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# The Impact of Climate Change on Productivity of Turkiye's Agricultural Sector: Empirical Evidence on the Role of Economic Growth

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## ABSTRACT
As the initial stage of the food supply chain, the agricultural sector holds significance not only for national economies but also for human health, sustainability, and food security. Agricultural production relies on various inputs, and numerous factors influence agricultural productivity. Notably, changes brought about by climate change affect many sectors, including agriculture, and consequently impact food production. In this context, this study aims to examine the effects of climate change and economic growth on Turkiye's agricultural sector for the period 1990–2021 using the ARDL (Autoregressive Distributed Lag) approach. The findings reveal the existence of a long-run cointegration relationship in the model. According to the long-run coefficient estimates, precipitation and economic growth have a positive effect on the agricultural sector, while temperature has a negative effect. To ensure the sustainability and increased productivity of Turkiye's agricultural sector, measures should be taken to reduce greenhouse gas emissions, which contribute to global warming. Furthermore, in regions with insufficient rainfall, irrigation and agricultural policies such as the Southeastern Anatolia Project (GAP) should be actively implemented.

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# İklim Değişikliğinin Türk Tarım Sektörü Verimliliği Üzerindeki Etkisi: Ekonomik Büyümenin Rolüne Dair Ampirik Kanıtlar

## ÖZET
Tarım sektörü gıda tedarik zincirinin ilk aşaması olması sadece ülke ekonomileri açısından değil, insan sağlığı ve sürdürülebilirliği, gıda güvenliği açısından da önem arz etmektedir. Tarımsal üretim birçok girdi ile gerçekleştirilmekte olduğundan tarımsal verimliliği etkileyen birçok faktör de ortaya çıkmaktadır. Özellikle iklim değişikliğinde görülen gelişmeler birçok alanda etkili olduğu gibi tarım sektörünü dolayısıyla da gıda üretimi üzerinde de etkili olmaktadır. Buradan hareketle bu çalışmanın amacı iklim değişikliğinin ve ekonomik büyümenin Türk tarım sektörü üzerindeki etkisini 1990-2021 dönemi için ARDL yöntemini kullanarak araştırmak olarak ifade edilebilir. Elde edilen sonuçlara göre modelde uzun dönem eşbütünleşme ilişkisi elde edilmiştir. Uzun dönem katsayı tahminlerine göre yağış miktarı ve ekonomik büyüme tarım sektörünü pozitif yönde etkilerken, sıcaklık ise negatif yönde etkilemektedir. Türk tarım sektörünün sürdürülebilirliği ve verimlilik artışları için küresel ısınmaya neden olan sera gazları emisyonunun azaltılması yönünde tedbirler alınmalıdır. Ayrıca yağış miktarının yetersiz olduğu bölgelerde GAP (Güneydoğu Anadolu Projesi) gibi sulama ve tarımsal politikalar aktif hale getirilmelidir.

**Tarım Ekonomisi**

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## INTRODUCTION

Climate change is among the most extensively debated global issues. Climate change can be defined as changes in average precipitation and temperature patterns. In particular, the increase in greenhouse gases, which contributes to climate change, poses a significant threat to human life, well-being, living standards, and biodiversity (Arora, 2019; Prentice et al., 2024). It can be said that the causes and consequences of climate change are complex. However, carbon emissions resulting from human activities and the spread of greenhouse gases have led to the destruction of vegetation and the warming and cooling of climate factors (Dietz et al., 2020). Global warming continues to increase because of climate change. In the 21st century, climate change has been a significant factor in hindering agricultural productivity and growth, weakening food security, and leading to new poverty deceptions driven by the price of food instability in developing economies (Praveen et al. 2022). Based on the Global Climate Report 2024 released by NOAA (National Center for Environmental Information), the global surface temperature in February 2024 was 1.40°C higher than the 20th-century average of 12.1°C, marking it as the warmest February ever recorded. Anomalies in temperature increase are shown in Figure 1. Temperatures have been rising, particularly since the 1950s, with a significant increase over the last few decades.

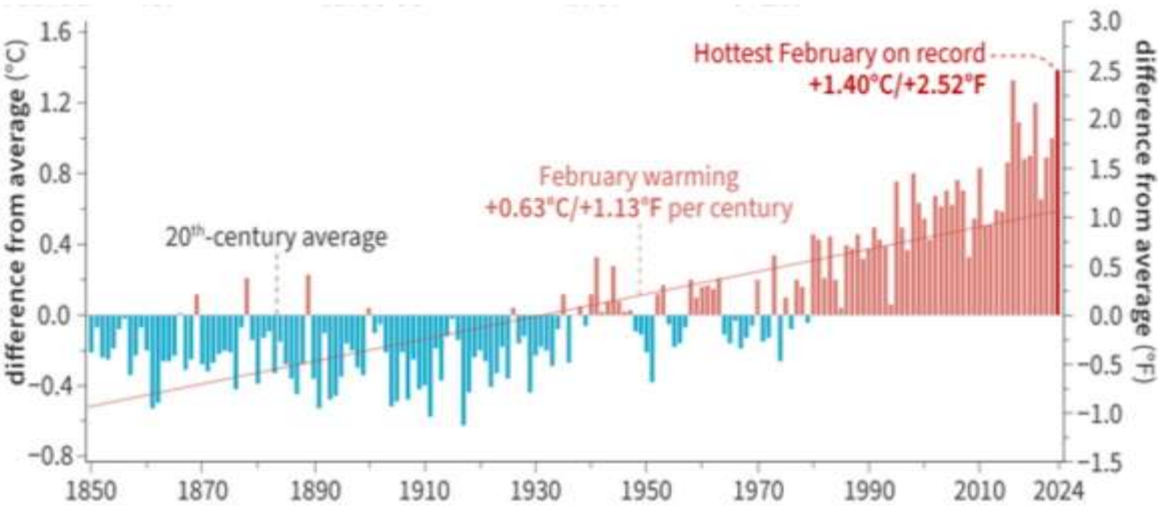


Figure 1: February global temperature compared to average (1850-2024)
*Şekil 1: Ortalamaya kıyasla Şubat ayı küresel sıcaklığı (1850-2024)*
*Resource: https://www.noaa.gov/climate*

The changes in temperature and precipitation for Turkiye are shown in Figure 2 below. Climate change is evident at the Turkiye level. Changes in temperature and precipitation for the period 1980-2024 are depicted. Parallel to global climate change, temperatures have increased, and precipitation has decreased in Turkiye over the last few decades. Recent studies have demonstrated that greenhouse gases alter climate conditions, leading to adverse effects on ecological systems, agriculture, and economies (Kweku et al., 2017; Malhi et al., 2021; Asfew & Bedemo, 2022). These adverse effects affect agricultural production and productivity while jeopardizing food security. The agricultural sector is sensitive and vulnerable to sudden increases in average surface temperature and changes in precipitation (Deschanes & Kolstad, 2011). Research indicates that changes in precipitation patterns and rising temperatures directly affect the growing season of crops. Increasing temperatures lead to a reduction in arable land and adversely affect agricultural production in the long term (Dumrul & Kılıçarslan, 2017; Pickson et al., 2020; Abdi et al., 2023). In regions where precipitation is insufficient, agricultural production is negatively affected, whereas increases in precipitation can adversely affect regions with no water issues. In other words, extreme climatic factors lead to natural climatic disasters, storms, droughts, and floods, resulting in economic losses (Adams et al., 1998; Dumrul & Kılıçarslan, 2017).

Turkiye is a highly fertile country for agricultural production due to its geographical location and soil characteristics. Climate change has affected many areas globally, including agriculture, biodiversity, soil, and economic activities. Thus, the potential effects of climate change on Turkish agriculture are inevitable. Some of the studies addressing this effect are Bayraç & Doğan (2016), Başoğlu & Telatar (2013), and Dumrul & Kılıçarslan (2017).

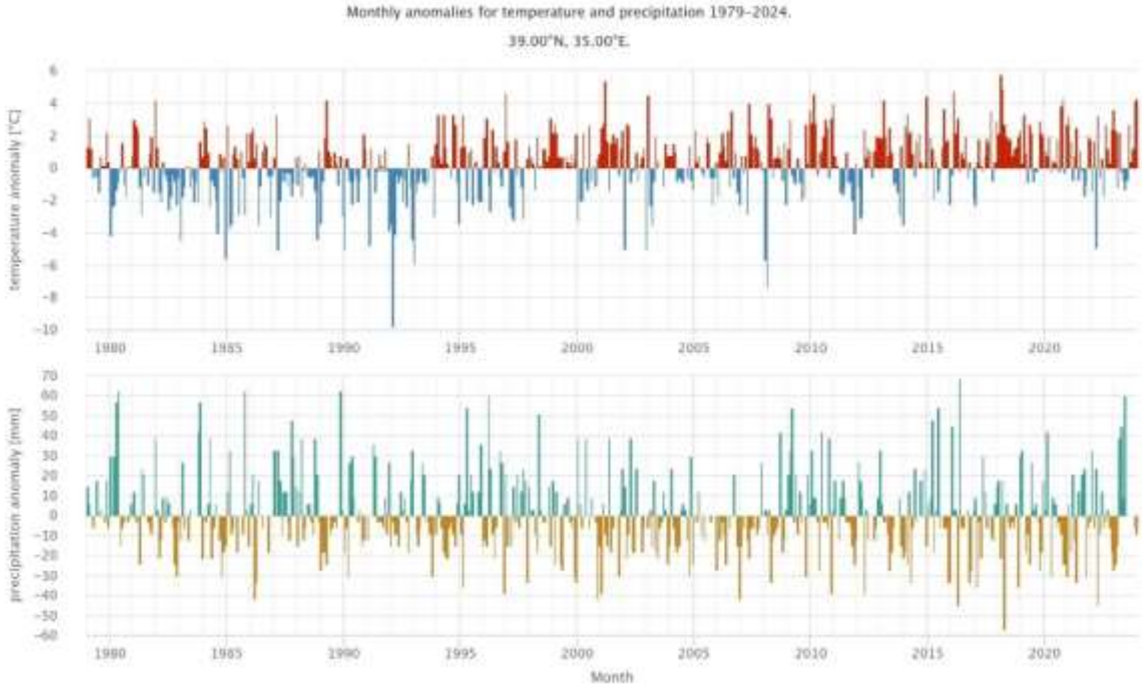


Figure 2: Turkiye's monthly anomalies in temperature and precipitation 1978-2024
*Şekil 2: Turkiye'nin aylık sıcaklık ve yağış anomalileri 1978-2024*
*Resource: https://www.noaa.gov/climate*

Therefore, this study investigates the impact of climate change and economic growth on agricultural productivity in Turkiye. This study covers the period from 1990 to 2021. From an empirical perspective, this model could alternatively be analyzed using methods such as the VECM or the Johansen cointegration test. Nevertheless, the ARDL approach is adopted in this study for two principal reasons. First, the ARDL framework enables the assessment of the impact of independent variables on the dependent variable by distinguishing between short-run dynamics and long-run relationships. Second, while the climate change variables are stationary at the level, the other variables exhibit stationarity at the first difference, which makes the ARDL technique particularly suitable. This study advances the literature in several respects: first, it incorporates economic growth into the model while analyzing the economic impacts of climate change. The study investigated the short and long-run linkage between the variables. The contributions are, in the short run, will economic growth or climate change will affect the agriculture sector in Turkiye, and in the long run, which indicators will have a high impact on agriculture. Is it climate change or economic growth? By using secondary data, this article focuses on. The specific effect of climate change on agriculture is that changes in rainfall or temperature will affect agriculture more severely. Furthermore, if Turkish farmers did not have credit or access to agricultural extension services or fertilizer, would that affect their productivity, i.e., how much of the budget is allocated for the agriculture sector to grow in Turkiye?

This paper is divided into five sections. Section 1" Introduction," Section 2 "Literature Review," Section 3 "Data Set and Methodology," Section 4 "Empirical Results," and Section 5 "Conclusion."

## LITERATURE REVIEW

Climate change has been one of the most discussed topics across various disciplines over the past few decades. While the causes of climate change are a significant area of research, its environmental, economic, and biodiversity impacts are also emerging as crucial concerns. Consequently, climate change is an important and worrisome issue for every country.

Countries must take measures against climate change. Turhan et al. (2016) noted that Turkiye was among the countries with the highest increase in greenhouse gas emissions, with a 110,4% rise between 1990 and 2013. Turkiye has fallen short of expectations in taking measures to reduce greenhouse gas emissions. However, Ahmed et al. (2023) have stated that Turkiye has now established a significant strategy for reducing greenhouse gas emissions in response to climate change. Studies in the literature that focus on the effects of climate change are important for observing the outcomes of the measures taken. For instance, Bayraç & Doğan (2016) examine the effects of climate change on the Turkish agricultural sector for the period 1980-2013. Agricultural GDP (Gross Domestic Product), productivity, $CO_2$ emissions, precipitation, and temperature data were analyzed using the

ARDL approach. Agricultural productivity and precipitation positively affect agricultural GDP, whereas CO2 emissions and temperature have a negative impact. Similarly, Başoğlu & Telatar (2013) analyzed the impact of climate change on agricultural GDP using regression analysis. They found a negative relationship between temperature change and a positive relationship with precipitation. Dumrul & Kılıçarslan (2017) studied the effects of precipitation and temperature on the Turkish agricultural sector. The study covered the period from 1980 to 2013 and was analyzed using the ARDL approach. The results indicated that precipitation positively affected the agricultural sector, whereas temperature had a negative impact. Other studies conducted by Akcan et al. (2022) for Turkiye. Akcan et al. (2022) investigated the effect of climate change on the Turkish agricultural sector using an ARDL approach. They examined the effects of precipitation, temperature, and humidity on agricultural GDP for the years 1985-2018. Precipitation and humidity positively influence agricultural GDP, whereas temperature has a negative effect.

Many studies examined the effect of climate change on other countries using the time series method. One of them, Chandio et al. (2019), researched the impacts of climate change on agricultural production in China. This study, covering 1982 to 2014, was analyzed using the ARDL approach. Precipitation and temperature harmed agricultural production in China. Likewise, Ren et al. (2023) investigated the role of climate change, innovation, and natural resource abundance in China's agricultural sector. Using time-series data from 1970 to 2021, this study employed spectral causality and cointegration techniques for the empirical analysis. It was observed that climate change had a substantial positive impact on green agricultural growth in China. In contrast, natural resource abundance had a negative effect on green agricultural growth. Specifically, all variables in the model, except for natural resource abundance, had a positive effect on agricultural green growth. There are different studies for Pakistan in the literature. For illustration, Ahmad et al. (2020) investigated the impact of climate change, foreign direct investment (FDI), economic growth, and CO2 on agricultural productivity in Pakistan, examining both the long and short run effects. The dataset spanning from 184 to 2014 was analyzed using the ARDL approach and causality analysis. The study concludes that FDI and economic growth positively affect Pakistan's agriculture, while CO2 and climate change have a negative impact. Ali et al. (2021) examined the impact of climate change, cultivated area, and fertilizer use on sugarcane production in Pakistan for the period 1989-2015 using the ARDL approach. Long-term results indicated that temperature and fertilizer use positively affected sugarcane production. Although the impact of temperature on sugarcane was positive, it was not statistically significant. Chandio et al. (2020) explored the long-run and short-run effects of climate change and official credit on agricultural production in Pakistan. Additionally, the study included technological factors such as tube wells, energy consumption, and labor as control variables in the model. The period covered by the study was from 1983 to 2016, and ARDL and VECM Granger causality tests were employed. The ARDL bound test approach results demonstrate a long-run nexus between official credit, climate change, technological factors, energy consumption, labor, and agricultural production. Official credit, technology utilization, and labor have both short- and long-term positive and significant effects on agricultural production. Although climate change appears to have a positive effect on agricultural production, the relationship is statistically insignificant. Unidirectional causality has been established from official credit to agricultural production, labor to agricultural production, technology factors, and energy consumption to climate change. Rashid et al. (2020) empirically examined the impact of climate change on cotton productivity in Pakistan for the period 1981-2015. Three climate variables (rainfall, maximum temperature, and minimum temperature) and three non-climatic variables (fertilizer, technology, and area) were used to assess climate change. The ARDL approach was employed for the empirical analysis. The cointegration results indicate that all climate variables had a statistically significant impact on cotton productivity in Pakistan. While both rainfall and the highest temperature had positive effects, the minimum temperature harmed cotton production. Additionally, both fertilizer and area had positive effects on cotton production. A long-term cointegration relationship was found between the climate change variables and cotton productivity. And Anh et al. (2023) analyzed the effect of climate change on agricultural production in Vietnam from both short- and long-term macro-perspectives. This study, for the period 1990-2019, utilized the ARDL approach and the Toda-Yamamoto causality test. The study concludes that global warming and rainfall have adverse effects on Vietnam's agricultural production. Asfew & Bedemo (2022) examined the effect of climate change on cereal production in Ethiopia using the ARDL approach. The findings indicated that temperature negatively affected cereal production, whereas rainfall had a positive effect. Food imports have a negative and insignificant short-term effect on economic growth but a statistically insignificant positive effect in the long term. Warsame et al. (2021) examined the impact of climate change, measured by temperature, rainfall, and carbon emissions, on crop production in Somalia, using data from 1985 to 2016. The Granger causality and ARDL bounds testing approach were used as methods. The results indicate long-term cointegration among the variables. Rainfall was found to increase crop production in the long run but hindered it in the short run, while temperature harmed crop production in both the long run and the short run. Agricultural labor had a negative influence on the productivity of other crops, while cereal cultivation had a positive effect. Furthermore, unidirectional causality from agriculture and cereal-cultivated land to temperature and from CO2 emissions to cereal-cultivated land was observed.

On the other hand, Xiang & Solaymani (2022) investigated the impact of climate change variables—namely $CO_2$ emissions, temperature, and average precipitation—on grain yield in Malaysia over the period 1969–2018, employing the ARDL approach. Their findings reveal a long-run cointegrating relationship between grain production and both climatic and non-climatic factors. While all climate variables exerted a negative influence on grain yield, energy consumption, and cultivated land had positive effects in both the short and long run. Specifically, in the long term, a 1% increase in temperature was associated with a 2.87% and 3.52% decline in grain production for the overall and predicted estimates, respectively. Zaied & Cheikh (2015) investigated the impact of climate change on the agricultural sector of Tunisia. They used Pedroni cointegration analysis and found that temperature negatively affected both cereal and date production, while rainfall had a positive effect. Acharya & Bhatta (2013) investigated the impact of climate change on annual agricultural GDP, rainfall, temperature, seed, and fertilizer distribution data in Nepal for the period 1975-2010. This study found that rainfall had a significant positive effect on agricultural income. However, improved seeds and chemical fertilizers were found to be insignificant. The impact of increasing temperature on agricultural income was negative and statistically insignificant. Dait (2022) examined the risks climate change poses to Philippine agriculture, focusing on the empirical assessment of the relationship between agricultural output and economic variables. Time series data from 1980 to 2014 were examined using Cointegration and Granger causality. A 1% increase in agricultural employment leads to a 0.2% increase in agricultural production. Conversely, a 1% increase in temperature results in a 0.08% decrease in agricultural production. Gershon & Mbajekwe (2020) investigated the connection between climate change and agricultural production in Nigeria for the period 1981-2017. The average annual rainfall, temperature, and carbon dioxide emissions were used to represent climate change, while the livestock production index and crop production were used to represent agricultural output. Econometric analysis was conducted using ARDL. The results showed a long-term relationship between climate change and crop production, but not between climate change and livestock. Additionally, rainfall and CO2 emissions had a positive and significant long-term effect on crop yield, whereas temperature had a negative and significant long-term effect.

Ghosh et al. (2023) examined the impact of climate change variables on agriculture for the period 1980-2014 in Bangladesh. The results indicated that the agricultural value-added, carbon emissions, and average rainfall had an positive effect on agricultural production in the long term. In another study for Bangladesh, Hossain et al. (2019) used the Ricardian method to measure the effects of climate change on agricultural income. Household farm and climate data from selected agro-ecological regions in Bangladesh were used to estimate the relationship between agricultural income and climate parameters. The results showed that agricultural income is sensitive to climate, particularly seasonal temperatures. An increase in temperature positively affects net crop income in regions with adequate irrigation facilities. Increases in temperature and rainfall are projected to lead to an increase in net income from crop farming in Bangladesh. Similarly, Ahmed & Saha (2023) studied the effects of temperature and carbon emissions on the agricultural GDP in India, Bangladesh, and Nepal. The study, covering the period from 1961 to 2018, was analyzed using the ARDL approach. The findings revealed that, in the long term, no significant relationship was observed between temperature and agricultural GDP in India and Nepal. However, for Bangladesh, it was found that temperature significantly and positively affected agricultural GDP. Praveen et al. (2022) researched the effect of environmental degradation due to greenhouse gas emissions on agricultural production in India for the period 1970-2016 using ARDL, FMOLS, and DOLS methods. The study found that agricultural methane emissions pose an environmental threat, leading to a decline in agricultural productivity in India. Houng et al. (2022) analyzed the impact of climate change on farm production in Vietnam for the period 1990-2020. After conducting the ADF and Phillips–Perron unit root tests, the ARDL bounds testing technique was used to estimate short and long-run cointegration. Despite the negative effects of the average temperature and rainfall, CO2 emissions were found to have a positive effect. Non-climatic factors, such as crop production and fertilizer consumption, were found to have beneficial effects on agricultural production and yield in both the long run and short run. Molua (2008) analyzed the impact of climate change on agricultural production in Cameroon from 1960 to 2001. The empirical results indicate that Cameroon's agriculture was affected by climate variables, potentially negatively impacting the economy, as agriculture accounts for approximately 30% of the national GDP. Nasrullah et al. (2021) in South Korea examined the effect of climate change, technology indicators, and agricultural policies on rice production. The findings suggest a long-run nexus between the variables, with an increase in CO2 emissions leading to a 0.15% rise in rice production. Average temperature was found to increase rice production by 1.16%, whereas rainfall had a negative effect, indicating issues with irrigation systems and weather forecasting reports. El-Khalifa et al. (2022) analyzed the long-term effect of climate change on Egypt's agriculture sector for the period 1990-2020 using the ARDL approach. The results demonstrate that climate change had a long-term effect on Egypt's agriculture, with CO2 being the primary driver of increasing temperatures.

Increased temperatures have been found to reduce agricultural GDP in the long term. While most of the studies have shown that temperature has a negative effect on agricultural production, Attiaoui & Boufateh (2019) have shown a positive effect. In another study, Attiaoui & Boufateh (2019) conducted a study addressing the impact of climate change on cereal production. This study investigated the effect of climate change on cereal production in Tunisia by ARDL and PMG approaches. This study shows that the negative effects of climate change are primarily experienced during periods of insufficient rainfall, while current temperature levels remain favorable for cereal crops.

It is seen that the effects of climate change are generally analyzed by time series methods on a country-by-country basis. However, some studies examine this relationship for country groups using panel data methods. One of them is the study that Imran et al. (2019) that examined the impact of climate change on the agricultural sector of South Asian countries from 1990 to 2014. CO2 emissions, labor, gross capital formation, and temperature were used as explanatory variables. The ARDL model was employed to assess the impact of climate change on the agricultural sector. The findings revealed that while temperature and CO2 had negative effects on agricultural production, labor participation had a positive impact. Similarly, Özdemir (2022) investigated how climate change affected agricultural productivity in Asia in the short and long terms from 1980 to 2016 using dynamic and asymmetric panel autoregressive distributed lag estimators. The results indicated a long-term correlation between agricultural productivity and climate change factors. In contrast, in the short term, agricultural productivity was influenced solely by CO2 emissions. It was concluded that temperature negatively affected agricultural yield. Behera et al. (2023) researched the linkage between food security and agricultural production in South Asian countries in the face of climate change for the period 2000-2019. An empirical analysis employing Driscoll-Kraay and panel-corrected standard error estimators produced robust results, effectively accounting for cross-sectional dependence and heteroskedasticity. Additionally, it has been found that changing precipitation patterns with increasing temperatures and rising CO2 emissions hinder food security in these countries. Furthermore, it was observed that non-climatic factors related to land use and agricultural land use triggered CO2 emissions, which is one of the main causes of climate change. Likewise, Chandio et al. (2022) examine the impact of climate change and financial development on agricultural production in ASEAN-4 countries for the period 1990-2016. In addition, the roles of renewable energy, institutional quality, and human capital in agricultural production have been investigated. Long-term relationships between variables were obtained using Westerlund's (2007) cointegration test. The results from the CS-ARDL model reveal that climate change has a detrimental impact on agricultural production, while renewable energy, institutional quality, and human capital have positive effects. Additionally, the analysis indicates a U-shaped connection between agricultural production and financial development, implying that financial development enhances agricultural production only after surpassing a specific threshold level. Jatuporn & Takeuchi (2023) investigated the impact of climate change on economic growth and variability in the agricultural sector across 76 provinces in Thailand from 1995 to 2019 using panel data. After determining stationary properties through unit root tests, panel data analysis utilized ARDL and PMG estimators. Findings from the PMG estimator indicated that extreme weather events harmed the agricultural economy, whereas an increase in total rainfall had a positive relationship with the agricultural economy. Jena (2021) empirically investigated the relationship between agricultural production and climate change in selected districts of Odisha, India, from 1993 to 2019 using a PARDL model. This study revealed that climate change adversely affected crop production in the districts of Odisha. When we look at climate change in African countries, Ogundari & Onyeaghala (2021) analyzed the effects of climate change on total factor productivity (TFP) growth in African agriculture and tested whether TFP levels converged across the region. Covering the years 1981-2010, they utilized panel data from 35 countries and a technological catch-up model based on a Ricardian analysis. The rainfall and temperature values of each country were used as indicators of climate change. Education, capital intensity, and irrigable land were also considered explanatory variables. The empirical results indicate that TFP levels in African agriculture converged over time, albeit at a relatively slow rate. Furthermore, rainfall was found to significantly increase agricultural growth, whereas temperature did not affect the TFP growth of African agriculture. Other findings suggest that education, capital intensity, and irrigated arable land significantly increase the agricultural TFP growth. Abdi et al. (2023) researched the impacts of climate change, CO2 emissions, cereal areas, and rural agriculture on cereal production in East Africa. The study covered the period from 1990 to 2018 and employed heterogeneous panel data methods, including panel Kao and Pedroni co-integration and Dumitrescu–Hurlin causality tests. Rainfall and CO2 emissions were found to have significant long-term effects on cereal production in the long run. In the long term, temperature negatively affected cereal production, whereas rainfall had a positive effect. Bidirectional causality was observed between cereal production, temperature, and CO2 emissions, whereas unidirectional causality was found for cereal production in rural populations. Alagidede et al. (2016) investigated the empirical understanding of how climate change impacts sustainable economic growth in Sub-Saharan Africa (SSA). They analyzed data on two climate factors, temperature and precipitation, and utilized panel cointegration econometric methods to examine both the long-term and short-term effects of climate change on growth. They found that temperatures exceeding 24.9 °C notably diminished economic performance in SSA. Additionally, the association between real GDP per capita and temperature is nonlinear. Bhardwaj et al. (2022) investigated the impact of climate change on wheat and rice yields in Punjab State, India, from 1987 to 2017, utilizing FMOLS, DOLS, and PMG approaches. The Pedroni cointegration test confirmed a long-term relationship between climate variables and the yields of rice and wheat. Findings from the FMOLS and DOLS models showed that minimum temperature positively influenced both wheat and rice yields, while maximum temperature negatively affected both crops. Rainfall was found to have a significant negative impact on wheat production. Furthermore, the Dumitrescu-Hurlin causality test identified a unidirectional causality from minimum and maximum temperature and rainfall to rice and wheat yield.

The effects of climate change have been studied for many countries and country groups, primarily using panel data and time series methods. The ARDL approach has been frequently employed in time series analyses, primarily since the temperature and precipitation series are stationary at the level, while the other variables become stationary after first differencing. While the impacts of climate change have been examined for countries from different regions, it can be said that the focus has predominantly been on Asian countries. Despite the positive effects of increased precipitation due to climate change, rising temperatures generally harm economic growth and agricultural production. In this study, based on Turkiye's latitudinal position, temperatures are expected to harm agricultural production, while precipitation is expected to have a positive effect.

## MATERIAL and METHOD

This study aims to investigate the impact of climate change and economic growth on agricultural productivity for Turkiye during the period 1990-2021. The data for this study were obtained from the World Development Indicators (WDI). The variable agriculture, forestry, and fishing value added (constant US$) was measured by Constant US Dollars so that the figures are adjusted for inflation using a base year. This allows for comparisons over time without the distorting effects of inflation and ensures that the measurement of value added in agriculture, forestry, and fishing is accurate, reliable, and comparable across different regions and time periods. Additionally, the variable "agriculture, forestry, and fishing value added (constant US$)" was utilized to explore the relationship with climate change, given the high sensitivity of these sectors to climatic conditions. Variations in temperature, precipitation patterns, and the frequency of extreme weather events can directly affect crop yields, forest health, and fish populations, highlighting their vulnerability to climate change. The variable Gross Domestic Product (GDP) is often used in studies examining the relationship with climate change because GDP represents the total economic output of a country, and it provides a comprehensive measure of the economic performance and can be used to assess how climate change impacts overall economic activity. Moreover, it measures GDP in constant dollars (constant prices), it is adjusted for inflation using a base year, and this allows for comparisons over time without the effects of inflation distorting the results. The variable temperature is often used in studies examining the relationship with climate change because temperature is a fundamental and direct indicator of climate change. Changes in average temperatures over time provide clear evidence of global warming and climate trends. Moreover, it measures the mean temperature for a given time (e.g., monthly, seasonal, or annual). The variable rainfall is often used in studies examining the relationship with climate change because Rainfall is essential for crop growth and agricultural productivity. Variations in precipitation can lead to droughts or floods, significantly impacting food security and livelihoods. Moreover, it measures the total amount of precipitation, including rain, snow, sleet, and hail, that falls in a specific area over a year. It is typically measured in millimeters (mm) or inches. The study period covered was 1990-2021. Table 1 displays the transformation of the variables in logarithmic form, variable descriptions, and data sources.

Table 1. Variables Details
*Çizelge 1. Değişken Detayları*

| Representation | Variables Description | Data Source |
|---|---|---|
| **logAGR** | Agriculture, forestry, and fishing, value added (constant 2015 USD) | World Bank |
| **logGDP** | Gross domestic production (Constant 2015 USD) | World Bank |
| **TEMP** | Average annual temperatures | World Bank |
| **RAIN** | Average annual rainfall | World Bank |

In this study, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests were initially employed to determine the stationarity levels of the series.

The Augmented Dickey-Fuller (ADF) unit root test is formulated as follows:

$$\Delta Y_t = \beta_1 + \beta_{2t} + \partial Y_{(t-1)} + \alpha_1 + u_t \quad (1)$$

In this specification, t denotes the time dimension; Δ represents the first-difference; u is the stochastic error term, and Y, indicates the series incorporated into the model. The ADF test is based on the assumption that the error term is independently distributed with constant variance. The decision rule relies on the t-statistic of the estimated coefficient: if the absolute value of the t-statistic exceeds the corresponding critical values, the null hypothesis of a unit root is rejected, implying stationarity of the series; otherwise, the series is considered non-stationary (Said and Dickey, 1984).

The Phillips-Perron (PP) unit root test was introduced as an alternative to the ADF test to address its limitations, particularly in the presence of serial correlation and heteroskedasticity in the error term. While the underlying hypotheses of the PP and ADF tests are similar, the PP test employs a non-parametric correction to the test statistics. The PP test is expressed as follows (Phillips and Perron, 1988, p. 338):

$$Y_t = \hat{u} + \hat{a} Y_{t-1} + \hat{u}_t \quad (2)$$

$$Y_t = \tilde{u} + \tilde{\beta}\left(t - \frac{1}{2}\lambda\right) + \tilde{\alpha} Y_{t-i} + \tilde{u}_t \quad (3)$$

In the subsequent stage, the relationship between the variables in the model was examined using the ARDL bounds testing approach. The ARDL method can be applied when the variables are integrated of different orders, provided that there are no integrated of order two, I(2). Moreover, this method offers an advantage by not only identifying the presence of a cointegration relationship but also providing both short- and long-run coefficients among the variables in the model.

The short-run estimation results of the ARDL model are presented in Equation (4), while the long-run estimation results are provided in Equation (5):

$$\Delta logARG_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} C_{t-i} + \sum_{i=1}^{p} \alpha_{2i} logGDP_{t-i} + \sum_{i=1}^{p} \alpha_{3i} TEMP_{t-i} + \sum_{i=1}^{p} \alpha_{4i} RAIN_{t-i} + \varphi ECT_{T-1} + \varepsilon_t \quad (4)$$

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$$\Delta logARG_t = \varphi_t + \varphi_1 logARG_{t-1} + \varphi_2 logGDP_{t-1} + \varphi_3 TEMP_{t-1} + \varphi_4 RAIN_{t-1} + \sum_{i=1}^{p} \alpha_{1i} logARG_{t-i} + \sum_{i=1}^{p} \alpha_{2i} logGDP_{t-i} + \sum_{i=1}^{p} \alpha_{3i} TEMP_{t-i} + \sum_{i=1}^{p} \alpha_{4i} RAIN_{t-i} + \varepsilon_t \quad (5)$$

Then, to meet the condition of 1. difference stationary for the ADF and PP method when the dependent variable is the natural logarithm of agriculture, it should check the optimal lag for the empirical model. The smallest lag length for this model is one and falls under AIC. The Pesaran, Shin, and Smith (PSS) bounds testing used the optimal lag for co-integration. Therefore, the unit root test results in Table 4 demonstrate a combination of I(0) and I(1).

## FINDING and DISCUSSION

Table 2 presents the descriptive statistics. The change in log of the agriculture value added has the lowest mean, about 10.66 on average, while temperature has the highest mean of approximately 739161.8. The standard deviations are in parentheses. However, comparing the log of agriculture with the log of GDP, it was confirmed that the log of GDP has the highest average of approximately 11.73. The descriptive statistics also contained the media, maximum, minimum, and Jarque–Bera statistics to show the normality of the residuals, as well as the probability of the normality test. In conclusion, the total sum and the sum of the square deviations are also indicated in the table below.

Table 3 shows the correlations among the variables. Correlation is used to check for the relationship between variables. The linkage between agricultural value and economic growth rate is positive. The rate of growth of agriculture also has a positive influence on rainfall and temperature growth in Turkiye. It can be observed that both rainfall and temperature growth are good for transforming agriculture in Turkiye.

The unit root indicates that the variables are non-stationary. In this case, we checked both the constant and the constant plus trend to see whether the variables are stationary at the level or integration of order zero and the first difference or integration of order 1, 2, etc. Table 4. Unit Root Test Results

Table 2. Descriptive Statistics
*Çizelge 2. Tanımlayıcı İstatistikler*

| | logAGR | logGDP | TEMP | RAIN |
|---|---|---|---|---|
| **Mean** | 10.65914 | 11.73178 | 739161.8 | 598.7850 |
| **Media** | 10.63915 | 11.73514 | 739262.0 | 607.5050 |
| **Max.** | 10.83019 | 12.05376 | 739616.0 | 723.8100 |
| **Min.** | 10.54377 | 11.46051 | 738926.0 | 456.6800 |
| **Std Dev.** | 0.091589 | 0.184471 | 181.1258 | 62.91641 |
| **Jargue-Bera** | 2.884887 | 2.303640 | 0.970510 | 0.215424 |
| **Porbility** | 0.236350 | 0.316061 | 0.615540 | 0.897886 |
| **Sum** | 341.0925 | 375.4168 | 23653178 | 19161.12 |
| **Sum Sq. Dv.** | 0.260043 | 1.054916 | 1017003. | 122712.7 |

Table 3. Correlation Analysis
*Çizelge 3. Korelasyon Analizi*

| | logAGR | logGDP | TEMP | RAIN |
|---|---|---|---|---|
| **logAGR** | 1.000 | 0.983 | 0.131 | 0.167 |
| **logGDP** | 0.983 | 1.000 | 0.213 | 0.147 |
| **TEMP** | 0.131 | 0.213 | 1.000 | 0.113 |
| **RAIN** | 0.167 | 0.147 | 0.113 | 1.000 |

*Table 4. Unit Root Test Results*
*Çizelge 4. Birim Kök Test Sonuçları*

| | | ADF | | PP | |
|---|---|---|---|---|---|
| **Variables** | Model | Level | 1. Difference | Level | 1. Difference |
| **logAGR** | C | 1.039 [0.995] | -9.519[a] [0.000] | 1.449 [0.998] | -9.675[a] [0.000] |
| | C+T | -1.736 [0.709] | -9.807[a] [0.000] | -2.891 [0.178] | -2.628[a] [0.000] |
| **logGDP** | C | 0.513 [0.948] | -5.508[a] [0.000] | 1.715 [0.999] | -6.343[a] [0.000] |
| | C+T | -2.581 [0.290] | -5.479[a] [0.000] | -2.5937 [0.285] | -7.064[a] [0.000] |
| **TEMP** | C | -4.075[a] [0.003] | -8.934[a] [0.000] | -4.106[a] [0.003] | -12.822[a] [0.000] |
| | C+T | -4.171[b] [0.013] | -6.681[a] [0.000] | -4.2415[b] [0.011] | -15.9193[a] [0.000] |
| **RAIN** | C | -6.547 [0.000][a] | -7.083[a] [0.000] | -6.677[a] [0.000] | -16.528[a] [0.000] |
| | C+T | -6.472 [0.000][a] | -7.038[a] [0.000] | -7.087[a] [0.000] | -17.412[a] [0.000] |

Note: C: Constant model. C + T: Constant and Trend model. [a], [b], and [c] denote the significance at the 1%, 5%, and 10% levels, respectively.

This unit provides the empirical outcomes of the analysis, which originates with the rapid unit root test of the variable used for the empirical study in Table 4. We designated four variables to determine the factors that determine the agricultural value-added, which included forestry, hunting, and fishing status in Turkiye. The outcomes show that, overall, used on the constant and constant plus trend, while RAIN and TEMP are stationary at the level, growth rate of agriculture and growth rate of GDP variables are stationary at the first differences, as ADF and PP tests. When the data are stationary at the level and I(1), we can use VAR or OLS. When the variables are all stationary at integrated order 1, then VECM is more appropriate to normalize our variables. In conclusion, we found that the most appropriate model for this study was the ARDL technique. The next table will tell us whether the appropriate mode will be the ARDL short run or the ARDL long run by applying F-bound and T-bound statistics.

Table 5 lists the ARDL bound testing approaches for cointegration. The outcomes in Table 5 specify the significant co-integration among the variables. In this model, the F-bound statistics value of 7.499 is larger than the critical value of upper bounds at all I(1) levels of significance, which shows co-integration between the agriculture sector as the dependent variable, growth of economics, rainfall, and temperature as exogenous variables. As co-integration exists, the long-term ARDL model is more appropriate for this study.

Table 5. ARDL Bound Test Cointegration Results
*Çizelge 5. ARDL Sınır Testi Eşbütünleşme Sonuçları*

| Test Statistic | Value | K |
|---|---|---|
| F | 7.499[a] | 3 |
| | Significance Level | |
| Critical Bounds | I(0) | I(1) |
| %1 | 4.29 | 5.61 |
| %5 | 3.23 | 4.35 |
| %10 | 2.72 | 3.77 |

Note: [a], denote the significance level at 1%, correspondingly

Table 6. Diagnostic tests
*Çizelge 6. Teşhis testleri*

| Tests | $X^2$ (P-Value) |
|---|---|
| Breusch Godfrey LM | 1.393(0.172) |
| Breusch Pagan Godfrey | 0.397(0.873) |
| Ramsey RESET Test | 3.149(0.089) |
| Jarque-Bera Test | 1.557(0.459) |

Variables from the bivariate analysis—specifically, Pearson product-moment correlation coefficients—were considered for further analysis in the ARDL regression model if they had a tolerance value greater than 0.20 and a variance inflation factor (VIF) below five after conducting a linear regression analysis followed by VIF assessment. Variables that passed the multicollinearity test were subjected to additional statistical scrutiny. The VIF results indicated no strong evidence of multicollinearity among the variables in the regression model, as all VIF values were well below the common threshold of 10, and the mean VIF was low, suggesting that multicollinearity is unlikely to pose a significant issue in the analysis. The results from the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity provide insights into whether the variance of the residuals in your regression model is constant (homoskedastic) or varying (heteroskedastic). Since the p-value is 0.873, which is greater than the typical significance level of 0.05, you fail to reject the null hypothesis. This means there is no significant evidence of heteroskedasticity in your model. The Breusch-Pagan/Cook-Weisberg test results suggest that there is no significant evidence of heteroskedasticity in your regression model. The residuals appear to have constant variance, which is consistent with the assumption of homoskedasticity. Therefore, your model's standard errors are likely to be reliable without requiring adjustments for heteroskedasticity. The results from the Breusch-Godfrey LM test for autocorrelation assess whether there is serial correlation (autocorrelation) in the residuals of your regression model. Since the p-value is 0.172, which is higher than the typical significance level of 0.05, you reject the null hypothesis. This suggests that there is significant evidence of autocorrelation in the residuals. It determined whether the errors were normally distributed in Table 6 above; therefore, we used Orthogonalization Cholesky (Lutkepohl) to test the normality of the residuals. The result confirmed from the Jarque-Bera normality component that jointly the errors in the ARDL models are normally distributed, with a p-value of 0.459 is higher than the 0.05 percentage level of alpha and indicates that the growth rate in agriculture, GDP, temperature, and rainfall follow a normal distribution in this study.

According to the diagnostic statistics reported in Table 6, the model is consistent with the assumptions of the ARDL methodology, implying that the estimated coefficients for both the long and short run are statistically reliable. The results of the long run and short run are shown in Table 7. In the long run, the results indicate that GDP growth has a significant impact on the growth of agriculture in Turkiye. Because of its higher GDP, the agriculture sector flourished over time in Turkiye. Most of Turkiye's land is used for agriculture and farming, and employs about 15% of the workforce in Turkiye. Agriculture contributes less to the GDP in Turkiye compared to the services and industrial sectors. An increase in the growth of GDP increases the agricultural growth by 0.5126 percent in the long run. Moreover, the temperature has a deteriorating effect on agricultural growth rate in Turkiye, and therefore, the results revealed that average temperature has a significant negative influence on the growth of agriculture in Turkiye in the long run. However, changes in rainfall led to positive changes in agriculture in Turkiye and a rise in average rainfall, with agricultural growth rising. In conclusion, in the long run, both the growth of GDP and the growth of rainfall are important to the growth of agriculture and food security in Turkiye, but the growth of average temperature has a significant adverse impact on agriculture, which will result in food loss and food spoilage until policymakers solve.

Table 7. ARDL Long-run and short-run estimates (1.0.0.2)
*Çizelge 7. ARDL Uzun dönem ve kısa dönem tahminleri (1.0.0.2)*

| Dependent variable=logAGR | coefficient | t-statistic | P-value |
|---|---|---|---|
| **Long-run** | | | |
| logGDP | 0.5126 | 2.850 | 0.000[a] |
| TEMP | -0.0001 | -2.817 | 0.009[a] |
| RAIN | 0.0001 | 1.831 | 0.080[c] |
| **Short-run** | | | |
| Cons | 3.3729 | 5.790 | 0.000[a] |
| D(logGDP) | 0.4019 | 0.118 | 0.002[a] |
| D(logGDP(-1)) | -0.4208 | 0.122 | 0.002[a] |
| CoinEq(-1) | -0.8094 | 0.139 | 0.000[a] |
| **$R^2$:**0.64 | | | |
| **Adj $R^2$:**0.60 | | | |
| **Durbin Watson:**2.230 | | | |

Not: [a] and [c] denote significance at the 1% and 10% levels, respectively.

It is evident that, particularly due to global warming, the long-term adverse effects of climate change on Turkiye's agricultural sector will intensify. According to a report published by the Turkish Ministry of Environment, Urbanization, and Climate Change, the temperature in Turkiye is expected to rise by 1.1-1.3°C over the next few decades. Consequently, agricultural productivity is projected to decrease by 6-7% between 2030-2039 and by 8-9% between 2040-2049. These declines in productivity are estimated to result in a 1% reduction in GDP during the first period and a 1.4% reduction in the second period (Özlü et al., 2022, p. 8). The findings align with the projected scenarios. While the findings are consistent with the projections, there is also the possibility of unforeseen outcomes where the actual situation may be either below or above the anticipated levels. If climate change occurs at a less severe level than predicted, the negative impacts on agricultural productivity and GDP may not materialize. However, if climate change is more severe than expected, agricultural production and economic growth will be more adversely affected. Policies should be formulated with this second possibility in mind. The anticipated effects of climate change should be taken more seriously, and measures should be adopted in preparation for scenarios involving higher-than-expected temperature increases.

In the short run, the results revealed that the change in GDP growth has a positive and significant impact on the differences in the growth of agriculture in Turkiye. This means that in the short term, the economics of Turkiye can be used to make agriculture more efficient and effective, and thereby production in this sector can rise through the provision of credit to farmers, by new agricultural technology such as provision of inputs such as pesticides, fertilizers, and tractors, and training new methods of forming such as research by application of different adaptation mechanisms to improve the yield and income of farmers. The results for these two indicators were not significant, and the coefficients were slightly positive. We all agree, in theory, that rainfall is good for agriculture and high temperatures are bad for many groups and animals.

Using ARDL modelling, it is shown that, in the long run, economic growth has a positive and significant impact on agricultural growth. This finding was confirmed by Olajide et al. (2012) and Rosyadi et al. (2023). The GDP per capita has a positive result on agriculture using the ARDL long run approaches. This is long-established by Ali et al., 2019. The study further revealed that average rainfall has an insignificant positive correlation with the differences in the growth of agriculture in the short run. Dumrul & Kılıçarslan (2017) show that an increase in precipitation affects agricultural GDP positively, while an increase in temperature has a negative effect on agricultural GDP. The average temperature has an insignificant impact on the growth of agriculture in the short term and in the short run. Other hands, average rainfall also have an insignificant but positive effect on the difference in the growth of agricultural Turkiye. This was confirmed by Acharya & Bhatta (2013), Başoğlu & Telatar (2013), Zaied & Cheikh (2015), Diat (2022), Özkurt (2024), Özdemir (2022), and Asfew & Bedemo (2022).

In Figure 3 below, after running the ARDL model, we run the cumulative sum test method (CUSUM) to identify the stability of our model. The tests demonstrated that the estimation and variance were stable as the error fall within 5% of the upper and lower critical values.

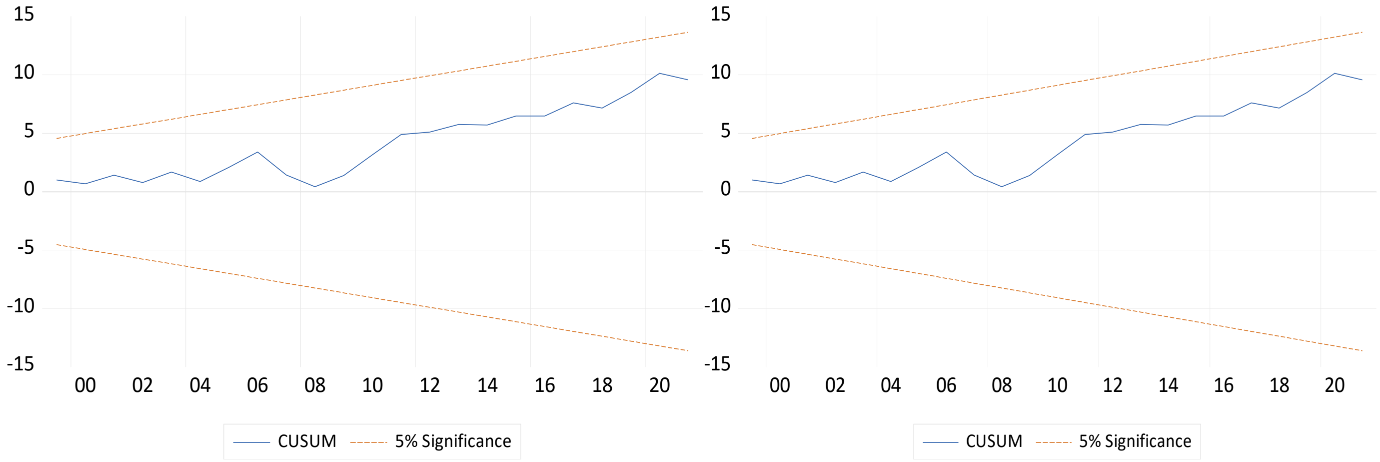


Figure 3: Cusum and Cusum Squares Tests For Stability of The Model
Şekil 3. Modelin Kararlılığı İçin Cusum ve Cusum Kareler Testleri

## CONCLUSION and RECOMMENDATION

In this study, the impacts of climate change and economic growth on agricultural production in Turkiye from 1990 to 2021 were examined using the ARDL approach. Temperature values and precipitation amounts were used as indicators of climate change. The empirical findings reveal a long-term relationship between climate change, economic growth, and agricultural production. According to the short-term coefficient estimates, statistically significant results were obtained for GDP on agricultural production, with a positive impact. Long-term results indicated a positive relationship between precipitation and agricultural production, while a negative relationship with temperature was observed. Economic growth was also found to have a positive effect on agricultural production in the long run. Due to its latitudinal position, Turkiye experiences high temperatures and generally limited rainfall, making Turkiye a country with predominantly temperate and semi-arid climate characteristics. This situation renders Turkiye vulnerable to the effects of climate change. Therefore, Turkiye must develop policies to mitigate the impacts of climate change and reduce the factors that contribute to it. The effectiveness of these policies should be monitored, and proactive measures should be taken against climate change with the most appropriate policy actions. In this context, several policy recommendations emerge. Firstly, regions in Turkiye with high temperatures and low rainfall are mostly arid and lack forests. Afforestation of arid regions is crucial to mitigate the effects of climate change. Secondly, the distribution of industrial facilities across regions in Turkiye is generally imbalanced. To address the negative consequences of this imbalance, a balanced industrialization policy should be implemented to reduce the density in industrial areas. In this framework, the establishment of new industrial facilities should be encouraged in regions with less industrialization. To reduce greenhouse gas emissions, especially carbon emissions, the use of green production systems should be promoted, including in newly industrialized areas. Thirdly, Turkiye, with its long hours of sunshine and abundant wind energy, is rich in renewable energy resources and should effectively utilize renewable energy systems instead of fossil fuels. For example, the electricity used in irrigation systems should be sourced from renewable energy. Fourthly, recycling systems should be developed to reduce the environmental and climatic impacts of consumption. For instance, the use of biodegradable materials in packaging can be expanded. Fifthly, to mitigate the negative impacts of rising temperatures and decreasing rainfall on agricultural productivity, particularly in the arid regions of Central Anatolia, Eastern Anatolia, and Southeastern Anatolia, modern irrigation systems should be employed to ensure the efficient use of water resources within the framework of sustainability. In this context, small-scale farmers should be especially educated and supported in irrigation practices. Finally, policy recommendations for Turkiye's investment in agricultural research and development to develop and promote the use of crop varieties that are more resistant to extreme weather conditions, pests, and diseases, and modernize and expand irrigation infrastructure to ensure efficient water use and reduce the dependency on rainfall.

This study is subject to several limitations. First, the analysis relies on annual, country-level data for the period 1990–2021. Consequently, seasonal and regional variations in climate impacts on agricultural production could not be captured. Second, climate change was proxied only by temperature and precipitation, without considering other extreme events such as droughts, floods, and heatwaves. In addition, factors such as agricultural input prices, government support policies, and technological change were not fully incorporated into the model. Future research could address these limitations in several ways. More granular data—both at seasonal frequency and at the regional level—could be employed to capture the heterogeneous impacts of climate change across different agro-ecological zones in Turkiye. Expanding the set of climate indicators to include drought indices (e.g., SPI, SPEI) and extreme weather events would provide deeper insights into climate risks. Incorporating additional explanatory variables, such as agricultural subsidies, input use, or technological adoption, could enrich the model. Methodologically, future studies may apply cointegration and causality approaches beyond ARDL, as well as scenario-based simulations using IPCC climate projections to forecast potential productivity losses. Finally, policy-oriented studies could evaluate the economic and social feasibility of adaptation measures, offering more detailed guidance for decision-makers.

## Contribution Rate Statement Summary of Researchers

The authors declare that they have contributed equally to the article.

## Conflict of Interest

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

## REFERENCES

Abdi, A. H., Warsame, A. A., & Sheik-Ali, İ. A. (2023). Modelling the impacts of climate change on cereal crop production in East Africa: Evidence from heterogeneous panel cointegration analysis. *Environmental Science and Pollution Research,* 35246-35257. https://doi.org/10.1007/s11356-022-24773-0

Acharya, S., & Bhatta, G. (2013). Impact of climate change on agricultural growth in Nepal. *NRB Working Paper Series*, *25*(2), 1-16. https://doi.org/10.3126/nrber.v25i2.52682

Adams, R., Hurd, B., Lenhart, S., & Leary, N. (1998). Effects of global climate change on agriculture: An interpretative review. *Climate Research, 11*(1), 19-30. https://doi.org/10.3354/cr011019

Ahmad, S., Tariq, M., Hussain, T., Abbas, Q., Elham, H., Haider, I., & Li, X. (2020). Does Chinese FDI, climate change, and CO2 emissions stimulate agricultural productivity? Empirical evidence from Pakistan. *Sustainability*, *12*(18), 7485. https://doi.org/10.3390/su12187485

Ahmed, M., & Saha, P. (2023). Economic impact of climate change on agriculture: A study of India and its neighbouring countries using the ARDL approach. *Nature Environment and Pollution Technology*, 22(4), 2173-2179. http://doi.org/10.46488/NET.2023.v22i04.043

Ahmed, N., Areche, F., Cabello, G., Turjillo, P., Sheikh, A., & Abiad, M. (2023). Intensifying effects of climate change in food loss: A threat to food security in Turkiye. *Sustainability*, *15*(350),1-12. https://doi.org/10.3390/su15010350

Akcan, A., Kurt, Ü., & Kılıç, C. (2022). Effects of climate change on the agricultural sector in Turkiye: ARDL bounds test approach. *Trends in Business and Economics*, 3(1), 125-132. https://doi.org/10.54614/TBE.2022.992490

Alagidede, P., Adu, G., & Frimpong, P. (2016). The effect of climate change on economic growth: evidence from Sub-Saharan Africa. *Environ Econ Policy Stud*, *18*, 417-436. https://doi.org/10.1007/s10018-015-0116-3

Ali, S., Zubair, M., & Hussain, S. (2021). The combined effect of climatic factors and technical advancement on the yield of sugarcane by using the ARDL approach: Evidence from Pakistan. *Environmental Science and Pollution Research*, *28*(29) 39787-39804. https://doi.org/10.1007/s11356-021-13313-x

Anh, D., Anh, N., & Chandio, A. (2023). Climate change and its impacts on Vietnam's agriculture: A macroeconomic perspective. *Ecological Informatics*, *74*(2023). https://doi.org/10.1016/j.ecoinf.2022.101960

Arora, N. (2019). Impact of climate change on agricultural production and its sustainable solutions. Environmental *Sustainability*, 2(2), 95-96. https://doi.org/10.1007/s42398-019-00078-w

Asfew, M., & Bedemo, A. (2022). Impact of climate change on cereal crop production in Ethiopia. *Hindawi Advances in Agriculture. 2021*(1), 2208694. https://doi.org/10.1155/2022/2208694

Attiaoui, I., & Boufateh, T. (2019). Impacts of climate change on cereal farming in Tunisia: A panel ARDL–PMG approach. *Environmental Science and Pollution Research*, *26*, 13334-13345. https://doi.org/10.1007/s11356-019-04867-y

Başoğlu, A., & Telatar, O. (2013.). İklim değişikliğinin etkileri: Tarım sektörü üzerine ekonometrik bir uygulama. *Karadeniz Teknik Üniversitesi Sosyal Bilimler Dergisi*, *6*, 7-25.

Bayraç, H., & Doğan, E. (2016). Türkiye'de iklim değişikliğinin tarim sektörü üzerine etkileri. *Eskişehir Osmangazi Üniversitesi İİBF Dergisi, 11*(1), 23-48.

Behera, B., Haldar, A., & Sethi, N. (2022). Agriculture, food security, and climate change in South Asia: A new perspective on sustainable development. Environment, Development and Sustainability. *26*(9), 22319-22344. https://doi.org/10.1007/s10668-023-03552-y

Bhardwaj, M., Kumar, P., Kumar, S., Dagar, V., & Kumar, A. (2022). A district-level analysis for measuring the effects of climate change on production of agricultural crops, ie, wheat and paddy: evidence from India. *Environmental Science and Pollution Research*, *29*(21), 31861-31885. https://doi.org/10.1007/s11356-021-17994-2

Chandio, A. A., Shah, M., Sethi, N., & Mushtaq, Z. (2022). Assessing the effect of climate change and financial development on agricultural production in ASEAN-4: The role of renewable energy, institutional quality, and human capital as moderators. *Environmental Science and Pollution Research*, 1-15. https://doi.org/10.1007/s11356-021-16670-9

Chandio, A., Jiang, Y., Rauf, A., Ahmad, F., Amin, W., & Shehzad, K. (2020). Assessment of formal credit and climate change impact on agricultural production in Pakistan: A time series ARDL modeling approach. *Sustainability*, *12*(13), 5241. https://doi.org/10.3390/su12135241

Chandio, A., Jiang, Y., Rehman, A., & Raud, A. (2019). Short and long-run impacts of climate change on agriculture: An empirical evidence from China. *International Journal of Climate Change Strategies and Management*, 12(2), 201-221. https://doi.org/10.1108/IJCCSM-05-2019-0026

Dait, J. (2022). Philippine agriculture: A cointegration and causality analysis. *Universal Journal of Agricultural Research, 10*(4), 405-416. https://doi.org/10.13189/ujar.2022.100410

Deschanes, O., & Kolstad, C. (2011). Economic impacts of climate change on California agriculture. *Climatic change*, *109*, 365-386. https://doi.org/10.1007/s10584-011-0322-3

Dietz, T., Shwom, R., & Whitely, C. (2020). Climate change and society. *Annual Review of Sociology*, *46*(1), 135-158. https://doi.org/10.1146/annurev-soc-121919-054614

Dumrul, Y., & Kılıçarslan, Z. (2017). Economic impacts of climate change on agriculture: empirical evidence from the ARDL approach for Turkiye. *Journal of Business, Economics and Finance, 6*(4), 336-347. https://doi.org/10.17261/Pressacademia.2017.766

El-Khalifa, Z., Zahran, H., & Ayoub, A. (2022). Climate change factors' impact on the Egyptian agricultural sector. *Asian Journal of Agriculture and Rural Development, 12*(3), 192-200. https://doi.org/10.55493/5005.v12i3.4600

Gershon, O., & Mbajekwe, C. (2020). Investigating the nexus of climate change and agricultural production in Nigeria. *International Journal of Energy Economics and Policy, 10*(6), 1-8. https://doi.org/10.32479/ijeep.9843

Ghosh, B., Eyasmin, F., & Adeleye, B. (2023). Climate change and agriculture nexus in Bangladesh: Evidence from ARDL and ECM techniques. *Plos Climate, 2*(7), e0000244. https://doi.org/10.1371/journal.pclm.0000244

Hossain, M., Arshad, M., Qian, L., Zhao, M., Mehmood, Y., & Kachele, H. (2019). Economic impact of climate change on crop farming in Bangladesh: An application of the Ricardian method. *Ecological Economics, 164*(2019). https://doi.org/10.1016/j.ecolecon.2019.106354

Houng, N., Nguyet, B., Hung, H., Duc, H., Chuong, N., Tri, D., & Hien, P. (2022). Economic impact of climate change on agriculture: A case of Vietnam. *AgBioForum*, *24*(1), 1-12.

Imran, A., Javed, Z., Shabbir, M., Waseem, L., & Naqvi, A. (2019). Climate Change and its impact on the agriculture sector in selected South Asian countries. *International Journal of Economic and Environmental Geology, 10*(4), 97-101.

Jatuporn, C., & Takeuchi, K. (2023). Assessing the impact of climate change on the agricultural economy in Thailand: an empirical study using panel data analysis. *Environmental Science and Pollution Research*, *30*(3), 8123-8132. https://doi.org/10.1007/s11356-022-22743-0

Jena, P. (2021). Nexus between Climate change and agricultural production in Odisha, India: An ARDL approach. *International Journal of Environment, Agriculture and Biotechnology, 6*(2), 136-145. https://dx.doi.org/10.22161/ijeab.62.15

Kweku, D., Bismark, O., Maxwell, A., Desmond, K., Danso, K., Oti-Mensah, E., Adormaa, B. (2017). Greenhouse effect: Greenhouse gases and their impact on global warming. *Journal of Scientific Research & Reports, 17*(6), 1-9. https://dx.doi.org/10.9734/JSRR/2017/39630

Malhi, G., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability*, *13*(3), 1318. https://doi.org/10.3390/su13031318

Molua, E. (2008). Turning up the heat on African agriculture: The impact of climate change on Cameroon's agriculture. *AgEcon Search, 2*(1), 45-66.

Nasrullah, M., Rizwanullah, M., Yu, X., Jo, H., Sohail, M. T., & Liang, L. (2021). An autoregressive distributed lag (ARDL) approach to study the impact of climate change and other factors on rice production in South Korea. Journal of water and climate change, 12(6), 2256-2270. https://doi.org/10.2166/wcc.2021.030

Ogundari, K., & Onyeaghala, R. (2021). The effects of climate change on African agricultural productivity growth revisited. *Environmental Science and Pollution Research*, *28*(23), 30035-30045. https://doi.org/10.1007/s11356-021-12684-5

Olajide, O., Akinlabi, B., & Tijan, A. (2012). Agriculture resource and economic growth in Nigeria. *European scientific journal, 8*(22),103-114.

Özdemir, D. (2022). The impact of climate change on agricultural productivity in Asian countries: a heterogeneous panel data approach. *Environmental Science and Pollution Research*, 8205-8217. https://doi.org/10.1007/s11356-021-16291-2

Özkurt, İ. C.(2024). İklim Değişikliğinin Türkiye'de Tarımsal Üretime Etkisi. KSÜ Tarım ve Doğa Derg 27(Ek Sayı 1), 263-275. https://doi.org/10.18016/ksutarimdoga.vi1394627

Özlü, H., Engürülü, B., Özbek, A., Aydın, A., & Özüstün Özer, A. (2022). İklim değişikliği ve tarım. Ankara: Türkiye Cumhuriyeti Tarım ve Ormancılık Bakanığı.

Pickson, R., He, G., Ntiamoah, E., & Li, C. (2020). Cereal production in the presence of climate change in China. *Environmental science and pollution research*, *27*, 45802-45813. https://doi.org/10.1007/s11356-020-10430-x

Praveen, B., Kumar, P., Baig, I., Bhardwaj, M., Singh, K., & Yadav, A. (2022). Impact of environmental degradation on agricultural efficiency in India: evidence from robust econometric models. *Journal of Bioeconomics*, *24*(3), 203-222. https://doi.org/10.1007/s10818-022-09327-1

Prentice, C., Vergunts, F., Minor, K., & Berry, H. (2024). Education outcomes in the era of global climate change. *Nature Climate Change, 14,* 214-224. https://doi.org/10.1038/s41558-024-01945-z

Rashid, M., Husnain, Z., Shakoor, U., & Husnain, M. (2020). Impact of climate change on cotton production in Pakistan: An ARDL bound testing approach. *Sarhad Journal of Agriculture, 36*(1), 333-341. http://dx.doi.org/10.17582/journal.sja/2020/36.1.333.341

Ren, X., He, J., & Huang, Z. (2023). Innovation, natural resources abundance, climate change, and green growth in agriculture. Resources Policy 85 (2023) 103970. https://doi.org/10.1016/j.resourpol.2023.103970

Rosyadi, R., Darma, S., & Darma, D. (2023). What drives the gross domestic product of agriculture? Lessons from Indonesia (2014-2021). *International Journal of Sustainable Development and Planning, 18*(3), 683-692. https://doi.org/10.18280/ijsdp.180304

Turhan, E., Mazlum, S., Şahin, Ü., Şorman , A., & Gündoğan, C. (2016). Beyond special circumstances: Climate change policy in Turkey 1992–2015. *WIREs Climate Change, 7,* 448-450. https://doi.org/10.1002/wcc.390

Warsame, A., Sheik-Ali, I., Ali, A., & Sarkodie, S. (2021). Climate change and crop production nexus in Somalia: an empirical evidence from the ARDL technique. *Environmental Science and Pollution Research*, *28*(16), 19838-19850. https://doi.org/10.1007/s11356-020-11739-3

Xiang, X., & Solaymani, S. (2022). Change in cereal production caused by climate change in Malaysia. *Ecological Informatics*, *70*, 101741. https://doi.org/10.1016/j.ecoinf.2022.101741

Zaied, Y., & Cheikh, N. (2015). Long-run versus short-run analysis of climate change impacts on agricultural crops. *Environmental Modeling & Assessment*, *20*, 259-271. https://doi.org/10.1007/s10666-014-94