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Does Climate Change Strengthen the Link between Environmental Degradation and Agricultural Output? Empirical Evidence on the Turkish Economy

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Abstract

Purpose: This study investigates the relationship between agricultural output and environmental degradation, climate change, agricultural employment and economic growth in the Turkish economy for the period 1990-2020.
Methodology: The direct and interactive effects of variables were examined using two district models. As an empirical method, the ARDL bounds test proposed by Pesaran et al. (2001) is utilized. As a result of the existence of cointegration relationship, short and long term estimation results are reported separately for the two models.
Finding: Empirical findings show the existence of cointegration relationship between the relevant variables. Long-run findings show that increases in temperature increase agricultural output, while increases in CO_2 emissions, economic growth and agricultural employment decrease agricultural output. In the short run, only economic growth has a negative effect on agricultural output.
Originality: In the long run, the interactive effect of climate change and environmental degradation on agricultural output is found to be higher and more negative than the direct effects. This result reveals the importance of addressing climate change and environmental degradation together.
Key woeds: Agriculture, Climate Change, Environmental Degradation, Time Series Analysis, Türkiye

İklim Değişikliği Çevresel Bozulma ile Tarımsal Hasıla Bağlantısını Güçlendiriyor mu? Türkiye Ekonomisi Üzerine Ampirik Kanıtlar
Özet

Amaç: Bu çalışmada Türkiye ekonomisinde 1990-2020 döneminde tarımsal hasıla ile çevresel bozulma, iklim değişikliği, tarımsal istihdam ve ekonomik büyüme ilişkisi araştırılmaktadır.
Metodoloji: Değişkenlerin doğrudan ve etkileşimli etkileri iki farklı model yardımıyla araştırılmıştır. Ampirik yöntem olarak Pesaran vd. (2001) tarafından önerilen ARDL Sınır Testinden yararlanılmıştır. Eşbütünleşme ilişkisinin varlığı sonrası kısa ve uzun dönem sonuçları iki model için ayrı ayrı raporlanmıştır.
Bulgular: Ampirik bulgular ilgili değişkenler arasında eşbütünleşme ilişkisinin varlığını göstermiştir. Uzun dönem bulguları sıcaklık artışlarının tarımsal hasılayı artırdığını; CO_2 emisyonu, iktisadi büyüme ve tarımsal istihdam artışlarının ise tarımsal hasılayı azalttığı sonucunu ortaya koymuştur. Kısa dönemde ise sadece ekonomik büyümenin tarımsal hasıla üzerindeki etkisinin negatif olduğu sonucuna ulaşılmıştır.
Özgünlük: Uzun dönemde iklim değişikliği ve çevresel bozulmanın tarımsal hasıla üzerindeki etkileşimli etkisinin, doğrudan etkilere göre daha yüksek derecede ve olumsuz yönde olduğu tespit edilmiştir. Bu sonuç, iklim değişikliği ve çevresel bozulma sorununun birlikte ele alınmasının önemini ortaya koymaktadır.
Anahtar kelimeler: Tarım, İklim Değişikliği, Çevresel Bozulma, Zaman Serisi Analizi, Türkiye

1. INTRODUCTION

The OPEC crisis in the 1970s led to stagflation. Stagflation, which means the simultaneous occurrence of inflation and economic stagnation, began to replace Keynesian approaches with monetarist approaches (Mishkin, 1992). Especially in the 1980s, the views put forward by Friedman played an important role (Kazgan, 1988; Bal, 2019). In terms of the Turkish economy, trade liberalization steps were taken with the January 24, 1980 decisions and import substitution policies were abandoned (Olgun and Togan, 1991). In the period in question, the Turkish economy experienced developments such as the convertibility of the national currency in the process following trade liberalization and steps towards financial liberalization. These processes increased industrialization in Türkiye and accelerated the urbanization process by reducing the rural population. The 1990s can be expressed as the years when globalization started to be felt in the Turkish economy (Bayar, 2008). With this period, economic integrations expanded, barriers to international trade were largely removed and international competition increased. With increasing international competition, high economic growth targets were set. The

2000s witnessed growth processes in which China and India came to the fore (Patel and Mohapatra, 2024; Can and Chan, 2020). For Türkiye, which is among the developing countries, the 2000s stand out as the years in which the growth trend increased. Figure 1 shows the course of GDP per capita in the Turkish economy for the period 1990-2021 (World Bank, 2024).

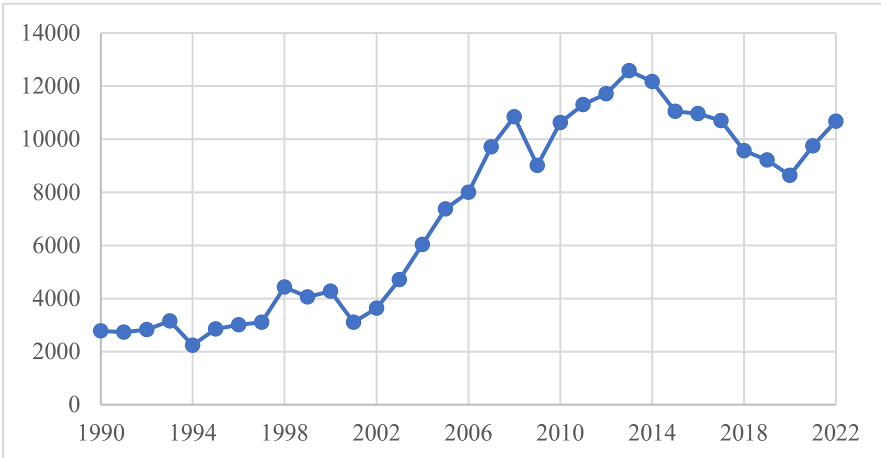

Figure 1. GDP Per Capita in the Turkish Economy (1990-2022)

Figure 1 shows that there was an upward trend in Türkiye's GDP per capita in the post-2000 period. With the 2008 Global Financial Crisis, this upward trend was disrupted, and the recovery period started to increase again in 2010. As of 2013, there was a downward trend again, and as of the end of 2020, when Covid-19 lost its effect, there was an increasing trend again.

With the 2000s, high rates of economic growth have been realized, particularly in developing countries. However, the sustainability of this growth is seriously debated. It is evaluated that significant costs have occurred, especially in terms of environmental degradation (Wen et al., 2021; Shittu et al., 2021). Problems such as the decrease in agricultural land, decrease in environmental quality, and increase in environmental pollution come to the fore. Climate change, which has been affecting the whole world recently, is among the serious problems (Ma et al., 2024; Skendžić et al., 2021; Regan et al., 2019). The problem of climate change is the subject of a wide debate. However, in this study, its relationship with agricultural output will be evaluated. Although there are many indicators of climate change, the temperature variable is among the most important indicators. Considering that the global warming process has occurred with the increase in environmental degradation, especially with the increase in CO_2 emissions, temperature changes stand out as an important indicator in terms of climate change. The average temperature in the Turkish economy for the period 1990-2000 was below 13°C, while the average for the period 2012-2022 was 14.21°C (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2024). This result indicates a temperature increase of approximately 1.5°C. On the other hand, when CO_2 emissions per capita are analyzed, it is determined that there is an increasing trend in the 1990-2021 period. This trend is shown in Figure 2 (World Bank, 2024).

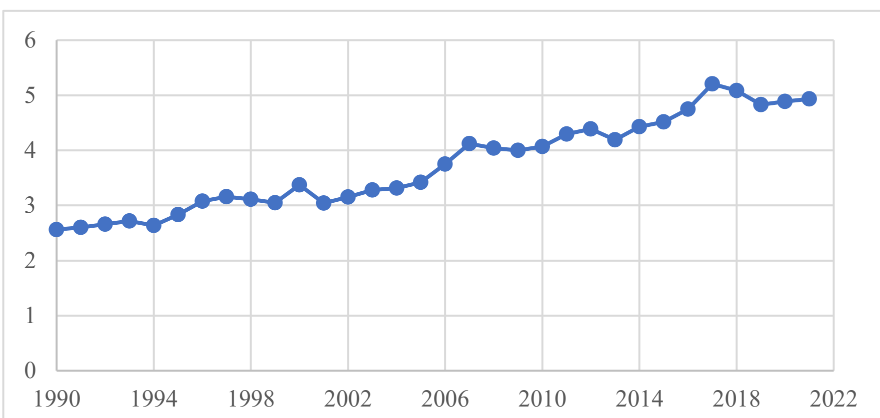

Figure 2. The Course of CO_2 emissions in the Turkish Economy (1990-2021)

When Figure 2 is analyzed, it is seen that CO_2 emissions have shown an increasing trend since the 1990s. When this increase is analyzed in percentage terms, it is seen that there is an increase of approximately 93% in 2021 compared to 1990. This situation is remarkable in terms of understanding environmental degradation. In the Turkish economy, it is seen that the economic growth trend has shown an upward trend and carbon emissions have increased.

The agricultural sector is among the most important issues in national economies. The agricultural sector, which has found an important discussion area under the title of food supply security in the literature, has started to be among the most important agenda items again with the recent food crises. In Türkiye, the "Department of Supply Security" was established within the Strategy Development Directorate of the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry, 2022). After the 1990s, it is observed that the share of agriculture decreased while the share of industry and services increased. This situation is shown in Figure 3 (TUİK, 2024).

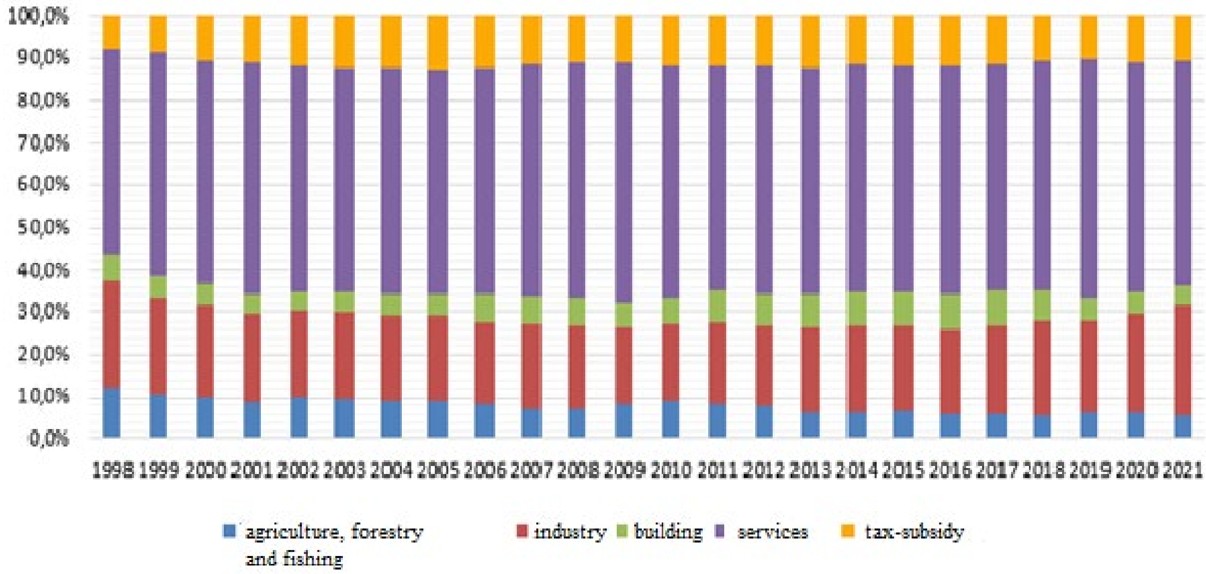

Figure 3. Sectoral Distribution of GDP at Current Prices in Türkiye (%) (1998-2021)

Figure 3 shows the percentage contribution of the branches of economic activity to GDP in the Turkish economy from the late 1990s until 2021. When this ratio is evaluated, the share of the agricultural sector follows a decreasing trend over the years. According to TURKSTAT data, GDP at current prices according to the production method increased by 43.6% in 2021 compared to the previous year and reached 7 trillion 248 billion 789 million TL. In 2021, excluding taxes and subsidies, GDP at current prices was TL 6,481,191,957,940. The share of agriculture, forestry and fishing sector was 5.5%; the share of industry sector was 22.2%; the share of construction sector was 5.1% and the share of services sector was 67.2%.

Another indicator that supports the decline in the share of agriculture in the sectoral distribution of the Turkish economy is rural employment. Figure 4 shows the course of rural employment by periods (World Bank, 2024).

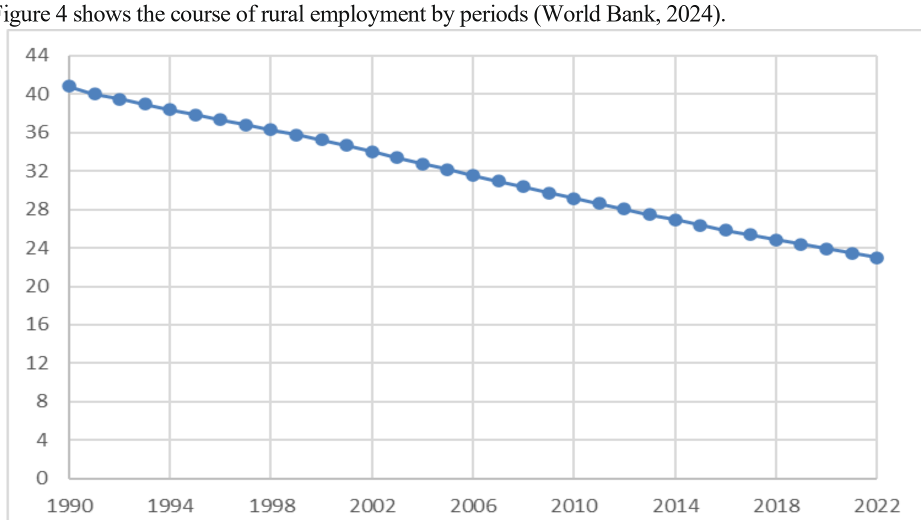

Figure 4. Rural employment in Türkiye (Rural employment/Total employment) (1990-2022)

Figure 4 shows that the share of rural employment in total employment declined steadily from the 1990s until 2022. In fact, while this ratio was over 40% in 1990, it dropped below 24% by 2022. This downward trend reveals the sectoral distribution in the

Turkish economy and the industrialization process in the Turkish economy in the relevant period. This study investigates the relationship between rural employment, climate change, economic growth, carbon dioxide emissions and agricultural employment. The study differs from other studies in that it covers the sample period when the globalization period started to deepen and the Turkish economy underwent a sectoral transformation. On the other hand, it is considered to be of unique value in terms of testing both climate change and environmental degradation at the same time. The most important part that distinguishes the study from other studies is that the interactive effect of climate change and temperature on agricultural output is investigated by constructing a second model with a moderating variable. The study will continue with the presentation of previous studies on the subject. In the third section, the data set and model will be introduced and the empirical analysis will be presented. In the fourth and final section, evaluations are made in the light of empirical findings, policy recommendations are presented and the study is concluded.

2.LITERATURE REVIEW

In the literature, there are many studies in which the relationships between agricultural output or agricultural value added, economic growth, environmental variables, climate change, urbanization, rural population, etc. are tested separately. In this context, the weight of studies where the dependent variable is economic growth is significant. These studies generally investigate the effects of the agricultural sector or environmental variables on economic growth. In fact, based on the Cobb-Douglas production function, capital and labor variables are also included in empirical models (Maestas et al., 2023; Bilenko, 2022; Bashir and Susetyo, 2018; Huffman and Orazem, 2007). Similarly, the relationship between economic growth and urbanization and rural population follows a similar methodology. When the studies in which agricultural output or agricultural value added is the dependent variable are examined, it can be seen that economic growth, rural population, rural employment, and environmental variables are among the explanatory variables (Sheng et al., 2022; Li and Fu, 2022; Zhao et al., 2021; Heyl et al., 2021; Edeme et al., 2020; Anwar et al., 2019; Oyakhilomen and Zibah, 2014; Gardner, 2000). Considering the recent studies examining the relationship between agricultural production and environmental variables (environmental degradation or environmental quality), Gökmenoğlu and Taşpınar (2018) investigated the relationship between agriculture and environmental factors for the Pakistani economy for the sample period 1971-2014. Maki (2012) cointegration test was used to test the hypothesis of Environmental Kuznets Curve due to agriculture. Using Toda-Yamamoto causality analysis and FMOLS estimation, the findings reveal an inelastic incremental effect of agriculture on environmental pollution. Agboola and Bekun (2019) conducted a similar study on the Nigerian economy and tested the effects of agricultural production on environmental pollution. Analyzing the 1981-2016 period as the sample period, the authors utilized Bayer and Hanck (2013) cointegration and ARDL bounds tests developed by Pesaran et al. (2001). Granger causality analysis was also conducted and the results showed that agricultural production has an inelastic positive effect on environmental pollution. Other recent studies showing that agriculture increases environmental pollution are Adedoyin et al. (2021), Gökmenoğlu and Taşpınar (2018), Raihan et al. (2022), Raihan and Tuspekova (2022). Some recent studies showing the opposite results are Bas et al. (2021), Raihan and Tuspekova (2022), Ali et al. (2019) and Wang et al. (2020).

Although there are many studies investigating the relationship between agricultural output or agricultural production and economic growth, there are fewer studies investigating the effects of economic growth on agriculture. Aluwani (2023) investigated the determinants of growth in the agricultural sector on the South African economy. Using data for the sample period 1990-2021, the study includes foreign trade, CO_2 emissions and renewable energy use variables. The study utilized ARDL test and CCR, FMOLS and DOLS techniques as empirical methods. The empirical findings show that renewable energy use decreases agricultural growth; however, increases in foreign trade and CO_2 emissions increase agricultural output. Ali et al. (2023) investigated the factors affecting agricultural output in selected African economies in the sample period 1997-2020. Using panel data methods, the study concludes that environmental pollution, capital and foreign direct investments reduce agricultural output. On the other hand, by including an index composed of economic growth and foreign direct investment in the model, it is concluded that economic growth increases agricultural output. Pakdemirli (2020), who investigated the relationship between agricultural sector and CO_2 emissions, utilized the 1961-2018 sample period of Turkey. In the study using ARDL and VAR analyses, he emphasized that CO_2 emissions have serious effects on the agricultural sector. The study emphasized the importance of reducing CO_2 emissions, which may have negative effects on agricultural output when population growth rates are taken into account. In Tıraşçı and Erdoğan (2021), the effects of global warming on the agricultural sector are discussed extensively. In the study where examples from Turkey and the world are introduced, various comparisons are made with current period data. In the related study, it was emphasized that extreme increases in temperatures will cause negative effects in the agricultural sector. It was evaluated that the decrease in soil fertility and water scarcity with high temperatures could lead to serious problems. Oğul (2022) found that increases in precipitation and humidity positively affect the share of agriculture in GDP, while increases in carbon dioxide emissions, population and temperature negatively affect the share of agriculture in GDP. Sharma et al. (2021) investigated the issue of agriculture and environmental pollution in the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) region. Using panel data analysis for the sample period 1985-2019, the empirical results show that agriculture has a positive impact on pollution in the early stages of development, but a negative impact beyond a certain threshold. In this study, agricultural production is used instead of the economic growth variable by utilizing the classical Environmental Kuznets Curve. This use is explained by the fact that the agricultural sector constitutes one of the most important sectors of the economy (Gökmenoğlu et al., 2019). Sharma et al. (2021) emphasized the importance of agriculture and agricultural productivity for the countries (Bangladesh, Bhutan, India, Myanmar, Nepal, Thailand and Sri Lanka). Considering the importance of the agricultural sector in Türkiye, the results are important. In BIMSTEC countries, climate change studies have received significant attention from both researchers and policy makers (Pattnayak et al., 2017). Since these countries are particularly vulnerable to extreme climate events such as storms, hurricanes and heavy rains, the impacts of climate change can be realized at high levels. Considering that 20 of the world's 23 largest cyclones in the last 200 years have occurred in these countries bordering the Bay of Bengal, the negative impacts of climate change are serious (Kamruzzaman and Action, 2019; Mahrous, 2019). Although the impact of climate change on economic growth is frequently discussed, the impact of climate change on the agricultural sector has received limited discussion. Among these studies, Apata (2010) investigated the effects of global warming on agriculture in the Nigerian economy. Multinomial selection and stochastic simulation model were utilized in the study by dividing the period 1971-2000 into three different equally spaced periods. The results of the analysis revealed that climate change has negative effects on the agricultural sector. Masud et al. (2012) obtained a similar result for Malaysia. Başoğlu and Telatar (2013), who conducted research on the Turkish economy, investigated the effects of climate change on the agricultural sector in the sample period 1973-2011. The results differed according to climate change indicators. Accordingly, it is concluded that increased precipitation increases the share of agriculture in GDP, while temperature increases decrease this share. Khalid et al. (2016) investigated the effects of climate change on both the economic and agricultural sectors in 10 selected economies and analyzed the sample period 1990-2014. Empirical results show that climate change has a negative impact on GDP in the relevant countries, while it has no impact on the agricultural sector. Hayaloğlu (2019) investigated the effects of climate change on the agricultural sector and economic growth in the 1990-2016 sample period. The 10 countries with the highest risk of climate change were selected as the country group. Using the panel data method, the empirical findings show that climate change has negative effects on economic growth and agricultural sector in the relevant countries. In this context, the effects of climate change on the agricultural sector and environmental factors constitute an important research topic. Huong et al. (2022), who investigated the relationship between the agricultural sector and climate change in Vietnam, used the sample period 1990-2020. The study utilized ARDL as an empirical method and concluded that CO_2 emissions and energy consumption positively affect the agricultural sector. On the other hand, it is found that temperature and precipitation have negative effects on the agricultural sector. Akcan et al. (2022), who conducted a similar study using similar variables, investigated the 1985-2018 period for the Turkish economy. Using the ARDL bounds test, the findings indicate that precipitation and humidity have positive effects on the agricultural sector. The study concluded that temperature and the number of snow-covered days have negative effects on the agricultural sector. Efeoğlu (2023) examined the relationship between climate change and the agricultural sector in the sample period 2002-2019 for 37 economies of less developed countries. Westerlund (2007) cointegration test was utilized in the study where panel data analysis techniques were used. In addition, Dumitrescu and Hurlin (2012) panel causality analysis was applied. Empirical findings reveal that climate change has a negative impact on the agricultural sector in 37 less developed countries.

When the studies cited in this section are analyzed, it is seen that there are very few studies in which the effects of both climate change and environmental impacts on agricultural output are discussed together. Considering that Türkiye has scarce potable and usable water resources and high geopolitical risks, it is important to identify the determinants of the agricultural sector in the economic development process. On the other hand, the use of economic growth and agricultural employment variables in addition to climate change and environmental degradation in this study is considered to contribute to the related literature.

3.RESEARCH FINDINGS

In this study, the relationship between agricultural output, climate change, environmental pollution, per capita income and agricultural employment of the Turkish economy for the period 1990-2020 will be analyzed. The unit root test of the variables will be analyzed with the ADF test and the cointegration relationship between the variables will be examined with the ARDL bounds test.

3.1. Data set and model

This study examines some variables affecting agricultural output in the Turkish economy for the period 1990-2020. Information on the variables is given in Table 1.

Table 1. Descriptive Information of Variables

Variable Symbol	Variable Type	Variable Description	Database
AO	Dependent Variable	Agricultural Output	FAO
TEMP	Independent Variable	Temperature	Republic of Türkiye General Directorate of Meteorology
CO_2	Independent Variable	Carbon Dioxide Emission	World Bank
GDP	Independent Variable	GDP Per Capita	World Bank
AE	Independent Variable	Agricultural Employment	World Bank
INDEX	Independent Variable	Temperature and Carbon Dioxide Emission	Republic of Türkiye General Directorate of Meteorology

Two different models were created for the econometric analysis.

Model 1:

$$lnAO_t = \beta_0 + \beta_1 lnTEMP_t + \beta_2 lnCO_{2_t} + \beta_3 lnGDP_t + \beta_4 lnAE_t + \varepsilon_{1t}$$

Model 2:

$$lnAO_t = a_0 + a_1 lnTEMP_t + a_2 lnCO_{2_t} + a_3 lnGDP_t + a_4 lnAE_t + +a_5 \ln\,(INDEX_t) + \varepsilon_{2t}$$

In the models, lnAO stands for logarithmic agricultural output, lnTEMP stands for logarithmic temperature, $lnCO_2$ stands for logarithmic carbon dioxide, lnGDP stands for logarithmic economic growth, lnAE stands for logarithmic agricultural employment and lnINDEX stands for the index constructed from logarithmic temperature and carbon dioxide emissions.

3.2 Unit root test

Unit root tests examine whether variables have a unit root process, in other words, their stationarity. In this study, Augmented Dickey-Fuller (ADF) unit root test is applied and the unit root process is analyzed. Table 2 presents the findings of the ADF test.

Table 2. ADF Unit Root Test Results

Variables	*Constant*	*Constant and Trend*
	Level	
lnAO	-1.132716 (0.6889)	-1.778409 (0.6890)
lnTEMP	-0.981676 (0.7437)	-5.739447*** (0.0003)
$lnCO_2$	-0.895062 (0.7753)	-3.210811 (0.1021)
lnGDP	-1.294424 (0.6184)	-1.016587 (0.9259)
lnAE	-0.365525 (0.9029)	-1.495764 (0.8094)
lnINDEX	1.112709 (0.6970)	-2.795804 (0.2099)
	1st Difference	
ΔAO	-4.368351*** (0.0019)	-3.884635** (0.0283)
ΔlnTEMP	-9.822718*** (0.0000)	-9.705727*** (0.0000)
$\Delta lnCO_2$	-5.795598*** (0.0000)	-5.707585*** (0.0004)
ΔlnGDP	-3.146508** (0.0349)	-3.245442* (0.0970)
ΔlnAE	-2.708894* (0.0847)	-1.951278* (0.0502)
ΔlnINDEX	-6.541887*** (0.0000)	-6.670018*** (0.0000)

Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels. Values in parentheses indicate probability values. Δ denotes the first difference.

As a result of the unit root test in Table 2, all variables are stationary at first difference in the model with constant. Considering that the variables are stationary at the I(1) level, that is, in their first differences, it seems possible to examine the cointegration relationship with the ARDL bounds test.

3.3 ARDL bounds test

The ARDL bounds test developed by Pesaran and Pesaran (1997) and Pesaran et al. (2001) has some advantages over other cointegration tests (Engle-Granger (1987), Johansen (1988-1991) and Johansen and Juselius (1990-1992).

- It provides better statistical results than other tests in analyzing samples with limited number of observations.
- By giving short and long-run results, it can give cointegration relationship through coefficients for both periods.
- It can be applied when the variables are cointegrated both in different degrees and in the same degree. Even if this is the case, the unit root level of the variables is still examined. Because the critical values in Pesaran et al. (2001) are only tabulated according to whether the variables are I(0) or I(1), unit root tests are utilized against the possibility of I(2) by determining the stationarity levels of the variables.
- Since the unconstrained error correction model is used, it provides more reliable and accurate results (Narayan, 2005).

ARDL test can be applied with 3 stages and 3 equations. In the 1st stage, cointegration relationship is examined, while in the 2nd and 3rd stages, long and short run coefficients are obtained (Narayan and Smyth, 2006). Thus, the cointegration relationship is examined in the 1st bounds test equation, while the long and short-run relationship is examined in the 2nd and 3rd equations (Pesaran and Shin, 1997). The ARDL equations for Model 1 and Model 2 are given in (1) and (2), respectively:

Model 1:

$$\Delta lnAO_t = b_0 + \sum_{i=1}^{k} b_{1i}\, \Delta lnAO_{t-i} + \sum_{i=0}^{k} b_{2i}\, \Delta lnTEMP_{t-i} + \sum_{i=0}^{k} b_{3i}\, \Delta lnCO_{2_{t-i}} + \sum_{i=0}^{k} b_{4i}\, \Delta lnGDP_{t-i} + \sum_{i=0}^{k} b_{5i}\, \Delta lnAE_{t-i} + b_6 lnAO_{t-1} + b_7 lnTEMP_{t-1} + b_8 lnCO_{2_{t-1}} + b_9 lnGDP_{t-1} + b_{10} lnAE_{t-1} + \varepsilon_{1t} \quad (1)$$

Model 2:

$$\Delta lnAO_t = a_0 + \sum_{i=1}^{k} a_{1i}\, \Delta lnAO_{t-i} + \sum_{i=0}^{k} a_{2i}\, \Delta lnTEMP_{t-i} + \sum_{i=0}^{k} a_{3i}\, \Delta lnCO_{2_{t-i}} + \sum_{i=0}^{k} a_{4i}\, \Delta lnGDP_{t-i} + \sum_{i=0}^{k} a_{5i}\, \Delta lnAE_{t-i} + \sum_{i=0}^{k} a_{6i}\, \Delta lnINDEX_{t-i} + a_7 lnAO_{t-1} + a_8 lnTEMP_{t-1} + a_9 lnCO_{2_{t-1}} + a_{10} lnGDP_{t-1} + a_{11} lnAE_{t-1} + a_{12} lnINDEX_{t-1} + \varepsilon_{2t} \quad (2)$$

In equations (1) and (2), Δ is the first order difference and k is the lag length of the variables. In order to determine the cointegration relationship, firstly, the lag length is obtained by using information criteria (such as Akaike (AIC) and Schwarz (SIC)) to determine the lag length. The main hypothesis (H0), which states that there is no cointegration relationship, can be revealed by examining the significance of one-period lagged values of the variables. The alternative hypothesis (H1) indicates a cointegration relationship.

Model 1:

$$H_0: b_6 = b_7 = b_8 = b_9 = b_{10} = 0$$
$$H_1: b_6 \neq b_7 \neq b_8 \neq b_9 \neq b_{10} \neq 0$$

Model 2:

$$H_0: a_7 = a_8 = a_9 = a_{10} = a_{11} = a_{12} = 0$$
$$H_1: a_7 \neq a_8 \neq a_9 \neq a_{10} \neq a_{11} \neq a_{12} \neq 0$$

The F statistic is used to test these hypotheses. The critical values for the F statistic are tabulated and presented to the literature by Pesaran et al. (2001). The lower and upper critical values obtained to examine the cointegration relationship are compared with the critical values of the F statistic. If the calculated F statistic is greater than the upper bound of the critical values, it can be stated that there is a cointegration relationship between the variables; if the F statistic is less than the lower bound of the critical values, it can be stated that there is no cointegration relationship between the variables.
Considering the F statistic value and finding a cointegration relationship between the variables according to the lower and upper critical values, the long-run relationship analysis is examined with equations (3) and (4) for model 1 and model 2, respectively:

Model 1:

$$\Delta lnAO_t = b_0 + \sum_{i=1}^{k} b_{1i}\, \Delta lnAO_{t-i} + \sum_{i=0}^{l} b_{2i}\, \Delta lnTEMP_{t-i} + \sum_{i=0}^{m} b_{3i}\, \Delta lnCO_{2_{t-i}} + \sum_{i=0}^{n} b_{4i}\, \Delta lnGDP_{t-i} + \sum_{i=0}^{p} b_{5i}\, \Delta lnAE_{t-i} + \varepsilon_{1t} \quad (3)$$

Model 2:

$$\Delta lnAO_t = a_0 + \sum_{i=1}^{k} a_{1i}\, \Delta lnAO_{t-i} + \sum_{i=0}^{l} a_{2i}\, \Delta lnTEMP_{t-i} + \sum_{i=0}^{m} a_{3i}\, \Delta lnCO_{2_{t-i}} + \sum_{i=0}^{n} a_{4i}\, \Delta lnGDP_{t-i} + \sum_{i=0}^{p} a_{5i}\, \Delta lnAE_{t-i} + \sum_{i=0}^{p} a_{6i}\, \Delta lnINDEX_{t-i} + \varepsilon_{2t} \quad (4)$$

The short-run relationship is given by the error correction model based on ARDL with equations (5) and (6) for model 1 and model 2, respectively.

Model 1:

$$\Delta lnAO_t = b_0 + \sum_{i=1}^{k} b_{1i}\, \Delta lnAO_{t-i} + \sum_{i=0}^{l} b_{2i}\, \Delta lnTEMP_{t-i} + \sum_{i=0}^{m} b_{3i}\, \Delta lnCO_{2_{t-i}} + \sum_{i=0}^{n} b_{4i}\, \Delta lnGDP_{t-i} + \sum_{i=0}^{p} b_{5i}\, \Delta lnAE_{t-i} + ECT1_{t-1} + \varepsilon_t \quad (5)$$

Model 2:

$$\Delta lnAO_t = a_0 + \sum_{i=1}^{k} a_{1i}\, \Delta lnAO_{t-i} + \sum_{i=0}^{l} a_{2i}\, \Delta lnTEMP_{t-i} + \sum_{i=0}^{m} a_{3i}\, \Delta lnCO_{2_{t-i}} + \sum_{i=0}^{n} a_{4i}\, \Delta lnGDP_{t-i} + \sum_{i=0}^{p} a_{5i}\, \Delta lnAE_{t-i} + \sum_{i=0}^{p} a_{6i}\, \Delta lnINDEX_{t-i} + ECT2_{t-1} + \varepsilon_t \quad (6)$$

ECT1 and ECT2 in (5) and (6) denote the error correction term in the respective models. The coefficient of this term should be between -1 and 0 and statistically significant (Akan et al., 2022). Table 3 presents the F statistics and descriptive tests of the ARDL bounds test for Model 1 and Model 2.

Table 3. F Statistic and Descriptive Tests

	Model 1						
ARDL (1,3,1,0,3)	**F Statistic**	**%1**		**%5**		**%10**	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
	9.633798	4.5	5.72	3.47	4.57	3.03	4.06
Diagnostic Tests	Test Statistic				Probability Value		
Breusch-Godfrey LM Test	1.929004				0.1914		
Heteroskedasticity Test: ARCH	0.021772				0.8839		
Jargue-Bera Normality Test	2.957312				0.2279		
	Model 2						
ARDL (1,3,3,3,3,3)	**F Statistics**	**%1**		**%5**		**%10**	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
	5.391211	3.93	5.23	3.12	4.25	2.75	3.79
Diagnostic Tests	Test Statistic				Probability Value		
Breusch-Godfrey LM Test	6.067772				0.1415		
Heteroskedasticity Test: ARCH	0.171003				0.6829		
Jargue-Bera Normality Test	0.024696				0.9877		

When compared with the lower and upper critical values in Table 3, it is concluded that the F statistic value of the model is large. This result is interpreted as a cointegration relationship between the dependent and independent variables. After examining the F statistic, the appropriateness of the model is examined with descriptive tests. Among these tests, the Breusch-Godfrey LM test examines the autocorrelation problem and the Heteroskedasticity test (ARCH) examines the problem of changing variance. According to Table 3, the findings show that there is no autocorrelation and changing variance problem. Another test is the Jargue-Bera test, which shows whether there is a normal distribution. According to Table 3, the findings indicate that there is no deterministic and stochastic problem in the model.

After determining the cointegration relationship and the appropriateness of the models, long-run coefficient estimates are made. Long-run coefficient estimates are shown in Table 4.

Table 4. Long Run Coefficients

Model 1	**Dependent Variable: lnAO**	
Independent Variables	***Coefficient***	***Probability Value***
lnTEMP	3.843476***	0.0003
$lnCO_2$	-5.949792***	0.0008
lnGDP	-0.655022***	0.0000
lnAE	-3.328233***	0.0000
Model 2	**Dependent Variable: lnAO**	
Independent Variables	***Coefficient***	***Probability Value***
lnTEMP	1.287438***	0.0065
$lnCO_2$	-2.257458***	0.0004
lnGDP	0.275733*	0.0868
lnAE	-2.162602***	0.0060
lnINDEX	-9.783062***	0.0007

Note: *** % 1, * % 10 refers to the level of importance.

According to the long-run results of Model 1 in Table 4, all explanatory variables (temperature, CO_2 emissions, economic growth, agricultural employment) are statistically significant. Moreover, when the coefficients of these variables are analyzed, it is seen that temperature is positive, while CO_2, economic growth and agricultural output are negative. The coefficient magnitudes are 3.843476 for temperature, -5.949792 for carbon emission, -0.655022 for economic growth and -3.328233 for agricultural employment. When the results of Model 2 are analyzed, it is observed that the results are close to Model 1. However, unlike Model 1, the effects of climate change and environmental degradation on agricultural output were analyzed together by using a moderator variable in Model 2. The variable in question, lnINDEX, is statistically significant at 1% significance level. Moreover, this variable has a strong negative effect on agricultural output. In fact, a 1% increase in lnINDEX decreases agricultural output by approximately 9%. This reveals that environmental degradation and climate change together have a significant negative impact on the agricultural sector through the multiplier effect mechanism.

The error correction model and short-run coefficients constructed to determine the cointegration relationship and the elimination of short-run imbalances in the long run are given in Table 5.

Table 5. Short Run Coefficients and Error Correction Model

Model 1	Dependent Variable: D(ln)AO	
Independent Variables	***Coefficient***	***Probability Value***
D(ln)TEMP	0.749719***	0.0009
D(ln)CO₂	0.967817***	0.0014
D(ln)GDP	-0.219131***	0.0012
D(ln)AE	1.903438***	0.0000
ECM_{t-1} [a]	-0.334540	0.0000
Model 2	**Dependent Variable: D(ln)AO**	
Independent Variables	***Coefficient***	***Probability Value***
D(ln)TEMP	0.749719***	0.0009
D(ln)CO₂	0.967817***	0.0014
D(ln)GDP	-0.219131***	0.0012
D(ln)INDEX	8.679003*	0.0866
ECM_{t-1} [a]	-0.334540	0.0000

Note: *** % 1, * % 10 refers to the level of importance.

The error correction term of the model in Table 5 is statistically significant and has a negative sign (Pesaran et al., 2001).
In the ARDL test, the CUSUM and CUSUMQ tests developed by Brown et al. (1975), which are known as the uncertainty that the sign of the estimate of consecutive errors in the long run is the same and remains the same for a long time, are applied for the model and shown in Figure 5.

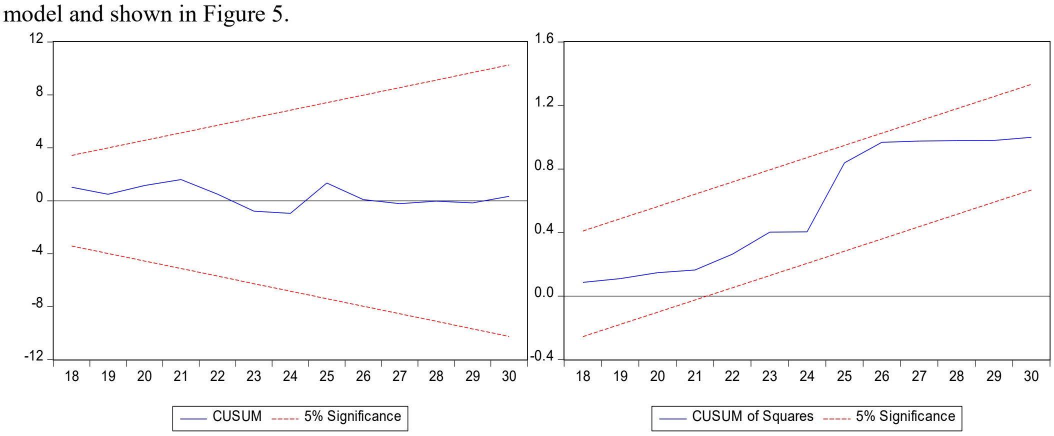

Figure 5. CUSUM and CUSUMQ test

4.CONCLUSIONS and SUGGESSTIONS

The Turkish economy relies heavily on imported fossil fuels for energy consumption. This can lead to both a current account deficit and environmental problems. Recently, climate change has become the most important agenda both globally and in Türkiye. With the Russia-Ukraine war, the agricultural sector has been seriously discussed. Climate change and agricultural output are affected by environmental factors. Decreasing environmental quality and increasing environmental degradation may interact with agricultural output through direct/indirect mechanisms. In this study, the sample period 1990-2020 is selected and the relationship between agricultural output, climate change, environmental pollution, per capita income and agricultural employment in Türkiye is analyzed. Long-run and short-run results showed differences in line with expectations. According to the long-run findings of the first model, agricultural output increased with increasing temperature, while agricultural output decreased with increasing CO_2 emissions, economic growth and agricultural employment. The positive effect of temperature increase on agricultural output can be attributed to the fact that hot weather increases the rate of photosynthesis of plants. This can increase the rate of plant growth. On the other hand, increased temperature may cause plants to grow and mature faster and produce more crops, thus increasing agricultural output. However, it should not be forgotten that high temperature increases can also cause many negative situations such as the emergence of problems in photosynthesis and fertilization events in plants, inefficiency of agricultural soils, irregular rainfall regime, and water shortages. An increase in CO_2 emissions, on the other hand, primarily causes environmental degradation and affects agricultural yields, thereby reducing agricultural output. An increase in economic growth may lead to a sectoral shift from agriculture to industry and services. As a matter of fact, the share of agriculture in the Turkish economy decreases in the 1990-2020 period and these shares shift to other sectors. The decrease in agricultural output due to the increase in agricultural employment may be caused by problems such as productivity decline, increases in costs, suppression of innovative activities in the agricultural sector and excessive land use. On the other hand, the predominance of hidden unemployment in Turkish agriculture is one of the important reasons for the decrease in production.

The agricultural sector is often recognized by countries as a "national security" priority. Agricultural products are essential for survival, and this has become more evident in recent times, both during Covid-19 and the Russian-Ukrainian war. Another importance of agricultural policies is that they are effective in the long run rather than the short run. In this context, it is important for policymakers to identify the factors affecting agricultural output in the long run. The findings of this study are expected to make important contributions to agricultural policies in Türkiye. In this context, increasing environmental quality is of great importance for increasing agricultural output in the Turkish economy. In this context, decisions to prevent environmental degradation should be prioritized. Therefore, steps such as reducing CO_2 emissions and promoting clean energy sources should be increased. Considering that the Turkish economy relies heavily on fossil fuel-based energy sources, taking relevant steps is important for the sustainability of the agricultural sector. According to the OECD, current agricultural policy practices in Türkiye target production levels rather than increasing efficiency and productivity. The report emphasizes that a relatively small portion of resource investments is allocated to innovation and capacity building, which supports the results of this study. Reducing agricultural costs and increasing productivity stand out as other measures. The fact that climate change does not cause any decline in agricultural output in the empirical findings shows that the agricultural sector in Türkiye has not yet been negatively affected by climate change in terms of output. However, it would not be a correct approach to generalize this result to the agricultural sector. Because agricultural output can also increase as a result of technological developments.

The results of Model 2, which investigates the interactive effect of climate change and environmental degradation on agricultural output, show that the coefficient of the interaction variable is approximately -9. This result reveals that the combined effect of climate change and environmental degradation is much stronger than their separate effects. Therefore, smoothing this negative effect of these two variables is of great importance in increasing agricultural output. In order to soften this result and weaken the link, it has been made clear that the focus should not only be on climate change or environmental degradation. Therefore, policies that prioritize climate change (especially global warming) should be prioritized alongside measures to improve environmental quality. In follow-up studies to this study, a similar analysis can be conducted on the economies with the highest carbon emissions and temperature increases. Thus, by obtaining the effects of the relevant variables on agricultural output in panel and country-specific studies, it is thought that it will both contribute to the related literature and provide broader policy recommendations.

Contribution Rate of Researchers Declaration Summary

The authors declare that they have contributed equally to the article and have not plagiarized.

Conflict of Interest Declaration

The authors of the article declare that there is no conflict of interest between them.

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