

# An economic repercussion to the impact of climate change on the most important Egyptian food security crops

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## Abstract

We examine how the Climate Change affected on the Agricultural Production, and how the impact of climatic changes on the productivity of the most important grain crops in Egypt, with the aim of determining the extent to which productivity has changed due to climate change in Egypt, using the Autoregressive Distributed lagged methodology (ARDL), where it was found that there is an inverse relationship between climate changes and the productivity of the most important cereal crops, a relationship that is consistent with the economic logic. The results indicate that a similar negative impact of the maximum temperature change on the productivity of the most important cereal crops in the long term, which is consistent with an economic theory.

**Keywords:** temperature, cereal crops, Autoregressive Distributed lagged Model (ARDL), partial correlation, stability, residuals.

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## INTRODUCTION

The world is facing by the climate fluctuations due to the phenomenon of "global warming", which leads to an increase in the emission of harmful gases into the atmosphere, threatening the natural wealth, agricultural production of plants and animals. Egypt is considered one of the countries are most affected by the negative effects of climate fluctuations, as most of its lands are located in desert and semi-arid areas, the temperature has increased by about 4 degrees Celsius, where it above the normal rate in 2021 (Enterprise 2021). In this study, we examine the impact of climate changes on the productivity of the most important cereal crops in Egypt. Our main objective is to see the impact of climate changes on the productivity of the most important cereal crops in Egypt during the period (2000-2020) (Enterprise 2021), by using the Autoregressive Distributed Lagged methodology (ARDL) to ensure that there is a long-term co-integration relationship between climate changes and the productivity of the most important cereal crops, to identify does the production change with climate changes through a study:

- 1- Evolution of maximum and minimum temperatures, rains and humidity during the study period.
- 2- Evolution of the productivity of the most important cereal crops in Egypt during the study period.
- 3- Estimation of the effect of the relationship between climate change and the productivity of the most important cereal crops in Egypt.

## Literature review:

Over the past years, many studies utilized the impact of climate change on the Agricultural production in the world. These section overviews the recent empirical analyses on the climate change on the Agricultural Sector.

Egypt is the most populous country on the African continent, where ensuring food security for a growing population is a long-term priority of government policy,

as the demand for food continues to increase due to population, growth and economic development, while arable land and other productive resources it causes a contraction because agricultural productivity is subject to climate change (Cline, 2007; Li et al., 2011; Yao et al., 2007). Moreover, among other factors such as socio-economic, cultural, institutional and political characteristics that can enhance or hinder the process of adaptation, adaptability to climate and adaptation strategies vary from plot to farm level, to local level and also vary in size. Therefore the analysis of system adaptation must take into account the scale analysis, capabilities and appropriate adaptation strategies (Vincent, 2007; Abid et al. 2015), the livelihoods of rural households and major agricultural crops including wheat, rice, cotton and sugarcane have also been severely affected over the past period due to changes in global climate. In advanced economies, carbon dioxide concentration is mainly caused by many production and consumption activities. On the other hand, global climate change is largely faced by developing countries, and most of the countries are located in the tropics and depend mainly on the agricultural sector. Practically all economic sectors are vulnerable to climate change but agriculture is the most. Climate change will address crop productivity issues through changes in rainfall patterns, sowing and harvest dates, rising temperatures, water supply and transpiration (Rosegrant et al., 2008; Zenghelis, 2006)

The challenges of global climate change and how climate change affects crop yields are important political and economic issues (Lobell et al., 2007; Peng et al., 2004; Wei et al., 2009; Xiong, 2014). Recently, some authors have investigated the impact of climate change on grain yield, agriculture, and economic growth using several econometric techniques.

(Siam, G. M., Fayyad, S. M. 2009), studied the impact of climate change on the future food situation in 2030 in Egypt, represented by the size and value of the food gap and the rates of self-sufficiency. Climate changes affect agriculture and food through the impact of carbon dioxide emissions on crop productivity, as well as the rise in sea levels on the sinking of the delta. The results showed that there is a large food deficit in the six scenarios under study in 2030, where the grain gap amounts to about 11.2 million tons in the first scenario, although the scenarios have a more severe impact of 5.3. As for legumes, vegetable oils and sugar, the results indicate an expected gap of about 1.4, 6.3, and 3.7 million tons, respectively, in the first scenario. It is worth noting that the current spending on agricultural research does not exceed 25 million pounds annually, which is absolutely not proportional to the challenges facing Egypt to achieve food security, and on the other hand, it is twice as high. This does not exceed 0.5% of the total agricultural product. The study also recommended the necessity of adopting appropriate strategies to resist rising sea levels

and prevent the erosion of the northern shores of the delta, as the cost of these measures is estimated at about \$300 million.

(Alam 2013), examined the response of agricultural output to climate change and its long-term impact on economic growth using time-series data between 1971 and 2011. ARDL and ECM-based approaches were used for procedures to examine the short- and long-term relationship between carbon dioxide emissions, agricultural production and economic growth. The results revealed a huge negative correlation between carbon dioxide emissions and economic growth, while there is a positive and significant correlation between agricultural production and economic growth.

(Wang et al. 2014), found that in southern regions in China, the introduction of new and improved crop varieties with similar climatic conditions is a practical approach to combating climate warming, as the result of climate change on agriculture.

(AlBaydi, K. R., Hammouda, A. B. M. 2015), studied the climate change has a strong effect on agricultural production, and consequently on food supply and security. We applied pairwise Granger causality to time-series data to examine the causal relationship between climatic conditions and annual production of important crops in Libya between 1980 and 2010. The climatic variables were rainfall and temperature, and the crops were wheat, barley, onion, watermelons, tomatoes and potatoes. There was bidirectional causality between temperature trend and potato production and unidirectional causality between temperature and watermelon and wheat production. There was no causality between temperature on the one hand and production of barley, onion and tomatoes on the other hand. The results also show a unidirectional causality running from rainfall to potatoes and wheat, and a bidirectional relationship between rainfall and watermelon. There was no directional causation from rainfall to barley or tomatoes. Based on these findings, Libyan authorities should pay more attention to the planting of crop varieties that are resistant to drought and heat and focus on the development of such varieties.

(Asuamah, Yeboah et al. 2015) studied the effect of carbon dioxide emissions on grain production in Ghana using the ARDL approach. Ghana time-series data from 1961-2010 were used, and the results of the empirical analysis revealed that there is a significant non-excited association between CO<sub>2</sub> emissions and cereal production while positive and significant short- and long-term relationships exist between cereal production and income.

(Zain, S. A. M. 2016), studied the climate changes is the one of the biggest challenges facing the environment and human development, especially in African countries because the human life and his activities are related to climatic conditions. The paper studied the effects of climate changes on grain production in Sudan, to show the effect of some elements of the climate in Sudan, So this research to study the climatic effects that limit the increase in production and productivity to get to this study relied on the analysis of the average annual rainfall for the period (2005-2015). The study was done in the statistical and analytical method in the analysis of climate data, production and productivity per acre as the correlation coefficient was used in order to show the standard questionnaire relationships between variables, the study found that the corn crop and millet is the mostly effect climate crops. The study recommended that must be an agricultural research stations equipped with weather stations in agricultural projects to know the weather conditions in order to help in the success of the crop and recommended to educate farmers and train them for different climatic conditions.

(Dumrul and Kilicaslan 2017) used an ARDL bound test approach and found a positive and significant effect of precipitation on agricultural production while temperature negatively affects agricultural production in Turkey. (Rahim and Puay 2017) examined the relationship between climate change and economic growth in Malaysia. The time frame of the study was from 1983 to 2013. The study analyzed the variable using unit root tests such as Dickey-Fuller GLS (DF-GLS), ADF, Johansson Co-Integration Approach (JCA) and Vector Error Correction Model (ECM). The variables in the study were GDP, precipitation, temperature, and arable land. The results of the analysis showed that there is a long-term association between the study variables. There is a one-way causal relationship from temperature and arable land to GDP.

(Dumrul and Kilicaslan, 2017) evaluated the effects of climate change in agricultural production in Turkey through the period 1961-2013. Were economic effects of climate change on agriculture analyzed for Turkey by using a Time Series Approach. The results showed that an increase in precipitation affects agricultural GDP positively, while the increase in temperature has a negative effect on agricultural GDP. The results showed that an in order to minimize the adverse effects of climate change in Turkey, which is one of the largest countries in the world in terms of agricultural land, it is important to establish policies, strategies, plans and programs to combat climate change.

(CCI, 2018), studied the effects of climate change on the oceans suggest that future generations, especially those in small island states, may not be able to grow there in a

sustainable manner. Agronomists have made great efforts to develop adaptation strategies in response to the potential negative impacts of future climate change on agriculture.

(Rehman, et al. 2019), studied the effects of CO<sub>2</sub> emissions and agricultural productivity in Pakistan using the ARDL boundary test approach showed that planted area, energy use, fertilizer uptake, GDP per capita, and water availability showed a significant association with CO<sub>2</sub> emissions, with improved seed distribution and grain total. Dietary food has a negative association with carbon dioxide emissions in Pakistan. To our knowledge, no pilot study has been conducted in the context of China to investigate the effects of climate change on agricultural production. This study aims to examine the short- and long-term interrelationships between climate change factors and agricultural production in the context of China.

(Bahloul, A. A., et al. 2019), studied the estimation of the economic effects of climate changes on the wheat crop in Egypt, where the study aimed to measure the economic effects of climate change on the wheat crop in the regions and governorates of Egypt. The study used the Ricardo model method to assess the economic effects of climate change on the net yield of agricultural crops. The study was based on the data of the Ministry of Agriculture and Land Reclamation, the data of the Meteorological Authority and the Central Laboratory for Agricultural Climate. The main results were as follows: - Future climate changes will have negative effects on agriculture and the food system in general, and on most agricultural crops in particular. The results also indicated an increase in the average net production of wheat crop with a significant growth rate and an estimated increase of 65.20 pounds per feddan during the period (2000-2017). The study also showed that there were negative effects of increasing the minimum temperature and relative and relative humidity (except for the high humidity of about 5%, and the positive effect on the net yield of the wheat crop), while the effects were positive, with an increase in the decrease in the minimum and relative temperatures and relative humidity. The study recommended the necessity of developing new varieties that can withstand high temperatures and high relative humidity, as well as planting appropriate varieties in suitable climatic areas, educating and training farmers on how to adapt and cultivate the wheat crop under the current and expected climatic conditions, and using appropriate planting dates, varieties and agricultural operations. Different types of wheat to increase the productivity and productivity of the wheat crop in Egypt.

(Zaher, B. K. A., et al. 2019), studied the factors affecting the agricultural production of the most important crops under study, whether economic or environmental

variables and then to identify the fluctuation of agricultural production of the most important strategic crops, whose production is affected by climate variability, where the problem of the study was the negative impact of the phenomenon of climate change and environmental pollution on agricultural production, especially In light of contemporary environmental and economic variables. The objective of the research was to identify the most important environmental and economic factors responsible for bringing about changes in agricultural production. The most important productive activities constituting plant production in the Arab Republic of Egypt and the importance of each activity for the average monetary value of both agricultural and plant production during the period (2013-2017). Field crops were ranked first with an average value of LE 107.15 billion representing about 38.34% of the total average value of agricultural production, representing about 65.3% of the value of plant production during the period (2013- 2017). The second, where the average value of about 30.51 billion LE, representing about 30.51% of the total average value of agricultural production and represents about 18.9% of the average value of plant production. The most important factors affecting Egyptian wheat production during the period (2003-2017) are the cultivated area of wheat crop, average minimum temperature and average bone temperature. The model showed a direct correlation between the amount of wheat production and the cultivated area of the wheat crop. The results are an increase of 90% in total wheat production by increasing the cultivated area of wheat by 10%.The model also showed a positive correlation between the quantity of wheat production and the average temperature of the smallest, where the results show an increase in total wheat crop production by about 10.4%, with an increase in the average small temperature by 10%. The model also showed an inverse relationship between the quantity of wheat crop production and the average bone temperature, where the results indicate a decrease in total wheat production, as the increase of bone temperatures by 10% leads to a decrease of agricultural production by 27% during the study period.

(Rizkallah, W. W. E. 2020), amid to measure the impact of climate changes represented in temperatures and precipitation on productivity of Egyptian agricultural crops (wheat and corn) in the long and short term, that during the period from 1981 to 2014, according to the division of governorates producing agricultural crops into three regions: Upper Egypt, Middle Egypt, and Lower Egypt. The scientific contribution of that study is to use the econometric method through real data, unlike other studies that use experimental data. Some of the modern econometric techniques of Full-Modified OLS (FMOLS) were used to estimate the Co-integration trend of Panel Data to derive long-term estimates of climate change effects on productivity on crops of wheat and maize. The study concluded that there is a long-term significant

relationship between the average temperatures and the productivity of both maize and wheat crops, that the temperature greatly affects the productivity of the two crops in the long term rather than in the short term. And that the average rainfall did not have a significant effect for both the long and the short term.

(AlJubouri, R. K., et al. 2020), studied the climate change that the world is witnessing is one of the most important challenges facing developed and developing countries (Arab) both, due to the accompanying effects and repercussions on various fields, The sector most sensitive to these changes is the agricultural (food) sector. As agricultural-food production in the Arab regions is negatively affected by climate change, especially in countries that are already exposed to climate fluctuations (drought, desertification, floods) and suffer from low incomes, widespread hunger and poverty. The effect appeared in the form of fluctuations in production and the widening of the gap. The increase in dependence on the outside world in providing food supplies in the Arab regions for the period (2005-2015). This is due to a group of reasons, including global warming, increased CO2 emissions, High temperatures, increased evaporation, and other reasons, which consequently affect directly and indirectly the agricultural-food production. The research found that climate change has negative and direct nutritional effects, including an imbalance in the quantities and components of consumption. As well as on the level of income for individuals who depend on agriculture to obtain it, which destine for consumption, which exposes them to the risk of not being able to cope with climate volatility

(Abbas et al. 2021) examined and explored the impact of global climate change on agricultural output in China over the period of 1982-2014. They used a unit root tests including augmented Dickey–Fuller, Phillips–Perron and Kwiatkowski, Phillips, Schmidt and Shin are used to check the order of integration among the study variables. The autoregressive distributed lag (ARDL) bounds testing approach to cointegration and the Johansen cointegration test are applied to assess the association among the study variables with the evidence of long-run and short-run analysis. The results showed a unit root test estimations, confirmed that all variables were stationary at the combination of I(0) and I(1). The results showed that CO2 emissions have a significant effect on agricultural output in both long-run and short-run analyses, while temperature and rainfall have a negative effect on agricultural output in the long-run. Among other determinants, the land area under cereal crops, fertilizer consumption, and energy consumption have a positive and significant association with agricultural output in both long-run and short-run analysis. The estimated coefficient of the error correction term is also highly significant.

## METHODOLOGY

This paper's quantitative research used the secondary data of the weather of Egypt, and Agricultural production (CAPMAS) database. The secondary data have been analyzed using descriptive statistics and ARDL methodology

Co-Integration by using an Autoregressive Distributed Lagged Model (ARDL):

Pesaran(1997), Shinand and Sun(1998); Pesaran et AI (2001) were developed the ARDL Methodology, where it does not require time series to be of the same order, i.e. stationary of the same degree, either in level or first differences, or a mixture of them, provided that the time series are not stationary in the second differences (Duasa 2007).

Characteristics of the Autoregressive Distributed Lagged Model (ARDL) (Inuomote and Odeniyi 2012):

1. The application of the ARDL test does not require time series to be static at the same rank, the possibility of estimating the short-term and long-term, at the same time in one equation.
2. The possibility of testing (ARDL) by allowing the explanatory variables, with different time lags.
3. The possibility of applying the ARDL test in the case of a small sample size, and it also helps to prevent the occurrence of autocorrelation, because the resulting estimators are efficient and unbiased.
4. It is characterized by simplicity in estimating the cointegration, by the ordinary least squares (OLS) method, after determining the maximum optimum time lag period.

The ARDL Model, is a mixture of the Lag- Distributed and Autoregressive model, it shows that when there is a state of conditioning in the dependent variable  $y_t$ , it is affected by changes in the explanatory variable  $x_t$ , and by lags for previous periods of time.  $(x_{t-r})$ , i.e. the effect of the explanatory variable, is not only for the current time period  $(t)$ , but over multiple previous periods of time  $(t-r)$ . The ARDL Model takes the following equation:

$$y_t = \beta_0 + \beta_1 x_t + \beta_2 x_{t-1} + \dots + \beta_p y_{t-p} + u_t \dots \dots (1)$$

The dynamic (kinetic) behavior can be expressed in the previous values of the dependent variable  $y_t$ , meaning the same dependent variable, it is an explanatory variable but

in a time-deceleration form for a previous period  $(i-y_t)$ , and it represents an autoregressive model and takes the following formula:

$$y_t = \lambda_1 y_{t-1} + \lambda_2 y_{t-2} + \dots + \lambda_p y_{t-p} + u_t \dots \dots (2)$$

According to equation (1) the right-hand side contains a time lagged explanatory variable  $(x_{t-1})$ , the dependent variable itself contains prior values  $(y_{t-i})$ , so it takes the following equation (Hassler and Jurgen 2005):

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \beta_0 x_t + \beta_1 x_{t-1} + u_t \dots \dots (3)$$

Where:  $(y, x)$  represents the variables that are stationary in zero degree, or the first degree, or a combination of both.

The ARDL Model has the possibility of a long-term relationship (co-integration) between the variables, whether the variables are static of zero degree, or of first degree, or a combination of them (Narayan 2015).

According to the Bound Test approach, lower and upper bounds of the F-test are determined by the null hypothesis  $(H_0)$ , which means that there is no possible long-term co-integration relationship between the model variables, when the value of Calculated (F) less than critical values then we reject the null hypothesis, and accepts the alternative hypothesis, which means the existence of co-integration from an applied point of view, the error-correction model and limits testing, is done after determining the degree of stationary of the studied variables, where the following equation is applied:

$$\Delta y_t = a_0 + \sum_{i=0}^r a_{1i} \Delta y_{t-1} + \sum_{i=0}^r a_{2i} \Delta p_{t-i} + \sum_{i=0}^r a_{3i} \Delta m_{t-i}$$

$$+ \beta_1 y_{(t-1)} + \beta_2 p_{(t-1)} + \beta_3 m_{(t-1)} + \epsilon_t \dots \dots (4)$$

Where:

$\Delta$  = the first difference of the values of the variable.

$a_0$  = constant.

$r$  = numbers of the optimal time lagged.

$a_{1i} a_{2i} a_{3i}$  = the short-term coefficients of the dynamic relationship.

$\beta_1, \beta_2, \beta_3$  = long-term coefficients by which the possibility of co-integration is known.

t= time

$\varepsilon_t$  = random error term

According to the previous equation, when there is a possibility of co-integration between the variables, according to the bound test, it will be estimate the short-run relationship, using the error-correction Model as follows:

$$\Delta y_t = a_0 + \sum_{i=0}^r a_{1i} \Delta y_{t-1} + \sum_{i=0}^r a_{2i} \Delta p_{t-i} + \sum_{i=0}^r a_{3i} \Delta m_{t-i} + yECT_{t-1} + \varepsilon_t \dots (5)$$

Where (ECT) represents the error correction term, as it is added to the model, (y) represents the ratio of the deviation that is corrected in period (t-1 to period t), and this means the speed of error correction of the dependent variable in the short term towards its equilibrium value in the long term.

## DISCUSSION

Obviously, there are some factors of Climate Change that significantly influence for the Agricultural Production in Egypt.

Table (1): Average of the productivity of the most important cereal crops, temperatures, rain and humidity during the period (2000-2020)

	2000	2020	Average	Min.	Max.	Percentage change from 2000
<b>Wheat yield (ton)</b>	2.8	2.71	2.78	2.43	2.88	-2.9
<b>Corn yield (ton)</b>	3.4	3.06	3.36	3.06	3.65	-9.8
<b>Rice yield (ton)</b>	3.83	3.79	4.00	3.79	4.24	-1.2
<b>Max. temperature</b>	28.4	30.2	29.04	26.6	31	6.2
<b>Min. temperature</b>	15.3	18.4	16.5	14.5	19.5	20.6
<b>Humidity rate (%)</b>	55.4	43	52.43	42.2	56	-22.4
<b>Amount of rain mm</b>	3.82	3.13	3.28	1.35	4.7	-18.1

Source: Calculated from the website of the Central Agency for Public Mobilization and Statistics [www.capmas.gov.eg](http://www.capmas.gov.eg)

First: Development of the study variables during the period (2000-2020):

Through the study of the productivity of the most important cereal crops (CAPMAS 2022), it was found that during the average study (2000-2020) it reached about 2.78 tons, 3.36 tons and 4.0 tons respectively, while it ranged between a minimum of about 2.43 tons, 3.06 tons, and 3.79 tons, and an upper limit of 2.88 tons, 3.65 tons, 4.24 tons respectively. It was also shown that the average productivity of wheat, corn and rice in 2020 decreased by about 2.9%, 9.8%, and 1.2% respectively, from the year 2000 - Figure (1).

It was also found that the average maximum and minimum temperatures were about 29.04 °C and 16.5 °C respectively, while they ranged between a minimum of about 26.6 °C and 14.5 °C, and a maximum of about 31.0 °C and 19.5 °C respectively. It also shows an increase in the average maximum and minimum temperatures in 2020 by about 6.2% and 20.6% respectively from the year 2000. While it was found that the average humidity levels amounted to about 52.43%, while it ranged between a minimum of about 42.2%, and a maximum of about 56% during the study period. It was also shown that the average humidity levels decreased in 2020 by about 22.4% from the year 2000. It was also found that the average amount of rain amounted to about 3.28 mm, while it ranged between a minimum of about 1.35 mm and a maximum of about 4.7 mm during the study period. It was also shown that the average amount of rain decreased in 2020 by about 18.1% from the year 2000 - Table (1), Fig. (2).

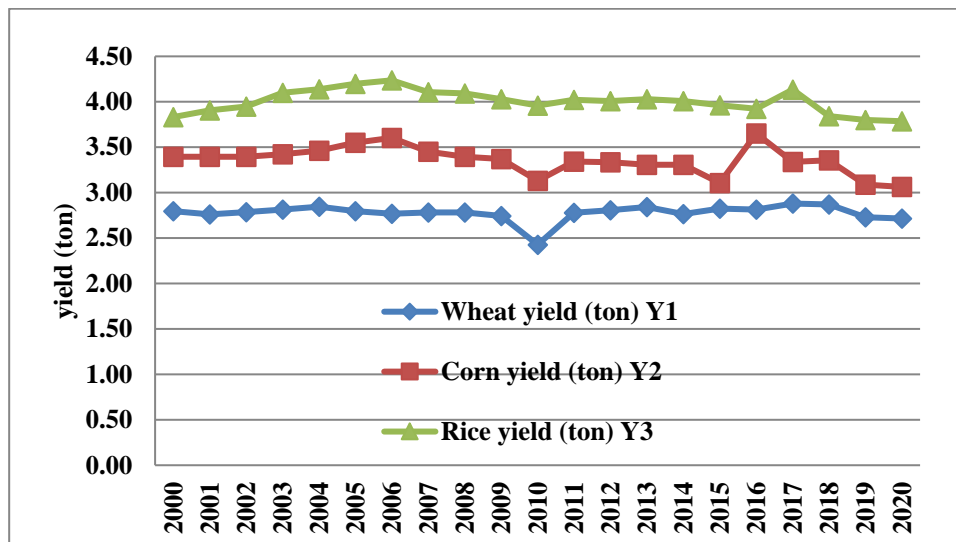


Figure (1): Evolution of the productivity of the most important cereal crops during the period (2000-2020)

Source: Calculated from: Central Agency for Public Mobilization and Statistics, Agricultural Statistics Bulletin, miscellaneous issues.

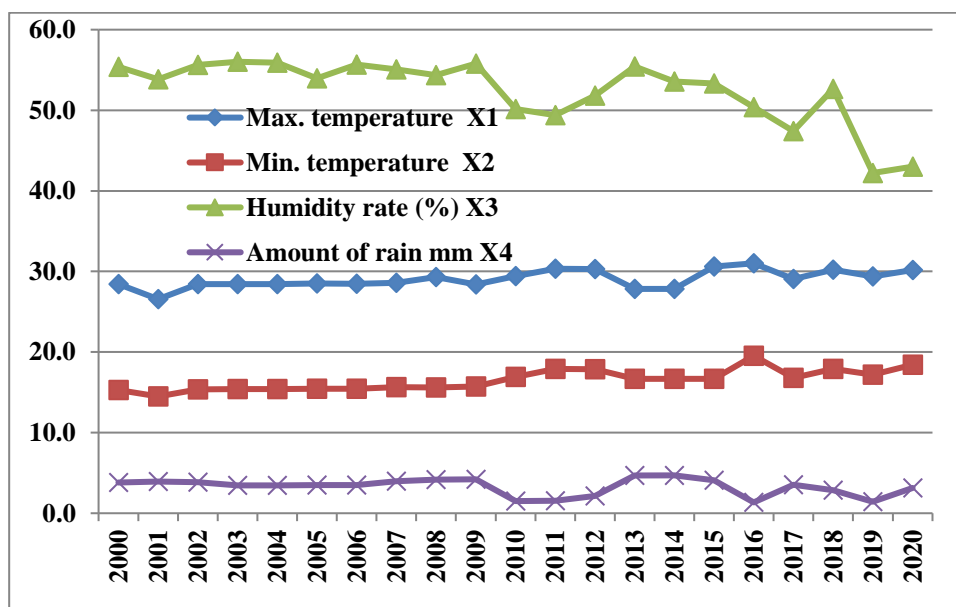


Figure (2): Evolution of the temperatures, humidity and rains during the period (2000-2020)

Source: Calculated from: Central Agency for Public Mobilization and Statistics, Agricultural Statistics Bulletin, miscellaneous issues.

Second: Estimation of the Autoregressive Distributed lagged Model (ARDL)

To estimate the models of the impact of climate change on the productivity of the most important cereal crops in Egypt by using the Autoregressive Distributed lagged Model (ARDL) methodology, the conditions for the

stability of time series must be met, (Augmented Dickey Fuller test) (Asia Tawil et al. 2021; Zahra Ali Abdel Rahman and Shoman Abdel Latif Hassan 2013), whether stable at the zero level I(0), or the first difference I(1), and to ensure the stationary of the time series, the Unit Root Test was conducted by using the Augmented Dickey Fuller Test (ADF), where it was found some variables of

the models are stationary at the zero level with a confidence level of 95%, and they do not have unit roots (Mostafa Ryad, ElBadry Mamdouh 2015), while it was found some of them aren't stationary at the zero level, and they have a unit roots, so the first difference was taken, where it was found after taking the first difference, the

calculated value of (t) is greater than its tabulate value at the level of significance of 0.05, which means that there is no unit root and the time series are stationary, which calls for the use of the (ARDL) methodology presented by (Pesaran, et. Al. 2001) - Table (2).

Table (2): Results of the Augmented Dickey Fuller Test (ADF)

Variable	Difference	With Constant	With constant and trend	Without constant and trend	degrees of integration
Wheat yield	Zero	-3.387	-3.488**	0.579	I(0)
	Frist	-5.757**	-5.909**	-6.075**	
Corn yield	Zero	-2.719	-3.623*	0.394	I(0)
	Frist	-7.113**	-7.148**	-7.190**	
Rice yield	Zero	-1.806	-2.674	-0.137	I(1)
	Frist	-5.059**	-5.681**	-5.191**	
Max. temperature	Zero	-2.845	-5.351**	1.168	I(0)
	Frist	-4.844**	-4.706**	-4.622**	
Min. temperature	Zero	-1.863	-4.650**	1.504	I(0)
	Frist	-4.574**	-4.390**	-7.375**	
Humidity rate	Zero	-1.295	-2.871	-1.106	I(1)
	Frist	-6.291**	-6.70**	-6.154**	
Amount of rain	Zero	-3.202*	-3.390	-0.946	I(0)
	Frist	-4.778**	-4.603**	-4.912**	

\*\*Significance at the 0.01 level. \*Significant at the 0.05 level.

Source: Calculated from data of table (1) by using the E-views10 program.

The ARDL models consist of one dependent variable and a numbers of explanatory independent variables (X1,X2.....Xn):

**a = constant**

**Y<sub>2</sub> = Corn yield (ton)**

**X<sub>1</sub> = Max. temperature**

**X<sub>3</sub> = Humidity rate (%)**

**Wheat Yield Model**

**Corn Yield Model**

**Rice Yield Model**

**Y<sub>1</sub> = Wheat yield (ton)**

**Y<sub>3</sub> = Rice yield (ton)**

**X<sub>2</sub> = Min. temperature**

**X<sub>4</sub> = Amount of rain**

**Y<sub>1</sub> = a + b<sub>1</sub> X<sub>1</sub> + b<sub>2</sub> X<sub>2</sub> + b<sub>3</sub> X<sub>3</sub> + b<sub>4</sub> X<sub>4</sub>**

**Y<sub>2</sub> = a + b<sub>1</sub> X<sub>1</sub> + b<sub>2</sub> X<sub>2</sub> + b<sub>3</sub> X<sub>3</sub> + b<sub>4</sub> X<sub>4</sub>**

**Y<sub>3</sub> = a + b<sub>1</sub> X<sub>1</sub> + b<sub>2</sub> X<sub>2</sub> + b<sub>3</sub> X<sub>3</sub> + b<sub>4</sub> X<sub>4</sub>**

After ensuring the stability and integrity of the time series, whether at the zero degree or the first degree, the ARDL model will be estimate through the following steps:

#### 1- The Bounds Test (AISawai Khaled 2012)

A bounds test was conducted to determine the extent of co-integration between the model variables or not. If the (F) calculated value is greater than the upper limit of

critical values then the null hypothesis is rejected, which states that there is no long-term equilibrium relationship between the variables and acceptance of the alternative hypothesis with the existence of a joint integration relationship between the variables, but if the (F) calculated value is less than the minimum critical values, then the alternative hypothesis is rejected and acceptance the null hypothesis , then absence of an equilibrium relationship in the long run, and existence of co-integration between the variables.

Table (3): Results of the (F Bounds Test)

Model	Min. level I(0)	Max. level I(1)	Sig.F	F
Wheat Model	3.74	5.06	1%	<b>6.4</b>
Corn Model	2.86	4.01	5%	<b>4.64</b>
Rice Model	2.45	3.52	10%	<b>24.5</b>

Source: Calculated from data of table (1) by using the E-views10 program.

According to the Bounds Test approach, it was found from the results of the bounds test, the (F) calculated value was about 6.4 for the wheat productivity model, 4.64 for the corn productivity model, 24.5 for the rice productivity model, which is greater than the upper limit of the critical values of the borders, which means rejecting the null hypothesis and accepting the alternative hypothesis, by existence of a long-term equilibrium relationship between the model variables at a level of significance of 5% - Table (3).

2-Estimating the equilibrium relationship in the long term (Adrewhish Hamani Mohamed and Abdel Qader Nassour 2013):

It was found a long-term relationship between the study variables, it was determined a maximum numbers of lagged periods, it was selected the ARDL model (3,2,2,2,1) for wheat crop, the ARDL model (1,0,0,0),0 for maize yield, ARDL model (3,0,2,2,2) for rice yield, which there are the best models for estimating the long-term equilibrium relationship.

The results of estimating of the impact of climate change model on wheat crop productivity in Egypt, by using the Autoregressive Distributed lagged methodology (ARDL) during the period (2000-2020), showed that there was a long-term inverse relationship between the dependent variable (wheat crop productivity) and the independent variable (Maximum temperature), it meaning that a decrease in the maximum temperature by 1% leads to an increase in the productivity of the wheat crop by about 0.15%, as it was found that there is a long-term direct relationship between the productivity of the wheat crop and both the minimum temperature and the relative humidity, it meaning that an increasing both the minimum temperature and the relative humidity by 1%, leads to an increase in the productivity of the wheat crop by about 0.3% and 0.12%, respectively. It was also found that there is a long-term inverse relationship between the productivity of the wheat crop and the amount of rain, it meaning that a decrease in the amount of rain by 1%, leads to an increase in the productivity of the wheat crop by about 0.19%, and this is consistent with the economic theory.

It was also found that the coefficient of R2 reached about 0.976, which means that the model variables explain about 97.6% of the fluctuations in wheat productivity, due to the change in the maximum temperature, minimum temperature, relative humidity and the amount of rain, while the rest of the fluctuations, it is due to other factors that were not included in the model. As it was shown through the F calculated value, it amounted to about 28 at a level of significance of 0.01, and then it shows the significance of the whole model, this means that the model is accepted from a statistical point of view.

The significance of the error correction coefficient, and its negative sign, where it reached (-0.531) at the level of significance of 0.01 indicates the existence of a co-integration relationship between the variables, that explain the productivity of the wheat crop, that is when wheat productivity deviates from the equilibrium value, during the short term, it quickly returns to its equilibrium value in the long term, to about 53.1% of the imbalance were corrected during period (t), until it reaches equilibrium again.

The results of estimating of the impact of climate change model on corn crop productivity in Egypt, by using the Autoregressive Distributed lagged methodology (ARDL) during the period (2000-2020), showed that there was a long-term inverse relationship between the dependent variable (corn crop productivity) and the independent variable (Maximum temperature), it meaning that a decrease in the maximum temperature by 1% leads to an increase in the productivity of the corn crop by about 0.07%, as it was found that there is a long-term direct relationship between the productivity of the corn crop and both the minimum temperature and the relative humidity, it meaning that an increasing both the minimum temperature and the relative humidity by 1%, leads to an increase in the productivity of the corn crop by about 0.1% and 0.05%, respectively. It was also found that there is a long-term inverse relationship between the productivity of the corn crop and the amount of rain, it meaning that a decrease in the amount of rain by 1%, leads to an increase in the productivity of the corn crop by about 0.1%, and this is consistent with the economic theory.

It was also found that the coefficient of R2 reached about 0.624, which means that the model variables explain about 62.4% of the fluctuations in corn productivity, due to the change in the maximum temperature, minimum temperature, relative humidity and the amount of rain, while the rest of the fluctuations, it is due to other factors that were not included in the model. As it was shown through the F calculated value, it amounted to about 29.8 at a level of significance of 0.01, and then it shows the significance of the whole model, this means that the model is accepted from a statistical point of view.

The significance of the error correction coefficient, and its negative sign, where it reached (-0.65) at the level of significance of 0.01 indicates the existence of a co-integration relationship between the variables, that explain the productivity of the corn crop, that is when corn productivity deviates from the equilibrium value, during the short term, it quickly returns to its equilibrium value in the long term, to about 65% of the imbalance were corrected during period (t), until it reaches equilibrium again.

The results of estimating of the impact of climate change model on rice crop productivity in Egypt, by using the Autoregressive Distributed lagged methodology (ARDL) during the period (2000-2020), showed that there was a long-term inverse relationship between the dependent variable (rice crop productivity) and the independent variable (Maximum temperature), it meaning that a decrease in the maximum temperature by 1% leads to an increase in the productivity of the rice crop by about 0.15%, as it was found that there is a long-term direct relationship between the productivity of the rice crop and

both the minimum temperature and the relative humidity, it meaning that an increasing both the minimum temperature and the relative humidity by 1%, leads to an increase in the productivity of the rice crop by about 0.06% and 0.03%, respectively. It was also found that there is a long-term positive relationship between the productivity of the rice crop and the amount of rain, it meaning that an increase in the amount of rain by 1%, leads to an increase in the productivity of the rice crop by about 0.19%, and this is consistent with the economic theory.

It was also found that the coefficient of R2 reached about 0.992, which means that the model variables explain about 99.2% of the fluctuations in rice productivity, due to the change in the maximum temperature, minimum temperature, relative humidity and the amount of rain, while the rest of the fluctuations, it is due to other factors that were not included in the model. As it was shown through the F calculated value, it amounted to about 107 at a level of significance of 0.01, and then it shows the significance of the whole model, this means that the model is accepted from a statistical point of view.

The significance of the error correction coefficient, and its negative sign, where it reached (-0.532) at the level of significance of 0.01 indicates the existence of a co-integration relationship between the variables, that explain the productivity of the rice crop, that is when rice productivity deviates from the equilibrium value, during the short term, it quickly returns to its equilibrium value in the long term, to about 53.2% of the imbalance were corrected during period (t), until it reaches equilibrium again.

Table (4): Results of Estimating the ARDL model in the long term and the error correction in the short term

Model	long term model	Error correction in the short term
Wheat yield	$Y_1 = -0.1518X_1 + 0.3040X_2 + 0.1149X_3 - 0.1862X_4$ R <sup>2</sup> =0.976 F= 28**	-0.531**
Corn yield	$Y_2 = -0.0725X_1 + 0.0996X_2 + 0.0540X_3 - 0.0994X_4$ R <sup>2</sup> =0.624 F= 29.8**	-0.650**
Rice yield	$Y_3 = -0.1516X_1 + 0.0623X_2 + 0.0266X_3 + 0.0315X_4$ R <sup>2</sup> =0.992 F= 107**	-0.532**

\*\*Significance at the 0.01 level. \*Significant at the 0.05 level.

Source: Calculated from data of table (1) by using the SPSS program.

Third: Diagnostic Residuals Tests (Maryam Azouzi and Asmaa Amiri 2019)

Diagnostic tests are used to judge the suitability of the model where used, to measure the estimated elasticity in the long term, to ensure the quality of the model were used

in the analysis , not to include the errors and measurement problems:

1- The Auto-correlation test between errors (LM Test) (Salami Asma and Salami Ahmed 2020)

This test is used to detect the possibility of a serial correlation between errors, in order to know the possibility of accepting the null hypothesis that there is no sequential autocorrelation problem, between the parameters of the estimated models, where it was found that the significance of the value (F) it about to 0.178,

0.844, 0.164 for wheat, maize and rice crop models, respectively, which are greater than the significance level of 0.05, therefore the null hypothesis is accepted, that there is no serial autocorrelation problem between the errors of the estimated models parameters - Table (5).

Table (5): Results of examining the model residuals

Model	Serial Correlation (LM Test) Breusch-Godfrey	Heteroskedasticity test (ARCH Test)	Normality Test (Jarque-Bera Test)
Wheat Model	$F = 15.3$ $Prob.(2, 1) = 0.178$	$F = 2.22$ $Prob.(1, 15) = 0.157$	$Jarque-Bera = 1.260$ $Prob. = 0.533$
Corn Model	$F = 0.172$ $Prob.(2, 12) = 0.844$	$F = 0.234$ $Prob.(1, 17) = 0.635$	$Jarque-Bera = 0.352$ $Prob. = 0.839$
Rice Model	$F = 5.08$ $Prob.(2, 2) = 0.164$	$F = 0.934$ $Prob.(1, 15) = 0.349$	$Jarque-Bera = 1.199$ $Prob. = 0.549$

Source: Calculated from data of table (1) by using the E-views10 program.

## 2- The ARCH Test (Mostafa Ryad, ElBadry Mamdouh 2015)

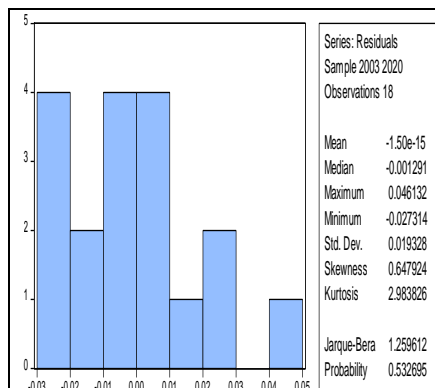
This test is used to detect the problem of the instability of the variance of the error term (Heteroskedasticity), which depends on the Lagrange Multiplier, where it was found that the significance of the value of (F) reached about 0.157, 0.635, 0.349 for the wheat, corn, and rice crop models respectively, which is greater than the level of significance. 0.05, therefore we reject the null hypothesis and accept the alternative hypothesis, with absence of the problem of instability of the variance of the error term for the estimated model variables - Table (5).

## 3- Normal Distribution of residuals test (Normality Test) (AlYoussef Noura Abdel Rahman 2013)

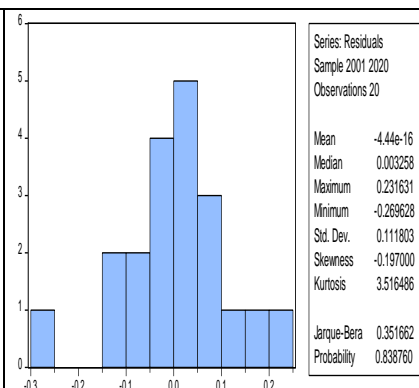
This test is used to detect the normal distribution for the residuals of the estimated models, as it depends on the (Jarque-Bera Test), it was shown from table (5) that the (Jarque-Bera test) is less than the tabulate value of the CHI-distribution, which was 1.26 for the wheat crop productivity model, with degrees of freedom 18, and the critical probability ratio is greater than of the significance ratio of 0.05, then we accept the null hypothesis  $H_0$ , that the residuals are normally distributed, in addition to that the skewness coefficient is about 0.648, where its value is limited between [-3, +3], so the probability distribution of the residuals of the estimated model is normal, which indicates the symmetry of the probability distribution of

the residuals of the estimated model, as it turned out that the probability distribution curve is positive, that it is slightly skewed to the right - Figure (3). It was shown that the (Jarque-Bera test) amounted about 0.352, it is less than the tabulate value of the CHI-distribution, which for the corn crop productivity model, with degrees of freedom 20, and the critical probability ratio is greater than of the significance ratio of 0.05, then we accept the null hypothesis  $H_0$ , that the residuals are normally distributed, in addition to that the skewness coefficient is about (-0.197), so the probability distribution of the residuals of the estimated model is normal, which indicates the symmetry of the probability distribution of the residuals of the estimated model, as it turned out that the probability distribution curve is negative, that it is slightly skewed to the left - Figure (4).

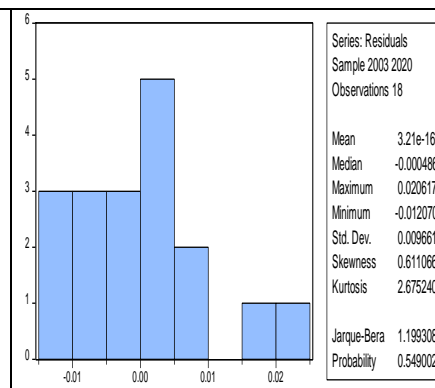
It was shown that the (Jarque-Bera test) amounted about 1.199, it is less than the tabulate value of the CHI-distribution, which for the rice crop productivity model, with degrees of freedom 18, and the critical probability ratio is greater than of the significance ratio of 0.05, then we accept the null hypothesis  $H_0$ , that the residuals are normally distributed, in addition to that the skewness coefficient is about 0.611, so the probability distribution of the residuals of the estimated model is normal, which indicates the symmetry of the probability distribution of the residuals of the estimated model, as it turned out that the probability distribution curve is positive, that it is slightly skewed to the right - Figure (5).



**Figure (3): Normal distribution test for the residues of the Wheat productivity Model**



**Figure (4): Normal distribution test for the residues of the Corn productivity Model**



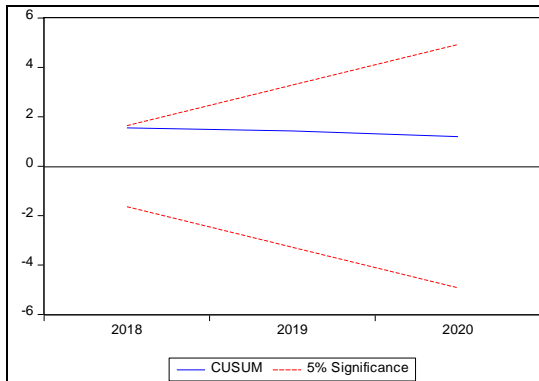
**Figure (5): Normal distribution test for the residues of the Rice productivity Model**

Source: Calculated from data of table (1) by using the E-views10 program.

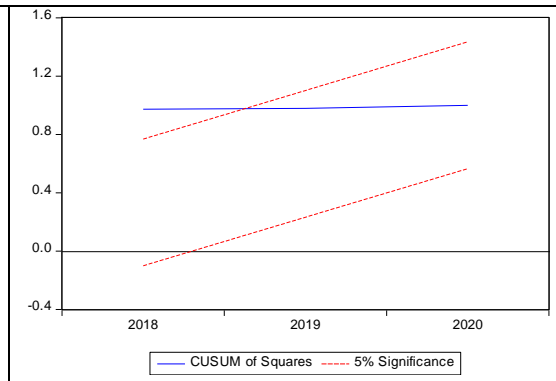
4- Model stability test: (Dickey, D.A., and W.A. Fuller. 1979; AlSawai Khaled 2012)

The (Cumulative Sum Squares) or (Cusum of Squares) test are used to detect the presence of any structural changes, to show the stability and consistency of the parameters of the long-term models with the short-term parameters, to verify the structural stability of the estimated error-correction coefficients for the self-

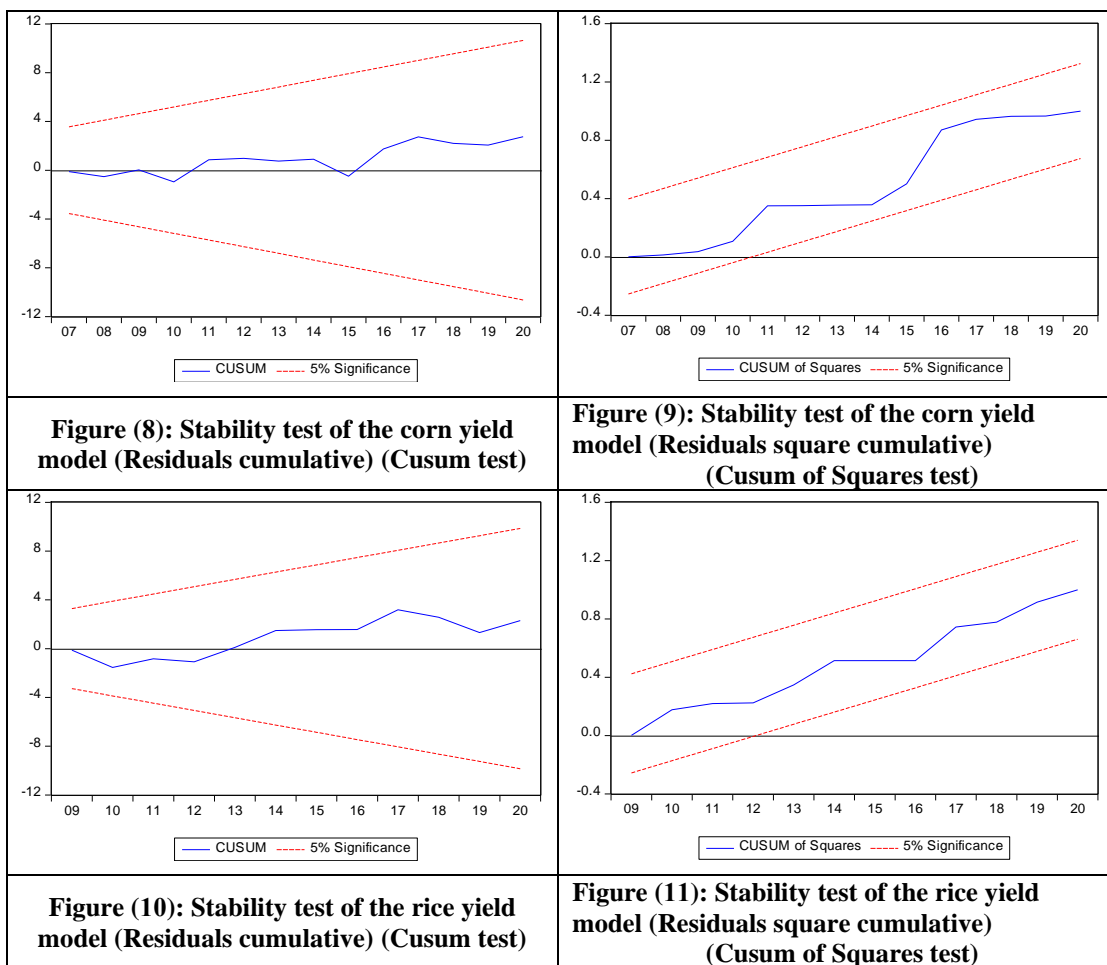
regressive models of the slow-distributed time-gaps. (ARDL), if the graph falls within the critical limits at the significance level of 0.05, it means that the parameters of the models are stable throughout the study period - Figures (6:11). It was found from the figures that the parameters of the estimated models are structurally stable throughout the study period. We also note the consistency of the models between the results of error correction in the long and short term, where the graphs fell within the critical limits at the level of significance of 0.05.



**Figure (6): Stability test of the wheat yield model (Residuals cumulative) (Cusum test)**



**Figure (7): Stability test of the wheat yield model (Residuals square cumulative) (Cusum of Squares test)**



Source: Calculated from data of table (1) by using the E-views10 program.

## CONCLUSION AND RECOMMENDATION

This paper identifies the factors influencing of the climatic changes on the productivity of the most important grain crops in Egypt, where it was found that there is an inverse relationship between climate changes and the productivity of the most important cereal crops, a relationship that is consistent with the economic logic as shown:

1- The stability of some variables of the estimated models, at the zero level, while some of them stabilized at the first difference, there is no degree of integration of the second degree, so the estimation conditions were applied, using the (ARDL) Methodology.

2- There is a long-term equilibrium relationship between climate changes and the productivity of the most important cereal crops, as its estimated significance has been proven.

3- The value of the error correction coefficient was about (-0.531), (0.650), (-0.532) for wheat, maize and rice crops, respectively, which indicates that when the productivity of the most important grain crops deviates from the equilibrium value during the short term, the speed of Its return to the equilibrium value in the long run, which is about 53.1%, 65%, 53.2% for crops of wheat, corn, and rice, respectively, from imbalance, until it reaches equilibrium after about 1.6 years, 1.4 years, 1.6 years for crops of wheat, corn, rice, respectively to return the long-term equilibrium position.

4- The presence of a negative impact of the maximum temperature change on the productivity of the most important cereal crops in the long term, i.e. an increase in maximum temperatures by 1% leads to a decrease in the productivity of the most important cereal crops, by about 0.15%, 0.07%, 0.15% for wheat crops, Corn, rice, respectively, which is consistent with economic theory.

Recommendations:

1. Selecting of genetically improved high-yielding varieties and seeds that can withstand climate change, drought and humidity.
2. Using the modern technology to store the grains, to reduce the waste of storage.
3. Depend on early warning systems for sudden weather changes, to achieve the food security stability.
4. Expansion of green economy projects and environmentally friendly projects.
5. Establish the economic policies to take into account adaptation to climate changes.
6. Uses of the optimum available water resources.

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