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Measurement and evaluation of urban growth and urban sprawl: Tekirdağ Example

Kentsel büyüme ve kentsel saçaklanmanın ölçülmesi ve değerlendirilmesi: Tekirdağ Örneği

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Abstract

With the increasing population, today's cities are undergoing rapid change and transformation. Increased human activities in cities result in numerous negative outcomes, such as the decline in biodiversity, increased environmental pollution, and the disruption of ecosystem cycles, ultimately leading to the degradation of nature. Especially, the uncontrolled growth and expansion of cities in response to increasing needs and demands can result in inappropriate land use, putting natural resources under pressure and leading to their loss. Indeed, especially in cities that are experiencing rapid population growth, this situation is more evident. In this context, urban sprawl, which indicates urban spread, has many negative effects if not managed correctly. In this study, it is aimed to evaluate urban growth and detect urban sprawl in three districts of Tekirdağ province, namely Süleymanpaşa, Çorlu, and Çerkezköy, which have been receiving rapid immigration and thus have seen a significant increase in their populations. In line with this, using the high-resolution data from the Urban Atlas, the land use situation for the years 2012 and 2018 has been presented. The results have shown an increase in artificial areas and a decrease in agricultural lands for all districts. For the detection of urban sprawl, the Normalized Urban Atlas Sprawl Indicator (NUASI) developed by Petrescu (2019) has been utilized. According to the NUASI findings, the urban sprawl trend in the Süleymanpaşa, Çorlu, and Çerkezköy have been determined as -1.90%, 0.70%, and 0.96%, respectively. This result indicates that Çerkezköy is the district with the highest urban sprawl development. Recommendations for spatial planning have been provided within the scope of the study.

Özet

Artan nüfusla birlikte günümüz kentleri hızlı bir değişim ve dönüşüm içerisindedir. Kentlerde artan insan faaliyetleri, biyolojik çeşitliliğin azalması, çevre kirliliğinin artması, ekosistem döngülerinin bozulması gibi pek çok olumsuz sonuç yaratmakta ve nihayetinde doğanın tahribatına neden olmaktadır. Bilhassa artan ihtiyaç ve taleplere yönelik olarak kentlerin kontrolsüz büyümesi ve genişlemesi, yanlış arazi kullanımları ile doğal kaynakların baskı altına girmesi ve kaybedilmeleri ile sonuçlanabilmektedir. Nitekim, özellikle hızlı nüfus artışına giren kentlerde bu durum daha fazla kendini göstermektedir. Bu konuda kentsel yayılımı işaret eden kentsel saçaklanma, doğru yönetilmediğinde pek çok olumsuz etkileri bulunmaktadır. Bu çalışmada hızlı şekilde göç alarak nüfusu artan Tekirdağ ilinin nüfusun büyük bir oranını oluşturan üç ilçesi olan Süleymanpaşa, Çorlu ve Çerkezköy ilçelerindeki kentsel büyümenin değerlendirilmesi, kentsel saçaklanmanın tespit edilmesi amaçlanmıştır. Bu doğrultuda yüksek çözünürlüklü veri sunan Kent Atlası verilerinden yararlanarak 2012 ve 2018 yıllarına ilişkin arazi kullanım durumu ortaya koyulmuştur. Sonuçlar, tüm ilçeler için yapay alanların arttığını, tarım alanlarının azaldığını göstermiştir. Kentsel saçaklanmanın tespiti için Petrescu (2019) tarafından geliştirilen Normalleştirilmiş Kent Atlası Saçaklanma İndeksi (NUASI) kullanılmıştır. NUASI bulgularına göre ise Süleymanpaşa, Çorlu ve Çerkezköy ilçelerindeki kentsel saçaklanma trendi sırasıyla % -1.90, %0.70, %0.96 olarak belirlenmiştir. Bu sonuç en fazla saçaklanma gelişimine sahip ilçenin Çerkezköy olduğunu göstermiştir. Çalışma kapsamında mekânsal planlamaya yönelik öneriler sunulmuştur.

INTRODUCTION

The rapid increase in population in the world has significantly increased the number of people living in cities and urbanization (National Geographic 2022). According to the World Urbanization Prospects 2018 Revision Report of the United Nations Department of Economic and Social Affairs (UN DESA), 55% of the world's population lives in urban areas today and this rate is expected to increase to 68% by 2050 (UN DESA 2018). Urbanization is essentially defined as the process of land cover change. The main reason for these land use and land cover changes and the resulting climate and ecosystem changes is human activities (Terzi et al. 2020). It is such that with land use changes, environmental

conditions also change, and the uncontrolled increase in residential areas and incorrect interventions to nature can lead to pollution of natural resources like air, water, and soil, the disruption of land integrity, and the loss of agricultural lands, forest areas, green areas, and water bodies (Lata et al. 2001, Jat et al. 2008, Hennig et al. 2015, Çavuş and Başaran Uysal 2018). For this reason, monitoring, measuring, and understanding land use changes are very important in terms of maintaining the functioning of ecosystems (Fang et al. 2005).

With urbanization, concepts that explain the process have emerged, and "urban sprawl" has been introduced to the literature as a concept that reveals changes in land use and land cover. Today, "urban sprawl," which occurs at the expense of losing open spaces and natural resources and can bring about problems in addition to its benefits has gained increasing importance and attention (Hasse and Lathrop 2003, Arribas-Bel et al. 2011). First introduced by Earle Draper in 1937 (Arribas-Bel et al. 2011), this concept is a complex, multi-dimensional, and dynamic phenomenon that reveals the extent of urbanization (Hasse and Lathrop 2003, Sudhira et al. 2004, Hamidi and Ewing 2014, Oueslati et al. 2015). However, many researchers mention the difficulties regarding the definition of the concept. These difficulties arise because the definition of the concept varies according to each perspective and approach. Indeed, there are very different definitions made for the concept in the literature (Jaeger et al. 2010a, Wang et al. 2020). According to Ottensmann (1977), urban sprawl is defined as the dispersion of new development areas into isolated areas separated from other areas by vacant lands (Lata et al. 2001). According to Forman (2014), sprawl refers to the spread of relatively less dense settlements that form in protrusions and scatterings, connected to high-density urban cores through a transportation network (Şenik and Uzun 2022). In other words, urban sprawl is the expansion of cities in a manner that is much more extensive and of lower density than what would be expected based on the population, resulting in lower population density and open spaces interspersed. When evaluated in this manner, urban sprawl and urban growth are different concepts (Öncel and Meşhur 2021). In line with this definition, urban growth can occur either in a manner that increases continuity by filling in or expanding axially around the urban core, or in a more disjointed manner at locations relatively distant from the city center (Şenik and Uzun 2022).

In general terms, urban sprawl occurs by making changes in land use and land cover (Fang et al. 2005, Bhatta et al. 2010). However, these changes can lead to the emergence of certain problems. For example, urban sprawl can lead to the emergence of areas that are unsystematic, dominated by a single type of land use, and unable to benefit from the amenities of the center (Çavuş and Başaran Uysal 2018). One of the biggest problems caused by sprawl is the misuse of lands (Sezgin and Varol 2012). When looking at the characteristics of urban sprawl areas, these areas can become trapped between urban and rural settings, taking on neither the characteristic features of the city nor the countryside. Especially, unplanned and uncontrolled land changes can result in the emergence of irregular settlement areas (Kanbak 2013).

On the other hand, with rapid urbanization and industrialization today, the pressure on natural resources is especially more pronounced in big cities (Lata et al. 2001). When evaluations are made in terms of population, the density of people living in cities in developing countries is higher compared to developed countries. This is because people in developing countries often seek urban amenities due to economic reasons (Bhatta et al. 2010). Furthermore, when looking at future population projection estimates for cities in developing countries, it is predicted that the number of people living in cities will increase, and the rate of urbanization will rise (Sudhira et al. 2004). This also indicates the potential for further sprawl. In particularly high-population cities in developing countries, urban sprawl occurs on a large scale in the form of land consumption, and natural resources are being depleted (Terzi and Bolen 2009). In this context, the increasing urban sprawl worldwide is a phenomenon that raises serious concerns about achieving sustainable land use in cities (Jaeger and Schwick 2014). In this context, there is a need to ensure urban sprawls occur in the most accurate and rational way without putting pressure on natural resources, and

to develop appropriate management strategies accordingly.

Studies that examine the temporal and spatial situation of land changes are also subjects that governments place great emphasis on. Indeed, with advancing technology, significant budgets are allocated by governments to obtain current and accurate data (Hasse and Lathrop 2003). Especially with the advancement of technology, efforts are being made to obtain this information in the most detailed manner using aerial photographs, satellite images, and Geographic Information Systems (GIS) (Hasse and Lathrop 2003, Sudhira et al. 2004, Jat et al. 2008, Tewolde and Cabral 2011). The state of urban sprawl in different time periods can be systematically monitored, mapped, and evaluated through remote sensing using satellite data (Lata et al. 2001). In this context, the spatial resolution of remote sensing data is also a very important issue. For example, a development area density estimate made using a 30-meter spatial resolution image produces an estimate that is four times that of an estimate made with a 15-meter spatial resolution image (Bhatta et al. 2010). Therefore, the dataset used is very important.

In land use/land cover (LULC) assessments, CORINE data is among the most commonly used (Sarı and Özşahin 2016). In this context, the Urban Atlas (UA) data offered in the Copernicus Land Monitoring Service data portal are derived from CORINE and have a resolution 100 times higher than that of CORINE. Since they are produced only for urban areas, they can provide detailed and high-resolution data. Studies have shown that the use of UA data provides more accurate results in LULC change assessments (Aksoy et al. 2022). In many studies, UA data has been used to monitor LULC changes (Pazúr et al. 2015, Pașca and Năsui 2016, Prastacos et al. 2017, Dobesova 2020, Micek et al. 2020, Aksoy et al. 2022, Duru et al. 2022).

Furthermore, to understand the characteristics of urban sprawl and to measure its dimensions, researchers have developed numerous spatial metrics, indices, and indicators. Malpezzi et al. (2001) suggested that the simplest parameter of urban sprawl, based on an evaluation over urbanized areas, is the average density of built-up areas (Wang et al. 2020). Similarly, the identification of impervious (built-up) areas is also generally considered as a parameter for measuring urban sprawl (Jat et al. 2008).

On the other hand, measuring the degree of urban sprawl and presenting numerical results is also very important in terms of putting forth scenarios related to landscape management (Jaeger et al. 2010b). According to Jat et al. (2008), urban growth is generally associated with the population density in a region and is directed by this density. In this context, this study aims to understand urban growth and observe urban sprawl in three districts of Tekirdağ province, namely Süleymanpaşa, Çorlu, and Çerkezköy, which have rapidly received migration and constitute a significant portion of the province's population. In this direction, using the UA data which provides high-resolution information, the land use status for the years 2012 and 2018 has been revealed. The Normalized Urban Atlas Sprawl Indicator (NUASI) developed by Petrescu (2019) has been used for the measurement of urban sprawl. Within the scope of the study, recommendations for spatial planning have been provided.

MATERIALS AND METHODS

Study Area

Süleymanpaşa, Çorlu, and Çerkezköy districts of Tekirdağ province have been chosen as the study area (Figure 1). Tekirdağ province is a rapidly growing region that receives migration (Çorlu Municipality 2020). Süleymanpaşa, the central district of Tekirdağ, is located between 40° 58’ 60” north latitude and 27° 31’ 0” east longitude (Anonymous 2023a). Its area is 1.082.34 km^2 (Süleymanpaşa Municipality 2015). To its east is located Çorlu, to the west Malkara and Şarköy, and to the north are the districts of Muratlı and Hayrabolu. The Sea of Marmara is located to its south. The district's coastline boundary with the sea extends 40 km (Süleymanpaşa Municipality 2023). The Çorlu district is located between 41º 07' 30" north latitude and 27º45'00" east longitude. Its area is 409 km^2. The districts of Silivri, Muratlı, and Ergene are located to its east. The district of Marmara Ereğlisi is located to its south. It has a coastline with the Sea of Marmara

(Anonymous 2023b, Çorlu Chamber of Commerce and Industry 2023). Previously referred to as an agricultural city, the district of Çorlu is now prominent for its industry. The district, with its highly developed industry, makes a significant contribution to the national economy (Çorlu Municipality 2020). In fact, due to Çorlu district's high population, surpassing many provinces, and its other advanced features, there has been recent discussion about it receiving provincial status (Çorlu Municipality 2020, Anonymous 2023c). The Çerkezköy district is located between 41 º 17' 06" north latitude and 28 º 00' 01" east longitude. The district is bordered by Istanbul to the east, Çorlu to the south and west, and Saray district to the north. The district, located 56 km away from the provincial center, has an altitude of 160 meters above sea level (Çerkezköy Chamber of Commerce and Industry 2023).

On the other hand, when examining the population data of Tekirdağ, it is observed that Süleymanpaşa, Çorlu, and Çerkezköy are the districts with the highest population in Tekirdağ. When looking at the population data for the years 2012 and 2018, which are the years the study is based on using UA data, it is observed that Tekirdağ's population was 852.321 in 2012 and reached 1.029.927 by 2018. It is observed that these three districts have been the three most populous districts of the province throughout this time period. According to TUIK (Turkish Statistical Institute)'s 2022 data, the population of Tekirdağ is 1.142.451. With a population of 290.155, Çorlu district has the highest population in the province. Following Çorlu, Süleymanpaşa comes with a population of 215.558 and Çerkezköy with 206.829 (TUIK 2023). The districts of Süleymanpaşa, Çorlu, and Çerkezköy, which have been determined as the study area, are significant urban areas of Tekirdağ due to both their demographic and economic structures. Especially for sustainable and ecological cities, and to ensure sustainable development, determining the Land Use/Land Cover (LULC) patterns in such rapidly growing and developing regions and researching the impacts of this growth is a crucial concern. This situation has played a role in determining the study area.

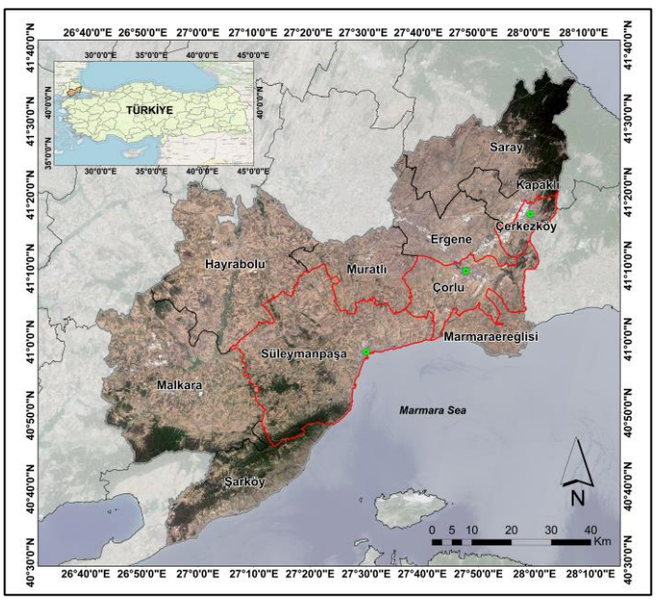

Figure 1. Study area

Data and Analysis

Data Set Used in the Study

The provincial and district boundaries related to the study area were obtained by downloading them from the Open Street Map website (OpenStreetMap 2023). Within the scope of the study, Urban Atlas (UA) data from 2012 and 2018 were utilized to determine land uses. These data were downloaded for free in vector data format from the Copernicus website. The Urban Atlas is a project of the Commission Directorate-General for Regional and Urban Policy and the Directorate-General for Defence Industry

and Space (DEFIS) within the framework of the EU Copernicus programme, supported by the European Space Agency and the European Environment Agency (CLMS 2023). Through these data, land use/land cover changes in urban areas can be determined and these data can be used to develop future recommendations and determine policies (Photis and Tsagkis 2018, Aksoy et al. 2022). For the processing, analysis, and presentation of the data, ArcMap 10.8, Adobe Photoshop, and Microsoft Excel software packages were utilized.

Calculation of NUASI

In the study, the Normalized Urban Atlas Sprawl Indicator (NUASI) calculation proposed by Petrescu (2019) was used to determine urban growth and sprawl. For this purpose, in the study, the 14 land covers in the Urban Atlas for the years 2012 and 2018 were reclassified, resulting in the formation of three land cover and use groups, categorized as C1 (Continuous Urban Fabric), C2 (Non-Continuous Urban Fabric), and C3 (Other Types of Artificial Surfaces). Accordingly, C1 includes continuous urban fabric (class code: 11100), C2 covers discontinuous urban fabric (class codes: 11210, 11220, 11230, 11240, 11300), and C3 comprises other types of artificial surfaces (class codes: 12100, 12210, 12220, 12230, 12300, 12400, 13100, 13300). In the NUASI calculation, the following ratio of C1, C2, and C3 is used (Petrescu 2019):

$$\text{NUASI} = \frac{\text{Area (C2)}}{\text{Area (C1)} + \text{Area (C2)} + \text{Area (C3)}} \quad \text{..... eq (1).}$$

The NUASI value calculated with this formula represents how much of the city's total built-up area is non-continuous built-up areas. This value is less than 1 (Petrescu 2019).

FINDINGS AND DISCUSSION

Findings on Urban Atlas (UA) Data

According to the UA data, within the boundaries of the study area, there are 22 classes for Süleymanpaşa and Çorlu districts, and 20 classes for Çerkezköy district (Figure 2, Table 1). When looking at the "continuous urban fabric" areas in the districts, Çorlu district is observed to have the largest area. In Çorlu district, these areas have shown an increase of +0.20% from 2012 to 2018. However, in terms of the total area owned by districts, Çerkezköy appears to have the largest continuous urban fabric. Looking at the "discontinuous dense urban fabric" areas with a density of 50%-80% in the districts, the largest increase is observed in Çorlu district with +16.26%. The areas with a density of 10%-30% have increased by +19.30% in Çerkezköy, rising from 101.13 ha to 120.65 ha. On the other hand, the areas with a structure of "discontinuous medium-density urban fabric" with a density of 30%-50% have shown the largest increase in Çorlu district, increasing by +26.20%. The "discontinuous very low-density urban fabric" areas with <10% density have increased by +41.76% in Çerkezköy district between the mentioned years, rising from 73.14 ha to 103.68 ha. These results indicate that the most significant changes in continuous and discontinuous urban fabric areas occurred in Çorlu. When looking at the "isolated structures" areas, according to the 2018 data, Süleymanpaşa district has the largest area with 138.5 ha, followed by Çerkezköy with 38.06 ha and Çorlu with 30.14 ha. When looking at the change between 2012 and 2018, it is observed that the largest change occurred in the Çerkezköy district with an increase of +44.94%. When evaluating the "industrial, commercial, public, military, and private units" areas, as of 2018, Süleymanpaşa district has the largest area with 1.479.85 ha. However, looking at the change between 2012 and 2018, the most notable increase occurred in Çorlu with +15.00% and in Çerkezköy with +14.39%. In terms of road classes for the districts, Süleymanpaşa appears to be the richest district in terms of road networks, followed by Çorlu and Çerkezköy. As of 2018, when looking at the expansion related to roads, the most significant change is observed in Çerkezköy. For the "railways and associated land" areas, as of 2018, the area covered is 45.04 ha in Süleymanpaşa, 26.56 ha in Çorlu, and 28.37 ha in Çerkezköy. Regarding "port areas" usage, it is found in the Süleymanpaşa district. From 2012, an area of 19.11 ha increased to 53.99 ha by 2018. "Airport" usage is present in the Çorlu district. Çorlu Atatürk Airport has been operational since 1998 (Çorlu Municipality 2020).

When examining the "mineral extraction and dump sites" areas in the districts, it's observed that these areas cover larger territories in the Süleymanpaşa and Çorlu districts.

These areas have increased in all districts from 2012 to 2018. The highest increase occurred in the Çorlu district, where it reached 452.29 ha from 360.29 ha, thus achieving a +25.53% growth. The most significant transformation in the districts occurred in the "construction sites" areas with code 13300. Specifically, for Süleymanpaşa, this area was 15.05 ha in 2012 and increased by +861.79% to 144.75 ha by 2018. For Çorlu district, it increased by +540.49% from 24.92 ha to 159.61 ha, and for Çerkezköy district it increased by +49.50% from 22.83 ha to 34.13 ha. When looking at the "land without current use" category, a decrease is observed across all districts, with Çorlu and Süleymanpaşa experiencing the most significant decrease. In Çorlu, it was observed that these areas decreased by -18.07% from 185.52 ha to 152 ha. This indicates that these areas have been repurposed. Considering "green urban areas", it's noteworthy that these spaces have seen a relatively modest increase compared to the rise in urban development. As of 2018, these areas cover 141.51 ha in Süleymanpaşa, 73.66 ha in Çorlu, and 25.66 ha in Çerkezköy, reflecting increases of +5.68%, +1.35%, and +4.65%, respectively. When we look at the use of "sports and leisure facilities", it is seen that these areas, which were 29.48 ha in Süleymanpaşa district as of 2012, decreased to 22.15 ha. These areas increased from 56.8 ha to 60.01 ha in Çorlu district, and from 5.25 ha to 5.33 ha in Çerkezköy district.

When examining the "arable land (annual crops)" areas in the districts, it's clear that these spaces occupy significant portions of the total areas in all districts. However, a notable outcome is that these areas have decreased in all districts from 2012 to 2018. The most significant reduction was in Çerkezköy, with a decrease of -3.70% from 5.847.70 ha to 5.631.47 ha. Considering the "permanent crops (vineyards, fruit trees, olive groves)" areas, these exist in Süleymanpaşa and Çorlu districts. In both districts, they cover quite limited areas, with 43.28 ha and 1.91 ha respectively, and haven't undergone any change.

The second most extensive land-use category in all districts is the "pastures" areas. However, these areas too have seen a decline between the mentioned years. The most significant decrease was in Çerkezköy, with a reduction of -3.66% from 1.979.12 ha to 1.906.64 ha. This was followed by Çorlu with a -2.62% decrease and Süleymanpaşa with a -1.05% decrease. When looking at the "forests" areas in the districts, a decrease in all districts between the specified years is evident. The most significant reduction was in Çorlu with -0.33%. For the "herbaceous vegetation associations (natural grassland, moors...)" areas, different trends were observed. There was a decline of -7.29% in Çorlu, while Çerkezköy and Süleymanpaşa saw increases of +12.69% and +8.10% respectively. The "open spaces with little or no vegetation (beaches, dunes, bare rocks, glaciers)" areas are only recorded for the Süleymanpaşa district, and these areas have increased from 32.11 ha to 33.2 ha. Lastly, regarding the water-covered areas in the districts, there was an increase in Süleymanpaşa from 242.57 ha to 379.6 ha, in Çorlu from 121.7 ha to 126.94 ha, while Çerkezköy saw no change.

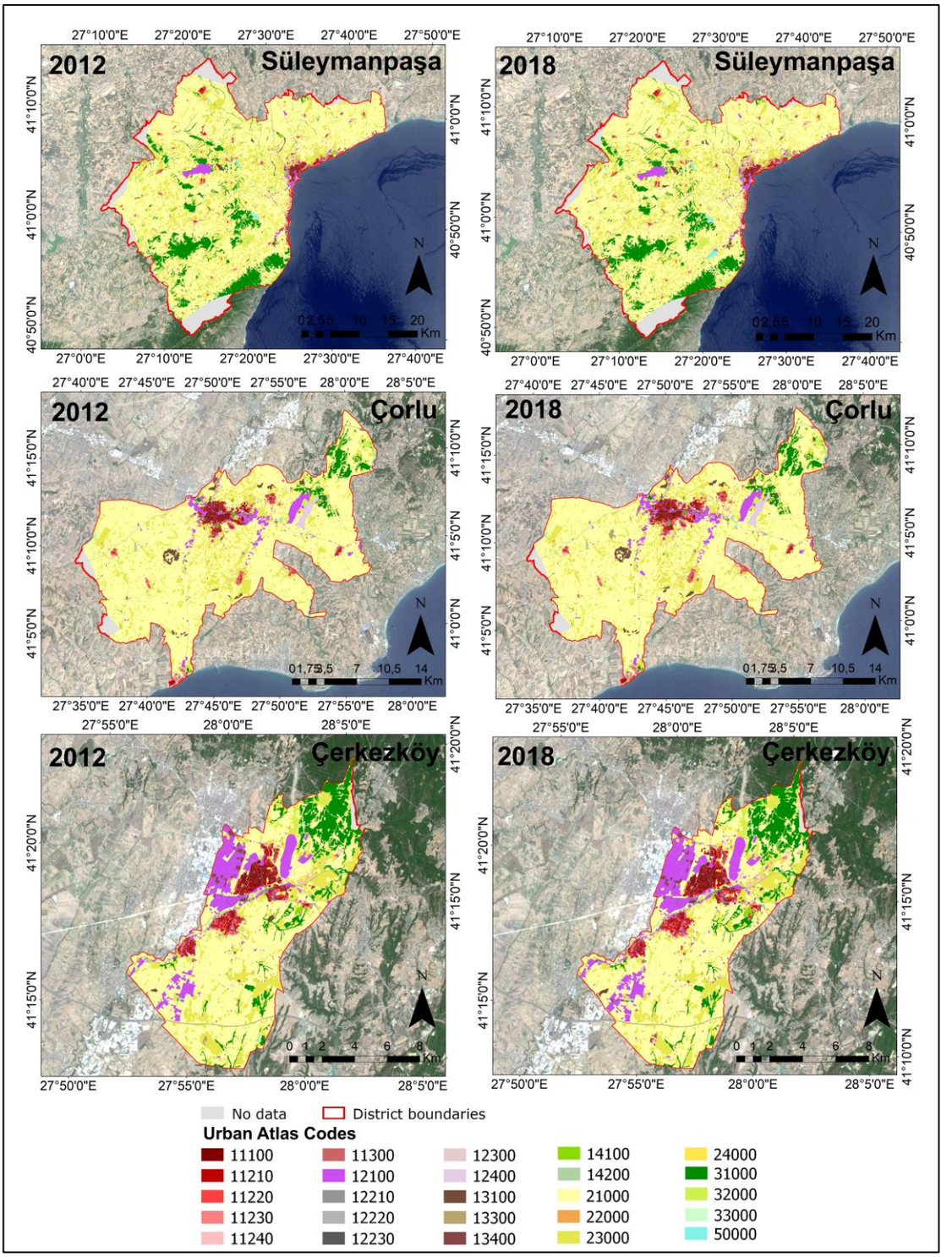

Figure 2. Spatial distribution of Urban Atlas Classes for Süleymanpaşa, Çorlu and Çerkezköy in 2012 and 2018

Table 1. Urban Atlas classes and spatial distributions of Süleymanpaşa, Çorlu and Çerkezköy districts for 2012 and 2018

Urban Atlas codes and nomenclature		Süleymanpaşa				Çorlu				Çerkezköy			
Codes	**Nomenclature**	**2012**		**2018**		**2012**		**2018**		**2012**		**2018**	
Artifical Areas		**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
11100	Continuous urban fabric (S.L.:> 80%)	231.59	0.21	231.59	0.21	297.91	0.73	298.51	0.73	174.66	1.50	174.66	1.50
11210	Discontinuous dense urban fabric (S.L.:50%- 80%)	425.37	0.39	478.62	0.44	366.76	0.90	426.39	1.04	272.76	2.35	292.36	2.51
11220	Discontinuous low density urban fabric (S.L.: 0% - 30%)	499.43	0.46	509.74	0.47	160.55	0.39	176.49	0.43	101.13	0.87	120.65	1.04
11230	Discontinuous medium density urban fabric (S.L.:30% - 50%)	586.25	0.54	596.27	0.55	238.8	0.58	301.37	0.74	50.19	0.43	57.98	0.50
11240	Discontinuous very low density urban fabric (S.L.:< 10%)	414.02	0.38	434.39	0.40	225.89	0.55	282.64	0.69	73.14	0.63	103.68	0.89
11300	Isolated structures	138.15	0.13	138.5	0.13	27.4	0.07	30.14	0.07	26.26	0.23	38.06	0.33
12100	Industrial, commercial, public, military and private units	1.344.01	1.24	1.479.85	1.37	1.186.31	2.90	1.364.21	3.33	1.106.01	9.51	1.265.16	10.88
12210	Fast transit roads and associated land	0.00	0.00	0.00	0.00	21.15	0.05	21.15	0.05	26.47	0.23	26.47	0.23
12220	Other roads and associated land	986.97	0.91	1.017.59	0.94	619.24	1.51	638.14	1.56	336.38	2.89	351.37	3.02
12230	Railways and associated land	45.04	0.04	45.04	0.04	26.56	0.06	26.56	0.06	28.37	0.24	28.37	0.24
12300	Port areas	19.11	0.02	53.99	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12400	Airports	0.00	0.00	0.00	0.00	249.97	0.61	249.97	0.61	0.00	0.00	0.00	0.00
13100	Mineral extraction and dump sites	388.71	0.36	458.6	0.42	360.29	0.88	452.29	1.10	31.6	0.27	36.54	0.31
13300	Construction sites	15.05	0.01	144.75	0.13	24.92	0.06	159.61	0.39	22.83	0.20	34.13	0.29
13400	Land without current use	82.66	0.08	76.21	0.07	185.52	0.45	152	0.37	130.32	1.12	129.51	1.11
14100	Green urban areas	133.9	0.12	141.51	0.13	72.68	0.18	73.66	0.18	24.52	0.21	25.66	0.22
14200	Sports and leisure facilities	29.48	0.03	22.15	0.02	56.8	0.14	60.01	0.15	5.25	0.05	5.33	0.05
Total area and %		5.339.76	4.93	5.828.79	5.38	4.120.73	10.06	4.713.12	11.51	2.409.89	20.72	2.689.94	23.13
Agricultural areas													
21000	Arable land (annual crops)	65.321.69	60.28	64.886.13	59.88	28.739.70	70.20	28.321.88	69.18	5.847.70	50.28	5.631.47	48.42
22000	Permanent crops (vineyards. fruit trees. olive groves)	43.28	0.04	43.28	0.04	1.91	0.00	1.91	0.00	0.00	0.00	0.00	0,00
23000	Pastures	20.962.96	19.35	20.743.33	19.14	6.101.92	14.90	5.942.32	14.51	1.979.12	17.02	1.906.64	16,39
Total area and %		86.327.93	79.67	85.672.74	79.07	34.843.53	85.10	34.266.10	83.69	7.826.82	67.30	7.538.12	64.82
Natural areas													
31000	Forests	9.504.73	8.77	9.495.65	8.76	1.009.53	2.47	1.006.15	2.46	1.228.54	10.56	1.228.08	10.56
32000	Herbaceous vegetation associations (natural grassland. moors...)	458.12	0.42	495.23	0.46	230.83	0.56	214.01	0.52	71.77	0.62	80.88	0.70
33000	Open spaces with little or no vegetation (beaches. dunes. bare rocks. glaciers)	32.11	0.03	33.2	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total area and %		9.994.96	9.22	10.024.09	9.25	1.240.36	3.03	1.220.16	2.98	1.300.30	11.18	1.308.96	11.26
Other types													
50000	Water	242.57	0.22	379.6	0.35	121.7	0.30	126.94	0.31	22.4	0.19	22.4	0.19
Total area and %		242.57	0.22	379.6	0.35	121.7	0.30	126.94	0.31	22.4	0.19	22.4	0.19
No data		6.450.54	5.95	6.450.54	5.95	615.52	1.50	615.52	1.50	70.32	0.60	70.32	0.60
Overall total area and %		108.355.77	100.00	108.355.77	100.00	40.941.85	100.00	40.941.85	100.00	11.629.74	100.00	11.629.74	100.00

In a general overview of the three districts, it's observed that the main land use occupying the most substantial area is agricultural areas. In Süleymanpaşa, these areas covered 79.67% of the district in 2012, which declined to 79.07% by 2018. While the use of agricultural areas covered 85.10% of the area in Çorlu district as of 2012, these areas decreased to 83.69% as of 2018. In Çerkezköy, the percentage declined from 67.30% in 2012 to 64.82% in 2018. This significant reduction in agricultural areas across all three districts is a crucial finding, indicating a loss of agricultural land.

For Süleymanpaşa, the second most extensive land use is natural areas. In 2012, these areas constituted 9.22% of the district, increasing slightly to 9.25% in 2018. The rise in the natural grasslands in the district has contributed to this increment. When considering the distribution of artificial areas in Süleymanpaşa, it was found that these regions, which made up 4.93% of the district in 2012, have grown to cover 5.38% by 2018.

The main land use type of "other areas" in the Süleymanpaşa district has the lowest area and has increased from 0.22% to 0.35% during the relevant years. For the Çorlu district, the second main land use type is artificial areas. These areas covered 10.06% of the district in 2012 and rose to 11.51% by 2018. When looking at the distribution of natural areas in the district, areas that made up 3.03% of the district in 2012 decreased slightly to 2.98% by 2018. The water usage areas in the district, on the other hand, saw a minor increase during the specified years, rising from 0.30% to 0.31%. Among the districts studied, Çerkezköy has the highest proportion of artificial areas relative to its total area. In 2012, these areas constituted 20.72% of the district, and by 2018, this percentage increased to 23.13%. Given the size of the district, nearly a quarter of it is made up of these areas, with a significant portion being industrial and commercial zones. When looking at the distribution of natural areas in the Çerkezköy district, it's observed that there was a very slight increase, going from 11.18% to 11.26%. When examining the distribution of water usage areas in the district, it was found that they measured 0.19% during the relevant years. There are areas in the districts for which there is no data related to the Urban Atlas classes. In Süleymanpaşa district, these areas constitute 5.95% of the total area and cover 6.450.54 ha. In the Çorlu district, these areas make up 1.50% of the total area and cover 615.52 ha. In the Çerkezköy district, areas without no Urban Atlas data are quite limited, making up 0.60% of the total area and covering 70.32 ha. The areas without data arise from the fact that Urban Atlas data is not produced for all provinces and regions but only covers urban centers (Figure 3).

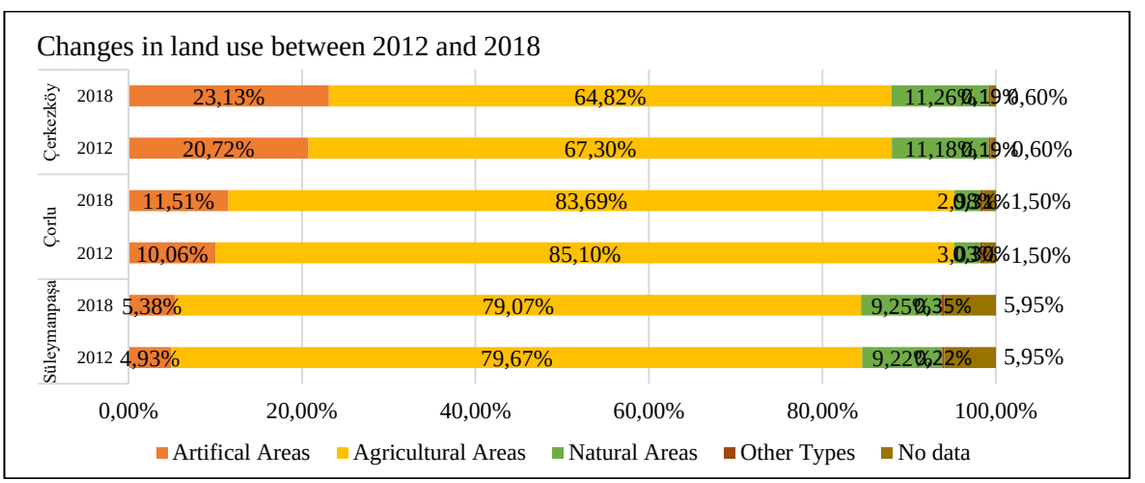

Figure 3. Main use types and spatial distributions of districts in 2012 and 2018, according to Urban Atlas (UA) data

In the scope of this study, the focus has been on the changes in artificial areas. In this context, to comprehend the condition of new constructions in the districts and to monitor urban growth areas and urban sprawl, maps displaying the distribution of artificial areas for the years 2012 and 2018 are provided in Figure 4. When the maps are examined, it is understood that the spread of new artificial areas for the Süleymanpaşa district occurs along the coastline and towards the inland areas. For Çorlu and Çerkezköy districts, it might be appropriate to mention two separate zones. Accordingly, when evaluating the Süleymanpaşa district, it is observed that as of 2018, the newly added urban fabric has expanded in the direction of the D-110-E84 Tekirdağ ring road for the northwest line. On the southwest front of the district, it can be seen that the sprawl occurs along the coastal line. When evaluating the Çorlu district, it is observed that the expansion mainly takes place around the central neighborhoods. However, as a second zone, it can also be seen that there's a sprawl in the direction southwest of the district center. The connections of the Çorlu ring road are believed to have influenced this occurrence. In these areas of the Çorlu district, there are integrated solid waste facilities and mining sites. In the Çerkezköy district, a situation similar to that in the Çorlu district has occurred. The main sprawl appears to spread around the district's central neighborhoods, resembling the spread of an oil stain. The sprawl that forms a second zone is observed to have taken place in the southwest of the district. When the results are evaluated, it is observed that the urban sprawl situations experienced in the districts overlap with the urban sprawl models in the literature. Indeed, according to Sudhira et al. (2004), when urban sprawl models are examined, it is seen that sprawl usually occurs radially around the city center, linearly along highways, and around urban areas. In this context, it is understood that these types of expansion have occurred for these three districts. On the other hand, according to Kanbak (2013), one of the reasons for sprawl is the relocation of industrial areas to the outskirts of cities. In this way, uncontrolled development is becoming widespread in sprawl areas. This situation is observed in the Çorlu and Çerkezköy districts. When the maps in Figure 4 are examined, it is seen that the settlement texture and industrial areas surround each other for these districts. Moreover, today, urban sprawl related to industrialization is a situation experienced in many cities. In fact, this situation can result in changing the type of economic activity of the regions and the status of the region. Aksoy and Sönmez (2021) demonstrated this in their evaluation for Hadımköy. Moreover, when evaluated from a sectoral perspective, as stated by Gülhan (2017), Süleymanpaşa district stands out with its services sector. Çorlu and Çerkezköy districts, on the other hand, are prominent with their industries. The influence of these areas is observed in the patterns of sprawl. On the other hand, topographical and natural environmental features also influence the direction of urban sprawl (Wang et al. 2020). When looking at the elevation maps for the districts (Özşahin and Eroğlu 2018, Aydoğdu and Bakırcı 2021), it is observed that the spread generally occurs in flat lands.

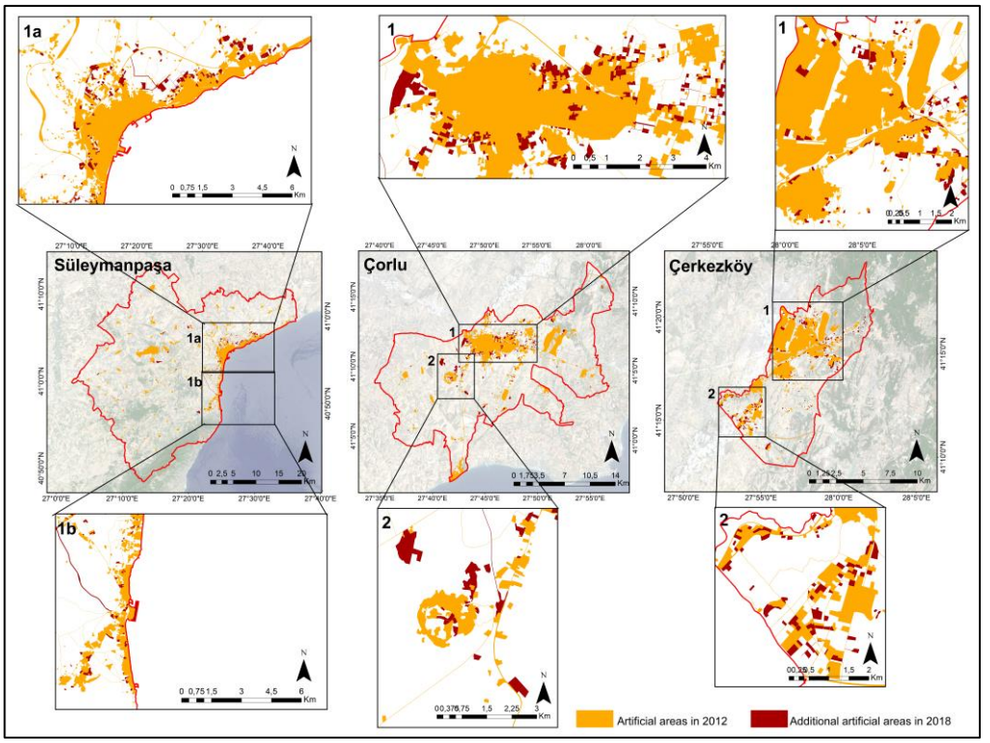

Figure 4. Artificial areas and spatial distributions of districts for 2012 and 2018 according to Urban Atlas data

Findings Regarding NUASI Value

When examining the categories used in NUASI calculation, for the years 2012 and 2018, the C1 category has the highest total area in Çorlu district. For the same years, the district with the least total area in this category is Çerkezköy. The total area of the C2 category in 2012 and 2018 is highest in the Süleymanpaşa district, whereas it has the lowest values in Çerkezköy for the same years. For the C3 category, it is observed that it is highest in the Süleymanpaşa district in both years and has the lowest value in the Çerkezköy district.

For the years in question, when looking at the areas in the C1 category, it is observed that these areas have not changed for Süleymanpaşa and Çerkezköy, whereas there is a slight increase in Çorlu. In the C2 category, for the Süleymanpaşa district, it is seen that from 2012 to 2018, there was an increase along the coastline. In the Çorlu district, it surrounds the areas in the C1 category. In the Çerkezköy district, an increase is observed towards the north and east of the city center where the areas in the C1 category are located. In the C3 category, it is observed that in Süleymanpaşa district, the majority of the areas expanded along the coastline. For the Çorlu district, there was a scattered increase primarily in the east and west of the city center. In the Çerkezköy district, the majority of the increase took place in the west of the city center and in the southwestern parts of the district.

According to the calculated NUASI values for the districts, the highest values for Çorlu and Çerkezköy districts were found for the year 2018. For the Süleymanpaşa district, the value was determined to be higher for the year 2012. For Süleymanpaşa, the value which was 40.51% in 2012 decreased to 38.60% by 2018. For the Çorlu district, the value, which was 26.79%, increased to 27.49% in 2018. For the Çerkezköy district, it is observed to have increased from 23.27% to 24.22%. These results indicate that between the relevant years, the tendency for urban sprawl decreased and declined in Süleymanpaşa, while it increased in Çorlu and Çerkezköy. When evaluating the trend between the relevant years, it has been concluded that Çerkezköy is the district with more urban sprawl development (Table 2).

When examining the results of studies using the NUASI in the literature, it is observed that these values create

differences for each region. For instance, Petrescu (2019) identified a trend between 1.25% and 4.14% during the years 2006-2012 in his analysis of Bucharest, Cluj-Napoca, Craiova, and Timişoara cities in Romania. On the other hand, Renata et al. (2021) found a trend between 4.68% and -1.10% in their urban sprawl analysis for Polish cities. They calculated values of -1.10% and -0.45% respectively for the cities of Rzeszów and Kielce. These researchers indicated with these results that discontinuous urban fabric might relatively decrease. This finding is consistent with the results for the Süleymanpaşa district in this study. However, they summarized that the primary cause of this change is not due to the halting of sprawl, but the emergence of new artificial surfaced areas and the densification of the current discontinuous urban fabric. Özmekik et al. (2022), in their studies on the central districts of Samsun province in Turkey, determined the trend for the Tekkeköy district as 43% during the study years. This result indicates that this district faced a significant urban sprawl situation between these years. In this study, the trend values for the districts were found to be -1.90%, 0.70%, and 0.96%, respectively. When compared, it is understood that the districts covered in this study have a lower tendency for urban sprawl.

Table 2. NUASI values of the districts for 2012 and 2018 and the differences between these years

Category 2012 (ha)	**Süleymanpaşa**	**Çorlu**	**Çerkezköy**
C1	231.59	297.91	174.66
C2	2.063.22	1.019.40	523.48
C3	2.798.89	2.488.43	1.551.66
NUASI	0.40505	0.26786	0.23268
Category 2018 (ha)			
C1	231.59	298.51	174.66
C2	2.157.52	1.217.03	612.73
C3	3.199.81	2.911.92	1.742.04
NUASI	0.38603	0.27488	0.24224
Trend	-0.01902	0.00702	0.00956

CONCLUSION AND SUGGESTIONS

In this study, the spatial distribution of urban growth between 2012 and 2018 in the districts of Süleymanpaşa, Çorlu, and Çerkezköy has been determined, and areas of urban sprawl have been identified. In line with this, the land use situation for the relevant years has been presented using Urban Atlas data. The results reveal that artificial areas have increased and agricultural areas have decreased for all districts. Based on the NUASI results for detecting urban sprawl, the trends have been calculated as -1.90% for Süleymanpaşa district, 0.70% for Çorlu district, and 0.96% for Çerkezköy district. This result indicates low urban sprawl tendencies, but it also shows that Çerkezköy district has experienced the most significant urban sprawl development. The spatial distributions of the data related to the C1, C2, and C3 classes, along with the numerical results related to NUASI, are seen to be consistent in reflecting low urban sprawl. In this context, it has been concluded that NUASI is guiding in determining urban sprawl and is deemed beneficial.

For all three districts, the increase in residential structures and construction sites from artificial areas has shown urban growth. However, without a doubt, the most striking result while this growth occurred has been the losses in agricultural areas. This indicates that the lands are being used for purposes other than their intended use. In this context, as Sezgin and Varol (2012) also pointed out, it is extremely important to ensure the balance between natural resources and urban uses by introducing smart growth models to prevent the misuse of lands and to protect natural resources. Because, as Wang et al. (2020) emphasized, urban sprawl can only contribute to ecological balance and sustainable development when it is properly managed.

On the other hand, with the advancing imaging technologies and software, using such spatial data to simulate future scenarios prepared based on the predicted population projection related to urban sprawl (as pointed out by Fang et al. 2005) will be beneficial in the context of developing strategies for management mechanisms.

In conclusion, reversing the negative effects that arise in urbanized areas is generally challenging and costly. Within the context of urban planning studies, when determining new residential areas, all parameters should

be addressed comprehensively with a multidimensional approach that encompasses ecological, socio-economic, and environmental perspectives within the framework of the concept of sustainability. For this purpose, stakeholders at every level of planning mechanisms, administrators, and the scientific community have significant responsibilities. In this context, interdisciplinary studies should be emphasized and prioritized.

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