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Detection of Population Density, LULC Variation and Cross-Regional Similarities Using K-Means Clustering Algorithm in Istanbul Example

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Abstract

In this study, the effect of urban sprawl on land change in Istanbul was examined using Geographic Information System (GIS) technologies and the CORINE Land Cover (CLC) data set produced for the years 1990-2018 and population information. According to this; It has been determined that urban sprawl in the study area has increased due to population growth, especially industrial units, city structures, mines and construction sites have increased by approximately 9%, while maquis areas, arable, mixed agricultural areas and forest areas have decreased by 9%. According to the K-means application, similarities in the districts were revealed between 1990 and 2018. According to the results obtained, it was determined that the districts that were in clusters with similar characteristics in the 1990s changed over time and were located in different clusters. As a result, it is predicted in the study that urban sprawl will increase further due to population growth in Istanbul.

Keywords: *Urbanization, urban development, natural areas, conservation, Istanbul*

İstanbul örneğinde K-Means Kümeleme Algoritması Kullanılarak Nüfus Yoğunluğu, LULC Değişimi ve Bölgeler Arası Benzerliklerin Tespiti

Öz

Bu çalışmada Coğrafi Bilgi Sistemi (CBS) teknolojileri kullanarak, 1990-2018 yılları için üretilen CORINE Arazi Örtüsü (CLC) veri setinden ve nüfus bilgilerinden yararlanarak İstanbul'da kentsel saçaklanmanın arazi değişimi üzerindeki etkisi incelenmiştir. Buna göre; çalışma alanında kentsel saçaklanmanın nüfus artışına bağlı olarak arttığı özellikle endüstri birimleri, şehir yapısı, maden ve inşaat sahalarının yaklaşık % 9 oranında artış gösterdiği buna karşılık makilik alanlar, ekilebilir, karışık tarım alanları ve ormanlık alanların % 9 oranında azaldığı tespit edilmiştir. K-means uygulamasına göre 1990 ve 2018 yıllarında ilçelerdeki benzerlikler ortaya çıkarılmıştır. Elde edilen sonuçlara göre 1990'lı yıllarda benzer özellikler gösteren kümelerde bulunan ilçelerin zamanla değişim gösterdiği ve farklı kümeler içerisinde yer aldığı tespit edilmiştir. Sonuç olarak çalışmada İstanbul'da nüfus artışına bağlı olarak kentsel saçaklanmanın daha fazla artacağı öngörülmüştür.

Anahtar kelimeler: *Kentleşme, kentsel gelişme, doğal alanlar, koruma, İstanbul*

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1. Introduction

Nowadays, more than half of the world's population lives in urban areas (Li et al., 2009; Shen & Zhou, 2014; Çoban & Uzun, 2023). Due to the growing human population, cities are growing rapidly today, and as a result, natural areas are being destroyed drastically. Cities are increasingly exposed to environmental problems such as construction, improper land use, biodiversity losses, climate change, water, air, and noise pollution, which negatively affect the quality of life (Westmacott, 1991; Doygun et al., 2010). Because of this, one of the best planning strategies for minimizing the adverse effects of urbanization on people and the natural environment is the protection of natural places. The beginning of urbanization is generally accepted as the beginning of civilization. Accordingly, urbanization started with the transition of people from a hunter and gatherer life to a settled life in the historical process. Although the history of cities dates back to Ancient Rome, it is seen that modern cities in today's sense developed rapidly in the 20th and 21st centuries (Uzun and Demir, 2016). The urbanization process causes cities to expand rapidly in space and spread to all urban and rural areas around them, and as a result, natural resources in the urban area are rapidly consumed.

This situation manifests itself with unplanned and uncontrolled growth due to rapid population growth, especially in the cities of developing countries (Sezgin and Varol, 2012). Cities are gradually expanding and developing towards the surrounding settlements, and with the new organization formed, some urban functions are out of the settlement area of the city. As a result, intermittent, disconnected settlement patterns formed and this new growth form of the city was called 'urban sprawl' (Clawson, 1962; Karataş, 2007). The effect of urbanization on the periphery of urban areas causes sprawl, which in turn threatens urban sustainable development and the continuity of the ecosystem, and leads to an increase in waste with the misuse and consumption of natural resources. Within the framework of the studies and research, the main causes of urban sprawl or sprawl are grouped under 7 headings (Gillham, 2002; Ludlow, 2006).

Macro-Economic Factors: Economic development, Globalization, Communication Technologies

Housing Preferences: Increase in the amount of space per person, Change in housing preferences

Urban Issues: Air pollution, Noisy, Small living/housing units, Security problem, Social problems, Insufficient open-green areas

Micro-Economic Factors: Rising standard of living, Land prices, Cheaper agricultural lands, Private propriety

Demographic Factors: Population growth, Increase in housing production

Planning: Regulation and standards, The zoning approach, Weak land use plan, Difficulties in the implementation of plans, Problems in horizontal and vertical coordination and cooperation

This issue has attracted the attention of many researchers in the world and in our country, and the effect of urban sprawl on natural areas in different provinces has been tried to be examined. Uzuneminoğlu (1993), from these studies, examined the urban development of Samsun and stated that the urban area of the city, which was 30 ha between 1850 and 1860, reached approximately 3552 ha in 1990. Aydoğdu et al., (2012) stated that between 2000 and 2010, residential areas increased by 38.66% in Ankara's Yenimahalle district, especially pasture areas decreased. Mansuroğlu et al. (2012) in their study on Antalya emphasized that the natural areas of the city have been adversely affected due to the intense population growth and urbanization pressure in the last 20 years and that future urban development decisions should be taken in line with ecological principles.

Öncel and Meşhur (2012) investigated the causes of urban sprawl in the growth of Konya's urban area and stated that public and private capital investments in recent years played an important role in the development of the city. Doygun and Erdem (2013) stated in their study on Bornova that urbanization puts significant pressure on other land use types and this situation is not sustainable, especially in terms of quality areas close to nature. Kanbak (2013), in his study examining urban sprawl in Istanbul, stated that the two most important reasons for urban sprawl in the area are migration and industrialization. Kurt and Duman (2016) stated that between 2000 and 2014, Sakarya's residential areas grew spatially due to population growth and tourism activities, while forest and bush areas decreased spatially. Ayazlı et al. (2015) used the SELUTH model supported by T-EFA (Total Exploratory Factor Analysis) to reveal the change in land cover caused by urban sprawl in Istanbul. According to the results obtained, they predicted that by 2040, approximately 1000 km2 of agricultural, forest, and wetlands will change with urban areas. In their study in the Arnavutköy district of Istanbul, Topaloğlu et al. (2021) stated that forests, arable lands and pastures in the area have decreased significantly due to urbanization. Bozkurt et al. (2023) found that urban areas increased by 9.69% in Istanbul between 1990 and 2018. CORINE data sets are one of the preferred data in studies aimed at monitoring urban sprawl. Studies conducted with the CORINE data set for all European countries between 1990 and 2006 found that city areas increased by 146% (Triantakonstantis and Stathakis, 2015). Bilozor et al. (2020) analyzed urban sprawl change in Poland using the CORINE dataset and Geographic Information Systems software. In another study using the CORINE data set from 2018, urban landscape density index (ULII) within the borders of 7 metropolises in Poland and 1 in Germany were evaluated. According to the results, it was concluded that transportation and settlement, which cause urban sprawl, directly or indirectly affect this index (Myga-Piątek et al., 2021). In the study covering Ankara, Istanbul and Izmir between 2000 and 2018, the CORINE data set was used to reveal the extent to which land use would change in 2024 with the help of linear and polynomial regression models (Dinç and Gül, 2021). The CORINE data set was analyzed with Gray and Lebart approaches to reveal the city dynamics of the Marmara Region between 2006 and 2018 (Genel and Guan, 2021).

In addition to these investigations, studies for clustering and detecting urban regions usually favor machine-learning methods. Urban sprawl studies also use the K-means approach, one of the machine learning techniques. In their study of urbanism, Liu et al. (2018) used local spatial entropy, gridded population density, and the K-Means approach. The K-Means approach was utilized by Nithya et al. (2017) to manage resources in the city of Salem. On the other side, Salvati and Sabbi (2014) preferred K-means to identify comparative urban sprawl in their study involving Lisbon, Athens, and Rome.

In this study, using the CORINE Land Cover (CLC) data set in Istanbul province, it was tried to determine how much urban settlement areas changed between 1990 and 2018 and how much natural area the urban sprawl covered. In addition, a K-means program was created using the population, land use and land cover data of the area, and similarities between the districts in 1990 and 2018 were determined. In line with these data obtained, suggestions were made for the protection of natural areas in the districts where the change was experienced.

2. Material and Method

2.1. Material

2.1.1. Study area

The main material of the study is the province of Istanbul. The research area covers the entire administrative area of Istanbul (Figure 1). Istanbul is located at the intersection of two peninsulas in a very strategic position, at the junction of the Asian and European continents, and is located between 28° 01' and 29° 55' east longitudes and 41° 33' and 40° 28' north latitudes. If we look at the land structure of Istanbul, it is generally low in height. The highest point of Istanbul is the 537 m Aydos Mountain between Kartal and Pendik districts. There are three notable lakes in Istanbul. The biggest of these is Terkos Lake, which is 50 km away from the city on the Black Sea coast and has an area of 25 km^2. Terkos Lake is followed by Büyükçekmece and Küçükçekmece Lakes.

The biggest stream in the province is Riva Stream. Riva Stream is the biggest stream of the Kocaeli Peninsula; It pours into the sea from the Riva Village of Beykoz (Istanbul Provincial Environmental Status Report, 2022). The climate of Istanbul is mostly a transitional climate and has a temperate climate (İBB, Geographical Location, and Strategic Importance, 2016-2021). The natural vegetation of the province consists of forest, maquis, pseudo-maquis (maquis plant communities adapted to the Black Sea climate, changed, humid character, more woody), and coastal plants. With the effect of the climate, moist plant species have developed in the northern parts of the city and relatively drier plant species have developed in the southern part (Akkemik, 2017).

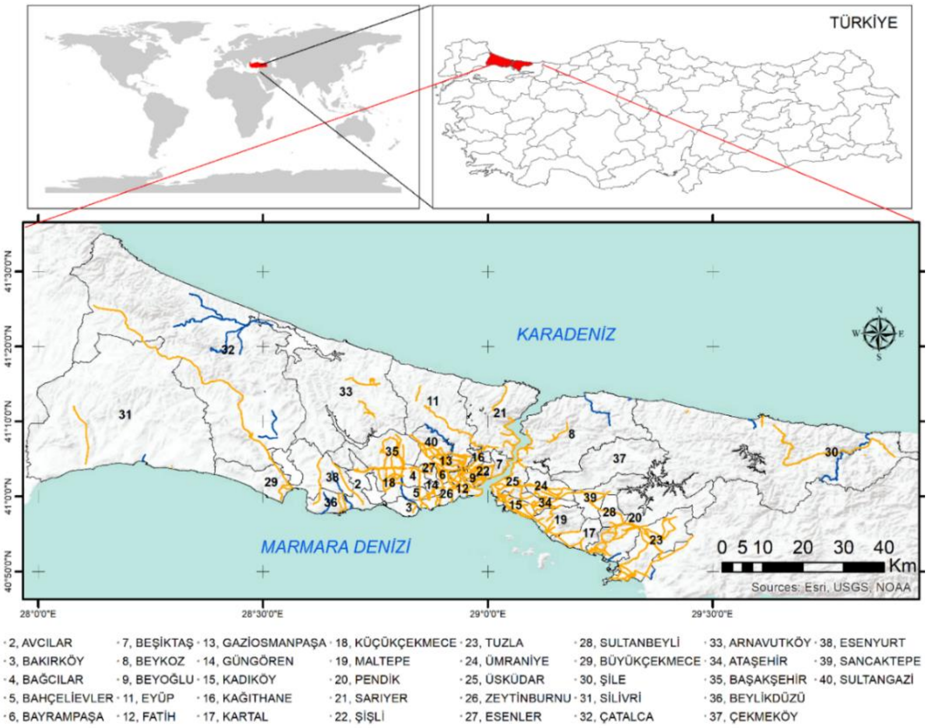


Figure 1. The geographical location of Istanbul province

2.1.2. Data set

The study highlighted two data sets, particularly the CLC (CORINE Land Cover) dataset, and population, to illustrate the impact of population growth and urbanization on other regions between 1990 and 2018.

The most important material in the field is the CORINE dataset. Information about these data is given in Table 1. The CORINE program, which has been a study aiming to collect information on environmental issues since 1985, has been supported by 39 countries as of 2018. Data sets using the EPSG:3035 (ETRS89, LAEA) coordinate system have thematic accuracy of 85% and above.

Table 1. CLC dataset properties

Data set	Satellite Data	Production time	Time Range	Number of Countries
1990	Landsat-5 MSS/TM	10 year	1986-1998	26
2018	Sentinel-2 and Landsat-8	1.5 year	2017-2018	39

Another dataset used in the study is population data. The population data set used in the study was obtained and organized from the web pages of SIS-State Institute of Statistics and TUIK-Turkish Statistical Institute's (TurkStat).

Population data was created also with the help of 1990 (Gökburun, 2017) and 2018 population data. Population densities were calculated by dividing the population data of these years by district area.

2.2. Method

2.2.1.Population density changing

In order to increase urban development, population change rates need to be determined. For this reason this study, firstly, it is aimed to determine how the population density in the area is distributed and how it fragments the urban area in measuring the urban sprawl. For this purpose, provincial and district population data and changes in the area for the years 1990-2018 were determined.

2.2.2. K-Means clustering algorithm

Using the K-means clustering method, the second stage showed the relationships between the districts' land uses and population densities and evaluated how those relationships had changed between 1990 and 2018.

Orange 3.34 with the open source feature was utilized in the study for the K-means algorithm. An open-source toolset for data mining, machine learning, and visualization is called Orange software. It has a visual programming front-end for interactive data visualization and exploratory qualitative data analysis.

Though the concept dates back to Hugo Steinhaus in 1956, James MacQueen employed K-means for the first time in 1967. It is frequently referred to as the Lloyd-Forgy algorithm because Edward W. Forgy presented roughly the same technique in 1965.

With K-Means clustering, n objects are divided into k clusters, and each object is assigned to the cluster that has the closest mean. The maximum number of distinct clusters produced by this method is k. It is necessary to compute the best number of clusters k that will result in the maximum separation (distance) because it is not known a priori. The squared error function, or total intra-cluster variance, is the goal of K-Means clustering.

Where J is the objective function, k is the number of clusters, n is the number of cases, i is the case of xi, and j is the centroid for cluster cj.

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2$$

K-Means is a reasonably successful method. We must predetermine the number of clusters because the final results are sensitive to initialization and often terminate at a local optimum. Unfortunately, there is no complete theoretical method to figure out how many clusters is just right. It is a good idea to compare the outcomes of multiple runs with different k values and choose the best one based on a preset criterion. Determining the number k in clustering analyses is quite uncertain. Analyses such as elbow and silhouette are used to determine the number k. In this study, silhouette analysis is preferred. The distance separating the generated clusters can be examined using silhouette analysis. The silhouette plot offers a visual means of evaluating factors such as the number of clusters by displaying a measure of the proximity between each point in a cluster and points in the nearby clusters. The range of this metric is [-1, 1].

A big k often reduces inaccuracy but raises the chance of overfitting. These data were used to assess manmade regions and woodland, semi-natural regions separately for the European and Anatolian sides in 1990 and 2018. This classification makes use of numerical data and visual maps to assess how much the area's urban sprawl has an impact on the change in land cover. Additionally, it has been made known how Istanbul's forests and natural spaces have changed due to different land uses.

2.2.3.Pixel-Based landuse/land cover change

Lastly, using the CLC dataset for the years 1990 and 2018, the land cover classification of Istanbul was made according to the Level 2 land cover classification since it contains more detailed information than the CLC dataset Level 1 data (Table 2). In the study, pixel information was obtained from the CLC dataset with 100m*100m pixel information using ArcGIS 10.5 software.

Table 2. Corine land cover classes (Corine, 2022).

CORINE LAND COVER CLASSES			
1	Artificial Surfaces	3	Forest and Semi-Natural Areas
11	Urban fabric	31	Forest
12	Industrial, commercial and transport units	32	Shrub and/or herbaceous vegetation associations
13	Mine, dump and construction sites	33	Open spaces with little or no vegetation
14	Artificial, non-agricultural vegetated areas	4	Wetlands
2	Agricultural areas	41	Inland wetlands
21	Arable Land	42	Coastal wetlands
22	Permanent crops	5	Water bodies
23	Pastures	51	Inland waters
24	Heterogeneous agricultural areas	52	Marine waters

3. Findings and Discussion

3.1. The Effect of population growth between 1990-2018 on urban sprawl in Istanbul

When Istanbul is examined in terms of population density, it is one of the most crowded cities in Turkey and even in the world. It is also the most important industrial and commercial center of the country. Due to these features, it constantly receives immigration and its population is increasing rapidly. Over the years that are the subject of our research; While the urban population was approximately 6.900.000 in 1990, this number increased to 15.000.000 in 2018 (Figure 2). During this period, the city has increased almost 2.5 times in terms of population. The correlation value of the population growth rate has a high value of 0.9966. When the correlation result is evaluated, it is possible to say that the population will increase rapidly in a positive direction in the coming years.

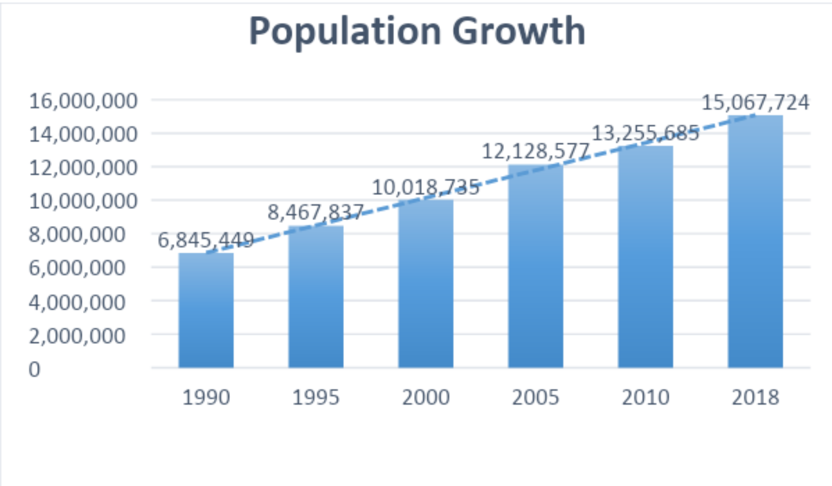


Figure 2. Population growth amount of Istanbul between 1990-2018 (DİE-State Institute of Statistics, 1990-1995-2000) data and TÜİK (2005-2010-2018 data)

The most negative effect of population growth in the city has been on urban sprawl. In order to meet the housing needs of the population coming from the villages, unplanned slums were built on empty lands, and urban sprawl gained momentum with the granting of zoning permits to these structures over time. The population growth and urban sprawl, which developed in parallel with the increase in industrial facilities in the region, caused the construction of new roads and bridges. Thus, the settlement area spread and expanded along the coasts of Tekirdag in the west, Izmit in the east, the Black Sea in the north, and the Marmara Sea in the south. Depending on the population increase, some central districts (such as Bakırköy and Kadıköy) were divided and new districts were formed. These districts are Arnavutköy, Avcılar, Bağcılar, Bahçelievler, Başakşehir, Beylikdüzü, Esenyurt, Esenler, Güngören and Sultangazi on the European side; On the Anatolian side, Ataşehir, Çekmeköy, Maltepe, Sancaktepe, Sultanbeyli and Tuzla districts are. As a result, a dense urban sprawl was detected in Istanbul between 1990 and 2018 due to demographic factors, macro and micro economic factors, changes in housing preferences, urban problems, and problems caused by planning inadequacies.

When examined in terms of population density, Bakırköy is seen as the district with the highest density in the 1990s, as it was before the division, as stated above. It has been determined that the population density is generally concentrated on the coast of the Marmara Sea and in the southern parts of Istanbul. However, as of 2018, it has been determined that the population mobility has increased towards the north and east of the city. This situation has been evaluated as the most important indicator of urban sprawl in Istanbul (Figure 3). Before clustering analyses, the data should be preprocessed according to the method to be used. For this purpose, the data were first categorized, digitized and normalized. The K-means method required categorization of the population density data. As a result, the ranges of population densities are as follows: 10, 11-50, 51-100, 101-150, 151-200, 201-250, 251-300, 301-350, 351-400, and >400 (Figure 3). Numbers such as 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 are used to classify these ranges. K-means were calculated using distribution percentages of categorized population density data within districts.

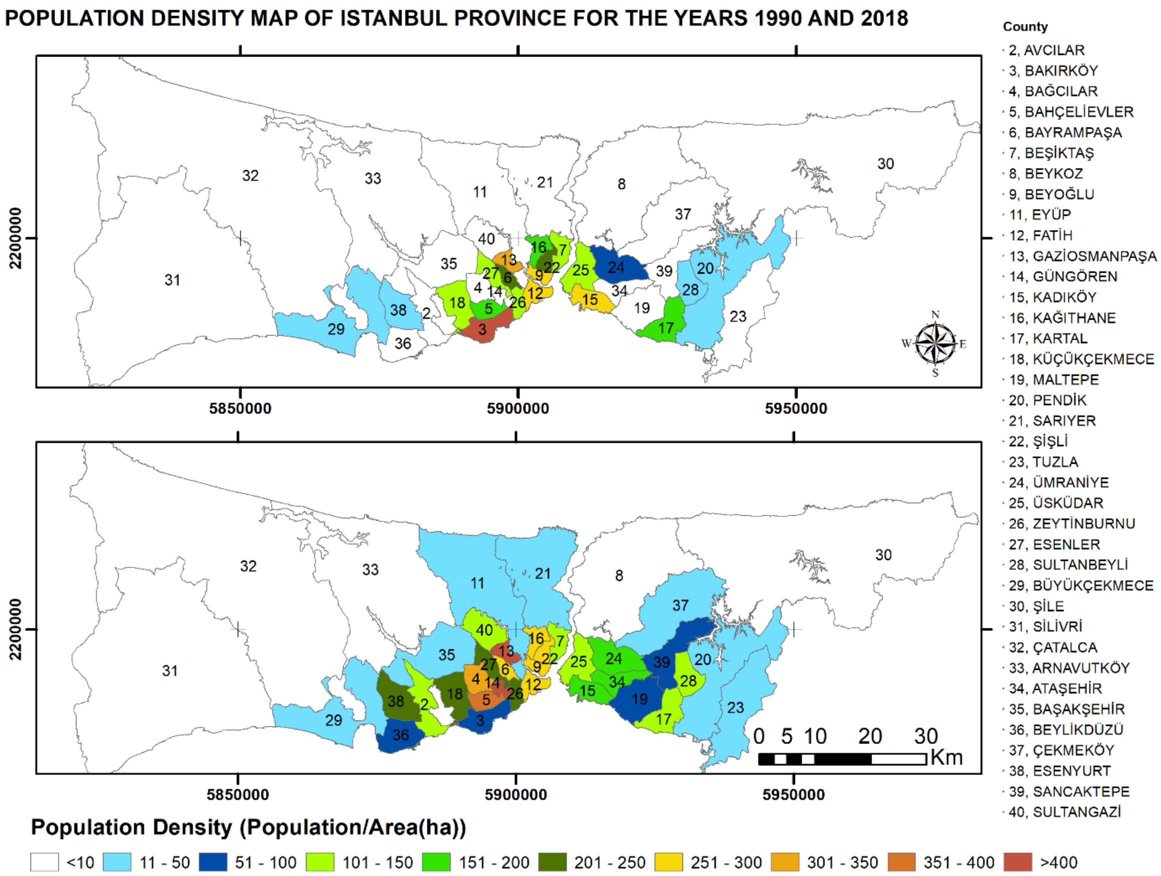
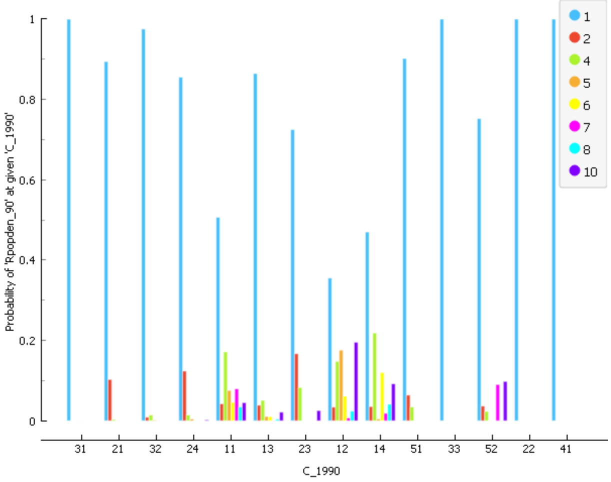


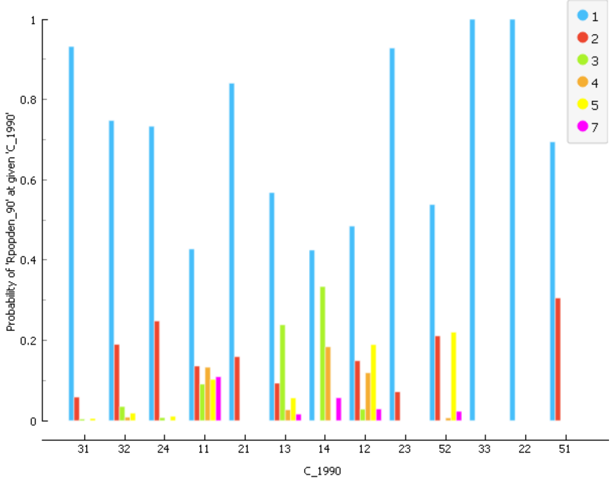
Figure 3. Population density map of Istanbul province for the years 1990 and 2018

3.2. Assessment of Land Use/Land Cover and Population Density

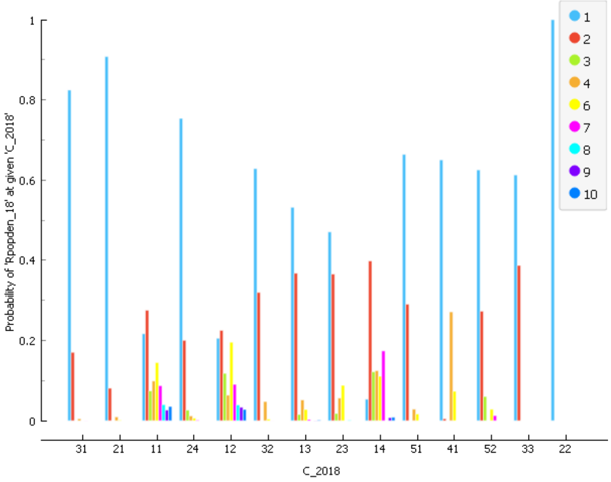
The distribution of the categorized population density with land use was examined separately for both sides of Istanbul and for both years. The codes for land use are given in Table 2. According to this, the high-density population, which was expressed as 10 in 1990, especially on the European side, is encountered in the land use areas expressed as 12 (Industrial, commercial, and transport units), 14 (Artificial, non-agricultural vegetated areas) and 52 (Marine waters) (Figure 4-a). In addition, the Anatolian side had much lower population densities in the 1990s. Only regions 11 and 14 show the population density categorized by the number 7 (Figure 4-b). When it comes to 2018, it is seen that the population densities categorized as 4 and 6 on the European side spread to almost all land uses. It is seen that the population density number 7 is in 11 (Urban fabric), 12 (Industrial, commercial, and transport units), and 14 (Artificial, non-agricultural vegetated areas) ((Figure 4-c). On the Anatolian side, it is seen that the population densities, which fall into the 4 and 5 categories, have begun to disperse towards other land use areas (Figure 4-d).



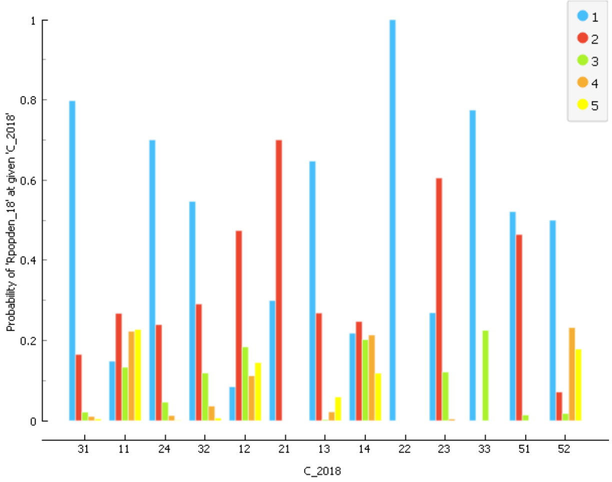
a. 1990 CLC and population density graph of european side



b. 1990 CLC and population density graph of anatolian side



c. 2018 CLC and population density graph of european side



d. 2018 CLC and population density graph of anatolian side

Figure 4. a, b, c, d Population density and CLC graphs

3.3. Analysis of K-Means Clustering Algorithm

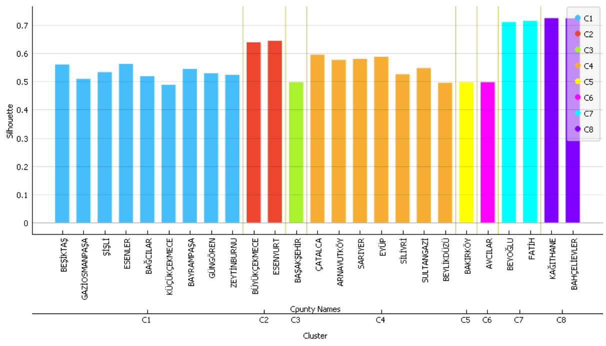
Percentages of land uses and categorical population density data were calculated by districts. These percentages were used in the K-Means clustering method. In this way, similarities between population density and land use were revealed.

In the study, according to the results of the software in silhouette; It has been observed that the number of clusters that emerged for the European and Anatolian Sides in 1990 and for the European and Anatolian Sides in 2018 was 8, 6, 2, and 6 as a result of silhouette analysis for optimal k. Here, especially since the formation of only 2 similar clusters in 2018 provides insufficient information for a dynamic city like Istanbul, the data were reanalyzed to form 8 clusters, which is the highest value of automatic clustering. Here, the criteria of city, population, and land use structure were evaluated in the interpretation and evaluation of both results.

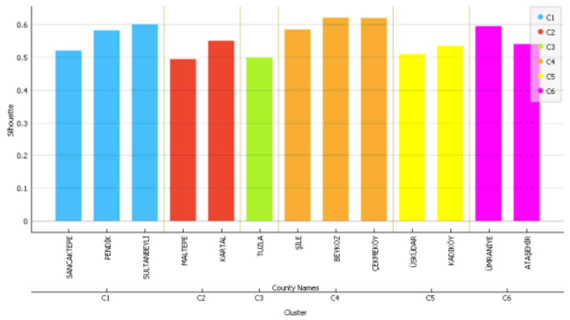
According to this evaluation, there were 8 clusters on the European side in 1990 and a more homogeneous distribution is observed. The first cluster in the distribution; When creating Beşiktaş, Gaziosmanpaşa, Şişli, Esenler, Bağcılar, Küçükçekmece, Bayrampaşa, Güngören, Zeytinburnu; the second cluster is Büyükçekmece and Esenyurt; the third cluster is Çatalca, Arnavutköy, Sarıyer, Eyüp, Silivri, Sultangazi, and Beylikdüzü; the fourth cluster is Beyoğlu and Fatih; The fifth cluster was composed of Kağıthane and Bahçelievler, while Başakşehir, Bakırköy, and Avcılar were not included in any cluster and formed their own clusters (Figure 5-a). In 1990, 6 clusters were formed on the

Anatolian side and Sancaktepe, Pendik, Suntanbeyli formed the first cluster; Maltepe and Kartal the second cluster; Şile, Beykoz, Çekmekoy, the third cluster; Üsküdar and Kadıköy are the fourth cluster; Ümraniye and Ataşehir formed the fifth cluster, while Tuzla formed its own cluster (Figure 5-b).

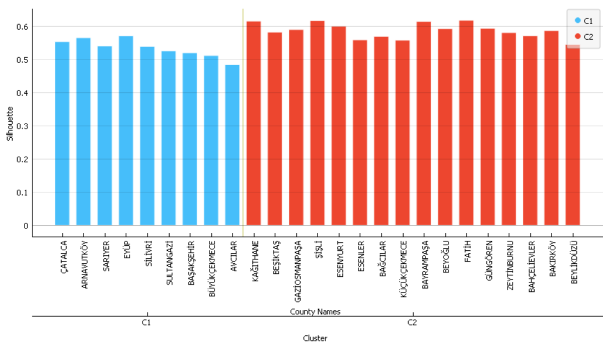
In 2018, the cluster did not show a balanced distribution on the European side, while Çatalca, Arnavutköy, Sarıyer, Eyüp, Silivri, Sultangazi, Başaksehir, Büyükçekmece, Avcılar were in the first cluster, while Kağıthane, Beşiktaş, Gaziosmanpasa, Şişli, Esenyurt, Esenler, Bağcılar, Küçükçekmece, Bayrampaşa, Beyoğlu, Fatih, Güngören, Zeytinburnu, Bahçelievler, Bakırköy and Beylikdüzü formed the second cluster (Figure 5-c). In 2018, a cluster distribution similar to 1990 is observed on the Anatolian side. Although the number of clusters did not change, the distribution changed in some districts depending on the population growth. According to this; Çekmeköy, Pendik the first cluster; Ümraniye, Kadıköy, and Ataşehir the third cluster; Üsküdar, Sultanbeyli, and Kartal the third cluster; Şile and Beykoz formed the fourth cluster, Sancaktepe and Maltepe formed the fifth cluster, while Tuzla formed its own cluster (Figure 5-d).



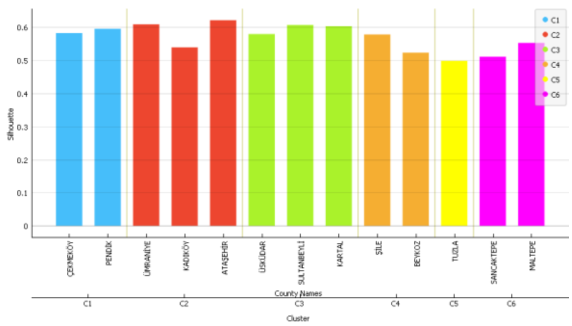
a. European side of K-Means 1990



b. Anatolian side of K-Means 1990



c. European side of K-Means 2018

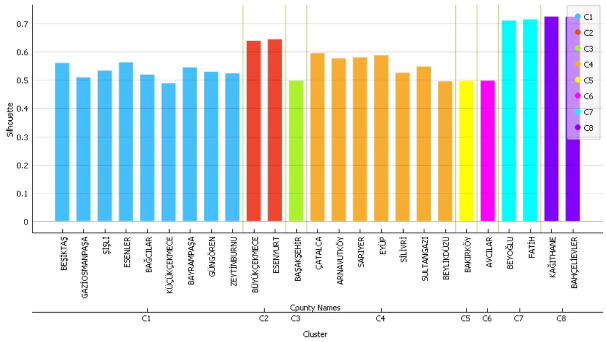


d.Anatolian side of K-Means 2018

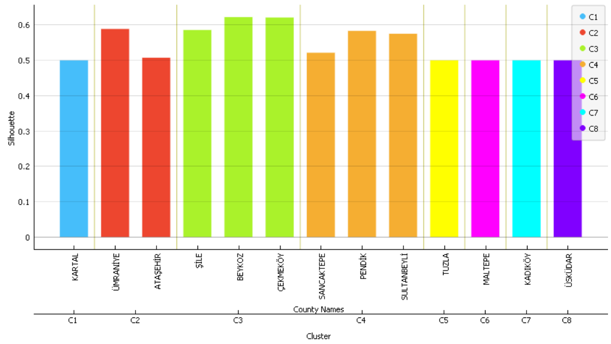
Figure 5. K-means with silhouette clustering

In order to be able to compare the K-Means results, the European data of 1990 were forced into 8 clusters in the operations of other times and regions, as they showed a good distribution in 8 clusters. Therefore, cluster distributions of land use and population density in 1990 did not change (Figure 6-a). In 2018, Esenyurt, Esenler and Küçükçekmece; Çatalca, Arnavutköy and Silivri; Kağıthane, Şişli, Beşiktaş, Bayrampaşa, Beyoğlu and Fatih; Sultangazi, Başaksehir and Büyükçekmece; Zeytinburnu, Bakırköy and Beylikdüzü; While Gaziosmanpaşa, Bağcılar, Güngören and Bahçelievler show the same cluster characteristics, Avcılar is again in a separate cluster as in 1990. Looking at 2018, it can be said that districts have a much more heterogeneous distribution and gained new identities compared to 1990 (Figure 6-c).

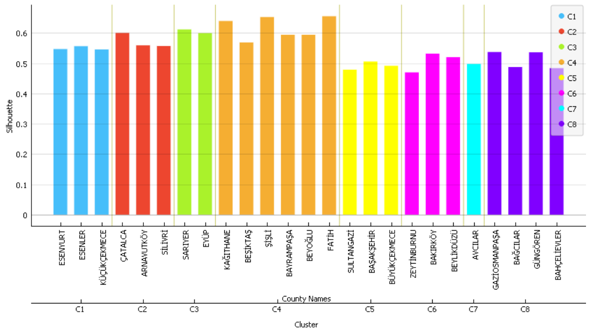
On the Anatolian side in 1990, Ümraniye and Ataşehir; Şile, Beykoz and Çekmeköy; Sancaktepe, Pendik and Sultanbeyli; Kartal, Tuzla, Kadıköy and Üsküdar were included in clusters with similar characteristics in terms of land use and population density (Figure 6-b). In 2018, Üsküdar, Şile, Beykoz and Kartal were in the same cluster, while Pendik, Çekmeköy; Ümraniye is in the same cluster as Ataşehir. Tuzla, Maltepe and Kadıköy formed their own clusters. They did not show any similarity with any district (Figure 6-d).



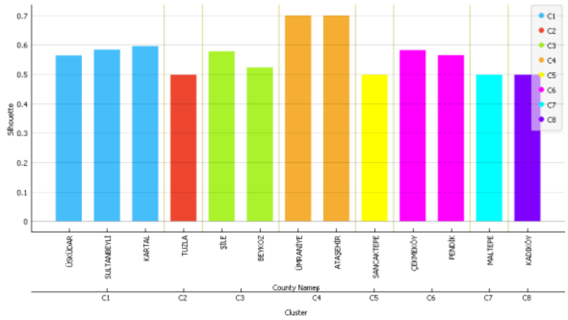
a.European side of K-Means 1990



b.Anatolian side of K-Means 1990



c.European side of K-Means 2018 (c)



d.Anatolian side of K-Means 2018

Figure 6. K-means with 8 clustering

3.4 The Impact of Urban Sprawl on Land Use/Land Cover Change in Istanbul

The most negative effect of urban sprawl in Istanbul has been on the change of area. In order to determine the temporal change in the area, CORINE Level 2 classification data of 1990 and 2018 were obtained and the artificial areas, forest, and semi-natural areas of the city were mapped (Figure 7-8), and the change in urban settlement areas was calculated (Table 3-4).

The distribution map showing the artificial areas of 1990 is shown in Figure 4. It is seen that these areas are generally located in the Historical Peninsula and the shores of the Bosphorus, which are the first settlement areas of Istanbul. Kilyos, on the other hand, is under the influence of open pit mines (Uça et al., 2006) and construction sites. By 2018, artificial zones started to be seen on the coast of the Marmara Sea and in the interior. Kilyos region, where open coal mine works were carried out before, left its place to Istanbul Airport, and Şile and Silivri coasts, which were previously preferred for holiday purposes, have become areas where urban sprawl has increased.

According to the data obtained in terms of urban change, between 1990 and 2018, industry-trade and transportation units, city structure, mine-discharge and construction sites increased by approximately 9%, while maquis and/or herbaceous plants, arable lands, mixed agricultural areas and It was determined that forest areas decreased by about 9% (Table 3). Accordingly, it is possible to say that natural and arable agricultural areas in the city in 1990 were transformed into artificial areas in 2018. When the change in artificial areas in the research area between 1990 and 2018 is examined in particular on the European and Anatolian side, it has been determined that the Anatolian side has increased almost twice. It was determined that the industrial trade and transportation units and the city structure on the Anatolian side showed an increase of 47% from 1990 to 2018. In total, it was determined that the rate of increase in artificial areas in the city was approximately 45% on the Anatolian side and 40% on the European side (Table 4).

Table 3. The rate of increase and decrease of land cover classes in Istanbul province in 1990-2018

Land Cover	1990		2018		Increase/Decrease (-)	
	Area (km^2)	Rate (%)	Area (km^2)	Rate (%)	Area (km^2)	Rate (%)
11 Urban fabric	473.52	8.89	687.43	12.91	213.91	4.01
12 Industrial, com., and trans. units	65.1	1.22	292.79	5.50	227.69	4.27
13 Mine, dump, and cons. sites	126.99	2.38	182.16	3.42	55.17	1.03
14 Artificial Non-Agr. Green Area	52.87	0.99	71.7	0.99	18.83	0.35
21 Arable Lands	1145.49	21.52	999.09	18.77	-146.40	-2.75
22 Permanent crops	5.33	0.10	14.9	0.27	9.570	0.17
23 Pastures	68.4	1.28	91.7	1.72	23.30	0,43
24 Heterogeneous agricultural areas	535.62	10.06	488.48	9.17	-47.14	-0.88
31 Forest	2187.98	41.10	2141.28	40.23	-46.70	-0.87
32 Shrub and/or herb. veg. assos.	621.85	11.68	316.01	5.93	-305.84	-5.74
33 Open spaces with little or no veg.	11.57	0.21	9.73	0.18	-1.84	-0.03
41 Inland wetlands	3.39	0.06	4.51	0.08	1.12	0.02
42 Coastal wetlands	11	0.20	16.81	0.31	5.81	0.10
52 Marine waters	13.34	0.25	5.86	0.11	-7.48	-0.14
Total	5322.45		5322.45			

Table 4. Areas of European and Anatolian side artificial zones (Ha)

	European Side		Anatolian Side	
	1990	2018	1990	2018
11 Urban fabric	27917	39557	19435	29186
12 Industrial, commercial and transport units	4457	17387	2053	11892
13 Mine, dump and construction sites	10197	13581	2502	4635
14 Artificial Non-Agricultural Green Area	2926	4518	2361	2652
Total Area	45497	75043	26351	48365

When we examine the area in terms of forest and semi-natural areas, it was determined that Basaksehir (35) districts on the European side and Maltepe (19) and Sultanbeyli (28) districts on the Anatolian side were exposed to urban sprawl and lost their natural vegetation form (Figure 8).

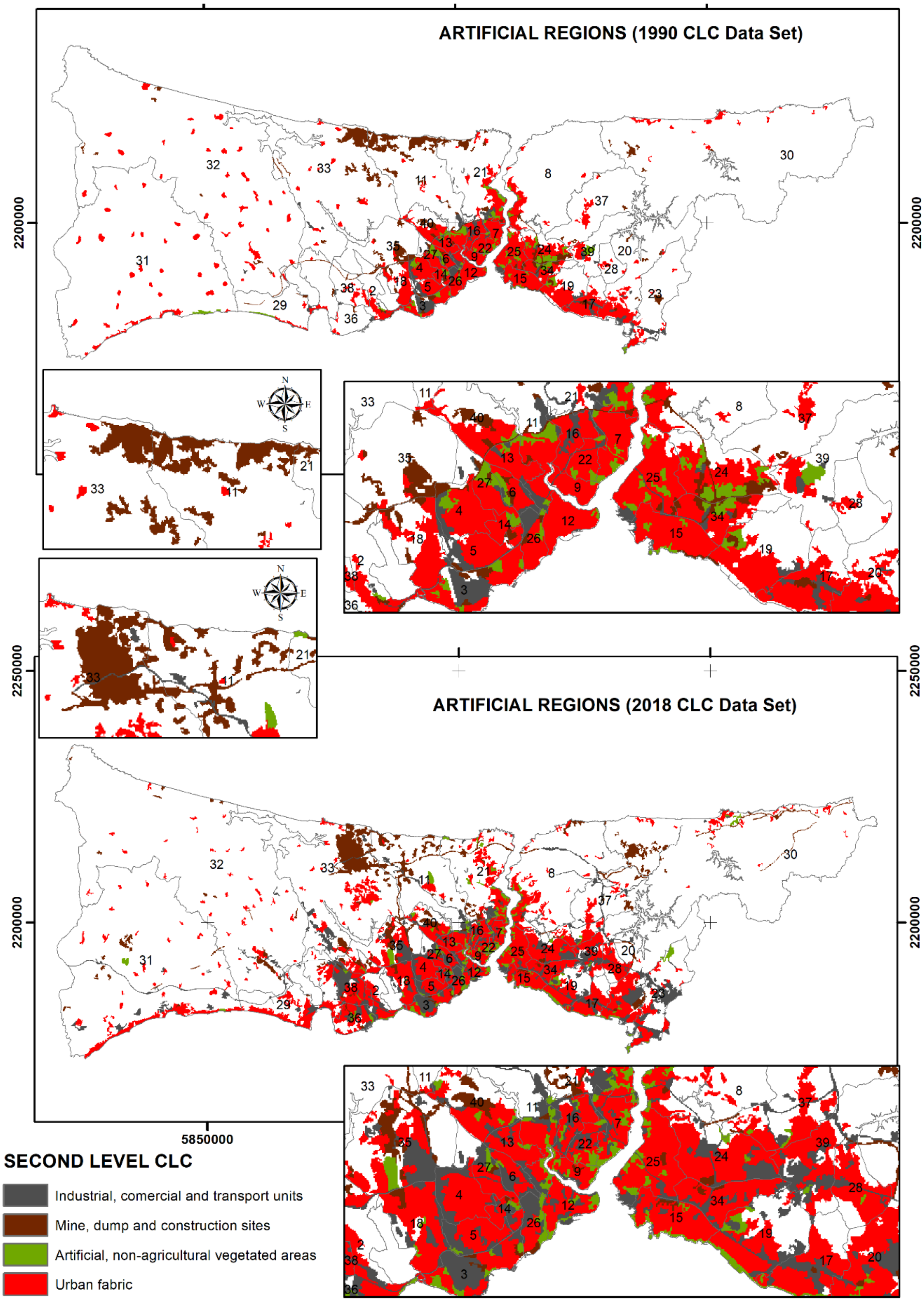


Figure 7. CORINE artificial areas distribution map for 1990 and 2018

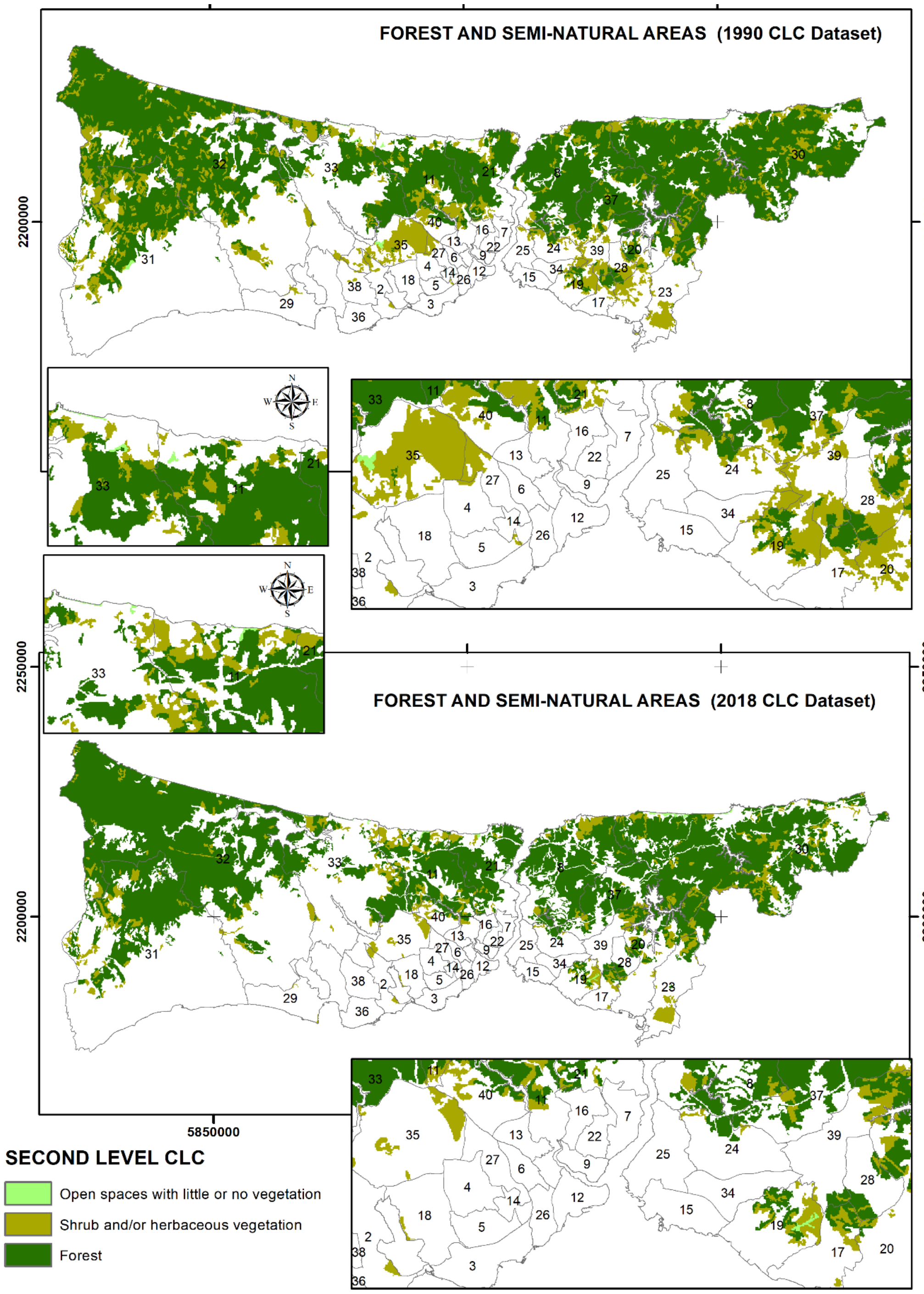


Figure 8. Distribution of forest and semi-natural areas in Istanbul between 1990-2018

When examined specifically on the European and Anatolian sides, it was determined that forest and semi-natural areas decreased by 16% on the Anatolian side and by 9% on the European side (Table 5). The reason for the increase in forest areas on the European side in 2018 was determined as the renewal of forest areas deteriorated as a result of bridge and road works and afforestation works incompatible with natural vegetation.

Table 5. European and Anatolian side agricultural areas and forest and semi-natural areas (Ha)

	European Side		Anatolian Side	
	1990	2018	1990	2018
31 Forest	116970	124276	101828	89852
32 Shrub and/or herbaceous veg. associations	38338	16185	23847	15416
33 Open spaces with little or no vegetation	717	411	440	562
Total	156025	140872	126115	105830

As a result, in this study, it has been determined that natural areas have changed and transformed into urban areas in the city of Istanbul between 1990 and 2018. Figure 9 and Table 6 have been created to examine this transformation in more detail.

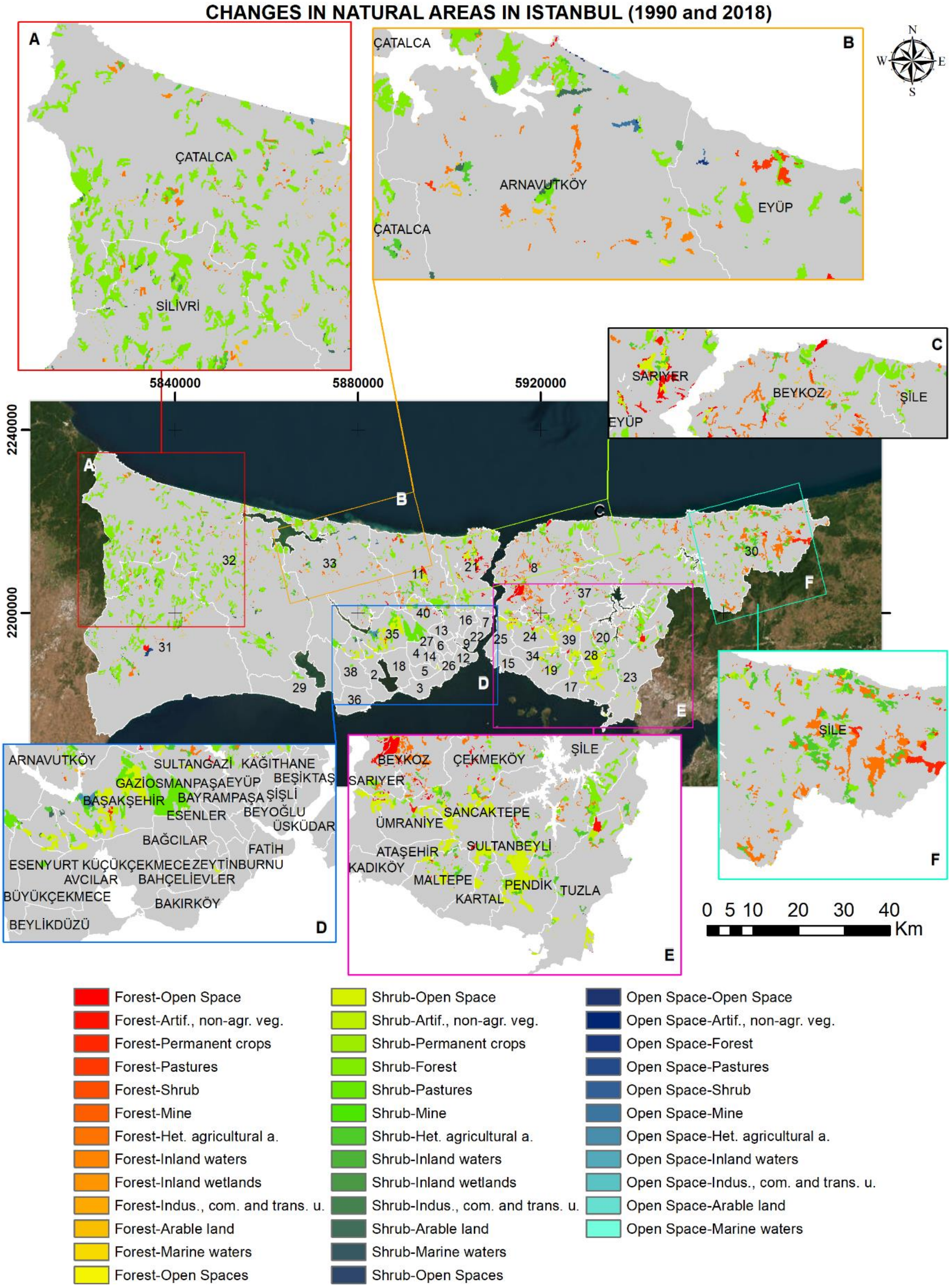


Figure 9. Map of changes in natural areas in Istanbul

Accordingly, from 1990 to 2018, it was determined that 1.34% of maquis or herbaceous plant areas were transformed into urban structures, and 1.54% of forested areas were transformed into mine-discharge and construction sites (Table 6).

Table 6. Artificial area changes in forest and semi-natural areas on the European and Anatolian sides

Land Cover/Land Use Arazi		Change (Ha)		Total	Change (%)		Total
1990	2018	European	Anatolian	(Ha)	European	Anatolian	(%)
31	11	517	971	1488	0.10	0.18	0.28
	12	599	1316	1915	0.11	0.25	0.36
	13	5627	2551	8178	1.06	0.48	1.54
	14	394	341	735	0.07	0.06	0.14
32	11	2436	4702	7138	0.46	0.88	1.34
	12	886	1856	2742	0.17	0.35	0.52
	13	2323	663	2986	0.44	0.12	0.56
	14	419	355	774	0.08	0.07	0.15
33	11	14	9	23	0.00	0.00	0.00
	12	1	4	5	0.00	0.00	0.00
	13	81	0	81	0.02	0.00	0.02
	14	18	0	18	0.00	0.00	0.00
Study Area Total (Ha)		532245					

4. Conclusion and Suggestions

In this study, the effect of urban sprawl on land change in Istanbul was tried to be determined with the CLC dataset, and the structural change of urbanization on natural areas was examined. According to the results of the examination, it was determined that the city was exposed to population growth and urban sprawl as it is the most important industrial and commercial center of the country. This situation has been determined as the most important reason for the land change and destruction of natural areas in the area.

As a result of processing the CLC dataset; The urbanization and urban sprawl that took place in Istanbul from 1990 to 2018 were examined, especially industry, trade and transportation units, city structure, mine discharge, and construction sites increased by about 9%, on the other hand, maquis and/or herbaceous plants, arable lands, mixed agriculture It has been determined that areas and forest areas have decreased by about 9%. When the area was evaluated separately for the European and Anatolian sides, it was seen that the artificial areas in the city increased by approximately 45% on the Anatolian side and 40% on the European side. Accordingly, it has been revealed that maquis or herbaceous plant areas, forest areas, and natural and arable agricultural areas in the city in 1990 turned into artificial areas in 2018. It has been determined that 1.34% of maquis or herbaceous plant areas have been transformed into urban structures in 2018, and 1.54% of forested areas in 1990 have been transformed into mine discharge and construction sites in 2018. It has been observed that these spatial changes are mostly experienced in the Başakşehir, Maltepe, and Sultanbeyli districts of Istanbul. It has been determined that the results obtained for Istanbul regarding land changes caused by urban sprawl due to population growth reveal similar results in Izmir and its districts. For example, land use change analyzes in Bornova district showed a 41% change throughout the district between 1984 and 2009 (Doygun and Erdem, 2013). While this situation was determined as 3% in the city of Aydin and its immediate surroundings between 1986-2002 (Eşbah, 2007), it was reported as 15% for Urla, Çeşme and Karaburun Districts between 1987-2010 (Erdoğan, 2011). There is an increase in urban sprawl and land use changes due to population growth in the districts bordering the Gulf of Izmir; The conversion rate for all districts shows the maximum value of 42% in the same period (Doygun et al., 2012). In addition, the study aimed to reveal the similarities between population density and land use by using K Means cluster analysis. According to the results of the K Means algorithm, the area was forced into 8 clusters in terms of land use and population density on the European and Anatolian sides. While no change was observed in these clusters in 1990, a more heterogeneous distribution was observed in 2018. In this case, it is an indication that urban sprawl has increased in 2018.

The rapid spread of urbanization shows that there is no comprehensive planning for Istanbul, small-scale planning is insufficient and the use of natural areas for urbanization cannot be prevented. The fact that urbanization is especially effective in natural areas shows that the institutions controlling these areas and the laws enacted for this purpose are not sufficient. Based on this, suggestions for future studies can be presented.

1. In order to prevent the impact of urban sprawl on land change and its spread to natural areas, lands should be classified and used according to their ability classes.

2. Arable land in Istanbul decreased from 1145.49 km^2 to 999.09 km^2 between 1990-2018. Conservation of arable agricultural lands in the area should not be used for other purposes.

3. Improvement and recycling studies should be carried out in order to classify the lands within the city limits of Istanbul and use them in accordance with their purpose. In areas where this is not possible, the areas used for purposes other than their intended use should not be exceeded.

4. The urban development plan prepared for the city should be made by considering the land capability classes map and the future development potential of the city.

5. Urban sprawl, land change, and misuse of natural areas should be monitored at required intervals using GIS systems.

6. Sanctions should be applied in terms of the implementation of the necessary laws and regulations regarding land use and the use of natural areas in our country.

Acknowledgment and Information Note

The article complies with national and international research and publication ethics.

Author Contribution and Conflict of Interest Declaration Information

All authors contributed equally to the article. There is no conflict of interest.

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