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The Impact of Climate Change on Agriculture and Adaptation Mechanisms: The Case of Egypt

Running title: Climate Change Impact on Agriculture

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Abstract

Climate change has adverse effect on agricultural production in developing countries, especially in those with low incomes and a high rate of hunger and poverty. Although the agricultural sector will be costly to adapt to climate change, it is essential to achieving food security. This study aims to analysis the impact of climate change on agriculture and adaptation mechanisms in Egypt during the period (1980:2018) using Autoregressive Distributed Lags Model (ARDL). The empirical results inferred that most of the variables are insignificant in the short-run. In the long run, the empirical results revealed that the impact of climate change on agricultural production, including the emissions of carbon dioxide and temperature, is positive. Hence, even if the impact of the rain variable is negative, its value is low, and then Egypt has not entered a critical or dangerous stage. On the other hand, the results indicated that the research directed at increasing productivity and developing new varieties more compatible with climate changes is insufficient. Even if the research is available, the Egyptian farmer does not use it due to a lack of agricultural extension. For mechanical and chemical technology effects, the long-run coefficient of Fertilizers is insignificant. The long-run coefficient of the number of tractors is negative and significant, while the rural population coefficient is positive and significant. This means that Egyptian agriculture is more dependent on manpower than mechanical technology.

Key-words: Agriculture; Climate Change; Autoregressive Distributed Lags Model (ARDL) Adaptation Mechanisms; Egypt.

JEL Classification: C51; C88; Q18; Q54.

1- INTRODUCTION

Climate change is any fundamental change in climate parameters - such as temperature, evaporation, rainfall, or wind - that extends over a long period (decades or more). The main reason for these changes is greenhouse gas emissions, resulting in the global warming (IPCC,2007). The mechanism of international conferences and agreements was used as a binding framework to regulate facing this environmental issue. The real interest in climate change goes back to the United Nations Framework Convention and the

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subsequent Kyoto Protocol and Bali Conference. They represent the beginning of the international community's interest in combating this dangerous phenomenon.

Agriculture both affects and is affected by climate change. Climate change will have an adverse effect on agricultural production in developing countries, especially in those with low incomes and a high rate of hunger and poverty (FAO, 2016; FAO, 2018). Although the agricultural sector will be costly to adapt to climate change, it is essential to achieving food security. (Mahmoud, 2019)

Egypt is not far and isolated from the world, as such climate changes will affect the natural resources available in Egypt. This leads to a direct impact on the agricultural sector, and then on Egyptian food security. On the other hand, Egypt is a net importer of food, which makes it vulnerable to the impact of global climate changes due to its negative impact on the global food supply, which leads to an increase in global food prices and thus an increase in The Egyptian food bill. (El Massah and Omran, 2014)

This study investigated the effect of climate change and other control variables on agricultural production by using the Autoregressive Distributed Lags Model (ARDL) approach for the period (1980: 2018). Climate change indicators are represented in CO2 emissions, Rainfall, and Temperature. The study also focused on the adaptation mechanisms to climate change through the other explanatory variables which are the agricultural land area and yield as a proxy of research and development in agricultural sectors. Mechanical and Chemical technology are represented in a number of Tractors and Fertilizers, respectively, and the rural population variable is used as a proxy of the labor force.

2-LITERATURE REVIEW

Many studies have been conducted to examine the connection between climate change and agriculture. Chandio *et al*. (2020a) studied the effect of climate change on China's agriculture using Autoregressive Distributed Lags Model (ARDL) during the period (1982-to 2014). The empirical results indicated that Climate change indicators represented in, Rainfall, and Temperature have a negative long-run effect on agricultural production, while CO2 emissions have a positive effect in the long-run and short-run. Also, Koondhar *et al*. (2020) evaluated the effect of air pollution and carbon dioxide emissions on agricultural productivity in china using Autoregressive Distributed Lags Model (ARDL) from 1998 to 2018.The results of the estimated model showed evidence of the environmental Kuznets curve (EKC) hypothesis.

Rehman *et al*. (2019) used Autoregressive Distributed Lags Model (ARDL) to analyze the relation between climate changes represented in, emissions of carbon dioxide and agricultural productivity in Pakistan during the period (1987- to 2017). Chandio, *et al*. (2020b) used also Autoregressive Distributed Lags Model (ARDL) to analyze the effect of carbon dioxide emissions on agricultural output in Pakistan during the period (1983-to 2016). The empirical results concluded that in the short and long runs, tractors and the labor force positively and significantly affect agricultural output, but carbon dioxide emissions were insignificant.

Asumadu-Sarkodie and Owusu (2016) showed that there was an equilibrium relationship in the long- run between climate change and agriculture using Autoregressive Distributed Lags Model (ARDL) and Vector Error-Correction Model (VECM) over the period (1961-2012) in Ghana. In addition, Houngbedji and Diaw (2018) showed that rainfall had an insignificant impact on agricultural output in Benin, while CO2 emissions and temperature had a significant negative impact in the short run depending on Autoregressive Distributed Lags Model (ARDL).

Furthermore, Ouraich and Tyner (2014) revealed the negative effect of climate change on productivity in Morocco using the General Equilibrium model. On the other hand, Pereira (2017) emphasized that the most

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important challenges facing Africa in adapting to climate changes were the existence of traditional agricultural systems that relied on a high percentage of rainwater in agriculture, in addition to the reliance of African agriculture on smallholder farmers.

Other empirical studies focused on a specific crop, Abd-Elmabod *et.al.* (2020) used MicroLEIS decision support system to examine climate change's effect on the productivity of wheat and sunflower in a Mediterranean area, and the results indicated the negative impact of Climate change on the productivity, but the decline in sunflower productivity was even greater than the decrease in wheat.

For empirical studies on Egypt, Mahmoud (2019) discussed the effect of climate change on agriculture in Egypt, and the adaptation actions to face these changes. Ahmed (2020) predicted the negative effect of climate change in Egypt, which was represented by a decrease in productivity, and agricultural income, and on the other hand, higher crop water needs and increased demand for imports, the study used a multi-market model.

Khalil and Omran (2018) confirmed the significant changes in temperature and humidity in Egypt depending on the temperature-humidity index (THI) during the forecast period of 2046:2060. The values of THI rise from 3%, 0%, and 4% for the Lower, Middle, and Upper Egypt in the period (2016 - 2030) to 16%, 7%, and 11% in the period (2046 - 2060), respectively.

Yassin (2018) investigated the effect of climate change on Egyptian food security using qualitative analysis by conducting a survey with specialists. The results showed that the existing policies are not effective to Mitigate and adapting the climate changes. While, Hashem, (2020) analyzed the effect of climate change on various dimensions of food security in Egypt using a quantitative method through Autoregressive Distributed Lags Model (ARDL), the empirical results concluded that the climate change had an adverse effect on food availability and access, while climate change effect was insignificant for food utilization indicator.

Other empirical studies focused on a specific crop, El Massah and Omran (2014) analyzed the effect of climate change on Egypt's grain imports using the multiple linear regression model over the period (1991:2011), and the results showed that Climate change had no negative effect on Egypt's imports of wheat from the United States of America, although it had a negative impact on Egypt's imports of wheat from Russia. On the other hand, Egypt's imports of maize were negatively affected by the various exporting countries.

Mahrous (2018) studied the effect of climate change on Egypt's grain productivity using Autoregressive Distributed Lags Model (ARDL) during the period (1961:2013); the results revealed that rainfall and temperature had a significant negative impact, a 1% increase in rainfall and temperature leading to decrease the agricultural productivity of grain by 0.037% and 0.643%, respectively.

Ali et al. (2020) inferred that the reduction in Egyptian wheat yield is about 8.7%, 11.4%, and 13.2% in the 2030s, 2050s, and 2080s, respectively. The study proposed the sowing delay mechanism as one of the effective mechanisms for adapting the wheat to the climate changes using the Global Climate Models GCMs and Decision Support System for Agro-technology Transfer (DSSAT).

Elbasiouny and Elbehiry (2020) concluded that the negative impact of climate change on rice cultivation. Moreover, Taha and Zohry (2018) used the Basic Irrigation Scheduling model (BISM) to evaluate the impact of Climate Change on Sugarcane in Egypt, The empirical results revealed that water demand will increase by 17% in 2040, but the use of gated pipes is the best mechanism to preserve the water used in sugarcane cultivation and the best mechanism to mitigate the effects of climate change.

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Additionally, Eid, *et al*. (2007) confirmed the negative effect of climate change on agriculture and water resources in Egypt using General Circulation Models, also Abd Ellah (2020); Khedr (2019) reached the same results. While Mohamed (2019) analyzed the socio-economic impacts of Food insecurity and Water Shortage resulting from climate change.

Hamada (2020); Abd El Mowla and Abd El Aziz (2020) evaluated Climate-smart agriculture (CSA) in Egypt; the study stressed the importance of creating new varieties compatible with climate changes, and able to increase agricultural productivity. Furthermore, Abdel Monem and El Ghandour (2020) focused on the scientific research and technology to adapt to the challenges of climate change in Egypt.

Fawaz and Soliman (2016) studied the benefits of the green economy in Egypt, where annual savings in the agriculture sector would be 1.3 US$ billion, and about 1.1 US$ billion in the Water Resources, moreover, Reducing carbon dioxide emissions by 13% and reducing crop water consumption by about 40%. On the other hand, Farag *et al*. (2018) investigated the carbon footprint of certain cereals the to adapt to climate changes.

Wang et al. (2018) indicated that climate change had a negative impact on production of major cereal crops grain except for millets because of their ability to adapt to climate changes. Hence, the study suggested using millet as an alternative to major grains. Moreover, Mustafa *et al*. (2019) introduced the crop diversification mechanism through wider use of underutilized crops to achieve food security and mitigate climate changes.

3- EGYPTIAN AGRICULTURE AND CLIMATE CHANGES

3-1 National Greenhouse Gas Inventory:

The total greenhouse gas emissions in Egypt were about 248770 Giga grams of carbon dioxide equivalents in 2005, then reached about 325614 Giga gram in 2015, which increased by 31% from 2005 to 2015, as shown in figure (1). Carbon dioxide comes at the forefront of the gases contributing about 73% of the total greenhouse gas emissions, while the Methane and Nitrous Oxide gases are about 13% and 12%, respectively.

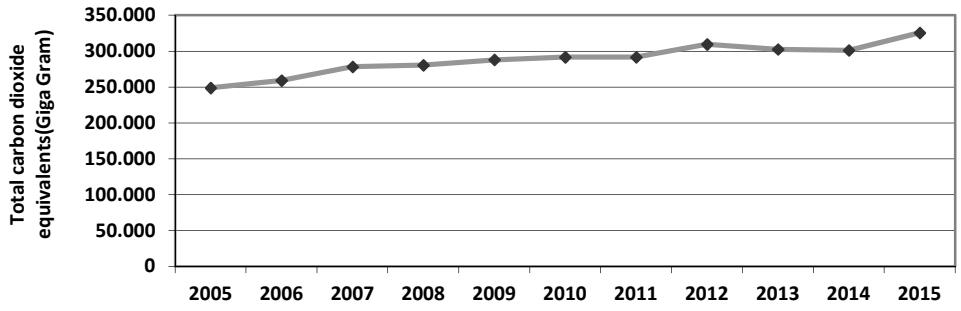


Figure (1) Total Greenhouse Gas (GHG) Emissions Trend In Egypt during the period (2005:2015)

Source: Ministry of Environment, (2018) *Report to the United Nations Framework Convention on Climate Change* (https://www.eeaa.gov.eg/en-us/home.aspx).

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Figure (2) shows the contribution of different sectors to the total greenhouse gas emissions, we find that the energy sector is the primary and main contributor to those emissions by 64.5%, due to Egypt's dependence on fossil fuels (petroleum and natural gas) with about 92% of total energy use. The second sector is the agricultural sector with 14.9%, and then the industrial sector, with a rate of 12.5%, and the emissions of the industrial sector are mainly represented in carbon dioxide emissions from the iron and cement industry, and then, in the end, the waste sector by 8.1%

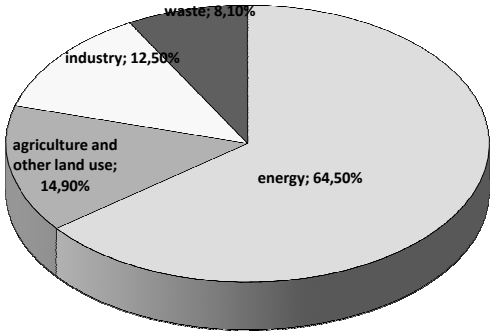


Figure (2) the contribution of the different sectors
to the total greenhouse gas emissions in 2015

Source: Ministry of Environment, (2018) *Report to the United Nations Framework Convention on Climate Change* (https://www.eeaa.gov.eg/en-us/home.aspx).

Furthermore, table (1) shows the percentage of the contribution of each sector to the total of each greenhouse gas in 2015. The energy sector has contributed 87% of carbon dioxide emissions, while industry represents 12% and the agricultural sector 1%. For methane gas, we find that the main sector contributing to methane emissions is the waste sector with 59%, followed by the agriculture sector, with 38%, and the energy sector, with 3%. For Nitrous Oxide gas, we find that the main sector contributing to Nitrous Oxide emissions in the agriculture sector by 81%, followed by the industrial sector by 12%, then the waste sector by 5%, and finally the energy sector by 2%.

Table (1) Contribution of each sector to the total of each Greenhouse gas emissions in 2015

Gas	Sector	%
carbon dioxide	Energy	87%
	Industry	12%
	agriculture	1%
Methane	Energy	3%
	agriculture	38%
	waste	59%
Nitrous Oxide	Energy	2%
	Industry	12%
	agriculture	81%
	waste	5%

Source: Ministry of Environment, (2018*) Report to the United Nations Framework Convention on Climate Change*. (https://www.eeaa.gov.eg/en-us/home.aspx).

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3-2 The impact of climate change on crops

Increasing the concentration of carbon dioxide will have a positive effect on crop productivity through increasing the ability of plants to conduct photosynthesis (El Massah and Omran, 2014; Mahrous, 2018), but from the other hand, the high temperature also affects the growth process. Table (2) shows that the productivity of the wheat in Egypt will decrease by 15% if the temperature increases about 2°C in 2050, the productivity of the rice, maize, Soybeans, barley will decrease by 11%, 14%, 28%, 20%, respectively. But, cotton productivity is expected to increase by 17%.

Table (2) the percentage change in productivity of some major crops in Egypt, when the temperature rises by 2°C in 2050

Crop	2050
Wheat	-15%
rice	-11%
Maize	-14%
Soybeans	-28%
barley	-20%
Cotton	+17%

Source: Ministry of Environment (2020).*Egypt National Environmental, Economic and Development Study (NEEDS) for Climate Change: under the United Nation framework convention on climate change*.

Most studies indicate that the global annual average temperature will lead to a change in the crop structure as the period of crop maturity changes - whether by increase or decrease - which leads to an increase in food prices as a result of the slow increase in global food supplies and the increase in global demand (FAO, 2018). On the other hand, increased temperatures raise soil erosion rates; raise the rates of evaporation and an imbalance of humidity; increase the number of agricultural pests and diseases (FAO, 2016); increase the rates of decomposition of the organic components of the soil, which reduces its water holding capacity, and reduces its fertility. (Elbasiouny and Elbehiry (2020)

3-3 The Impact of climate changes on water resources:

Many studies discussed the impact of climate changes on water resources, which are directly related to food production, and this can be explained as follows:

- The expected increase in global temperature will lead to an increase in the water needs of agricultural crops, which will increase the demand for water resources and reduce the productivity of these crops, thus threatening food security (Hashem, 2020). In Egypt, for example, the water consumption of wheat increased by 2.5% compared to the current water consumption of it, while the water consumption of rice, maize, and cotton increased by 16%, 8%, and 10%, respectively. (Mahmoud, 2019)
- It is expected that some rivers will be affected by drought as a result of changing rainfall rates at the headwaters of the river, Strzepek *et al*. (2001) came up with nine different scenarios to explain the impact of climate change on the Nile River. All these scenarios indicate a decline in the rate of water flow in the Nile by about 20% until 2040, while only one scenario predicts an increase in the rate of flow of the Nile water after 2045, and that will severely affect agricultural productivity (Abdel Monem and El Ghandour, 2020)
- Egypt is considered one of the Nile Basin countries most affected by what climate changes can have on the size of the flood, as it will not only be affected by what climate changes can cause within its borders,

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but it will be affected by the climate changes in the rest of the basin countries and on the rates of consumption of Nile River water in these countries. (Khedr, 2019)

3-4 Institutional Arrangements that Egypt has taken to confront climate changes:
Egypt is considered one of the most active Arab and African nations in terms of climate change adaptation, in the following part we summarize the most important policies and procedures that Egypt has undertaken in this field:

A- In 1994, Egypt signed the United Nations Framework Convention on Climate Change (Gelil, 2014).

B- In 1995, Egypt has implemented two schemes: The "Strengthening the National Action Plan" program, where many studies were conducted in the field of climate change, and The "Egyptian Capacity Building in the Field of Climate Change" in cooperation with the Global Environmental Facility. (Ministry of Environment, 2010)

C- Egypt signed the Kyoto Protocol on March 5, 1999, intending to impose obligations on industrialized countries to reduce their emissions of greenhouse gases, compared to the emissions of greenhouse gases in 1990 (Gelil, 2014).

D- In 2005, Egypt activated the clean development mechanism, which aims to implement projects aimed at reducing greenhouse gases from various sectors such as industry, waste recycling, and transportation, as well as gardening projects that absorb greenhouse gases (Ministry of Environment, 2020).

4- MATERIALS AND METHODS

4-1 The data: The analysis uses observations of nine variables for the period (1980:2018). All the variables are in logarithmic form. Data were collected from Food and Agriculture Organization (FAO), World Development Indicator (WDI), and Central Agency for Public Mobilization and Statistics (CAPMAS).

4-2 Methodology: The Autoregressive Distributed Lags Model (ARDL) developed by Pesaran *et al*. (1999, 2001) will be used to reveal the existence of an equilibrium relationship (cointegration) between the variables under study. ARDL model does not require that time series be Integrated to the same degree, but the only condition for applying this model is that the time series not be Integrated to a second degree I(2). (Asumadu-Sarkodie and Owusu, 2016; Mahrous, 2018)

Moreover, this model has better properties in the case of short time series compared to the other usual methods of testing co-integration such as the two-stage Engle & Granger method or Johansen's cointegration test in Vector Autoregression (VAR) method (Chandio *et a*l. 2020a; Chandio *et a*l. 2020b). Furthermore, The (ARDL) model provides estimation in both the short and long run. (Rehman *et al.* 2019 ; Houngbedji and Diaw 2018).

The study model can be described as:

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$$\Delta \ln AGRI_t = \alpha + \beta_1 \ln AGRI_{t-1} + \beta_2 \ln CO_{t-1} + \beta_3 \ln RAIN_{t-1} + \beta_4 \ln TEMP_{t-1} +$$

$$\beta_5 \ln YLD_{t-1} + \beta_6 \ln AREA_{t-1} + \beta_7 \ln TR_{t-1} + \beta_8 \ln F_{t-1} + \beta_9 \ln RPOP_{t-1} + \sum_{i=1}^{q1} \gamma_1 \Delta \ln CO_{t-i}$$

$$+ \sum_{i=1}^{q2} \gamma_2 \Delta \ln RAIN_{t-i} + \sum_{i=1}^{q3} \gamma_3 \Delta \ln TEMP + \sum_{i=1}^{q4} \gamma_4 \Delta \ln YLD_{t-i} + \sum_{i=1}^{q5} \gamma_5 \Delta \ln AREA_{t-i}$$

$$+ \sum_{i=1}^{q6} \gamma_6 \Delta \ln TR_{t-i} + \sum_{i=1}^{q7} \gamma_7 \Delta \ln F_{t-i} + \sum_{i=1}^{q} \gamma_8 \Delta \ln RPOP_{t-i} + \sum_{i=1}^{q} \gamma_8 \Delta \ln AGRI_{t-i} + \varepsilon_t$$

Where: AGRI	Agricultural value added (constant US$)
CO	CO2 emissions (metric tons per capita)
RAIN	Rainfall (MM)
TEMP	Temperature (Celsius)
YLD	Yield (hectograms per hectare (hg/ha))
AREA	Agricultural Land area (hectare)
TR	No. of Tractors
F	Fertilizers(tons)
RPOP	Rural population

The Autoregressive Distributed Lags approach involves checking the long-term equilibrium relationship between the model variables, and for this we calculate the (F) statistic through (Wald test). (Koondhar *et al.* 2020)

H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$

H_1: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq \beta_7 \neq \beta_8 \neq \beta_9 \neq 0$

5- RESULTS AND DISCUSSIONS

5-1 Results of Augmented Dickey Fuller (ADF) Test

Table (3) shows the results of Augmented Dickey Fuller test, we find that some variables are stationary in levels and some variables are stationary in first-differences, so we can use ARDL model.

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Table (3) Results of Augmented Dickey Fuller (ADF) test

	Augmented Dickey Fuller (ADF)				
	Log level		Log difference		
	Intercept	Trend and intercept	Intercept	Trend and intercept	
LNAGRI	1.469882	-3.347409	-3.52648**	-3.191369	I(1)
LNCO	-1.241682	-1.782172	-4.6027***	-4.555127***	I(1)
LNRAIN	-4.33815***	-4.806687***			I(0)
LNTEMP	-0.643065	-5.148648***			I(0)
LNYLD	-1.837122	-1.126876	-4.2785***	-4.891752***	I(1)
LNAREA	-1.000558	-1.095716	-5.2737***	-5.383822***	I(1)
LNTR	-1.718770	-2.279060	-3.1819**	-3.164450	I(1)
LNF	-1.551473	-2.059300	-4.9333***	-4.934021***	I(1)
LNRPOP	-0.784067	-5.477036***			I(0)

Source: Compiled by researcher from unit root test depending on the E-Views program depending on the data of Food and Agriculture Organization (FAO), World Development Indicator (WDI), and Central Agency for Public Mobilization and Statistics (CAPMAS).

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Note: *** indicates statistical significance at 1% level, **significance at 5%level, * significance at 10%level.

Table (4) shows that the value of F-Statistic is greater than the upper bound value. Hence, the model's variables have a long-run equilibrium relationship.

Table (4) ARDL Bounds test results (Unrestricted intercept and no trend)

F-Statistic	Significance Levels	Lower Bound	Upper Bound
	10 percent	1.95	3.06
6.609812	5 percent	2.22	3.39
	1 percent	2.79	4.10

Source: Compiled by researcher depending on the E-Views program, depending on the data of Food and Agriculture Organization (FAO), World Development Indicator (WDI), and Central Agency for Public Mobilization and Statistics (CAPMAS).

Table (5) shows that most of the variables are insignificant in the short-run which means the effect of the explanatory variables on agricultural production is the weak in short run. But rural population variable is

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significant and negative, which reflects the negative impact of the rural population on agricultural production. The error correction term ECT_{t_1} denotes the speed of adjustment toward the long-run equilibrium. The value of ECT is negative and significant, so the model can get back to the long-run equilibrium at speed of 26%.

Table (5) Results of ARDL model in Long-run and short-run

long-run estimation				
variables	**Coefficient**	**Standard Error**	**T-Statistic**	**Prob.**
LNCO	0.147838***	0.041525	3.560234	0.0013
LNTEMP	0.406485**	0.179542	2.264006	0.0310
LNRAIN	-0.029380**	0.014109	-2.082266	0.0459
LNYLD	-0.241539***	0.067645	-3.570661	0.0012
LNAREA	0.191164	0.115313	1.657784	0.1078
LNTR	-0.233781***	0.060303	-3.876764	0.0005
LNF	-0.007157	0.037995	-0.188362	0.8519
LNRPOP	1.549177***	0.102979	15.04358	0.0000
C	-1.356739	1.758111	-0.771702	0.4463
Short-run estimation				
ΔLNCO	-0.026990	0.020049	-1.346184	0.1899
ΔLNTEMP	0.036227	0.054036	0.670419	0.5085
ΔLNRAIN	0.001035	0.003480	0.297399	0.7685
ΔLNYLD	-0.008322	0.032630	-0.255056	0.8007
ΔLNAREA	-0.057691	0.039487	-1.461004	0.1560
ΔLNTR	-0.047812	0.029534	-1.618879	0.1175
ΔLNF	0.022652	0.013974	1.620962	0.1171
ΔLNRPOP	-0.996441***	0.358306	-2.780979	0.0099
ECT(_1)	-0.263110***	0.081520	-3.227554	0.0034
Residual diagnostic tests				
Breusch-Godfrey Serial Correlation LM Test: 0.771222(0.388202)			**F-statistic**	3.295774***
ARCH Test: 0.037163 (0.848281)			**R-squared**	0.559006
White Heteroskedasticity Test: 0.527830 **(**0.911602**)**				
Ramsey RESET Test: 1.231473 (0.277681)				
CUSUM Test stable				

Source: Compiled by researcher depending on the E-Views program, depending on the data of Food and Agriculture Organization (FAO), World Development Indicator (WDI), and Central Agency for Public Mobilization and Statistics (CAPMAS)..

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Note: ***, **, and * indicate significant at the 1%, 5%, and 10% significance levels, respectively

In the long run, the empirical results revealed that the emissions of carbon dioxide and temperature have a significant positive effect on agricultural production, a 1% increase in CO2 emissions and temperature can increase agricultural production by 0.147838%, and 0.406485%, respectively. However, rainfall has a significant negative impact, with a 1% increase in rainfall leading to a decrease the agricultural production of about 0.029380%. Consequently, the impact of climate change, including the emissions of carbon dioxide and temperature on agricultural production, is positive. Hence, if the impact of the rain variable is negative, but its value is low, then Egypt has not entered a critical or dangerous stage.

Moreover, the long-run coefficient of agricultural land area is positive but insignificant, while the long-run coefficient of yield has a significant negative effect, so the increase in yields by 1% led to a decline in agricultural production by 0.241539%. The study used to yield as a proxy of research and development in agricultural sectors. This indicates that the research directed at developing new varieties more adaptable to climate changes is inadequate. Even if the research is available, the Egyptian farmer does not use it due to a lack of agricultural Extension.

Furthermore, the long-run coefficient of Fertilizers is insignificant. The study used rural population as a proxy of the labor force, the long-run coefficient of the rural population is positive and significant, with a 1 % increase in rural population leading to an increase the agricultural production by 1.549177%. The long-run coefficient of the number of tractors is negative and significant a 1% per cent increase in the number of tractors, production decreased by 0.233781%. This means that Egyptian agriculture is more dependent on manpower than mechanical technology.

The quality of the model should be tested, and this is done by diagnostic tests as shown in table (5):

- The Breusch-Godfrey Serial Correlation LM Test results indicate that we can't reject the null hypothesis of no serial correlation.
- The White Heteroskedasticity Test results indicate the model isn't Heteroskedasticity.
- The Autoregressive Conditional Heteroscedasticity (ARCH) test indicates that we can't reject the null hypothesis of the homoscedasticity in the estimated model.
- The Ramsey RESET test confirms the validity of the functional form used in the estimated model
- The value of the F test is significant, which means that the estimated model had a good fit.
- Figure (3) shows the results of CUSUM Test, the model is stable as CUSUM line falls within the critical limits at a 5% level of significance.

Hence, the model's results can help investors, and policymakers in drawing various agricultural policies.

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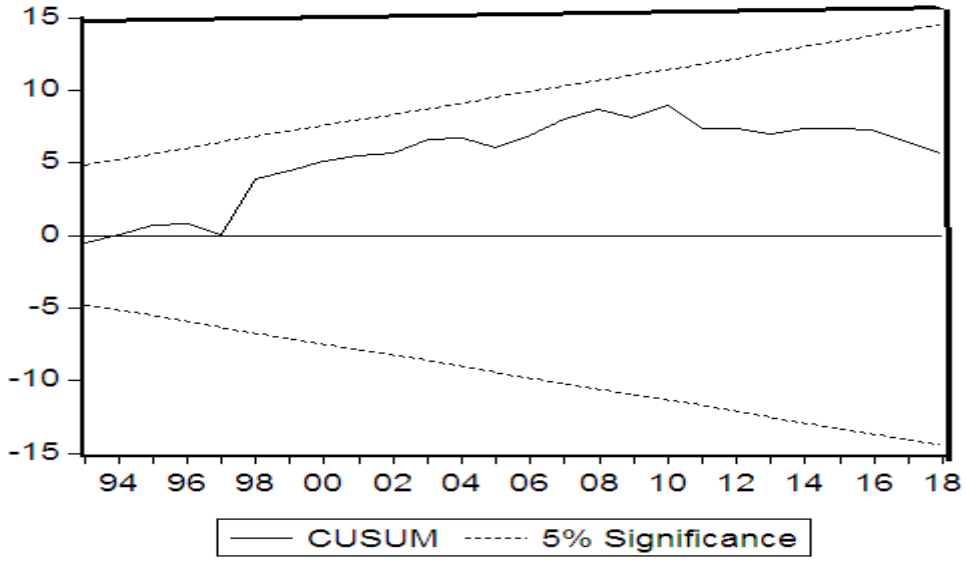


Figure (3) results of CUSUM Test

Source: Compiled by researcher depending on the E-Views program**.**

6- CONCLUSION

This study aims to examine the impact of climate change on agriculture and adaptation mechanisms in Egypt from 1980 to 2018 using Autoregressive Distributed Lags Model (ARDL). Climate change indicators are represented in carbon dioxide emissions, Rainfall, and Temperature. The non-climatic indicators are expressed in agricultural land area and yield as a proxy of research and development in agricultural sectors. Mechanical and Chemical technology are represented in a number of Tractors and Fertilizers, Respectively, and the rural population variable is used as a proxy of the labor force.

The empirical results revealed that most of the variables are insignificant in the short-run except the rural population variable is significant and negative. In the long run, the results revealed that the impact of climate change on agricultural production, including the emissions of carbon dioxide and temperature, is positive, even if the impact of the rain variable is negative, but its value is low. Hence, Egypt has not entered a critical or dangerous stage

Moreover, the results indicated that the research directed at developing new varieties more adaptable to climate changes is inadequate. Even if the research is available, the Egyptian farmer does not use it due to a lack of agricultural Extension. For mechanical and chemical technology effect, the long-run coefficient of Fertilizers is insignificant. The long-run coefficient of the number of tractors is negative and significant, the study used the rural population as a proxy of the labor force, and the long-run coefficient of the rural population is positive and significant. This means that Egyptian agriculture is more dependent on manpower than mechanical technology.

Previous results clearly show that the Egyptian state is making significant efforts, whether at the level of institutions or policies, to confront the challenges of climate change, but there remains a need for a number of complementary measures, especially at the level of scientific research, developing community awareness, and activating the role of civil society.

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