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Front cover photography: Large avalanches like the January 2021 »twin avalanche« in the upper Soča Valley that reach the valley floor will be unavoidable in the Alps in the future, as climate warming actually triggers them, contrary to expectations (photograph: Jure Tičar).
Fotografija na naslovnici: Velikim snežnim plazovom, kakršen je bil »dvojček« januarja 2021 v Zgornjem Posočju, ki dosežejo dolinsko dno, se v Alpah tudi v prihodnosti ne bomo izognili, saj jih otoplitev podnebja, nepričakovano, celo povzroča (fotografija Jure Tičar).

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FRACTAL ANALYSIS OF SPATIO-TEMPORAL CHANGES OF FOREST COVER IN ISTANBUL, TURKEY

Derya Ozturk

Pressure of rapid urbanization on forests in Turkey.

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Derya Ozturk[1]

Fractal analysis of spatio-temporal changes of forest cover in Istanbul, Turkey

ABSTRACT: In this study, the spatio-temporal changes in forest cover in Istanbul, one of the provinces with the most changes in forest areas in Turkey due to the pressure of urbanization and industrialization, were investigated using fractal analysis. The areal changes and changes in spatial patterns were determined to assess the spatio-temporal changes in the period 2000–2017. Fragmentation/compactness and heterogeneity/homogeneity of forest cover were determined by fractal dimension and lacunarity index, respectively. The results show that the forest areas have significantly decreased and become more fragmented and heterogeneous. In conclusion, this study reveals that fractal analysis can provide considerable information in the examination and interpretation of spatial changes in forest areas.

KEY WORDS: fractal analysis, fractal dimension, lacunarity index, spatio-temporal changes, forest cover, land use change

Fraktalna analiza prostorsko-časovnih sprememb gozdnatosti v Carigradu v Turčiji

POVZETEK: V članku s fraktalno analizo raziskujemo prostorsko-časovne spremembe gozdnatosti v Carigradu, eni od turških pokrajin z največjimi spremembami gozda zaradi pritiska urbanizacije in industrializacije. Za oceno prostorsko-časovnih sprememb v obdobju 2000–2017 smo ugotavljali spremembe površine gozda in prostorskih vzorcev gozdnih zemljišč. S fraktalno analizo oziroma indeksom lakunarnosti smo določili razdrobljenost/kompaktnost ter heterogenost/homogenost gozdne pokrovnosti. Rezultati so pokazali, da so se gozdne površine znatno zmanjšale, obenem pa postale bolj razdrobljene in raznolike. V sklepu razkrivamo, da lahko fraktalna analiza zagotavlja precej informacij pri preučevanju in razlagi prostorskih sprememb na gozdnih območjih.

KLJUČNE BESEDE: fraktalna analiza, fraktalna dimenzija, indeks lakunarnosti, prostorsko-časovne spremembe, gozdna pokrovnost, sprememba rabe zemljišč

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1 Introduction

Forests are natural resources that provide a wide range of ecosystem services (Nunoo 2008). Forest areas are being changed into other land use types such as agricultural land, settlements, roads etc. due to urbanization and industrialization. A decrease in forest areas has adverse impacts on the forest ecosystem and the whole ecological environment associated with the forest ecosystem (Chakravarty et al. 2012; Balthazar et al. 2015). A decrease in forest areas also has a strong negative impact on climate. Other adverse effects are the increase in the negative effects of hydro-meteorological disasters such as erosion, floods, landslides, and a decrease in biodiversity (Atmiş et al. 2007; Drăghici et al. 2017).

Since drastic changes in forests affect the overall ecological balance, it is crucial to determine changes, identify the causes of the changes, and develop effective management strategies (Drăghici et al. 2017). In this context, information technologies have been used effectively in monitoring forest areas, in recent years. The term of digital forestry, emerging with information technologies, is defined as science and technology that includes acquisition, integration, query, and analysis of digital data and information to ensure forest sustainability (Zhao et al. 2005; Ianăş and Germain 2018).

Remote sensing and Geographic Information System (GIS) technologies are very important in digital forestry. Remotely sensed satellite imagery offers significant advantages over traditional ground survey of forests with the characteristics of fast and inexpensive data acquisition of large areas with a synoptic view, monitoring of changes with the repetitive image acquisition and observation of the same location, easy integration with other GIS layers and maps, provision of data for inaccessible areas, and creation of historical data (Jovanović et al. 2018). With its spatial data analysis, simulation and decision support system facilities, GIS offers significant advantages in forest ecosystem management, forest fires control, silvicultural activities, and planning forest access roads (Shao and Reynolds 2006; Reddy et al. 2015).

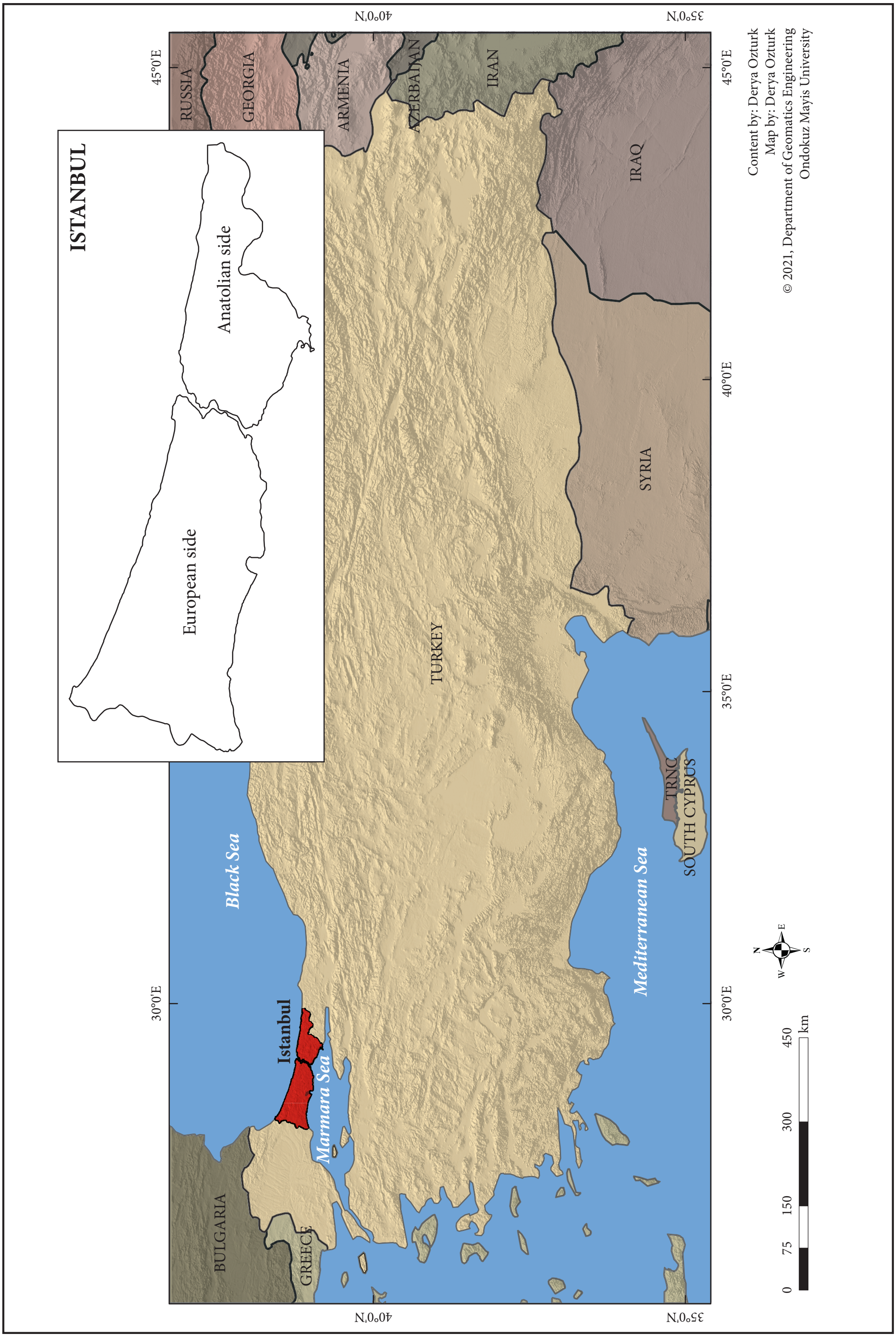
The rapid developments in GIS have enabled spatial data to be examined with more innovative perspectives. In this context, fractal analysis, an effective tool for identifying and analyzing the irregularities of objects, events, and phenomena, has recently been integrated into GIS to study the spatial pattern of objects in many subjects such as urbanization (Li et al. 2011; Tannier et al. 2011; Terzi and Kaya 2011; Ozturk 2017; Purevtseren et al. 2018; Man and Chen 2020), transportation (Lu and Tang 2004; Sun et al. 2007; Dasari and Gupta 2020; Karpinski et al. 2020; Sahitya and Prasad 2020), and geology (Wang et al. 2012; Pourghasemi et al. 2014; Ni et al. 2017; Sun et al. 2017; Yang et al. 2019). Although fractal analysis has the potential to improve the accuracy of measurement and identification of forest areas (Lorimer et al. 1994), very few studies have been conducted on the use of fractal analysis in forest areas. To quantify the landscape pattern and dynamics is necessary to monitor and evaluate the ecological consequences of the changes in spatial usage (Tian et al. 2007; Polenšek and Pirnat 2018; Foški 2019). Fractal dimension and lacunarity index are calculated within the scope of the fractal analysis. For forested areas, deforested areas, and afforested areas, the fractal dimension shows the degree of fragmentation/compactness and the lacunarity index measures the degree of spatial heterogeneity/homogeneity (Drăghici et al. 2017).

Due to anthropogenic activities, Istanbul is one of the provinces that experienced the most changes in forest areas in Turkey. In this study, the spatial changes of forest cover during the period 2000–2017 in Istanbul were examined based on fractal analysis and GIS. Global Forest Change data generated based on the analysis of Landsat satellite images were used in the analyzes. Areal and spatial changes were determined in the GIS environment and the spatial pattern of forest cover for the years 2000 and 2017, deforested and afforested areas in the period 2000–2017 were examined by fractal analysis, and the changes were discussed.

2 Study Area: Istanbul, Turkey

Istanbul (Figure 1) is located between 28°01'–29°55' east longitude and 40°28'–41°33' north latitude. It is located on a peninsula surrounded by the Black Sea, Marmara Sea, the Bosphorus, and the Golden Horn. The Bosphorus connects the Black Sea to the Marmara Sea, separates Asia and the European continent, and divides Istanbul into two regions: the European side and the Anatolian side (Dogan 2013).

Figure 1: Location of Istanbul. ➤ p. 10


ISTANBUL
Anatolian side
European side
RUSSIA
GEORGIA
ARMENIA
AZERBAIJAN
IRAN
IRAQ
SYRIA
TURKEY
TRNC
SOUTH CYPRUS
BULGARIA
GREECE
Black Sea
Marmara Sea
Mediterranean Sea
Istanbul
45°0'E
40°0'E
35°0'E
30°0'E
40°0'N
35°0'N
0 75 150 300 450 km
N S E W
Content by: Derya Ozturk
Map by: Derya Ozturk
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According to the data from Turkish Meteorological Service, the average annual precipitation in Istanbul is 817.4 mm, and the average temperature is 14.4° C for the measurement period 1929–2017 (Official Statistics 2019). Istanbul has 39 administrative districts, 14 of which are on the Anatolian side and 25 on the European side (Dogan 2013). The European side has an area of 3546 km^2 and the Anatolian side has an area of 1904 km^2 (Provincial and district surface areas 2018).

Its geographical location has given Istanbul strategic importance and led it to be one of the most populous cities in the world (Karaburun et al. 2010). According to Address Based Population Registration of the Turkish Statistical Institute, the population, which was 11.08 million in 2000, reached 15.46 million in 2020 (Statistics 2021). In metropolitan cities with rapid population growth, such as Istanbul, it becomes difficult to protect natural areas. Forest areas are being destroyed in Istanbul due to urbanization and industrialization pressures (Çakir et al. 2008; Karaburun et al. 2010).

3 Data and methods

In this study, spatio-temporal changes in forest cover during 2000–2017 were determined by overlay analysis and cross-tabulation; spatio-temporal changes of spatial pattern characteristics were determined by fractal analysis. In fractal analysis, fractal dimension and lacunarity index were calculated. In this way, the degree of fragmentation and dispersion of the forest areas during 2000–2017 was determined, and thus how much forest areas were affected by deforestation and afforestation. In addition, the fractal dimension and the lacunarity index were calculated for deforested and afforested areas. All analyzes were performed separately for the European side, Anatolian side, and for the whole of Istanbul.

Forest area boundaries for 2000 and 2017 were obtained from the Global Forest Change database with a pixel size of 1 arc second. Tree cover data are defined as canopy closure for all vegetation with height more than 5 m. Values are encoded in the range of 0–100 as a percentage on the pixel base (Global Forest Change 2000–2017 Database 2018). In this study, a threshold of 30% was chosen for the 2000 tree canopy cover data, and areas with a canopy closure value greater than 30% were identified as »forest cover« and the other areas were identified as »other areas«. Then, forest cover was coded as 1 and other areas as 0, and binary images were generated for fractal analysis. Forest cover for the year 2000 was updated with loss and gain data and the forest cover was determined for the year 2017. The binary images for fractal analysis are shown in Figure 2.

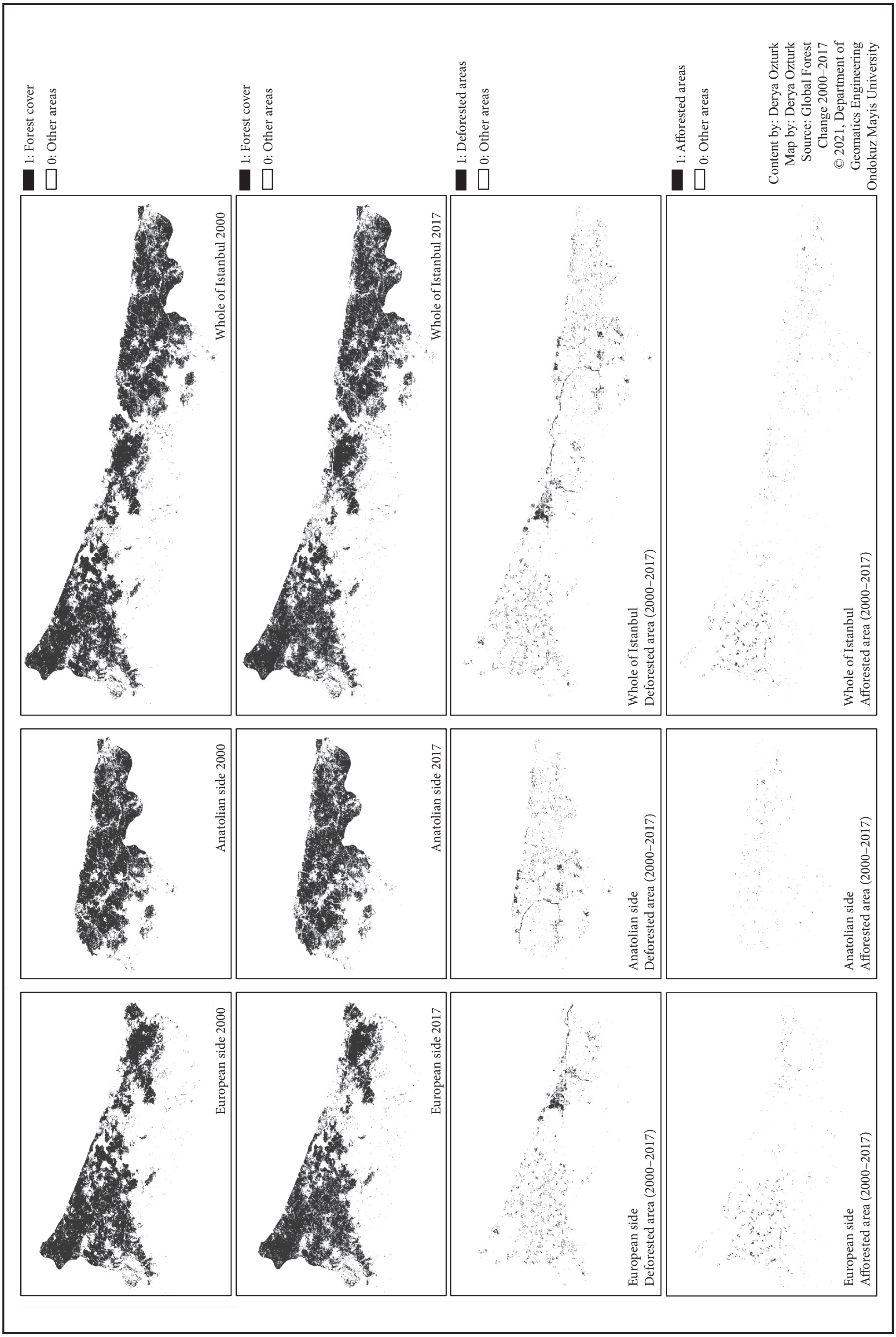
The degrees of fragmentation/compactness and heterogeneity/homogeneity were determined using the binary images for the forest areas 2000 and 2017 and for the deforested and afforested areas in the period 2000–2017. The binary coding of the images, the calculations of the areal changes, and the analyzes of the spatial changes with overlay and cross-tabulation were performed using ArcGIS 10.0 software (Esri, Redlands, CA), and the fractal analyzes for the fractal dimension and lacunarity index were implemented using ImageJ software (National Institutes of Health, USA) and the FracLac plugin.

3.1 Fractal analysis

In this study, fractal analysis was used to measure the changes in the spatial pattern of forest cover. For this purpose, fractal dimension was calculated by box-counting algorithm and lacunarity index was calculated by the gliding-box algorithm. In the fractal analyzes, the calculations were made using 5 different grid locations with a minimum grid size of 3 pixels and a maximum grid size of 45% of the image.

A fractal is a rough or fragmented geometric shape, that can be divided into parts, where approximately each part is a reduced copy of the whole (Jiang and Brandt 2016; Diaconu et al. 2017). The fractal dimension is beneficial in determining the irregularity or roughness of man-made and natural objects that do not conform to classical geometry (Drăghici et al. 2017) and measures the degree of irregularity, complexity, and fragmentation of a spatial structure (Oliveira et al. 2014; Diaconu et al. 2017). A lower fractal dimension represents a more compact object, while a higher fractal dimension represents a more complex object (Hu et al. 2015). The lacunarity index is complementary to the fractal dimension and measures the

Figure 2: Binary images for fractal analysis. ➤ p. 12


1: Forest cover
0: Other areas
Whole of Istanbul 2000
Anatolian side 2000
European side 2000
1: Forest cover
0: Other areas
Whole of Istanbul 2017
Anatolian side 2017
European side 2017
1: Deforested areas
0: Other areas
Whole of Istanbul
Deforested area (2000–2017)
Anatolian side
Deforested area (2000–2017)
European side
Deforested area (2000–2017)
1: Afforested areas
0: Other areas
Whole of Istanbul
Afforested area (2000–2017)
Anatolian side
Afforested area (2000–2017)
European side
Afforested area (2000–2017)
Content by: Derya Ozturk
Map by: Derya Ozturk
Source: Global Forest
Change 2000–2017
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heterogeneity/homogeneity of the spatial distribution of the object (Drăghici et al. 2017). Lacunarity is concerned with the distribution of gap sizes in a geometric object. A lower lacunarity index value represents a more homogeneous object, as it expresses gap sizes almost close to each other. In comparison, a higher lacunarity index value represents a more heterogeneous object since it expresses gap sizes that differ from each other (Dong 2000).

To calculate the fractal dimension using the box-counting algorithm, the most commonly used method for calculating the fractal dimension, the object is covered with grids (boxes) of different sizes, and the number of grids that cover all the object or part of the object is determined. The fractal dimension is calculated using the different grid sizes and the numbers of the filled grids depending on grid size. The calculation of the fractal dimension using the box-counting method is given in Equation 1 (Morency and Chapleau 2003; Peitgen et al. 2004).

$$D_B = (\log N_2 - \log N_1) / (\log S_2 - \log S_1) \quad (1)$$

Where D_B is a fractal dimension by box-counting, N is the number of the grid, and S is grid size.

To calculate the lacunarity index using the gliding-box algorithm, the most commonly used method for calculating the lacunarity index, an r x r-dimensional grid is placed in the upper left corner of the image. The number of pixels in the grid is determined. To calculate the number of full pixels for each position of the grid, the grid is systematically moved one column to the right, and when one row is complete, it continues on the next row (Allain and Cloitre 1991; Dong 2000). The Q(S,r) value is calculated by using Equation 2, where the total number of positions of the grid is N(r) and the number of grid positions with S full pixels in the r x r dimensional grid is S(s,r). Using the Q(S,r) and S values, the 1st and 2nd statistical moments (Z_1 and Z_2) are calculated as in Equations 3 and 4. The lacunarity index (Λ) is calculated using the 1st and 2nd statistical moments according to Equation 5 (Allain and Cloitre 1991):

$$Q(S,r) = n(S,r) / N(r) \quad (2)$$

$$Z_1 = \Sigma\, S Q(S,r) \quad (3)$$

$$Z_2 = \Sigma\, S^2 Q(S,r) \quad (4)$$

$$\Lambda(r) = Z_2 / Z_1^2 \quad (5)$$

4 Results

The values of surface area, fractal dimension, and lacunarity index of forest areas on the European side, Anatolian side, and the whole of Istanbul in 2000 and 2017 and the amount of the change for the period 2000–2017 are shown in Table 1.

Table 1: Forest area (F), fractal dimension (D_B) and lacunarity index (Λ(r)) for 2000 and 2017, changes (Δ) in the period 2000–2017.

	2000			2017			2000–2017		
	F (km²)	D_B	*Λ(r)*	F (km²)	D_B	*Λ(r)*	ΔF (km²)	ΔD_B	*Λ(r)*
European Side	1231	1.699	1.127	1151	1.715	1.227	–80	0.016	0.100
Anatolian Side	1018	1.743	0.673	950	1.745	0.700	–68	0.002	0.027
Whole of Istanbul	2249	1.698	0.876	2101	1.708	0.933	–148	0.010	0.057

Table 2: Surface area (F), fractal dimension (D_B), and lacunarity index ($\Lambda(r)$) of the deforested and afforested area in the period 2000–2017.

	Deforested			Afforested			Total loss ($F_{def} - F_{af}$)
	F_{def} (km²)	D_B	$\Delta(r)$	F_{af} (km²)	D_B	$\Delta(r)$	
European Side	114	1.537	2.126	34	1.470	2.961	80
Anatolian Side	78	1.585	1.103	10	1.394	1.340	68
Whole of Istanbul	192	1.558	1.419	44	1.458	2.769	148

Table 2 shows the surface area, fractal dimension, and lacunarity index of the deforested and afforested areas on the European side, Anatolian side, and the whole of Istanbul in the period 2000–2017.

According to Table 1, the forest area on European side was 1231 km² in 2000, and decreased to 1151 km² in 2017, while the forest area on the Anatolian side was 1018 km² in 2000 and decreased to 950 km² in 2017. Accordingly, the forest area was 2249 m² in 2000, and decreased to 2101 km² in 2017.

According to Table 2, 114 km² forest area was lost and 34 km² area changed as forest on the European side while 78 km² forest area was lost and 10 km² area changed as forest on the Anatolian side in the period 2000–2017. In this context, the loss is higher than the gain as the total loss was 80 km² on the European side, 68 km² on the Anatolian side and accordingly, the total loss for the whole of Istanbul is 148 km².

The spatial changes of forest areas on the European side, the Anatolian side, and for the whole of Istanbul in the period 2000–2017 are shown in Figure 2. The green color indicates the forest areas in both 2000 and 2017, the red color indicates the losses (non-forest areas in 2017 while they were in forest in 2000), and the yellow color indicates the gains (forest areas in 2017 while they were in non-forest in 2000).

The fractal dimension shows the degree of complexity of forest cover, it also explains how and to what extent forest areas are spatially fragmented by deforestation and afforestation. A higher fractal dimension indicates a more complex or disperse forest cover form. An increase in the fractal dimension indicates that the forest cover has become more complex and fragmented, and irregular uses have occurred. Similarly, the fractal dimension of deforested and afforested areas reveals the complexity of the spatial distributions of change. The lacunarity index shows the degree of heterogeneity of the spatial distribution of forest, deforested and afforested areas and is complementary to the fractal dimension. A higher lacunarity index indicates a more heterogeneous forest cover form. An increase in the lacunarity index indicates that the forest cover has become more heterogeneous. Similarly, the lacunarity index of deforested and afforested areas reveals the heterogeneity of the spatial distributions of change.

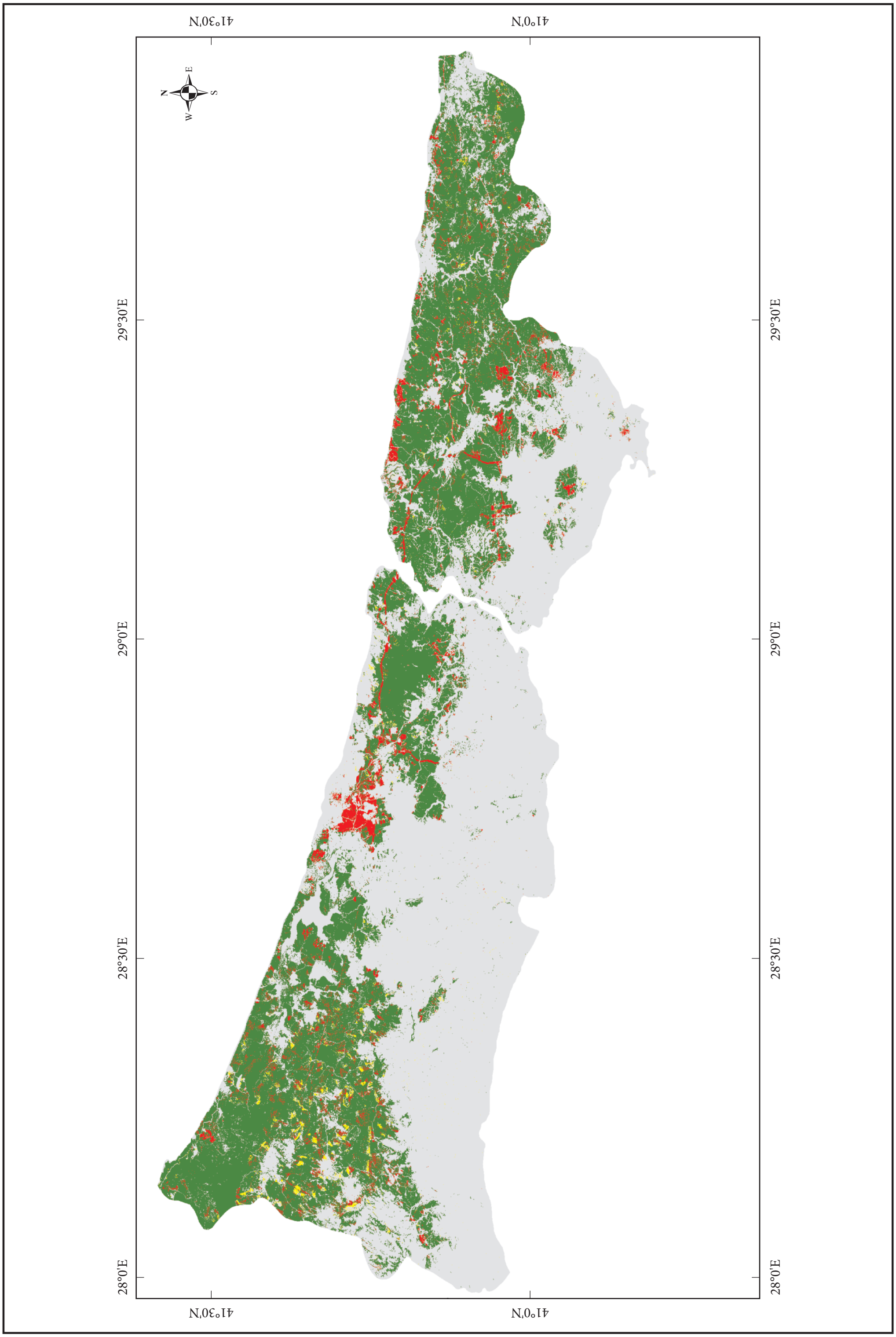
According to Table 1, the fractal dimension of forest areas on the European side was 1.715 in 2017, while it was 1.699 in 2000. The value of the lacunarity index was 1.227 in 2017, while it was 1.127 in 2000. According to Table 2, in the period 2000–2017, the fractal dimension was 1.537 and the lacunarity index was 2.126 for deforested areas, while the fractal dimension was 1.470 and the lacunarity index was 2.961 for afforested areas.

According to Table 1, the fractal dimension of forest areas on the Anatolian side was 1.745 in 2017, while it was 1.743 in 2000. The value of the lacunarity index was 0.700 in 2017, while it was 0.673 in 2000. According to Table 2, during 2000–2017, the fractal dimension was 1.585 and the lacunarity index was 1.103 for deforested areas, while the fractal dimension was 1.394 and the lacunarity index was 1.340 for afforested areas.

According to Table 1, the fractal dimension for the whole of Istanbul was 1.698 in 2000 and 1.708 in 2017, while the lacunarity of the forest areas was 0.876 in 2000 and 0.933 in 2017. According to Table 2, during 2000–2017, the fractal dimension was 1.558 and the lacunarity index was 1.419 for deforested areas, while the fractal dimension was 1.458 and the lacunarity index was 2.769 for afforested areas.

The fractal dimension increased by 0.016 on the European side and by 0.002 on the Anatolian side. These increases indicate that the forest areas have become more fragmented. The increase in fragmentation on the European side is higher than on the Anatolian side. The lacunarity index increased by 0.100 on the European side and by 0.027 on the Anatolian side. These increases indicate that forest areas have become more heterogeneous. The increase in heterogeneity on the European side is higher than on the Anatolian side.

Figure 3: The spatial change of forest cover in Istanbul. ➤


41°30'N
41°0'N
29°30'E
29°0'E
28°30'E
28°0'E
N
E
S
W

5 Discussion

Determining dynamics of the forest landscape is an important issue in terms of sustainable land and forest management (Çakir et al. 2008). Particularly in areas under urbanization and industrialization pressure, determining changes in the landscape in terms of both area and spatial characteristics is essential for monitoring and protecting forest areas in order to prepare effective development plans and sustainable forest management plans (Çakir and Özdemir 2015; Ren et al. 2019).

Migration from rural to urban areas, which started in the 1950s in Turkey, led to excessive population growth in Istanbul in a short period of time, especially after the 1980s (Işık 2005; Çakir et al. 2008). The natural resources in Istanbul started to be destroyed rapidly due to various reasons resulting from this rapid population increase. Urbanization and industrialization, which have developed in parallel with the population increase in Istanbul, have also led to significant changes in forest areas (Atmiş et al. 2007; Gökburun 2017).

In this study, forest areas were found to decrease by 6.5% on the European side, 6.7% on the Anatolian side, and 6.6% in the whole of Istanbul during period 2000–2017. These rates show that the decline of 5.4% reported by Karaburun et al. (2010) for the period 1987–2007 is still increasing, and the decline of forest areas continues. These changes in forest areas revealed a general downward trend in Istanbul.

In addition, in terms of spatial pattern features, forest fragmentation is the fragmentation of large, continuous, and compact forest areas (Bogaert et al. 2011), and spatial heterogeneity of forest is based on the gaps of different sizes (Buajan et al. 2017). Deforestation due to urbanization, road development, agricultural development, and forest fires generally leads to an increase in forest fragmentation and heterogeneity (Broadbent et al. 2008). Identification of the fragmentation/compactness and heterogeneity/homogeneity is essential in terms of species in the forest ecosystem and landscape characteristics (Bogaert et al. 2011; Peh et al. 2014).

Considering the results of the fractal analysis of this study, it can be summarized that the fractal dimension of forest areas on the Anatolian side is higher than on the European side in both 2000 and 2017. This shows that the forest areas on the Anatolian side are more fragmented and complex than those on the European side. The Anatolian side has more forest area in percentage than the European side and the percentage decrease in forest areas due to urbanization activities on the Anatolian side is higher than on the European side. This situation results in more fragmented forest areas. The lacunarity index is higher on the European side than on the Anatolian side in both 2000 and 2017, indicating that forest areas are more heterogeneous on the European side than on the Anatolian side. Moreover, for the European side, Anatolian side, and the whole of Istanbul, the fractal dimension and lacunarity index have increased during the period 2000–2017, which means that complexity and heterogeneity have increased due to deforestation. The amount of increase is greater on the European side for both fractal dimension and lacunarity index. This shows that the changes in the form of forest areas on the European side during the 2000–2017 period were greater than on the Anatolian side.

Fractal analysis has been used in some geographical studies related to forest change, deforestation, and afforestation. Andronache et al. (2016), Pintilii et al. (2016), Drăghici et al. (2017), Andronache et al. (2019), and Diaconu et al. (2020) obtained complementary interpretations for forest areas with the integrated use of fractal dimension and lacunarity index. Andronache et al. (2016) analyzed the change of forest areas for the period 2000–2012 in the North-Eastern Development Region in Romania, where large forest areas were converted to different land uses due to local economic pressure. The results of the analysis showed that the afforested areas were more compact and had more homogeneous arrangement than the deforested areas. Considerable differences were found between the deforested and afforested areas. The maximum difference was observed in Iaşi county, while the minimum difference was observed in Vaslui county. Pintilii et al. (2016) analysed the changes in Suceava-Cârlibaba in Romania for the period 2000–2013 and found that the deforested areas were more fragmented and heterogeneous. Drăghici et al. (2017) analyzed the changes in the forest areas in the Northern Carpathian Mountains for the period 2000–2014, and it was determined that the forest areas turned into a more complex and more heterogeneous structure. Andronache et al. (2019) performed the analysis of the deforested areas of the Apuseni Mountains for the period 2000–2014 and determined an increase in fragmentation and heterogeneity with a decrease in the tree cover area. Diaconu et al. (2020) analyzed the deforestation in the mountain area, the northern and central groups of the Eastern Carpathians for the period 2000–2017 and determined that deforestation causes the fragmentation of forests. Consistent with these studies, the fragmentation/compactness and heterogeneity/homogeneity degree could be evaluated separately using the fractal dimension and lacunarity index, respectively. When the results of the fractal analysis of deforested and afforested areas are examined, it is clear that the deforested areas are more fragmented and homogenous than the afforested areas for the European side, the Anatolian side and the whole of Istanbul. Notable differences were determined for the values of fractal dimension and lacunarity index of deforested and afforested areas. The difference between the fractal dimension of deforested and afforested areas is higher on the Anatolian side, while the difference between the lacunarity index is higher on the European side.

6 Conclusion

Protecting forests is vital for adapting to and mitigating climate change, protecting biodiversity and preventing natural disasters such as erosion, floods and landslides. Therefore, forest areas and changes should be monitored and necessary measures such as forest conservation and management plans should be taken.

In this study, the spatio-temporal changes of forest cover in Istanbul, Turkey, during 2000–2017 were examined. In addition to the changes in area, the spatial patterns of both forest areas and areas of change were investigated using fractal analysis. The results show that forest areas degraded by cutting trees due to urbanization and industrialization pressures have resulted in a decrease in total forest area and more fragmented and heterogeneous landscapes. The results of this study can be used to investigate possible interactions and transitions between forest, deforested and afforested areas, and the results contribute to the assessment of forest areas under pressure.

The evaluation of spatio-temporal changes of forest cover in Istanbul was carried out using the Global Forest Change database (2000 and 2017). The results of the study showed that the Global Forest Change database with a spatial resolution 1 arc second can be effectively used in the quantitative analysis of the spatial patterns of forest, deforested and afforested areas with the integration of GIS and fractal analysis, providing new and complementary information in addition to the traditional change detection studies. The results obtained provide additional information that can be integrated into forest land management and organization plans. Similar approaches can be adapted to land cover/use classes other than forests, and new information can be provided through innovative approaches to spatial analysis.

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