

Article

# Climatic Change Effects on Yellow Corn Output across Iraq (1995–2020)

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**Abstract:** This study examines climatic-change effects on the output of yellow maize in Iraq from 1995 to 2020. A semi-annual period of time series data were used which was consistent with our goals and used linear modelling in EViews 10 software. The association between yellow maize output and climate indicators (temperature, precipitation, wind speed, and relative humidity) and their relation in short- and long-run periods was discussed. The significance of the study is the economic and agricultural value of the yellow maize crop in Iraq as well as climate fluctuations and its sensitivity (especially in the process of growth, flowering and grain filling) as it is affected by climate and its production is of great importance for agriculture. It used semi-annual data from 1995 to 2020 to measure the association linking climate indicators with yellow maize output and to assess the nature and magnitude of the effect from climate variables upon crop yield. As we found the climatic factors are very much on the rise in yellow maize production, rainfall has a favorable effect on crop yield; indicating that water availability in all stages of plant growth is necessary and wind speed is not on the rise and the plant growth and pollination efficiency are affected with high wind speed. We found that temperature is very important to yellow maize production and it depends on how well it meets the crop temperature throughout the growth stages. The corresponding relative humidity of the crop is high and the crop productivity is higher. To understand the persistent equilibrium linkage among variables, we used cointegration analysis to find a long-term linkage connecting climate and yellow maize output. The analysis findings showed that the relationship between climatic and crop production is not only short-term and the change in climatic conditions is in the long term. This indicates the importance of climatic variables to future agricultural policies and strategies to ensure the sustainability of yellow maize production in Iraq.

**Keywords:** Climate change, climatic factors, yellow maize production, temperature, rainfall.

## Introduction

Yellow maize (*Zea mays* L.) is a strategic agricultural crop that is of considerable economic and nutritional importance with a variety of applications in human nutrition, animal feed and food and fodder production. Maize production is also very much dependent on the environmental and climatic conditions at different stages of growth; climate and climatic conditions are the major factors affecting the yield and quality of maize. It is important to study the relationship between climate and maize as

we are dealing with rapid climate change in which the temperature is rising at a rapid rate and rainfall, humidity, and solar radiation patterns are changing, but the production and development of maize are also influenced by climate with the same effect on the production of maize in plants. The response of maize to different climatic factors varies depending on the growth stage: high and low temperatures and adequate solar radiation promote good growth, while unfavorable conditions hinder crop development. The volume and timing of rainfall and its distribution are also important to determine the water requirements for the crop, particularly during the stages of germination, vegetative growth, flowering, and grain filling. On the other hand, fluctuations in humidity can influence the efficiency of the production process, so understanding the influence of various climatic conditions on maize productivity and identifying optimal growing conditions is valuable [1]. Therefore, studying climatic effects on maize production is a central area of agricultural research as it can help to improve crop management, determine appropriate planting dates, and select the best varieties for the climate. It also supports planning for the future of agriculture, preparing farmers to adapt to a changing climate, and plays a key role in enhancing secure food supplies [2].

### Research Methodology

1- This research is meant to explore climatic-change effects on yellow maize output within Iraq during the period 1995-2020 by measuring the pattern and direction of the association linking crop production and climatic variables (namely, temperature, rainfall, relative humidity and wind speed). It aims to investigate the extent to which these variables affect crop production and the form of the short- and long-term relationship between them, and provide scientific indicators that can inform agricultural planning and climate change adaptation policies.

2- Research Problem: The central issue concerns fluctuations of yellow maize production in Iraq that may be related to changes and variations in climatic conditions (i.e., rising temperature, irregular rain and changes in humidity and wind speed). The main problem is to find out how these climatic factors affect crop production and whether the association linking climatic variables with crop output is only in the short-term or long-term.

3- Thus, this study seeks to address this question: What are the nature and magnitude of the impact of changes in key climatic factors on yellow maize output across Iraq over 1995-2020 and does a persistent equilibrium association among these variables exist? The researchers assume that the climatic factors that affect yellow maize production in Iraq are different and that the impact of the climatic elements depends on the nature and level of the climatic element of the field from the time of crop growth stage. Meanwhile, the long-term equilibrium relationship is found between climatic elements and yellow maize production and short-term relationship is also discernible with annual or semi-annual production fluctuations.

4- The analysis is very important in that it is not just a general description of the change in climatic factors and result of the crop yield but also a quantitative one for the nature of climatic-change effects and maize output. In addition, the results are also meaningful for crop production decision making and we can see the impact on the more flexible variety, the season to plant, the efficiency of water use and crop extension (more stability and sustainability).

5- Spatial and temporal study scope: A- Spatial Scope: This research covers the Republic of Iraq and analyses the local production of yellow maize and connects it to the climatic factors that affect production. B - Temporal Scope: The research is conducted from 1995 to 2020 and studied the trends in yellow maize and climatic elements together with short- and long-run relationship between them. The analysis uses semi-annual observations across this interval to monitor the changes and the production of the yellow maize as climatic changes occur.

### The Reality of Yellow Corn Output across Iraq (1995–2020).

#### The Economic Importance of Yellow Corn in Iraq

Yellow maize (*Zea mays* L.) is a major field crop in Iraq because it is a nutritional, economic and industrial crop. The kernels are used in various fields and are important for food and for many industries and therefore are used by many industries. It is also a critical agricultural crop as it is rich in vitamins, minerals and dietary fiber and thus a significant sector of food security and feed of the population. According to research [3]. Yellow maize is planted in Iraq in two seasons; spring and autumn. The productivity of plant growth and grain formation and filling is affected by seasonality of the season and weather conditions and crops are cultivated according to the planting date and environmental conditions during the growing season. Grain yields are higher in fall plantings as compared to spring plantings. That is because of the suitability of temperature and climate for plants to grow and grain formation and filling in different stages of plant growth and it is attributed to the agricultural factors which influence other agricultural factors [4].

#### The Status of Maize Production across Iraq (1995–2020).

Despite the high importance of yellow corn, its domestic output is not at the level of production potential in terms of available agricultural production and domestic demand, in contrast to production in other major global producers. Yellow corn comes in fourth in Iraq in terms of number and volume of fields and production area and is behind wheat, barley, and rice. This means that we have to pay more attention to this crop and we need to grow it and modernize our cultivation methods to increase the productivity per unit area and crop quality.

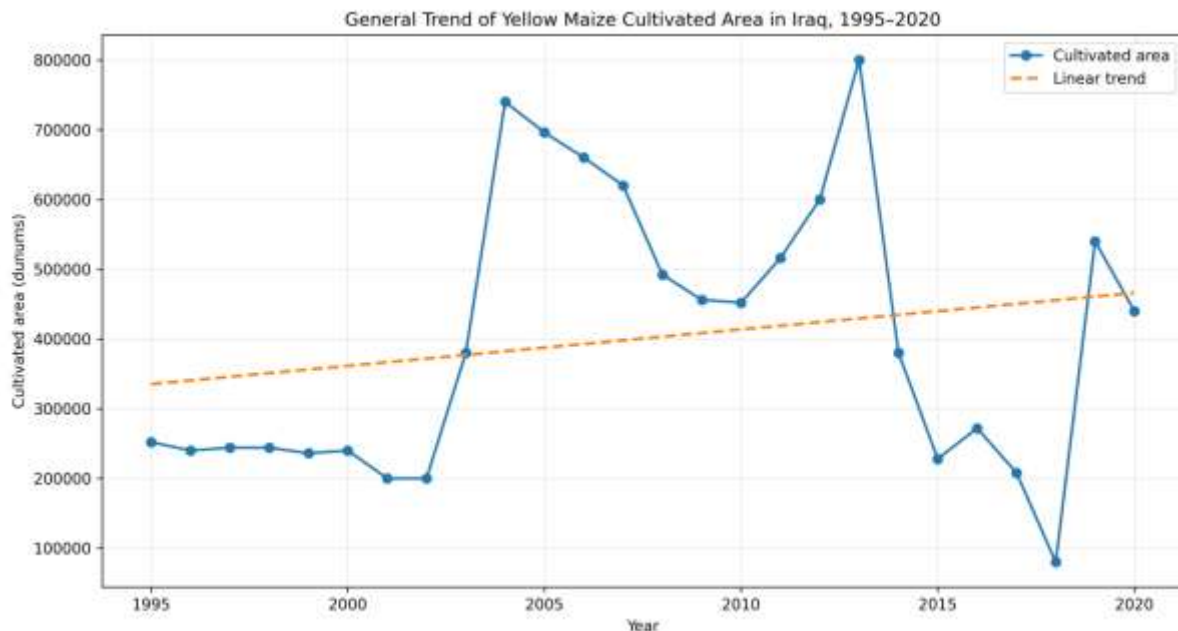
**Table 1.** Area and yellow corn output in Iraq

| Yellow Corn<br>Production<br>(Tonnes) | Area of<br>maize<br>cultivated<br>in Iraq<br>(donums) | The years      | Yellow Corn<br>Production<br>(Tonnes) | Area of<br>maize<br>cultivated<br>in Iraq<br>(donums) | The years |
|---------------------------------------|-------------------------------------------------------|----------------|---------------------------------------|-------------------------------------------------------|-----------|
| 266699                                | 452000                                                | 2010           | 101081                                | 252000                                                | 1995      |
| 335760                                | 516000                                                | 2011           | 357856                                | 240000                                                | 1996      |
| 503389                                | 600000                                                | 2012           | 409845                                | 244000                                                | 1997      |
| 831345                                | 800000                                                | 2013           | 573690                                | 244000                                                | 1998      |
| 289288                                | 380000                                                | 2014           | 368227                                | 236000                                                | 1999      |
| 182340                                | 228000                                                | 2015           | 170255                                | 240000                                                | 2000      |
| 259536                                | 272000                                                | 2016           | 231825                                | 200000                                                | 2001      |
| 185291                                | 208000                                                | 2017           | 578630                                | 200000                                                | 2002      |
| 63307                                 | 80000                                                 | 2018           | 235715                                | 380000                                                | 2003      |
| 473064                                | 540000                                                | 2019           | 415971                                | 740000                                                | 2004      |
| 419345                                | 440000                                                | 2020           | 401082                                | 696000                                                | 2005      |
| <b>8963118</b>                        | <b>10416000</b>                                       | <b>Total</b>   | 399038                                | 660000                                                | 2006      |
| <b>34473531</b>                       | <b>40061538</b>                                       | <b>Average</b> | 384471                                | 620000                                                | 2007      |
| <b>831345</b>                         | <b>800000</b>                                         | <b>Maximum</b> | 287955                                | 492000                                                | 2008      |
| <b>63307</b>                          | <b>80000</b>                                          | <b>Minimum</b> | 238113                                | 456000                                                | 2009      |

Ministry of Planning / Central Statistical Organization / Directorate of Agricultural Statistics

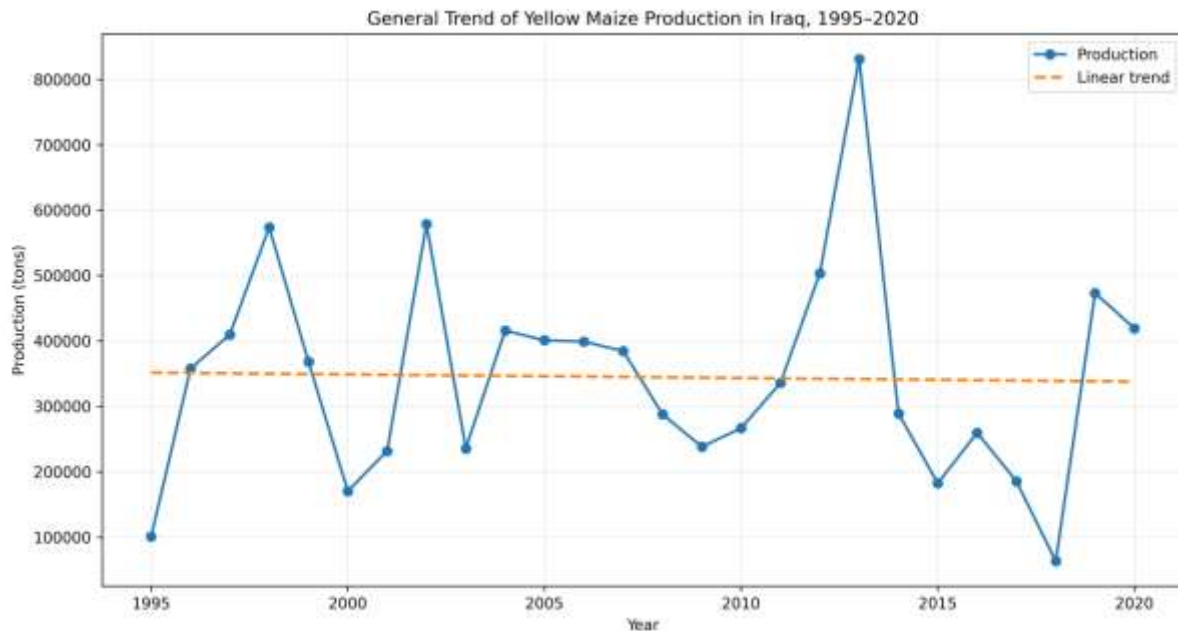
Data on maize cultivation in Iraq from 1995 to 2020 show significant fluctuations in the cultivated area and production, indicating relative instability in the crop's production activity over the study interval. The average planted area reached an average of 400.6 thousand dunams per year and the average annual production was about 344.7 thousand tons; total cultivated area was 10.416 million dunams with total production of 8.963 million tons. The maximum of 800 thousand dunams was recorded in 2013 and the lowest of 80 thousand dunams was measured in 2018. This leaves a difference of 720 thousand dunams between the maximum and the minimum and hence, the land for maize

cultivation is very variable in the study period. The area in the beginning (1995-2002) was about 200,000 to 252,000 and then rose to 380,000 in 2003 and 740,000 in 2004. The area was above 696,000, 660,000 and 620,000 in 2005-2007 and then fell to 492,000 at the beginning of 2008 and 452,000 at the end of 2010. It rose again in 2011 and 2012 and ended up at 800 K dunams in 2013. The result suggests that the area with yellow corn did not follow a consistent trend throughout the period but was in different phases of expansion and contraction. From an agricultural point of view, this is because of irrigation water, agricultural policy, crop and production input prices, farming supplies and climate.



**Figure 1.** General trend of yellow corn cultivation area in Iraq, 1995–2020

As for production, it reached a high of 831,345 tons in 2013 and a low of 63,307 tons in 2018. There is a difference of about 768,038 tons between the two extremes. In 2013, the highest cultivated area (800,000 dunams) was combined with the greatest production (831,345 tons), which means that as we grew the land became bigger the output also increased. However, 2018 is one of the most significant years when the cultivated area and production are dropping, and we find that production dropped to 63,307 tons and area dropped to 380,000 dunams in 2014 and 228,000 dunams in 2015, respectively. This implies that after the 2013 peak year it was a big jump. In 2019, there was a big surge in the cultivated area from 80,000 to 540,000, and total production from 63,307 to 473,064 tons. Production was still high in 2020 at 419,345 tons, but the cultivated area was reduced to 440,000. In general, the maize production in Iraq from 1995 to 2020 was characterized by huge variation in the cultivated area and production volume. Production peaked in 2013 for 800,000 dunams and production of 831,345 tons, while 2018 achieved the lowest level for both fields with 80,000 dunams and production of 63,307 tons.



**Figure 2.** General trend of yellow maize production in Iraq 1995–2020

### Climatic factors affecting yellow maize cultivation

Climatic elements determine the distribution and productivity of agricultural crops, and yellow maize farming depends on temperature, solar radiation, rainfall, wind and relative humidity, and water availability, the impact of these is different from moment to moment of the crop's growth and environment [5].

1. Solar radiation is the main source of energy needed for photosynthesis and plant growth whereas leaf growth, chlorophyll content and plant hormones have different effects. The amount of radiation is based on latitude, season and day length. Low light levels limit the growth of the plants and foliage area and productivity and the day length impacts both vegetative growth and reproduction in maize [6].

2. Temperature: Temperature is crucial for yellow maize because their growth stages determine the temperature at which the kernels germinate and develop physically. The biological zero for maize is about 8°C for germination and 10°C for the following growth stage. Temperature changes impact growth rate [7].

3. Irrigation: Yellow corn requires water from the planting stage to maturity. The flowering stage is particularly sensitive to this water shortage (15 days before and 15 days after flowering) as this is the time when the farmers are working on the plant. Irrigation is more or less random according to the climate and the soil and continues until the kernels reach physiological maturity .

4. Rainfall: Rainfall is a fundamental part of the plants' water supply and the level of rain is related to the possibility and productivity of yellow maize. Maize grows in the rainfed areas where it rains about 250-500 mm and the actual water requirement is 410-640 mm [8].

5. Wind impacts the crop through evaporation and transpiration rates, and the plant's water needs. Strong winds can also cause stem breakage, damage flowers and disrupt the plant's equilibrium with water, and irrigation water distribution [9], especially sprinkler irrigation.

6. Relative humidity is particularly important during the flowering and grain filling stages. Thus, the perfect balance between temperature and humidity is important in order for the yellow maize to grow and produce.

7. We adopt a standard model to consider the role of climatic factors within the farm sector. In this paper, we consider climatic factors as independent variables for the production of agricultural crops and they are expressed as follows:  $Y = F(X_1, X_2, X_3, X_4, X_5, \dots)$  (1). In general, the success of the

production of yellow maize depends on the environmental conditions in which climatic and water-related factors in the crop are put together and in terms of the physiological requirements of the crop; a lack of them (from climate and water) affects the crop growth and productivity.

Y = Yellow corn production (tons).

X1 = Percentage of humidity (%) .

X2 = Average annual temperature (°C).

X3 = Actual annual sunshine duration (hours/day).

X4 = Average annual rainfall (mm/year).

X5 = Average annual wind speed (km/h).

**Table 2.** Climatic factors affecting yellow maize crop production for the period 1995–2020

| Average wind speed (km/h) | Annual rainfall (mm/year) | Actual annual sunshine duration (sunshine in hours/day) | Average annual temperature (°C) | Humidity level(%) | Yellow Corn Production (Tonnes) | Years          |
|---------------------------|---------------------------|---------------------------------------------------------|---------------------------------|-------------------|---------------------------------|----------------|
| 19.56                     | 142.90                    | 8.667                                                   | 22.49                           | 39.75             | 101081                          | 1995           |
| 20.52                     | 149.19                    | 8.250                                                   | 22.87                           | 62.08             | 357856                          | 1996           |
| 19.74                     | 152.70                    | 8.250                                                   | 22.16                           | 57.80             | 409845                          | 1997           |
| 20.45                     | 139.16                    | 8.250                                                   | 23.37                           | 45.07             | 573690                          | 1998           |
| 20.21                     | 123.19                    | 8.250                                                   | 23.37                           | 24.96             | 368227                          | 1999           |
| 20.29                     | 130.64                    | 8.250                                                   | 22.86                           | 43.46             | 170255                          | 2000           |
| 20.18                     | 141.35                    | 8.508                                                   | 23.48                           | 54.25             | 231825                          | 2001           |
| 20.29                     | 139.82                    | 8.400                                                   | 22.84                           | 51.22             | 578630                          | 2002           |
| 19.90                     | 142.67                    | 8.073                                                   | 23.01                           | 54.64             | 235715                          | 2003           |
| 20.27                     | 143.19                    | 8.208                                                   | 22.88                           | 63.65             | 415971                          | 2004           |
| 19.74                     | 135.86                    | 8.455                                                   | 22.96                           | 49.97             | 401082                          | 2005           |
| 20.48                     | 143.19                    | 8.355                                                   | 23.00                           | 64.97             | 399038                          | 2006           |
| 20.16                     | 136.90                    | 8.225                                                   | 22.92                           | 51.89             | 384471                          | 2007           |
| 20.09                     | 129.40                    | 8.305                                                   | 23.09                           | 41.84             | 287955                          | 2008           |
| 19.74                     | 141.85                    | 7.986                                                   | 23.07                           | 43.43             | 238113                          | 2009           |
| 20.48                     | 128.54                    | 8.231                                                   | 24.47                           | 41.51             | 266699                          | 2010           |
| 19.77                     | 138.62                    | 8.301                                                   | 22.61                           | 39.35             | 335760                          | 2011           |
| 19.85                     | 139.34                    | 7.878                                                   | 23.21                           | 47.26             | 503389                          | 2012           |
| 19.49                     | 149.93                    | 8.435                                                   | 22.87                           | 56.61             | 831345                          | 2013           |
| 19.99                     | 148.56                    | 8.089                                                   | 23.32                           | 47.67             | 289288                          | 2014           |
| 20.09                     | 144.88                    | 7.615                                                   | 23.54                           | 62.93             | 182340                          | 2015           |
| 19.74                     | 140.46                    | 7.883                                                   | 23.36                           | 58.51             | 259536                          | 2016           |
| 19.89                     | 129.54                    | 8.151                                                   | 23.38                           | 30.33             | 185291                          | 2017           |
| 19.48                     | 157.73                    | 7.781                                                   | 24.18                           | 0.26              | 63307                           | 2018           |
| 19.87                     | 161.65                    | 8.383                                                   | 23.55                           | 0.22              | 473064                          | 2019           |
| 19.75                     | 149.64                    | 8.167                                                   | 23.43                           | 10.27             | 419345                          | 2020           |
| <b>213.346</b>            | <b>3680.90</b>            | <b>1143.90</b>                                          | <b>602.29</b>                   | <b>520.02</b>     | <b>8963118</b>                  | <b>Total</b>   |
| <b>8.206</b>              | <b>141.57</b>             | <b>44.00</b>                                            | <b>23.17</b>                    | <b>20.00</b>      | <b>344735.31</b>                | <b>Average</b> |
| <b>8.667</b>              | <b>161.65</b>             | <b>64.97</b>                                            | <b>24.47</b>                    | <b>20.52</b>      | <b>831345</b>                   | <b>Maximum</b> |
| <b>7.615</b>              | <b>123.19</b>             | <b>0.22</b>                                             | <b>22.16</b>                    | <b>19.48</b>      | <b>63307</b>                    | <b>Minimum</b> |

Iraqi Meteorological Organization and Seismology

## Economic and Econometric Analysis of Climatic Factors Affecting Yellow Corn Production in Iraq (1995–2020).

### Testing the Stationarity of Time Series for Economic Variables

Table (3) reports outcomes from the Augmented Dickey-Fuller (ADF) unit-root procedure, implemented under three settings: including an intercept only; including an intercept plus a time trend; and with neither an intercept nor a time trend. The results indicate the presence of a unit-root behavior across the series for most variables at their original levels, confirming a lack of stationarity and supporting retention of the null hypothesis regarding the existence of a unit root. However, after taking first differences of the variables and re-conducting the test, the findings show that stationarity is achieved at the first difference for all variables; this therefore implies rejection of H0 together with the acceptance of H1, confirming that all series are stationary at their first difference.

**Table 3.** Results of the variable stationarity test using the Augmented Dickey-Fuller (ADF) test.

#### UNIT ROOT TEST RESULTS TABLE (ADF)

Null Hypothesis: the variable has a unit root

|                          |             | <u>At Level</u>            |         |         |         |         |         |
|--------------------------|-------------|----------------------------|---------|---------|---------|---------|---------|
|                          |             | Y                          | X1      | X2      | X3      | X4      | X5      |
| With Constant            | t-Statistic | -4.3197                    | -1.5374 | -4.7337 | -4.6006 | -3.1601 | -1.8404 |
|                          | Prob.       | 0.0025                     | 0.4987  | 0.0009  | 0.0013  | 0.0348  | 0.3531  |
|                          |             | ***                        | n0      | ***     | ***     | **      | n0      |
| With Constant & Trend    | t-Statistic | -4.2915                    | -2.1910 | -6.2458 | -3.4165 | -3.3813 | -4.5520 |
|                          | Prob.       | 0.0120                     | 0.4738  | 0.0002  | 0.0748  | 0.0767  | 0.0075  |
|                          |             | **                         | n0      | ***     | *       | *       | ***     |
| Without Constant & Trend | t-Statistic | -1.1886                    | -0.9262 | 0.4304  | -1.5861 | -0.0384 | -0.8201 |
|                          | Prob.       | 0.2080                     | 0.3057  | 0.7989  | 0.1041  | 0.6603  | 0.3492  |
|                          |             | n0                         | n0      | n0      | n0      | n0      | n0      |
|                          |             | <u>At First Difference</u> |         |         |         |         |         |
|                          |             | d(Y)                       | d(X1)   | d(X2)   | d(X3)   | d(X4)   | d(X5)   |
| With Constant            | t-Statistic | -6.2017                    | -4.6440 | -9.7933 | -4.7396 | -5.6440 | -5.0934 |
|                          | Prob.       | 0.0000                     | 0.0012  | 0.0000  | 0.0014  | 0.0001  | 0.0005  |
|                          |             | ***                        | ***     | ***     | ***     | ***     | ***     |
| With Constant & Trend    | t-Statistic | -6.0526                    | -4.4690 | -9.5753 | -4.7369 | -5.1712 | -5.0274 |
|                          | Prob.       | 0.0003                     | 0.0085  | 0.0000  | 0.0062  | 0.0020  | 0.0030  |
|                          |             | ***                        | ***     | ***     | ***     | ***     | ***     |
| Without Constant & Trend | t-Statistic | -6.3436                    | -4.6336 | -9.9553 | -7.2799 | -5.7809 | -5.0731 |
|                          | Prob.       | 0.0000                     | 0.0001  | 0.0000  | 0.0000  | 0.0000  | 0.0000  |
|                          |             | ***                        | ***     | ***     | ***     | ***     | ***     |

#### Notes:

a: (\*)Significant at the 10%; (\*\*)Significant at the 5%; (\*\*\*) Significant at the 1% and (no) Not Significant

b: Lag Length based on SIC

c: Probability based on MacKinnon (1996) one-sided p-values.

Source: Prepared by the researcher based on outputs from the EViews 10 software.

Findings in Table (3) indicate that some variables are stationary at the level, while others are stationary at the first difference; consequently, the ARDL model will be specified here.

Second: Estimation using an ARDL specification:

ARDL serves to test for cointegration—a method developed [10], via the Bounds Test. It is employed when sample sizes are small, contrasting relative to cointegration procedures introduced by Engle & Granger and Johansen, which require large sample sizes to yield more accurate and efficient results.

The general formula for the ARDL model is:

$$\Delta Y = a_0 + a_1 X1_{t-1} + a_2 X2_{t-1} + a_3 X3_{t-1} + a_4 X4_{t-1} + a_5 X5_{t-1} + \sum_{i=1}^m B_1 \Delta Y_{t-1} + \sum_{i=1}^m B_2 \Delta X1_{t-1} + \sum_{i=1}^m B_3 \Delta X2_{t-1} + \sum_{i=1}^m B_4 \Delta X3_{t-1} + \sum_{i=1}^m B_5 \Delta X4_{t-1} + \sum_{i=1}^m B_6 \Delta X5_{t-1} + Et$$

Testing the ARDL model involves determining whether a long-run equilibrium association links the model's variables; once this relationship holds, the process proceeds to the stage of estimating the long-run parameters.

Several attempts were made to achieve the best estimation results—prioritizing adherence to diagnostic criteria, the absence of statistical issues, and overall model quality. The results presented in Table (4) represent the optimal outcome obtained using the ARDL model via EViews 10 software. This table details the estimated effects for the explanatory variables (including their lag structures) and the lagged response variable itself on the dependent variable. The analysis identified the (2, 0, 1, 3, 0, 1) specification as the best among the 2,048 models automatically evaluated by the software (as illustrated in Figure 3). The coefficient of determination value reached 0.83, indicating that 83% of observed variation comes from attributable to the variables included in the model, while the remaining variation is due to variables excluded from the model—the effects of which were absorbed by the stochastic error term.

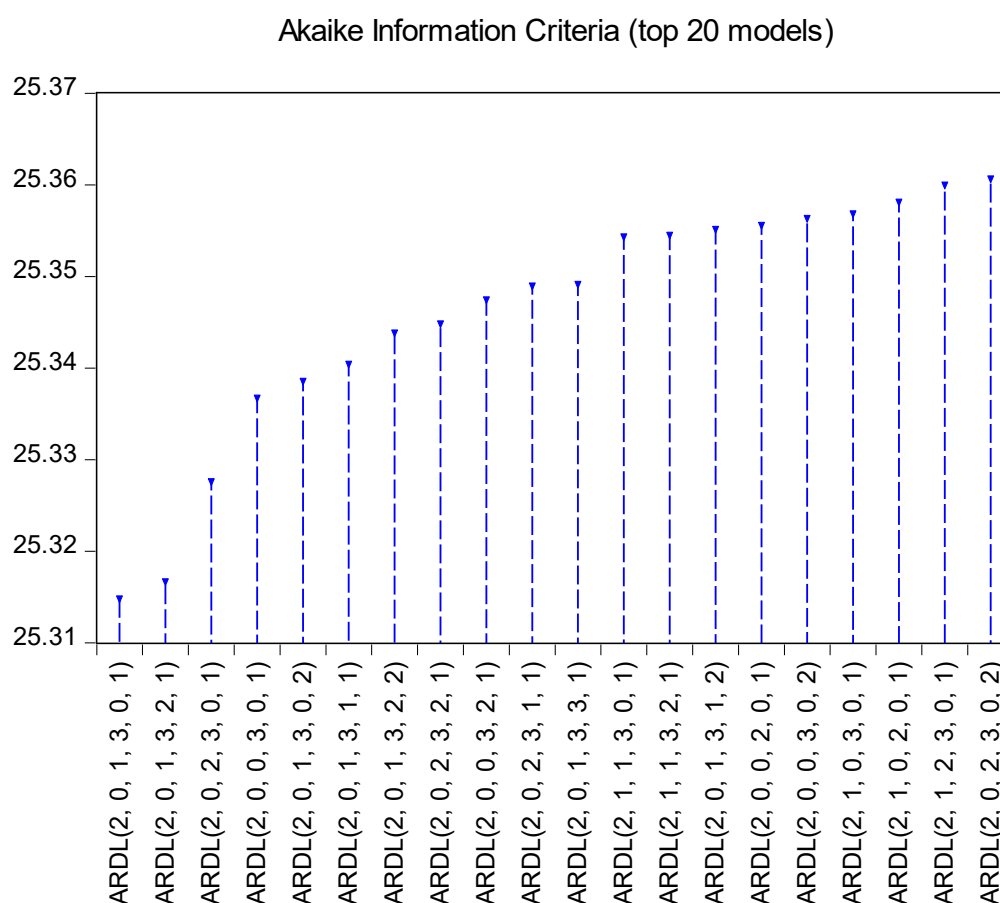
**Table 4.** Initial estimation of the estimated ARDL model

| Dependent Variable: Y                                  |             |                       |             |          |
|--------------------------------------------------------|-------------|-----------------------|-------------|----------|
| Method: ARDL                                           |             |                       |             |          |
| Date: 08/14/26 Time: 15:22                             |             |                       |             |          |
| Sample (adjusted): 1996S2 2020S1                       |             |                       |             |          |
| Included observations: 48 after adjustments            |             |                       |             |          |
| Maximum dependent lags: 2 (Automatic selection)        |             |                       |             |          |
| Model selection method: Akaike info criterion (AIC)    |             |                       |             |          |
| Dynamic regressors (3 lags, automatic): X1 X2 X3 X4 X5 |             |                       |             |          |
| Fixed regressors: C                                    |             |                       |             |          |
| Number of models evaluated: 2048                       |             |                       |             |          |
| Selected Model: ARDL(2, 0, 1, 3, 0, 1)                 |             |                       |             |          |
| Variable                                               | Coefficient | Std. Error            | t-Statistic | Prob.*   |
| Y(-1)                                                  | 487.5900    | 910.2751              | 0.535651    | 0.5956   |
| Y(-2)                                                  | 1.113854    | 0.128085              | 8.696194    | 0.0000   |
| X1                                                     | -0.534672   | 0.127588              | -4.190619   | 0.0002   |
| X2                                                     | -59866.28   | 46383.26              | -1.290687   | 0.2053   |
| X2(-1)                                                 | 65132.37    | 42958.65              | 1.516164    | 0.1385   |
| X3                                                     | 261963.3    | 100415.9              | 2.608784    | 0.0133   |
| X3(-1)                                                 | -234189.4   | 152929.9              | -1.531352   | 0.1347   |
| X3(-2)                                                 | 15707.94    | 152818.4              | 0.102788    | 0.9187   |
| X3(-3)                                                 | 204631.2    | 109124.7              | 1.875206    | 0.0691   |
| X4                                                     | -18.40888   | 1702.537              | -0.010813   | 0.9914   |
| X5                                                     | 41267.75    | 69259.99              | 0.595838    | 0.5551   |
| X5(-1)                                                 | -186390.5   | 69756.00              | -2.672036   | 0.0114   |
| C                                                      | 880237.2    | 1608802.              | 0.547138    | 0.5878   |
| R-squared                                              | 0.836245    | Mean dependent var    |             | 353700.4 |
| Adjusted R-squared                                     | 0.780101    | S.D. dependent var    |             | 144760.9 |
| S.E. of regression                                     | 67883.37    | Akaike info criterion |             | 25.31478 |
| Sum squared resid                                      | 1.61E+11    | Schwarz criterion     |             | 25.82157 |

|                   |           |                      |          |
|-------------------|-----------|----------------------|----------|
| Log likelihood    | -594.5548 | Hannan-Quinn criter. | 25.50630 |
| F-statistic       | 14.89451  | Durbin-Watson stat   | 1.783581 |
| Prob(F-statistic) | 0.000000  |                      |          |

\*Note: p-values and any subsequent tests do not account for model selection.

Source: EViews 10 software output.



**Figure 3.** Best estimated model according to the Akaike criterion.

Source: EViews 10 software output

#### ARDL Model Analysis and Tests

##### A- Test for Normal Distribution

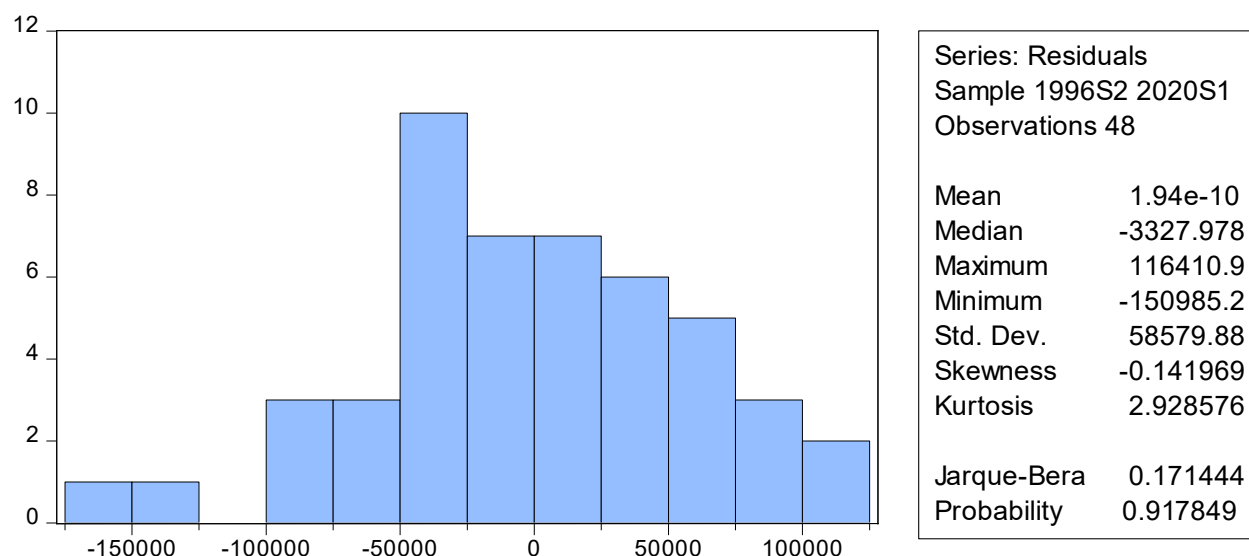
This is a statistical test concerned with the normal distribution of a series. This procedure statistic quantifies the discrepancy in these distributional moments between the sample and a Gaussian distribution, and it is calculated as follows:

$$Jarque - Bera = \frac{N}{6} \left( S^2 + \frac{(K - 3)^2}{4} \right)$$

where S denotes skewness and K denotes kurtosis.

Assuming normality under H0, the Jarque-Bera statistic follows a chi-square ( $\chi^2$ ) distribution with two degrees of freedom. Here, the reported probability gives the chance that the absolute Jarque-Bera statistic is larger than its observed value, and when it is small, the null hypothesis of normality is rejected, while the alternative hypothesis is not normally distributed. Figure (4) and its accompanying table show that the Jarque-Bera test is not of any significance as it gives only 0.17 probability, so we

retain the null assumption of normality and so the residual series of the estimated ARDL model has a normal distribution.



**Figure 4.** Assessment for residual normality based on Jarque-Bera criterion

**A- Source: EViews 10 software output.**

One important test in this field is the test for serial dependence within the model's disturbance term using a Lagrange Multiplier (LM) procedure, developed [11,12] . As shown in Table (5), the LM test results indicate the absence of serial dependence; the Chi-square probability value of 0.39 lies above the 0.05 cutoff. Consequently,  $H_0$  is retained, implying that the model is well-specified and there is no serial dependence among the disturbances.

**Table 5.** Lagrange Multiplier (LM) Test

| Breusch-Godfrey Serial Correlation LM Test: |          |                     |        |
|---------------------------------------------|----------|---------------------|--------|
| F-statistic                                 | 0.515054 | Prob. F(1,34)       | 0.4779 |
| Obs*R-squared                               | 0.716284 | Prob. Chi-Square(1) | 0.3974 |

**Source: EViews 10 software output.**

**A- Heteroskedasticity Test**

Based on the Breusch-Pagan-Godfrey (BPG) test, the reported F-statistic equaled 2.36 with a significance level of 0.10. Furthermore, the heteroskedasticity test results for the model showed a Chi-Square statistic of 0.47, which exceeds the 0.05 threshold. Consequently, there is no heteroskedasticity in the error term; thus,  $H_0$  is retained —indicating the absence of the problem— as shown in Table (6).

**Table 6.** Heteroskedasticity Test

| Heteroskedasticity Test: Breusch-Pagan-Godfrey |          |                      |        |
|------------------------------------------------|----------|----------------------|--------|
| F-statistic                                    | 2.621200 | Prob. F(12,35)       | 0.0131 |
| Obs*R-squared                                  | 22.71951 | Prob. Chi-Square(12) | 0.0302 |
| Scaled explained SS                            | 11.64821 | Prob. Chi-Square(12) | 0.4743 |

**Source: EViews 10 software output.**

### B- CUSUM and CUSUMSQ Stability Tests

CUSUM and CUSUMSQ procedures are used to evaluate structural stability of the model in both the short and long run. Structural stability for the coefficients of the estimated ARDL model (2, 0, 1, 3, 0, 1) is confirmed if the plots of the CUSUM and CUSUMSQ statistics fall within the critical bounds at the 5% significance level; conversely, the coefficients are considered unstable if the plots of these test statistics move outside the bounds at this level.

The results indicate parameter stability among the study variables and model consistency in both the short and long run, as shown in Figure (5).

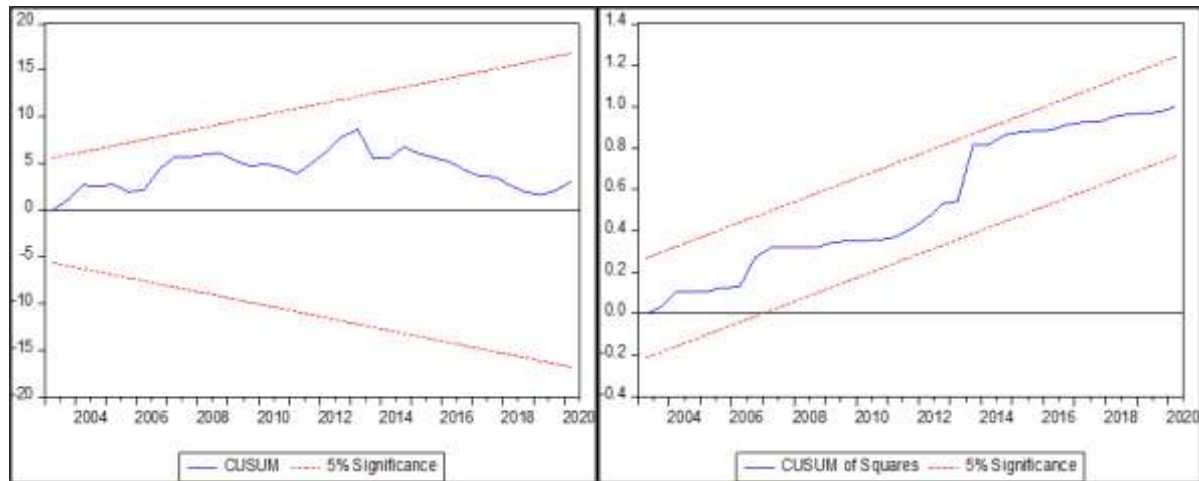


Figure 5. CUSUM and CUSUMSQ tests

Source: EViews 10 software output.

#### 1. Error Correction Model ECM

The following short-horizon error-correction specification was applied in the estimation:

$$d(Y_t) = \beta_0 + \sum_{i=1}^k \beta_1 dY_{t-i} + \sum_{i=1}^k \beta_2 dX1_{t-i} + \sum_{i=0}^k \beta_3 dX2_{t-i} + \sum_{i=0}^k \beta_4 dX3_{t-i} + \sum_{i=0}^k \beta_5 dX4_{t-i} + \sum_{i=0}^k \beta_6 dX5_{t-i}$$

Where:  $k$  denotes lag count,  $i$ 's  $\beta$  are the short-run parameters of the Error Correction Model, and  $\varepsilon_i$  is the random error term.

What matters here is that the error-correction coefficient (CointEq(-1)) appears statistically significant—a necessary condition—and negative—a sufficient condition. The negative sign indicates evidence of cointegration and the potential for short-term error correction to restore long-term equilibrium; the absolute value of this coefficient represents the proportion of errors corrected per unit of time—meaning that, following a shock, this specific proportion can be rectified within each time unit (year).

**Table 7.** Short-run model or error-correction model

ARDL Error Correction Regression

Dependent Variable: D(Y)

Selected Model: ARDL(2, 0, 1, 3, 0, 1)

Case 2: Restricted Constant and No Trend

Date: 08/14/26 Time: 15:43

Sample: 1995S1 2020S2

Included observations: 48

ECM Regression

Case 2: Restricted Constant and No Trend

| Variable           | Coefficient | Std. Error            | t-Statistic | Prob.    |
|--------------------|-------------|-----------------------|-------------|----------|
| D(Y(-1))           | 0.534672    | 0.105682              | 5.059261    | 0.0000   |
| D(X2)              | -59866.28   | 33763.32              | -1.773116   | 0.0849   |
| D(X3)              | 261963.3    | 83084.19              | 3.152986    | 0.0033   |
| D(X3(-1))          | -220339.1   | 83158.94              | -2.649614   | 0.0120   |
| D(X3(-2))          | -204631.2   | 79392.66              | -2.577457   | 0.0143   |
| D(X5)              | 41267.75    | 52128.25              | 0.791658    | 0.4339   |
| CointEq(-1)*       | -0.420818   | 0.078381              | -5.368842   | 0.0000   |
| R-squared          | 0.690082    | Mean dependent var    |             | 1281.021 |
| Adjusted R-squared | 0.644728    | S.D. dependent var    |             | 105226.5 |
| S.E. of regression | 62719.92    | Akaike info criterion |             | 25.06478 |
| Sum squared resid  | 1.61E+11    | Schwarz criterion     |             | 25.33767 |
| Log likelihood     | -594.5548   | Hannan-Quinn criter.  |             | 25.16791 |
| Durbin-Watson stat | 1.783581    |                       |             |          |

\* p-value incompatible with t-Bounds distribution.

Source: EViews 10 software output.

The findings in Table (7) show that the error correction coefficient is -0.42, and is significant at a 1% level. This result means that to correct a shock (or short-term deviation) in this model takes more than one year, since 42% of the shock's impact is adjusted in an annual way. In other words, the time needed to correct the impact of the shock and return to equilibrium state is the reciprocal of this value ( $1/0.42 = 2.38$  years) or more than two years and three months. The error-correction model represents short-run dynamic where errors or shocks to the model are corrected and the equilibrium is returned to the original state. Long-run function and Bounds Test.

The long-run parameters (reflecting the long-term relationship) and Bounds Test are shown in Table (8). The first part of Table (8) shows the long-run information, i.e. variables without the difference operator (D) are related to the long run, and from them we can derive the long-run function using the equation  $\beta_n = -\beta_n / \lambda_1$  (where  $\beta$  is the estimated coefficient and  $\lambda$  is the parameter) and these values are shown in the table under the heading "Levels Equation." On the other hand, the variables with the difference operator (D) are related to the short-run function or to its error-correction model.

**Table 8.** Long-term equation

ARDL Long Run Form and Bounds Test

Dependent Variable: D(Y)

Selected Model: ARDL(2, 0, 1, 3, 0, 1)

Case 2: Restricted Constant and No Trend

Date: 08/14/26 Time: 16:06

Sample: 1995S1 2020S2

Included observations: 48

## Conditional Error Correction Regression

| Variable  | Coefficient | Std. Error | t-Statistic | Prob.  |
|-----------|-------------|------------|-------------|--------|
| C         | 880237.2    | 1608802.   | 0.000000    | 0.0000 |
| Y(-1)*    | 487.5900    | 910.2751   | 0.535651    | 0.5956 |
| X1**      | -0.420818   | 0.091592   | -4.594504   | 0.0001 |
| X2(-1)    | 0.534672    | 0.127588   | 4.190619    | 0.0002 |
| X3(-1)    | 248112.9    | 114934.4   | 2.158735    | 0.0378 |
| X4**      | -18.40888   | 1702.537   | -0.010813   | 0.9914 |
| X5(-1)    | -145122.8   | 79642.28   | -1.822183   | 0.0770 |
| D(Y(-1))  | 5266.088    | 46156.98   | 0.114091    | 0.9098 |
| D(X2)     | -59866.28   | 46383.26   | -1.290687   | 0.2053 |
| D(X3)     | 261963.3    | 100415.9   | 2.608784    | 0.0133 |
| D(X3(-1)) | -220339.1   | 105882.7   | -2.080973   | 0.0448 |
| D(X3(-2)) | -204631.2   | 109124.7   | -1.875206   | 0.0691 |
| D(X5)     | 41267.75    | 69259.99   | 0.595838    | 0.5551 |

\* p-value incompatible with t-Bounds distribution.

\*\* Variable interpreted as  $Z = Z(-1) + D(Z)$ .

The results of the ARDL model presented in Table (8) show different effects of climatic factors on yellow maize production in Iraq. Humidity levels (X\_1) were strongly negative and may have been caused by the growth of pests and fungal diseases due to excessive moisture; temperature levels (X\_2)—lagged values—were positively very strong and had to be taken into account [13] as the crop needs a temperature range for growth. Sunlight (X\_3) was also a strong positive factor as it is essential that a lot of the plants use sunlight to develop photosynthesis while growing the grain [14]. Rainfall rate (X\_4) was completely non-significant because the cultivation is all about artificial irrigation [15]. Wind speed (X\_5) was negatively significant in the sense of evaporation rate and plant stress and pollination was disrupted by strong winds in this case [16].

**Table 9.** Bound Test Results

Levels Equation

Case 1: No Constant and No Trend

| Variable                                                                                  | Coefficient | Std. Error                              | t-Statistic | Prob.  |
|-------------------------------------------------------------------------------------------|-------------|-----------------------------------------|-------------|--------|
| X1                                                                                        | 1497.855    | 0.606783                                | 2.468518    | 0.0200 |
| X2                                                                                        | 48292.34    | 8.870913                                | 5.443897    | 0.0000 |
| X3                                                                                        | 640415.2    | 259368.0                                | 2.469138    | 0.0184 |
| X4                                                                                        | 1056.009    | 3589.326                                | 0.294208    | 0.7703 |
| X5                                                                                        | -311117.6   | 176647.6                                | -1.761233   | 0.0867 |
| EC = Y - (1497.8555*X1 + 48292.3387*X2 + 640415.2421*X3 + 1056.0093*X4 - 311117.6203*X5 ) |             |                                         |             |        |
| F-Bounds Test                                                                             |             | Null Hypothesis: No levels relationship |             |        |
| Test Statistic                                                                            | Value       | Signif.                                 | I(0)        | I(1)   |
| Asymptotic:<br>n=1000                                                                     |             |                                         |             |        |
| F-statistic                                                                               | 4.931557    | 10%                                     | 1.81        | 2.93   |
| K                                                                                         | 5           | 5%                                      | 2.14        | 3.34   |
|                                                                                           |             | 2.5%                                    | 2.44        | 3.71   |
|                                                                                           |             | 1%                                      | 2.82        | 4.21   |

**Source: EViews 10 software output.**

Table (9) presents the Bound Test for the complete model. The results of the F-statistic will be obtained by comparing the F-statistic with the lower and upper bound. If the F-statistic exceeds the upper bound at some significance level, then the model is robust. This indicates that cointegration among the variables exists (levels relationship). When the F-statistic falls below the lower limit at some level, H0 is taken into account (no cointegration). If the F-statistic falls between the two bounds, then the result is inconclusive. The F-statistic is 4.93, which exceeds the upper bound at the 1% significance level, thereby confirming the existence of cointegration among the variables.

Climatic factors are of major importance in yellow maize production and the research found a positive association linking rainfall and wind speed whereas temperature and humidity depend on the crop's requirements. The study also found a long-term relationship between climatic variables and production and that climate change is an important determinant of sustainability of yellow maize production in Iraq. It is suggested that developing heat- and drought-tolerant cultivars (high-intensity crops) and the use of modern irrigation methods and water conservation should be encouraged and agricultural extension services should be developed to adjust to the climate. It is also suggested to increase climate monitoring, forecasting and applied research and to include climate change issues in agricultural planning so that the sustainability of yellow maize production is ensured.<sup>4</sup>

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