

Table 5: Estimates of the costs of adaptation to climate change

source	**Cost of adaptation in US $ billion**	**comments**
World Bank (2006)	9-41 by 2009	Cost of climate proofing FDI, GDI and ODA flows
Stern (2006)	4-37 by 2009	Update with slight modification of world bank 2006
UNDP (2007)	86-109 by 2015	World bank 2006 plus costing of climate proofing poverty reduction strategies and better disaster response
UNFCCC (2007)	49- 171 by 2030 (of which 27-66	This estimate aggregates costs from

	bn in developing countries)	sectoral studies of agriculture, water, human health, coasts and infrastructure.
Oxfam (2007)	50 billion by 2009	This estimate is based on world bank 2006 but adds additional costs derived from developing country National Adaptation programs of Action (NAPAS) and civil society projects
World Bank (2010)	75-100 bn (2010-2050)	Higher estimates under the wetter NCAR scenario than the drier CSIRO scenario. Assumes a 2 degree warmer world.
UNEP (2016)	140-300 bn by 2030 280-500 bn by 2050	The cost of adaptation are likely to be two to three times higher than previous global estimates by 2030 and potentially four to five times higher by 2050

The above studies indicate a large range of adaptation cost with the lowest at 4$ billion and the highest at above 300$ billion. The estimates indicate that tens of billions of dollars annually will be wanted and the recent studies show that real costs may be greater. Generally, estimates are extremely not certain because of unknown impacts of climate change. The various estimates are closely correlated in methodology. A lot of studies are relied on the ways determined in World Bank 2006 that concentrates on the cost of financial flows of climate proofing for development. More new studies have tried to take an approach of sector by sector to estimate the cost of adaptation. There are some factors that affect the estimation cost of adaptation and the causes why cost estimates differ.

a) **Coverage:** adaptation cost relies on the sectors and risks coverage. Studies with larger coverage will lead to greater estimates as they involve a large number of effects.
b) **Goals and methods of Quantification:** adaptation costs estimates are affected by the aim or objective determined, and trade off degree between the effects of a climate change, adaptation costs and the residual costs after adaptation.
c) **Uncertainty:** studies that involve uncertainty consideration in general have greater costs in the case of comparing them with studies that do not involve it and use optimal policies. **(**UNEP ,2016**:** p14-16)
d) **The baseline:** It is important to define a baseline (the case without fulfilling an intervention of adaptation) and the project line (the case with successful application of adaptation) to know the costs by doing a comparison of the two cases. **(**UN,2010:20)
e) **Scales of time:** the costs' analysis timeframe choice of climate change adaptation will likely have an effect on the total estimates of cost, with a longer timeframe that makes higher costs than would a shorter one. The timeframe up to 2050 was determined as it expected climate change and its effects on the economy.

5. Food security and Climate change in Egypt

Agricultural sector is one of the greatest sectors in the Egyptian economy, representing 13.7% of GDP. Agriculture employs 30% of all labor force. Egypt is subject to problems resulting from climate change, studies show that Upper Egypt will be exposed to temperature raises from 1.5- 2 degrees by 2040, 1.9- 2.2 degrees by 2060 and 3- 3.5 degrees by 2100 (WFP, 2018: 23). Climate change will influence all four dimensions of food security: food availability, food access, food utilization and food stability.

5.1 Food Availability and climate change in Egypt

Production of food in Egypt will be affected by climate change through three ways:

First: raise in temperature will lower yields and production of food. A study by EEAA, 2010 shows projected crop yields changes, depended on several field studies, projected a decrease in the major crops' production in Egypt as a summary of a lot of studies.

Table 6: Projected changes in crop production of some major crops in Egypt under climate change

Crop	change	
	2050s	2100s
wheat	-15	-36
Rice	-11	
Maize	-14	-20
Soybeans	-28	
Cotton	+17	+31

Source: EEAA (2010), Egypt second National communication under the United Nations, Egypt Environmental Affairs Agency, Cairo.

All crops of which are predicted to lower except cotton. Yields of soybeans in Egypt predicted to lower by 28%, wheat to lower by 15% and Rice yields by 11%.

Second: Raise in temperature will properly increase water demand and irrigation change. A study of (Attaher & Medany, 2008) found that the requirements of water for crop of the essential strategic crops in Egypt are going to rise under climate change range from 5% to 13% during the 2100s.

Third: a rise in Sea level (sea level Rise SLR) could lead to low lying and unprotected agricultural lands along the Mediterranean coast which is the most productive agricultural area in Egypt. The impacts of sea level rise on the Nile Delta coast would lower the cultivated area and hence most likely have a negative impact on the productivity of agricultural sector.

There are also direct and indirect ways that climate change could influence production of food in Egypt. A climate change could impact pests and illness. Also, a world change in supply and demand for some crops could impact production in Egypt (UNDP, 2012: 18).

Table 7: food production in Egypt (1990-2017)

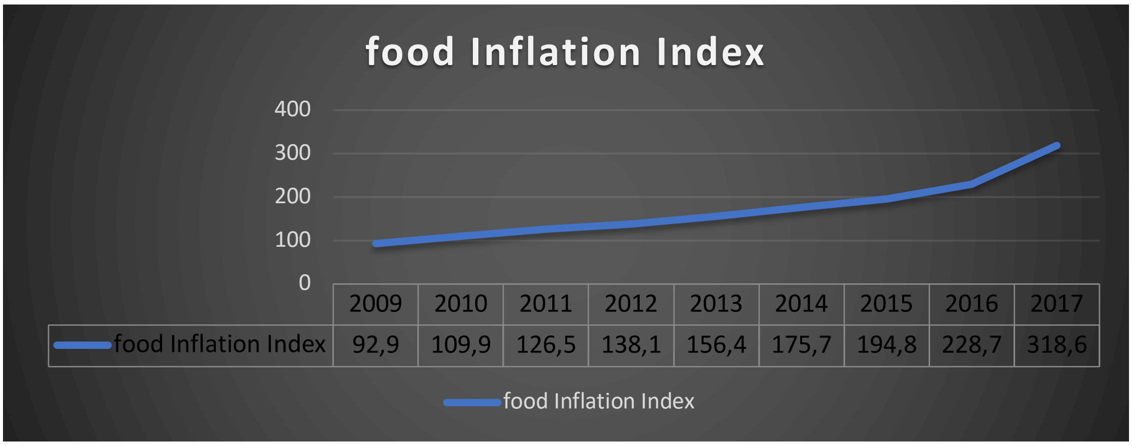
periods	Wheat			Maize			Rice		
	TQ 000 tons	Yield Ton/ha	GR	TQ 000 tons	Yield Ton/ha	GR	TQ 000 tons	Yield Ton/ ha	GR
1990-1999	5238	5.46	2.50	5313	6.48	3.34	4472	8.04	3.14
2000-2009	7376	6.45	0.10	6656	7.85	0.39	6239	9.65	0.77
2010-2017	8751	6.45	0.90	7774	7.63	-0.04	5472	9.43	-0.76

Source: CAPMAS, statistical yearbook

The land productivity rate of growth has decreased during (2000-2017). Yields of wheat, maize and rice at the national level grew by less than one percent yearly during (2000- 2017). The decrease in productivity of land can be due to the land fertility and water resources degradation and the decrease in government expenditure on Research and development of Agricultural sector (Hamdy Sayed & Dawn Thilmany, 2019: 4457)

5.2 Food Access and climate change in Egypt

Figure 2: Food Index in Egypt (2009-2017)



Source: CAMPAS

We found that prices of food in Egypt witnessed a remarkable increase. The developing countries involving Egypt have a problem of increasing prices of food. The Egyptian family's food expenditure increases from 34% of its income in 2015 to more than 37% in 2017/2018. For the change in the value of average family's spending on food prices during the period (2015- 2018), there is a rise by 34% at current prices while it lower by 16% at constant prices that shows that the rise is because of a rise in prices only. Climate change will lead to more pressure on already increasing prices of food. It is predicted that prices of food rise by 16% to 68% in 2030.

5.3 food utilization and climate change in Egypt

Lowering production of crops, which may cause from a climate change, may lead to a malnutrition rise. According to a demographic and health survey in 2014, only a small number of children in Egypt are consuming food which is in accordance with the recommendations of national and international health organization. The children percentage that is stunted ranges from a low of 15% in frontier governorates to a high of 30% in the urban regions of Upper Egypt. The prevalence of undernourishment as % of population lowered from 5.5 in 2000 to 4.4 in 2014 and then rose to 4.5 in 2017 (world bank database).

5.4 food stability and climate change in Egypt

Egypt is a country that has a deficit of food that leads to sensitivity of the system of food to fluctuations of world prices of commodity and foreign reserves' variability (WFP world food programme, 2018: 4)

Table (8): self sufficiency in the main food commodities in Egypt

Main food commodities	Production(1000 tons)	Requirements (1000 tons)	Self sufficiency
wheat	7388	13591	54.4
Rice	4553	3273	139.1
Maize	6300	11900	53.2

Source: Sustainable Agricultural strategy towards 2030.

Egypt depends on an import of 40% of its food that indicates inability of Egypt to meet the increased demand and highly relies on imports. The table above shows that Egypt is incapable of achieving self sufficiency of food. The increasing population without raising production of crops is a major problem as it indicates that the share of person of water and food will lower.

6. Climate Finance in Egypt

There is no sole definition of climate finance. However, the nearest definition is got by the United Nations framework convention on climate change which "finance its goals is lowering emissions and improving sinks of greenhouse gases and target to reduce vulnerability and maintaining and increasing the resilience of ecological systems and human to negative impacts of climate change" (UNFCCC, 2014).

6.1 Adaptation cost in Egypt

Two methods have been used to predict costs of adaptation in Egypt. **First**: the first method includes developing estimate of adaptation particularly for Egypt. The Egypt Environmental affairs agency published a study (National Environmental Economic and development) (NEEDS) for a climate change and predicted costs of adaptation for the sectors of agriculture and coastal. Its findings were an average yearly cost of 100$ to 270$ million (Ministry of state for Environmental affairs, 2013: 120-121).

Table (9): Estimated adaptation costs in Egypt- NEEDS study

Items	**Finance needed**	
	2020	**2050**
Observation & control of climate change	90	210
Land and agriculture production	311	948
Irrigation	2055	2150
Socioeconomic studies	16	28
Capacity building, enlightenment and training	17	51
Coasts and seashore regions	330	620
Total	**2819**	**4007**

Source: EEAA(2010), National Environmental, Economic and development study (NEEDS) for climate change, Egypt

Second: the second method is a top down method which depends on overall yearly adaptation costs estimates in all developing countries or regions. This method depended on two new published overall yearly adaptation costs estimates in all developing countries (UNFCCC 2007 and World Bank 2010). A very simple method for using these two studies to predict costs of adaptation in Egypt is to depend on an assumption that the predicted yearly adaptation costs by 2030 are spread equally among population in developing countries. There are around 6 billion persons in the developed countries. By depending on an assumption of receiving 8 million persons in Egypt the same percentage of finance of adaptation as all other persons, so yearly costs of adaptation in Egypt may be 400$ million to 1.2 $ billion.

Table (10): estimated adaptation costs in Egypt-2030 ($ million per year)

study	**Agriculture & Irrigation**	**Total adaptation**
NEEDS	2680	3215
UNFCCC 2007	74	400-960
World Bank 2010	N/A	1065-1200
Nelson et al 2009	57-65	N/A

We reached that the three predicted costs (UNFCCC, World Bank and Nelson &etal) are well under the predicted costs through the country relied on survey of NEEDS.

6.2 climate finance in Egypt

Egypt is a receiver of international climate finance from main donors whether are bilateral and multilateral. According to data of OECD, main funders were Japan 786$ million, EIB (European Investment Bank) 316$ million, World Bank 302 $ million, France 110$ million, GCF (Green climate fund) 84$ million, EBRD (European Bank for Reconstruction & Development) 81$ million and IFC (International finance corporation) 58$ million in 2016 (European Institute of the Mediterranean 2018: 33).

7. Estimate the Impacts of climate change on food security

To assess the impacts of climate change on food security in Egypt we use ARDL model (Autoregressive distributed lag) model. We estimate the impacts of climate change (temperature & CO2 emission per capita) on food availability (measured by food production Index), Food Access (measured by food inflation) and food utilization (measured by prevalence of undernourishments as % of population). Then investigate the impacts of biodiversity (measured by Red list Index) on the relationship between climate change and food security. Also forecast the expected value of food production index, food inflation and prevalence of under nourishment of population in 2030 and 2050

7.1 Descriptive Statistics for variables

Table 11: Descriptive Statistics

Variable	Mean	Std. Deviation	Minimum	Median	Maximum
Food production Index	86.696	24.989	43.180	86.696	124.980
co2emissionpercapita	1.889	0.397	1.284	1.889	2.483
Red list Index	0.939	0.019	0.906	0.939	0.973
Prevalence of under nourishment of pop	4.789	0.296	4.400	4.789	5.500
Food inflation food access	165.931	51.020	105.000	165.931	360.433
Temperature	23.055	0.506	21.778	23.055	24.728

The mean of the time series Temperature is23.055 while Median is 23.055 , Minimum is 21.778, Maximum is 24.728, Std. Deviation is 0.506. while for co2 emission per capita The mean is 1.889 while Median is 1.889, Minimum is 1.284, Maximum is 2.483, Std. Deviation is 0.397 The mean of the time series Red list Index is 0.939 while Median is 0.939, Minimum is 0.906, Maximum is 0.973, Std. Deviation is 0.019 The mean of the time series Food production Index is 86.696 while Median is 86.696, Minimum is 43.180, Maximum is 124.980, and Std. Deviation is 24.989 while for food inflation the mean is 165.931 while Median is 165.931, Minimum is 105.000, Maximum is 360.433, Std. Deviation is 51.020. The mean of the time series Prevalence of under nourishment of pop is 4.789 while Median is 4.789, Minimum is 4.400, Maximum is 5.500, Std. Deviation is 0.296

7.2 ARDL model estimation

First we will check stability using Augmented Ducky Fuller

Table 12: unit root test

Variable	level ADF	1different ADF	2different ADF
Temperature	-3.620*	-	-
prevalence of under nourishment of pop	-	-3.855*	-

food production Index	-	-5.500*	-
co2emissionpercapita	-	-6.003*	-
Food inflation food access	-3.498*	-	-
Red list Index	-	-4.961*	-

From the table above, There is stability for Temperature, food inflation variables in level 0 as the value of prob. is less than α=0.05. Also there is stability in time series of food production , Red list index and prevalence of under nourishment of pop , co2 emissions in level 1 , the value of prob. is less than α=0.05. We conclude that all series are stationary at most one difference so we will use ARDL model to detect the effect of independent variables on dependent variable.

Estimated model 1

Table 13: ARDL models

	Food production Index		Prevalence of under nourishment of pop		Food inflation food access	
	B	Prob.	B	Prob.	B	Prob.
co2emissionpercapita	-0.601	0.9542	-0.06393	0.3313	1.7543	0.0039
Temperature	-0.126	0.0009	0.000519	0.3231	0.015273	0.005

Food production Index=-0.60141(co2emissionpercapita) -0.12669(temperature)

The independent variable co2emissionpercapita had a non-significant effect on the dependent variable Food production Index where is the value of prob.=0.954 is more than α=0.05

The independent variable temperature had a significant effect on the dependent variable Food production Index where is the value of prob.=0.0009 is less than α=0.05 , when the temperature increase by one unit the Food production Index decreases by 0.12669

Prevalence of under nourishment of pop=-0.06393(co2emissionpercapita)+ 0.000519(temperature)

The independent variable co2emissionpercapita had a non-significant effect on the dependent variable Prevalence of under nourishment of pop where is the value of prob.=0.3313 is more than α=0.05

The independent variable temperature had a non-significant effect on the dependent variable Prevalence of under nourishment of pop where is the value of prob.=0.3231 is more than α=0.05

Food inflation food access=1.7543(co2emissionpercapita)+ 0.015273(temperature)

The independent variable co2emissionpercapita had a significant effect on the dependent variable Food inflation where is the value of prob.=0.0039 is less than α=0.05 , when the co2 emissions increase by one unit the Food inflation increase by 1.7543

The independent variable temperature had a significant effect on the dependent variable Food inflation where is the value of prob.=0.005 is less than α=0.05 , when the temperature increase by one unit the Food inflation increase by 0.015273

Estimating model (2)

Table 14: ARDL model

	Food production Index		Prevalence of under nourishment of pop		Food inflation food access	
	β	Prob.	B	Prob.	β	Prob.
co2emissionpercapita	-0.64221	0.952	-0.0089	0.9189	1.63509	0.0053
Temperature	-0.12888	0.0012	0.000747	0.2008	0.016148	0.003
Red list Index	-23.454	0.7959	1.83638	0.347	9.90288	0.1461

From the previous table, we can see that:-

Food production Index=-0.64221(co2emissionpercapita) -0.12888(temperature) -23.454(Red list Index)

The independent variable co2emissionpercapita had a non-significant effect on the dependent variable Food production Index where is the value of prob.=0.952 is more than α=0.05

The independent variable temperature had a significant effect on the dependent variable Food production Index where is the value of prob.=0.0012 is less than α=0.05 , when the temperature increase by one unit the Food production Index decreases by 0.12888

The independent variable Red list Index had a non-significant effect on the dependent variable Food production Index where is the value of prob.=0.7959 is more than α=0.05

Prevalence of under nourishment of pop=-0.0089 (co2emissionpercapita)+ 0.000747 (temperature)+ 1.83638(Red list Index)

The independent variable co2emissionpercapita had a non-significant effect on the dependent variable Prevalence of under nourishment of pop where is the value of prob.=0.9189 is more than α=0.05

The independent variable temperature had a non-significant effect on the dependent variable Prevalence of under nourishment of pop where is the value of prob.=0.2008 is more than α=0.05

The independent variable Red list Index had a non-significant effect on the dependent variable Prevalence of under nourishment of pop where is the value of prob.=0.347 is more than α=0.05

Food inflation =1.63509 (co2emissionpercapita)+ 0.016148 (temperature)+ 9.90288(Red list Index)

The independent variable co2emissionpercapita had a significant effect on the dependent variable Food inflation where is the value of prob.= 0.0053 is less than α=0.05 , when the co2 emissions increase by one unit the Food inflation increase by 1.63509

The independent variable temperature had a significant effect on the dependent variable Food inflation where is the value of prob.=0.003 is less than α=0.05 , when the temperature increase by one unit the Food inflation increase by 0.016148

The independent variable Red list Index had a non-significant effect on the dependent variable Food inflation where is the value of prob.=0.1461 is more than α=0.05

7.3 Forecasting the impact of temperature on food production and food Inflation

Table 15: the Impacts of climate change (temperature) on food production and food inflation in 2030 and 2050

	Population		**temperature**	**Food production**	**Food prices**
	No of population	**Yearly change**			
2030	**120,831,557**	**1.58%**	**1-1.5**	**-4 % - -15%**	**7% - 29%**
2050	**159,956,808**	**1.25%**	**1.7-2.5**	**-10% - -35%**	**15% -56%**

The table above estimates the potential impacts of climate change (measured by temperature) on food security (food Availability and food Access) in 2030 and 2050. Food production is estimated to decrease by 4 to 15% by 2030 and decrease by 10 to 35% by 2060. While food prices is estimated to increase by 7% to 29% by 2030 and increase by 15% to 56% by 2050.

Conclusion

Food insecurity is an important challenge facing the Egyptian economy. This paper analyses the impacts of climate change on food security in Egypt. Climate change presents a high risk to food security in Egypt from food production to food Access and food utilization. To estimate the impacts of climate change on food security in Egypt we use ARDL model (Auto regressive distributed lag) model

The study found that temperature had a significant effect on food production and food Access. Increase in temperature will decrease food production and increase food prices. Also, the study found that Red list index had no significant impact on food production and food inflation in Egypt. This may be due to that indicator is not the best indicator to measure biodiversity. Results indicate that Egypt without sufficient adaptation will suffer from negative impacts on food production and food access that will lead to large food insecurity. This study recommended developing a comprehensive adaptation system to decrease the negative impacts of climate change on food security.

Study limitations: the main limitation in this study that due to the limited availability of data the study has not studied the four dimensions of food security. Also, Red list Index is not the best indicator to measure biodiversity but there is a shortage of suitable indicators to measure biodiversity.

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