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INVESTIGATION OF THE RELATIONSHIP BETWEEN THE USE OF SELECTED ENERGY TYPES AND AGRICULTURAL AREA UTILISED BY ARDL BOUND TEST: THE CASE OF TURKEY

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Abstract

The relationship between the types of energy used and farmland is a critical factor that has a profound impact on the productivity, sustainability and environmental impacts of modern agriculture. This relationship examines how agriculture's energy demand is met and the impacts of these processes on farming practices. This energy is provided from sources such as fossil fuels, electricity, solar energy and biomass. The size, geographical location and farming methods of agricultural land affect the types and amounts of energy used. Therefore, the relationship between energy consumption and agricultural land utilisation has important consequences both economically and environmentally. In this study, the effects of Hydroelectricity Use, Coal Use, Petroleum Use and Renewable Energy Use on Turkey's Agricultural Land Use are analysed by ARDL bounds test. According to the results obtained; there is a significant relationship between Coal Utilisation and Petroleum Utilisation and the dependent variable, Agricultural Areas Utilised. There is no significant relationship between Hydroelectricity Utilisation and Renewable Energy Utilisation and the dependent variable of Agricultural Areas Utilised.

Keywords: ARDL Boundary Test, Energy Use, Agricultural Areas

SEÇİLİ ENERJİ TÜRLERİNİN KULLANIMI İLE KULLANILAN TARIMSAL ALAN ARASINDAKİ İLİŞKİNİN ARDL SINIR TESTİ İLE İNCELENMESİ: TÜRKİYE ÖRNEĞİ

Öz

Kullanılan enerji türleri ile tarım arazileri arasındaki ilişki, modern tarımın verimliliği, sürdürülebilirliği ve çevresel etkileri üzerinde derin bir etkiye sahip olan kritik bir faktördür. Bu ilişki, tarımın enerji talebinin nasıl

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karşılandığını ve bu süreçlerin tarım uygulamaları üzerindeki etkilerini incelemektedir. Bu enerji fosil yakıtlar, elektrik, güneş enerjisi ve biyokütle gibi kaynaklardan sağlanmaktadır. Tarım arazilerinin büyüklüğü, coğrafi konumu ve tarım yöntemleri kullanılan enerji türlerini ve miktarlarını etkilemektedir. Bu nedenle, enerji tüketimi ve tarımsal arazi kullanımı arasındaki ilişkinin hem ekonomik hem de çevresel açıdan önemli sonuçları vardır. Bu çalışmada, Hidroelektrik Kullanımı, Kömür Kullanımı, Petrol Kullanımı ve Yenilenebilir Enerji Kullanımının Türkiye'nin Tarımsal Arazi Kullanımı üzerindeki etkileri ARDL sınır testi ile analiz edilmiştir. Elde edilen sonuçlara göre; Kömür Kullanımı ve Petrol Kullanımı ile bağımlı değişken olan Kullanılan Tarımsal Alanlar arasında anlamlı bir ilişki vardır. Hidroelektrik Kullanımı ve Yenilenebilir Enerji Kullanımı ile bağımlı değişken olan Kullanılan Tarımsal Alanlar arasında anlamlı bir ilişki yoktur.

Anahtar Kelimeler: ARDL Sınır Testi, Enerji Kullanımı, Tarımsal Alanlar

INTRODUCTION

Economic development is a critical issue for all countries, particularly those that are highly developed. The impact of development, which is a crucial aspect of progress, is felt across all societies. This issue has become widespread, affecting both socio-economic and socio-cultural factors. The growth and development of nations and societies is crucial in advancing the world and improving global well-being. Examining the historical trajectory of developed nations reveals that economic growth and advancement are essential. Environmental, social, cultural, and economic factors all play significant roles in driving economic development. One sector that holds a strategic position among these is agriculture. Agriculture is crucial for sustaining a nation's population, achieving economic growth, poverty reduction, and ensuring food security. The agricultural industry is a fundamental aspect of developed countries' welfare level, fulfilling human needs and providing raw materials for industrialization. On the other hand, developing countries consider the agricultural industry a vital component in achieving economic growth (Köseoğlu and Ünal, 2019). The need for advanced technology has emerged as old techniques have generated significant environmental concerns during energy production and consumption. The establishment of coal, oil, and natural gas power plants not only endangers specific regions but also poses a global threat to the environment. The burning of fossil fuels emits carbon dioxide, sulfur dioxide, nitrous oxide, and particulate matter into the atmosphere, causing environmental pollution and leading to deaths. Moreover, carbon dioxide and other greenhouse gases play a significant role in global climate change, endangering life in all nations worldwide (Altun and İşleyen, 2018).

According to a report published by the International Panel on Climate Change (IPCC), it is estimated that emissions from the agricultural sector can be reduced by up to 80 per cent by 2030. Converting natural animal manures into energy to replace non-renewable energy instead of artificial fertilisers used in the agricultural sector and using renewable energy in agricultural activities can reduce global warming. The demand for energy and natural resources is increasing day by day due to the increasing population and growing economy in Turkey. Looking at the reports of current energy data, it is seen that Turkey is an energy importer country and approximately 73% of its energy needs depend on these imports. In this context, Turkey is in serious need of renewable energy resources both to reduce external dependence to meet its energy needs and to reduce the environmental damage of fossil-based energy types such as oil, natural gas and coal (Okumuş, 2020).

Energy sources that can be used without harming nature are called renewable energy sources due to their structure. Increasing the availability of renewable energy resources reduces foreign dependency in energy needs. Especially in recent years, the demand for renewable energy resources has been increasing and governments have included renewable energy resources in their policies. Because renewable energy resources play a very important role in the energy policies of developing countries, both in terms of their impact on economic growth and in ensuring financial stability. At the same time, one of the biggest problems of developing countries is the problem of not providing enough employment for the growing population. The solution to this problem can be met with renewable energy. With the increase in renewable energy resources, it contributes to the activation of new production units. In this context, it leads to an increase in new employment areas (Ordu and Songur, 2023).

The risk of loss of agricultural land in the future is a complex and multifaceted issue influenced by various factors, including climate change, urbanization, land degradation, and socio-economic pressures. Here are key considerations related to the risk of agricultural land loss:

Climate Change:

Changes in climate patterns, including temperature increases, altered precipitation patterns, and extreme weather events, pose a significant threat to agricultural land. Shifts in climate can impact crop yields, alter growing seasons, and contribute to the spread of pests and diseases.

Land Degradation:

Soil erosion, salinization, deforestation, and other forms of land degradation can reduce the fertility and productivity of agricultural land. Unsustainable farming practices, improper land management, and overuse of water resources contribute to these issues.

Urbanization and Infrastructure Development:

The expansion of urban areas and infrastructure development often leads to the conversion of agricultural land into residential, commercial, or industrial zones. This urban encroachment can result in the loss of valuable farmland.

Population Growth and Food Demand:

The world's population is steadily growing, and with it, the demand for food is increasing. This puts pressure on agricultural land to produce more crops. Intensification of agriculture, however, can lead to soil degradation and may not be sustainable in the long term.

Water Scarcity:

Water scarcity is a critical factor affecting agricultural productivity. Competition for water resources among agriculture, industry, and urban areas can lead to reduced water availability for farming, impacting the suitability of land for cultivation.

Globalization and Land Grabbing:

The globalization of agricultural markets has led to international investments in land, sometimes referred to as "land grabbing." Large-scale acquisitions of agricultural land by foreign entities can displace local farmers and alter land use patterns.

Policy and Governance:

Inadequate land-use planning, weak land tenure systems, and poor governance can contribute to unsustainable land practices and the loss of agricultural land. Effective policies are crucial to address these issues and promote sustainable land management.

Technology and Sustainable Practices:

The adoption of advanced technologies and sustainable agricultural practices can mitigate the risk of land loss. Precision farming, agroecology, and conservation agriculture are examples of approaches that aim to maximize yields while minimizing environmental impact.

Biodiversity Loss:

Agricultural expansion and intensification can contribute to the loss of biodiversity, affecting ecosystems and the services they provide. This loss can have cascading effects on the resilience of agricultural systems.

Land Use Planning and Conservation Efforts:

Strategic land use planning and conservation efforts, such as protected areas and agroforestry initiatives, can help safeguard agricultural land from irreversible losses.

Addressing the risk of agricultural land loss requires a holistic approach that integrates sustainable agricultural practices, conservation efforts, and thoughtful land-use policies. Global cooperation and awareness are crucial to finding solutions to ensure food security and environmental sustainability in the face of evolving challenges.

In this study, it was aimed to examine the effects of the use of selected energy types (Hydroelectric, Coal, Petroleum, Renewable Energy) on agricultural areas.

LITERATURE REVIEW

Energy has become one of the basic needs of modern societies and has raised important issues such as efficient use of energy resources, sustainability and environmental impacts. Therefore, studies on the utilisation of energy types are of great importance in the fields of engineering aiming to increase energy efficiency, environmental sciences aiming to reduce environmental impacts, and economics and statistics for the use of indicators such as economic. Therefore, there is a large literature on the utilisation of energy types. The following review of some studies summarises this situation.

In their research, Koç and Kaya (2015) aimed to provide a comprehensive assessment of energy, energy resources, and renewable energy resources on a global scale, with a specific focus on Turkey. Within this framework, they scrutinized the energy consumption trends in both the world and Turkey for the years 2013-2014, along with the production-consumption dynamics of renewable energy resources in the world and Turkey from 2005 to 2014. Their findings revealed a notable increase in Turkey's solar energy installed capacity in recent years, reaching 58 MW by the conclusion of 2014.

Tatli and Barak (2017) conducted an empirical study analyzing the effects of coal and hydroelectricity consumption on industrial production in Turkey, using data from 1990 to 2014. In order to achieve this objective, they utilized Johansen co-integration and DOLS analysis methods. Through the co-integration tests, the results revealed a persistent correlation between coal consumption, hydroelectricity consumption, and industrial production. The DOLS findings demonstrate that both coal and hydroelectricity consumption play a role in the growth of industrial production.

Sağbaş and Başbuğ (2018) evaluated Turkey's outlook and potential on energy, investigated studies on energy efficiency and climate change, and in the light of this information, examined in depth the current and future status of energy efficiency in our country. Suggestions have been made for ensuring and increasing energy efficiency. ODEX is evaluated on a sectoral basis and the saving potentials of energy efficiency applications are presented comparatively.

The relationship between hydroelectric power consumption as a renewable energy source and CO_2 emissions in the US was examined by Kuşkaya and Bilgili (2020). The industrial production index (IPI), total energy consumption from fossil fuels, total energy consumption from nuclear power plants, total energy consumption from hydroelectric power plants, and total CO_2 emissions were all included as study variables. The Morlet wavelet coherence model was used as the analytical tool. After adjusting for TBiomass, TFossil, Nuclear, and IPI, the research showed that using hydroelectricity resulted in a decrease in CO_2 emissions between January and December of 2015.

In a research published in 2020, Okumuş examined the relationship between CO_2 emissions, openness to global trade, agricultural value added, urbanization rate, economic growth, and non-renewable/renewable energy use between 1968 and 2014. According to the study's analysis, the results confirm a long-term association between the factors. Furthermore, the study confirms the environmental Kuznets curve (EKC) hypothesis' existence in Turkey. The findings imply that trade liberalization, urbanization, agricultural value added, and non-renewable energy usage all contribute to short- and long-term increases in CO_2 emissions. On the other hand, while using renewable energy reduces carbon emissions temporarily, its long-term effects are not statistically significant.

In their study conducted in 2020, Demir and Görür analysed the relationship between economic growth and the types of energy used with panel data analysis. In the study, a positive relationship was found between economic growth and hydroelectric and renewable energy consumption, while a negative relationship was found between thermal energy consumption and economic growth.

Öymen and Ömeroğlu (2020) conducted a study to examine the impact of renewable energy on sustainability. The release of carbon compounds into the atmosphere, in addition to regional and local pollution, leads to the greenhouse effect and impacts the Earth's climate. Fossil fuel sources are responsible for global environmental issues including changes in weather patterns and acid rain. Awareness regarding the role of clean and renewable energy is steadily increasing, highlighting the significance of their utilization for resource sustainability. The study initially explains the concepts of renewable energy and sustainability, followed by in-depth interviews with 16 energy sector professionals in an attempt to reveal the vital role of renewable energy in promoting sustainability.

Eygü (2022) analyzed the correlation between gross domestic product per capita, capital, labor, and consumption of renewable energy sources (such as wind, hydroelectricity, biogas, solar, geothermal, and biomass energy) as well as waste resources from 1995 to 2020 using time series analysis. Based on the results of the Toda-Yamamoto causality test that analyzed the cointegrated series in this study, it is evident that there exists a unidirectional causality that runs from renewable energy consumption to growth. Thus, the study concludes that an increase in renewable energy consumption will lead to a positive impact on economic growth. In a similar study, Eygu and Soğukpınar (2023) investigated economic growth and energy consumption for Turkey with the Augmented ARDL method. Long-term estimation results suggest that among the energy sources examined in the study, economic growth has a positive effect coal consumption, natural gas consumption, and renewable energy. Using data from 1980 to 2018, Daştan and Eygü (2023) used the augmented autoregressive distributed lag (A-ARDL) model to investigate the effects of GDP and UNE on environmental performance in Turkey. Additionally, study variables REC, total NRR, FDI, FIN and URB were used.

In their study conducted in 2023, Demir et al. analysed the relationship between CO_2 emissions and the types of energy used with ARDL bounds test. In the study, it was observed that coal energy, natural gas energy and renewable energy consumption have a significant effect on CO_2 emissions.

Ateş et al. (2023) researched the relationship among net energy imports, the current account balance, and renewable energy to examine their impact on the Turkish economy. The study utilized ARDL bounds test and cointegration analysis based on the data set from 2016 to 2022. The analysis revealed a long and short-term correlation between the variables considered. Alternatively, renewable energy production has been found to have a causal relationship with current account balance and net energy imports. Furthermore, utilizing renewable energy resources can contribute to a stronger economic position for Turkey by reducing the current account deficit.

Using data from 1972 to 2021, Demir et al. (2023) used the ARDL Boundary test to investigate the effects of coal, natural gas, hydroelectricity, and renewable energy consumption on CO_2 emissions in Turkey. A Toda-Yamamoto test was used for the causality analysis. The analysis's findings show that, at a 5% significance level, the use of coal, natural gas, and renewable energy has no statistically significant impact ($p > 0.05$) on CO_2 emissions. Crucially, it is discovered that using renewable energy reduces CO_2 emissions whereas the other three factors cause emissions to rise. The causal analysis revealed a mutual correlation between natural gas and hydroelectricity, as well as between CO_2 and natural gas. Moreover, a uni-directional link was observed The shift has occurred from coal to natural gas and from hydroelectricity to coal. Nevertheless, renewable energy demonstrated no causal relationship with any of the variables.

In Özkan 2023 study conducted a study investigating the correlation between Turkish farmers' willingness and behavior to adopt Renewable Energy (RE) technologies on their farms. The study's objective was to determine the inclination of farmers to adopt RE technologies and their actual behavior in implementing them. The research specifically focused on agricultural and livestock enterprises situated in the South Marmara Region, particularly in Bursa, Balıkesir, and Çanakkale provinces. A survey was conducted in person with 400 participants, and the data collected were analyzed using version 28 of the SPSS statistical analysis software. To ensure the data's appropriateness for use, validity and reliability assessments were conducted. The analysis revealed that income from agricultural and non-agricultural activities, cultivated land extent, electricity and diesel oil expenses, government support, and access to relevant information all have a positive influence on the willingness to adopt renewable energy technologies. This holds true at a significance level of 5%.

MATERIAL AND METHOD

The study examines the impact of hydroelectricity utilization (HU), coal utilization (CU), petroleum utilization (PU), and renewable energy utilization (REU) on Turkey's agricultural area used (ALU) utilizing the ARDL bounds test. The analysis is based on data from the World Bank website spanning from 1973 to 2020. To apply the ARDL bounds test, we first examine the stationary nature of the series by conducting the Extended Dickey-Fuller (ADF) and Phillips Perron (PP) unit root tests, stationarizing the non-stationary series. Once the series becomes stationary, we test the ARDL model assumptions and choose the proper model using the AIC information criterion. After ensuring the assumptions were met, we proceeded to analyze the results obtained through ARDL and long-run cointegration tests using the appropriate model selected. We then investigated any potential structural breaks and examined the existence of short-run cointegration accordingly. The analyses were conducted using the Eviews 12 software package.

Stationarity in Time Series

When a time series is said to be stationar, it means that its variance, mean, and stationarity do not change over time due to the absence of a unit root. Static time series are dispersed around and gravitate toward the mean over extended periods of time. A stationary series may return to the mean when a one-unit transient shock is administered to it (Gujarati and Porter, 2009). According to Altun et al. (2018), spurious regression is a relationship that can be seen in non-stationary series and produce results that are not trustworthy. Several tests are used to find out if unit root is present. The stationarity of the series is assessed in this study using the Phillips-Perron (PP) and Augmented Dickey-Fuller (ADF) unit root tests.

Extended Dickey-Fuller Unit Root Test (ADF)

Since the unit root test developed by Dickey and Fuller (1979) did not consider the autocorrelation in the model error terms, Dickey and Fuller (1981) attempted to eliminate the autocorrelation issue in the unit root test by including the lagged terms of the dependent variable to the model. The 1979 test is referred to as DF, and the 1981 test is known as ADF since it is an enhanced version of the original test. Critical table values from DF were utilized in the ADF test to detect a unit root. Various measurement criteria can determine appropriate lag lengths, and this study employs the Akaike information criterion (AIC), which yields superior results in finite samples, to ascertain the suitable lag length.

Equations with AR(p) process are used to deal with autocorrelation. For the ADF test, the fixed model in equation (1) and the fixed + trended model in equation (2) are constructed by adding the $\beta_1 t$ parameters to the fixed model.

$$\Delta Y_t = \beta_0 + \theta\, Y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-i} + \varepsilon_t \tag{1}$$

$$\Delta Y_t = \beta_0 + \beta_1 t + \theta\, Y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-i} + \varepsilon_t \tag{2}$$

Here; the first difference of variables ΔY_t is denoted by the constant term β_0, trend t, appropriate lag length p, lagged difference trend Y_{t-1}, error term ε_t,, and relationship coefficients β_1, θ and α (Demir, 2021a). Hypothesis tests for ADF are constructed as follows.

H_0: *ρ =1 (Series is non-stationary)*

H_1: *ρ <1 (Series is stationary).*

Phillips and Perron (1988) introduced the Phillips Perron

Unit Root Test (PP) as a non-parametric test based on autoregressive-moving average processes (ARMA) to address autocorrelation among error terms. This test is a suitable alternative to the Dickey and Fuller unit root tests and is found to provide better results with respect to the stationarity of trended time series. Equations (3) and (4) depict the equations relevant to the Phillips Perron Unit Root Test.

$$y_t = \hat{\mu} + \hat{\alpha} y_{t-1} + \hat{\varepsilon}_t \tag{3}$$

$$y_t = \tilde{\mu} + \tilde{\beta}\left(t - \frac{1}{2}T\right) + \tilde{\alpha} y_{t-1} + \tilde{\varepsilon}_t \tag{4}$$

Where the coefficients for the regression model are μ, α, and β, T represents the number of observations, and ε denotes the error term. These two models do not undergo any changes in their t-statistic, coefficients, or data generation processes when a non-zero constant term is included. Thus, equation (5) utilizes these models instead.

$$y_t = \mu + \alpha y_{t-1} + \varepsilon_t \qquad t = 1,2, \dots n \tag{5}$$

Because this test follows the same restricted distribution as the DF test, the DF critical values are used, expressing the same assumptions as the ADF test (Demir, 2021b).

Cointegration Test

Time series analysis is essential to understanding economics and economic research. Cointegration analysis has become increasingly popular in recent years, particularly in examining the correlation among variables in economic time series. Cointegration refers to determining long-term relationships among variables with shared stochastic tendencies. Cointegration was first proposed by Granger (1981) and Engle and Granger (1987). Nowadays, it is commonly used in econometric analysis. Cointegration presupposes that variable movements are interconnected, hence not independent of each other (İşleyen et al., 2017). Nonetheless, cointegration analysis assumes that the time series are stationary. Due to the application of non-stationary time series analysis, the relationships between variables may be spurious instead of genuine (Demir, 2021b).

Autoregressive Model with Distributed Lags (ARDL) Border Test Approach

The ARDL method, which is derived from the ECM method, was proposed by Pesaran and Shin (1998) and Pesaran et al. (2001) to ascertain the presence of an autoregressive relationship between variables in a time series. ARDL focuses on variables that are cointegrated. Cointegration implies a long-term relationship between variables, even if they may exhibit short-term fluctuations. In other words, the variables move together in the long run, although they may diverge in the short run.

The basic ARDL model involves specifying a relationship between a dependent variable and one or more lagged values of itself (autoregressive terms) and lagged values of other variables in the system (distributed lag terms). The model captures both short-term and long-term relationships. The sequential and distributed lag models are frequently implemented regression analysis techniques for time series data. Sequence model includes one or more delayed values of dependent variable as independent variables, while distributed lag model includes delayed values of independent variables as well as their current values. Equation (6) displays the sequential model, and Equation (7) presents the distributed lag model (Demir, 2021b).

$$Y_t = \alpha + \beta X_t + yY_{t-1} + \varepsilon_t \quad (6)$$

$$Y_t = \alpha + \beta_0 X_t + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \varepsilon_t \quad (7)$$

The estimated long-term equilibrium deviation is used in the Engle-Granger analysis of the cointegration between two variables. It is advised to use the ARDL model to ascertain the cointegration relationship because failing to consider the lag values for the variables could result in specification mistakes (Sevüktekin and Çınar, 2017). Assuming the series are stationar, the ARDL limits test has several advantages, one of which is the capacity to determine the cointegration relationship between the series. Furthermore, the test successfully avoids the issues of serial correlation and endogeneity and yields reliable results with small sample sizes (Narayan, 2004 and Demir, 2021a).

The following hypotheses are formulated for the ARDL cointegration bounds test.

$H_0: y_1 = y_2 =\ldots= 0$, There is no cointegration relationship,

$H_1: y_1 \neq y_2 \neq\ldots\neq 0$, There is a cointegration relationship.

If the F statistic exceeds the upper bound of the critical value, then it indicates cointegration between the variables. Conversely, if the F statistic falls below the lower bound of the critical value, it suggests no cointegration between the variables. However, the F statistic that falls between the lower and upper bounds of the critical value fails to provide any insight into cointegration.

ANALAYSIS AND FINDINGS

The abbreviations of the variables used in the analysis are given in Table 1 below.

Table 1

Abbreviations	**Variables**
ALU	Agricultural Land Use (Dependent variable)
HU	Hydroelectricity Use
CU	Coal use
PU	Petroleum Use
REU	Renewable Energy Use

Before proceeding to the ARDL bounds test analysis, it is very important to determine the order of integration of the variables, generally expressed as I(d). In this context, if the series are non-stationary, differences are taken to make the series stationary. The order of integration reflects the number of differences needed to make the series stationary. Table 2 presents the results of the unit root tests of the variables according to the ADF and PP tests.

Table 2.

Unit Root Test Results

		I(0)				***I(1)***			
		Fixed		**Fixed+Trend**		**Fixed**		**Fixed+Trend**	
Test	***Variable***	**t-İst.**	**p-value**	**t-İst.**	**p-value**	**t-İst.**	**p-value**	**t-İst.**	**p-value**
ADF	ALU	-1.261	0.639	-1.112	0.915	-5.761	0.001	-5.833	0.001
	HU	-2.391	0.149	-3.907	0.083	-8.306	0.001	-8.326	0.001
	CU	-2.934	0.041	-6.704	0.037				
	PU	-1.750	0.399	-1.208	0.895	-5.211	0.001	-5.660	0.001
	REU	-0.456	0.890	-1.671	0.746	-8.112	0.001	-8.628	0.001
PP	ALU	-1.407	0.570	-1.262	0.885	-5.775	0.001	-5.814	0.001
	HU	-2.279	0.182	-3.763	0.124	-9.011	0.001	-9.063	0.001
	CU	-2.945	0.038	-7.402	0.031				
	PU	-1.658	0.432	-2.381	0.351	-4.658	0.001	-3.902	0.019
	REU	0.139	0.965	-1.219	0.894	-8.417	0.001	-13.653	0.001

$p<0.05$

Examining Table 2, the Fixed and Fixed+Trend variables have undergone ADF and PP unit root tests. It is evident from the table that the CU variable is stationary at the level, as indicated by both ADF and PP unit root tests ($p<0.05$). In contrast, the other variables at the level exhibit non-stationarity, implying the presence of a unit root ($p>0.05$). To deal with this, the ALU, HU, PU, and REU variables were differenced (I(1)) to make them stationary. When the variables do not exhibit stationarity at the same level, ARDL is a suitable approach for identifying cointegration among them. For this particular study, a maximum of four lags was considered. We used the Akaike information criterion (AIC) to determine the most appropriate model within the ARDL framework. Based on the AIC information criterion, the optimal model was found to be ARDL (2, 0, 0, 0, 2, 0). Further details on the assumptions for ARDL are provided in Table 3.

Table 3.

Diagnostic Test Results for the ARDL (2, 0, 0, 0, 2, 0) Model

Diagnostic Tests	*Test Statistics*	*p*
R^2	0.729	
Adjusted R^2	0.673	
F- İstatistik	19.073	0.001
Breush-Godfrey LM Test	0.363	0.833
Breusch-Pagan-Godfrey Test	2.599	0.761
Jargue-Bera Normality Test	1.425	0.490
Ramsey-Reset Test	0.005	0.939

When Table 3 is analyzed, the R^2 value, which determines the explanatory power of the independent variables for the dependent variable, is determined as 0.729. In this case, it can be interpreted that the independent variables explain 73% of the dependent variable ALU. It can be said that this rate is high. The significance of the model is determined by the F-statistic and the ARDL (2, 0, 0, 0, 2, 0) model is significant ($p<0.05$). The presence of autocorrelation problem was tested by Breusch-Godfrey LM test and it was observed that there was no autocorrelation problem ($p>0.05$). Breusch-Pagan-Godfrey test was used to examine the problem of changing variance and no such problem was found ($p>0.05$). The Jargue-Bera normality test was used to examine whether the errors were normally distributed and the existence of a normal distribution was determined ($p>0.05$). The Ramsey-RESET test was used to test for the presence of model fitting error and no such error was found ($p>0.05$).

In regression analysis, the Variance Inflation Factor (VIF) serves as a statistical measure to primarily assess the degree of multicollinearity. Multicollinearity happens when two or more independent variables are correlated with each other, which further complicates their respective effects on the dependent variable. Hence, VIF delves into the rise of regression coefficients in an analysis arising from multicollinearity. In a regression model, if the independent variables are correlated, it causes the problem of multicollinearity to occur. The existence of this problem can be detected by VIF. If VIF values are greater than 10, the existence of such a problem can be mentioned. The multicollinearity problem is given in Table 4 below.

Table 4.

Multiple Linear Correlation Problem

	HU(VIF)	*CU (VIF)*	*PU(VIF)*	*REU (VIF)*
0	1.863	1.322	1.619	1.019
-1			1.549	
-2			1.247	

Upon analyzing Table 4, it is evident that the VIF values of all independent variables are less than 10, indicating that there is no issue of multicollinearity.

To test for cointegration, the F-statistic test in Table 5 is employed. The table also provides the lower and upper bounds for each variable at the 1%, 5%, and 10% significance levels.

Table 5.

ARDL Cointegration Border Test

Number of Independent Variables (k)	*F-statistic*	*Significance Level*	*Critical Values*	
			Lower Limit	*Upper Limit*
		%1	4.306	5.874
4	9.164	%5	3.136	4.416
		%10	4.306	5.874

It can be seen that the F-statistic value (9.164) exceeds the lower and upper limits of all independent variables when analyzing Table 5 at the 5% significance level. Therefore, it can be concluded that there is cointegration between the dependent variable and the independent variables.

After establishing cointegration, long-run ARDL cointegration outcomes are presented in Table 6.

Table 6.

Long Run ARDL Cointegration Results

Variable	*Coefficients*	*Standard Error*	*t*	*p*
Fixed	-1.301	0.560	-2.322	0.025*
HU	-0.009	0.016	-0.557	0.580
CU	0.040	0.018	2.194	0.034*
PU	-0.060	0.044	-1.340	0.047*
REU	0.010	0.102	0.103	0.918

Once the data are appropriately differenced, the ARDL model can be estimated using standard econometric techniques such as ordinary least squares (OLS). The estimation process involves finding coefficients for the lagged values of the variables to represent their short-term and long-term effects. According to Table 6, there is a significant relationship between CU and PU and the dependent variable ALU ($p<0.05$). In this case, it is concluded that a change in CU leads to an increase of 0.04 in ALU, while a change in PU leads to a decrease of 0.06 in ALU.

Cumulative Sum (CUSUM) plots are a graphical tool used in econometrics and time series analysis, including the analysis of Autoregressive Distributed Lag (ARDL) models. CUSUM plots are particularly helpful in detecting structural breaks or shifts in the relationships between variables over time. CUSUM plots are used to monitor the cumulative sum of the differences between observed values and expected values in a time series. In the context of ARDL models, CUSUM plots help identify periods where the relationships between variables might have changed, indicating the presence of structural breaks. In ARDL analysis, CUSUM plots can be applied to assess the stability of the estimated coefficients over time. If the CUSUM plot shows a consistent pattern or a clear deviation from the expected stability, it suggests the need for further investigation into potential structural breaks. In order to test for structural breaks in the variables, CUSUM and CUSUMQ plots were constructed using the squares of the reversible error terms and the stability of the ARDL model was analyzed with the help of these plots.

Figure 1.

CUSUM and CUSUMQ Plot for Structural Fracture

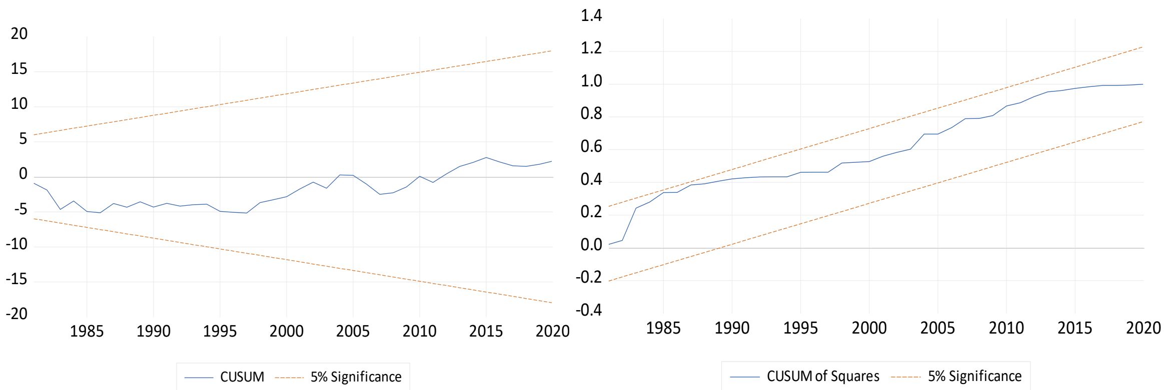

Figure 1 is a significant indicator that the ARDL model is stable, confirming that the model coefficients remain stable. Figure 1's analysis reveals that the variables fall within critical boundaries with a 5% significance level and don't deviate from them. These findings confirm a lack of structural disruption between the variables, and the long-run coefficients remain stable.

The error correction coefficient is represented by the term CointEq(-1) and for this coefficient to be statistically significant, it must have a negative value between 0 and 1, which is also stated in the literature (Polat and Gemici, 2017).

Table 7 presents the results of the short-run cointegration analysis and also identifies the presence of an error correction term.

Table 7.

ARDL (2, 0, 0, 0, 2, 0) Short Run Cointegration Results and Error Correction Term

Variable	*Coefficients*	*Standard Error*	*t-statistics*	*p*
CointEq(-1)*	-0.924	0.135	-7.099	0.001
Fixed	-0.072	0.271	-5.697	0.001
ALU	0.219	0.305	3.483	0.090
ALU (-1)	0.103	0.140	2.963	0.071
HU	-0.013	0.043	0.384	0.087
CU	0.021	0.036	4.352	0.001
PU	-0.019	0.017	3.183	0.007
PU(-1)	-0.013	0.011	5.173	0.001
REU	0.142	0.108	0.307	0.640
R^2	0.693			
Adjusted R^2	0.637			
Test	Statistic Value	Significance Level	Lower limit	Upper Limit
F-Test	6.438	%5	3.75	5.012

According to Table 7, the error correction term is -0.924, which is statistically significant. This indicates that a long-run deviation between the variables shows a correction of approximately 92% in the subsequent period. In other words, it can be predicted that short-term deviations that may occur for ALU may tend to rebalance in the long run by approaching the equilibrium point. Since the value of the F statistic (6.438) is above the upper bound of the critical value (5.012) at the 5% significance level, this result indicates that cointegration exists in the short run. Although the R^2 and adjusted R^2 values calculated in the short run are lower than the long run values, it is concluded that the independent variables are still effective in explaining the dependent variable.

DISCUSSION AND CONCLUSION

The relationship between agricultural areas and the types of energy used is complex and multifaceted. Agriculture meets a large share of energy requirements. This energy is used for tractors, irrigation systems, fertilizer production, harvesting machinery and other agricultural operations. Various energy sources such as fossil fuels, electricity, solar energy and biomass are used in the growing, processing and transportation of agricultural products. At the same time, the size of agricultural areas and crop diversity affect energy consumption. While industrial farming practices are common on large farms, small family farms can use more sustainable and energy efficient methods. Therefore, agriculture's energy consumption and energy types are an important factor affecting both agricultural productivity and environmental sustainability. In this context, increased use of renewable energy sources and improved energy efficiency in the agricultural sector can both reduce energy costs and minimize environmental impacts.

Agriculture's energy consumption also greatly affects environmental impacts. For example, intensive use of fossil fuels can increase greenhouse gas emissions and lead to environmental problems. Therefore, reducing energy consumption in the agriculture sector and switching to cleaner energy sources plays an important role in combating climate change. However, there can also be a mutually beneficial relationship between agricultural areas and energy production. For example, agricultural waste and crops can be used to produce biomass energy. In addition, renewable energy sources such as solar panels and wind turbines can be used on agricultural land to generate additional sources of income. Consequently, the relationship between agricultural land and the types of energy used is a complex issue that affects both the productivity of agriculture and environmental sustainability. Therefore, careful planning and management are required to optimize energy consumption and minimize environmental impacts in the agricultural sector.

Energy Use in Agriculture:

Agriculture is a significant consumer of energy, and the types of energy used in this sector vary widely. Common energy sources in agriculture include fossil fuels (such as diesel for machinery), electricity, and, in some cases, renewable energy sources.

Fossil Fuel Dependency:

Historically, agriculture has been heavily dependent on fossil fuels for various activities such as plowing, planting, harvesting, and transportation. The use of tractors, combines, and other machinery contributes to this dependency.

Renewable Energy in Agriculture:

There is an increasing interest in integrating renewable energy sources into agriculture. Solar panels, wind turbines, and bioenergy systems are being explored as alternatives to traditional fossil fuel-based energy sources. These can help reduce greenhouse gas emissions and make agriculture more sustainable.

Energy Efficiency Measures:

Research focuses on improving energy efficiency in agricultural practices. This includes the development of energy-efficient machinery, precision agriculture technologies, and the optimization of irrigation systems to reduce energy consumption.

Environmental Impact:

The environmental impact of energy use in agriculture is a crucial aspect of research. Scientists and policymakers are exploring ways to minimize the carbon footprint of agricultural activities, including the adoption of cleaner energy sources.

Government Policies and Incentives:

Government policies and incentives play a significant role in shaping the energy landscape in agriculture. Subsidies, tax credits, and regulations can influence the adoption of renewable energy technologies in the agricultural sector.

Challenges and Opportunities:

Challenges associated with the transition to cleaner energy in agriculture include initial investment costs, technological barriers, and the need for education and awareness. However, there are also significant opportunities for economic and environmental benefits.

In this study, the effects of the HU, CU, PU and REU on Turkey's ALU are analyzed using the ARDL bounds test. According to the findings obtained, it can be said that there is a significant relationship between the dependent variable ALU and the dependent variables of CU and PU ($p<0.05$). On the other hand, there is no significant relationship between the dependent variable ALU and the independent variables HU and REU ($p>0.05$). In this case, it is concluded that the change in CU causes an increase of 0.04 in ALU, while the change in PU causes a decrease of 0.06 in ALU. A review of the literature reveals that the studies conducted in Turkey generally examine the relationship between energy use and economic growth with different methods or examine the relationship between CO_2 use and energy types. Therefore, we believe that the relationship between the types of energy used and the agricultural areas used will also contribute to the literature. In this case, we think that this study will contribute to the literature in this respect.

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