A dynamic analysis on the load capacity curve of forests in Türkiye

Forestry
Economics
Review

Pınar Karahan-Dursun
Department of Economics and Finance, Mudanya University, Bursa, Turkey, and
Şerif Canbay
Department of Economics, Duzce Universitesi, Duzce, Turkey

Received 3 January 2026
Revised 19 April 2026
Accepted 23 June 2026

Abstract

Purpose – Forests are essential for maintaining ecological balance, preserving biodiversity and mitigating climate change. The study aims to test the validity of the Load Capacity Curve (LCC) hypothesis, which suggests a U-shaped relationship between economic growth and environmental load capacity, in the context of Türkiye's forest ecosystems. The study also examines the effects of tourism and energy consumption on forest environmental quality.

Design/methodology/approach – The study area is Türkiye, which has diverse forest ecosystems across various climatic and geographical regions. The study employs the Bound test, the Autoregressive Distributed Lag (ARDL) model and the Kalman filter technique for the period 1974–2022. The forest load capacity (FLC) is measured by the ratio of forest biocapacity (FB) to forest footprint (FF).

Findings – The ARDL model results show that economic growth initially reduces FLC, but beyond a certain turning point, the relationship is reversed. This confirms the LCC hypothesis in both the short and long run. Furthermore, tourism positively impacts forest sustainability, whereas energy consumption negatively affects it. The Kalman filter analysis reveals dynamic patterns, indicating that the negative impact of economic growth on forests has intensified over the last two decades. Meanwhile, the positive influence of tourism has weakened in the past ten years.

Research limitations/implications – The results emphasize the growing pressure of economic expansion on forest ecosystems and provide important findings regarding policies to be implemented to ensure the environmental quality of forests in Türkiye.

Originality/value – This study contributes to the existing literature in three areas. Firstly, we observed that this is the first study to examine the LCC hypothesis for forests for Türkiye. Although the LCC hypothesis has been investigated for Türkiye, this study differs from the existing literature in terms of its specific focus. Secondly, the forest LCC hypothesis is analyzed by including tourism and energy consumption variables in the analysis. Despite the importance of the issue, there are very few studies on the environmental impact of tourism in Türkiye. Thirdly, the non-linear relationship between FLC and economic growth is tested by using the Kalman filter technique, which is a time-varying parameter method. In this study, the environmental quality of forests is analyzed dynamically during the sample period.

Keywords Forests, Environmental sustainability, Load capacity curve, Economic growth, Tourism

Paper type Research article

Introduction

One of the problems directly related to environmental pollution and climate change is deforestation. Forests worldwide are currently facing several threats due to rapidly advancing climate change (Bärmann *et al.*, 2025). In addition, forests have undergone major human-induced changes and today 75% of the world's forests have been modified by humans (FAO, 2020; Astigarraga *et al.*, 2025). Activities such as energy production, urbanization and expansion of agricultural areas, which accelerated with the industrial revolution, have not only increased atmospheric pollution, but also caused the rapid destruction of forested areas.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Forestry Economics Review
Emerald Publishing Limited
2631-3030
DOI 10.1108/FER-01-2026-0001

This process has further exacerbated climate change by leading to a decrease in carbon sinks. Forests contribute to maintaining the global climate balance by reducing greenhouse gas emissions thanks to their carbon storage capacity (FAO, 2020). They also provide multifaceted ecosystem services such as erosion control by regulating the water cycle, maintaining soil fertility and supporting biodiversity (MEA, 2005). Lambin and Meyfroidt (2011) state that economic globalization has accelerated deforestation processes and made environmental sustainability efforts more complex.

Deforestation, land use changes and biodiversity loss have increased pressures on climate change. Foley *et al.* (2011) state that land use changes increase forest loss, and this leads to biodiversity loss. Hansen *et al.* (2013) show that rapid deforestation in tropical regions is caused by human activities and that this affects global climate systems. Deforestation triggers climate instability and soil erosion as well as the reduction of carbon sink capacities (MEA, 2005; Bonan, 2008).

In recent years, there has been an increase in the number of studies showing that the carrying capacity of forests under increasing pressure from economic activities and tourism is under threat (Sun *et al.*, 2020; Kocak and Cavusoglu, 2024). In particular, the impact of tourism on forest areas contributes to economic growth on the one hand and increases environmental pressure on the other. Buckley (2012) emphasizes the impacts of sustainable tourism on forest ecosystems, while Gössling and Hall (2006) elaborate on the contribution of tourism to global environmental changes. Furthermore, Lindberg *et al.* (1996) discuss the pressures of ecotourism on forest areas, while Eagles *et al.* (2002) emphasize the importance of sustainable tourism management in protected areas.

In this context, the protection of Türkiye's forest assets and natural resources is of particular importance in terms of the environmental impacts of tourism. According to the Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Forestry report, approximately 29.8% of Türkiye's total surface area consists of forest areas and this ratio has increased in recent years. From 20.2 million hectares in 1973, the forest area reached 23.1 million hectares by 2023. This increase has been realized thanks to intensive afforestation efforts and forest protection policies. However, natural disasters also pose a serious threat to forest ecosystems. For example, 139,503 hectares of forest areas were damaged in fires in 2021. However, thanks to the measures taken in 2023, the areas affected by fires were significantly reduced (GDF, 2025). Following this structural framework, Figure 1 illustrates the evolution of the forest footprint (FF) over the period 1974–2022. The figure reveals a fluctuating but overall increasing trend, particularly becoming more pronounced after the early 2000s. While relatively lower and stable levels are observed during the 1980s and early 1990s, a notable increase emerges in the subsequent period. This indicates that although forest areas

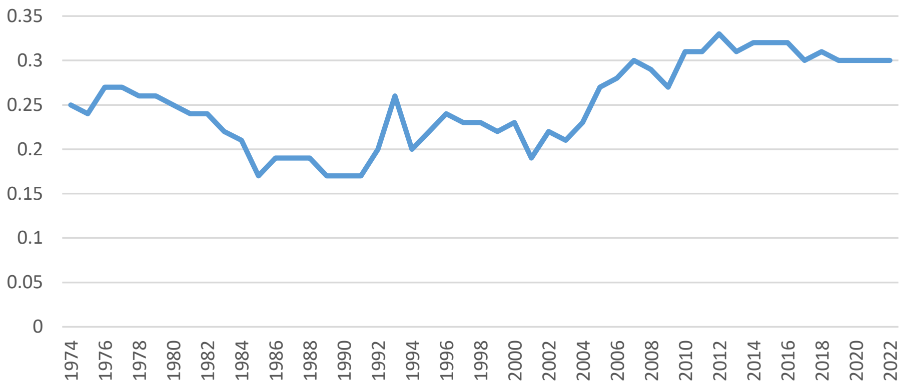

Figure 1. Forest footprint in Türkiye. *Source*: Global footprint network

have expanded through afforestation policies, the demand pressure on forest resources has also increased over time.

The conservation and sustainable management of forests in Türkiye is also closely linked to economic growth and the development of the tourism sector. The impact of tourism activities on forest ecosystems and balancing this impact with environmental sustainability is a critical problem for developing countries. Especially in developing countries with rich ecosystems such as Türkiye, ensuring the balance between economic growth and the protection of natural resources is of great importance in terms of sustainable development goals. Türkiye's economy has recorded significant growth in recent years, displaying a remarkable performance on a global scale. By 2023, according to the International Monetary Fund (IMF), Türkiye's Gross Domestic Product (GDP) reached $1.024 trillion, making it the 17th largest economy in the world. One of the important driving forces of this economic growth has been the tourism sector. According to 2024 data, Türkiye's tourism sector exhibited a strong growth. Compared to the previous year, tourism revenue increased by 8.3% to USD 61.1 billion, while the number of visitors increased by 9% to 62.2 million people (TurkStat, 2025). As of 2023, Türkiye ranked 5th in the world in terms of the number of tourists and 7th in terms of tourism revenues. The tourism sector plays a critical role with its direct and indirect contributions to the national economy. The sector directly and indirectly creates over 2 million jobs in Türkiye and contributes USD 60 billion in GDP. It also played an important role in improving the foreign trade balance by making a net contribution of USD 41.6 billion to the current account deficit of USD 45 billion in 2023 (TTYD, 2025).

The Load Capacity Curve (LCC) hypothesis, one of the important theoretical approaches of environmental economics, states that there is a U-shaped relationship between economic growth and the load capacity factor (the ratio of biocapacity to footprint) of the environment. The aim of this study is to investigate the validity of the LCC hypothesis for forests in Türkiye over the period 1974–2022. This study contributes to the existing literature in three areas. Firstly, we observed that this is the first study to examine the LCC hypothesis for forests for Türkiye. Although the LCC hypothesis has been investigated for Türkiye, this study differs from the existing literature in terms of its specific focus. Secondly, the forest LCC hypothesis is analyzed by including tourism and energy consumption variables in the analysis. Despite the importance of the issue, there are very few studies on the environmental impact of tourism in Türkiye. Thirdly, the non-linear relationship between FLC and economic growth is tested by using the Kalman filter technique, which is a time-varying parameter (TVP) method. In this study, the environmental quality of forests is analyzed dynamically during the sample period.

The LCC hypothesis provides an important analytical framework for environmental sustainability. Hakkak *et al.* (2023) confirmed the validity of the LCC hypothesis in Russia and identified a U-shaped relationship between economic growth and the LCF. Yang *et al.* (2023) found that the LCC hypothesis is valid in BRICS countries. Hossain *et al.* (2024) confirmed the LCC by finding a U-shaped relationship between income and load capacity factor in the Nordic Region. Javed *et al.* (2024) showed that green investments and environmental policies in G-7 countries support the LCC hypothesis by increasing freight capacity. Shahbaz *et al.* (2024), on the other hand, showed that the LCC hypothesis is valid in the analysis conducted with the A-ARDL method in the Netherlands. In Türkiye, Daştan (2024) found that renewable energy use and human capital confirmed the LCC hypothesis in the short and long run by increasing ecological welfare.

Some studies have revealed that the LCC hypothesis is not valid under certain conditions. Pata and Tanrıöver (2023) found that financial development decreases environmental quality in the most popular tourism destinations, but tourism does not support the LCC hypothesis by increasing environmental quality. Aydın and Değirmenci (2024) examined the impact of clean energy, green innovation and technological diffusion in EU countries and found that LCC is not generally valid, but it is supported in countries such as Denmark, France, Portugal and Spain. In the analysis conducted by Shahzad *et al.* (2024) using data from G20 countries for the period 2000–2020, it was found that the LCC hypothesis is not valid. The study conducted by Tiwari *et al.* (2024) on India does not support the validity of the LCC hypothesis.

In the case of Türkiye, Pata and Balsalobre-Lorente (2022) found that tourism, energy consumption and economic growth reduce the load capacity factor in the long run and that the LCC hypothesis is not valid. These findings show that the LCC varies depending on country groups and the characteristics of economic structures and may not be sufficient to explain environmental sustainability in all cases. Altıntaş *et al.* (2024) validate the LCC hypothesis in both in the long- and the short-run in Malaysia. Their analysis also reveals that banking sector development positively affects LCC while renewable energy consumption has a negative impact on environmental sustainability.

In some studies, the validity of the LCC hypothesis varies according to country, sector and environmental indicators. Bekun *et al.* (2024) stated that LCC is not valid in MINT economies, but renewable energy increases environmental sustainability. Feng *et al.* (2024) found a U-shaped relationship between economic growth and load capacity factor in E-7 countries and showed that growth negatively affects environmental quality in the first stage but improves it after a certain threshold. In addition, it is determined that the use of renewable energy improves environmental quality, but the environmental impacts of technological innovations are negative. The study by Altıntaş *et al.* (2025) examines the LCC hypothesis using data from the Middle East, North Africa and Türkiye (MENAT) region for the period 1984–2018. The analysis reveals an inverted U-shaped relationship in Egypt and Iraq, whereas a U-shaped relationship is observed in Morocco. These findings indicate that the LCC hypothesis is valid for Morocco, while it is not supported in the cases of Egypt and Iraq.

In general, the validity of the LCC hypothesis varies according to country groups and economic structure and has limited explanatory power in some regions. These findings show that LCC alone is not sufficient in environmental sustainability analyses and should be considered together with different factors.

Although the tourism sector is recognized as an important driver of economic growth, it also causes environmental problems such as depletion of natural resources, deforestation and increased carbon emissions. Tourism may influence forest load capacity (FLC) through multiple and potentially opposing mechanisms. On the one hand, the expansion of tourism activities can exert significant pressure on forest ecosystems through land-use change, infrastructure development and increased demand for natural resources. In particular, the conversion of forest lands into tourism facilities, transportation networks and recreational areas may lead to habitat fragmentation and ecosystem degradation (Gössling, 2002; Davenport and Davenport, 2006). In addition, tourism-related activities increase energy and water consumption, waste generation and environmental stress, which may intensify the FF and reduce the regenerative capacity of forest ecosystems (Gössling *et al.*, 2012). On the other hand, tourism can also contribute positively to environmental sustainability when managed effectively. Revenues generated from tourism can support conservation financing, protected area management and ecotourism practices, thereby enhancing the preservation of forest ecosystem services (Eagles *et al.*, 2002; Balmford *et al.*, 2009). Therefore, the relationship between tourism and FLC is theoretically ambiguous, as tourism may either increase environmental pressure or promote conservation depending on its scale, structure and management.

In this context, the LCC hypothesis provides an important theoretical framework for assessing the environmental impacts of tourism. In the literature, there has been a recent increase in the number of studies analyzing the environmental impacts of tourism activities in different methods and contexts. Akadiri *et al.* (2019), one of the researchers focusing on the effects of tourism activities on the environment, stated that tourism increases carbon emissions in the context of globalization and energy consumption and that the ecological footprint expands in intensive tourism regions. Similarly, Gao *et al.* (2021), focusing on the Mediterranean region, revealed that tourism activities increase CO_2 emissions through energy consumption and cause regional ecological degradation. Mikayilov *et al.* (2019) examined the long-term impacts of tourism on ecological footprint in the context of Azerbaijan. The research findings showed that although tourism activities increase the ecological footprint, urbanization and management quality do not play a significant role in environmental impacts. In line with these results, it is determined that the EKC hypothesis is not valid in Azerbaijan. In another study, Lee and Chen (2021) examined the impact of tourism revenues on ecological footprint over the period 1992–2016 with a panel data analysis covering 123 countries. In the study, different ecological footprint components (forest area, grasslands, carbon emissions, agricultural land, fishing grounds) were considered and it was determined that tourism revenues increase the ecological footprint. It was also found that the EKC hypothesis is valid in upper-middle income countries.

For the United Arab Emirates, Majumdar and Paris (2022) investigated the environmental impact of tourism and found that the EKC hypothesis is valid. The study highlighted that tourism activities increase carbon emissions through energy intensive sectors (transport, hotels, shopping malls). Similarly, Porto *et al.* (2023), in their study of 69 countries, found that tourism activities increase environmental pressure by increasing carbon emissions. The study found that the tourism-induced EKC hypothesis is valid in the Americas and Asia-Oceania regions, but not in Europe. Rahman *et al.* (2022), in a panel cointegration and CS-ARDL model analysis of the top ten tourist destinations, found that tourism confirms the EKC hypothesis by increasing carbon emissions in the long run.

In the recent literature, Magazzino *et al.* (2023) tested the environmental impact of tourism in post-Brexit European Union (EU) countries. In the analysis for the period 1998–2019, it was determined that tourism reduces carbon emissions in the long run, but economic growth increases emissions. Şeker and Avşar (2023) examined the relationship between tourism and ecological footprint with ARDL bounds test using data for the period 1975–2018 in Türkiye. The study found an N-shaped relationship between the number of international tourists and the ecological footprint in the short and long run, suggesting that the classical inverted-U-shaped EKC hypothesis is not valid for Türkiye. Similarly, Pata and Tanrıöver (2023) tested the LCC hypothesis for the period 1990–2022 in Türkiye. The study searched the relationships between tourism, financial development and environmental quality using ARDL bounds test and Fourier ARDL method. The findings revealed that tourism activities have an increasing effect on environmental quality, but financial development has a negative impact on environmental sustainability. Voumik *et al.* (2023) determined that tourism plays an important role in reducing carbon emissions in 10 tourism destinations in the Middle East. They emphasized that the use of ecotourism and renewable energy with the AMG method increases environmental sustainability. Shahzad *et al.* (2024) identified significant effects of tourism mobility on the load capacity factor in their study on G20 countries. Mahadevan and Suardi (2024) examined the tourism-induced EKC hypothesis using a panel fixed effects model covering 117 countries. The study indicated that tourism has an inverted U-shaped relationship with carbon emissions and ecological footprint in developed countries, whereas there is a U-shaped relationship in developing countries. Tiwari *et al.* (2024) found that tourism mobility in India contributes to economic growth while simultaneously leading to environmental degradation. Finally, Ngo *et al.* (2024) investigated the impact of aviation-based tourism on carbon emissions in the case of New Zealand. The study revealed that in the short run, tourism growth reduces air transport carbon emissions, but in the long run, carbon emissions increase with economic growth. The long-term results show that the EKC hypothesis is valid and that there is an improvement in environmental quality. Overall, the findings reveal that the environmental impacts of tourism vary in different contexts.

Furthermore, Radulescu *et al.* (2024) examine the dynamic effects of resource productivity and green technologies on renewable energy consumption in 28 middle-income countries over the period 2006–2022 using MMQR, QR and causality approaches. The findings indicate that green technological innovation significantly increases renewable energy use, while resource productivity promotes renewable energy consumption particularly at higher quantiles by decoupling economic growth from natural resource use. Aydin *et al.* (2024) tested the EKC hypothesis for Finland over the period 1970–2018 using the FF and found that economic growth initially increases environmental degradation but reduces it after a certain threshold.

Additionally, biomass energy consumption and forest product trade were found to have no significant long-run effects. Cutçu and Radulescu (2025) analyze the determinants of the cropland footprint for the top 10 agricultural countries over the period 1991–2021 using the MMQR approach. The findings indicate that arable land has a positive and significant effect on the cropland footprint, particularly at medium and high levels, while GDP per capita increases environmental pressure across almost all quantiles. Additionally, urbanization, temperature and agricultural employment are found to have no statistically significant impact.

Material and methods

This study aims to analyze the validity of the LCC hypothesis for forest area in Türkiye. For this purpose, we use the Bound test, ARDL (Autoregressive Distributed Lag) model and Kalman filter technique covering the period from 1974 to 2022. The study also investigates the effects of tourism income and energy consumption on FLC. The estimated model of this study is presented in Equation 1.

$$\mathrm{LFLC_t} = \alpha_0 + \beta_1 \mathrm{LY_t} + \beta_2 \mathrm{LY_t^2} + \beta_3 \mathrm{LTI_t} + \beta_4 \mathrm{LEC_t} + \varepsilon_t \qquad \text{(Eq. 1)}$$

FLC refers to forest sustainability measured as FB divided by FF. If the value of FLC is above 1, it indicates sustainability, whereas a value below 1 indicates non-sustainability (Ayad *et al.*, 2024). L, Y, Y^2, TI and EC represent natural logarithm, real GDP per capita (constant 2015 USD), the square of real GDP per capita, tourism income (% of GDP) and primary energy consumption. α_0 is the constant term, and β_1, β_2, β_3 and β_4 are the long-term coefficients. The FLC curve suggests the U-shaped relationship between FLC and economic growth, and this relationship is confirmed if $\beta_1 < 0$, and $\beta_2 > 0$.

FLC (FB/FF) is obtained from the Global Footprint Network (GFN, 2025) database. Real GDP per capita is derived from the World Bank database (2025). Tourism income as percentage of GDP is extracted from Turkish Statistical Institute (2025) and World Bank database (2025). Finally, energy consumption is obtained from the British Petroleum (BP, 2025) Statistical Review of World Energy. Table 1 presents the definitions, measurement units and data sources of the variables used in the empirical analysis, while Table 2 reports the summary statistics of these variables.

Table 1. Description of the variables

Variable	Abbreviation	Measurement unit	Source
Forest load capacity	FLC	Ratio of forest biocapacity to forest footprint	Global Footprint Network
Economic growth	GDP	Constant 2015 US$ per capita	World Bank
Tourism income	TI	% of GDP	Turkish Statistical Institute, World Bank
Energy consumption	EC	Primary energy consumption (Exajoules, EJ)	BP Statistical Review

Table 2. Summary statistics

	LFLC	LY	LY^2	LTI	LEC
Mean	1.064	8.767	77.021	3.024	5.579
Median	1.112	8.698	75.657	3.343	5.673
Maximum	1.609	9.551	91.217	3.947	6.565
Minimum	0.542	8.183	66.957	1.131	4.317
Std. Dev	0.351	0.403	7.129	0.843	0.658

Every environmental asset has a dual nature. On the demand side, the FF summarizes the demand calculated based on a country’s annual consumption of timber, pulp, timber products and fuelwood. On the other hand, the supply side is represented by FB and refers to the ability to replenish what people demand from forested surfaces. FLC is used to express the environmental sustainability of forest areas and is obtained by dividing FB by FF. FLC encompasses the supply and demand sides of forests, thereby providing substantial evidence on deforestation and FB simultaneously (GFN, 2025; Ayad *et al.*, 2024). Figure 1 shows the FF, FB and FLC (FB/FF) per capita in Türkiye from 1974 to 2022.

Figure 2 shows that the FB has decreased continuously over the period. This indicates that the capacity of the ecosystem to regenerate what people demand from forest surfaces is gradually decreasing and deforestation is increasing. In addition, FF has generally been on an upward trend over the last 2 decades, although it did show small decreases at the beginning. Biocapacity reserve (FB-FF) decreased from 0.84 at baseline to 0.23 in 2022. Even though biocapacity deficit implying that FF is more than FB was not observed during this period, the gap between FB and FF was gradually closing. Finally, FLC decreased from 4.36 in 1974 to 1.77 in 2022, meaning a 59.4% reduction in FLC over the period. Accordingly, Figure 1 reveals that the environmental sustainability of forests in Türkiye is gradually decreasing.

In the empirical analysis, we explore the cointegration analysis by using the Bound test developed by Pesaran *et al.* (2001). The bound test allows the application of cointegration analysis regardless of the degree of stationarity of the variables (Narayan and Narayan, 2005). Equation 2 (The equation to estimate the Bound test) presents the Unrestricted Error Correction Model (UECM) for the application of the Bound test in this study.

$$\mathrm{LFLC}_t = a_0 + a_{1t+}\sum_{i=1}^{m} a_{2i}\Delta\mathrm{LFLC}_{t-i} + \sum_{i=0}^{m} a_{3i}\Delta\mathrm{LY}_{t-i} + \sum_{i=0}^{m} a_{4i}\Delta\mathrm{L}Y^2{}_{t-i} + \sum_{i=0}^{m} a_{5i}\Delta\mathrm{LTI}_{t-i} + \sum_{i=0}^{m} a_{6i}\Delta\mathrm{LEC}_{t-i} + a_7 LFLC_{t-1} + a_8 LY_{t-1} + a_9 LY^2_{t-1} + a_{10} L\mathrm{TI}_{t-1} + a_{11} L\mathrm{EC}_{t-1} + \varepsilon_t \qquad \text{(Eq. 2)}$$

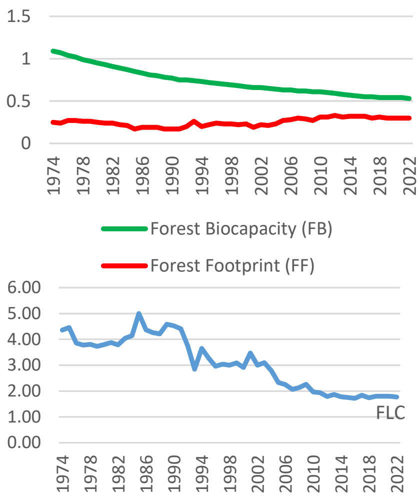

Figure 2. FF, FB and FLC in Türkiye

In Eq. (2) “m” and “t” specify the lag and trend variable, respectively. The null hypothesis for the Bound test is that there is no cointegration relationship between the variables. Therefore, the null hypothesis of the Bound test for this study is established as Ho: $\alpha_7 = \alpha_8 = \alpha_9 = \alpha_{10} = \alpha_{11}$. The null hypothesis is tested by comparing the calculated F-statistic with the critical values of Pesaran *et al.* (2001). If the estimated F-statistic is greater than the upper critical value, the null hypothesis is rejected; if the estimated F-statistic is less than the lower bound of the critical values, the null hypothesis cannot be rejected (Pesaran *et al.*, 2001; Narayan and Narayan, 2005).

Following the cointegration analysis, the ARDL model is applied to detect the long and short-run static relationships between the series. ARDL allows simultaneous analysis of short- and long-term effects of independent variables on the dependent variable (Şeker *et al.*, 2015). The ARDL model specifications for this study are presented in Equation (3) (The equation to estimate the long-run ARDL model) and Equation (4) (The equation to estimate the short-run ARDL model).

$$\mathrm{LFLC}_t = a_0 + \sum_{i=1}^{p} a_{1i}\mathrm{LFLC}_{2t-i} + \sum_{i=0}^{q} a_{2i}\mathrm{LY}_{t-i} + \sum_{i=0}^{r} a_{3i}\mathrm{L}Y^2{}_{t-i} + \sum_{i=0}^{s} a_{4i}\mathrm{LTI}_{t-i} + \sum_{i=0}^{s} a_{5i}\mathrm{LEC}_{t-i} + \varepsilon_t \quad \text{(Eq. 3)}$$

$$\Delta\mathrm{LFLC}_t = a_0 + a_1\mathrm{ECT}_{t-1} + \sum_{i=0}^{n} a_{1i}\,\Delta\mathrm{LFLC}_{t-i} + \sum_{i=0}^{n} a_{2i}\Delta\mathrm{LY}_{t-i} + \sum_{i=0}^{n} a_{3i}\Delta\mathrm{L}Y^2{}_{t-i} + \sum_{i=0}^{n} a_{4i}\Delta\mathrm{LTI}_{t-i} + \sum_{i=0}^{n} a_{5i}\Delta\mathrm{LEC}_{t-i} + \varepsilon_t \quad \text{(Eq. 4)}$$

ECT is the error correction term that indicates the speed of the adjustment process and is expected to be negative and statistically significant.

We lastly employ the Kalman filter methodology to examine the validity of the FLC Curve hypothesis dynamically. The study also explores the dynamic impacts of the control variables on forest sustainability. The Kalman filter is an algorithm for correctly computing the state of time-varying systems with noisy and incomplete observations. This method is used to obtain the best estimate of dynamical systems with observed data, and to continuously update the estimated data with new observations to obtain the most accurate state (Harvey, 1990). The recursive implementation of the Kalman filter can be used in real time, which is an attractive feature of this technique. After estimating the new state at time (t), the Kalman filter algorithm adds a correction term. This new ’corrected’ state acts as an initial condition in the next stage ($t + 1$). In this way, the estimation of the state variables uses all the information available up to that point, not just the information from the stage prior to the estimation. The Kalman filter permits the identification of the hidden (unmeasurable) state of a dynamic linear system. It works even when the system is subject to additive white noise (Urrea and Agramonte, 2021).

A linear state space representation of the dynamic system is presented in.

Equation (5) (The Kalman filter equation).

$$\mathrm{yt} = \mathrm{ct} + \mathrm{Zt}\alpha\mathrm{t} + \varepsilon\mathrm{t}$$

$$\alpha\mathrm{t} + 1 = \mathrm{dt} + \mathrm{Tt}\alpha\mathrm{t} + \nu\mathrm{t} \quad \text{(Eq. 5)}$$

where αt is the mx1 vector of unobserved state variables; ct, Zt, dt and Tt are appropriate vectors and matrices and εt and νt are vectors of mean zero and Gaussian disturbances. As expressed in Equation (5), it is assumed that the unobserved state vector, αt, changes over time as a first-order vector autoregression (Bulut, 2017). The Kalman filter specification used in this study is presented in Equation (6) (The equation to estimate the Kalman filter).

$$\mathrm{LFLCt} = \alpha_0 + \alpha_{1,t}\,\mathrm{LYt} + \alpha_{2,t}\,\mathrm{LY2t} + \alpha_{3,t}\,\mathrm{LTI} + \alpha_{4,t}\,\mathrm{LEC}$$

$$\alpha \mathrm{i,t} = \alpha \mathrm{i,t} - 1 + \nu \mathrm{it} \qquad \text{(Eq. 6)}$$

where $\alpha_{1,t}$, $\alpha_{2,t}$, $\alpha_{3,t}$ and $\alpha_{4,t}$ are the TVP estimates associated with the elasticities of FLC.

Results and discussion

The Bound test assumes that the variables are I(0) or I(1) and the procedure does not work in the presence of I(2) variables (Frimpong and Oteng-Abayie, 2006). Thus, the study first analyzes the stationary properties of the variables by using Augmented Dickey-Fuller (ADF), Phillips Perron (PP) and Ng-Perron tests. Table 3 presents the results of the unit root tests.

The null hypothesis of the ADF and PP tests is that the series include unit roots. The results of both the ADF and PP tests show that the t-statistics calculated for all the series are greater than the critical values in their level forms and that they become stationary after differencing. The null hypothesis for the Ng-Perron test is that the series are non-stationary according to the MZa and MZt tests, while the null hypothesis for the MSB and MPT tests is that the series are stationary. The estimated t-statistics for all series are less than the critical values in level forms according to the MZa and MZt tests, and greater than the critical values in level forms according to the MSB and MPT tests. In conclusion, the results of the ADF, PP and Ng-Perron tests used in this study indicate that all series are integrated of order 1 (I(1)). After confirming that none of the variables are integrated in two and beyond, the study uses the Bound test for cointegration analysis. Table 4 demonstrates the results of the Bound test.

According to Table 4, the null hypothesis that there is no cointegration relationship between the series is rejected since the F-statistic is greater than the upper bound of the critical values. Accordingly, we detect the cointegration relationship between FLC and the explanatory variables.

After establishing the existence of a cointegration relationship among the series, the study analyzes both long-run and short-run relationships using the ARDL model. Table 5 presents

Table 3. Unit root test results

	ADF test	PP test	Ng-perron test MZa	MZt	MSB	MPT
LFLC	−2.570	−2.445	−9.497	−2.178	0.229	9.598
LY	−1.778	−1.773	−5.882	−1.567	0.266	15.278
LY2	−1.552	−1.515	−4.731	−1.353	0.286	18.119
LTI	−2.023	−6.423	−7.296	−1.897	0.260	12.512
LEC	−2.680	−2.680	−6.829	−1.706	0.249	13.470
ΔLFLC	−8.850	−8.878	−22.312	−3.339	0.149	1.102
ΔLY	−6.566	−6.559	−23.338	−3.415	0.146	1.052
ΔLY2	−6.475	−6.470	−23.351	−3.415	0.146	1.057
ΔLTI	−6.423	−7.495	−23.299	−3.357	0.144	1.240
ΔLEC	−7.276	−7.416	−11.655	−2.351	0.202	2.346

Note(s): ADF Critical Values (Level): 1% = −4.16 5% = −3.51 ADF Critical Values (First-Differences): 1% = −3.57 5% = −2.92
Ng-Perron critical values (Level) at %5 significance for MZa, MZt, MSB and MPT: 17.30, −2.91, 0.17, 5.48 respectively
Ng-Perron critical values (First-Differences) at %5 significance for MZa, MZt, MSB and MPT: 8.10, −1.98, −0.23, 3.17 respectively

Table 4. Bound test results

k	F statistics	Critical values at 5% significant level Lower bound	Upper bound
4	4.38	3.05	3.97

Note(s): k is the number of independent variables in Equation (2)
Critical values are obtained from Table CI (iv) at Pesaran *et al.* (2001, p. 301)

Table 5. ARDL (1,1,0,2,0) model results

Variables	Coefficient	*T*-statistics
Long-run estimation		
LY	−22.001***	−4.581
LY^2	1.211***	4.726
LTI	0.499***	6.677
LEC	−0.657**	−2.071
C	102.897***	4.79
Short-run estimation		
ΔLY	−13.221***	−3.005
ΔLY^2	0.686***	2.805
ΔLTI	0.146***	5.276
ΔLTI_{t-1}	−0.154***	−4.082
ΔLEC	−0.565**	−2.676
ΔECT	−0.602***	−6.437
Diagnostic tests		
Serial correlation LM test (Breusch–Godfrey)	0.702 [0.502]	
Heteroscedasticity test (Breusch–Pagan–Godfrey)	0.631 [0.747]	
Ramsey reset test	1.644 [0.186]	
Jarque-Bera normality test	0.387 [0.824]	

Note(s): *** and ** indicate the 1% and 5% significance levels, respectively
p values in parentheses

the results of the estimated ARDL (1,1,0,2,0) model. Optimal lengths are determined via the Schwarz criterion (SIC).

The diagnostic results in Table 5 show that the estimated ARDL model does not contain problems of serial correlation, heteroskedasticity, misspecification and normality. In addition, the estimated coefficients in the model are found to be stable, shown by the results of CUSUM and CUSUM-squared tests in Figure 3.

The long-run ARDL model results show that all estimated coefficients are statistically significant. The signs of LY and LY^2 are found to be negative and positive, respectively. The negative sign of the income and the positive sign of the square of the income imply the presence of the U-shaped relationship between FLC and economic growth. This result means that FLC deteriorates in the initial stages of income; however, after income reaches a turning point, it begins to improve forest sustainability. Accordingly, this study corroborates the LCC hypothesis for forest area in Türkiye. This result is consistent with the findings of Ayad *et al.* (2024) for validation in forest LCC for Brazil, as well as with the conclusions of Yang *et al.* (2023), Hossain *et al.* (2024), Shahbaz *et al.* (2024) and Daştan (2024) that confirm the LCC hypothesis. Furthermore, the findings reveal that tourism has a positive effect on environmental quality in forest areas, a 1% rise in tourism income increases the FLC by nearly 0.50% in the long-run. The positive impact of tourism on the environment is consistent with Pata and Tanrıöver (2023), Magazzino *et al.* (2023), Voumik *et al.* (2023) and

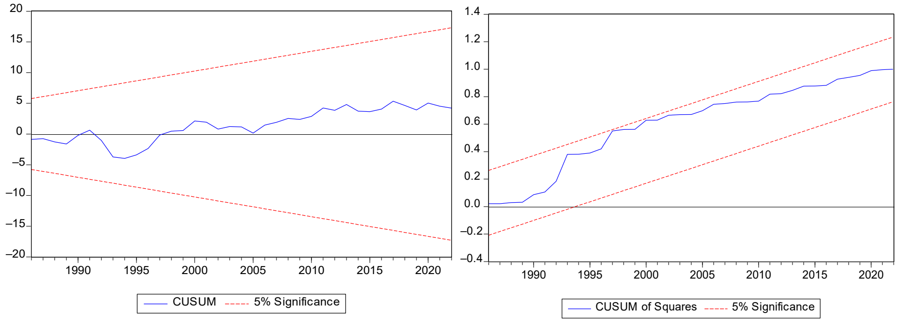

Figure 3. CUSUM and CUSUM of square test results

Ngo *et al.* (2024). On the other hand, energy consumption has a detrimental impact on FLC, as a 1% increase in energy consumption leads to a decrease in environmental quality of forests by 0.66% in the long-run.

Variables with zero lag length in the ARDL model enter the short-run equation only in first-difference form (ΔXt) in the error correction representation. The short-run ARDL model results show that all the estimated short-run coefficients are statistically significant. In line with the long-run ARDL model results, LY and LY^2 are found to be negative and positive, respectively. This finding validates the forests' LCC hypothesis in the short-run. In the short-run, tourism improves the FLC while energy consumption has a negative impact on environmental sustainability of forests. The error correction term, ΔECT, is found to be negative and statistically significant. The estimated coefficient of the error correction term is -0.60, indicating that 60% of the disequilibrium caused by the previous year's shock is eliminated within the current year. This suggests that the adjustment process is working at a high speed.

In the empirical analysis, we finally applied the Kalman filter approach to test the LCC hypothesis for forests dynamically in Türkiye. The dynamic analysis also includes the control variables used in the study. The results of the Kalman filter estimation show that all the coefficients of the variables are statistically significant, in line with the results obtained from the ARDL model, except for energy consumption. The signs of the estimated coefficients of LY, LY^2 and LTI in equation (6) are negative, positive and positive, respectively.

Figure 4 demonstrates the dynamic impact of income, the square of income and tourism on FLC, respectively. As seen from Figure 4, income has a negative effect on the environmental quality of forests, and the square of income increases the FLC in the sample period of the study. Hence, the Kalman filter results support the ARDL model results and show that the LCC hypothesis is valid for forests in Türkiye. The results of the dynamic effect of the income on the load capacity of forests in Figure 3 indicate that the negative effect of income on the environmental quality of forests generally decreased until 2005, although it fluctuated. This negative impact significantly weakened between 1990 and 2005. In this period, the change in the estimated TVP magnitude was found to be 1.81. However, the change in the magnitude of TVP over the last ten years was found to be -0.14, meaning that the negative impact of economic growth on the carrying capacity of forests has increased over the last decade.

The TVP results in Figure 4 show that the positive effect of tourism on the load capacity of forests increased particularly between 1980 and 1996 and decreased between 1996 and 2002. In addition, this effect has generally been seen to be steady over the last two decades, although it has shown small fluctuations. On the other hand, the change in the magnitude of the calculated TVP was found to be –0.012 in the last decade, implying that the positive impact of tourism on FLC has begun to weaken.

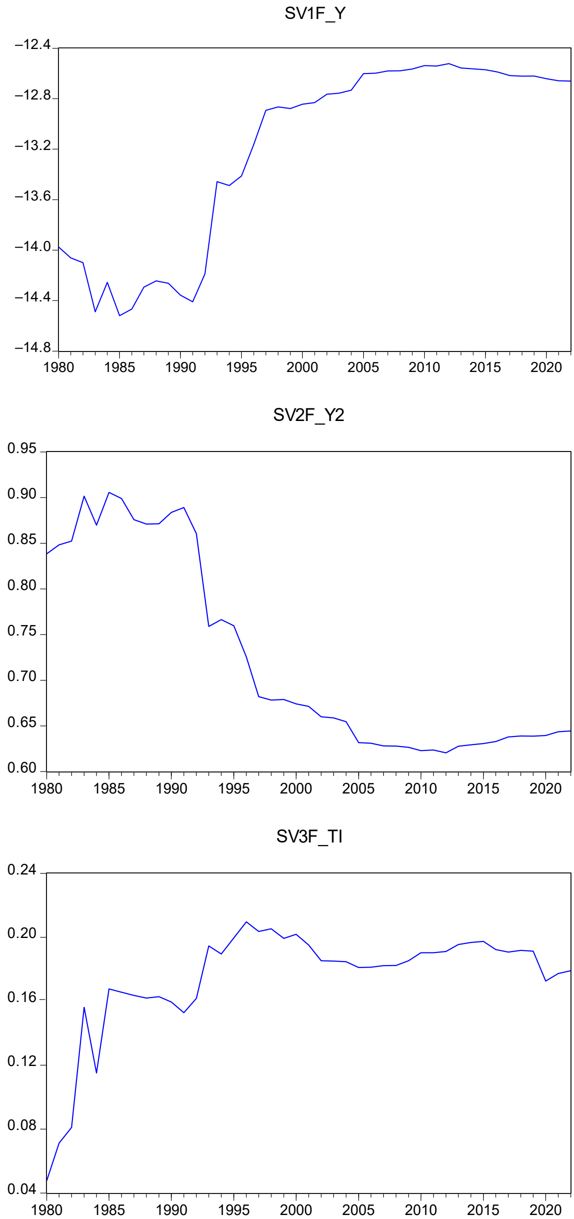

Figure 4. Time-varying parameter estimates for LY, LY^2 and LTI

Conclusion

Forests play a critical role in maintaining ecosystem sustainability, conserving biodiversity and regulating the global carbon cycle. In this context, FLC, which reflects the balance between forest biocapacity (FB) and FF, serves as an important indicator for evaluating environmental sustainability. This study investigates the relationship between FLC and economic growth in Türkiye over the period 1974–2022 within the framework of the LCC hypothesis. In the empirical analysis, the ARDL Bound testing approach is employed to identify the long-run relationship among the variables, while short-run and long-run effects are estimated using the ARDL model. Furthermore, to capture the time-varying nature of this relationship, the Kalman filter method is applied to analyze the dynamic evolution of the coefficients over time. In this respect, the study contributes to the literature by testing the forest-based LCC hypothesis for Türkiye and by incorporating a dynamic analytical approach.

The findings reveal a U-shaped relationship between economic growth and FLC in Türkiye. Accordingly, in the early stages of economic growth, pressure on forest ecosystems increases, whereas environmental improvement is observed after a certain income threshold is reached. This suggests that, in the initial phase, economic growth exerts a negative impact on forests through channels such as intensive natural resource use, energy-intensive production structures and land-use pressures. However, as income levels rise, factors such as stronger environmental regulations, technological progress and increased environmental awareness contribute positively to forest sustainability. Nevertheless, the TVP results indicate that this improvement is neither linear nor guaranteed over time. In particular, the adverse impact of economic growth on FLC has shown a tendency to increase again in recent years. This finding highlights that environmental improvement cannot be left solely to the process of economic growth and requires active policy interventions. Therefore, while the LCC hypothesis is validated, it does not imply that environmental sustainability will automatically be achieved without appropriate policy measures.

The results regarding control variables also provide important insights. The positive impact of tourism income on FLC suggests that tourism, when properly managed, can support environmental sustainability. However, the dynamic analysis indicates that this positive effect has weakened in recent years. This implies that the environmental impact of tourism depends largely on its structure and management, and that uncontrolled expansion of tourism activities may exert increasing pressure on forest ecosystems.

The negative effect of energy consumption on FLC indicates that economic growth in Türkiye is still characterized by an energy-intensive structure with significant environmental externalities. A fossil fuel-based energy mix contributes to environmental degradation through increased carbon emissions and pressure on natural resources, thereby indirectly affecting forest ecosystems. This finding underscores that not only the level but also the composition of energy consumption is crucial for environmental sustainability.

Based on these findings, several policy implications can be derived. First, to mitigate the adverse effects of economic growth on forest ecosystems, land-use planning should be strengthened, and activities such as mining, industrial expansion and agricultural encroachment that threaten forest areas should be more strictly regulated. In addition, policies that promote energy efficiency and environmentally friendly production processes should be effectively implemented.

Second, sustainable tourism policies should be restructured to reduce the pressure of tourism activities on forest ecosystems. In this regard, carrying capacity-based planning should be adopted, particularly in ecologically sensitive forest areas, while ecotourism practices should be encouraged. Moreover, stricter environmental standards should be introduced for tourism enterprises and the environmental impacts of tourism activities should be regularly monitored and controlled.

Finally, to reduce the negative impact of energy consumption on forest ecosystems, the energy transition process should be accelerated. Reducing the share of fossil fuels, increasing the use of renewable energy sources and promoting energy efficiency-enhancing technologies are of critical importance. In particular, stricter environmental regulations in energy-intensive sectors will contribute indirectly to the protection of forest ecosystems.

In conclusion, this study demonstrates that the relationship between economic growth and FLC in Türkiye is nonlinear and time-varying. This finding indicates that environmental sustainability cannot be ensured solely through economic growth, and that coordinated policies in energy, tourism and natural resource management are essential for maintaining forest sustainability.

References

Akadiri, S.S., Lasisi, T.T., Uzuner, G. and Akadiri, A.C. (2019), “Examining the impact of globalization in the environmental Kuznets curve hypothesis: the case of tourist destination states”, *Environmental Science and Pollution Research*, Vol. 26 No. 12, pp. 12605-12615, doi: 10.1007/s11356-019-04722-0.

Altıntaş, N., Açıkgöz, F., Okur, M., Öztürk, M. and Aydın, A. (2024), “Renewable energy and banking sector development impact on load capacity factor in Malaysia”, *Journal of Cleaner Production*, Vol. 434, 140143, pp. 1-10, doi: 10.1016/j.jclepro.2023.140143.

Altıntaş, N., Açıkgöz, F. and Yeniyurt, M. (2025), “Investigating the LCC hypothesis in the Middle East, North Africa, and Turkey (MENAT): evidence from second-generation panel techniques”, *Environment, Development and Sustainability*, Vol. 27 No. 3, pp. 1-20, doi: 10.1007/s10668-023-04216-7.

Astigarraga, J., Calatayud, J., Ruiz-Benito, P., Madrigal-González, J., Tijerín-Triviño, J., Zavala, M.A. and Herrero, A. (2025), “Forest structural diversity modulates tree growth synchrony in response to climate change”, *Forest Ecology and Management*, Vol. 579, 122505, doi: 10.1016/j.foreco.2025.122505.

Ayad, H., Hassoun, S.S., Abdelkader, S.B. and Sallam, O.A.A.J. (2024), “Assessing deforestation in the Brazilian forests: an econometric inquiry into the load capacity curve for deforestation”, *Forest Policy and Economics*, Vol. 159, 103135, doi: 10.1016/j.forpol.2023.103135.

Aydin, M., Cutcu, I., Cayir, B. and Magdalena, R. (2024), “Investigating the role of biomass energy consumption and forest products trade on the forest footprint in Finland: an environmental Kuznets curve analysis”, *Environment, Development and Sustainability*, Vol. 28 No. 6, pp. 1-15, doi: 10.1007/s10668-024-05449-w.

Aydin, M. and Degirmenci, T. (2024), “The impact of clean energy consumption, green innovation, and technological diffusion on environmental sustainability: new evidence from load capacity curve hypothesis for 10 European union countries”, *Sustainable Development*, Vol. 32 No. 3, pp. 2358-2370, doi: 10.1002/sd.2794.

Balmford, A., Beresford, J., Green, J., Naidoo, R., Walpole, M. and Manica, A. (2009), “A global perspective on trends in nature-based tourism”, *PLoS Biology*, Vol. 7 No. 6, e1000144, doi: 10.1371/journal.pbio.1000144.

Bärmann, L., Kaufmann, S. and Hauck, M. (2025), “Climate change adaption of European beech forests: silver fir admixtures drive understorey plant diversity”, *Forest Ecology and Management*, Vol. 579, 122499, doi: 10.1016/j.foreco.2025.122499.

Bekun, F.V., Uzuner, G., Meo, M.S. and Yadav, A. (2024), “Another look at energy consumption and environmental sustainability target through the lens of the load capacity factor: accessing evidence from MINT economies”, in *Natural Resources Forum*, Blackwell Publishing, Oxford, doi: 10.1111/14778947.12481.

Bonan, G.B. (2008), “Forests and climate change: forcings, feedbacks, and the climate benefits of forests”, *Science*, Vol. 320 No. 5882, pp. 1444-1449, doi: 10.1126/science.1155121.

British Petroleum (BP (2025), “Statistical review of world energy”, available at: https://www.bp.com/en/global/corporate/energy-economics.html

Buckley, R. (2012), “Sustainable tourism: research and reality”, *Annals of Tourism Research*, Vol. 39 No. 2, pp. 528-546, doi: 10.1016/j.annals.2012.02.003.

Bulut, U. (2017), “The impacts of non-renewable and renewable energy on CO2 emissions in Türkiye”, *Environmental Science and Pollution Research*, Vol. 24 No. 18, pp. 15416-15426, doi: 10.1007/s11356-017-9175-2.

Cutcu, I. and Radulescu, M. (2025), “Analysing the drivers of cropland footprint in leading agricultural nations: evidence from MMQR approach”, *Geological Journal*, gj.70072, doi: 10.1002/gj.70072.

Daştan, M. (2024), "The role of renewable energy, technological innovation, and human capital on environmental quality in Türkiye: testing the LCC hypothesis with smooth structural shifts", *Yüzüncü Yıl Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, No. 65, pp. 76-91, doi: 10.53568/yyusbed.1480175.

Davenport, J. and Davenport, J.L. (2006), "The impact of tourism and personal leisure transport on coastal environments: a review", *Estuarine, Coastal and Shelf Science*, Vol. 67 Nos 1-2, pp. 280-292, doi: 10.1016/j.ecss.2005.11.026.

Eagles, P.F.J., McCool, S.F. and Haynes, C.D.A. (2002), *Sustainable Tourism in Protected Areas: Guidelines for Planning and Management*, IUCN, Gland and Cambridge.

FAO (2020), *Global Forest Resources Assessment 2020: Main Report*, Rome, doi: 10.4060/ca9825en.

Feng, Z., Durani, F., Anwar, A., Ahmad, P., Syed, Q.R. and Abbas, A. (2024), "From brown to green: are emerging countries moving in right direction? Testing the validity of LCC hypothesis", *Energy and Environment*. doi: 10.1177/0958305X24122851.

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller, N.D., O'Connell, C., Ray, D.K., West, P.C., Balzer, C., Bennett, E.M., Carpenter, S.R., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., Tilman, D. and Zaks, D.P.M. (2011), "Solutions for a cultivated planet", *Nature*, Vol. 478 No. 7369, pp. 337-342, doi: 10.1038/nature10452.

Frimpong, J.M. and Oteng-Abayie, E.F. (2006), "Bounds testing approach: an examination of foreign direct investment, trade, and growth relationships", *MPRA Munich Personal RePEc Archive*, Vol. 352 No. 10, pp. 1-19.

Gao, J., Xu, W. and Zhang, L. (2021), "Tourism, economic growth, and tourism-induced EKC hypothesis: evidence from the Mediterranean region", *Empirical Economics*, Vol. 60 No. 3, pp. 1507-1529, doi: 10.1007/s00181-019-01787-1.

GDF (2025), *2023 Performance Program January/2023*, General Directorate of Forestry, Ankara, available at: https://www.ogm.gov.tr/tr/duyurular/orman-genel-mudurlugu-2023-yili-performans-programi

GFN (2025), *Global Footprint Network*, available at: https://data.footprintnetwork.org/#/countryTrends?cn=223&type=BCpc,EFCpc

Gössling, S. (2002), "Global environmental consequences of tourism", *Global Environmental Change*, Vol. 12 No. 4, pp. 283-302, doi: 10.1016/S0959-3780(02)00044-4.

Gössling, S. and Hall, M.C. (2006), *Tourism and Global Environmental Change*, Taylor & Francis.

Gössling, S., Peeters, P., Hall, C.M., Ceron, J.P., Dubois, G., Lehmann, L.V. and Scott, D. (2012), "Tourism and water use: supply, demand, and security. An international review", *Tourism Management*, Vol. 33 No. 1, pp. 1-15, doi: 10.1016/j.tourman.2011.03.015.

Hakkak, M., Altintaş, N. and Hakkak, S. (2023), "Exploring the relationship between nuclear and renewable energy usage, ecological footprint, and load capacity factor: a study of the Russian Federation testing the EKC and LCC hypothesis", *Renewable Energy Focus*, Vol. 46, pp. 356-366, doi: 10.1016/j.ref.2023.07.005.

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O. and Townshend, J.R.G. (2013), "High-resolution global maps of 21st-century forest cover change", *Science*, Vol. 342 No. 6160, pp. 850-853, doi: 10.1126/science.1244693.

Harvey, A.C. (1990), *Forecasting, Structural Time Series Models and the Kalman Filter*, Cambridge University Press.

Hossain, M.S., Ridwan, M., Akhter, A., Nayeem, M.B., Choudhury, M.T.H., Asrafuzzaman, M., Shoha, S., Abir, S.I. and Sumaira, (2024), "Exploring the LCC hypothesis in the Nordic region: the role of AI innovation, environmental taxes, and financial accessibility via panel ARDL", *Global Sustainability Research*, Vol. 3 No. 3, pp. 54-80, doi: 10.56556/gssr.v3i3.972.

Javed, A., Usman, M. and Rapposelli, A. (2024), "Transition toward a sustainable future: exploring the role of green investment, environmental policy, and financial development in the context of load capacity factor in G-7 countries", *Sustainable Development*, Vol. 33 No. 2, pp. 1589-1609, doi: 10.1002/sd.3192.

Kocak, E. and Cavusoglu, M. (2024), "Is there a conservation relationship between tourism, economic output, and forest areas?", *Conservation Science and Practice*, Vol. 6 No. 8, e13171, doi: 10.1111/csp2.13171.

Lambin, E.F. and Meyfroidt, P. (2011), "Global land use change, economic globalization, and the looming land scarcity", *Proceedings of the National Academy of Sciences*, Vol. 108 No. 9, pp. 3465-3472, doi: 10.1073/pnas.1100480108.

Lee, C.C. and Chen, M.P. (2021), "Ecological footprint, tourism development, and country risk: international evidence", *Journal of Cleaner Production*, Vol. 279, 123671, doi: 10.1016/j.jclepro.2020.123671.

Lindberg, K., Enriquez, J. and Sproule, K. (1996), "Ecotourism questioned: case studies from Belize", *Annals of Tourism Research*, Vol. 23 No. 3, pp. 543-562, doi: 10.1016/0160-7383(95)00074-7.

Magazzino, C., Adedoyin, F.F., Bilgili, F. and Shahzad, U. (2023), "If tourism induces the EKC hypothesis, how does governance moderate its impact in the EU without the UK?", *The International Journal of Sustainable Development and World Ecology*, Vol. 30 No. 6, pp. 685-698, doi: 10.1080/13504509.2023.2189321.

Mahadevan, R. and Suardi, S. (2024), "Globalisation, tourism and environmental kuznets curve", *Tourism Economics*, Vol. 31 No. 5, doi: 10.1177/13548166241295799.

Majumdar, S. and Paris, C.M. (2022), "Environmental impact of urbanization, bank credits, and energy use in the UAE—a tourism-induced EKC model", *Sustainability*, Vol. 14 No. 13, p. 7834, doi: 10.3390/su14137834.

MEA (2005), *Millennium Ecosystem Assessment Synthesis Report*, Island Press, Washington DC.

Mikayilov, J.I., Mukhtarov, S., Mammadov, J. and Azizov, M. (2019), "Re-evaluating the environmental impacts of tourism: does EKC exist?", *Environmental Science and Pollution Research*, Vol. 26 No. 19, pp. 19389-19402, doi: 10.1007/s11356-019-05269-w.

Narayan, P.K. and Narayan, S. (2005), "Estimating income and price elasticities of imports for Fiji in a cointegration framework", *Economic Modelling*, Vol. 22 No. 3, pp. 423-438, doi: 10.1016/j.econmod.2004.06.004.

Ngo, T., Tsui, W.H.K. and Nguyen, H. (2024), "Aviation pollution, tourism, and economic development: a study of the EKC hypothesis at the regional level", *Экономика региона*, Vol. 20 No. 3, pp. 718-731, doi: 10.17059/ekon.reg.2024-3-8.

Pata, U.K. and Balsalobre-Lorente, D. (2022), "Exploring the impact of tourism and energy consumption on the load capacity factor in Türkiye: a novel dynamic ARDL approach", *Environmental Science and Pollution Research*, Vol. 29 No. 9, pp. 13491-13503, doi: 10.1007/s11356-021-16675-4.

Pata, U. and Tanrıöver, B. (2023), "Is the load capacity curve hypothesis valid for the top ten tourism destinations?", *Sustainability*, Vol. 15 No. 2, p. 960, doi: 10.3390/su15020960.

Pesaran, M.H., Shin, Y. and Smith, R.J. (2001), "Bounds testing approaches to the analysis of level relationships", *Journal of Applied Econometrics*, Vol. 16 No. 3, pp. 289-326, doi: 10.1002/jae.616.

Porto, N., Pitetti, D.A. and Ciaschi, M. (2023), "A worldwide tourism-extended environmental Kuznets curve. New approaches in a comparative analysis", *Journal of Sustainable Tourism*, Vol. 31 No. 9, pp. 2100-2118, doi: 10.1080/09669582.2021.2023165.

Radulescu, M., Barut, A., Si Mohammed, K., Nassani, A.A. and Cutcu, I. (2024), "Insights of resources productivity and green technologies impact on renewable energy consumption: novel MMQR approach", *Geological Journal*, Vol. 59 No. 11, pp. 3033-3047, doi: 10.1002/gj.5044.

Rahman, M.H., Voumik, L.C., Islam, M.J., Halim, M.A. and Esquivias, M.A. (2022), "Economic growth, energy mix, and tourism-induced EKC hypothesis: evidence from top ten tourist destinations", *Sustainability*, Vol. 14 No. 24, 16328, doi: 10.3390/su142416328.

Şeker, H. and Avşar, M. (2023), "The tourism-based environmental Kuznets curve hypothesis: evidence from the Turkish economy", *International Journal of Social Inquiry*, Vol. 16 No. 2, pp. 479-496, doi: 10.37093/ijsi.1356600.

Şeker, F., Ertuğrul, H.M. and Cetin, M. (2015), "The impact of foreign direct investment on environmental quality: a bounds testing and causality analysis for Türkiye", *Renewable and Sustainable Energy Reviews*, Vol. 52, pp. 347-356, doi: 10.1016/j.rser.2015.07.1181364-0321/and2015.

Shahbaz, M., Aydin, M., Degirmenci, T. and Bozatli, O. (2024), "The role of agriculture-forestry-fisheries sectors, biodiversity expenditures, and renewable energy on environmental quality for the Netherlands: evidence from novel Fourier ARDL", in *Natural Resources Forum*, Blackwell Publishing, Oxford, doi: 10.1111/1477-8947.12517.

Shahzad, U., Tiwari, S., Mohammed, K.S. and Zenchenko, S. (2024), "Asymmetric nexus between renewable energy, economic progress, and ecological issues: testing the LCC hypothesis in the context of sustainability perspective", *Gondwana Research*, Vol. 129, pp. 465-475, doi: 10.1016/j.gr.2023.07.008.

Sun, Q., Zhang, N., Liu, Z. and Liao, B. (2020), "Tourism resources and carrying capacity of scenic tourism areas based on forest ecological environment", *Southern Forests: A Journal of Forest Science*, Vol. 82 No. 1, pp. 10-14, doi: 10.2989/20702620.2020.1733766.

Tiwari, S., Raza, S.A., Gupta, S.K., Shahzadi, I. and Kuruva, M.B. (2024), "Testing the LCC hypothesis by considering environmental sustainability and economic development: role of green energy and resource management", *Geoscience Frontiers*, Vol. 15 No. 3, 101666, doi: 10.1016/j.gsf.2023.101666.

TTYD (2025), "Turkish tourism's global journey and farewell to 2024", available at: https://ttyd.org.tr/2025/01/02/turk-turizminin-kuresel-yolculugu-ve-2024e-veda/

TurkStat (2025), "Tourism statistics, Q4: October-December and annual, 2024", Bulletin No: 53660), available at: https://data.tuik.gov.tr/Bulten/Index?p=Turizm-Istatistikleri-IV.-Ceyrek:-Ekim-Aralik-ve-Yillik,-2024-53660

Urrea, C. and Agramonte, R. (2021), "Kalman filter: historical overview and review of its use in robotics 60 Years after its creation", *Journal of Sensors*, Vol. 1, 9674015, doi: 10.1155/2021/9674015.

Voumik, L.C., Md Nafi, S., Bekun, F.V. and Haseki, M.I. (2023), "Modeling energy, education, trade, and tourism-induced environmental Kuznets curve (EKC) hypothesis: evidence from the Middle East", *Sustainability*, Vol. 15 No. 6, p. 4919, doi: 10.3390/su15064919.

Yang, B., Shao, Y. and Zhang, Z. (2023), "The relationship between economic growth and ecological footprint: evidence from BRICS countries using a dynamic panel model", *Global Environmental Change*, Vol. 48 No. 2, pp. 525-548, doi: 10.1111/1477-8947.12331.

Corresponding author
Pınar Karahan-Dursun can be contacted at: pinarkarahan.dursun@mudanya.edu.tr