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Article

The Role of Ecology on Urban Landscape: The Case of Antalya-Muratpaşa

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Abstract: Urban ecology is a factor that significantly affects the urban landscape. Proper management and sustainable planning of ecosystems in cities can help urban landscapes to increase biodiversity and contribute to the efficient use of natural resources. In this framework, the integration of green spaces and ecosystem services can improve the quality of urban landscapes by increasing the health and resilience of urban ecosystems. This paper, which examines the effects of ecological factors on urban landscape in Antalya-Muratpaşa, presents a detailed analysis using various data sets. Within the scope of the research, the number of vehicles, carbon emissions by years, the ratio of green areas to population, CORINE data and land surface temperatures were analyzed. In addition, the change in land use from 1990 to 2018 and the land surface temperature forecast for 2040 and 2041 shed light on the evolutionary processes in the city. In an effort to understand the ecological status of Antalya-Muratpaşa, the paper highlights the potential impacts on the sustainability of the urban landscape. In particular, predicting the possible impacts of future land use on the urban landscape with population growth offers a strategic approach in planning processes. This study can be an important resource for urban planners, researchers and local governments because the data in the Antalya-Muratpaşa case provides a comprehensive overview that can guide those who want to consider sustainability and environmental factors in urban landscape planning. In line with this perspective, it is recommended to encourage green roof and green facade practices, rainwater harvesting, gray water recycling, etc. in new constructions.

Keywords: urban landscape; urban ecosystem; climate change; antalya

1. Introduction

In parallel with the continuous increase in the world population and the rapid development of the global economy, urban populations and the areal size of cities are also increasing rapidly. More and more people are migrating from rural areas to cities. The population of 4.6 billion towns and cities in mid-2023 is expected to reach 5 billion by 2030 [1]. Urban areas are important hotspots that drive environmental change to a large extent due to their dense populations. The rapid and worldwide urbanization of the human population raises concerns about the sustainability of cities [2]). Urbanization is a process characterized by the expansion of urban areas, intensive and economic use of land, economic development and the transfer of rural labor [3]. The increase in the number of cities, the growth of their areas and the consequent expansion of urban impervious surfaces, economic development, and intensified production and consumption activities negatively affect air quality, land use and cover, water resources, biodiversity and, most importantly, climate in cities [4–8]. Human-related production and living spaces are intensively encroaching on ecological areas and

regional ecological networks are shrinking and becoming less interconnected [9]. This leads to increased pollution and deterioration of ecological functions [10,11], posing serious threats to the development and sustainability of urban areas. These pressures of urbanization on the natural environment have led to the emergence of the concept of "resilience" in the urban perspective. Today, the concept of "resilient city" is increasingly used in scientific and policy circles as a regulating principle to guide research designs and make decision-making processes for cities more informed and easier [12]. Ecologists stayed away from urban areas for most of the 20th century, so ecological science has contributed little to environmental issues in cities and their impact on the urban landscape [13,14]. Especially with the increase in the number and spatial size of cities worldwide, the need for studies on urban ecology increased in the early 2000s [14–16]. There are very few studies that collectively address the impacts of urbanization on the natural environment. In contrast to this study, most of the existing studies in the literature have independently addressed the increasing number of vehicles and the resulting increase in carbon emissions due to urbanization, the changes in green space and land use caused by urbanization, and the heat island caused by cities and its effects on climate. For example, Newman et al. [22] focused on the challenges that cities face in finding solutions to the increasing number of automobiles, fossil fuel dependency and the associated carbon footprint, and the inability to recover the natural resources consumed. Abdul-Manan (2021) stated that 16% of the world's carbon emissions today come from the transportation sector. Krecl et al. [23] analyzed black carbon concentrations between 2013-2019 and particle number concentrations between 2009-2019 by vehicle type on roads and rooftops in Stockholm to determine the effectiveness of European Carbon Emission Reduction policies. Lu et al. [24] followed a semi-natural experimental method by taking 258 cities in China as a sample to determine the effects of smart transportation policies produced to reduce the increasing number of vehicles and carbon emissions with urbanization. Some studies have also included not only gasoline, diesel and autogas but also coal-using vehicles and found that there is a close relationship between the efficient use of coal in transportation and carbon emissions [17,18]. Tabarelli et al. [25] and Newbold et al. [4] stated that the reduction in biodiversity caused by economic development leads to soil erosion and land degradation. According to Nor et al. [26], the expansion of cities can lead to the reduction and fragmentation of green spaces. Roussel and Alexander [27] stated that social policies are effective in the regional positive or negative change of vegetation cover in Paris. In China, increasing urban population density and non-agricultural working population have significantly affected the distribution of green spaces [19]. Liu et al. [3] focused on the changes in green areas due to urbanization in the Nanjing metropolitan area between 2000 and 2020 using Landsat imagery. They found that the distribution of green areas is influenced by a combination of physical geography, socio-economic characteristics and management policies. With good and sustainable policies, both rapid economic development and vegetation improvement can be achieved simultaneously in a region [7]. Shu et al. [28] used land use and land cover data, land surface temperatures, Normalized Difference Vegetation Index (NDVI), Normalized Difference Buildup Index (NDBI) and Modified Normalized Difference Water Index (MNDWI) obtained from Landsat 5 TM and Landsat 8 OLI in four-year periods between 1992 and 2021. In this context, they concluded that urban expansion, the resulting increase in the areal extent of impervious surfaces, climate change and surface temperatures are positively correlated with each other. Sun and Kafatos [29] found a strong negative correlation between NDVI and LST.

In this context, this research was carried out in Muratpaşa district, the central district of Antalya city, which is a rapidly growing and especially an important tourism center. Muratpaşa district, which will be evaluated in 4 different categories, is based on the effect of ecology on the urban landscape. The aim of the research is to reveal the effects on the urban landscape by using ecological variables. In this context, Antalya/Muratpaşa district's vehicle carbon emissions over the years, the distribution of green areas at the neighborhood scale, land use and surface temperature over the years were analyzed.

2. Materials and Methods

The study was carried out in 5 stages within the scope of the purpose of the study and the variables obtained. Firstly, the amount of carbon emission was revealed through the number of vehicles by years. In the second stage, the distribution of urban green areas at the neighborhood scale was analyzed. In the third stage, CORINE land use maps were created. Fourthly, the change in urban surface temperature over the years was analyzed. Finally, land use maps were prepared by identifying agricultural, residential and forest areas.

The first phase of the study was conducted to understand the relationship between the number of motor vehicles in the Muratpaşa district of Antalya and their environmental impacts. During the research process, the Turkish Statistical Institute (TUIK) collected motorized land vehicle data for Antalya between 1994 and 2023. This data was used to determine the change in the number of vehicles in the district over time. Then, the population ratios of Muratpaşa district with other districts were calculated and these ratios were divided by the number of vehicles to determine the average number of vehicles in the district between 1994 and 2023. Then, the average carbon dioxide emission of vehicles in Muratpaşa district was calculated by formulating the number of vehicles with the most recent 2023 carbon emission rates of the GHG Protocol. These steps are an appropriate method to analyze how the number of vehicles is related to population and environmental factors and to understand the environmental impacts of transportation in the district. The main reason for using the GHG Protocol in this process is to measure environmental impacts in a standardized way and to obtain comparable data. The GHG Protocol is recognized as a global standard for calculating and reporting greenhouse gas emissions. It provides a comprehensive framework for calculating and reporting emissions of greenhouse gases according to a specific process and methodology. Therefore, the use of the GHG Protocol has enabled the identification of carbon dioxide emissions of vehicles in Muratpaşa district and a clear measurement of environmental impacts. Thus, calculating GHG emissions and relating these emissions to population and vehicle numbers will contribute to understanding the environmental impacts of the district and guide future landscaping sustainability efforts. The determination of carbon dioxide emissions from vehicles is an important element that increases the reliability and comparability of the research.

Another stage of the study is the collection and analysis of park and green area data in the neighborhoods within the borders of Muratpaşa district. First, neighborhood-based park and green area data were obtained from Muratpaşa Municipality. This data includes the square meters of parks and green areas in each neighborhood. Then, the total square meters of parks and green areas in each neighborhood were divided by the number of population in that neighborhood to determine the average park and green area per capita. The purpose of this step is to determine how the area of parks and green spaces, which have psychological effects on people and environmental aesthetic value, is distributed according to the population density in each neighborhood. In terms of landscape architecture, the amount and distribution of green spaces in neighborhoods can directly affect the quality of the urban environment and people's quality of life. Therefore, determining the amount of parks and green spaces per capita can provide important data to be used in urban planning and landscape design. The determined data will provide a basis for analyzing and improving the urban landscape in Muratpaşa district, and the ratio of the amount of green space to the population will be a guide in determining the sustainability efforts and green space policies of the district.

In another stage of the study, CORINE data for the years 1990, 2000, 2006, 2012 and 2018 published by Copernicus Land Monitoring Service were used. CORINE data is a detailed and reliable source covering land cover over various periods. These data are an important basis for understanding and monitoring land use in and around Muratpaşa district of Antalya province. CORINE land cover classes were used to classify the study area according to the characteristics of each year and the legends were prepared accordingly. This classification defines various land types and plays an important role in determining the changes that have occurred over the years. Using the Geographic Information Systems software ArcGIS 10.8.1, the 1990, 2000, 2006, 2012 and 2018 land cover data of Muratpaşa district and its surroundings were digitized and mapped. Thanks to this digitization process, the land use of each year can be analyzed in detail. The data obtained will contribute to the

understanding of landscape changes in the region by calculating and tabulating the area covered in square kilometers for each year. The use of CORINE data can provide urban planners and environmental experts with an important basis for improving various aspects of the landscape, such as urban regeneration projects and the protection of green spaces.

Within the scope of the research, Landsat 5 TM (Thematic Mapper) of 1984, Landsat 5 TM of 2005 and Landsat 8 OLI-TIRS (Operational Land Imager and Thermal Infrared Sensor) of 2023, which have low cloudiness, were preferred by the United States Geological Survey (USGS). These images constituted the main data sources of the research and provided the basis for the analytical processes. The details of the imagery are presented in detail in Table 1. Landsat 5 TM satellite collects data in the visible, shortwave infrared (SWIR), near infrared (NIR) and thermal infrared (TIR) ranges while imaging the earth. These ranges have a spatial resolution of 30 m in bands 1-5 and 7 and 120 m in band 6. Landsat 8 OLI-TIRS satellite acquires imagery in multiple spectral and thermal ranges. With a spatial resolution of 30 m in bands 1-7 and 9, 15 m in band 8, and 100 m in bands 10 and 11, this satellite played an important role in the spectral analysis of the study.

For the determination of land surface temperature values (LST), Landsat 5 TM (1984 and 2005) and Landsat 8 OLI-TIRS (2023) satellite images with metadata information were obtained from the USGS service (Table 1).

Table 1. Landsat 5 TM (1984 and 2005) and Landsat 8 OLI-TIRS (2023) satellite imageries properties.

Satellite Image	Image Number	Shooting Date	Path/Row	Format
LANDSAT 5 TM	LT51780341984182FUI00	1984.06.30	178-034	GeoTiff
LANDSAT 5 TM	LT51780342005159MTI00	2005.06.08	178-034	GeoTiff
LANDSAT 8 OLI-TIRS	LC81780342023193LGN00	2023.07.12	178-034	GeoTiff

The thermal infrared (TIR) bands of these satellite images were tested for their suitability for the study area and pixel accuracy using ArcGIS 10.8.1. After confirming the data, the numerical values (DN) in the Thermal Infrared (TIR) bands were converted into Spectral Radiance values with formula1 for the calculation of the EQS.

$$L_{\lambda} = \frac{(LMax_{\lambda} - LMin_{\lambda})}{(QCalMax_{\lambda} - QCalMin)} \times (DN - QCalMin) + LMin_{\lambda}$$

Formula 1. Formula Used to Find Radiance Values in LST.

In Formula 1, L_{λ} ; represents the Spectral Radiance value, DN; cell value, L min and L max; represent the maximum and minimum Spectral reflectance value in the thermal band obtained from metadata, Q Cal Min and Q Cal Max; represent the calibrated minimum and maximum cell value. The obtained Spectral Radiance value was converted to Kelvin temperature value using Formula 2.

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L_{\lambda}}\right) + 1}$$

Formula 1. Formula Used to Convert Radiance Value to Kelvin Value.

T in Formula 2 represents the temperature value in Kelvin, and K1 and K2 values represent the calibration constant values (Table 2) for the bands of Landsat satellite images used in the study. The obtained Kelvin temperature value was converted to degrees using Formula 3 and the EQS values were obtained.

$$T(^{\circ}\text{C}) = T - 273(\text{K})$$

Formula 2. Formula Used to Convert Kelvin Value to Degrees.

Table 2. Landsat Satellite Calibration Constants Used to Convert Kelvin Value to Degrees.

	Landsat 5 TM	Landsat 8-OLI TIRS	
		Band 10	Band 11
K1	607.76	774.89	1321.08
K2	1260.56	480.89	1201.14

For the calculation of the estimated Land Surface Temperature of Muratpaşa and its surroundings for 2041, 50,000 random point data were added to the study area with the Create Random Points tool in ArcGIS 10.8.1 software. To these points, 1984, 2005 and 2023 AQS data (degrees) were integrated. The variational relationship between these data was determined by averaging the changes over the years, and the estimated Land Surface Temperature map of 2041 was created with these change rates.

In another stage of the study, Landsat 8 OLI-TIRS (Operational Land Imager and Thermal Infrared Sensor) satellite images of 2013 and 2023, which have low cloudiness, were preferred by the United States Geological Survey (USGS) to classify the land use of Muratpaşa and its surroundings in detail and to predict future land use (Table 3). In order to clearly reveal the change between the two years, a 10-year period was determined between the image acquisition dates and Landsat 8 OLI-TIRS satellite image was preferred because the image quality should be good in the analysis to be performed. In order to obtain the natural appearance of Muratpaşa and its surroundings, a combination of Red, Green and Blue bands was made using ArcGIS 10.8.1. In the natural view formed with the Classification tool, a sample group was formed in 4 classes. These are Forest, Plant-Agriculture Land, Build Up Area and Bare Land. For each sample, 50 samples were taken from the study area and detailed land use maps of 2013 and 2023 were created with the Interactive Supervised Classification analysis in the Classification tool.

Table 3. Landsat 8 OLI-TIRS (2013 and 2023) satellite imageries properties.

Satellite Image	Image Number	Shooting Date	Path/Row	Format
LANDSAT 8 OLI-TIRS	LC81780342013117LGN02	2013.04.27	178-034	GeoTiff
LANDSAT 8 OLI-TIRS	LC81780342023257LGN00	2023.09.19	178-034	GeoTiff

In addition to the land use data for 2013 and 2023 obtained as a result of the analyzes made with ArcGIS 10.8.1, Digital Elevation Model (DEM), road data and river data of Muratpaşa and its surroundings were integrated into QGIS 2.18 software, another Geographic Information Systems software, by installing Molusce plug-in. Finally, by applying the Artificial Neural Network method, the estimated land use map of Muratpaşa and its surroundings for the year 2040 was created. The accuracy of this map was compared with TerrSet Geospatial Monitoring and Modeling Software, another Geographic Information Systems software, and a positive result was obtained.

3. Results

Table 4. Number of cars, minibuses, buses, vans, trucks and motorcycles and estimated carbon emission values in kilograms of Antalya/Muratpaşa (1994-2023).

Years	Car	Avg. Carbon (KG)	Minibus	Avg. Carbon (KG)	Bus	Avg. Carbon (KG)	Van	Avg. Carbon (KG)	Truck	Avg. Carbon (KG)	Motorcycle	Avg. Carbon (KG)
1994	16956	33084585.83	704	1551852.95	496	1092836.48	3094	15320454.18	1833	12893934.92	11836	14732994.97
1995	19315	37687458.61	762	1679706.85	558	1229912.63	3536	17510570.12	1893	13322082.60	12390	15422709.13
1996	21569	42085157.40	843	1858702.32	630	1388786.82	4081	20207256.30	1986	13976345.77	13111	16319526.88
1997	23979	46787463.51	954	2102253.52	678	1494842.68	4984	24681646.21	2073	14587794.18	14043	17480017.10
1998	25829	50396374.00	1053	2322329.91	720	1587065.17	5898	29206881.46	2187	15385219.23	14715	18316242.26
1999	26569	51840012.40	1096	2415809.98	708	1561075.20	6258	30988351.52	2176	15307617.46	15316	19064655.49
2000	28925	56438061.93	1218	2684931.97	772	1701924.09	6984	34584246.95	2281	16047510.17	16117	20061119.67

2001	30438	59389525.17	1281	2823265.70	828	1825166.87	7539	37328953.72	2323	16345875.58	16794	20903972.14
2002	32333	63087480.44	1354	2985912.63	895	1972303.65	8310	41147062.12	2411	16961337.87	17348	21594159.68
2003	34406	67131968.28	1431	3154428.26	940	2071233.23	9444	46762647.44	2499	17586165.89	18167	22613109.38
2004	37949	74044439.89	1787	3939157.79	1094	2410779.66	11644	57658615.47	3298	23204266.20	21764	27090334.15
2005	41637	81240741.72	2012	4435901.65	1187	2615765.10	13552	67106432.89	3462	24358926.97	27167	33815402.20
2006	44463	86755581.40	2134	4705023.63	1205	2656846.03	15427	76390415.33	3619	25465421.13	32921	40977399.68
2007	47150	91997721.46	2248	4954862.74	1296	2857639.53	17306	85696054.11	3760	26458188.56	35776	44531534.12
2008	49979	97517013.37	2295	5058822.63	1516	3342226.78	18797	93078985.78	3808	26792678.93	38670	48133243.22
2009	52150	101752947.48	2277	5018999.28	1497	3301145.86	19887	98476124.46	3641	25620624.66	40449	50347949.93
2010	55331	107959368.24	2282	5031155.89	1598	3522899.02	21485	106385399.56	3642	25628652.43	41615	51799568.64
2011	60253	117563218.15	2350	5181646.22	1729	3811723.08	23312	115435870.06	3615	25438661.90	43237	53818532.86
2012	64823	126479939.22	2413	5318722.37	1875	4134082.60	25039	123986361.39	3755	26420725.64	44940	55938563.64
2013	69873	136333114.50	2484	5476338.98	1866	4114380.52	26432	130882496.01	3737	26290943.37	45982	57235623.89
2014	74876	146095018.88	2361	5204282.65	1914	4220017.19	28104	139164636.94	3900	27442928.22	47547	59183344.48
2015	80710	157477909.18	2482	5470889.47	1964	4328588.21	30401	150535161.47	4134	29091296.78	49137	61161834.74
2016	85298	166430990.20	2497	5503586.54	1955	4310562.90	32063	158764573.89	4278	30098781.79	49924	62142204.01
2017	90767	177101151.28	2615	5764324.66	2020	4453088.57	33662	166685147.96	4395	30921628.11	51320	63879744.03
2018	94890	185146717.64	2786	6141598.47	2062	4546149.44	34783	172233881.07	4451	31319002.67	52992	65960484.30
2019	98917	193004176.92	2999	6611094.77	2112	4655558.85	35772	177132923.73	4530	31872918.73	55089	68571646.47
2020	105076	205021511.23	3099	6830751.97	2111	4652624.49	37446	185418830.98	4725	33247005.18	57463	71525535.51
2021	110880	216344296.30	3136	6912913.82	2107	4645079.02	39226	194234847.97	4970	34972975.51	60596	75426183.86
2022	118371	230962109.03	3394	7481339.70	2172	4787604.68	41518	205583716.16	5284	37176598.09	68129	84802651.35
2023	126855	247515903.57	3844	8473569.83	2277	5018580.09	43557	215681224.03	5542	38992211.84	81117	100969513.30

Table 1 shows that the number of cars in Antalya Muratpaşa district has increased dramatically since 1994. The increase in the mobility needs of individuals and businesses in parallel with population growth is the most important reason for the number of cars. The rise in income levels due to population growth and economic development, which are especially characteristic of developing countries, has enabled more people to own cars. For this reason, the number of vehicles, which has a significant impact on urban ecology, affects the urban landscape depending on air and environmental quality.

The carbon dioxide emissions in Muratpaşa District between 1994 (33084585.83 KG) and 2023 (247515903.57 KG) showed an increase every year in parallel with the increase in the number of vehicles (Table 1). Although there is a decreasing trend in carbon emissions per vehicle, the total carbon emissions increasing every year is a major threat to future generations and the urban landscape.

The number of Minibuses, another transportation node, has generally increased over the years observed between 1994 (704) and 2023 (3844). This increase can be attributed to factors such as increased need for public transportation, urbanization and population growth. Increasing population density and transportation needs in cities, especially in developing countries, have increased the demand for minibuses. However, it is noteworthy that carbon emissions per minibus fluctuate between 1994 (1551852.95 KG) and 2023 (8473569.83 KG). The reason for these fluctuations is that older and less efficient van models are still in use in certain years. However, there has been a general upward trend in the carbon emissions of minibuses in recent years. This increase is due to the fact that minibuses are generally diesel-powered and have less efficient technologies.

The number of buses in Muratpaşa district increased dramatically between 1994 (496) and 2023 (2277). This can be attributed to the increase in the district's population and transportation demand. Especially in a touristic region like Antalya, the development of transportation infrastructure and the expansion of public transportation services lead to more widespread use of buses. There is a significant increase in the average carbon emissions of buses in Muratpaşa district between 1994 (1092836.48 KG) and 2023 (5018580.09 KG) (Table 1). It has also increased. This increase is a result of the transportation demand in the district and the growth of bus fleets.

Between 1994 (3094) and 2023 (43557), there was a significant increase in the number of vans in Muratpaşa district (Table 1). This increase is due to the need for commercial transportation and

logistics requirements, along with the increase in the population and commercial activities of the district. Especially in the Muratpaşa district of Antalya, which is a touristic region, the increase in touristic activities and the expansion of the service sector have increased the demand for pickup trucks. Between 1994 (15320454.18 KG) and 2023 (215681224.03 KG), the average carbon emissions of pickup trucks in Muratpaşa district also increased (Table 1). This increase can be attributed to the fact that pickup trucks generally run on fossil fuels, increasing the carbon footprint of commercial transportation activities. Especially in the district, which is a touristic destination, intensive tourist and material transportation causes carbon emissions to increase.

There was a significant increase in the number of trucks in Muratpaşa district between 1994 (1833) and 2023 (5542), just like the number of vans Table 1). In this period, with the increase in commercial activities and logistics needs, it is seen that the demand for trucks increased in addition to vans. The fact that the district is a touristic region and the increase in activities in the construction sector also creates an additional demand for trucks. Between 1994 (12893934.92 KG) and 2023 (38992211.84 KG), the average carbon emissions of trucks in Muratpaşa district also increased (Table 1). This increase can be attributed to the fact that trucks generally run on fossil fuels, increasing the carbon footprint of commercial transportation activities. Construction activities, material transportation and logistics requirements in the district have also increased carbon emissions, but the continued use of old trucks also contributes to the increase in carbon emissions.

The number of motorcycles in Muratpaşa district increased significantly between 1994 (11836) and 2023 (81117). During this period, it is observed that the use of motorcycles increased as a result of the effects of individuals' personal transportation preferences, changes in transportation infrastructure and the climate of the city being suitable for motorcycling. In particular, the intensity of urban transportation and traffic problems can also affect individuals' preference for motorcycles. The average carbon emission of motorcycles in Muratpaşa district has shown an increasing trend between 1994 (14732994.97 KG) and 2023 (100969513.30 KG) (Table 1). This increase is accompanied by an increase in the use of motorcycles, and it is inevitable that carbon emissions will increase as more motorized vehicles travel on the roads.

Looking at Table 1, the increase in the number of vehicles and the related increase in carbon emissions show an important trend that should be taken into account in terms of transportation and environmental policies of Muratpaşa district. These increases are likely to have emerged with the growth of the district's population and economy. However, the increasing number of vehicles and carbon emissions are a major concern in terms of environmental sustainability and urban landscape.

There are 55 neighborhoods in the Muratpaşa district of Antalya province. When we look at Figure 1, we see the distribution of green areas (park areas) at the neighborhood scale of Antalya Muratpaşa district. When Figure 1 is examined, it is seen that green areas are concentrated close to the coast. The 10 neighborhoods that do not have green areas are located in neighborhoods far from the coast of Muratpaşa district (Figure 1).

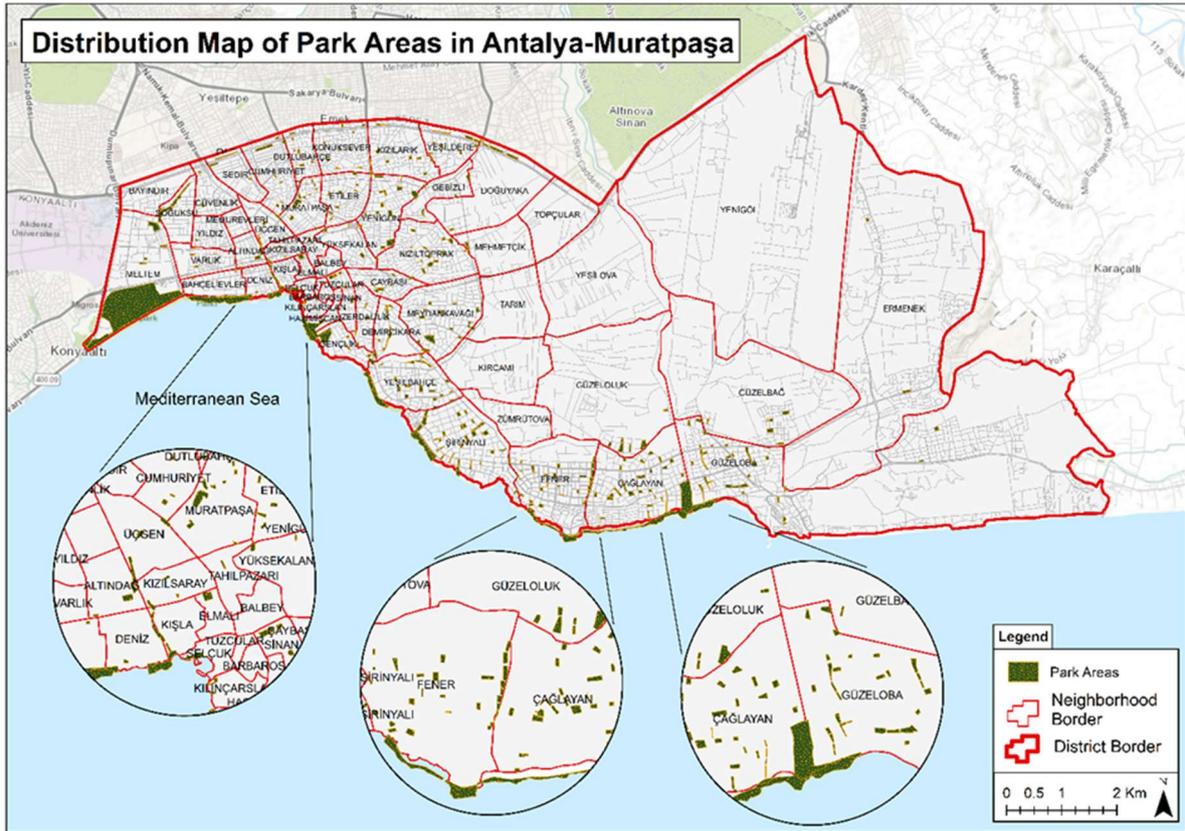


Figure 1. Antalya/Muratpaşa district green area distribution.

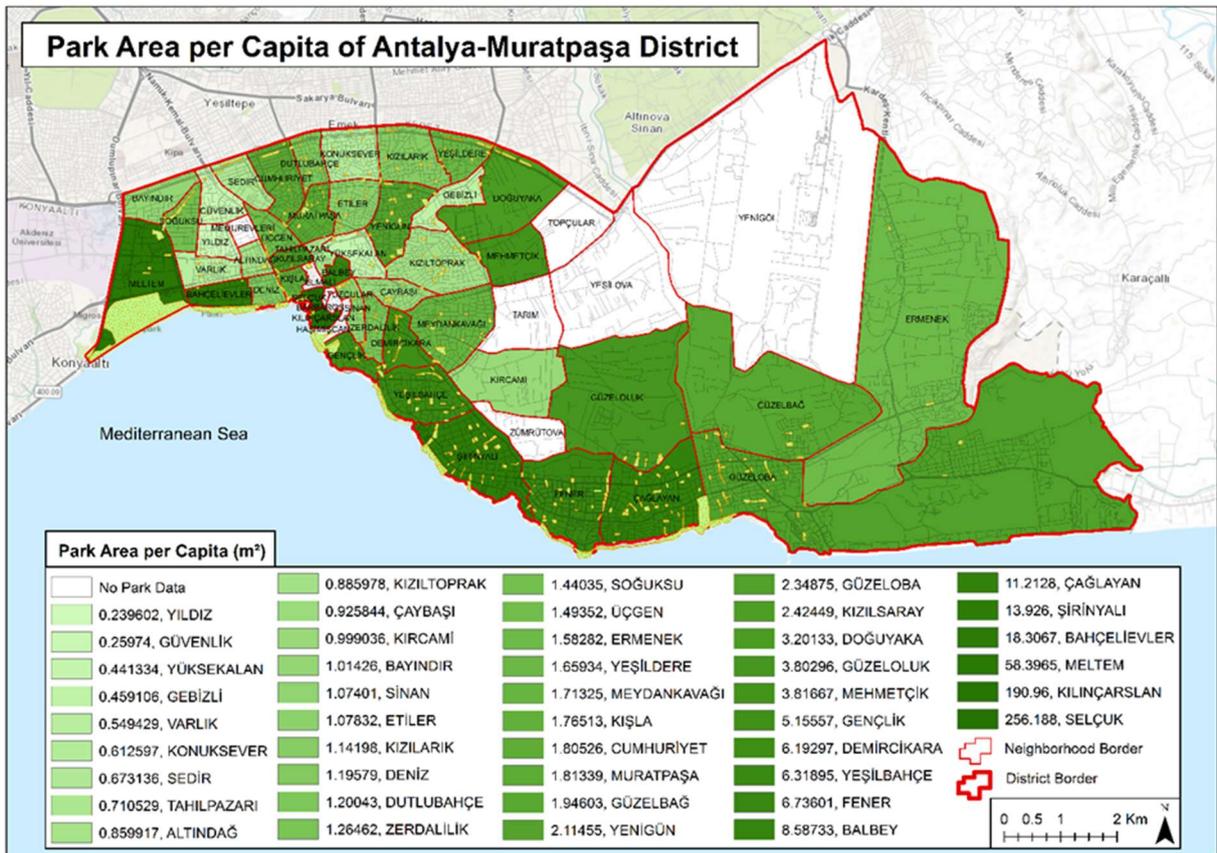


Figure 2. Per capita green area per neighborhood in Antalya Muratpaşa district (m²).

One of the most important dynamics in urban landscape is the green area per capita in the city. In this context, the square meter area per capita was found by proportioning the green areas to the neighborhood population at the neighborhood scale of Muratpaşa district. Figure 2 shows the square meter green area per capita at the neighborhood scale. According to the analysis, the ratio of green space per capita is high in the neighborhoods close to the sea, while this ratio is low in the neighborhoods in the inner parts of the district. There are no green areas in 10 neighborhoods in Muratpaşa district. Neighborhoods with no data are shown in white on Figure 2. The 5 neighborhoods with the least park area per capita are Yıldız (0.24 m²), Güvenlik (0.26 m²), Yüksekalan (0.45 m²), Gebizli (0.46 m²) and Varlık (0.55 m²). The 5 neighborhoods with the highest park area per capita are Selçuk (256.19 m²), Kılınçarslan (190.96 m²), Meltem (58.40 m²), Bahçelievler (18.31 m²) and Şirinyalı (12.93 m²), respectively (Figure 2). According to the Spatial Plans Construction Regulation of the Zoning Law No. 3194, the average green area per capita in Turkey is stated as 10 m². In this direction, 6 neighborhoods were observed in Antalya-Muratpaşa district that comply with the regulation (Selçuk, Kılınçarslan, Meltem, Bahçelievler, Şirinyalı and Çağlayan).

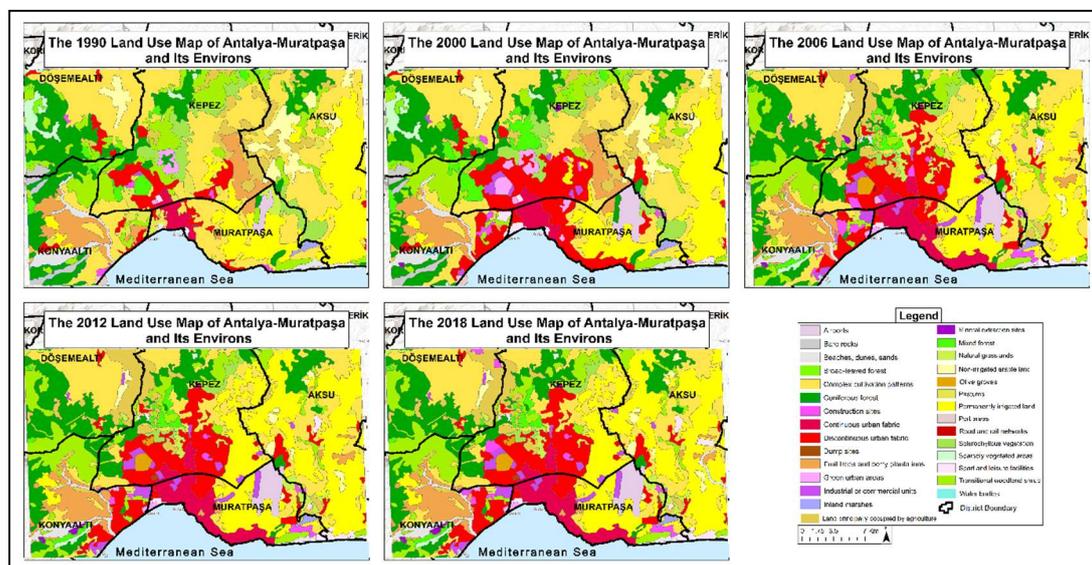


Figure 3. CORINE land use maps of Antalya Muratpaşa district and its immediate surroundings by years.

CORINE (Coordinated Information on the Environment) is a program developed by the European Union that aims to collect, process and share environmental information. CORINE enables the use of a database covering various environmental topics such as land use, land cover and natural habitats to reveal the status of the region in 1990, 2000, 2006, 2012 and 2018. Looking at the distribution of artificial surface and urban structure of Antalya/Muratpaşa district in 1990 using the Corine Land Cover Classes program, agricultural lands irrigated by irrigation canals and irrigation ponds are concentrated in the center and east of the district. Dryland agricultural lands are generally located in the east and north of Muratpaşa district. In these lands, mostly cereals and legumes are grown. Lands with fruit trees are located in the north of Muratpaşa. In these areas, citrus fruits, grapes and figs are generally grown. Broad-leaved forests are seen in the coastal area in the southeast of Muratpaşa district, while coniferous forests are seen in the northeastern part of the district. In 1990, continuous urban construction is located in the center of the district.

Looking at the 2000 land use map, it is seen that there is an increase in continuous urbanization in Muratpaşa district. Around the continuous urbanization, the area of discontinuous urbanization has expanded and moved inland from the south of Kepez district. However, discontinuous urban development has increased along the coastal area of Muratpaşa district. No change was observed in the broad-leaved trees in the southeast of Antalya, while the area of coniferous forest in the northeast

expanded. Some of the continuously irrigated agricultural land has been degraded and used as an airport.

By 2006, there was an increase in the area of permanently irrigated agricultural land. Although there is not much change in Muratpaşa district, there are increases in Aksu district in general and in the intersection of Muratpaşa district in the southeast of Kepez district. In contrast to 2000, the area of continuous urbanization continues to expand along the coast. Discontinuous urbanization, on the other hand, has moved east of Muratpaşa district towards the outskirts of the city, while continuing to expand north towards Kepez district. The coniferous forest area in the northeast of Muratpaşa district has been converted into a mining area.

In 2012, there was not much change in the area of permanent urban development, but discontinuous urban development continued to expand. Although it increased in the north of Muratpaşa district, it moved from the south to the center of Kepez district and started to gain a foothold in the southeast of Konyaalti district. There is a slight increase in permanently irrigated agricultural areas north of Aksu district and east of Kepez district. However, in the surrounding districts, mixed forest areas and broad-leaved forest areas have been destroyed with the expansion of construction.

In 2018 (Figure 3), no change was observed in Muratpaşa district. An increase in construction sites was observed in Kepez, Döşemealtı and Konyaalti. Coniferous forests in the north of Aksu and continuously irrigated agricultural areas in the east have been destroyed.

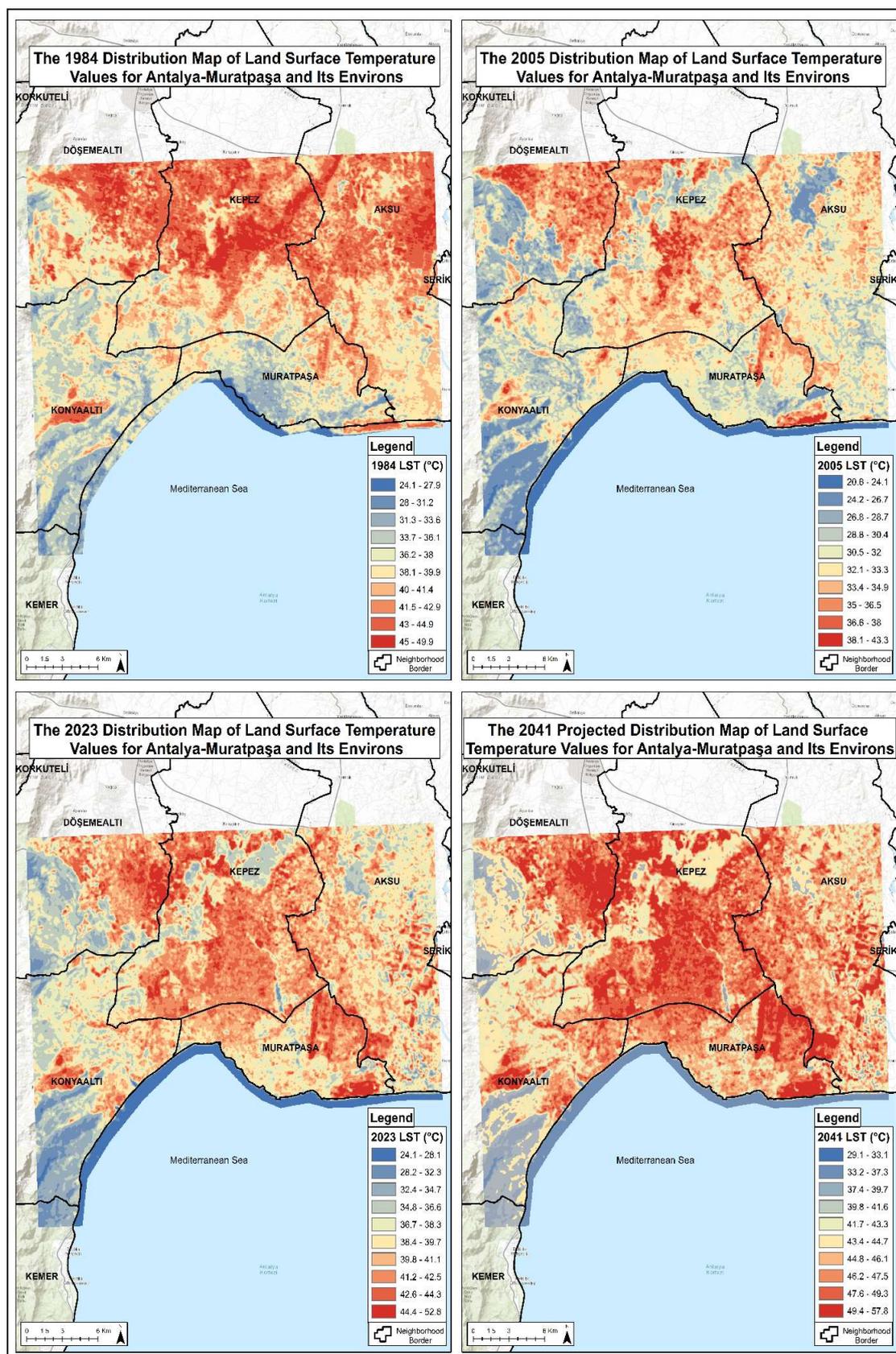


Figure 4. Land Surface Temperature in Antalya/Muratpaşa and its immediate surroundings (1984-2005-2023 and 2041).

Land surface temperature is the temperature of a given land or ground surface. This temperature is affected by various factors such as absorption, emission and reflection of solar radiation. The

resulting land surface temperature can be detected with thermal bands supported by satellite imagery such as Landsat. The detected results play an important role in climate systems and their environmental impacts are one of the factors to be considered in areas such as urban planning and landscape design [20]. In this part of the research, land surface temperatures of Antalya Muratpaşa district will be analyzed. Surface temperature analysis, which is one of the important indicators of urban ecology studies, is ignored in urban landscape and planning. Especially the effect of urban green space and urban heat islands play an important role in urban planning. The analysis reveals the land surface temperatures of Antalya/Muratpaşa and its immediate surroundings in 1984, 2005 and 2023. In addition, in the light of the data obtained, future impacts are estimated by presenting the land surface temperature scenario for 2041.

Looking at the Land Surface Temperature (LST) values of Antalya/Muratpaşa and its immediate surroundings in 2005, it is observed that it varies between 20.6°C and 43.3°C. Although the LLR is generally low in the coastal coast of Muratpaşa district (except for the east of Muratpaşa, because the coast is located there), it is in the range of 26.8-33.3°C in the district center. In the northeastern part of the district, due to the abundance of wide plains and the scarcity of green areas, the AQI is between 33.3-43.3°C. In the west of the district, AYS values are generally in the range of 32.1-34.9°C, although they partially increase. Kepez district is located in the north of Muratpaşa district. At the intersection of the districts, the AQI values increase and are in the range of 33.4-43.3°C. At the border of Konyaaltı district, which is located to the west of Muratpaşa, AYS values are generally between 28.8-33.3°C, while values decrease towards the center of Konyaaltı and decrease to 24.2-30.4°C. At the border of Aksu district, which is located to the east of Muratpaşa, EQoS values were observed to vary between 32.1-36.5°C (Figure 4).

Looking at the Land Surface Temperature values of Muratpaşa and its immediate surroundings in 2023, it is seen that they vary between 24.1°C and 52.8°C. In 2023, when increases in values are observed compared to 2005, Muratpaşa experiences an increase in the LLR values in the coastal area and ranges between 36.7-41.1°C. In the central part of the district, the increasing AQI values are in the range of 28.2-32.3°C in a small area, while the temperature range of 32.4-41.1°C is dominant in the center. The values in the northeast of the district increase rapidly and it is seen that 42.6-52.8°C values cover a large area. Looking at the borders of neighboring districts, it is determined that the AQS values generally vary between 39.8-44.3°C, while Konyaaltı is the district where the range of 28.2-36.6°C is the most common (Figure 4).

Looking at the estimated Land Surface Temperature values of Muratpaşa and neighboring districts in 2041, it is predicted to be between 29.1°C and 57.8°C. In 2041, while it is seen that the LLR values may increase by an average of 5°C compared to 2023, it is noteworthy that high values dominate the district. While the AQI values in the coastal part of Muratpaşa district were determined in the range of 43.3- 47.5°C, it was determined that they could be between 46.2-57.8°C with the effect of destruction, construction and concretization in the coastal part in the east and in the northeastern areas. In the center of Muratpaşa district, values in the range of 44.8-49.3°C are expected. Although it is predicted that values in the range of 43.4-49.3°C will be common with the increase in the LULUC values in the neighboring districts, Konyaaltı is the only district where LULUC values can be common in the range of 33.2-41.6°C (Figure 4).

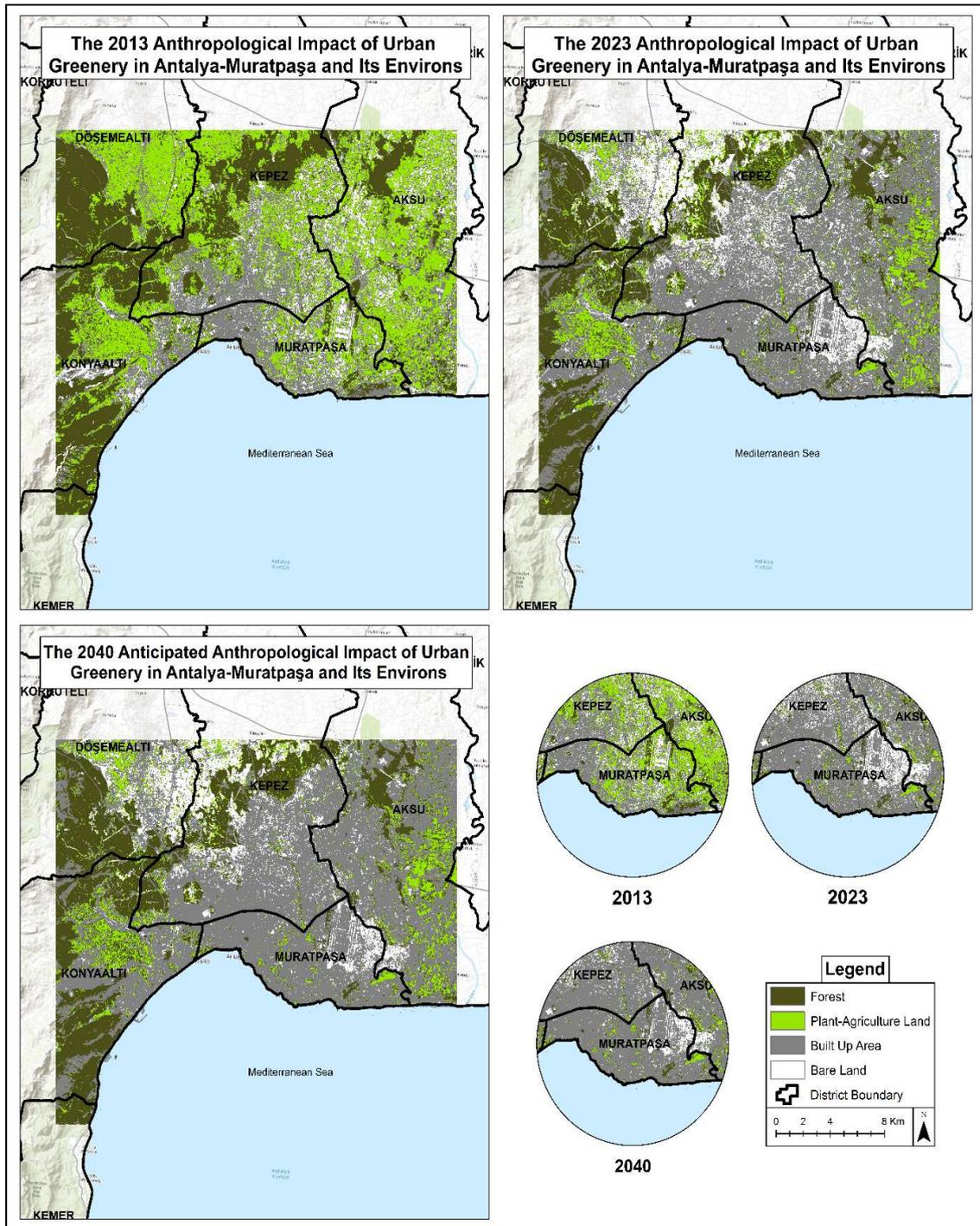


Figure 5. Land Use Maps of Antalya/Muratpaşa and its immediate surroundings (2013-2023 and 2040).

The anthropological impact of urban greenery in the Muratpaşa district of Antalya and its immediate surroundings in 2013 was divided into 4 main categories: Forest, Plant-Agricultural Area, Building Area, Bare Land. It is seen that Muratpaşa district, located in the north of the Gulf of Antalya, is densely urbanized. Built-up areas, shown in gray, constitute the largest part of the city. Built-up areas contain urban functions such as housing, workplaces and infrastructure. Plant-agricultural areas, shown in light green, are concentrated in the north and east of Muratpaşa district. These areas provide food and agricultural products to the city. They also function as green areas. Forested areas, shown in dark green, are located in the north and southeast of the district. Forests help to improve the district's air quality, reduce noise pollution and protect biodiversity. Bare land, shown in white,

is located in the northeast of the district. Looking at the immediate surroundings of Muratpaşa district, Döşemealtı district has the most forests and plant-agricultural areas. In Aksu district to the east, there are more plant-agricultural areas (Figure 5).

In 2023, the plant-agricultural areas in Muratpaşa district have been visibly reduced and transformed into bare land and building areas. The building area has spread dramatically compared to 2013 and increased its density in the center and eastern parts of the district. In 2023, it is seen that forest areas decreased in the southeast of Muratpaşa district. Looking at the neighboring districts of Muratpaşa district, it is observed that plant-agricultural areas in Aksu are mostly converted into building areas, while the northern parts of Kepez district are converted into bare land, while the eastern parts are converted into building areas. In Döşemealtı and Konyaaltı districts, plant-agricultural areas were transformed into construction areas, while no significant change was observed in forested areas.

Looking at the 2040 land use forecasts, it is seen that the bare land in Muratpaşa district will continue to be converted into building areas (Figure 5). It is seen that the green areas in the district center will be further destroyed and opened to construction, and the city center will be covered with concrete. By 2040, a significant decrease in forest areas is expected. This reduction will occur due to the expansion of urbanization and the contraction of agricultural activities. It is observed that the remaining forest will be located in a small area in the southeast of Muratpaşa, i.e. outside the district center. The situation is similar in the surrounding districts. With the expansion of building areas, it is estimated that there will be a contraction in bare land and agricultural-vegetation areas.

4. Discussion

Land use maps in Muratpaşa show that between 2013 and 2023, built-up areas increased while forest and vegetation cover decreased. Projections for 2040 indicate that this trend will continue. These findings are in line with studies by Seto et al. [30] and Grimm et al. [14]. These researchers emphasized that urban development leads to fragmentation of natural areas, habitat loss and reduction in biodiversity. Similarly, the decrease in green areas in Muratpaşa may lead to a threat to biodiversity.

Analysis of carbon dioxide emissions from transportation revealed that the increase in the number of motor vehicles contributes to air pollution and climate change in Muratpaşa. These findings are in line with studies by Nieuwenhuijsen and Khreis [31], Guo et al. [32] and Reşitoğlu et al. [33]. These researchers emphasized that motorized vehicle use in urban areas has negative impacts on health and the environment, causing air pollution and greenhouse gas emissions. Sustainable transportation systems, public transport infrastructure and transition to alternative energy sources can contribute to reducing transportation-related emissions in Muratpaşa.

The fact that the amount of parks and green spaces per capita varies on a neighborhood basis in Muratpaşa is in line with the studies conducted by Maller et al. [34], Kabisch et al. [34] and Wolch et al. [21]. These researchers emphasized that equal distribution of green spaces is important for human health, welfare and environmental justice. The lack of green space in some neighborhoods in Muratpaşa can be considered as a deficiency in this sense. In the process of urban landscape planning, fair distribution and accessibility of green spaces should be taken into consideration.

The increase in the amount of carbon emitted from vehicles and the hypothetical dangers it may pose are in line with the studies by Nieuwenhuijsen and Khreis [31], Guo et al. [32] and Reşitoğlu et al. [33]. These researchers emphasized that the use of motor vehicles in urban areas causes air pollution, greenhouse gas emissions, and thus climate change. The increasing carbon dioxide emissions in Muratpaşa are a reflection of these trends. Sustainable transportation systems, public transport infrastructure and a shift to alternative energy sources can contribute to reducing emissions.

The low amount of parks and green spaces per capita and its possible consequences are in line with the studies by Maller et al. [34], Kabisch et al. [34] and Wolch et al. [21]. These researchers emphasized that equal distribution of green spaces is important for human health, well-being and environmental justice. The inequality in the distribution of green spaces in Muratpaşa means that

some neighborhoods are deprived of green spaces. The equitable distribution and accessibility of green spaces should be considered in the urban landscape planning process.

The fact that anthropological impacts will constrain landscape studies in the future and green areas may become extinct is in line with studies by Seto et al. [30] and Grimm et al. [14]. These researchers emphasized that urban development leads to fragmentation of natural areas, habitat loss, and reduced biodiversity. The predicted development trend in Muratpaşa may lead to similar results. Sustainable urban planning, preservation of green areas and protection of sensitive natural areas are of great importance in preventing these negative impacts.

The findings of this study clearly reveal that ecological factors should be taken into account for the sustainability, quality of life and ecological balance of urban areas. Conservation of green areas, afforestation efforts, sustainable transportation systems and transition to alternative energy sources can be among the strategies that will serve this purpose. However, it is also important to continuously monitor and evaluate the relationship between ecological factors and the urban landscape.

5. Conclusions

This study has comprehensively examined the ecological dynamics in the urban landscape of the Muratpaşa district of Antalya, Turkey and examined the role of ecological factors. The findings clearly demonstrate that ecological factors are vital for sustainable urban development.

Land surface temperature analyses have shown a significant temperature increase in Muratpaşa from 1984 to 2023. This is a reflection of the urban heat island effect and is directly related to the reduction in green areas. Projections for 2041 indicate that this problem will deepen unless appropriate measures are taken.

CORINE land cover data shows that during the 1990-2018 period, artificial surfaces increased in Muratpaşa, while agricultural areas and semi-natural areas decreased. This situation concretely reflects the pressure of urban development on natural areas. Protecting green areas, adopting appropriate landscape design strategies and sustainable land use planning can contribute to reversing this negative trend.

It has been determined that transportation-related carbon dioxide emissions in Muratpaşa have increased significantly in the last 20 years. The main reason for this increase is the high rate of increase in private vehicle use. The results of the analysis show that the increase in the number of motor vehicles directly contributes to air pollution and climate change.

The study found that the amount of parks and green space per capita in Muratpaşa varies significantly by neighborhood. In some neighborhoods, access to green space is quite limited (there are only 6 neighborhoods that comply with the green space per capita provision deemed sufficient by law), while other neighborhoods have higher amounts of green space. This points to inequality in the distribution of green space in the region.

The settlement forecast maps, where the anthropological impact is analyzed, show that built-up areas in Muratpaşa will increase significantly by 2040. This increase is projected to put pressure on existing green areas and natural habitats. If future development continues unchecked, there is a risk that the ecological balance of the region will be seriously disrupted.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org. Figure S1: title; Table S1: title; Video S1: title.

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