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Analysis of Urban Growth and Land Use Changes in Çankaya District Using Urban Atlas Data

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Abstract

The aim of this study is to monitor the land use/land cover (LULC) changes in Çankaya district. In the study, the LULC changes of Çankaya district between 2012 and 2018 were examined using Urban Atlas data. Continuous urban fabric in Çankaya increased from 632.16 hectares to 644.03 hectares, and discontinuous dense urban fabric increased from 1,735.30 hectares to 1,795.05 hectares. Construction areas saw a significant rise from 122.40 hectares to 666.04 hectares. In contrast, arable lands decreased from 11,844.45 hectares to 11,347.11 hectares, pastures from 2,089.28 hectares to 2,025.83 hectares, and forests from 1,803.52 hectares to 1,793.67 hectares. Additionally, herbaceous vegetation associations reduced from 16,097.70 hectares to 15,666.54 hectares. These changes clearly illustrate the impact of urban expansion on natural and agricultural lands in Çankaya. The results highlight the need to balance urban growth with the conservation of natural and agricultural areas. Future research could benefit from expanding the scope of Urban Atlas data and integrating additional datasets to enable more comprehensive and long-term analyses of urban development. Effective use and management of such high-resolution data are crucial for supporting sustainable urban development.

Keywords: *Urban atlas, land use, landscape planning, urban growth, Çankaya.*

Kent Atlası Verileriyle Çankaya İlçesi'ndeki Kentsel Büyüme ve Arazi Kullanım Değişikliklerinin Analizi

Öz

Bu çalışmanın amacı Çankaya ilçesindeki arazi kullanımı/arazi örtüsü (AKAÖ) değişimlerini izlemektir. Çalışmada, Kent Atlası verileri kullanılarak Çankaya ilçesinin 2012 ve 2018 yılları arasındaki AKAÖ değişiklikleri incelenmiştir. Çankaya'daki sürekli kentsel doku 632.16 hektardan 644.03 hektara, süreksiz yüksek yoğunluklu kentsel doku ise 1,735.30 hektardan 1,795.05 hektara artmıştır. İnşaat alanları 122.40 hektardan 666.04 hektara büyük bir artış göstermiştir. Tarıma elverişli alanlar 11,844.45 hektardan 11,347.11 hektara, mera alanları 2,089.28 hektardan 2,025.83 hektara, ve ormanlar 1,803.52 hektardan 1,793.67 hektara düşmüştür. Ayrıca, otsu bitki toplulukları da 16,097.70 hektardan 15,666.54 hektara gerilemiştir. Bu değişiklikler, Çankaya ilçesindeki kentsel genişlemenin doğal ve tarımsal alanlar üzerindeki etkilerini net bir şekilde ortaya koymaktadır. Sonuçlar, kentsel büyüme ile doğal ve tarımsal alanların korunması arasında denge sağlanması gerekliliğini vurgulamaktadır. Gelecek araştırmalar, Kent Atlası'nın kapsama alanının genişletilmesi ve ek veri setleri ile entegrasyon sağlanması suretiyle, daha kapsamlı ve uzun vadeli kentsel gelişim analizlerinin yapılmasına olanak tanıyabilir. Sürdürülebilir kentsel gelişimi desteklemek için, bu tür yüksek çözünürlüklü verilerin etkili kullanımı ve yönetimi büyük önem arz etmektedir.

Anahtar kelimeler: *Kent atlası, arazi kullanımı, peyzaj planlama, kentsel büyüme, Çankaya.*

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1. Introduction

Land use (LU) refers to how land is used by habitats and people. Land cover (LC) refers to the biophysical extent of the Earth's surface (Petrisor & Petrişor, 2015; Regasa et al., 2021). Changes in land use and land cover are not only changes of natural origin, but are also realised by humans in line with the new needs that arise with the increasing human population (Regasa et al., 2021). The rapid population growth in urban areas, particularly in developing countries, is placing significant pressure on natural resources (Bokaie et al., 2016). Indeed, the rate of human-induced transformations on the Earth's surface today is occurring at an unprecedented pace in human history (Lambin et al., 2001; Mohan et al., 2011). This causes changes on a global scale today (Lambin et al., 2001; Regasa et al., 2021; Topal & Konakoğlu, 2023). These changes include the gradual loss of habitat (Lumia et al., 2023), decrease in biodiversity, negative impact on water yield, water cycle and flow, increase in environmental pollution such as water, soil and air pollution (Regasa et al., 2021); increased risk of natural disasters such as drought and floods, greenhouse gas emissions (Arowolo & Deng, 2018); loss of agricultural areas, forest areas, green and natural areas to create new settlements (Pauleit et al., 2005; Mohan et al., 2011); urban temperature increase and urban heat island effects due to increasing impervious surfaces with high urbanisation (Jiang & Tian, 2010; Pal & Ziaul, 2017; Tran et al., 2017; Das et al., 2021); adverse impact on local climate and global climate change (Han et al., 2015; Pal & Ziaul, 2017; Regasa et al., 2021); decrease in quality of life and welfare level (Demir & Demirel, 2018). In this context, studies aimed at understanding the factors affecting LULC in urban areas and studies on the detection and modelling of LULC are very important (Mohan et al., 2011; Han et al., 2015; Arowolo & Deng, 2018; Wang et al., 2022) . Because, there is a need to realise urban sprawl in the most accurate and rational way without putting pressure on natural resources, to monitor effective urban planning and decision-making processes and to develop appropriate management strategies in this direction (Aksoy et al., 2022; Topal, 2023a).

The purpose of the LULC classification is to automatically generate labels that describe land type and use (residential, industrial, etc.) (Helber et al., 2019). Quantitative assessment of LULC is very important for land use planning, natural resource management, environmental assessment and decision-making processes (Mohan et al., 2011; Han et al., 2015; Arowolo & Deng, 2018; Talukdar et al., 2020; Wang et al., 2022). Therefore, it is of great importance to monitor and map the changes in LULC over time (Srivastava et al., 2012).

In the last few decades, with the advent of remote sensing technology and the launch of numerous satellites, satellite imagery and aerial spatial imagery and data have increased exponentially thanks to advances in technology (Wang et al., 2022). Satellite imagery provides both multi-temporal availability and wide spatial coverage for mapping the LULC (Talukdar et al., 2020).

The European Space Agency (ESA) is making a significant effort to improve Earth observation within the framework of the Copernicus programme and operates a series of satellites known as Sentinel (Helber et al., 2019). Urban Atlas (UA) is a GIS database created by the European Space Agency in 2009, which contains spatial and statistical data such as area and population data for different land cover zones, where land use and land cover of Functional Urban Areas (FUAs) with more than 100.000 inhabitants can be monitored. These data can be accessed free of charge from the Copernicus Land Monitoring Service data portal (Prastacos et al., 2012; Petrisor & Petrişor, 2015; Pazúr et al., 2017; Tsagkis & Photis, 2018; Dobesova, 2020; Alomar-Garau, 2023). The first Urban Atlas database contains 319 FUAs with 2006 data. The next database contains 785 FUAs with more than 50.000 inhabitants with 2012 data. The last UA database is from 2018 and includes 788 FUAs. In addition, changes between the relevant years are also among the data provided (Alomar-Garau, 2023).

Urban atlas data has become an important data in recent years (Micek et al., 2020), and is widely used by researchers due to its high resolution (Pazúr et al., 2015; Kolcsár et al., 2021; Aksoy et al., 2022; Duru et al., 2022; Özmekik et al., 2022; Alomar-Garau, 2023; Topal, 2023a, 2023b). Specifically, the spatial resolution of the Urban Atlas is 0.25 hectares, with temporal resolutions available for the years 2006, 2012, and 2018, providing a six-year interval (Alomar-Garau, 2023).

1.1. Aim(s) of Study

The importance of appropriate urban interventions in addressing environmental issues cannot be overstated. Monitoring temporal and spatial changes in land cover is essential for effectively tackling these issues and making informed decisions. This challenge is even more pronounced in developing countries, particularly in rapidly growing cities with expanding urban areas.

Ankara, the capital of Türkiye, is the second most populous city in the country. In this context, this study aims to monitor land use/land cover changes in Çankaya district, the most populous district of Ankara, using Urban Atlas (UA) data.

2. Material and Method

Çankaya district, which constitutes the main material of this study, is located in Ankara, the capital of Türkiye. It is located between 39° 55′ 4″ North latitude and 32° 51′ 45″ East longitude (Anonymous, 2024). The district is situated in the Upper Sakarya Region in the northwestern part of Central Anatolia. Çankaya is bordered by the districts of Mamak and Altındağ to the east and northeast, Gölbaşı to the south, and Etimesgut to the west (Republic of Türkiye Ministry of Environment Urbanization and Climate Change, 2021) (Figure 1).

Ankara is one of the most populous cities in Türkiye, ranking second after Istanbul. The population of many of its districts is higher than many cities in Türkiye. Çankaya district, in particular, has experienced significant population growth in recent years, leading to a rapid increase in new residential areas. According to 2023 population data from TUIK, Ankara's population is 5,803,482. Çankaya district is the most populous in the province, with a population of 937,546. Reviewing the population data for 2012 and 2018, which correspond to the study years for which Urban Atlas data is available, the district's population increased from 832,075 in 2012 to 920,890 in 2018 (TUIK, 2024a; TUIK, 2024b).

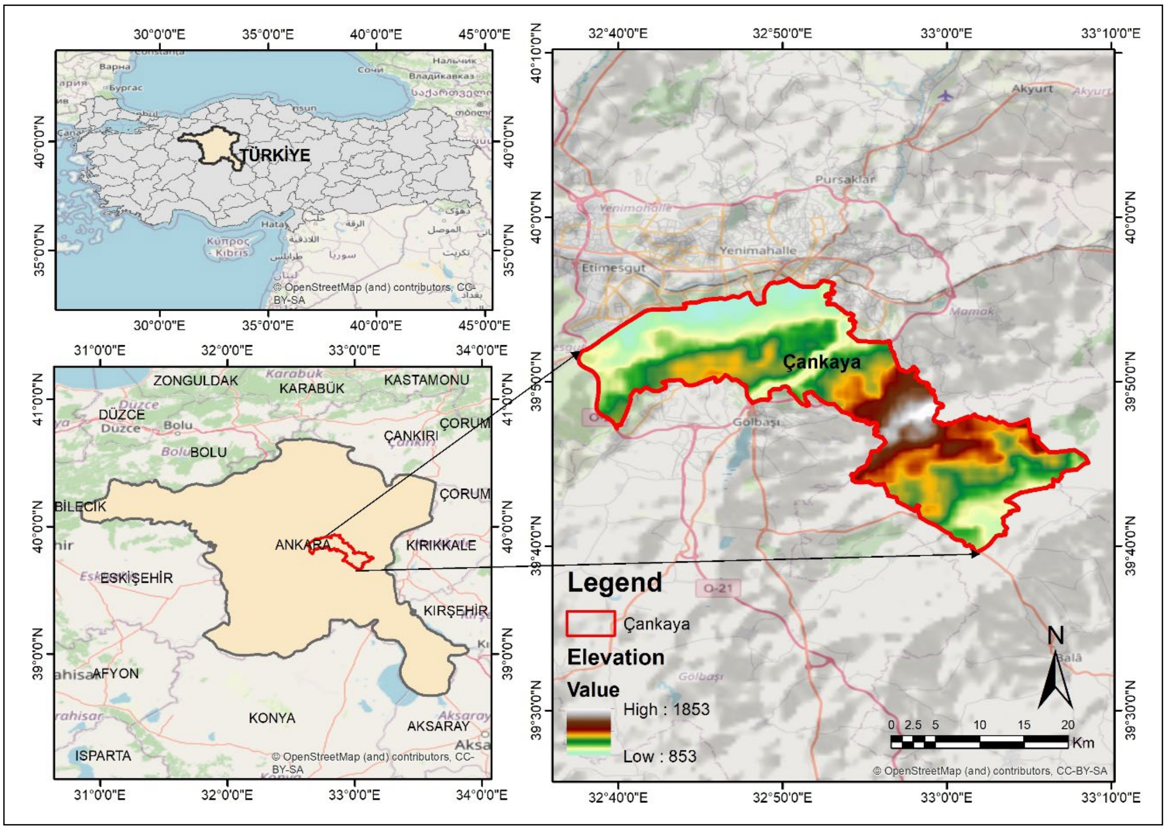

Figure 1. Location map of the study area (Authors, 2024)

The provincial and district boundaries of the study area were obtained from OpenStreetMap (OpenStreetMap, 2024). To determine land use within the study, Urban Atlas data from the years 2012 and 2018 were utilized. These data were downloaded free of charge in vector format from the

Copernicus website. Area calculations of land use classes were made using the downloaded vector formatted data. The Urban Atlas is a project under the EU Copernicus program, managed by the European Space Agency (ESA) and the European Environment Agency (Copernicus Land Monitoring Service, 2024). ArcMap 10.8 software was used for data processing and presentation.

3. Findings and Discussion

According to Urban Atlas data, there are 23 land use classes for the Çankaya district (Table 1, Figure 2). Analyzing changes in the urban fabric of the district between 2012 and 2018 reveals that the area of continuous urban fabric increased from 632.16 hectares to 644.03 hectares. Areas with discontinuous dense urban fabric, with 50%-80% density, increased from 1,735.30 hectares to 1,795.05 hectares. On the other hand, areas with discontinuous medium density urban fabric, with 30%-50% density, decreased from 1,228.16 hectares to 1,215.55 hectares, showing a -1% reduction. Areas with discontinuous low density urban fabric, with 10%-30% density, increased from 1,119.67 hectares to 1,160.60 hectares, reflecting a +4% increase. Additionally, areas with discontinuous very low density urban fabric, with less than 10% density, increased from 646.64 hectares to 743.37 hectares, showing a +15% increase. Overall, the continuous and discontinuous urban fabric areas grew from 5,361.93 hectares in 2012 to 5,558.60 hectares in 2018. These results indicate an increase in the settlement fabric within the district.

When examining the area of isolated structures, it is observed that these areas increased from 25.49 hectares to 39.08 hectares, reflecting a +53% rise. In terms of industrial, commercial, public, military, and private units, the area covered by these uses grew from 2,357.80 hectares in 2012 to 2,589.67 hectares in 2018, indicating a +10% increase. Evaluating the classes related to roads in the district, it is noted that the area designated for fast transit roads and associated lands remained unchanged at 103.72 hectares between 2012 and 2018. Additionally, other roads and associated lands, another transportation-related class, increased from 1,712.36 hectares to 1,728.60 hectares, showing a +1% rise. The area of mineral extraction and dump sites in the district expanded from 419.67 hectares in 2012 to 490.04 hectares in 2018, resulting in a +17% increase.

The most significant change in the district has undeniably occurred in construction areas. Such that, while these areas were 122.40 hectares as of 2012, they increased by +444% as of 2018 and reached 666.04 hectares. It has also been observed that the land without current use areas in the district have also decreased. These areas decreased by -14% from 659.56 hectares to 564.43 hectares. This shows that these areas have been given a function. Looking at the green urban areas class in the district, it is noteworthy that these areas have increased at a lower rate compared to the increase in built-up areas such as roads and urban fabric. In fact, these areas cover an area of 715.25 hectares as of 2018 and have increased by +3%. Looking at the areas of sports and leisure facilities, it is seen that these areas, which were 115.03 hectares as of 2012, reached 116.65 hectares.

Among the land uses in the district, arable land (annual crops) hold the second-largest share within the district's total area. However, it is noteworthy that these areas have decreased from 11,844.45 hectares in 2012 to 11,347.11 hectares in 2018, reflecting a -4% reduction. One of the areas with the largest share in the district is pasture areas. Yet, these areas have also decreased during the same period, showing a -3% reduction from 2,089.28 hectares to 2,025.83 hectares. Similarly, forest areas have decreased by -1%, from 1,803.52 hectares to 1,793.67 hectares.

Another noteworthy finding is the decrease in areas covered by herbaceous vegetation associations, which represent the largest share of land in the district. These areas, which covered 16,097.70 hectares in 2012, decreased by -3% to 15,666.54 hectares by 2018.

In general, it is observed that the main use type covering the largest area is natural areas. While these areas covered 18,484.11 hectares as of 2012, they decreased to 18,043.10 hectares as of 2018. The second main use type for the district was agricultural areas. While these areas covered 13,933.73 hectares as of 2012, it was observed that they covered 13,372.94 hectares in 2018. This is an important finding in terms of showing that natural areas and agricultural areas have been lost in the district. Looking at the total area of artificial areas for Çankaya district, it was observed that the area of 11,575.48 hectares in 2012 increased to 12,576.64 hectares in 2018. For the district, the main use type of other areas with water and wetland use has the lowest area and increased from 150.01 hectares to 150.64 hectares in the relevant years.

Table 1. Urban Atlas Classes and Spatial Distribution of Çankaya District in 2012 and 2018 (Authors, 2024)

	Legend Code	Nomenclature	2012		2018	
			ha	%	ha	%
Artifical Areas	11100	Continuous Urban fabric (S.L. > 80%)	632.16	1.43	644.03	1.46
	11210	Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)	1,735.30	3.93	1,795.05	4.07
	11220	Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)	1,228.16	2.78	1,215.55	2.75
	11230	Discontinuous Low Density Urban Fabric (S.L.: 10% - 30%)	1,119.67	2.54	1,160.60	2.63
	11240	Discontinuous very low density urban fabric (S.L. < 10%)	646.64	1.46	743.37	1.68
	11300	Isolated Structures	25.49	0.06	39.08	0.09
	12100	Industrial, commercial, public, military and private units	2,357.80	5.34	2,589.67	5.87
	12210	Fast transit roads and associated land	103.72	0.23	103.72	0.23
	12220	Other roads and associated land	1,712.36	3.88	1,728.60	3.92
	12230	Railways and associated land	3.92	0.01	3.92	0.01
	12400	Airports	0.64	0.00	0.64	0.00
	13100	Mineral extraction and dump sites	419.67	0.95	490.04	1.11
	13300	Construction sites	122.40	0.28	666.04	1.51
	13400	Land without current use	659.56	1.49	564.43	1.28
	14100	Green urban areas	692.96	1.57	715.25	1.62
	14200	Sports and leisure facilities	115.03	0.26	116.65	0.26
Agricultural areas	21000	Arable land (annual crops)	11,844.45	26.83	11,347.11	25.71
	23000	Pastures	2,089.28	4.73	2,025.83	4.59
Natural areas	31000	Forests	1,803.52	4.09	1,793.67	4.06
	32000	Herbaceous vegetation associations (natural grassland, moors...)	16,097.70	36.47	15,666.54	35.49
	33000	Open spaces with little or no vegetations (beaches, dunes, bare rocks, glaciers)	582.89	1.32	582.89	1.32
Other types	40000	Wetlands	11.94	0.03	11.94	0.03
	50000	Water	138.07	0.31	138.70	0.31

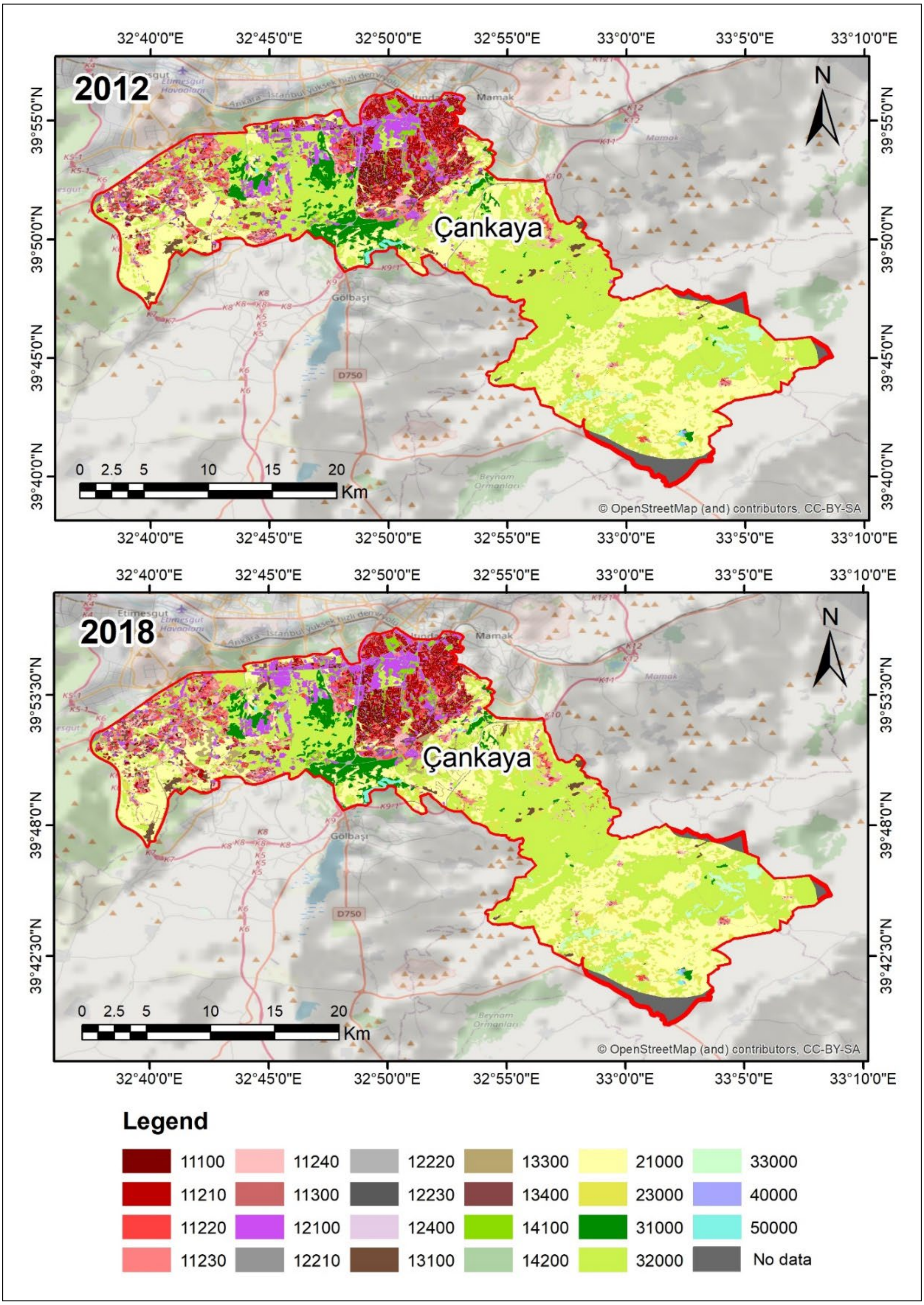

Figure 2. Spatial Distribution of Urban Atlas Classes of Çankaya for 2012 and 2018 (Authors, 2024)

4. Conclusion and Suggestions

In this study, Urban Atlas (UA) data was used to monitor land cover changes in Çankaya district between 2012 and 2018. The numerical data obtained from the study indicate that artificial areas in Çankaya district have increased, while agricultural and natural areas have decreased. The +444% increase in construction areas, along with the expansion of built-up areas, demonstrates significant urban growth. However, the most striking result of this growth is undoubtedly the loss of agricultural and natural lands. Detailed examination reveals that the increase in construction areas is primarily due to the conversion of agricultural areas (338.06 ha), followed by the transformation of herbaceous vegetation associations (192.73 ha) and pastures (39.89 ha). This indicates that land is being used for purposes other than originally intended. In this context, it is crucial to implement smart growth models to prevent the misuse of land and to protect natural resources, ensuring a balance between natural resources and urban uses.

As stated by Poyatos et al. (2003), information obtained from aerial imagery can provide crucial insights into land use and cover changes. According to Roy & Roy (2010), satellite-based remote sensing has revolutionized the study of land use and land cover changes at specific times and locations. In this study, Urban Atlas (UA) data was used as the dataset. These data provide high-accuracy results due to their high resolution. Thus, Urban Atlas data is an effective tool for monitoring changes. However, these data are produced specifically for urban areas and cover European countries and surrounding central regions. The data available are from the years 2006, 2012, and 2018. For Türkiye, data access is limited to 2012 and 2018, which confines the analysis to these periods. Expanding the production area boundaries of Urban Atlas data and developing new high-accuracy databases could broaden research scopes and enable long-term monitoring of changes. As emphasized by Petrisor & Petrişor (2015), frequent acquisition of Urban Atlas data could become a significant tool for identifying urban changes at appropriate temporal and spatial scales.

On the other hand, with the developing imaging technologies and software, simulations of future scenarios to be prepared for the urban growth areas that will emerge according to the future population projection by using such high accuracy data can also be useful in developing the right strategies in the management of cities. However, as stated by Prastacos et al. (2012) Urban Atlas data will provide an important dataset that can be used for the estimation of various indicators within the scope of urban planning studies, especially when combined with other datasets for the analysis of urban areas.

In conclusion, the negative impacts resulting from urbanization increasingly affect our cities and, on a global scale, our world. These issues arise from human activities that often come at the expense of destroying natural resources. Therefore, in urban planning, it is essential to adopt a multidimensional approach that includes ecological, socioeconomic, and environmental considerations within the framework of sustainability. This approach should guide ecological planning and design decisions with a holistic perspective. To achieve this, significant responsibilities fall upon stakeholders, managers, and the scientific community at every level of planning services. Emphasis should particularly be placed on interdisciplinary research in this regard.

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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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