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Determination of Temporal Changes in Bursa Land Cover/Use with CORINE Data and Landscape Metrics[A]

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Abstract: Land cover/use constantly changes due to various factors worldwide. This uncontrolled, sudden, and unconscious change can negatively affect land and water resources. In order to develop sustainable use of land and water resources and policies, it is necessary to evaluate the changes in current land cover/use, determine the causes of the change, and monitor and control possible changes. The use of remote sensing and geographic information systems methods allows for the rapid and easy detection of land cover/use changes in large areas and, therefore, the easy detection and monitoring of the changes that occur. This study aims to examine the changes in land cover/use in Bursa province in the 28 years between 1990-2018 using CORINE data. CORINE is land cover/use data based on land cover/use classification with remote sensing, geographic information systems technologies, and computer-aided visual interpretation methods. According to the research results, artificial regions are rapidly increasing throughout Bursa. The increase in artificial areas in Bursa province has been revealed to affect other land cover/use classes, primarily agricultural, forest, and semi-natural regions. When the data for 1990 and 2018 were examined, it was concluded that artificial areas increased by 2.21% throughout Bursa, agricultural areas decreased by 0.85%, forests and natural areas decreased by 1.52%, wetlands increased by 0.15% and there was no proportional change in water bodies. Some landscape metrics were used to express and interpret land cover/use class changes numerically. In the obtained results, the changes in class patch numbers and mean patch sizes indicate fragmentation in land cover/use classes when evaluated together

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with the results of other landscape metrics. The analysis of land cover/use with landscape metrics allows an understanding of land change from a broad perspective.

Keywords: Bursa, CORINE, land cover/use, landscape metrics, Türkiye.

Bursa Arazi Örtüsü/Kullanımındaki Zamansal Değişimlerin CORINE Verileri ve Peyzaj Metrikleri ile Belirlenmesi

Öz: Tüm dünyada arazi örtüsü/kullanımı çeşitli faktörlerin etkisi altında sürekli olarak değişmektedir. Bu değişimin kontrolsüz, ani ve bilinçsiz olarak meydana gelmesi toprak ve su kaynakları üzerinde olumsuz sonuçlara neden olabilmektedir. Arazi ve su kaynaklarının sürdürülebilir kullanımı ve politikaların geliştirilebilmesi için mevcut arazi örtüsü/kullanımındaki değişikliklerin değerlendirilmesi, değişimin nedenlerinin belirlenmesi ve olası değişikliklerin izlenerek kontrol altına alınması gerekmektedir. Uzaktan algılama ve coğrafi bilgi sistemleri yöntemlerinin kullanılması, geniş alanlardaki arazi örtüsü/kullanım değişikliklerinin hızlı ve kolay bir şekilde tespit edilmesine ve dolayısıyla meydana gelen değişikliklerin kolaylıkla tespit edilip izlenebilmesine olanak sağlamaktadır. Bu çalışma, CORINE verilerini kullanarak Bursa ilindeki arazi örtüsü/kullanımındaki değişiklikleri 1990-2018 yılları arası 28 yıllık dönemde incelemeyi amaçlamaktadır. CORINE, uzaktan algılama, coğrafi bilgi sistemleri teknolojileri ve bilgisayar destekli görsel yorumlama yöntemiyle arazi örtüsü/kullanım sınıflandırmasına dayalı olarak üretilen arazi örtüsü/kullanım verileridir. Araştırma sonuçlarına göre, Bursa genelinde yapay bölgelerin hızla arttığı sonucuna ulaşılmıştır. Bursa ilinde yapay bölgelerdeki artışın tarım alanları, orman alanları ve yarı doğal alanlar başta olmak üzere diğer arazi örtüsü/kullanım sınıflarını etkilediği ortaya konmuştur. 1990 ve 2018 yılı verileri incelendiğinde Bursa genelinde yapay alanların %2,21 oranında arttığı, tarım alanlarının %0,85 oranında azaldığı, orman ve doğal alanların %1,52 oranında azaldığı, sulak alanların %0,15 oranında arttığı, su kütlelerinde ise oransal bir değişim olmadığı sonucuna ulaşılmıştır. Arazi örtüsü/kullanımı sınıflarında meydana gelen değişiklikleri sayısal olarak ifade etmek ve yorumlamak için bazı peyzaj metriklerinden yararlanılmıştır. Elde edilen sonuçlarda sınıf leke sayıları ve ortalama leke büyüklüklerindeki değişimler, diğer peyzaj metrikleri sonuçlarıyla birlikte değerlendirildiğinde arazi örtüsü/kullanımı sınıflarındaki parçalanmayı işaret etmektedir. Arazi örtüsü/kullanımının peyzaj metrikleri ile analizi geniş bir bakış açısıyla arazi değişimini anlamaya imkân sağlamaktadır.

Anahtar Kelimeler: Bursa, CORINE, arazi örtüsü/kullanımı, peyzaj metrikleri, Türkiye.

Introduction

Land cover/use (LC/LU) is in a constant state of change due to both natural and human factors (Altürk et al., 2019). Uncontrolled/unconscious modifications in land cover/use can cause irreversible negative results in the lands (Yiğit, 2018). For this reason, lands should be used according to their potential, and their usage patterns should be planned (Gülersoy, 2013). Detection of temporal changes in land is the basis of effective and sustainable land management (Sarı and Özşahin, 2016).

The ability to transfer lands to future generations without degradation depends on detecting land changes, determining change trends, and planning them correctly (Bayar and Karabacak, 2017). Since it is impossible to follow up the land cover/use changes that occurred in the past quickly and up-to-date from a technical perspective, it has yet to be possible to prevent rapid and uncontrolled changes in land cover/use (Kara and Karatepe, 2012). Today, remote sensing (RS) and geographic information systems (GIS) are using determining changes in land cover/land use. The combined use of RS and GIS provides excellent convenience in determining current land cover/uses and temporal-spatial changes (Turan et al., 2021). Analyzing land use changes over the years using Geographic Information Systems and remote sensing techniques offers advantages such as access to multi-year data, quicker study execution, and cost and time savings (Özsoy, 2021). Temporal data should be kept regularly to assess the changes in land cover/use (Bayar and Karabacak, 2017). CORINE (Coordination of Information on the Environment) data is important in determining the temporal changes in land cover/use over time.

In addition to evaluating the area change in land cover use, how the change occurred should also be examined. It is also necessary to evaluate how the change is located, whether it increases in a fragmented or isolated structure, etc. The evaluation of the change that has occurred in LC/LU with landscape metrics allows for a more comprehensive interpretation of the effects of the changes and the development of suggestions. (Kesgin Atak, 2020)

The study aims to determine the changes in the cover/use of Bursa province by using CORINE 1990-2000-2006-2012-2018 years data, analyze the change with landscape metrics, and reveal the reasons for the change.

Material and Methods

Description of the Study Area

Bursa province was selected as the study area. Bursa is located in the northwest of Turkey and southeast of the Sea of Marmara, between 40 degrees longitude and 28-30 degrees latitude (Bursa Çevre, Şehircilik ve İklim Değişikliği İl Müdürlüğü, 2023). Surrounded by the provinces of Yalova, Kocaeli, Sakarya, Bilecik, Kütahya, and Balıkesir and having a 135 km coastline to the Marmara Sea, Bursa province has 17 districts (Anonymous, 2023a). According to 2022 data, Bursa is the fourth most populous province in our country and the fifth most migrant-receiving province between provinces (TÜİK, 2023). In the early 1960s, Bursa was selected as the first

Organized Industrial Zone in our country, and this situation led to the establishment of rapid urbanization due to population migration. Bursa province has an essential share in our country's agricultural production with its climate and soil conditions. In addition to agricultural production, the development of agriculture-based industry increases the importance of agriculture in Bursa (Turhan et al., 2013). Bursa, where much of the province's area is covered with forests, is also rich in natural vegetation. Bursa is an important province in terms of surface and groundwater resources and wetlands.

Figure 1: *Study area map*

Data and Method

CORINE data and ArcGIS programs were used to process the data. CORINE is land cover/use data produced by computer-aided visual interpretation from satellite images according to the land cover classification determined by the European Environment Agency. It allows changes in land cover/use to be easily defined and monitored regularly (Anonymous, 2022). In the first step of the study, CORINE land cover/use classification data for the years 1990, 2000, 2006, 2012, and 2018 were downloaded in vector format from the Copernicus (Copernicus, 2023) website. Then, Türkiye country and province border data were downloaded from the General Directorate of Mapping website (Anonymous, 2023b). After the download process, CORINE data were cut according to the borders of our country using the “clip” command in the ArcGIS program, Bursa land cover/use data were created, and the necessary projection transformation was made. Using the “dissolve” command, CORINE Level 1 land cover/use data for Bursa were obtained, and tables and maps were created. CORINE LC/LU classification consists of 5 basic classes at the first level: artificial surfaces, agricultural areas, forest and semi-natural areas,

wetlands, and water bodies (Anonymous, 2022). In addition to examining the LC/LU class areas, evaluating the fragmentation and changes that occur in the classes is also important. Therefore, class-level landscape metrics were analyzed using the "Patch Analyst" add-on in the ArcMap 10.8v program. The satellite images in the study were obtained using the Google Earth Pro.

Table 1. Landscape metrics used in the study (Cengiz and Günaydın, 2021; Yeşil and Güzel, 2021; Eren and Taşlı, 2023)

Landscape Metrics	**Description**
Number of Patches	It is the total number of patches belonging to a class.
Mean Patch Size	It is the value obtained by dividing a class area by the number of patches.
Total Edge	It is the total edge length of the patch belonging to a class.
Edge Density	It is the value obtained by dividing the total side length by the total landscape area.
Mean Perimeter-Area Ratio	It is the ratio of the patch shape compared to the patch size. An increase in the patch size while the patch shape is constant causes the mean perimeter-area ratio value to decrease.
Mean Patch Edge	The mean amount of edges per patch.
Mean Shape Index	The mean shape index value deviating from 1 indicates that the patches are not regular in shape.

Results and Discussion

Artificial Surfaces

The areal and proportional distribution of artificial surfaces by year is given in Table 2. It was found that there was a 2.21% increase of 23 939.53 ha in artificial areas in the change that occurred between 1990 and 2018. The area of the artificial regions, which was 16 979.11 ha in 1990, increased to 40 918.64 ha in 2018. In this case, the area of artificial areas in 2018 was more than twice the area in 1990.

Table 2. Analysis of artificial surfaces change

1990		**2000**		**2006**		**2012**		**2018**		**Relative Change %**
ha	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	
16 979.11	1.57	27 345.28	2.53	33 193.73	3.07	37 825.42	3.50	40 918.64	3.78	140.99

In the last 28 years, it has been observed that the number of patches has continuously increased along with the increase in the area of the artificial regions class. The increase in the number of patches, which gives the number of patches forming the class, indicates fragmentation (Doygun, 2017). When the mean patch size is examined, it is seen that a continuous increase has occurred. In this case, the change in the number of patches and the mean size can be interpreted as the artificial regions tending to grow by fragmentation. It has been determined that the total edge and edge density values, which indicate a tendency for fragmentation, approximately doubled. In addition, the mean patch edge values have also increased. While the shape is constant

in the mean perimeter area ratio value, an increase in the patch size will cause a decrease in the perimeter-area ratio. The mean patch size has increased during the 28 years. With this increase, it is observed that the mean perimeter area value has also increased, which can be interpreted as the patch shapes are not regular. The mean shape index value greater than 1 indicates that the patches do not have a regular round or square shape. The more shape irregularities indicate that the central area of the patch is not developed (Tağıl et al., 2016). When Table 3 is examined, it is seen that the mean shape index values also increased over time. However, unlike other classes, the class with the lowest mean shape index value is artificial regions. Artificial surface maps for 1990 and 2018 are given in Figure 2. The increase in artificial areas is seen in the maps.

Table 3. Analysis of artificial surfaces change with landscape metrics

	Number of Patches	Mean Patch Size	Total Edge	Edge Density	Mean Perimeter-Area Ratio	Mean Patch Edge	Mean Shape Index
1990	204	83.23	913 060.22	0.84	79.65	4 475.79	1.51
2000	235	116.36	1 232 746.49	1.14	78.68	5 245.73	1.54
2006	262	126.69	1 482 717.53	1.37	81.16	5 659.23	1.57
2012	298	126.93	1 670 932.78	1.54	121.66	5 607.16	1.59
2018	304	134.60	1 822 890.37	1.69	124.16	5 996.35	1.62

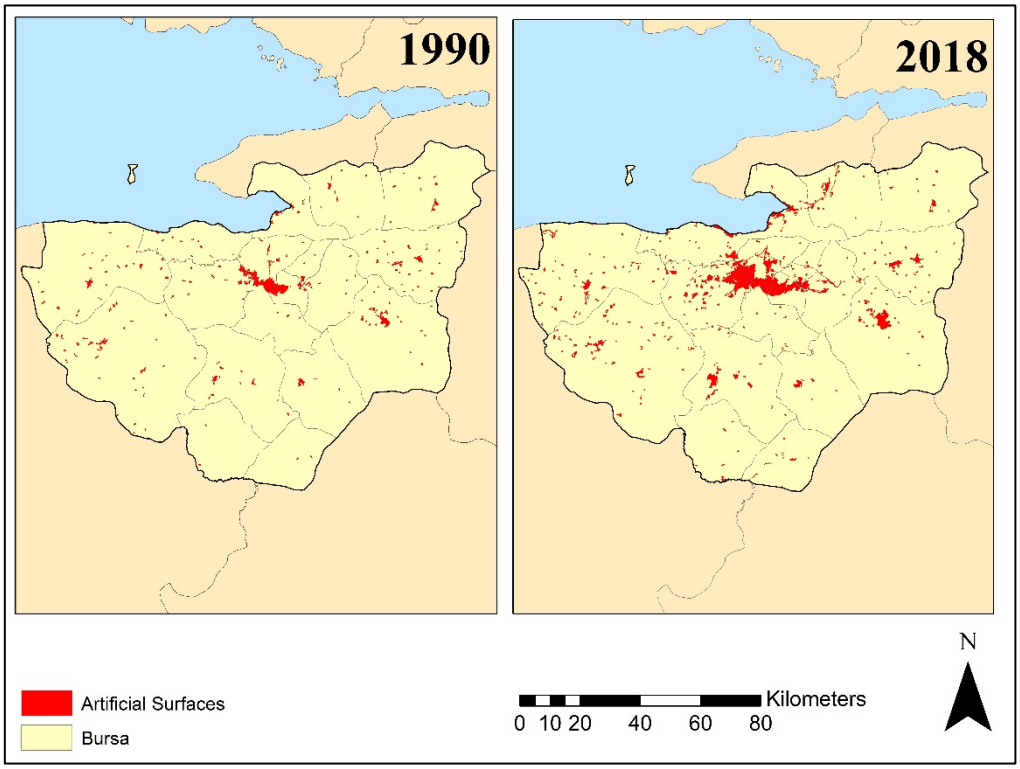

Figure 2: *1990 and 2018 artificial surface maps*

When the changes in artificial areas were evaluated on a district basis, it was determined that the most significant change occurred in the Nilüfer district. It was determined that the artificial areas class area, which was 1 278.89 ha in Nilüfer district in 1990, reached 7 394.41 ha in 2018. Changes in artificial surfaces in Bursa were examined in detail through satellite images presented in Figure 3. Satellite images show that artificial surfaces rapidly expand from the city center to the periphery. The expansion of artificial surface areas affects other land cover/use classes.

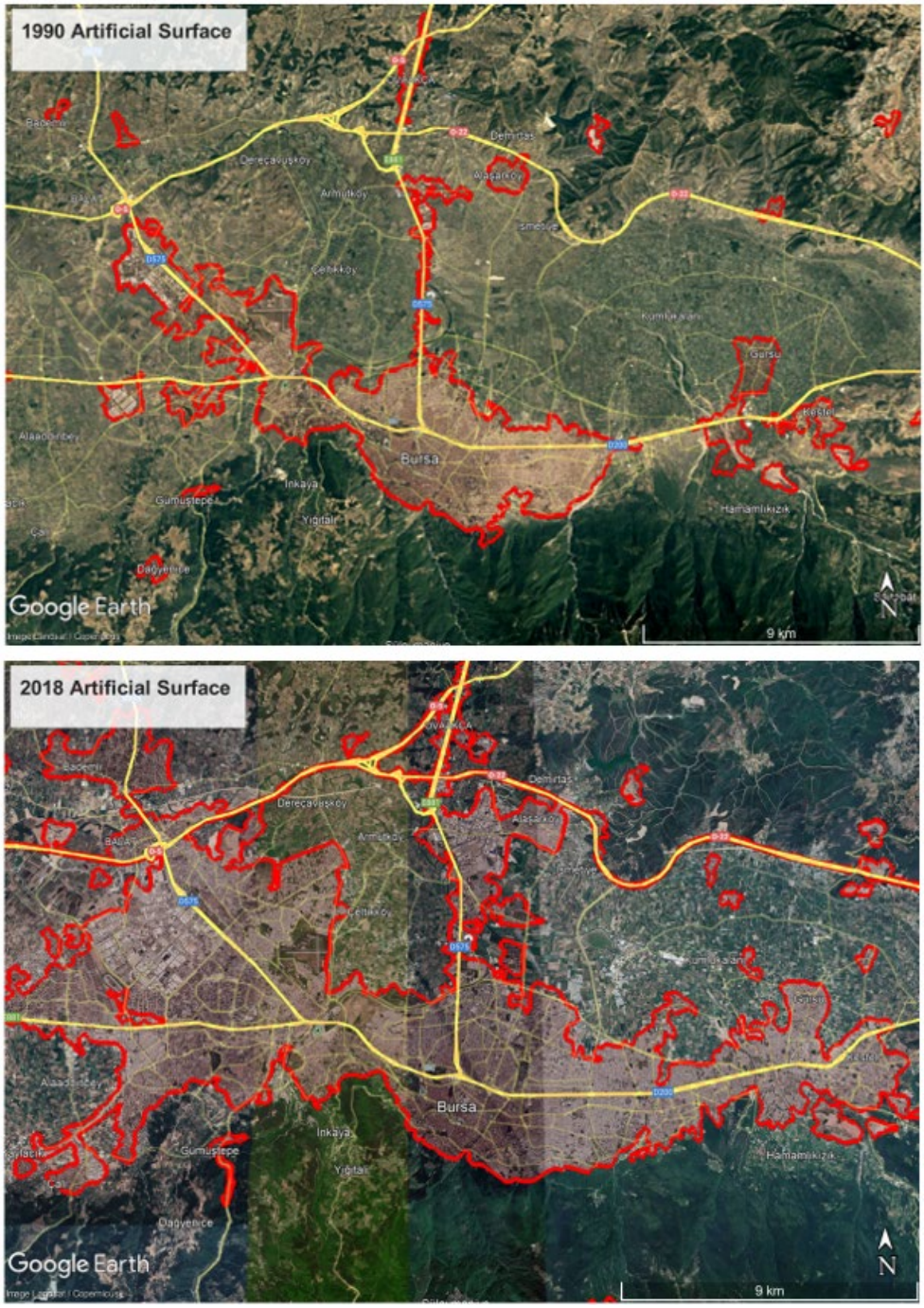

Figure 3: *1990-2018 Satellite images of artificial surfaces*

Agricultural Areas

Agricultural areas, which are very important for our country and Bursa province, have decreased by 0.85% in the province in 28 years. Agricultural areas, which had an area of 489 738.53 ha in 1990, declined to 480 551.25 ha in 2018. Despite the changes over the years, it maintains its feature of being the class with the largest area in Bursa after semi-natural forests and regions (Table 4).

Table 4. Analysis of agricultural areas change

1990		2000		2006		2012		2018		Relative Change %
ha	%	ha	%	ha	%	ha	%	ha	%	
489 738.53	45.28	480 820.27	44.45	479 061.42	44.29	482 496.35	44.61	480 551.25	44.43	-1.91

When the class areas of 1990 and 2018 are compared (Table 4), it is seen that the class area has decreased. However, the number of patches has continuously increased (Table 5). When evaluated in terms of fragmentation, it is seen that the number of patches, an important metric, is the highest in the agricultural areas class compared to other courses. While the mean patch sizes are pretty large compared to other classes, these values have continuously decreased. In the last 28 years, the number of patches has continually increased, and the mean patch sizes have continuously decreased. It has also been observed that there has been a continuous increase in the total edge and edge density values. The high edge density can be interpreted as the class being more fragmented (Yiğit, 2018). The edge density values are approximately 8 times the artificial zones class. It was found that the mean perimeter area ratio value in agricultural areas first decreased, showed a sudden increase in 2006, and then decreased again. There was no great change in the mean shape index value, although there was a decrease and an increase. The mean shape index shows that the patches belonging to the classes do not have a regular round or square shape. When all the changes are evaluated together, it can be interpreted that agricultural areas tend to become fragmented and smaller. Agricultural area maps for 1990 and 2018 are given in Figure 4.

Table 5. Analysis of agricultural areas change with landscape metrics

	Number of Patches	Mean Patch Size	Total Edge	Edge Density	Mean Perimeter-Area Ratio	Mean Patch Edge	Mean Shape Index
1990	312	1 569.67	9 679 262.88	8.95	98.13	31 023.28	2.23
2000	321	1 497.88	9 853 902.86	9.11	97.19	30 697.52	2.26
2006	363	1 319.73	10 535 484.03	9.74	257.95	29 023.37	2.26
2012	365	1 321.91	10 575 128.49	9.78	160.21	28 972.95	2.23
2018	375	1 281.47	10 610 185.59	9.81	158.14	28 293.83	2.24

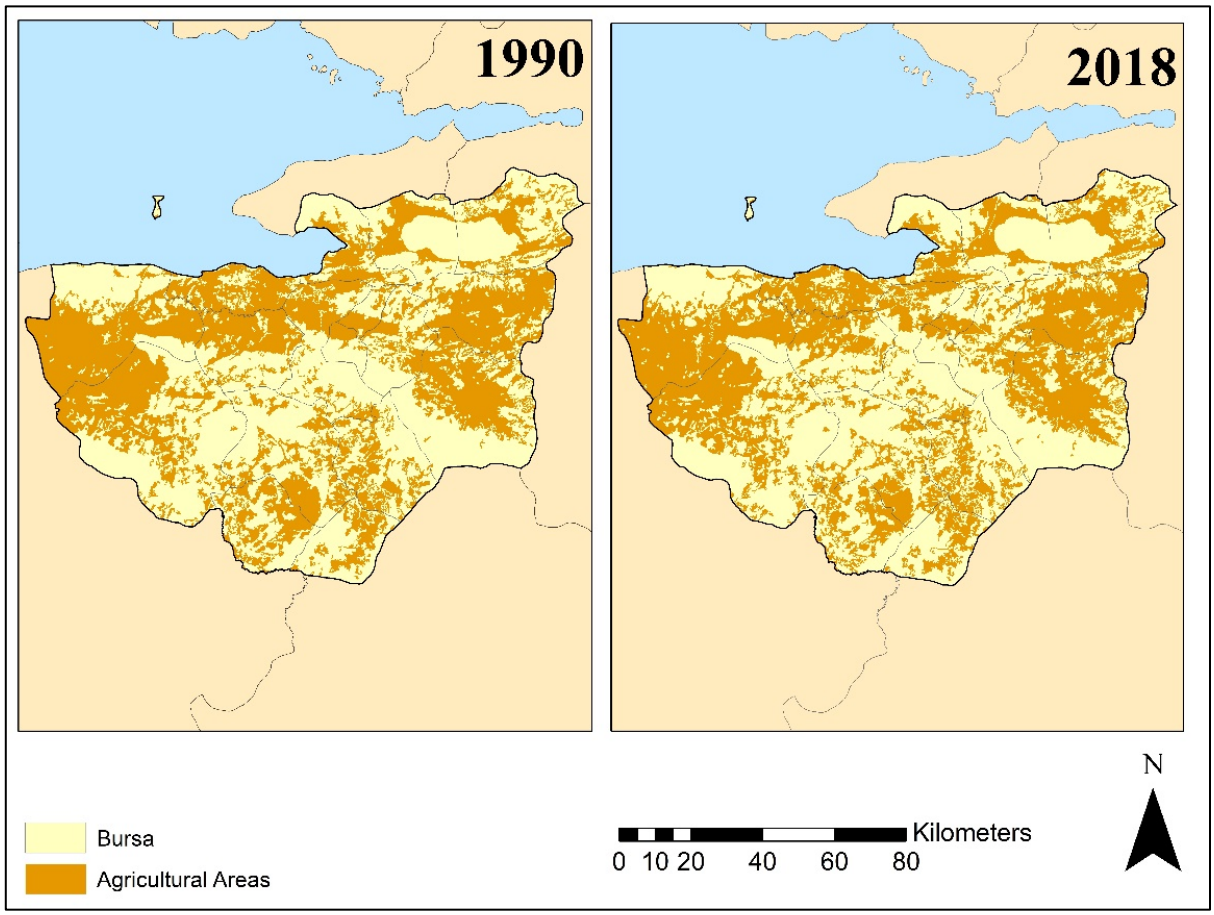

Figure 4: *1990 and 2018 agricultural areas maps*

When the changes in agricultural areas were evaluated on a district basis, it was determined that the biggest change occurred in the Nilüfer district. It was determined that the agricultural areas class area, which had an area of 30 009.34 ha in 1990, decreased to 24 737.85 ha in 2018. The changes that occur are given in Figure 5 with satellite images.

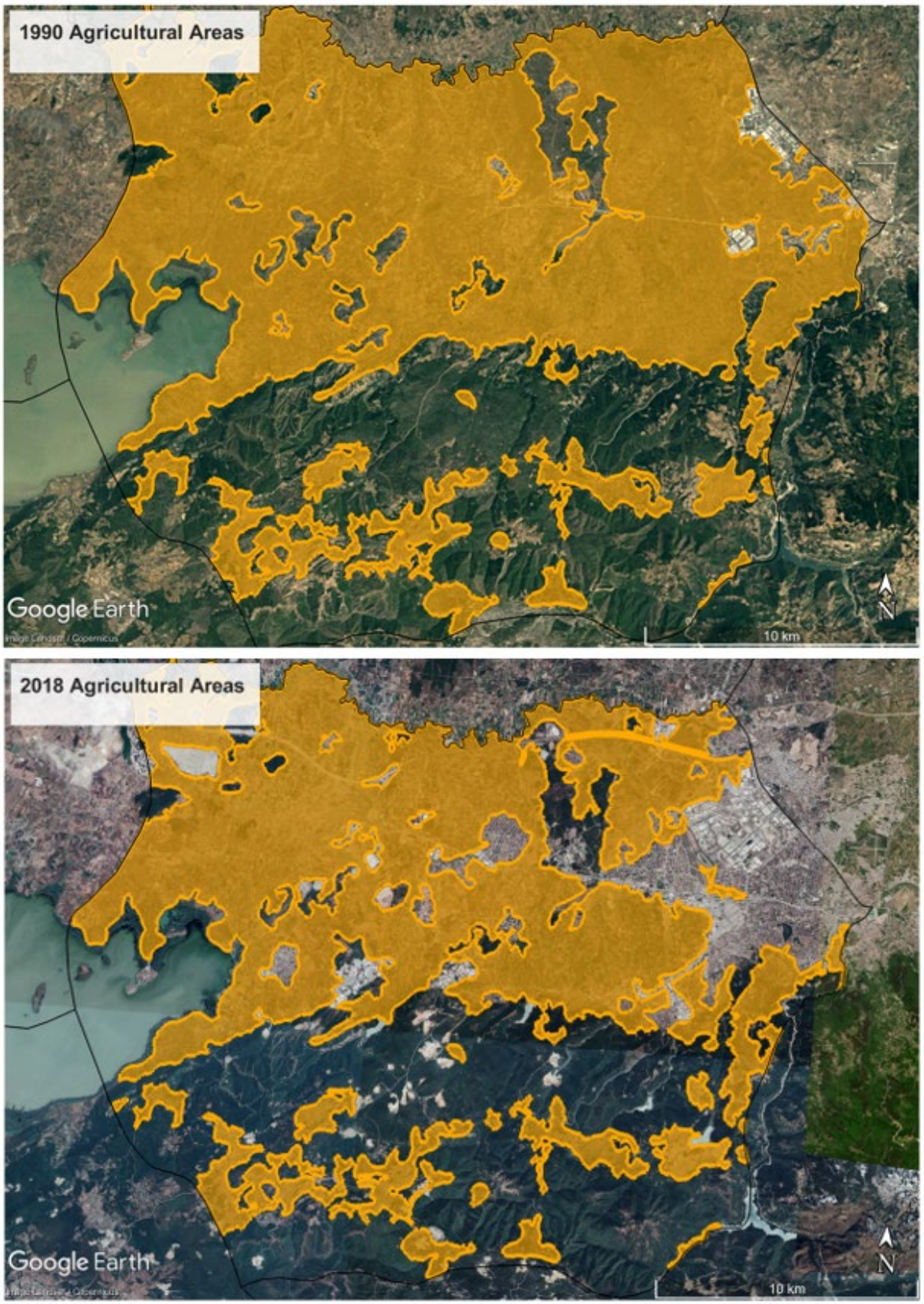

Figure 5: *1990-2018 Satellite images of agricultural areas in Nilüfer district*

Forest and Seminatural Areas

According to the data obtained, the largest land class in Bursa province is forest and semi-natural areas. Despite the changes in LC/LU classes over the years and the decrease in forest and semi-natural areas, it is seen that the forest and semi-natural areas class maintains its areal superiority compared to other land classes. Forest and the semi-natural regions constituted 47.02% of Bursa in 2018 (Table 6).

Table 6. Analysis of forest and seminatural areas change

1990		2000		2006		2012		2018		Relative Change %
ha	%	ha	%	ha	%	ha	%	ha	%	
525 015.57	48.54	523 348.96	48.38	519 476.06	48.03	509 972.71	47.15	508 589.72	47.02	-3.13

When evaluated in terms of landscape metrics, the changes in agricultural areas and forest and semi-natural area classes are similar (Table 7). It is seen that the forest and semi-natural areas class area is decreasing. However, the number of patches is continuously increasing. Although the mean patch sizes are pretty large compared to other classes, these values have continually reduced. In the 28 years, the number of patches continuously increased, and the mean patch sizes decreased. In addition, it has been observed that there has been a continuous increase in the total edge and edge density values. The edge density values are approximately 8 times the artificial surface class. Although there was a slight decrease and increase in the average shape index value over time, there was no significant change. The obtained value of the mean shape index indicates that the patches belonging to the forest and semi-natural class do not have a regular round or square shape. When all the changes are evaluated together, it can be commented that agricultural areas tend to fragment and shrink. The maps of the 1990 and 2018 forest semi-natural areas are given in Figure 6.

Table 7. Analysis of forest and seminatural areas change with landscape metrics

	Number of Patches	Mean Patch Size	Total Edge	Edge Density	Mean Perimeter-Area Ratio	Mean Patch Edge	Mean Shape Index
1990	282	1 861.76	9 152 281.18	8.46	688.56	32 454.90	2.10
2000	282	1 855.85	9 175 703.90	8.48	688.94	32 537.96	2.07
2006	361	1 438.99	9 734 182.54	9.00	1 299.47	26 964.49	2.07
2012	370	1 378.30	9 829 533.27	9.09	350.30	26 566.31	2.09
2018	373	1 363.51	9 841 466.68	9.10	348.76	26 384.63	2.09

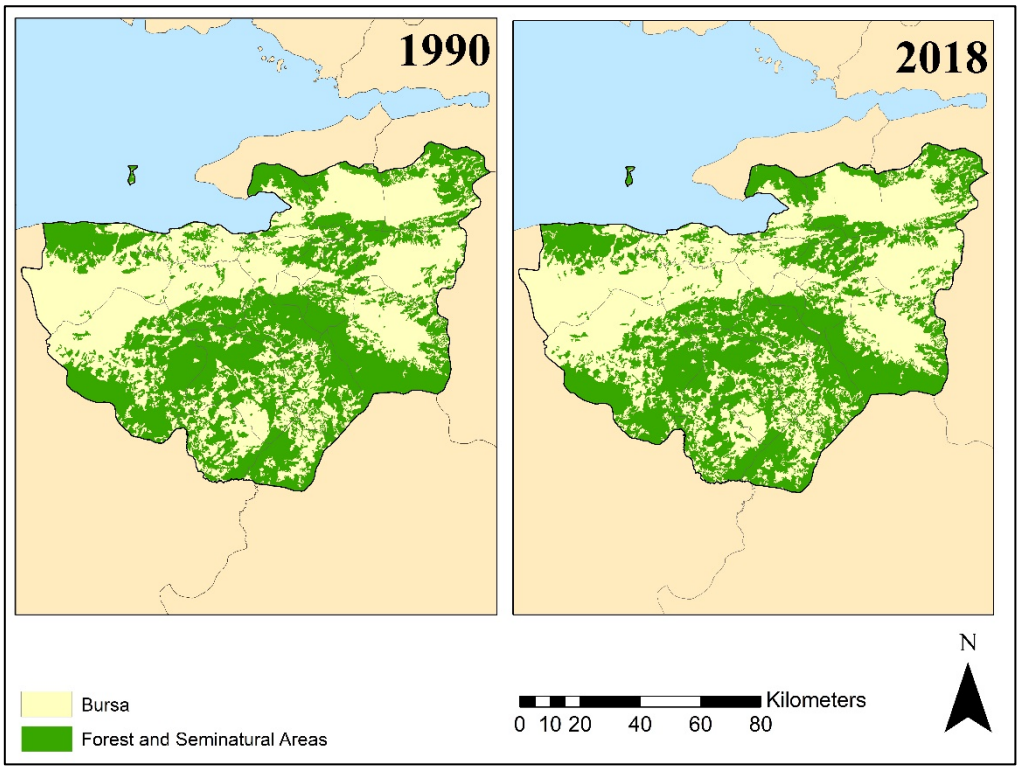

Figure 6: *1990 and 2018 forest and seminatural areas maps*

Since forest and semi-natural lands class was evaluated on a district basis, it was determined that the most change occurred in the Iznik district. It was determined that the forest and semi-natural lands class area, which had an area of 35 222.06 ha in 1990, decreased to 31 222.79 ha in 2018. It was determined that with this decrease in the forest and semi-natural land class, there was an increase in agricultural areas at the same rate. The changes in forest and semi-natural areas that occur are given in Figure 7 with satellite images.

Studies examining land cover/use changes in other provinces in the Marmara Region reveal similar results to the decrease in forest and semi-natural areas detected in Bursa province (Çoban and Uzun, 2023; Kurt and Duman, 2016; Sarı and Özşahin, 2016). In their study in Bilecik province, Çoban and Uzun (2023) stated that the majority of the changes in land cover/use in the 28-year period were in the form of the conversion of forest-semi-natural areas into agricultural areas. In their study in Sakarya province, Kurt and Duman (2016) stated that one of the most important land cover changes in the last 10-15 years was the expansion of settlement areas by occupying agricultural areas and the invasion of agricultural areas into forest areas.

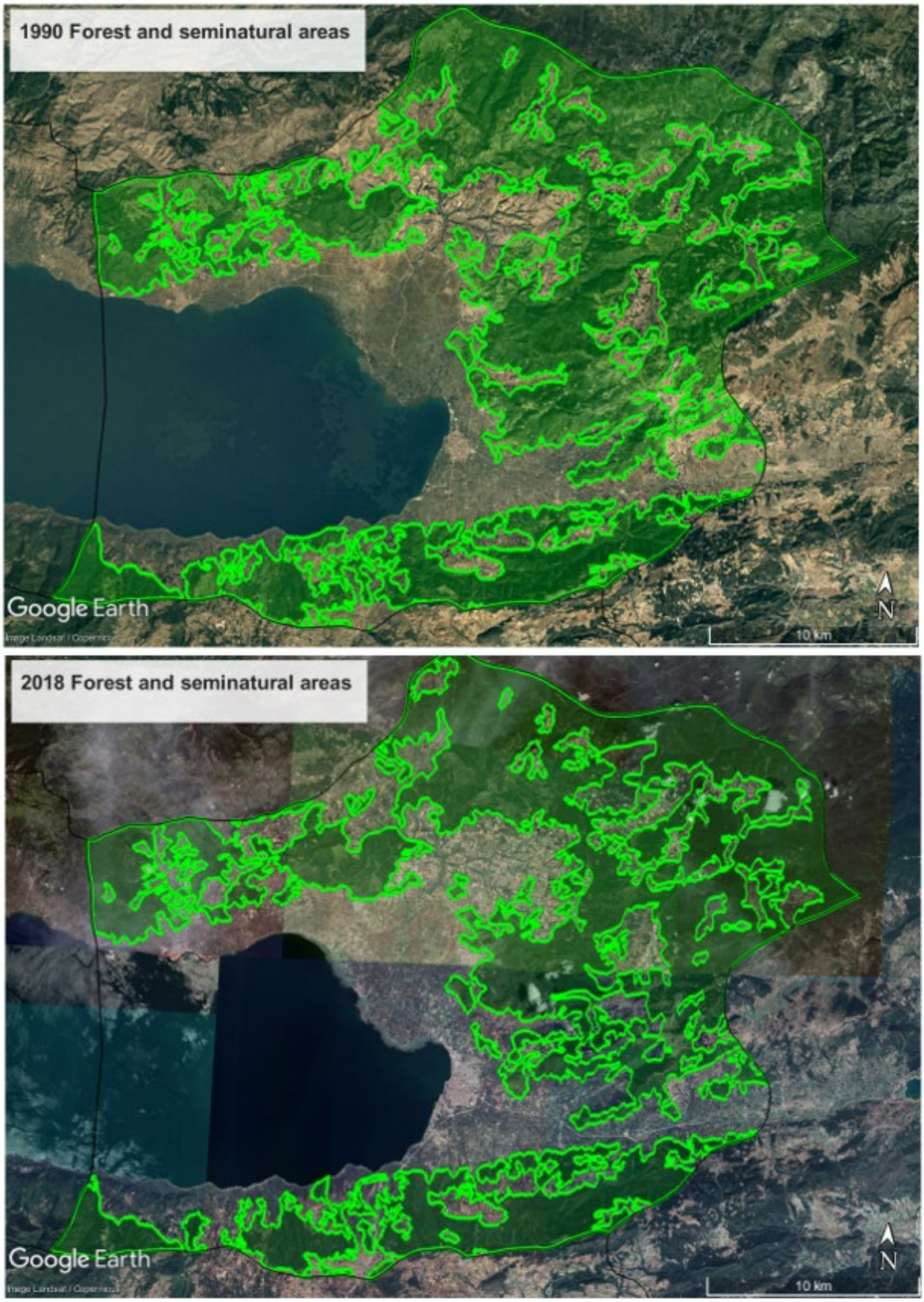

Figure 7: *1990-2018 Satellite images of forest and seminatural areas in İznik district*

Wetlands

While wetlands had a share of 0.38% in Bursa in 1990, this rate increased to 0.53% in 2000, and an increase of 0.15% was found. It is seen that there was no significant area change between 2000 and 2018 (Table 8).

Table 8. Analysis of wetlands change

1990		2000		2006		2012		2018		Relative Change %
ha	%	ha	%	ha	%	ha	%	ha	%	
4 075.00	0.38	5 730.53	0.53	5 642.62	0.52	5 701.08	0.53	5 701.08	0.53	39.90

Among Bursa LC/LU classes, wetlands are the class with the least area. In addition, the wetlands class has the least number of patches compared to other courses, and it is seen that the number of patches has decreased over time (Table 9). It is seen that the landscape metric values of the wetlands class in 2012 and 2018 are the same. Although the number of patches gradually decreased, the mean patch size values increased. There was an increase in the total edge and edge density values in 2000, and then the values declined, and no significant change occurred. The increase in these values may be the increase in the class area in the wetlands class in 2000. The mean patch edge value, which was 8 355.87 ha in 1990, approximately doubled in 2018 and reached 16 018.33 ha. It was determined that the mean perimeter area ratio decreased and then increased, and the mean shape index continuously increased.

When the land cover/use maps of Bursa province are examined in Figure 8, it can be said that most of the change in the wetland class occurred around Uluabat Lake.The findings obtained reveal that the change occurred largely between the wetland and water mass classes. It can be said that the decrease in water masses and the increase in wetlands are related to the decrease or shallowing of the lake water. In the study conducted by Kuşçu (2024), it was determined that Lake Uluabat lost a total area of 12.60 km² (6%) between 1987-2023.

Table 9. Analysis of wetlands change with landscape metrics

	Number of Patches	Mean Patch Size	Total Edge	Edge Density	Mean Perimeter-Area Ratio	Mean Patch Edge	Mean Shape Index
1990	27	150.93	225 608.50	0.21	91.87	8 355.87	2.21
2000	20	286.53	259 437.85	0.24	90.41	12 971.89	2.39
2006	16	352.66	237 925.37	0.22	87.99	14 870.34	2.42
2012	15	380.07	240 274.92	0.22	89.30	16 018.33	2.52
2018	15	380.07	240 274.92	0.22	89.30	16 018.33	2.52

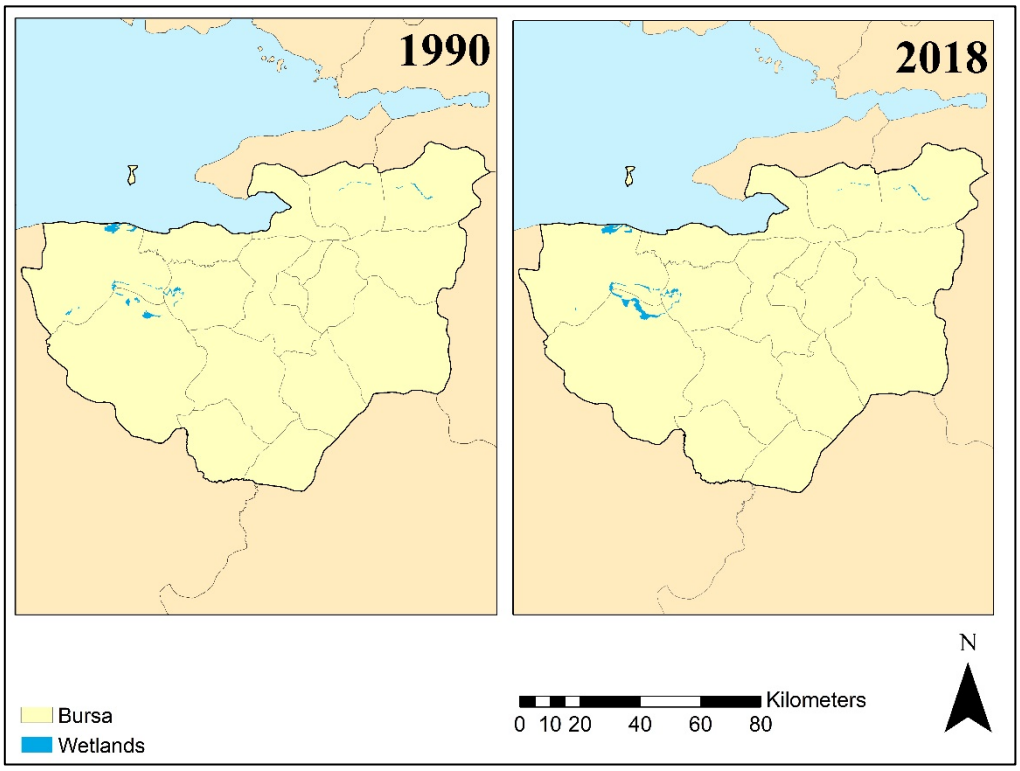

Figure 8: *1990 and 2018 wetlands maps*

Water Bodies

When the data for 1990 and 2018 were compared, it was observed that there was no significant area change in water bodies (Table 10).

Table 10. Analysis of water bodies change

1990		2000		2006		2012		2018		Relative Change %
ha	%	ha	%	ha	%	ha	%	ha	%	
45 848.08	4.24	44 411.25	4.11	44 282.47	4.09	45 660.73	4.22	45 895.60	4.24	0.10

The water bodies class covers an area of 4.24% in Bursa. Although there were minor areal changes in the class area between 1990 and 2018, the class area of Bursa province between 1990 and 2018 did not change. However, when examined with landscape metrics, it is seen that there has been a continuous increase in the number of patches. However, the mean patch size has also decreased continuously. This situation can be shown as a sign of fragmentation. There have been increases in the total edge, edge density, mean perimeter area ratio, mean patch edge, and mean shape index values. Since this class also includes the waterways class, the edge metrics and shape index values may be high (Table 11). The map of water bodies is given in Figure 9.

Table 11. Analysis of water bodies change with landscape metrics

	Number of Patches	Mean Patch Size	Total Edge	Edge Density	Mean Perimeter-Area Ratio	Mean Patch Edge	Mean Shape Index
1990	111	413.05	477 594.86	0.44	6 361.72	4 302.66	2.72
2000	122	364.03	498 251.21	0.46	6 190.66	4 084.03	2.63
2006	123	360.02	495 160.68	0.46	6 717.01	4 025.70	2.67
2012	133	343.31	590 654.78	0.55	10 809.54	4 441.01	2.78
2018	136	337.47	611 341.79	0.57	10 573.37	4 495.16	2.76

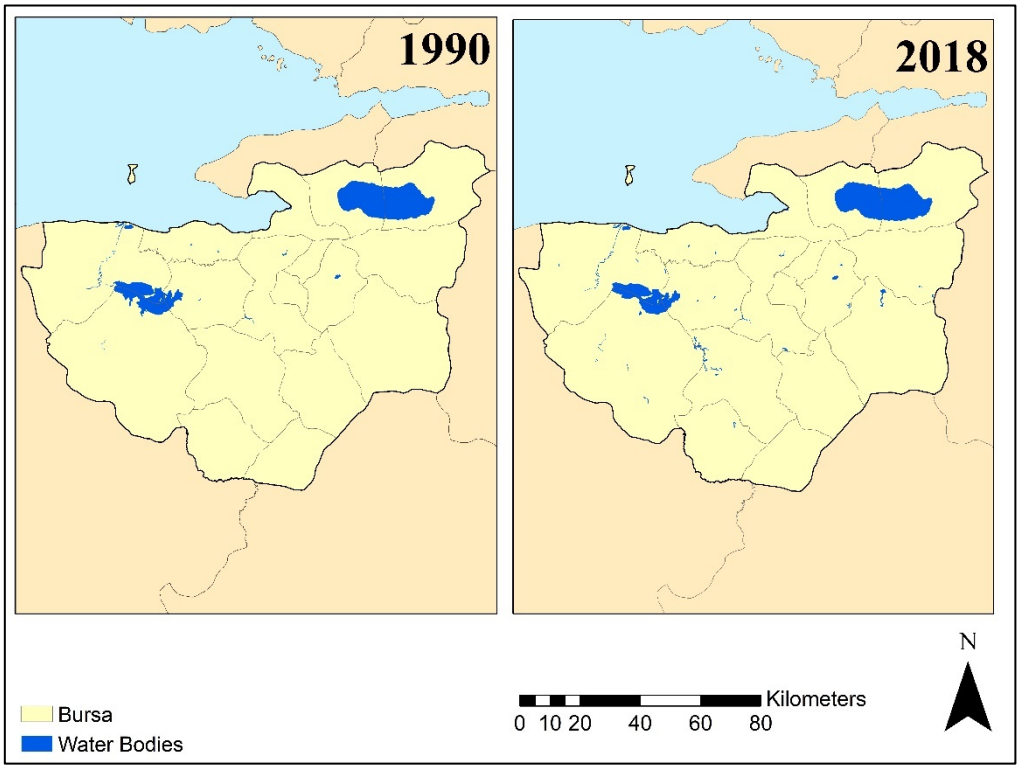

Figure 9: *1990 and 2018 water bodies maps*

Conclusion

Sustainable use of our limited natural resources, such as land and water, depends on correct and planned management. Research on land cover/use reveals the temporal process of class area change and creates a prediction for future change processes by examining the direction of change. In addition to area change, the number of patches, sizes, and shapes of land classes may also change in temporal. The analysis made with landscape metrics and the evaluation of fragmentation elements together is critical in predicting the direction of change and taking precautions against problems.

The limited spatial and temporal resolution of CORINE data may limit the determination of changes occurring in very small areas, and the long update intervals the monitoring of sudden changes. However, CORINE data offers significant advantages in determining environmental changes in large areas with its standardized structure. These data allow for identification and regular monitoring of changes in land cover and use.

Using CORINE data and landscape metrics to determine change is easy and fast. It would be more beneficial to develop CORINE data, re-evaluate the current situation as new data are released in 6-year periods, and support detailed data collection studies in the regions where the studies are analyzed. The findings show that the rapid development of the artificial regions class causes pressure on other class areas. The unplanned growth of the class of the artificial region continues, indicating that other land classes around the city and district center may be negatively affected.

Each of the LC/LU classes has a different value for our country; their changes should be followed carefully, and the lands should be evaluated by their potential. Detailed and regular planning studies should be carried out throughout our country. Considering these perspectives, assessing the change in LC/LU is essential. The study emphasizes the importance of evaluating the areas of class with landscape metrics on LC/LU change issues. Examining the changes with landscape metrics will be extremely useful in revealing the whole situation in detail.

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