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Defining the effects of urban expansion on land use/cover change: a case study in Kastamonu, Turkey

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Abstract In addition to the growing world population, continuous migration from rural areas to city centers leads to rapid population growth in urban centers, bringing with it a change in land use/cover in those areas. This change usually manifests itself as an increase in artificial surfaces and a decrease in agricultural areas and forestlands. However, agricultural areas and forests in the vicinity of city centers contain sensitive ecosystems that require careful monitoring. It is crucial that the impact of population growth in the city centers on these areas is determined. This study aims to determine the changes in the land cover in Kastamonu city center between 1999 and 2014. As part of the study, changes in the population of the city center, as well as in the use of urban spaces within the past 15 years, were investigated to determine how population growth affected land use/cover. Changes in land use/cover were assessed under 12 classes with the use of remote sensing methods on stand-type maps created by the aerial photos. According to the results of the study, a 519.5-ha agricultural area and a 86-ha forest area became artificial surfaces in 1999 and 2014.

Keywords Land use/land cover change · Spatiotemporal analysis · Urban forest · Environmental monitoring · Turkey

Highlights
- Assesses the land use/change in urban areas using land use-type map-made aerial photos.
- Uses maximum likelihood classification to determine land use/change.
- Unplanned settlement is the most important influence of the land use/change.
- Agricultural areas are preferred rather than forests for new constructions.

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Introduction

In the 1900s, only 9% of the world's human population lived in urban areas, but this rate rose to 47% by 2000. The figure is expected to exceed 60% by 2025 (Konijnendijk 2003; Cetin et al. 2017). In European countries, more than two thirds of the total population live in urban areas (Sevik et al. 2016). This rapid urban expansion has put a lot of strain on the land and natural resources (Hoogstra and Van Dijk 2004). Population growth in urban areas leads, directly or indirectly, to the destruction of nature and the disruption of ecological balance, as well as air, water, and soil pollution (Mutlu et al. 2016; Kulaç and Yıldız 2016). In particular, the

scale of the destructive impact on forests is alarming. Studies conducted so far indicate that at least 60% of the world's forest ecosystems have been destroyed or unsustainably overused (Brockhause and Botoni 2009). Urban landscape planning has many benefits in terms of the environment. Urban landscape planning requires making decisions about the future situation of urban land. In this case, it is necessary to predict how the land will change over time, and what effects natural factors and human activities will have on the land. In this way, successful and sustainable landscape planning studies can be achieved. Determination of land cover and green area change related to the urban area and its immediate surroundings: Land use change is the result of human activities and natural factors. Land cover is one of the most important pieces of data used to demonstrate the effects of changes in land use, especially human activities. Land use maps can be produced by using different methods on satellite images or aerial photos. Using land cover maps, the changes in urban development and green areas over time have been evaluated. At the same time, the relationship between changes in the land cover over time and changes in the urban population has been examined. The recent study aims to develop a landscape plan according to the goal of sustaining the natural and cultural landscape values of an area by considering landscape variables such as the number of potential visitors, vegetation cover, cultural values, and the topographic structure. ArcGIS was used as the geographical information system to evaluate the landscape variables, and the study data were obtained through a land survey, questionnaires, and mapping. The area has a highly variable topographic structure, meaning it has a rich structure in terms of surface forms, and therefore has visual landscape value. This surface variety also makes the area rich in vegetation cover and climate values; this richness can be called location advantage. It has enabled the formation of rich flora and therefore fauna variety. Although the summers are hot and the winters are warm in this area, the region receives sufficient rainfall in all seasons (Cetin 2015a, 2015b, 2016; Cetin and Sevik 2016; Cetin et al. 2018a, 2018b; Yucedag et al. 2018).

Areas that exert the highest pressure on the forest ecosystems are those that border living spaces. In these areas, forest limits, structure, and quality are being altered by humans, and these changes, most of the time, bear negative consequences for the forestlands. It is recognized that these changes in boundaries are directly linked to the urban population, especially in city centers. Therefore, a large number of studies have been conducted to discover the effects of urban population on changes in forest limits and structures (Wakeel et al. 2005; Geymen and Baz 2008; Hayes and Cohen 2007; Fan et al. 2008; Sen et al. 2015). Yet, since time and change are parallel phenomena, these changes must be constantly monitored.

Man-made deforestation brings many problems with it. First of all, due to deforestation or degradation, forests can no longer fulfill their ecological, economic, social, and esthetic functions properly. One should remember that forests have many functions, such as reducing air pollution, preventing erosion, regulating precipitation, supporting wildlife, and serving as an economic resource (Güngör 2011; Sevik et al. 2016; Yigit et al. 2016; Bayramoğlu and Kadıoğulları 2018; Aydın et al. 2018; Turkyilmaz et al. 2018). In the case of deforestation or forest degradation, these functions are impaired.

Urban forests, green spaces, and herbaceous open spaces all play a vital role in the environmental and esthetic health of cities (Iverson and Cook 2000). Furthermore, these forests simultaneously fulfill many ecological, economic, and social functions. Forests reduce all kinds of air pollution (Sevik et al. 2017; Nowak et al. 2018), reduce noise levels (Mansfield et al. 2005; Aricak et al. 2016), have a positive psychological effect, and allow energy saving (Cetin 2015c), serve as an important economic resource (Tunçtaner et al. 2007; Sevik 2012; Yigit et al. 2016), prevent erosion (Güneş Şen and Aydın 2016; Mateos et al. 2017), decrease wind speed, hold the soil together to prevent it from being washed away by precipitation or streams, and protect wildlife, water resources (Güneş Şen and Aydın 2017), and prey resources. Open green spaces are important areas for both adults and children to engage in various activities (Özel and Ertekin 2012). These functions play an important role, particularly in densely populated areas. In the wake of increased migration from rural areas to cities, public expectations of forest resources have changed (Atmis et al. 2012). New demands have given birth to pressure. Changes in the size and structure of forests due to this man-made pressure adversely affect the functions expected from forests (Atmis 2016). Therefore, it is essential to monitor the changes in the limits and structures of forests near city centers and, if necessary, to adopt preventive and restorative measures in the face of destruction, so that a healthy, secure, and happy environment can be provided for the urban residents. It is due to these considerations that green spaces have become an important component of the city

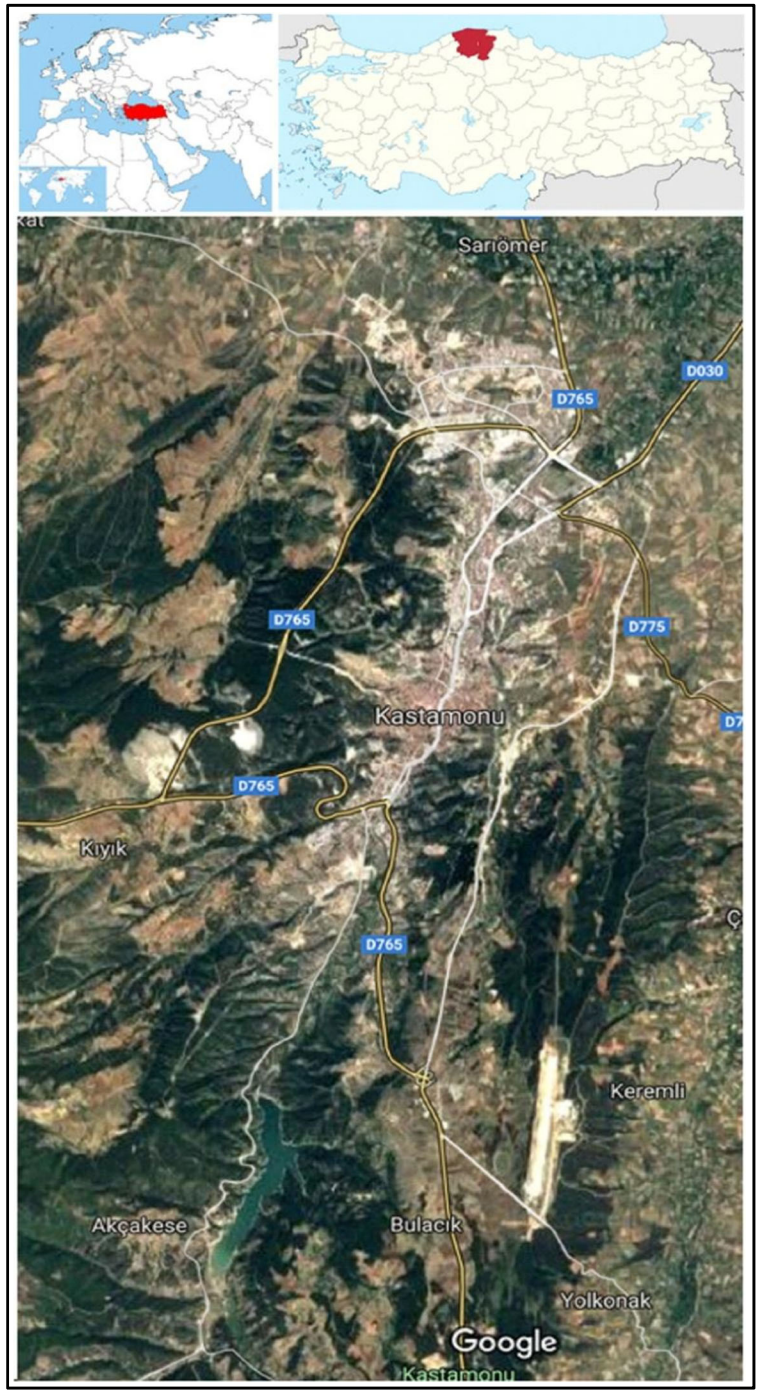

Fig. 1 Location of Kastamonu urban center

and urban planning in the past century (Ignatieva et al. 2011).

The ratio of city and district residents in the total population rose to 92.1% in 2015 while that of rural residents dropped to 7.9% (URL1 2017), particularly following the population growth that began in the 1950s. As in almost all parts of the world, migration from rural areas to cities continues in Turkey as well, bringing many problems with it.

This study aims to monitor and determine the changes in the forestlands and other land classes near Kastamonu city center between 1999 and 2014. As part of the study,

Table 1 LULC class descriptions

LULC classes	Productive hardwood	PCF	Productive* pure stands made up of coniferous trees
	Productive softwood	PBF	Productive pure stands made up of broad-leaved trees
	Productive mixed	PMF	Productive mixed hardwood and softwood
	Degrade hardwood	DCF	Degraded** pure stands made up of coniferous trees
	Degrade softwood	DBF	Degraded pure stands made up of broad-leaved
	Degrade mixed	DMF	Degraded** mixed wood,
	Artificial surfaces	AS	Settlement areas, roads, airport vb.
	Agriculture	AG	Agricultural land
	Water	W	Areas covered with standing water
	Stony	S	Stony and rocky fields
	Open area	OA	Pasture field, meadows
	Stone pit	SP	Areas operated as stone pit

*Productive forest (PF): productive forest with a > 10% estimated tree crown cover

**Degraded forest (DF): degraded forest with a < 10% estimated tree crown cover

changes in the population of the city center, as well as in the land use/cover (LULC) in the city center within the last 15 years, were analyzed to determine how population growth in the city center influenced the LULC.

Study area

The study was conducted in Kastamonu city center and its close vicinity. Kastamonu is in the western part of the Black Sea region between the Eastern longitudes of 33–46 and Northern latitudes of 41–42 (Öztürk and Özdemir 2013). The location of the study area is shown in Fig. 1.

Data and methods

The most important aspects of landscape assessment are how and in what size the landscape changes (Antrop 2000). This research identified the effects of urban expansion on land use/land cover (LULC) change in three stages. In the first step of the research, stand-type maps created by the General Directorate of Forestry in 1999 and 2014 were digitized and corrected, creating a spatial database using Arc/Info GIS. The stand-type maps were created using the stereo interpretation of aerial photographs. Then, these maps were scanned and recorded on a scale of 1:25,000 using the nearest neighbors to the UTM projection. Afterward, this research used ArcGIS® software to make overlays depicting changes in LULC to place on top of maps in order to calculate changes in the land area over time (Çakır et al. 2008; Sen et al. 2015; Şen and Güngör 2018). After that, transitions seen in images taken between 1999 and 2014 were compared in order to identify changes in LULC. A polygonal representation of forest cover for 1999 and 2014 was overlaid, and the transformations of each were compared and spatially calculated using ArcGIS (Çakır et al. 2008). The research used the approximate level classification method. This classification simplifies land use. For example, what areas had the cover of what type of land, and what was the land being used for (Karahalil et al. 2009). When the analysis was made of all the results, 12 classes of forest cover were taken into consideration (Table 1). Spatial analysis was done for land cover classes only.

Results

The study identified the LULC in the Kastamonu urban center in 1999 and 2014 using digitized stand-type maps, which are shown in Figs. 2 and 3, respectively.

LULC in the study area in 1999 and 2014 is shown in Table 2.

A closer look at Table 2 reveals that in 1999, Kastamonu city center consisted of 7% artificial surfaces, 51.8% agricultural areas, 39.9% forests, and 0.8% open area. By 2014, the LULC changed: the share of artificial surfaces rose to 7.7% and forests to 41%, whereas agricultural areas decreased to 50.6%, and open areas have all been transformed into other areas.

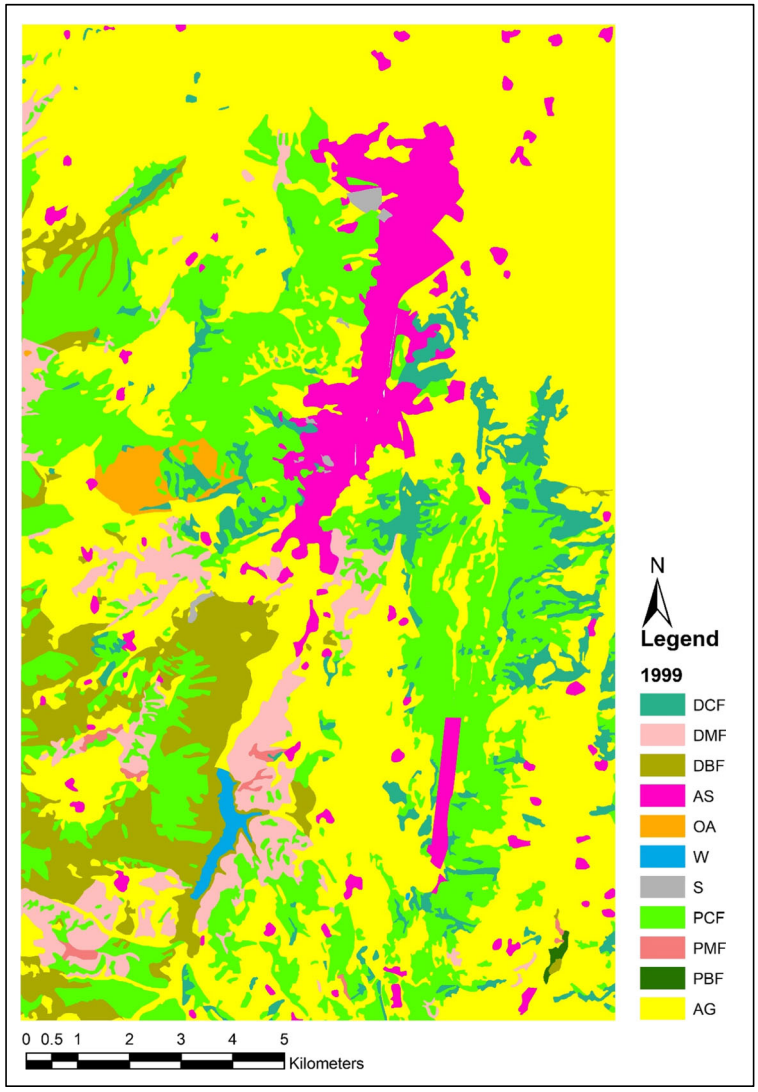

Fig. 2 LULC in the Kastamonu city center in 1999

The study also analyzed the change in the LULC in the Kastamonu city center between 1999 and 2014. This change is shown in Fig. 4 and the interclass transition matrix is shown in Table 3.

A closer look at Table 3 and Fig. 4 reveals that the biggest spatial change took place between 1999 and 2014 in the productive hardwood forest areas. It is also seen that all productive forest areas increased in this period while there was a fall in the size of degraded forest areas. In 1999, total artificial surfaces measured 1555.4 ha, whereas in 2014, 1725.1 ha remained as artificial surface while 322.1 ha had been turned into agricultural land, and 114.7 ha into the forest. In the period of 1999–2014, 519.5 ha of agricultural area, 86 ha of forest area, and 0.8 ha of the open area turned into artificial surfaces.

Significant changes in the agricultural areas and open areas also stand out. Between 1999 and 2014, 1479.6 ha of agricultural areas turned into forests, 519.5 ha turned into artificial surfaces, and 1.4 ha turned into the open area, while 1339 ha forestland and 322.1 ha artificial surface turned into agricultural land. Furthermore, 75.7 ha open areas turned into the forest, 98.9 ha turned into agricultural land, 0.8 ha turned into the artificial surface, and 11.5 ha turned into quarries. No change was seen in 1118.8 ha artificial surface, 9540.3 ha agricultural land, and 5975 ha forest between 1999 and 2014.

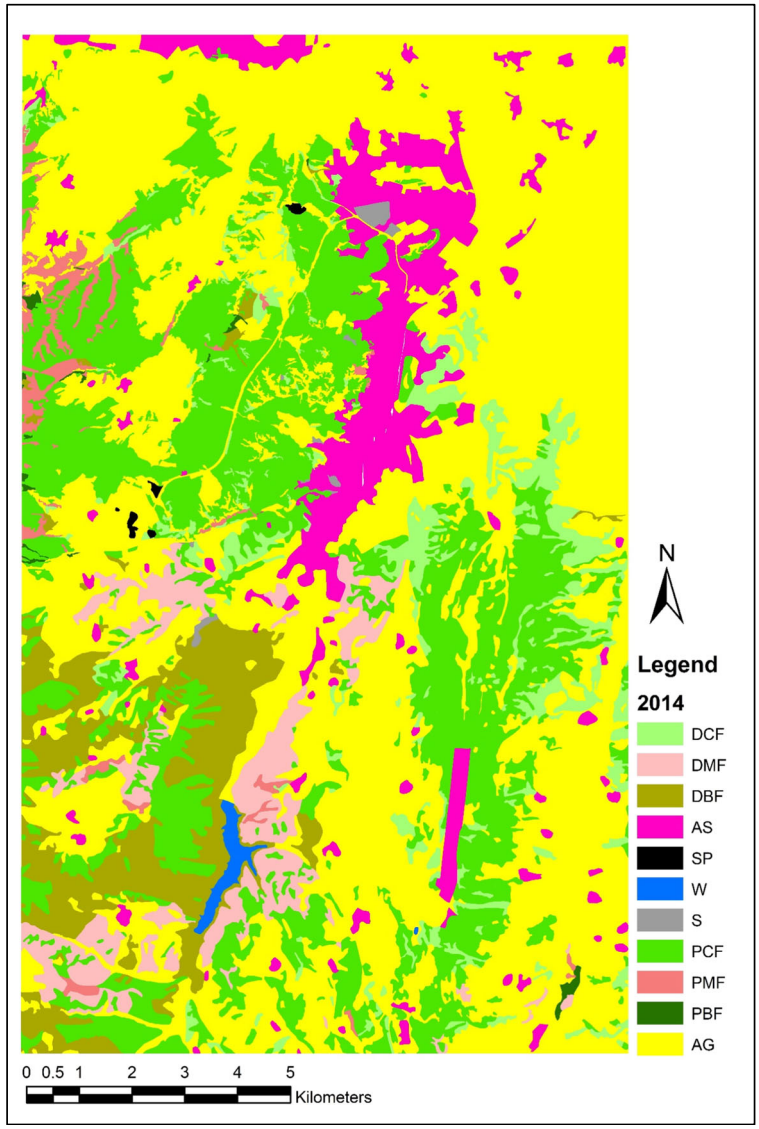

Fig. 3 LULC in the Kastamonu city center in 2014

Demographic development

The province of Kastamonu accommodates 20 districts and 1071 villages within its boundaries. The major industry shaping the economy of the city is agriculture. In addition to this, forestry constitutes to be an important source of livelihood, particularly in the rural areas. While 48% of the population lives in the city center, the rest live in the districts and villages. The rural and urban populations of Kastamonu central district between 2007 and 2017 are shown in Fig. 5 (TUIK 2017). Between 1999 and 2007, due to the fact that there was no address-based population census system, the data do not fully reflect the actual situation. For this reason, city center population data of that period were not used.

Figure 5 reveals that between 2007 and 2014, the total population was increasing all the time. However, while the rural population decreased during this period, the population in provincial and district centers increased. In the same period, Kastamonu city center population also increased. In particular, students attending the recently established university play an important role in this growth. Within the same period, the rural population decreased by 21.2% across the province down to 138,559 residents, whereas the urban

Table 2 LULC status of Kastamonu city center in 1999 and 2014

Class	Year				Percent change during 1999–2014	
	1999		2014			
	(ha)	%	(ha)	%	(ha)	%
PCF	5114.9	23.0	5391.3	24.2	276.40	5.4
PBF	14.2	0.1	40.7	0.2	26.50	186.6
PMF	57.0	0.3	307.2	1.4	250.20	438.9
DCF	1071.1	4.8	1045.3	4.7	− 25.80	− 2.4
DBF	1544.6	6.9	1398.4	6.3	− 146.20	− 9.5
DMF	1068.9	4.8	944.2	4.2	− 124.70	− 11.7
AS	1555.4	7.0	1725.1	7.7	169.70	10.9
AG	11,541.4	51.8	11,284.8	50.6	− 256.60	− 2.2
W	75.9	0.3	74.9	0.3	− 1.00	− 1.3
S	51.8	0.2	51.8	0.2	0.00	0.0
OA	186.9	0.8	0	0	− 186.90	− 100.0
SP	0	0	18.6	0.1	18.6	–
Total	22,282.1	100.0	22,282.1	100.0	0.00	0.0

population increased by 26.6 to reach 233,814 inhabitants. Furthermore, the population of the city, which was 80,582 in 2007, grew by a sizeable 44.9% and reached 11,6737 residents in 2016. Based on this data, it can be argued that a significant amount of migration took place into Kastamonu city center.

Discussion

Until 150 years ago, no significant level of deforestation took place in the world. However, serious destruction began after the Industrial Revolution in particular. Deforestation on an average of 5,160,000 ha per year took place between 1990 and 2015 (FAO 2016). It has occurred on a much larger scale in the city centers and nearby areas since the 1970s (Boyce and Martin 1993).

The findings of the study reveal that significant changes have taken place, especially in artificial areas. Agricultural areas and forests have mostly been turned into artificial surfaces. While the number of buildings within the Kastamonu city center and municipal district borders was 27,740 in 1990, this figure rose to 39,292 by 2000 (TUIK 2001) and continues to increase further.

Within the study area, it is evident that artificial surfaces have increased significantly, especially in the northern parts of the city, with agricultural and pasture land in these parts turning into artificial surfaces. During the 15-year period, a 519.5-ha agricultural area and a 86-ha forest became artificial surfaces. Major land changes in the northern parts of the city are linked to the fact that the newly founded university is located in this region, and that students generally prefer living in the vicinity of the university, as well as to the fact that some governmental and municipal bodies were moved to this area due to congestion in the city center. This situation is truly alarming since perhaps one of the biggest issues facing humankind is hunger, which leads to problems on a global scale. This problem will only worsen because areas, where agriculture or livestock activities take place, are shrinking.

On the other hand, there is a noticeable growth in forestland. While some part of the agricultural and pasture lands became artificial areas, other parts turned into forests. One major reason forcing the young population in rural areas to seek employment in the city centers is the increase in input prices in agriculture. Education is another important factor. The agricultural areas have shrunk due to decreasing village populations. This has led to a reduction in agriculture and livestock farming, in turn leading to farm and pasture land being transformed into forests. The scale of increase in forestland is pleasing. According to a study of Istanbul, forestlands shrank by 1.01% (5.5 ha) between 1990 and 2005 due to the pressure of urbanization brought about by excessive migration, whereas artificial surface areas increased by 4.55% (24.7 ha) during the same period (Geymen and Baz 2008).

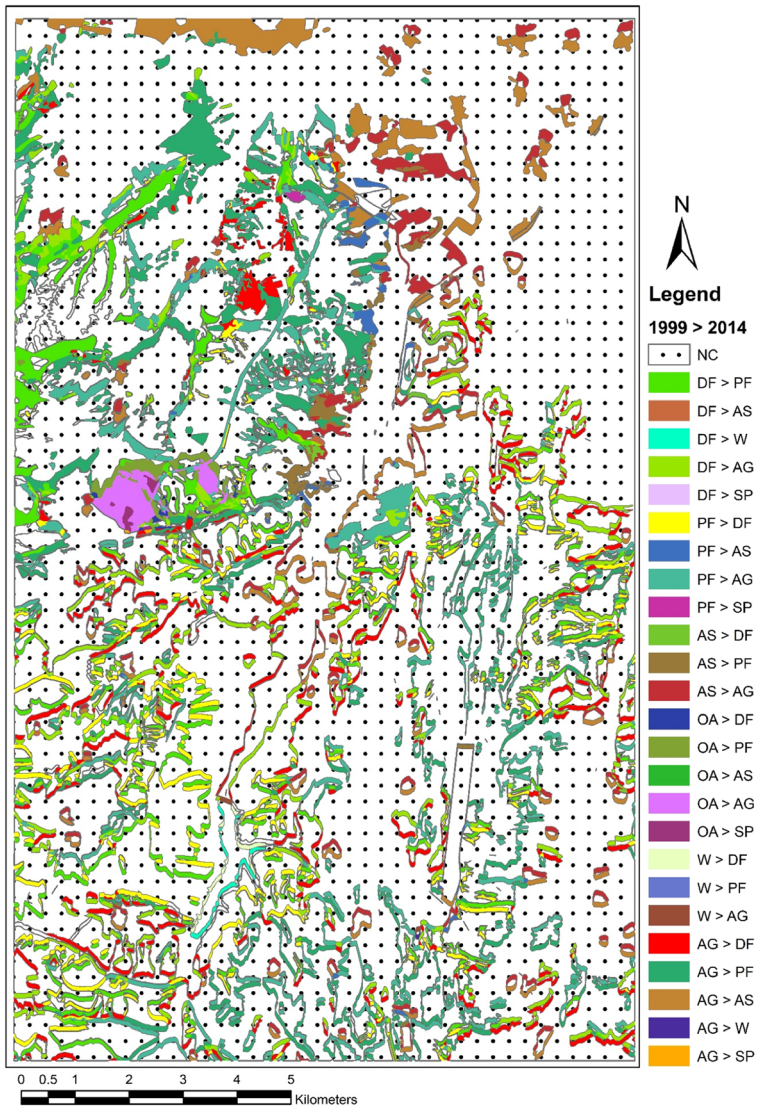

Fig. 4 The transition matrix of LULC changes in Kastamonu city center from 1999 to 2014

Studies have been conducted on a global scale to show changes in LULC, especially changes in the forests (Chauchard et al. 2010; Xystrakis et al. 2017; Gehrig-Fasel et al. 2007; Kucuk et al. 2017). However, these studies generally found that forests shrink, and the primary factors causing deforestation were changes in the soil use (forests turning into agricultural or residential land), climate change, and wildfires. In reality, it is acknowledged that all three factors are the result of human activity. Forests are destroyed and repurposed to meet the demands and needs of the growing population. Forests are also damaged by disruptions in the ecosystem brought on by global climate change, and again, humans are behind more than 90% of wildfires (Harvey 2016; Šturm and Podobnikar 2017). It is crucial to identify the changes in the forestlands caused by these factors. Thanks to the analyses made as part of this study, spatial and structural analysis of periodical changes can be conducted (Lele and Joshi 2009; Sen et al. 2015). Many studies that monitor changes in forests bring to light the seriousness of the change for the worse in forests. For example, according to the findings of a study conducted in South America, the total deforested area and related gross carbon losses from 1990 to 2005 reached 57.7 million ha in deforestation and 6460 Tg C (De Sy et al. 2015). According to other studies, the deforestation rate was 3.74–4.09 million ha in deforestation a year in the 1990s, and 3.28–4.87 million ha of

Table 3 LULC classes transition matrix in Kastamonu city center between 1999 and 2014

1999	2014											
	PCF (ha)	PBF (ha)	PMF (ha)	DCF (ha)	DBF (ha)	DMF (ha)	AS (ha)	AG (ha)	W (ha)	S (ha)	SP (ha)	Total
PCF (ha)	3690.7	110.7	8.7	216.0	138.7	109.1	67.2	768.6	–	–	5.3	5114.9
PBF (ha)	–	0.6	9.9	–	–	0.1	–	3.6	–	–	–	14.2
PMF (ha)	3.2	23.7	0.2	0.4	0.3	20.5	–	8.7	–	–	–	57.0
DCF (ha)	288.2	3.8	0.5	530.0	1.8	0.3	12.4	233.9	0.0	–	0.3	1071.1
DBF (ha)	200.5	56.7	5.8	6.9	1091.4	14.4	3.9	152.1	12.9	–	–	1544.6
DMF (ha)	160.0	45.3	3.2	8.4	32.1	662.1	2.5	154.1	1.3	–	–	1068.9
AS (ha)	82.3	1.6	–	24.7	1.7	4.4	1118.8	322.1	–	–	–	1555.4
AG (ha)	899.8	63.5	12.3	250.6	120.9	132.5	519.5	9540.3	0.7	–	1.4	11,541.4
W (ha)	–	0.6	0.3	–	11.6	0.9	–	2.5	60.1	–	–	75.9
S (ha)	–	–	–	–	–	–	–	–	–	51.8	–	51.8
OA (ha)	66.5	0.8	–	8.4	–	–	0.8	98.9	–	–	11.5	186.9
Total	5391.3	307.2	40.7	1045.3	1398.4	944.2	1725.1	11,284.8	74.9	51.8	18.6	22,282.1

deforestation a year in the 2000s (De Fries et al. 2002; Hansen et al. 2010; Harris et al. 2012; Eva et al. 2012; Achard et al. 2014).

A large number of studies have been conducted to determine the anthropogenic effects on forests since humans are the main source of strain on the forest ecosystem. In these studies, the changes in population-forest limits and structures particularly stand out. There are studies conducted by Liu et al. (1993) in the Philippines, by Schmitz et al. (1998) in Spain, by Gaona-Ochoa and Gonzalez-Espinoza (1999) in Mexico, by Verburg et al. (1999) in Java, by Kammerbauer and Ardon (1999) in Honduras, by Luque (2000) in New Jersey, by Latorre et al. (2000) in the Mediterranean region, by Nagashima et al. (2002) in New Zealand, by Vasquez et al. (2002) in Peru, by Wardell et al.

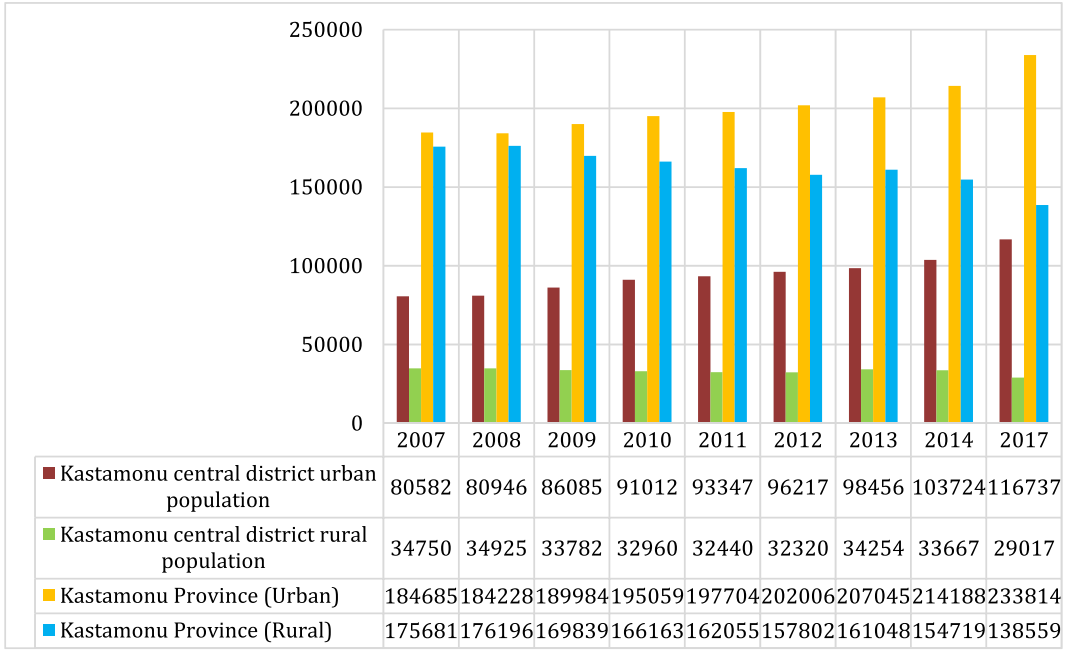

Fig. 5 Population of Kastamonu: rural areas, urban areas, and urban and rural of the central district

(2003) in Sudano-Sahelian, by Yıldırım et al. (2002) in Kocaeli, by Yuliang et al. (2004) in China, by Siddiqui et al. (2004) in Pakistan, by Sen (2011) in Macka-Turkey, and by Bayramoğlu and Kadıoğulları (2018) in Torul-Turkey investigating changes in the forests.

The effects of deforestation are not limited to a regional scale; they have global implications. According to studies that have been made, deforestation is the second largest source of anthropogenic CO_2 emissions and causes a net reduction of carbon storage in terrestrial ecosystems (De Sy et al. 2015). Carbon loss due to deforestation was calculated as 306–698 Pg C a year for the 1990s, and 322–845 Pg C a year for the 2000s (Baccini et al. 2012; Harris et al. 2012; Eva et al. 2012; Achard et al. 2014; Houghton 2012; Tyukavina et al. 2015). Deforestation also has many other negative effects such as in reducing biodiversity, reducing the population, or even causing the extinction of endemic and rare creatures (De Sy et al. 2015; Ochoa-Quintero et al. 2015; Barlow et al. 2016). Deforestation, therefore, means not just the loss of an ecosystem; it has many other effects, some of which are at a global scale and affect humans, plants, and animals both directly and indirectly.

Conclusions

The findings of the study reveal that the LULC in the Kastamonu city center changed significantly between 1999 and 2014. The fact that this change ended up in favor of forests is the good news. However, the changes involved, for the most part, the transformation of agricultural and pasture lands into artificial surfaces. Agriculture and livestock are essential activities for meeting food demand and are a priority matter for every country. Therefore, it is crucial that these areas are protected and maintain their nature. The soil needed for agricultural and pasture land is an asset that takes years to be formed, with hardly any substitute. Soil loss can, therefore, result in irreversible problems. Recent legislation in Turkey that aims to protect agricultural areas looks promising. However, land in the city centers or in the surrounding areas is always under heavy strain, and it is crucial that these areas are continuously monitored to predict potential destruction and take the necessary precautions.

Therefore, similar studies must be conducted through diversification and augmentation, both in the area covered as part of this study and in those city centers with growing populations that border on agricultural areas, forests, and pasturelands.

Author contributions Gokhan Sen, Ersin Güngör, and Hakan Sevik designed the research, coordinated the data analysis, and wrote the paper.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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