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# Spatiotemporal forest and land cover change in Türkiye: The role of economic factors in driving environmental transformations

**Gökhan Şen[a,*], Emre Aktürk[a]**

**Abstract:** Industrial advancements, urbanization, climate change, economic developments, and numerous other factors significantly influence land use preferences, subsequently causing changes in land cover. However, these changes are not homogeneus at the country scale. In this study, we aim to determine the total and provincial-based land cover changes in Türkiye between 2006 and 2018 and the impacts of macroeconomic variables on these changes. The land cover status for 2006 and 2018 and the changes occurring during this period were determined according to the Coordination of Information on the Environment (CORINE) system. For this purpose, five land cover classes were used. Correlation analysis was utilized to identify relationships between macroeconomic variables and cover changes and regression analysis was used to develop models aiming to predict future changes in land cover based on macroeconomic variables. Research findings indicate that 5.31% of forest areas, 2.9% of agricultural areas, and 7.19% of shrub and/or herbaceous vegetation associations have been converted to other uses. During this period, forest cover increased in 38 provinces in Türkiye, decreased in 41 provinces, and remained unchanged in two provinces. The province with the highest percentage increase in forest areas was Iğdır, at 19.98%, while the province with the most significant percentage decrease in forest areas was Ordu, at 0.62%. There was a statistically significant negative correlation between changes in forest areas and certain macroeconomic factors: gross domestic product (-0.310), number of automobiles (-0.308), number of motor vehicles (-0.326), and the number of buildings according to the building use permit (-0.287).
**Keywords:** Land use, Macroeconomic factors, CORINE, Türkiye

# Türkiye'de orman ve arazi örtüsü değişimi: çevresel dönüşümlerin yönlendirilmesinde ekonomik faktörlerin rolü

**Özet:** Endüstriyel gelişmeler, kentleşme, iklim değişikliği, ekonomik gelişmeler ve diğer birçok faktör arazi kullanım tercihlerini önemli ölçüde etkileyerek arazi örtüsünde değişikliklere neden olmaktadır. Ancak bu değişimler ülke ölçeğinde homojen değildir. Bu çalışmada, Türkiye'de 2006-2018 yılları arasında toplam ve il bazında arazi örtüsü değişimlerinin ve makroekonomik değişkenlerin bu değişimler üzerindeki etkilerinin belirlenmesi amaçlanmaktadır. 2006-2018 yıllarına ait arazi örtüsü durumu ve bu dönemde meydana gelen değişimler Çevresel Bilginin Koordinasyonu (CORINE) sistemine göre belirlenmiştir. Bu amaçla beş arazi örtüsü sınıfı kullanılmıştır. Makroekonomik değişkenler ve örtü değişiklikleri arasındaki ilişkileri belirlemek için korelasyon analizi ve makroekonomik değişkenlere dayalı olarak arazi örtüsünde gelecekteki değişiklikleri tahmin etmeyi amaçlayan modeller geliştirmek için regresyon analizi kullanılmıştır. Araştırma bulguları, orman alanlarının %5,31'inin, tarım alanlarının %2,9'unun ve çalı ve/veya otsu bitki birliklerinin %7,19'unun diğer kullanımlara dönüştürüldüğünü göstermektedir. Bu dönemde Türkiye'de 38 ilde orman alanları artmış, 41 ilde azalmış, 2 ilde ise değişmemiştir. Orman alanlarının yüzde olarak en fazla arttığı il %19,98 ile Iğdır, en fazla azaldığı il ise %0,62 ile Ordu olmuştur. Orman alanlarındaki değişim ile gayrisafi yurtiçi hasıla (-0,310), otomobil sayısı (-0,308), motorlu taşıt sayısı (-0,326) ve yapı kullanım iznine göre bina sayısı (-0,287) arasında istatistiksel olarak anlamlı bir negatif korelasyon belirlenmiştir.
**Anahtar kelimeler:** Arazi kullanımı, Makro-ekonomik faktörler, CORINE, Türkiye

## 1. Introduction

Anthropogenic activities have caused changes to approximately three-quarters of the Earth's land surface over the last millennium despite numerous studies aiming to protect ecosystems at both global and local levels (Luyssaert et al., 2014; Arneth et al., 2019; Isinkaralar et al., 2024). In particular, the rapid increase in demand for raw materials following the Industrial Revolution has led to humans' destruction of natural resources, the effects of which are currently being experienced in climate change (Walter et al., 2003; Emmott, 2013). As a result, monitoring land cover status, its spatiotemporal change dynamics and identifying the causes of this transformation have gained significant importance in current research (Winkler et al., 2021).

Forests, as one of the most critical ecosystems on terrestrial surfaces, play a vital role for humans and other living organisms due to their products and services (FAO, 2010). In addition to these characteristics, forests are central to efforts to achieve the goals outlined in the Paris Agreement to combat climate change (Grassi et al., 2017). However, numerous studies have shown that forest ecosystems are significantly degraded or endangered in many parts of the world (Winkler et al., 2021). Understanding the changes in these resources and the human impacts that largely influence them is crucial for protecting and managing forest resources

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and their biodiversity. As a result of human interventions, the dominant land cover and/or land use type in an area can be transformed into a different type, leading to consequences such as deforestation, desertification, habitat fragmentation, biodiversity loss, and ultimately, global warming (Noss, 2001; Sherbinin et al., 2007). This can also reduce environmental services (Lele and Joshi, 2009).

Identifying the specific human factors at play is crucial for planning appropriate measures, while the causes of land cover changes are generally human-induced. Population status, structure, migration, population change, countries' socio-economic goals, development strategies, implemented policies, and social and economic structures can significantly impact land cover. Additionally, agricultural policies and practices are particularly influential in driving changes in land cover (Winkler et al., 2021). In Türkiye, a shift from agriculture to the service sector and industrialization began in conjunction with the development push initiated in the 1980s (Kaştan, 2016). Rural-to-urban migration that started after this period led to rapid changes in the natural structure of cities. These changes have primarily affected forests and agricultural fields for the purpose of settlement and industrialization, particularly in the urban peripheries. In contrast, rural areas have experienced a decline in livestock and agricultural activities due to depopulated villages, leading to the reforestation of these areas (Toksoy et al., 2011; Şen et al., 2018).

Determining the changes in land cover due to anthropogenic and natural factors is particularly important for environmental studies. In this context, numerous studies have been conducted worldwide, including in Türkiye (Turner et al., 1993; Lambin et al., 2003; Şen et al., 2015; Şen and Güngör, 2018; Akturk and Guney, 2021; Roy et al., 2022; Dogan et al., 2023; Lagarias and Stratigea, 2023; Zeren Çetin et al., 2023; Işınkaralar, 2024). These studies have gained momentum and diversified with advancements in geospatial computing and remote sensing techniques (Wulder et al., 2018). Initial studies on the land cover were primarily focused on determining the cover of the Earth's surface or monitoring changes over specific time intervals. However, over time, these studies have evolved to concentrate on identifying the causes of these changes, enabling predictions of potential futufre changes (Huang et al., 2020). In such research, the focus is often on local and small-scale land cover change study sites. In contrast, some of the most influential factors in land cover change are a country's social, economic, cultural, and other characteristics, which vary significantly between countries. In this context, conducting studies at a national scale to examine land cover changes, determine the influential factors, and identify the relationships between them is important for management planning and future projections.

Another important consideration is the fact that the social, economic, cultural, and other variables within countries are not homogeneously distributed. Countries are divided into subunits based on various characteristics (Açıkgöz, 2011). In this regard, provinces emerge as units that can distinguish areas with similar features and provide accurate data. Thus, examining land cover change at the provincial level, encompassing the entire country, and investigating the influencing factors will yield valuable results. A literature review reveals a limited number of studies conducted in this scope.

In light of the reasons mentioned above, this study aims to investigate the impacts of economic variables on land cover changes in Türkiye between 2006 and 2018 and to identify predictive models that can foresee potential changes in land cover due to these economic variables. The outcomes of this research hold the potential to significantly contribute to the understanding of land cover change dynamics and their underlying driving factors, ultimately benefiting decision-makers in predicting land cover changes, thereby promoting the conservation of forest resources and related natural resources, establishing a balance in resource use, and informing planning and project development in related areas. Moreover, the findings of this study will provide a valuable reference for future research on land cover change and its connections with socio-economic factors, fostering the development of more targeted and effective management strategies. Additionally, the predictive models obtained from this study can serve as a foundation for further research in similar countries, enhancing the applicability and value of the findings for a broader range of contexts. Overall, this study addresses a crucial gap in the existing literature and aims to advance our understanding of the complex relationship between land cover change and economic factors, paving the way for more sustainable and informed land management practices.

## 2. Materials and Methods

### *2.1. Study area*

Türkiye is located at the confluence of Asia, Europe, Africa, and the Middle East, between the latitudes of 36° - 42° north and longitudes of 26° - 45° east (Figure 1). Among the region's countries; it is one of the largest in terms of area and population. The country, forming a peninsula, is surrounded by the Black Sea to the north, the Aegean Sea to the west, and the Mediterranean Sea to the south. Türkiye is predominantly characterized by mountainous terrain, with limited plains and coastal areas. About a quarter of the country's surface is elevated above 1,200 meters, with steep slopes prevalent across the nation and flat or gently sloping lands comprising only one-sixth of the total area.

The study area's climate is diverse, significantly influenced by the presence of seas to the north, south, and west, as well as the mountains that cover most of the country. Certain regions exhibit the Mediterranean climate's characteristic maximum winter precipitation, and summer droughts are prevalent. However, due to Türkiye's elevation, winters tend to be substantially colder than those typically encountered in Mediterranean climates, resulting in notable temperature variations between the winter and summer months (Sensoy et al., 2008).

Owing to its strategic position as a bridge between three continents, its location on crucial migration routes, its unique topographic features and varied climatic patterns, and its position at the intersection of distinct floristic regions (Euro-Siberian, Mediterranean, and Irano-Turanian), Türkiye is recognized as one of the world's most vital gene centers in terms of plant biodiversity (Aksoy et al., 2014). According to the Angiosperm Phylogeny Group (APG) system, the Turkish Flora comprises 11707 taxa, including 11466 native, 171 foreign, and 70 agricultural plants. Moreover, 3649 of these plant taxa are endemic to Türkiye, yielding an endemism rate of 31.8%. Recent investigations have increased these figures, demonstrating that 12975 of the 374000 plant taxa documented globally (Christenhusz and Byng, 2016) are present within Türkiye's borders. The number of endemic plant taxa stands at 4157 (Özhatay et al., 2013; 2015; 2017; 2019), and the endemism rate has been updated to 32%. These values are anticipated to continue their upward trajectory with each new study (Karaköse, 2020).

### *2.2. Dataset & CLC change analyzing*

The Coordination of Information on the Environment (CORINE) Land Cover (CLC) products provide land cover data for the European continent at a 100-meter spatial resolution for five different years (1990, 2000, 2006, 2012, and 2018) (Copernicus Land Monitoring Service, 2020). Initiated by the European Union in 1985, the primary aim of this project was to establish a standardized land cover dataset for environmental research across European countries (Heymann et al., 1994).

CLC offers users 44 distinct land cover classes within five main categories, enabling a detailed examination of changes between these numerous classes (Bossard et al., 2000). The 'Land Cover Classification Project' was launched in 1988 as part of the adaptation process with the European Union, making Türkiye one of the European countries included in the CLC products (Ateşoğlu, 2016). Since the first CLC product release, these datasets have been widely used and continue to be employed in various studies in Türkiye (Vural et al., 1997; Ikiel et al., 2013; Ateşoğlu, 2016; Sari and Özşahin, 2016; Konukçu et al., 2017; Aktürk et al., 2020; Akturk and Guney, 2021). The frequent use of CLC products in academic research can be attributed to their free access, providing information on numerous sub-land cover classes, and data availability at an acceptable spatial resolution of 100 meters. In this study, the 2006 and 2018 CLC products were used due to the variety of land cover classes they provide and their coverage of the study area. Using these datasets enables an in-depth investigation of land cover changes in Türkiye and contributes to understanding the driving factors behind these shifts. Although data from the CLC for the years 1990 and 2000 are available for the study area, they were not included in the study due to the unavailability of all relevant economic data for these periods. Furthermore, the CLC data for the year 2012 is not deemed suitable for use in the study, in order to avoid an increase in data processing capacity and an increase in the temporal coverage time.

Geographical operations for this study were performed using ArcMap version 10.8.1. First, spatial alignment was ensured, and all CLC raster and province borders vector datasets used in the study were transformed into the ETRS89 LAEA geographic coordinate system. Then, the cell resolutions of the CLC maps were kept constant at 100 meters, and the level 3 CLC land cover classes were re-categorized according to the study objectives and grouped under six main classes based on the study's purposes (Table 1).

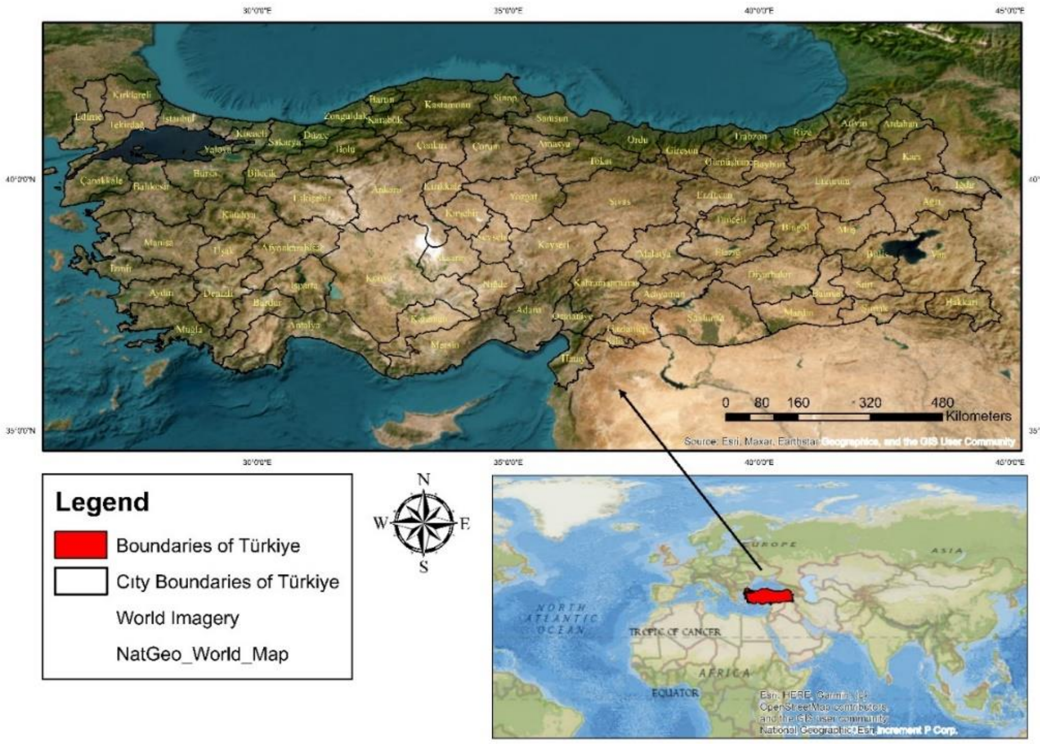


Figure 1. National country and city boundaries of the study area

Table 1. CLC Level 1 and Level 3 land cover classes and their new re-categorized classes according to the aims of the study (AS: Artificial surfaces, AA: Agricultural areas, FA: Forest Areas, SH: Shrub and/or herbaceous vegetation associations, OS: open spaces, W: Wetlands)

| CORINE Level 1 | CORINE Level 3 | Re-categorized Class |
|---|---|---|
| Artificial surfaces | 111 - Continuous urban fabric | AS |
| | 112 - Discontinuous urban fabric | AS |
| | 121 - Industrial or commercial units | AS |
| | 122 - Road and rail networks and associated land | AS |
| | 123 - Port areas | AS |
| | 124 – Airports | AS |
| | 131 – Mineral extraction sites | AS |
| | 132 – Dump sites | AS |
| | 133 – Construction sites | AS |
| | 141 – Green urban areas | AS |
| | 142 – Sport and leisure facilities | AS |
| Agricultural areas | 211 – Non-irrigated arable land | AA |
| | 212 – Permanently irrigated land | AA |
| | 213 – Rice fields | AA |
| | 221 – Vineyards | AA |
| | 222 – Fruit trees and berry plantations | AA |
| | 223 – Olive groves | AA |
| | 231 – Pastures | SH |
| | 241 – Annual crops associated with permanent crops | AA |
| | 242 – Complex cultivation patterns | AA |
| | 243 – Land principally occupied by agriculture, with significant areas of natural vegetation | AA |
| | 244 – Agro-forestry areas | AA |
| Forest and semi natural areas | 311 - Broad-leaved forest | FA |
| | 312 – Coniferous forest | FA |
| | 313 – Mixed forest | FA |
| | 321 – Natural grasslands | SH |
| | 322 – Moors and heathland | SH |
| | 323 – Sclerophyllous vegetation | SH |
| | 324 – Transitional woodland-shrub | SH |
| | 331 – Beaches, dunes, sands | OS |
| | 332 – Bare rocks | OS |
| | 333 – Sparsely vegetated areas | OS |
| | 334 – Burnt areas | OS |
| | 335 – Glaciers and perpetual snow | OS |
| Wetlands | 411 – Inland marshes | W |
| | 412 – Peat bogs | W |
| | 421 – Salt marshes | W |
| | 422 – Salines | W |
| | 423 – Intertidal flats | W |
| Water bodies | 511 – Water courses | W |
| | 512 – Water bodies | W |
| | 521 – Coastal lagoons | W |
| | 522 – Estuaries | W |
| | 523 – Sea and ocean | W |

In addition to the spatial change analysis of land cover classes, temporal transitions between cover types were also examined. These changes were conducted based on the land cover classes specified in Table 1, taking the years 2006-2018 as a reference. Furthermore, Türkiye's annual deforestation rate was determined at the national and provincial levels. Although this rate can be calculated using several formulas (Liu et al., 1993; FAO, 1995; Menon and Bawa, 1997; Armenteras et al., 2006; Lele and Joshi, 2009), the widely used Formula (1) (Puyravaud, 2003) was employed in this study. That is:

$$r = \left(\frac{1}{t_2 - t_1} ln \frac{A_2}{A_1}\right) * 100 \quad (1)$$

where P is the percentage of forest loss per year, and A1 and A2 are the amount of forest cover at time t1 and t2, respectively.

### *2.3. Analysis of macro-economics factors-land cover change relations*

As specified in the study objectives, macroeconomic factors causing land cover change between 2006 and 2018 were determined by identifying macroeconomic variables. In determining these economic variables that could affect land cover change, attention was given to the availability of data for the relevant years for each province provided by the Turkish Statistical Institute or other institutions. If data for the relevant year were unavailable, data from the nearest one or two years were used. Within this scope, 18 variables were identified for use in the analyses. These include (1) plant production value (1000 TL/year) (PPV), (2) production quantity of cereals and other plant products (tons/year) (PQ), (3) total cultivated agricultural land size (year/hectares (ha)) (CAL), (4) production quantity of greenhouse vegetables and fruits (year/tons) (PGV) , (5) the number of large livestock (NLL), (6) total value of animal products (TL) (VAP), (7) number of small livestock (NSL), (8) gross domestic product (GDP) (TL), (9) GDP per capita (TL) (GDPC), (10) the number of automobiles (NA), (11) number of motor vehicles (NM), (12) the number of motor vehicles per capita (NMC), (13) total electricity consumption per capita (kWh) (TEC), (14) number of buildings according to occupancy permits (BOP), (15) number of buildings according to construction permits (BCP), (16) export revenues (TL) (ER), (17) export revenues per capita (TL) (ERC) (TUİK, 2023), and (18) development levels of provinces (DLP) (STB, 2023).

A correlation analysis was applied to reveal the relationship between the changes in land cover and the economic factors that influenced these changes between 2006 and 2018. If the correlation value is between (+-)0.00-0.25, the correlation level is very weak, between (+-) 0.26-0.49 weak, between (+-) 0.50-0.69 moderate, between (+-) 0.70-0.89 high, and between (+-) 0.90-1.00 it is considered very high (Özdamar, 2002; Büyüköztürk, 2010). The analysis used 12 dependent and independent variables (economic variables) mentioned above. The dependent variables in the correlation analysis are the changes in artificial surfaces (AS), agricultural areas (AA), forest areas (FA), shrub and/or herbaceous vegetation associations (SH), open spaces with little or no vegetation (OS), and wetlands (W) land cover classes between 2006 and 2018 and their values per square kilometer (psq).

The stepwise method from multiple regression techniques was employed in the analysis aimed at estimating the changes in land cover due to economic variables (Özdamar, 2002; Büyüköztürk, 2010). Independent variables that did not show a normal distribution and had multicollinearity issues were removed from the analysis. The first 15 independent variables and the 12 dependent variables mentioned above were used in the modeling.

## 3. Results and Discussion

As a results of this study, produced land cover maps of Türkiye for the years 2006 and 2018 are given in Figure 2, and the area-based land cover results are shared in Table 2 below. According to the results, the total area of Türkiye's the FA class in 2018 was 11522103 ha. This area represents approximately 15% of Türkiye's total land area. Between 2006 and 2018, the AS class experienced an increase of 20.42% (263461 ha), the AA class grew by 0.15% (47716 ha), the SH class increased by 0.87% (169176 ha), and the W class expanded by 4.39% (76932 ha). Conversely, the FA class decreased by 0.96% (111932 ha), and the OS class declined by 3.78% (445353 ha).

Changes in LULC and transitions between land use classes between 2006-2018 are presented in Figure 3 and Table 3, and the provincial basis is presented in Table 4.

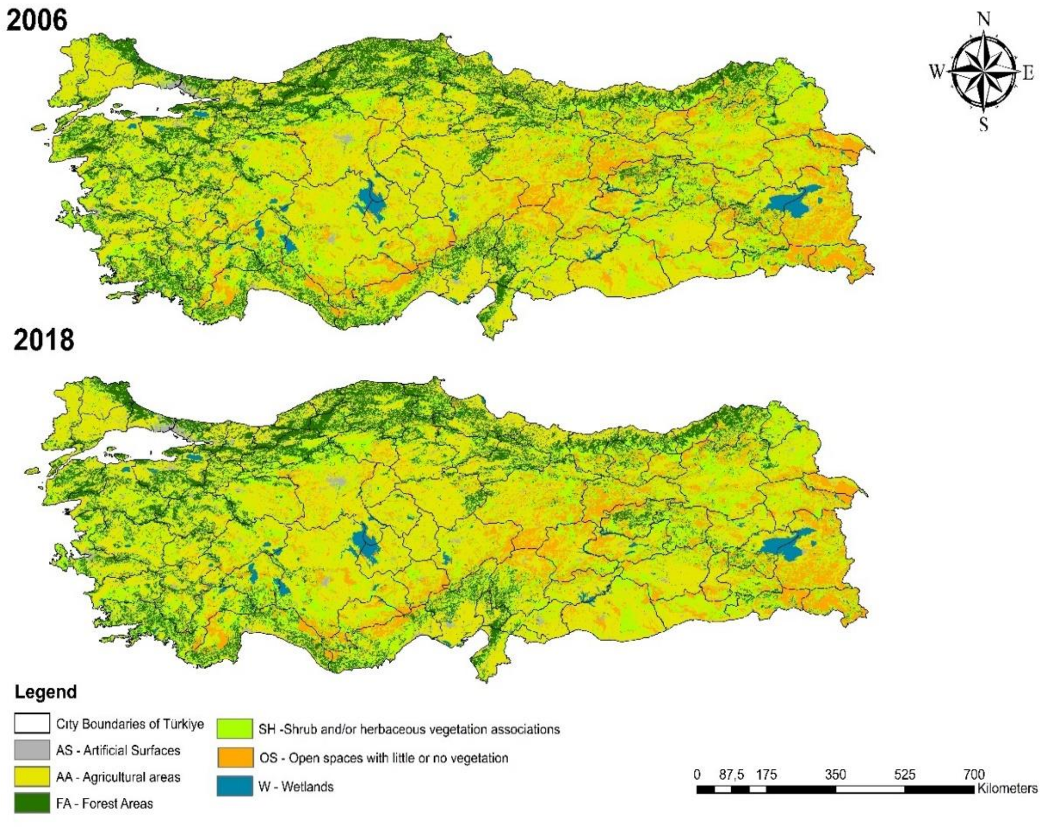


Figure 2. 2006 and 2018 land cover maps of Türkiye and its cities derived from CLC.

Table 2. Area coverage of land cover classes for 2006 and 2018 and cover change within 12 years

| | | Area (ha) | | Change (%) |
|---|---|---|---|---|
| | | 2006 | 2018 | |
| LULC Classes | Artificial Surfaces (AS) | 1290342 | 1,553805 | 20.42 |
| | Agricultural areas (AA) | 32017143 | 32064930 | 0.15 |
| | Forest Areas (FA) | 11634050 | 11522103 | -0.96 |
| | Shrub and/or herbaceous vegetation associations (SH) | 19531874 | 19701165 | 0.87 |
| | Open spaces with little or no vegetation (OS) | 11775822 | 11330566 | -3.78 |
| | Wetlands (W) | 1750661 | 1827620 | 4.39 |
| | Total | 77999892 | 78000189 | |

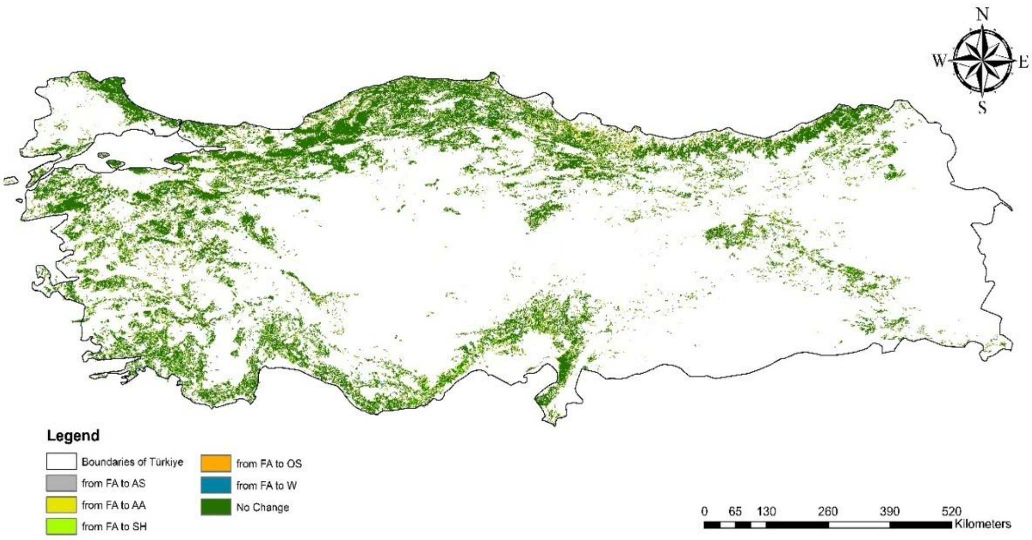


Figure 3. Forest Areas (FA) land cover class change map of Türkiye from 2006 to 2018

Table 3. The change matrix of land cover classes for Türkiye from 2006 to 2018

| | | 2018 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AS | | AA | | FA | | SH | | OS | | W | | Total | |
| | | Area (ha) | % | Area (ha) | % | Area (ha) | % | Area (ha) | % | Area (ha) | % | Area (ha) | % | Area (ha) | % |
| 2006 | AS | | | 44678 | 3.46 | 2779 | 0.22 | 19013 | 1.47 | 5112 | 0.40 | 4589 | 0.36 | 76171 | 5.90 |
| | AA | 205151 | 0.64 | | | 118151 | 0.37 | 400597 | 1.25 | 137402 | 0.43 | 66429 | 0.21 | 927730 | 2.90 |
| | FA | 23724 | 0.20 | 148781 | 1.28 | | | 422723 | 3.63 | 15834 | 0.14 | 7186 | 0.06 | 618248 | 5.31 |
| | SH | 78759 | 0.40 | 552007 | 2.83 | 365842 | 1.87 | | | 377078 | 1.93 | 30123 | 0.15 | 1403809 | 7.19 |
| | OS | 29138 | 0.25 | 211538 | 1.80 | 18396 | 016 | 718173 | 6.10 | | | 15696 | 0.13 | 992941 | 8.43 |
| | W | 286 | 0.02 | 18442 | 1.05 | 1148 | 6.22 | 12479 | 0.71 | 12162 | 0.69 | | | 44517 | 2.54 |

Table 4. City-level status of the land cover classes for 2006 and 2018 based on CLC

| City | Land Cover Change (ha) | | | | | | Transition matrix of Land Cover Classes (ha) | | | | | | | | | | | Deforestation rate (for FA) (%) | Coastal or Not |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AS | AA | FA | SH | OS | W | FA-AS | FA-AA | FA-SH | FA-OS | FA-W | AS-FA | AA-FA | SH-FA | OS-FA | W-FA | No Change | | |
| Adana | 7888 | -22720 | 183 | 13274 | -2554 | 3929 | 1001 | 4155 | 25275 | 566 | 1309 | 130 | 10978 | 20424 | 885 | 72 | 1250598 | 0.006 | + |
| Adıyaman | 2359 | 317 | 629 | -2334 | -860 | -111 | 15 | 92 | 217 | 53 | 0 | 0 | 107 | 792 | 104 | 3 | 703011 | 0.514 | - |
| Afyonkarahisar | 3009 | 1885 | 2009 | -8296 | 948 | 445 | 163 | 335 | 1561 | 128 | 2 | 18 | 394 | 3674 | 111 | 1 | 1361346 | 0183 | - |
| Ağrı | 3971 | 6420 | 0 | -6214 | -4666 | 517 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1075077 | 0.000 | - |
| Aksaray | 1143 | 5354 | 135 | -1909 | -6462 | 1739 | 0 | 8 | 116 | 1 | 0 | 0 | 3 | 238 | 19 | 0 | 727829 | 0.504 | - |
| Amasya | 929 | 451 | 964 | 5724 | -8385 | 317 | 144 | 1189 | 3830 | 434 | 37 | 6 | 1243 | 4989 | 353 | 7 | 531150 | 0.061 | - |
| Ankara | 17618 | -11524 | 303 | 8743 | -17846 | 2706 | 13 | 287 | 2245 | 48 | 4 | 17 | 270 | 2558 | 53 | 2 | 2473675 | 0.018 | - |
| Antalya | 6896 | -1734 | -4585 | -573 | -2001 | 1997 | 983 | 3333 | 29939 | 2138 | 413 | 126 | 2965 | 28566 | 526 | 38 | 1914548 | -0.069 | + |
| Ardahan | 1232 | 10454 | 253 | -5327 | -2175 | -4413 | 76 | 97 | 588 | 38 | 0 | 1 | 56 | 945 | 48 | 0 | 464332 | 0.069 | - |
| Artvin | 589 | -2485 | -315 | 3144 | -3642 | 2730 | 272 | 1775 | 4261 | 411 | 89 | 174 | 1928 | 3964 | 406 | 12 | 710223 | -0.008 | + |
| Aydın | 2794 | 2378 | -5753 | 2591 | -2661 | 651 | 142 | 1342 | 7173 | 37 | 30 | 43 | 713 | 2090 | 115 | 10 | 782250 | -.375 | + |
| Balıkesir | 7504 | -3068 | -5109 | -1155 | 231 | 1597 | 1103 | 3410 | 14152 | 35 | 344 | 40 | 2976 | 10843 | 53 | 23 | 1394204 | -0.106 | + |
| Bartın | 355 | -883 | 399 | 115 | -1 | 15 | 162 | 1118 | 426 | 2 | 35 | 15 | 1777 | 331 | 2 | 17 | 228511 | 0.027 | + |
| Batman | 1201 | 803 | 1145 | 22517 | -25676 | 10 | 1 | 12 | 282 | 14 | 0 | 0 | 78 | 1281 | 95 | 0 | 415167 | 1.204 | - |
| Bayburt | 200 | -719 | 83 | 33673 | -33630 | 393 | 0 | 71 | 221 | 69 | 0 | 1 | 40 | 337 | 66 | 0 | 331010 | 0.060 | - |
| Bilecik | -313 | 6280 | -899 | -1003 | -4325 | 260 | 352 | 2724 | 3693 | 16 | 47 | 42 | 2277 | 3589 | 25 | 0 | 385597 | -0.052 | - |
| Bingöl | 1304 | -1427 | 4095 | -4977 | 63 | 942 | 129 | 340 | 2726 | 538 | 71 | 6 | 595 | 6508 | 770 | 20 | 771055 | 0.337 | - |
| Bitlis | 1336 | 1099 | -12520 | 17987 | -7715 | -187 | 49 | 160 | 13651 | 1758 | 22 | 3 | 164 | 2061 | 889 | 3 | 789941 | -1.228 | - |
| Bolu | 2006 | -1411 | -109 | -1777 | 61 | 1230 | 200 | 1641 | 2771 | 39 | 46 | 31 | 1457 | 3061 | 35 | 4 | 812697 | -0.002 | - |
| Burdur | 2120 | 1235 | -3938 | 2475 | -2599 | 707 | 203 | 490 | 7795 | 106 | 66 | 7 | 437 | 4132 | 122 | 24 | 694162 | -0.255 | - |
| Bursa | 7664 | 2027 | -8539 | -2606 | -188 | 1642 | 1329 | 7086 | 8109 | 90 | 353 | 65 | 2720 | 5608 | 17 | 18 | 1036093 | -0.197 | + |
| Çanakkale | 1067 | 1699 | -7187 | 2997 | -9 | 1433 | 233 | 2259 | 14500 | 21 | 307 | 48 | 1753 | 8296 | 11 | 25 | 942955 | -0.177 | + |
| Çankırı | 1788 | -976 | 809 | 6551 | -8462 | 290 | 70 | 128 | 1194 | 96 | 62 | 0 | 211 | 1993 | 153 | 2 | 727288 | 0.078 | - |
| Çorum | 951 | 451 | 579 | -2703 | -6780 | 7502 | 143 | 2049 | 1823 | 188 | 204 | 8 | 1129 | 3591 | 257 | 1 | 1191319 | 0.023 | - |
| Denizli | 3142 | 1134 | -1396 | 2011 | -4576 | -315 | 36 | 2527 | 15714 | 217 | 75 | 21 | 2273 | 14574 | 296 | 9 | 1148009 | -0.042 | - |
| Diyarbakır | 6881 | 5053 | 209 | -12161 | -514 | 532 | 0 | 69 | 546 | 89 | 4 | 0 | 43 | 814 | 60 | 0 | 1453932 | 0.081 | - |

Table 4 continued

| City | Land Cover Change (ha) AS | AA | FA | SH | OS | W | Transition matrix of Land Cover Classes (ha) FA-AS | FA-AA | FA-SH | FA-OS | FA-W | AS-FA | AA-FA | SH-FA | OS-FA | W-FA | No Change | Deforestation rate (for FA) (%) | Coastal or Not |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Düzce | 1518 | -1727 | -788 | 865 | 1 | 131 | 63 | 526 | 936 | 1 | 8 | 5 | 644 | 94 | 0 | 3 | 244393 | -0.055 | + |
| Edirne | 1911 | 1075 | 607 | -4629 | -137 | 1173 | 29 | 605 | 2368 | 82 | 77 | 4 | 546 | 3204 | 0 | 14 | 595170 | 0.099 | - |
| Elazığ | 2555 | 6430 | 992 | 955 | -10365 | -567 | 2 | 40 | 225 | 41 | 19 | 4 | 295 | 969 | 45 | 6 | 901333 | 0.537 | - |
| Erzincan | 3558 | -3877 | -2998 | 3420 | -954 | 851 | 58 | 465 | 4884 | 798 | 2 | 1 | 402 | 2309 | 495 | 2 | 2390649 | -0.202 | - |
| Erzurum | 3518 | 167 | -1454 | 7666 | -10609 | 712 | 37 | 887 | 4603 | 37 | 5 | 16 | 975 | 3061 | 56 | 7 | 1349033 | -0.083 | - |
| Eskişehir | 10449 | -25537 | 1183 | 10733 | 2925 | 268 | 104 | 261 | 1138 | 20 | 4 | 68 | 515 | 2114 | 13 | 0 | 622438 | 0.426 | - |
| Gaziantep | 2255 | -1966 | -973 | 13240 | -12391 | -165 | 8 | 162 | 1602 | 440 | 4 | 0 | 135 | 979 | 126 | 3 | 1127010 | -0.214 | - |
| Giresun | 2779 | -2252 | -117 | 4643 | -5408 | 355 | 148 | 4377 | 1919 | 146 | 14 | 10 | 3421 | 2863 | 189 | 4 | 671246 | -0.005 | + |
| Gümüşhane | 944 | -3457 | 10027 | -6438 | -2009 | 933 | 215 | 456 | 1483 | 227 | 194 | 9 | 2277 | 9798 | 515 | 3 | 634503 | 0.672 | - |
| Hakkari | 1294 | 4577 | 3764 | 18930 | -27906 | -650 | 0 | 338 | 1974 | 669 | 0 | 0 | 74 | 6270 | 401 | 0 | 628335 | 1.523 | - |
| Hatay | 1712 | 1653 | -6266 | 3729 | -1220 | 420 | 229 | 2866 | 6171 | 73 | 12 | 42 | 653 | 2367 | 46 | 1 | 529485 | -0.372 | + |
| Iğdır | 1118 | 3370 | 350 | -2408 | -1637 | -779 | 0 | 0 | 0 | 1 | 0 | 0 | 33 | 307 | 2 | 9 | 351335 | 19.982 | - |
| Isparta | 2242 | 799 | 1543 | -2685 | -2351 | 452 | 297 | 754 | 3835 | 130 | 66 | 20 | 364 | 5831 | 384 | 26 | 869866 | 0.116 | - |
| İstanbul | 14164 | -4247 | -1075 | -8850 | 37 | -29 | 6946 | 1369 | 5275 | 33 | 230 | 693 | 1078 | 10801 | 13 | 193 | 498524 | -0.041 | + |
| İzmir | 5851 | -2245 | -12741 | 10382 | -2275 | 1028 | 950 | 2192 | 21795 | 193 | 48 | 233 | 2570 | 9390 | 221 | 23 | 1124985 | -0.447 | + |
| Kahramanmaraş | 5396 | -5111 | 7716 | -1008 | -9533 | 2540 | 66 | 1417 | 3733 | 111 | 127 | 5 | 2365 | 10552 | 210 | 38 | 1397440 | 0.356 | - |
| Karabük | 889 | -2965 | 653 | 1389 | -50 | 84 | 144 | 758 | 3333 | 33 | 122 | 4 | 2696 | 2272 | 34 | 37 | 397336 | 0.024 | - |
| Karaman | 865 | 1641 | 4719 | 7792 | -22449 | 7432 | 10 | 445 | 1680 | 582 | 635 | 4 | 423 | 7435 | 209 | 0 | 777816 | 0.754 | - |
| Kars | 3850 | 859 | -555 | -5300 | 935 | 255 | 0 | 86 | 1224 | 34 | 0 | 3 | 36 | 729 | 21 | 0 | 963091 | -0.150 | - |
| Kastamonu | 1499 | 8095 | 2568 | -8907 | -3618 | 363 | 446 | 6996 | 4835 | 297 | 41 | 24 | 5687 | 9175 | 264 | 33 | 1258314 | 0.031 | + |
| Kayseri | 5996 | 10415 | -825 | -17756 | 840 | 1330 | 88 | 127 | 1480 | 313 | 71 | 0 | 362 | 816 | 76 | 0 | 1596848 | -0.290 | - |
| Kırıkkale | 1465 | -1825 | 132 | 3578 | -3479 | 129 | 0 | 48 | 301 | 5 | 0 | 0 | 40 | 439 | 7 | 0 | 465521 | 0.086 | - |
| Kırklareli | 714 | 146 | 7399 | -9746 | -107 | 1594 | 67 | 717 | 2284 | 11 | 37 | 5 | 672 | 9793 | 8 | 37 | 624957 | 0.305 | + |
| Kırşehir | 718 | -395 | 111 | -700 | -1821 | 2087 | 2 | 39 | 81 | 8 | 3 | 1 | 44 | 189 | 2 | 8 | 641282 | 0.092 | - |
| Kilis | 409 | -218 | 238 | 156 | -568 | -18 | 0 | 28 | 49 | 0 | 1 | 0 | 31 | 272 | 14 | 0 | 136250 | 0.602 | - |
| Kocaeli | 3579 | 3761 | -8974 | 1410 | -65 | 289 | 690 | 5512 | 7105 | 0 | 55 | 55 | 1386 | 2939 | 2 | 6 | 313187 | -0.597 | + |
| Konya | 9592 | 9845 | 8239 | -44194 | 19100 | -2582 | 85 | 577 | 3836 | 175 | 13 | 8 | 710 | 12008 | 188 | 11 | 3889023 | 0.686 | - |
| Kütahya | 3436 | 18480 | -1812 | -5748 | -14941 | 585 | 666 | 3500 | 6773 | 105 | 68 | 59 | 2122 | 6893 | 224 | 2 | 1094072 | -0.047 | - |
| Malatya | 2088 | 2521 | -219 | -5704 | 719 | 595 | 18 | 86 | 388 | 47 | 0 | 0 | 28 | 251 | 41 | 0 | 1160180 | -0.169 | - |
| Manisa | 3773 | 536 | -14054 | 8410 | 497 | 838 | 392 | 3266 | 17646 | 60 | 66 | 44 | 2225 | 5027 | 72 | 8 | 1284202 | -0.512 | - |
| Mardin | 3498 | -8611 | -74 | -19215 | 24573 | -166 | 0 | 32 | 100 | 0 | 0 | 0 | 1 | 57 | 0 | 0 | 805825 | -0.259 | - |
| Mersin | 8571 | 2177 | -44160 | 50486 | -18314 | 1240 | 1044 | 7012 | 72435 | 584 | 134 | 120 | 9681 | 26443 | 790 | 15 | 1358465 | -1.119 | + |
| Muğla | 2980 | -6255 | -8841 | 16257 | -5217 | 1076 | 819 | 2041 | 17595 | 181 | 98 | 188 | 3232 | 8027 | 380 | 66 | 1208272 | -0.167 | + |
| Muş | 2711 | -3557 | -2936 | 4949 | -9764 | 8597 | 7 | 85 | 4835 | 168 | 6 | 0 | 92 | 1789 | 284 | 0 | 812093 | -0.755 | - |
| Nevşehir | 2636 | -4669 | 0 | -1458 | 2374 | 1117 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 526608 | 0.000 | - |
| Niğde | 2937 | 6962 | -161 | -19858 | 10021 | 99 | 18 | 54 | 532 | 50 | 0 | 0 | 73 | 371 | 49 | 0 | 670706 | -0.177 | - |
| Ordu | 602 | 14166 | -12709 | -2053 | -283 | 277 | 229 | 17641 | 3669 | 34 | 23 | 84 | 5244 | 3523 | 32 | 4 | 539345 | -0.620 | + |
| Osmaniye | 2610 | -2157 | -2776 | 2586 | -315 | 52 | 239 | 2229 | 5456 | 37 | 48 | 12 | 1576 | 3575 | 38 | 32 | 311678 | -0.209 | - |
| Rize | 159 | 1476 | -1690 | 2887 | -2728 | -104 | 27 | 1963 | 654 | 32 | 30 | 1 | 497 | 464 | 24 | 30 | 374826 | -0.083 | + |
| Sakarya | 5699 | -6979 | 1061 | -235 | -425 | 879 | 282 | 3299 | 2594 | 8 | 49 | 13 | 3389 | 3863 | 0 | 28 | 457510 | 0.050 | + |
| Samsun | 1551 | 12620 | -8315 | -3443 | -3389 | 976 | 214 | 16867 | 2350 | 228 | 401 | 58 | 6727 | 4548 | 315 | 97 | 920268 | -0.211 | + |
| Siirt | 1506 | 6491 | -833 | -6045 | -2063 | 944 | 0 | 345 | 1429 | 219 | 0 | 0 | 42 | 986 | 132 | 0 | 552403 | -0.165 | - |
| Sinop | 5941 | 4591 | 2664 | 26774 | -40746 | 776 | 83 | 650 | 4344 | 595 | 1 | 9 | 827 | 6978 | 520 | 3 | 2648775 | 0.196 | + |
| Sivas | 1483 | -4057 | 2211 | 1795 | -3974 | 2542 | 389 | 2246 | 5560 | 39 | 606 | 26 | 4699 | 6230 | 62 | 34 | 536214 | 0.063 | - |
| Şanlıurfa | 10793 | 12404 | 863 | 6878 | -34457 | 3520 | 0 | 10 | 18 | 1 | 0 | 2 | 21 | 745 | 124 | 0 | 1840244 | 4.949 | - |
| Şırnak | 2947 | 2631 | 2121 | -6294 | -1478 | 91 | 7 | 30 | 2383 | 125 | 0 | 1 | 13 | 3787 | 866 | 0 | 668382 | 0.314 | - |
| Tekirdağ | 3183 | 1904 | 3801 | -11269 | -107 | 2488 | 108 | 1171 | 905 | 3 | 48 | 14 | 458 | 5552 | 8 | 4 | 594754 | 0.447 | + |
| Tokat | 4916 | 8895 | -2100 | -6634 | -5155 | 78 | 430 | 9076 | 6529 | 325 | 75 | 5 | 5008 | 7946 | 1351 | 25 | 931468 | -0.056 | - |
| Trabzon | 1419 | -426 | -731 | 1425 | -1516 | -171 | 139 | 3128 | 1509 | 5 | 4 | 28 | 2594 | 1418 | 9 | 5 | 448266 | -0.034 | + |
| Tunceli | -21 | -5726 | 3755 | 34382 | -34526 | 2136 | 82 | 609 | 6567 | 1090 | 172 | 8 | 1084 | 8088 | 3081 | 14 | 682059 | 0.199 | - |
| Uşak | 2415 | -5066 | 1731 | 1259 | -487 | 148 | 199 | 1029 | 2941 | 60 | 11 | 6 | 1282 | 4580 | 94 | 9 | 525039 | 0.174 | - |
| Van | 4101 | -10733 | -87 | 59669 | -53508 | 643 | 0 | 10 | 189 | 25 | 0 | 0 | 89 | 33 | 15 | 0 | 1955614 | -0.381 | - |
| Yalova | 956 | 338 | -2634 | 1137 | 0 | 203 | 479 | 1015 | 2103 | 0 | 13 | 21 | 264 | 688 | 0 | 3 | 72905 | -0.499 | + |
| Yozgat | 3245 | 13065 | -354 | -8675 | -10516 | 3235 | 57 | 1274 | 1719 | 219 | 1 | 12 | 663 | 1368 | 872 | 1 | 1309635 | -0.023 | - |
| Zonguldak | 854 | -338 | -588 | -6 | 7 | 71 | 293 | 1368 | 543 | 2 | 24 | 52 | 1199 | 377 | 1 | 13 | 328490 | -0.031 | + |

*Area based calculations are given in hectares.

As shown in Table 3, and Figure 3 between 2006 and 2018, 0.2% (23724 ha) of FA class converted to AS class, 1.28% (148781 ha) to AA class, 0.14% (15834 ha) to OS class, and 3.63% (422723 ha) to SH class. The highest conversion rate occurred from FA to SH classes, indicating structural degradation of forests. The subsequent significant change occurred due to deforestation for agricultural land conversion, aimed at generating higher income.

Regarding AA class, 0.64% (205151 ha) of AA converted to AS land cover class, 0.37% (118151 ha) to FA class, 1.25% (400597 ha) to SH class, and 0.43% (137402 ha) to OS class. The primary reason for AA class transitions to FA and SH classes can be attributed to the transformation of agricultural lands back to forest areas due to rural-to-urban migration.

During the same period, 0.4% (78759 ha) of SH class converted to AS class, 2.83% (552007 ha) to AA class, 1.87% (365842 ha) to FA class, and 1.93% (377078 ha) to OS class. Since the SH class is much easier to convert into agricultural land, approximately four times more area was converted to the AA class than the FA class.

In addition, 1148 ha of W class area changed to FA class within the same period. If this trend continues, it could exacerbate future water shortages resulting from climate change.

When examining coastal and non-coastal regions, forest areas increased by 25.9% in coastal regions while decreasing in the others. In non-coastal provinces, forests increased by 55.6% and dropped in the rest. These results indicate a higher rate of forest decline in coastal regions, with tourism being a significant contributing factor.

Between 2006 and 2018, the most substantial increase in AS occurred in Aydin (17618 ha), Usak (14164 ha), and Rize (10,793 ha). Only two cities experienced a decrease in AS: Diyarbakir (313 ha) and Ordu (21 ha).

Similar results were found in a study conducted in Mount Bambouto Caldera in Cameroon. Between 1980 and 2016, croplands increased by 4%, settlements by 0.43%, and bare lands by 5.7%, while savanna/grassland areas decreased by 4.4% and natural forests by 5.8%. The study highlights an increasing trend in bare lands, buildings, and agricultural lands due to anthropogenic activity, with a decline in savannas and dense woody vegetation. The primary cause is the increased use of land resources, particularly the conversion of grasslands and natural forests to agricultural areas, settlements, and agroforestry (Toh et al., 2018).

Another study in Tanzania found a decreasing trend in forests, shrublands, and wetlands from 1990 to 2016. Between 1990 and 2010, forest areas decreased by 2752 km², with 56% of these forests converting to shrublands, 23.2% to grasslands, and 18.9% to agricultural lands. Between 2010 and 2016, forest areas decreased by 377 km², with 39.5% converting to grasslands, 30.5% to shrublands, and 27.0% to agricultural lands. However, from 2010 to 2016, 1359 km² of shrubland areas were converted back to forests. During the same period, 72.6% of wetlands were converted to grasslands and 18.9% to agricultural lands, resulting in a decrease of 705 km² (Msofe et al., 2019).

When examining Table 4, between 2006 and 2018, the top three provinces with the highest deforestation rates were seen Bitlis (-1.23%), Mersin (-1.12%), and Muş (-0.76%) respectively. The top three provinces with the highest afforestation rates were Iğdır (19.98%), Şanlıurfa (4.95%), and Hakkari (1.52%). The deforestation rate in Türkiye during the same period was -0.08%. In addition, the deforestation rate in 63% of all provinces (54 provinces) was higher than the national average. Between 2006 and 2018, the percentage of provinces with increasing forest areas was 47% (38 provinces), decreasing forest areas was 51% (41 provinces), and unchanged forest areas were 2% (2 provinces).

Between 2000 and 2021, the global tree cover loss was calculated as 11% (WRI, 2023). According to FAO data, the global deforestation rate between 2015 and 2020 was 10 million ha per year (0.25%) (FAO, 2022). In this context, Türkiye's situation appears relatively favorable. However, when comparing our findings with data from the General Directorate of Forestry (GDF), which manages Türkiye's forests, it is stated that forest areas increased by 1.7 million ha between 2004 and 2020 (GDF, 2020). This contradicts this study’s findings. The discrepancy may be attributed to GDF's definition of forested areas, which considers both productive and degraded areas together and does not include forest losses due to mining, tourism, and construction within the official forest area boundaries (Plieninger et al., 2016).

### *3.1. Impacts of macro-economic factors on land cover change*

In Türkiye, significant transformations have occurred in rural and urban areas after the development of industrialization and tourism, particularly in the post-1980 period. Especially after incentives provided by the government, excessive and irregular construction in the provincial centers and increased income levels led to higher utilization and degradation of natural resources (Çekirge, 2013; Dokuyucu, 2023). Forests, in particular, have been structurally damaged and spatially reduced due to various reasons, such as construction, clearing land for agriculture, usage as fuel, illegal logging, opening up to tourism, and mining (Şen and Toksoy, 2006; Şen, 2022).

Looking at the changes in the Turkish average of macroeconomic variables that we believe could be effective in this transformation between 2006 and 2008, the value of plant production increased by 191.9%, the production amount of cereals and other plant products increased by 49.1%, greenhouse vegetable, and fruit production increased by 80.6%, the number of large cattle increased by 57%, the value of animal products increased by 106%, the number of small cattle increased by 43%, the GDP ($) increased by 44.3%, the GDP per capita ($) increased by 23.5%, the number of automobiles increased by 101.9 percent, the number of motor vehicles increased by 87%, the number of motor vehicles per capita increased by 74.3%, and the total electricity consumption per capita (kWh) increased by 56.4%. In contrast, it was determined that the entire cultivated agricultural land decreased by 14.2%, the number of buildings according to the building permits decreased by 8.5%, export revenues ($) decreased by 41.6%, and export revenues per capita ($) decreased by 35.8%.

A correlation analysis was conducted to determine whether the changes in macroeconomic indicators were effective on land cover. The results of correlation analyses at the provincial level and per square kilometer between the changes in land cover and the changes in macroeconomic variables during the 2006-2018 period are presented in Table 5.

According to the results of the correlation analysis conducted for the 2006-2018 period (Table 5), the following relationships have been identified between the macroeconomic variables and the spatial changes in the provinces:

- In agricultural land (AS), statistically significant positive relationships were found with the values of plant production (0.506: moderate intensity), production amounts of cereals and other plant products (0.360; weak intensity), the number of large cattle (0.548: moderate intensity), greenhouse vegetable and fruit production (0.315: weak intensity), total animal product value (0.288: weak intensity), the number of small cattle (0.442: weak intensity), Gross Domestic Product (GDP) (moderate intensity), the number of automobiles (0.589: moderate intensity), the number of motor vehicles (0.624: moderate intensity), export revenues (0.506: moderate intensity), and export revenues per capita (0.267: weak intensity). A statistically significant negative relationship was found with the change in the total cultivated agricultural land (-0.422: weak intensity).
- In residential areas (AA), a statistically significant positive relationship was found with the change in total animal product value (0.228: weak intensity), and a statistically significant negative relationship was found with the change in export revenues per capita (-0.228: weak intensity).
- In forest areas (FA), statistically significant negative relationships were found with the change in Gross Domestic Product (-0.310: weak intensity), the number of automobiles (-0.308: weak intensity), the number of motor vehicles (-0.326: weak intensity), and the number of buildings according to building usage permits (-0.287: weak intensity).
- In wetlands (W), no statistically significant relationship was found between the spatial changes and macroeconomic variables.
- In open and green spaces (OS), statistically significant positive relationships were found with the change in total animal product value (0.02), Gross Domestic Product (0.037: very weak intensity), the number of buildings according to building usage permits (0.035: very weak intensity), export revenues (0.011: very weak intensity), and export revenues per capita (0.009: very weak intensity).
- In the spatial changes of agricultural land (AS) per square kilometer, statistically significant positive relationships were found with export revenues (0.346: weak intensity) and export revenues per capita (0.333: weak intensity).

- In the spatial changes of residential areas (AA) per square kilometer, a statistically significant negative relationship was found with the change in the number of buildings according to building usage permits (-0.222: very weak intensity).
- In the spatial changes of forest areas (FA) per square kilometer, statistically significant positive relationships were found with the number of buildings according to building usage permits (0.223: very weak intensity) and the number of buildings according to building permits (-0.254: very weak intensity), while a statistically significant negative relationship was found with the change in total electricity consumption per capita (-0.223: very weak intensity).
- In the spatial changes of wetlands (W) per square kilometer, statistically significant positive relationships were found with the change in total electricity consumption per capita (0.228: very weak intensity) and the change in export revenues per capita (-0.257: very weak intensity), while a statistically significant negative relationship was found with the change in total animal product value (-0.292: very weak intensity).
- In the spatial changes of open and green spaces (OS) per square kilometer, no statistically significant relationship was found with the changes in macroeconomic variables.

The changes occurring in Artificial Surfaces (AS) generally increase in parallel with the value increases of economic variables at the provincial level. This could particularly be associated with the augmentation of housing stock and infrastructure due to economic development. Conversely, the same increase in AS demonstrates an inverse relationship with the amount of cultivated agricultural land. Additionally, migrations caused by urbanization and the aging of the rural population could be factors reducing the amount of cultivated agricultural land.

The change in the amount of animal products, directly proportional to changes in agricultural areas, is significant as it reveals the intertwined nature of agriculture and animal husbandry. The complementarity of these two sectors is vital for planning efforts to prevent the reduction of agricultural areas.

When we examine the variables where meaningful relationships are found between changes in forest areas and economic indicators, they are generally related to Gross Domestic Product (GDP), automobiles, and buildings, all of which are indicators of affluence. This pattern of behavior is prevalent worldwide and is similarly observed in Türkiye. As people's income increases, they have built more roads and buildings. Furthermore, when commercial structures, Renewable Energy Resources (RES), Hydroelectric Power Plants (HPS), and particularly highways constructed for transit transportation are added to the mix, it becomes inevitable to mitigate impacts on forests. This is because, in general, new tourism, energy, and other government-supported investments are primarily implemented in forested areas owned by the state.

Table 5**.** Correlation analysis results between land cover changes (2006-2018) and macroeconomic variables

| | | PPV | PO | CAL | PGV | NLL | VAP | NSL | GDP | GDPC | NA | NAC | NMV | NMVC | TEC | BOP | BCP | ER | ERC | DLP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land cover change | N | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 |
| AS | Correlation Coefficient | 0.506 | 0.360 | -0.422 | 0.315 | 0.548 | 0.288 | 0.442 | 0.683 | 0.075 | 0.589 | -0.013 | 0.624 | -0.186 | 0.014 | 0.419 | 0.152 | 0.506 | 0.267 | 0.093 |
| | Sig. (2-tailed) | **0** | **0.001** | **0** | **0.004** | **0** | **0.009** | **0** | **0** | 0.504 | **0** | 0.91 | **0** | 0.097 | 0.898 | 0 | 0.177 | **0** | **0.016** | 0.408 |
| AA | Correlation Coefficient | 0.113 | 0.041 | -0.032 | 0.029 | 0.121 | 0.228 | 0.192 | -0.019 | -0.177 | -0.008 | -0.038 | 0.008 | -0.018 | -0.113 | 0.075 | 0.166 | -0.184 | -0.228 | 0.006 |
| | Sig. (2-tailed) | 0.317 | 0.717 | 0.776 | 0.799 | 0.28 | **0.04** | 0.086 | 0.868 | 0.115 | 0.944 | 0.735 | 0.944 | 0.874 | 0.316 | 0.507 | 0.139 | 0.101 | **0.04** | 0.956 |
| FA | Correlation Coefficient | -0.207 | -0.066 | 0.161 | -0.112 | -0.087 | -0.03 | -0.047 | -0.31 | -0.188 | -0.308 | -0.057 | -0.326 | 0.13 | 0.103 | -0.287 | -0.106 | -0.2 | -0.126 | -0.16 |
| | Sig. (2-tailed) | 0.064 | 0.56 | 0.15 | 0.32 | 0.442 | 0.793 | 0.68 | **0.005** | 0.094 | **0.005** | 0.614 | **0.003** | 0.247 | 0.362 | **0.009** | 0.344 | 0.074 | 0.264 | 0.155 |
| SH | Correlation Coefficient | -0.01 | -0.024 | 0.095 | 0.112 | -0.077 | -0.019 | -0.063 | -0.02 | 0.088 | -0.013 | -0.072 | -0.01 | -0.047 | -0.021 | -0.054 | -0.056 | -0.03 | -0.034 | -0.015 |
| | Sig. (2-tailed) | 0.93 | 0.834 | 0.398 | 0.322 | 0.493 | 0.863 | 0.575 | 0.858 | 0.436 | 0.909 | 0.525 | 0.93 | 0.676 | 0.856 | 0.631 | 0.617 | 0.791 | 0.762 | 0.895 |
| OS | Correlation Coefficient | 0.061 | -0.004 | -0.094 | -0.181 | 0.082 | -0.259 | 0.018 | 0.232 | 0.195 | 0.215 | 0.124 | 0.203 | -0.098 | 0.132 | 0.234 | 0.078 | 0.283 | 0.29 | 0.012 |
| | Sig. (2-tailed) | 0.586 | 0.975 | 0.405 | 0.107 | 0.464 | **0.02** | 0.87 | **0.037** | 0.081 | 0.054 | 0.271 | 0.069 | 0.386 | 0.241 | **0.035** | 0.49 | **0.011** | **0.009** | 0.915 |
| W | Correlation Coefficient | 0.319 | 0.241 | -0.256 | 0.199 | 0.23 | 0.089 | 0.154 | 0.186 | 0.143 | 0.249 | 0.236 | 0.249 | -0.072 | 0.102 | 0.056 | -0.102 | 0.07 | -0.007 | 0.012 |
| | Sig. (2-tailed) | **0.004** | **0.03** | **0.021** | 0.075 | **0.039** | 0.43 | 0.17 | 0.097 | 0.202 | **0.025** | **0.034** | **0.025** | 0.523 | 0.364 | 0.617 | 0.363 | 0.533 | 0.952 | 0.914 |
| $AS_{psq}$ | Correlation Coefficient | 0.098 | 0.052 | -0.079 | 0.13 | 0.1 | 0.077 | 0.096 | 0.208 | 0.201 | 0.174 | 0.001 | 0.177 | -0.127 | 0.122 | 0.094 | 0.083 | 0.346 | 0.333 | -0.225 |
| | Sig. (2-tailed) | 0.383 | 0.647 | 0.485 | 0.249 | 0.373 | 0.494 | 0.394 | 0.062 | 0.073 | 0.12 | 0.994 | 0.115 | 0.259 | 0.277 | 0.404 | 0.461 | **0.002** | **0.002** | 0.044 |
| $AA_{psq}$ | Correlation Coefficient | 0.005 | -0.063 | 0.033 | 0.006 | 0.064 | 0.209 | 0.079 | -0.087 | -0.124 | -0.125 | -0.073 | -0.111 | -0.188 | -0.087 | -0.222 | -0.048 | -0.175 | -0.216 | -0.06 |
| | Sig. (2-tailed) | 0.967 | 0.579 | 0.769 | 0.954 | 0.573 | 0.061 | 0.481 | 0.438 | 0.27 | 0.267 | 0.518 | 0.322 | 0.094 | 0.442 | **0.046** | 0.674 | 0.119 | 0.053 | 0.592 |
| $FA_{psq}$ | Correlation Coefficient | 0.082 | 0.078 | -0.052 | 0.041 | -0.013 | -0.059 | -0.077 | 0.206 | -0.027 | 0.187 | -0.194 | 0.193 | -0.099 | -0.223 | 0.223 | 0.254 | 0.146 | 0.019 | 0.022 |
| | Sig. (2-tailed) | 0.469 | 0.486 | 0.645 | 0.716 | 0.909 | 0.598 | 0.496 | 0.065 | 0.81 | 0.095 | 0.083 | 0.084 | 0.38 | **0.045** | **0.045** | **0.022** | 0.194 | 0.866 | 0.842 |
| $SH_{psq}$ | Correlation Coefficient | -0.093 | -0.078 | -0.081 | -0.067 | -0.007 | -0.292 | 0.142 | -0.019 | 0.131 | 0.001 | 0.144 | -0.011 | 0.042 | 0.228 | 0.14 | -0.001 | 0.126 | 0.257 | -0.061 |
| | Sig. (2-tailed) | 0.408 | 0.488 | 0.474 | 0.55 | 0.949 | **0.008** | 0.207 | 0.87 | 0.244 | 0.994 | 0.2 | 0.923 | 0.712 | **0.041** | 0.213 | 0.992 | 0.262 | **0.021** | 0.59 |
| $OS_{psq}$ | Correlation Coefficient | 0.101 | 0.116 | -0.047 | 0.107 | -0.028 | 0.197 | -0.054 | 0.021 | -0.115 | -0.041 | -0.097 | -0.008 | 0.02 | -0.028 | -0.148 | 0.092 | -0.064 | -0.129 | 0.043 |
| | Sig. (2-tailed) | 0.37 | 0.302 | 0.68 | 0.342 | 0.801 | 0.078 | 0.634 | 0.854 | 0.308 | 0.719 | 0.391 | 0.945 | 0.861 | 0.805 | 0.187 | 0.415 | 0.572 | 0.25 | 0.704 |
| $W_{psq}$ | | 0.279 | 0.05 | -0.203 | 0.204 | 0.227 | 0.166 | 0.191 | 0.157 | 0.147 | 0.215 | 0.153 | 0.203 | 0.059 | -0.005 | 0.084 | 0.076 | 0.181 | 0.127 | 0.081 |
| | | **0.012** | 0.659 | 0.068 | | **0.042** | 0.138 | 0.087 | 0.162 | 0.191 | 0.054 | 0.172 | 0.069 | 0.598 | 0.963 | 0.457 | 0.499 | 0.106 | 0.259 | 0.473 |

Significance level: p≤0,05

Similar results have been observed in various other studies. A study conducted in Thailand noted that the transition from subsistence farming to manufacturing and service sectors, mainly due to tourism development in the context of agricultural and economic development, has lifted many people from poverty to the middle-income level. This has, in turn, helped maintain the forest cover at approximately 31-32%, thus staving off deforestation. However, it is also mentioned that forested areas have decreased due to the expansion of agricultural activities, particularly rubber plantations. However, it is anticipated that a decline in rubber prices could potentially lead to an increase in forest areas again (Trisurat et al., 2019). In the changes in land use that occurred in Tanzania between 1990 and 2016, economic variables, such as increasing market demand and price incentives for agriculture and forestry products, is stated to have been influential (Msofe et al., 2019). In another study conducted in India, it is asserted that the fundamental challenges faced by the country's environmental resources are, in many ways, connected to poverty and economic growth. In rural fields of India, the per capita agricultural land has declined from 0.638 ha in 1950-51 to 0.271 ha in 1998-99, while the per capita forest area has shrunk from approximately 0.113 ha to 0.071 ha. These figures are considerably low by global standards. It is reported that in India, 270 million people in rural areas rely on forests for their livelihood, and forests provide these individuals with employment and income. This high dependence has led to the unsustainable exploitation of forests and, ultimately, their degradation (Nagdeve, 2007). These findings demonstrate that land cover or land use changes are closely related to economic changes. However, these relationships vary depending on the conditions of countries, societies, and settlements.

### *3.2. Formulating land cover change prediction models for land use policies*

The formation of land use policies necessitates the reliable collection of existing inventory data and the importance of predictive models based on these data in planning. In this context, change models have been developed for each land use class in this study, taking macroeconomic variables as a basis to determine possible changes in LULC. Regression analysis results (Tables 6, 7, 8, 9) and developed equations are given below.

According to the regression analysis results, the prediction model between the change in AS in 2006-2018 and macroeconomic variables (Formula 2) is as follows;

$AS_{Change} = 1805.632 - 0.017\ NMV_{Change} + 0.001\ PPV_{Change} + 0.01\ BBH + 0.048\ NA_{Change} - 0.001\ PO_{Change} - 13685.657\ NAC_{Change}$ ($R2$:0.768, $p<0.000$) (2)

According to the regression analysis results, the prediction model between the change in FA in 2006-2018 and macroeconomic variables (Formula 3) is as follows;

$FA_{Change} = -760.727 - 0.015 PGV_{Change}$ ($R2$:0.165, $p<0.000$) (3)

According to the regression analysis results, the prediction model between the change in AS in 2006-2018 and macroeconomic variables (Formula 4) is as follows;

$SH_{Change} = 9894.689 + 0.063\ CAL_{Change} + 0.02\ PGV_{Change} - 101164.432$ ($R2$:0.227, $p<0.000$) (4)

Table 6. Regression analysis results between change in AS in 2006-2018 and macroeconomic variables

| ANOVA | | | | | | | Model Summary | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Model | | Sum of squares | df | Mean square | F | Sig. | R | R square | Adjusted R square | Std. error of the estimate |
| 1 | Regression | 445922446.758 | 1 | 445922446.758 | 93.998 | 0.000 | 0.737 | 0.543 | 0.538 | 2178.062 |
| | Residual | 374772402.131 | 79 | 4743954.457 | | | | | | |
| | Total | 820694848.889 | 80 | | | | | | | |
| 2 | Regression | 554389637.530 | 2 | 277194818.765 | 81.190 | 0.000 | 0.822 | 0.676 | 0.667 | 1847.747 |
| | Residual | 266305211.359 | 78 | 3414169.376 | | | | | | |
| | Total | 820694848.889 | 80 | | | | | | | |
| 3 | Regression | 589274932.033 | 3 | 196424977.344 | 65.356 | 0.000 | 0.847 | 0.718 | 0.707 | 1733.624 |
| | Residual | 231419916.856 | 77 | 3005453.466 | | | | | | |
| | Total | 820694848.889 | 80 | | | | | | | |
| 4 | Regression | 618576957.411 | 4 | 154644239.353 | 58.149 | 0.000 | 0.868 | 0.754 | 0.741 | 1630.781 |
| | Residual | 202117891.477 | 76 | 2659445.940 | | | | | | |
| | Total | 820694848.889 | 80 | | | | | | | |
| 5 | Regression | 633145961.429 | 5 | 126629192.286 | 50.638 | 0.000 | 0.878 | 0.771 | 0.756 | 1581.345 |
| | Residual | 187548887.459 | 75 | 2500651.833 | | | | | | |
| | Total | 820694848.889 | 80 | | | | | | | |
| 6 | Regression | 644801572.895 | 6 | 107466928.816 | 45.212 | 0.000 | 0.886 | 0.786 | 0.768 | 1541.732 |
| | Residual | 175893275.994 | 74 | 2376936.162 | | | | | | |
| | Total | 820694848.889 | 80 | | | | | | | |
| 7 | Regression | 657668675.129 | 7 | 93952667.876 | 42.070 | 0.000 | ,0.895 | 0.801 | 0.782 | 1494.401 |
| | Residual | 163026173.760 | 73 | 2233235.257 | | | | | | |
| | Total | 820694848.889 | 80 | | | | | | | |

Significance level: p≤0,05

Table 7. Regression analysis results between change in FA in 2006-2018 and macroeconomic variables

| Anova | | | | | | | Model summary | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Model | | Sum of squares | df | Mean square | F | Sig. | R | R square | Adjusted R square | Std. error of the estimate |
| 1 | Regression | 562759772.125 | 1 | 562759772.125 | 15.557 | 0.000 | 0.406 | 0.165 | 0.154 | 6014.419 |
| | Residual | 2857685182.566 | 79 | 36173230.159 | | | | | | |
| | Total | 3420444954.691 | 80 | | | | | | | |

Significance level: p≤0,05

Table 8. Regression analysis results between change in SH in 2006-2018 and macroeconomic variables

| | Anova | | | | | | Model Summary | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Model | Sum of squares | df | Mean square | F | Sig. | R | R Square | Adjusted R square | Std. error of the estimate |
| 1 | Regression | 2027043486.606 | 1 | 2027043486.606 | 11.896 | 0.001 | 0.362 | 0.131 | 0.120 | 13053.572 |
| | Residual | 13461263724.381 | 79 | 170395743.347 | | | | | | |
| | Total | 15488307210.988 | 80 | | | | | | | |
| 2 | Regression | 2855120028.686 | 2 | 1427560014.343 | 8.814 | 0.000 | 0.429 | 0.184 | 0.163 | 12726.505 |
| | Residual | 12633187182.301 | 78 | 161963938.235 | | | | | | |
| | Total | 15488307210.988 | 80 | | | | | | | |
| 3 | Regression | 3521166465.115 | 3 | 1173722155.038 | 7.552 | 0.000 | 0.477 | 0.227 | 0.197 | 12466.652 |
| | Residual | 11967140745.873 | 77 | 155417412.284 | | | | | | |
| | Total | 15488307210.988 | 80 | | | | | | | |

Significance level: p≤0,05

Table 9. Regression analysis results between change in OS in 2006-2018 and macroeconomic variables

| | Anova | | | | | | Model Summary | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Model | Sum of squares | df | Mean square | F | Sig. | R | R square | Adjusted R square | Std. error of the estimate |
| 1 | Regression | 636074576.769 | 1 | 636074576.769 | 4.977 | 0.029 | 0.243 | 0.059 | 0.047 | 11304.602 |
| | Residual | 10095728502.219 | 79 | 127794031.674 | | | | | | |
| | Total | 10731803078.988 | 80 | | | | | | | |
| 2 | Regression | 1236610472.905 | 2 | 618305236.453 | 5.079 | 0.008 | 0.339 | 0.115 | 0.093 | 11033.279 |
| | Residual | 9495192606.083 | 78 | 121733238.540 | | | | | | |
| | Total | 10731803078.988 | 80 | | | | | | | |

Significance level: p≤0,05

According to the regression analysis results, the prediction model between the change in OS in 2006-2018 and macroeconomic variables (Formula 5) is as follows;

$$OS_{Change} = -12729{,}241 + 97427{,}412\ NAC_{Change} - 0{,}033\ CAL_{Change}\ (R2{:}0{,}115,\ p<0{,}008) \quad (5)$$

No statistically significant relationship was found between the change in AA and macroeconomic variables.

The AS change model has shown the highest success in modeling land cover changes based on provinces. Upon examination of the models, it is mainly determined that the increase in grains and other plant species leads to a decrease in AS areas. In the change of forest areas, the decrease in undergrowth fruit and vegetable production was found to be influential. Indeed, forest areas are generally decreasing.

Various studies are being conducted to predict the future status of land uses depending on socio-economic variables. In this context, a simulation for Beijing predicts that in a rapid development scenario between 2010-2020, a 60.7% reduction in water areas could lead to a water shortage in Beijing, construction land would increase by 31.4% primarily from cultivated land, waters, and unused land, while the changing trend of forests and pastures would be lower. In a scenario where a dominant cultivated land protection policy is observed, it is anticipated that forest areas would increase slightly, the increase rate of construction area would be 17.2%, water areas would decrease by 20.9%, and cultivated areas would decrease by 11% (Han et al., 2015). A predictive study in the United States estimates that by 2030, developed use areas will increase by approximately 70 million acres, and the most significant percentage will be deflected from forests. The primary reason for this is stated to be the increase in population and personal incomes (Alig and Plantinga, 2004).

The study results also show that FA and SH areas, which are concentrated in rural areas, will decrease, especially with the increase in agricultural activities.

## 4. Conclusions

The findings of this study demonstrate that land cover in Türkiye underwent substantial alterations between 1998 and 2018, with a noteworthy change of approximately 30.6%. Regrettably, this transformation has been characterized by a significant expansion of artificial surfaces (AS) and a decline in forest areas (FA), a development that is cause for concern. While the increase in shrubland (SH) areas can be considered positive, the rise in water bodies in Türkiye, in light of climate change and the consequent reduction in water resources, can also be interpreted favorably. During times of prevalent food crises, the importance of agricultural lands is continually escalating. Hence, converting these lands into artificial surfaces or open spaces (OS) indicates potential deficiencies in management and planning. Notably, recent regulations permitting construction in non-forest and agricultural lands suggest that such degradation may persist in the future. This situation necessitates prompt and efficient policy intervention.

This research underscores the need for a comprehensive and sustainable land use policy. It calls for new measures that can effectively minimize the loss of critical resources such as agricultural lands, forests, and water bodies. Such a policy should involve strategic planning and management that prioritize the conservation of these critical land use classes while facilitating economic development. Moreover, it is essential to mitigate pressures, particularly from the construction, mining, and energy sectors, on these vital areas. This could be achieved through more rigorous regulation of these sectors and the implementation of sustainable practices, as well as through the promotion of alternative or less damaging land use models. In the face of rapid economic development and population growth, our study further implies that efficient land use practices can provide a practical path to achieve a balance between ecological sustainability and economic development. As we move forward, it becomes increasingly crucial to understand and consider the impacts of macroeconomic factors on land cover changes to facilitate better-informed decision-making processes in land use planning and policy.

In conclusion, this research is a pertinent reminder of the urgent need for careful consideration and strategic planning in land use policies to protect our vital land resources from further degradation. The interplay between land use, socio-economic factors, and sustainability is complex and dynamic, underscoring the need for ongoing research and proactive management in this important area.

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