applied sciences

MDPI

Article

Exploring Land Use/Land Cover Dynamics and Statistical Assessment of Various Indicators

Semih Sami Akay

Department of Map and Cadastre, Istanbul Topkapi University, 34020 Kazlicesme, Istanbul, Turkey; semihsamiakay@topkapi.edu.tr

Abstract: Current information on urban land use and surface cover is derived from the land classification of cities, facilitating accurate future urban planning. Key insights are driven by multi-year remote sensing data. These data, when analyzed, produce high-resolution changes on the Earth's surface. In this context, publicly accessible Urban Atlas data are employed for the high-precision and high-resolution classification and monitoring of terrestrial surfaces. These datasets, which are useful for preserving natural resources, guiding spatial developments, and mitigating pollution, are crucial for monitoring changes and managing cities. This research aims to analyze and contrast land use and land cover (LULC) changes in Gaziantep (Turkey) between 2010 and 2018 using Urban Atlas data, and to investigate correlations between the city's statistical data and LULC changes. Gaziantep's urban dynamics were analyzed using Urban Atlas datasets from 2010 to 2015 and 2012 to 2018, the latter part of Copernicus, the European Earth Observation Programme. To understand the impact of LULC changes on urban landscapes, people, and the environment, official environmental and demographic statistics spanning four years were sourced and studied. The findings reveal a trend of agricultural and vacant lands evolving into residential and industrial zones, with such changes likely to increase in the near future, given the growth of building zones. While some land classes have shown consistent area values annually, residential and industrial zones have expanded in response to housing and employment demands. The most significant alterations have occurred in the last three years. Shifts in urban configurations align closely with migratory patterns, reflecting notable variations in factors like population, consumption, and pollution.

Keywords: Urban Atlas; LULC; change detection; urban mapping; spatio-temporal statistic evaluation

Citation: Akay, S.S. Exploring Land Use/Land Cover Dynamics and Statistical Assessment of Various Indicators. *Appl. Sci.* **2024**, *14*, 2434. https://doi.org/10.3390/app14062434

Academic Editors: Dibyendu Sarkar, Abdeltif Amrane and Paola Grenni

Received: 25 December 2023
Revised: 8 March 2024
Accepted: 11 March 2024
Published: 13 March 2024

1. Introduction

The world's population is continuously growing across every continent and will continue to grow into the future, and there is also an expansion of human habitats for land use and land cover (LULC). Urbanization is progressing rapidly in most countries as a result of population growth, migration to urban centers, and socio-economic factors. Population growth is the one of the main factors of LULC changes, and contributes to urbanization due to built-up areas, agricultural activities, energy generation, etc. However, similar to other countries, urban areas are expanding with population growth and the development of networks in Turkey. LULC changes have impacts on attributes of the environment, landscape, natural resources, and the Earth's surface [1–4]. Developed urban areas easily provide many socio-economic resources for human life, and cities undergoing unplanned growth provide negative conditions due to the restriction in required resourced and the increase in consumption. Also, these cities consume resources faster than developed ones, and negative environmental impacts occur, such as pollution, global warming, and climate change [3,5]. Urban areas undergo changes due to natural events and human-induced factors such as floods, earthquakes, landslides, construction, agriculture, and the management of urban fabric. Nowadays, human-induced factors cause urban sprawl and LULC changes. In particular, new settlement areas, transportation networks, and transportation types are developed according to the distribution of the population in cities, and this leads to LULC changes [6,7]. Urban sprawl has had a great impact on demographic structure, natural ecosystems (temperature, air pollution, water pollution, water level, climate, etc.), consumption, and the expenditure of social services due to different LULC areas and their geometric patterns, such as asphalt, concrete, vegetation, stones, and the environmental impacts vary within cities. Therefore, LULC urban patterns affect the budget, consumption, production, and environmental activities of cities [4,5,8–19].

LULC changes and the consequential urbanization will continue with increasing time, spatial expansion, and construction areas, and the management of urbanization is crucial to protect human life and natural resources with spatio-temporal data. Spatio-temporal monitoring, which demonstrates the demands of city dynamics and provides insight into population growth, allows us to observe the relationship between LULC and human activities [7,20]. Spatio-temporal monitoring with remote sensing data is used to monitor changes with regard to temperature, air, vegetation, residential areas, the military, the public, and industry using bands and LULC methodology, and provides information about monitoring the Earth's surface with flexibility, less time, and low cost [7,21–23]. In addition, remote sensing data can provide detailed information about the LULC of the Earth's surface from past to present within certain time periods. Attributes of urban information systems can be determined for cities, such as urbanization, natural resources, pollution, disaster history, the protection of cultural heritage, and the level of development, by analyzing current data and satellite image analyses of the past. Therefore, LULC changes and predicting the future of cities will be examined with spatio-temporal data [2,7,24]. LULC facilitates planning on policy-making, transportation network development, urban sprawl, environmental improvement, and economic growth, enabling more orderly and human-harmonized development. Priority areas can be identified and controlled, such as agriculture, water resources, and forests, with the monitoring of LULC changes. More sustainable cities will be created for the future in areas such as natural resources, human health, and material losses by strengthening the connections between urbanization, land use, and ecosystem change [3,18,25].

Urban growth is a dynamic process that brings about significant changes in various parameters, shaping the overall landscape and functionality of a city. As cities expand, several key parameters undergo transformations, influencing the urban environment and its sustainability. The growth of urbanization and industrialization both swallow up arable land and influence environmental factors in cities, including air pollution, energy consumption, waste production, etc. [26–28]. The interaction between LULC changes and city parameters plays a crucial role in understanding the evolving nature of cities. As urbanization progresses, shifts in population dynamics, land consumption, and resource utilization significantly impact the urban fabric. There is a complex relationship between LULC changes and various city parameters, such as population, climate change, inequality, poverty, and other key indicators [29,30]. Understanding these changes is crucial for effective urban planning, resource management, and environmental sustainability.

Recent studies show that classification processes were carried out with satellite images and various methodologies in order to extract detailed information about the Earth surface. Earth surface classes were produced to give information about LULC with different nomenclatures and scales [2,31,32]. Nowadays, the Urban Atlas and CORINE, which are the most used methodologies in urban planning and LULC nomenclature, provide information about the Earth's surface at different levels and scales by classifying satellite images according to their own methodology. Additionally, these data are updated in certain years and are available to the public as an open data source [14,33–36].

Gaziantep is the city with the ninth highest population in Turkey according to population density as a metropolitan municipality [37], and which constantly receives immigrants due to its geographical location and developing industrial facilities. Thus, the aim of this study was to determine the LULC changes in Gaziantep with Urban Atlas data, which were produced over four years by researchers and the European Environment Agency project. Urban Atlas maps for the years 2010 and 2015 using remote sensing data were produced for the scope of this LULC study for Gaziantep. Meanwhile, the European Space Agency (ESA) carried out the production of maps for the years 2012 and 2018 within the framework of Copernicus, the European Earth Observation Programme. Areal values of the LULC classes belonging to the Urban Atlas nomenclature were calculated and compared over four years. The size and direction of urbanization were determined in the city center. Further, the environmental, demographic, and statistical data of the city along with spatial changes, which were collected from official sources related to the city, were examined. The aim of this study is to demonstrate the relationship between LULC changes and different parameters within the city, highlighting the impact of urban development on various types of parameters in the city.

2. Materials and Methods

Gaziantep is located in the southeast of Turkey, and is the most densely populated city in the region. The history of the city dates back to 4000 BC, and it is one of the oldest cultural centers of the Southeastern Anatolia Region. Gaziantep is a prominent city in Turkey with its economy centered on food, clothing, tourism, industry, and agricultural activities. The city also hosts important industrial enterprises. However, more than half of its lands are suitable for agriculture, whereby olives, peanuts, fruit, vegetable gardens, vineyards, cotton, and wheat products are grown. Due to the high mountainous terrain and extensive agricultural areas, there are not many forested areas within the provincial border. In the mountainous parts of the province, there is pine, fir, cedar forest, steppe, and semi-steppe vegetation [38].

Since Gaziantep is a border neighbor to Syria, which is a developed city of the region, its population has increased due to domestic and foreign migration. Gaziantep's population has been increasing since 2010, and this increase was between 50,000 and 100,000 in a two- or three-year period. The population was 1,700,763, 1,889,466, 1,931,836, and 2,028,563 in 2010, 2012, 2015, and 2018, respectively [37]. Considering the population data, Gaziantep was evaluated within the scope of the Urban Atlas, which is available to users free of charge through Copernicus, the European Earth Observation Programme. In this context, the Gaziantep Urban Atlas, which covers the city center and districts with dense settlements in Gaziantep, studies were carried out using the EEA for the years 2012 and 2018, and the Gaziantep Urban Atlas methodology for 2010 and 2015, with Spot 5 and Spot 6 satellite images produced to determine the LULC change in the city center [2,35]. The reason for selecting the city center as the study area was that the central districts, namely Şehitkamil and Şahinbey, received more migration compared to other districts and experienced a higher degree of urbanization. Additionally, the study area encompassed the majority of the city's industrial, military, and forested areas, in addition to the abundance of the population and residential zones. Therefore, spatial city parameters affected by the changes occurring in the city predominantly influence this area. Although Gaziantep has 6887 km^2 of surface area, this study was carried out in an area of 608 km^2 in the city center [38,39]. In Figure 1, the location and provincial border of Gaziantep and the study area, which is the city center of Gaziantep, are seen.

2.1. Methodology and Sources of Land Use/Land Cover Data

The Urban Atlas is an LULC map that provides high-resolution and detailed information about urban areas with the classification of satellite images and auxiliary data. The first Urban Atlas project was conducted in 2006, and was funded by the ERDF (European Regional Development Fund) and the European Commission (EC) as part of GMES (Global Monitoring for Environment and Security) [40–42]. The Urban Atlas project was conducted for approximately 300 European cities with a population of more than 100,000 in 2006. The Urban Atlas project was expanded for 2012 and 2018, and Urban Atlas maps were produced for more than 800 cities in the EU, EFTA, West Balkan countries, United Kingdom, and Turkey with a population of over 50,000. In addition, Urban Atlas maps were produced for the city and its surroundings according to the Functional Urban Area (FUA), which was defined in line with the approach developed by the DG Regional and Urban Policy (REGIO) of the European Commission. While there was no FUA from Turkey in the Urban Atlas for 2006, there were 76 FUAs in the Urban Atlas for the 2012 and 2018 Urban Atlas datasets [40–42].

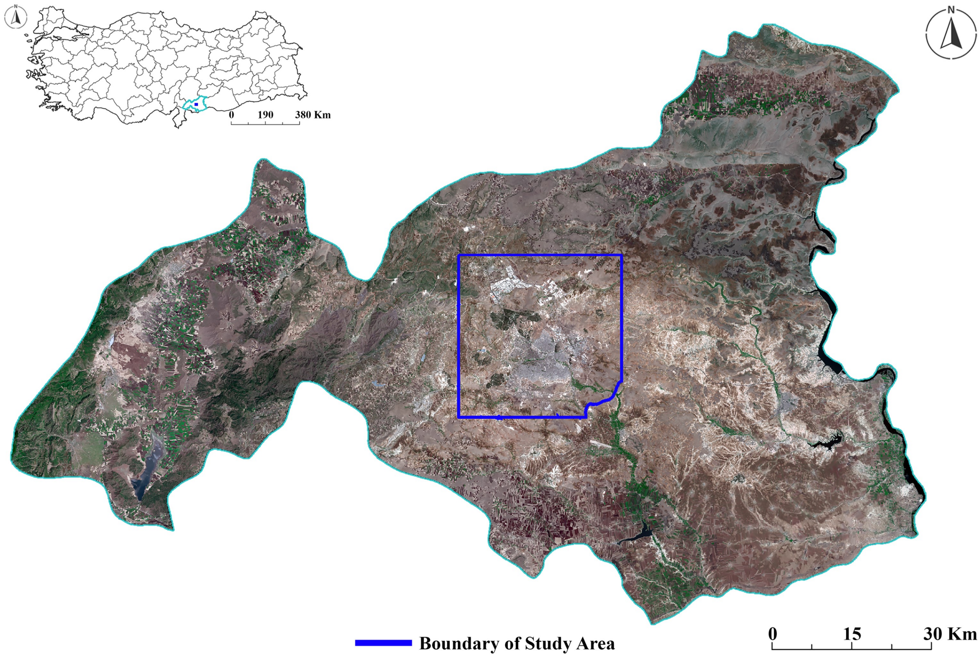

Figure 1. Location of Gaziantep and city center of Gaziantep.

The Urban Atlas shows LULC information, and it can give information about the direction of urban sprawl with high accuracy. The Urban Atlas aims to assist in the planning of cities according to the needs of the local population by evaluating the risk of economic, ecological, and social problems and taking into account the needs of living spaces (public transportation systems, infrastructure systems, etc.). Accordingly, it provides production of data that will enable the analysis of transportation, the environment, and land use [41]. In the Urban Atlas methodology, an LULC map is produced with 27 subclasses under 5 main classes (urban fabric, arable land, forest, wetland, and water). Within the scope of the Urban Atlas methodology, the minimum mapping unit for map production is 0.25 ha for urban fabric areas and 1 ha for other areas. The minimum accuracy of overall classification (for all classes) for the Urban Atlas is 80%, and the classification accuracy of the classes is stated to be 85% for urban classes and 85% for rural classes in the mapping guide. Google Earth, city maps, COTS (Commercial Off the Shelf) navigation data, cadastral and zoning maps, and higher-resolution satellite images are used as control points [35,42]. High-resolution satellite images with a 2.5 m spatial resolution were used for the first Urban Atlas projects in 2006, and it was observed that with the update made, high-resolution satellite images with a 2 m to 4 m spatial resolution were used for the Urban Atlas projects in 2012 and 2018 [41].

The Urban Atlas for Gaziantep was not selected as an FUA and completed by the European Commission before 2012, but the surface classification processes for Gaziantep were produced with the Urban Atlas methodology for 2010 and 2015 with the object-based classification method. Cloud-free satellite images from the summer months were obtained to ensure similarity in cloud and environmental conditions to monitor LULC changes. The classification process was then carried out on these acquired satellite images. The satellite images were segmented according to the appropriate scale and shape parameters, and the objects' segments were classified according to their reflectance, shape, and index properties [2]. These datasets were produced through the object-based classification of Spot 5 and Spot 6 satellite images that were acquired on 5 June 2010 and 7 July 2015 with

2.5 m and 1.5 m spatial resolutions, respectively. In addition, a 1:1000-scale Gaziantep master zoning map (including industrial and residential areas) was used as auxiliary data for segmentation in classification and attribution in the data processing stages. Forest type map, Open Street Map, CORINE 2012, and online map (e.g., Google Earth, Yandex) data were used for the sample dataset and visual interpretation stages. Furthermore, in the classification process, various functions provided by the eCognition Developer 9 software and NDVI and NDWI indices were utilized to classify surface objects. The asymmetry, rectangular fit, and relations of the border to functions were used, which enable the classification of objects based on the geometric shapes of segments [43]. The overall accuracy of classification was 95% for the 2010 Spot 5 image and found to be 96.27% with a kappa value of 0.957 for the 2015 Spot 6 image. The classification accuracy of the classes was between 90% and 98% for urban classes and between 90% and 99% for rural classes. The comparison of the Urban Atlas for 2010 and 2015 and Urban Atlas for 2012 and 2018 shows that the geometric shapes of the objects are similar in the city center; however, the crossroads were more detailed in the Urban Atlas for 2010 and 2015 due to traces and paths. In the years of production for the Urban Atlas 2010 and 2015, the Urban Atlas methodology had 20 classes for LULC. The new subclasses were not included in Urban Atlas for 2010 and 2015, so the features of the subclasses were combined in order to determine the changes in the main classes for each year. Therefore, change detections were achieved with nine classes for four years. The aim of this study was to emphasize the relationship between the change in artificial objects and environmental effects in settlement. The classes were generalized into nine main classes. The main urban fabric class (code 11000) was created by combining the 3rd-level classes (codes 11100–11240) of the urban fabric class and the isolated structures class (codes 11300). The main road class (code 12100) was created by combining the 3rd-level classes of the road classes (codes 12210–12230), port class (code 12300), and airport class (code 12400). The construction sites class (code 13300) and land without current use class (code 13400) were combined to create the main construction site class (codes 13100). Also, the green urban areas and sports class (code 14100) and leisure facilities class (code 14200) were combined to create the main green area class (codes 14000). Finally, the arable, permanent crops, pastures, complex and mixed cultivation patterns, and orchards classes (codes 21000–25000); the herbaceous vegetation associations and open spaces with little or no vegetation classes (codes 32000–33000); and the wetlands class (codes 40000) were combined to define the semi-natural and wetland areas class (code 20000). Figure 2 shows the original Urban Atlas nomenclature and the Urban Atlas nomenclature for this study, which include 27 and 9 classes, respectively.

Inspection of the Urban Atlas for 2012 and 2018 showed that the commercial, military, and green areas (zoo) were protected within the same borders for both years, where these borders were specified as the Civil Administrative Boundary (Figure 3). Therefore, the boundaries of commercial and green areas were revised for the Urban Atlas 2010 and 2015 according to the boundaries of the Urban Atlas 2012 and 2018. The change detection analyses were examined with these revised Urban Atlas maps. The revised Urban Atlas map accuracy was also between 80% and 85% for each class. Figure 3 shows the reference (2012 and 2018) and revised (2010 and 2015) boundaries of commercial, military, and green (zoo) areas. Changes among LULC classes can reveal shifts in the population living in the city and their emerging needs and consumption. Needs increase in settlements with the population, and industrial areas could develop for business and production purposes in line with these needs. Moreover, by identifying consumption and need parameters, sustainable information for urban planning is brought to light.

In this study, an analysis of change detection was carried out by using the Urban Atlas for 2012, 2018 (FUA), 2010, and 2015 (produced through classification processes). The Gaziantep Urban Atlas is shown in Figure 4 for 2010, 2012, 2015, and 2018.

Figure 2. The original Urban Atlas nomenclature and the Urban Atlas nomenclature for the land use/cover classes used in the study.

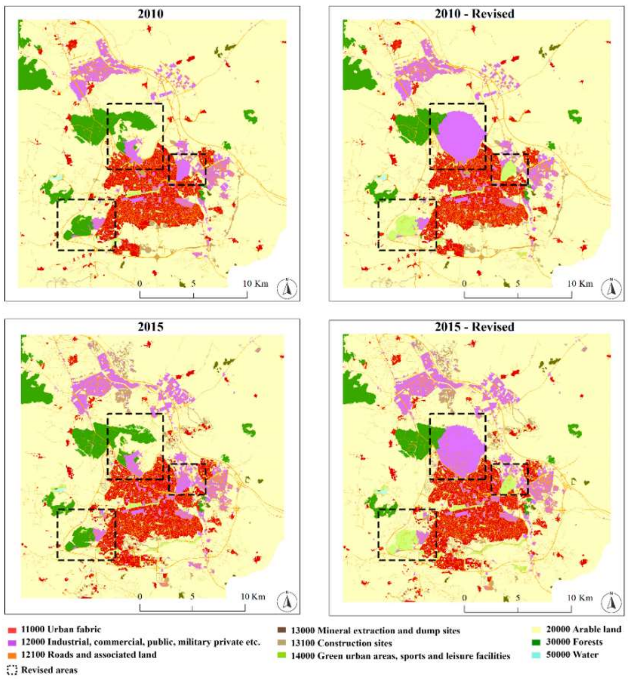

Figure 3. Representation of revised area for Urban Atlas 2010 and 2015.

2.2. Identification of Urban LULC and Change Detection

Time series datasets, which were of different types and had different production stages, were examined for urban fabric, and changes, developments, or differences in cities could be observed due to the dynamic structures of cities [32]. The urbanization level of Gaziantep was extracted using satellite images for the 8-year period. The overall rate of variation between classes ranged from 0.04% to 13.7%, while the highest change was in the arable land class and the lowest change occurred in the water class for the 8-year period. In addition, the rate of changes in LULC classes are shown in Figure 5 over four years. It was clear that although changes in LULC classes had decreased in some classes and regions, they had not increased steadily from 2010 to 2018. The reasons for this change may be different classification processes and a change in the area of the classes. For instance, there were changes within the classes in the urban fabric class, forest class, and green areas class. When the direction of change was examined regionally, the most significant change was observed in the construction area class (code 13100). Particularly, an increase in the construction area class (code 13100) was noticeable north and west of the settlement area. There was also an increase in the industrial, commercial, public, military, and private class (code 12000) in the northern and eastern regions. Also, construction areas were observed to be on agricultural and vacant lands. On the other hand, the urban fabric class (code 11000) increased in the southern and western regions of the city. The city was seen to expand towards the south and west in terms of settlement, while changes are occurring in the northern part in terms of industry.

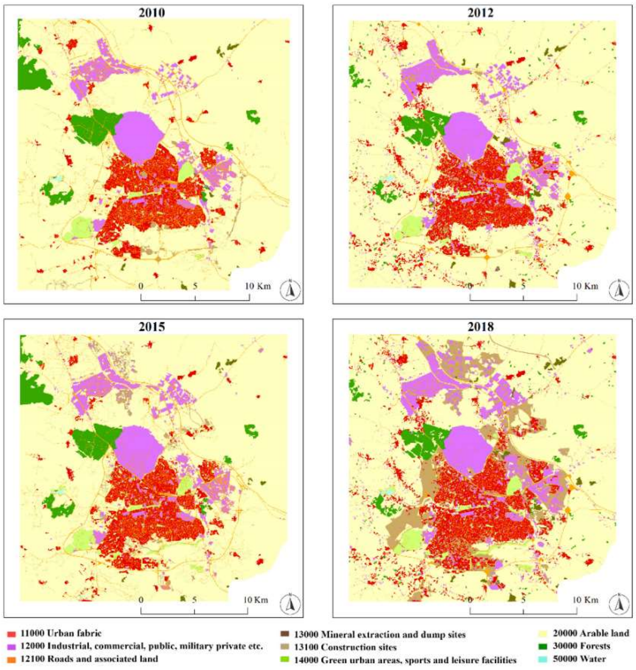

Figure 4. Representation of the Gaziantep Urban Atlas for 2010, 2012, 2015, and 2018.

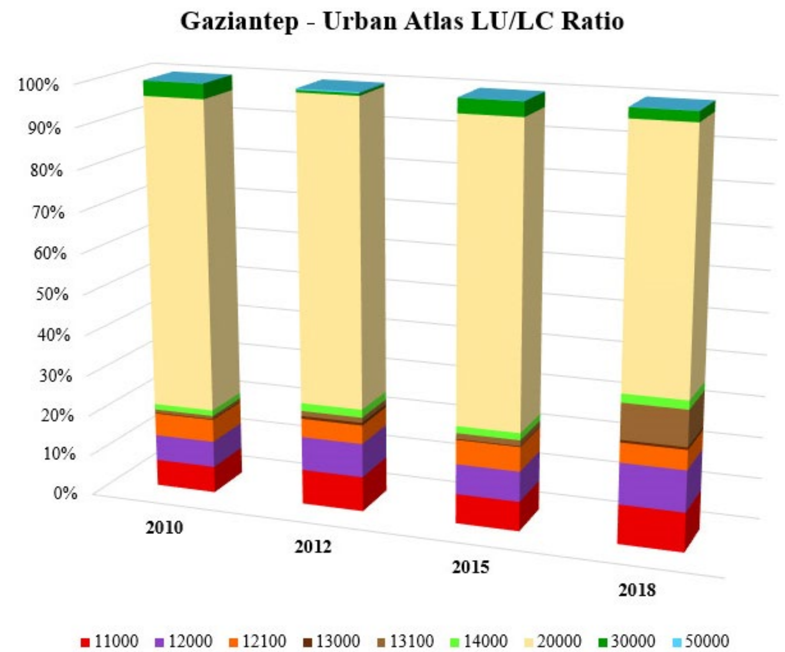

Figure 5. Representation of LULC ratio for each year.

A change detection analysis was conducted on classified images to identify changes within classes and determine which classes were undergoing changes in relation to each other. In this context, the Semi-Automatic Classification Plugin (SCP) tool, which facilitates the post-processing of classified images by comparing classes and conducting change analysis, resulting in the generation of change images, was employed within the QGIS 2.18 software [44]. Changes in classes were calculated over consecutive two- and three-year periods. Figure 6 shows the LULC changes in each class for the Urban Atlas 2010, 2012, 2015, and 2015. It was observed that there were changes in the direction of increase in general in the classes.

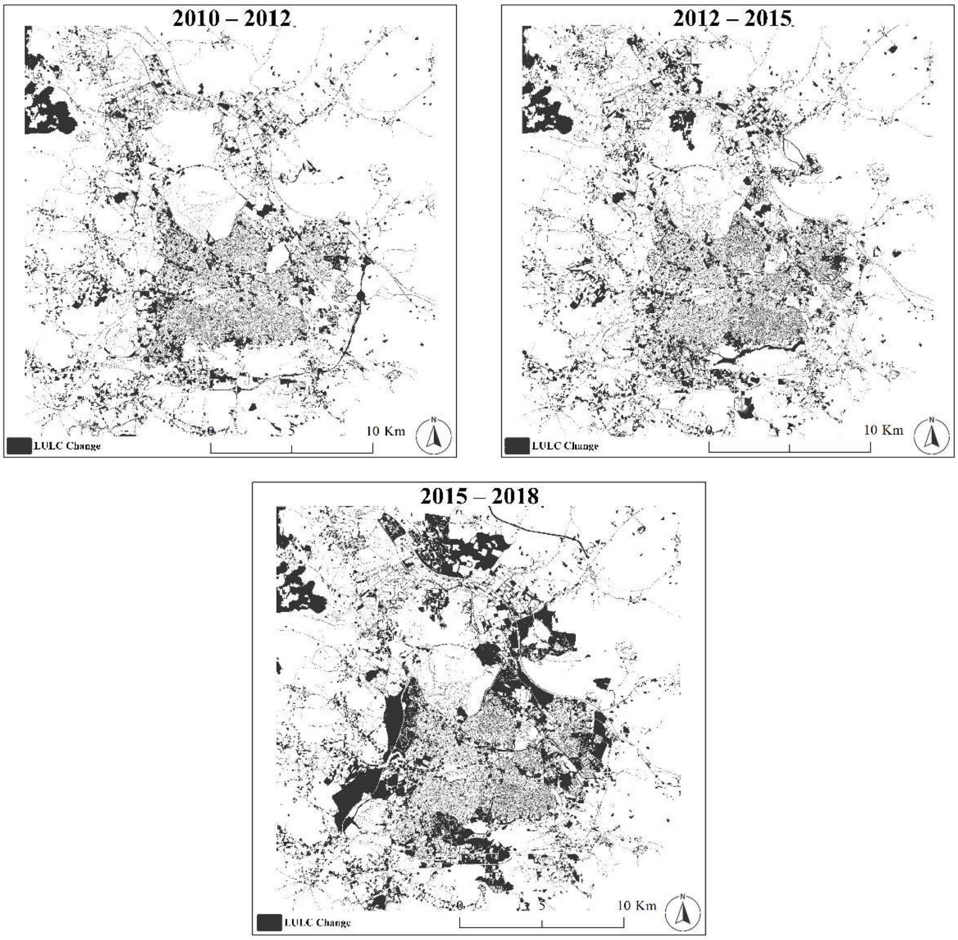

Figure 6. Representation of change detection in Urban Atlas class according to the consecutive years.

After 2015, serious changes were observed in the construction area class (code 13100) and arable land class (code 20000), and these changes included an increase of 4.686 ha and a decrease of 7.265 ha, respectively. Change detection can also be seen in Figure 4 with visual interpretation. The new urban fabric and commercial areas started to form around the settlement center and commercial areas. When the values of class area were also examined, the highest change occurred between 2015 and 2018 in the arable land class (code 20000) and construction areas class (code 13100), with 7% and 11%, respectively. The least change occurred in the water class (code 50000), and these changes were between 0.002% and 0.007%. Also, the changes in the mine extraction and dump sites class (code 13000) and green urban areas, sports and leisure facilities class (code 14000) were similar, and these changes corresponded to approximately 0.2% and 0.4%. The urban fabric class (code 11000) and industrial, commercial, public, military, and private class (code 12000) areas were increased, except between 2012 and 2015. The same classification methodology was used for each year, but the auxiliary data and producer for the classification process were different. So, this might explain the difference in changes between these classes. A similar situation was also observed for the forests class (code 30000) due to the classification process, since the zoo area was classified as a forest area for 2010 and 2015, and was revised to a green, sports, and leisure facilities class (code 14000). However, the forest area in the northwest of the study area was identified as forest with the forest type maps in the classification process for the years 2010 and 2015, and the revision process was not carried out for the Urban Atlas. Therefore, classifications into the forests class (code 30000) in 2010 and 2015 was more than in the other years.

When spatio-temporal changes were examined with visual interpretation, an increase was observed in the construction areas class (code 13100) in 2018. Also, the construction areas of urban fabric and roads and associated land classes were completed in 2010. As of 2018, the construction of urban fabric and commercial areas started in the west and north of the city center. In addition, the construction areas on the north side were completed and assigned to the commercial area class (code 13100).

In order to compare the data with similar data production stages, the Urban Atlas 2010 and 2015 and the Urban Atlas 2012 and 2018 were compared. In Figure 7, the changes in the class data produced with the same processing steps can be seen. In this analysis, there was a change in the direction of increase in the areas of the classes, and it was similar to the change in consecutive years. However, the magnitude of the changes in the construction areas class (code 13100) and arable land class (code 20000) was also demonstrated. Also, there was an increase in class areas with spatio-temporal data.

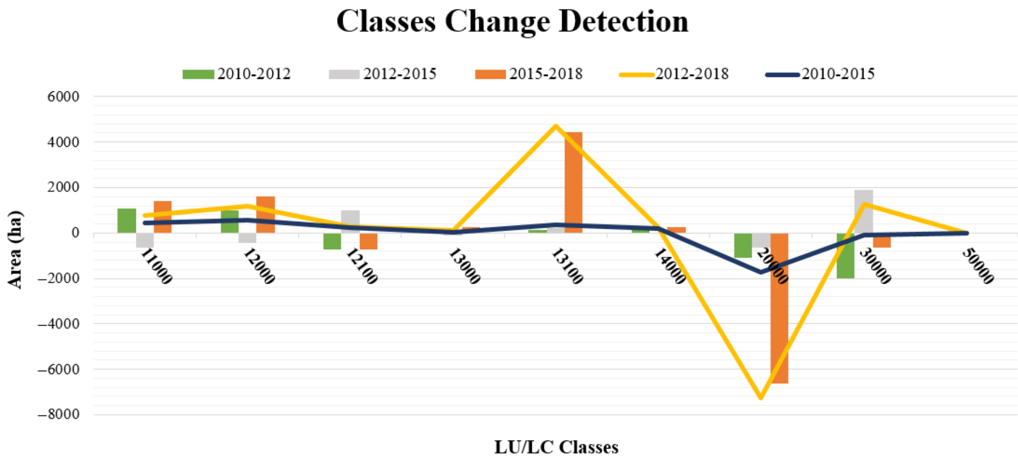

Figure 7. Representation of change detection in nine Urban Atlas classes according to same methodology.

In general, there was an increase in area value for classes with multi-temporal data, but the value of the arable land class (code 20000) area was decreased due to the use of arable land for different purposes. For the construction area class (code 13100), the amount of change between 2012 and 2018 was approximately 12 times the amount of change between 2010 and 2015, which was the highest change for Gaziantep. Similarly, the amount of change between 2012 and 2018 was higher than the amount of change between 2010 and 2015 for the arable land class, the urban fabric class, and the industrial, commercial, public, military, and private class (code 12000), at 4, 1.7, and 2 times, respectively. However, the change in the mine extraction and dump site class (code 13000) was from 12.6 ha between 2010 and 2015 to 115.9 ha between 2012 and 2018.

Due to the classification process, the areas of the forest class (code 30000) in the Urban Atlas 2010 and 2015 were higher than in the Urban Atlas 2012 and 2018. However, there was an increase as well as yearly differences for the forest class (code 30000) area. Therefore, it was interpreted that urban forest areas had increased from past to present.

In Figure 7, the area changes for each class in 2012 and 2018 were more than the changes in 2010 and 2015. Therefore, long-term changes in the Urban Atlas show that there was more change in the city center between 2012 and 2018. The closest changes were in the road and association land (codes 12100), mineral extraction and dump sites (code 13000), green urban areas, sports, and leisure facilities (code 14000), and water (code 50000) classes. As a result of the analyses, the increase in classes such as urban fabric, construction sites, industrial, commercial, public, military, and private also indicates that the city center continued to develop and sprawl with the population. In addition, the transportation network expanded with the effect of these classes.

2.3. Sources and Methodology of Spatial City Parameters

The aim of this study was to identify and obtain various settlement parameters specific to Gaziantep to determine the spatial factors influencing urban life as a result of development and change in the city. These data were obtained from the Turkish Statistical Institute (TUİK), which provides spatial and non-spatial statistics for the country [37]. In this study, parameters with meaningful data within the timeframe of 2010 to 2018 were selected from the TUİK database, as spatial changes were examined based on Urban Atlas UA data for these years. These parameters were population, budget, air pollution, migration, judicial penalties, unemployment rate, the number of vehicles and hospitals, and energy consumption values. The data related to these parameters are numerically stored in the database on an annual and monthly basis. These data were organized according to the methodology in a manner that can be directly and indirectly affected by spatial changes. The relationship between LULC changes and urban parameters assisted in determining the characteristics of a city's growth and expansion. Changes occurring in various parameters within the scope of LULC could indicate a sustainable development situation. Changes were expected in parameters such as population, budget, air pollution, migration, judicial penalties, unemployment rate, and the number of vehicles and hospitals, and energy consumption values due to LULC changes. However, the rates of these changes are crucial in assessing whether the city is developing sustainably and for future planning considerations. Furthermore, the rate of change for these parameters has been determined over the years, and their relationship with spatial changes has been elucidated. Data were correlated with changes occurring based on the class characteristics of the Urban Atlas. The establishment of relationships between spatial changes and parameters associated with the city is crucial for anticipating both positive and negative scenarios in the preparation of future urban models. This allows for informed actions based on the potential outcomes of spatial changes in the city.

3. Results

Evaluation of City Parameters for Urban Areas

Although there are many factors affecting urban LULC, population is the most important factor for this situation. Also, there will be a proportional increase in human-induced artificial objects on the surface with an increase in population. As a result of population growth, there may be simultaneous increases in residence, industry, and green areas to meet the growing demands. So, there may be a decrease in agriculture and open-space areas. Therefore, energy consumption and waste amounts will be increased. LULC classified data obtained with satellite imagery and statistical data are related to each other for cities [18,45]. This relationship was examined between the changes in the Gaziantep Urban Atlas spatio-temporal data and the statistical data of city parameters (Table 1).

The change analysis for Gaziantep showed that the population had increased, and this had an impact on the construction and the urban fabric of areas. When the population was analyzed for Gaziantep, it was found that the city received continuous migration, so there was an 18% increase in its population, approximately 320,000 people, in 8 years. It could be interpreted that population growth occurred every year, and in particular, that the increase in the Syrian population triggered the population growth of Gaziantep [36]. There was a 13.5% increase in the population between 2010 and 2015, and there were 311,759 Syrians in the city, which was 16% of the 2015 population. As expected, the population increase also led to an increase in the number of vehicles due to migration [36]. Therefore, the increasing number of people and vehicles caused requirements for buildings and roads in the urban area. Changes in LULC occur in every developing city due to population growth, and residence sales increased by 21% between 2015 and 2018. Also, population growth occurred with existing and new residences. The number of hospitals continuously increased each year by a factor of 2 to 3, proportionate to population growth, from 2010 to 2018. When spatially examined, it was believed that the increase in hospital numbers has an impact on the growth of public areas, as indicated by the Urban Atlas. Additionally, the number of patients per thousand people increased from 1.2 in 2010 to 1.4 in 2012, and this rate was maintained at 1.4 from 2012 to 2018. Therefore, it was observed that the increase in population and the number of hospitals correlates with an increase in the number of doctors [36]. When examining the Urban Atlas maps, the increase in construction areas in 2018 was close to residential and industrial areas in the city center. Therefore, this increase will provide the residential, public, and industrial business needs associated with the population. As seen in the Gaziantep Urban Atlas spatio-temporal data, the increase in urban fabric, commercial, industrial, private, and road areas was compatible with population-related data.

Table 1. List of city parameters for urban areas.

Parameter	2010	2012	2015	2018
Population	1,700,763	1,889,466	1,931,836	2,028,563
Energy consumption (Mwh)	8,443,682	9,950,493	12,435,590	16,179,416
Waste collected by the municipality (ton/year)	413,233	522,679	No Data	650,984
Water consumption (thousand m^3/year)	100,367	107,480	No Data	165,759
Number of vehicles	17,037	22,203	22,340	15,980
Residence sales	No Data	No Data	23,986	29,240
Average air pollution (SO_2 μg/m^3)	16.75	12.50	11.16	6.97
Maximum air pollution (SO_2 μg/m^3)	177.47	273.97	231.22	495.86
Number of doctors (doctors per thousand)	1.2	1.4	1.4	1.4
Number of hospitals	21	24	28	30
Budgets (TL)	149,052,581	141,187,829	285,677,956	No Data
Syrian population		240,556	311,759	421,986

In terms of urban landscaping such as parks and sports fields, the municipal budgets were similar in 2010 and 2012, but the budget in 2015 was 90% and 102% higher than the other years, respectively [37]. Therefore, increases in the green urban areas and sports class (code 14000) could also be evaluated with the budget increase in the Urban Atlas spatio-temporal data due to population growth and urbanization. The budget change can also be partially seen in Figures 6 and 7 with increases in the green urban areas and sports class (code 14000) for urban landscaping. The sulfur dioxide (SO_2) values were evaluated from meteorological stations to determine air pollution. When the relationship was analyzed between the increase in population/urban fabric and air pollution, the maximum air pollution increased from 2010 to 2018, with values of 177.47 μg/m^3, 273.97 μg/m^3, 231.22 μg/m^3, and 495.86 μg/m^3, respectively. Also, air pollution was lower in 2015 than 2012. The average air pollution decreased by 25%, 11%, and 38% compared to the previous year from 2010 to 2018, respectively. Urban Atlas spatio-temporal data showed that the urban fabric spread outside the city center and the maximum value around the station may have decreased. Moreover, the 28% decrease in the number of vehicles for 2018 might have an effect on the change in air pollution [37,46]. The development of urban fabric, green, public. and industrial areas also increased electricity and water consumption. In the 8-year spatio-temporal data, energy and water consumption increased by 90% and 65%, respectively. Also, the amount of waste collected by the municipality increased by 57% from 2010 to 2018 along with consumption and air pollution [37]. Therefore, the amount of waste material increased in direct proportion to the increase in urbanization and population. However, the Urban Atlas spatio-temporal data showed an increase in urbanization, i.e., human activities, and so it could be interpreted that the amount of pollution and waste might increase in direct proportion to human activities.

A correlation between the classes with the most significant changes (code 11000, code 12000, code 13100, and code 20000) and city parameters was observed. The correlation value between code 11000 and parameters such as population, housing, water usage, energy, waste, the number of doctors, hospitals, and SO_2 was between 0.699 and 1 (0.849 population/code 11000, 1 residence sales/code 11000, 0.864 water consumption/code 11000, 0.799 energy consumption/code 11000, 0.989 waste collection/code 11000, 0.699 doctor number/code 11000, 0.714 hospital number/code 11000, 0.952 maximum air pollution/code 11000). The correlation values between code 12000 and the population, energy consumption, water consumption, waste, and maximum air pollution parameters were 0.876, 0.881, 0.932, 0.999, and 0.985, respectively. The correlation values between code 13100 and the population, energy consumption, water consumption, and waste parameters were 0.723, 0.903, 0.997, and 0.899, respectively. The current situation indicated a decrease in arable land, and the negative correlations between code 20000 and the population, energy consumption, water consumption, and waste parameters were −0.806, −0.945, −0.997, and −0.936, respectively. This suggested a significant correlation among these variables that indicated a notable relationship between LULC and various urban parameters.

4. Discussion

City parameters undergo changes associated with LULC transformation in the city, and these parameters can provide insights for predicting sustainable urban expansion. Through LULC changes, it becomes possible to anticipate which urban classes may be needed and where changes might occur in the coming years. When examining LULC and city parameters, an increase in population is expected to lead to a demand for residential and industrial areas due to residence and employment needs. Consequently, new construction areas may emerge. Additionally, an analysis of LULC changes reveals the northward progression of the industrial class into residential areas, towards the south and west. Therefore, it might be necessary to implement environmentally sustainable measures and undertake various initiatives to manage water and energy consumption in these directions. Also, investments and measures can be identified based on the city's growth direction and needs. Particularly, environmentally friendly practices can be taken to preserve environmental factors and create a sustainable city, addressing issues such as energy consumption, water usage, waste accumulation, and air pollution. Additionally, the examination and improvement of building stock can contribute to meeting the housing needs of the population.

The Urban Atlas can provide detailed information about the LULC of cities in terms of urbanization and settlement densities. In addition, information such as the distance of industrial zones from urban fabric, sprawl, and the direction of transportation, construction, urban, green and sports facilities can be obtained in the city with the Urban Atlas. The results presented here emphasize the ongoing change in Gaziantep LULC over an 8-year period. The expansion of construction areas reflects ongoing urbanization processes, driven by population growth and economic development [47]. Similarly, the growth of residential areas reflects the demand for housing and basic amenities driven by population growth and urban migration [48]. Information on LULC changes for years and current conditions, including transportation, urban texture, green space, public space, and construction, was obtained for Gaziantep. Gaziantep's population and its residential areas increased in line with current migrations, so urbanization developed in response to needs. During this period, there was a 19% increase in the population and a total increase of approximately 11% in construction and residential areas. The dynamics of LULC indicate a high rate of change in construction sites, which is proportionally associated with an increase in commercial and residential areas due to a human influence on LULC. However, the increase in green urban, sports, and leisure facilities areas has not been as significant as in these classes.

As natural landscapes are converted into built-up areas, industrial zones, and transportation networks, the release of pollutants into the environment increases. Construction activities, industrial processes, and urbanization-related land disturbances generate significant amounts of waste, leading to environmental pollution and health hazards [48,49]. The conversion of arable lands into residential, commercial, and construction areas has led to an increase in the consumption parameter, consequently resulting in higher levels of waste and air pollution for Gaziantep. So, the consumption of energy and water and waste material production increased by approximately 90%, 65%, and 57%, respectively, over an 8-year period. Despite these areas and consumption parameters increasing, water areas were preserved. In addition, the loss of natural habitats and failure to increase green areas led to air pollution [50]. Accordingly, there was an increase in the maximum values of air pollution for urban areas. In addition to these increases, there were also rises in the city budget. Changes in LULC patterns influence population distribution and demographic characteristics, with urban areas experiencing higher population densities and increased demand for healthcare services. The relationship between land use change and health is also directly affected [51]. The number of health services was observed to increase due to population growth. Moreover, healthcare services (the number of doctor and hospitals) maintained similar service levels in proportion to population growth.

5. Conclusions

Cities will undergo LULC changes over the years, and these changes in settlement areas will typically occur on agricultural and vacant lands. Determining the changes in parameters caused by these changes, along with other urban parameters resulting from these alterations, is crucial for projecting the development of the city in the coming years. Therefore, examining the current urban parameters and identifying the parameters that will affect the city in subsequent years are essential for future development projections. Spatio-temporal data can be compared with the statistical data of the cities, as well as showing the changes in artificial and natural surfaces. Therefore, all surface change is actually caused by environmental and human-induced effects. The Urban Atlas spatio-temporal data, which is a suggested and usable methodology for studies, are from reliable datasets, and these data are used to analyze LULC changes with high resolution and accuracy. Significant differences were observed between construction sites and arable areas for the city center, and there is a more notable difference than other classes in this study. So, the identified changes in arable and open-space areas were mostly in favor of urban fabric and construction sites. Environmental consumption and pollution have also increased in this direction. Therefore, the impact of urbanization on natural surfaces was observed in a developing city. Population growth was the primary cause of this urbanization, and this obviously revealed environmental and human-induced impacts. As human needs increase, LULC changes will also increase within cities, and these changes will have an impact on natural resources and land use. If precautions are not taken regarding the protection and consumption of natural resources and areas, problematic urbanization will have negative effects on human life.

Urban changes can be determined by satellite images, and the direction of change can be predicted with an analysis of LULC and city parameters. Therefore, comments and predictions can be made directly on waste, urbanization, energy consumption, environmental expenditure, etc., in urban change analyses in the future. The changes in cities over time, which include the development and direction of industry and urban fabric, connections of the transportation network, green space needs, etc., can be determined with many analyses of Urban Atlas spatio-temporal and urban planning. Future forecasts can also be made by determining the needs and consumption of cities with spatio-temporal analysis. In this context, research and development processes can be established for improvements, and it will be possible to take precautions against conditions that may be unfavorable for the future. Also, both LULC data and environmental impact data can be considered in the reorganization and renewal of cities, especially after natural disasters. Therefore, it has been revealed that temporal LULC and statistical environmental data will assist in establishing more environmentally sensitive and healthier living spaces for future urban developments.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data and materials used in this analysis are available upon request from the corresponding author. The data are not publicly available due to privacy.

Acknowledgments: The author would like to thank the Land Monitoring Service of Copernicus for generously providing the Urban Atlas data. Research assistance given by Orkan Özcan is gratefully acknowledged. The author would like to thank the anonymous reviewers, whose comments and suggestions allowed for improvement of the paper.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Sundarakumar, K.; Harika, M.; Begum, A.; Yamini, S.; Balakrishna, K. Land use and land cover change detection and urban sprawl analysis of Vijayawada city using multitemporal LANDSAT data. *Int. J. Eng. Sci. Technol.* **2012**, *4*, 170–178.
2. Akay, S.S.; Sertel, E. Urban land cover/use change detection using high resolution Spot 5 and Spot 6 Images and Urban Atlas Nomenclature. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.* **2016**, *41*, 789–796. [CrossRef]
3. Mukherjee, F.; Singh, D. Assessing land use–land cover change and its impact on land surface temperature using LANDSAT data: A comparison of two urban areas in India. *Earth Syst. Environ.* **2020**, *4*, 385–407. [CrossRef]
4. Rousta, I.; Sarif, M.O.; Gupta, R.D.; Olafsson, H.; Ranagalage, M.; Murayama, Y.; Zhang, H.; Mushore, T.D. Spatiotemporal analysis of land use/land cover and its effects on surface urban heat island using Landsat data: A Case Study of Metropolitan City Tehran (1988–2018). *Sustainability* **2018**, *10*, 4433. [CrossRef]
5. Mirzaei, P.A. Recent challenges in modeling of urban heat island. *Sustain. Cities Soc.* **2015**, *19*, 200–206. [CrossRef]
6. Huang, W.; Liu, H.; Luan, Q.; Jiang, Q.; Liu, J.; Liu, H. Detection and prediction of land use change in Beijing based on Remote Sensing and GIS. The International Archives of the Photogrammetry. *Remote Sens. Spat. Inf. Sci.* **2008**, *37*, 75–82.
7. Das, S.; Angadi, D.P. Land use land cover change detection and monitoring of urban growth using remote sensing and GIS techniques: A micro-level study. *GeoJournal* **2022**, *87*, 2101–2123. [CrossRef]
8. Ranagalage, M.; Estoque, R.C.; Murayama, Y. An urban heat island study of the Colombo metropolitan area, Sri Lanka, based on Landsat data (1997–2017). *ISPRS Int. J. Geo-Inf.* **2017**, *6*, 189. [CrossRef]
9. Estoque, R.C.; Murayama, Y.; Myint, S.W. Effects of landscape composition and pattern on land surface temperature: An urban heat island study in the megacities of Southeast Asia. *Sci. Total Environ.* **2017**, *577*, 349–359. [CrossRef]
10. Hoelscher, K.; Aijaz, R. Challenges and opportunities in an urbanizing India. *Int. Area Stud. Rev.* **2016**, *19*, 3–11. [CrossRef]
11. Ullah, S.; Tahir, A.; Akbar, T.; Hassan, Q.; Dewan, A.; Khan, A.; Khan, M. Remote sensing-based quantification of the relationships between land use land cover changes and surface temperature over the lower Himalayan region. *Sustainability* **2019**, *11*, 5492. [CrossRef]
12. Zhou, G.; Wang, H.; Chen, W.; Zhang, G.; Luo, Q.; Jia, B. Impacts of urban land surface temperature on tract landscape pattern, physical and social variables. *Int. J. Remote Sens.* **2019**, *41*, 683–703. [CrossRef]
13. Yamamoto, Y.; Ishikawa, H. Influence of urban spatial configuration and sea breeze on land surface temperature on summer clear-sky days. *Urban Clim.* **2020**, *31*, 100578. [CrossRef]
14. Janssen, S.; Dumont, G.; Fierens, F.; Mensink, C. Spatial interpolation of air pollution measurements using CORINE land cover data. *Atmos. Environ.* **2008**, *42*, 4884–4903. [CrossRef]
15. Prestele, R.; Alexander, P.; Rounsevell, M.D.A.; Arneth, A.; Calvin, K.; Doelman, J.; Eitelberg, D.A.; Engström, K.; Fujimori, S.; Hasegawa, T.; et al. Hotspots of uncertainty in land-use and land-cover change projections: A global-scale model comparison. *Glob. Change Biol.* **2016**, *22*, 3967–3983. [CrossRef]
16. Tao, H.; Xing, J.; Zhou, H.; Chang, X.; Li, G.; Chen, L.; Li, J. Impacts of land use and land cover change on regional meteorology and air quality over the Beijing-Tianjin-Hebei region, China. *Atmos. Environ.* **2018**, *189*, 9–21. [CrossRef]
17. Wright, C.K.; Wimberly, M.C. Recent land use change in the Western Corn Belt threatens grasslands and wetlands. *Proc. Natl. Acad. Sci. USA* **2013**, *110*, 4134–4139. [CrossRef] [PubMed]
18. Hua, A.K. Land use land cover changes in detection of water quality: A study based on remote sensing and multivariate statistics. *J. Environ. Public Health* **2017**, *2017*, 7515130. [CrossRef]
19. Gupta, N.; Mathew, A.; Khandelwal, S. Spatio-temporal impact assessment of land use / land cover (LU-LC) change on land surface temperatures over Jaipur city in India. *Int. J. Urban Sustain. Dev.* **2020**, *12*, 283–299. [CrossRef]
20. Sarvestani, M.S.; Ibrahim, A.; Kanaroglou, P. Three decades of urban growth in the city of Shiraz, Iran: A remote sensing and geographic information systems application. *Cities* **2011**, *28*, 320–329. [CrossRef]

21. Dewan, A.M.; Yamaguchi, Y. Using remote sensing and GIS to detect and monitor Land Use and Land Cover change in Dhaka Metropolitan of Bangladesh during 1960–2005. *Environ. Assess. J.* **2009**, *150*, 237–249. [CrossRef]
22. Belal, A.A.; Moghanm, F.S. Detecting urban growth using remote sensing and GIS techniques in Al Gharbiya governorate, Egypt. *Egypt. J. Remote Sens. Space Sci.* **2011**, *14*, 73–79. [CrossRef]
23. Mozumder, C.; Reddy, K.V.; Pratap, D. Air pollution modeling from remotely sensed data using regression techniques. *J. Indian Soc. Remote Sens.* **2013**, *41*, 269–277. [CrossRef]
24. Rawat, J.; Kumar, M. Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. *Egypt. J. Remote Sens. Space Sci.* **2015**, *18*, 77–84. [CrossRef]
25. Wang, R.; Derdouri, A.; Murayama, Y. Spatiotemporal simulation of future land use/cover change scenarios in the Tokyo metropolitan area. *Sustainability* **2018**, *10*, 2056. [CrossRef]
26. Wang, S.; Liu, X.; Zhou, C.; Hu, J.; Ou, J. Examining the impacts of socioeconomic factors, urban form, and transportation networks on CO2 emissions in China's megacities. *Appl. Energy* **2017**, *185*, 189–200. [CrossRef]
27. Mcdonald, R.; Green, P.; Balk, D.; Fekete, B.; Revenga, C.; Todd, M.; Montgomery, M. Urban Growth, Climate Change, and Freshwater Availability. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 6312–6317. [CrossRef] [PubMed]
28. Wu, W.; Lin, Y. The impact of rapid urbanization on residential energy consumption in China. *PLoS ONE* **2022**, *28*, e0270226. [CrossRef] [PubMed]
29. Rani, A.; Gupta, S.K.; Singh, S.K.; Meraj, G.; Kumar, P.; Kanga, S.; Đurin, B.; Dogančić, D. Predicting Future Land Use Utilizing Economic and Land Surface Parameters with ANN and Markov Chain Models. *Earth* **2023**, *4*, 728–751. [CrossRef]
30. Fang, Z.; Ding, T.; Chen, J.; Xue, S.; Zhou, Q.; Wang, Y.; Wang, Y.; Huang, Z.; Yang, S. Impacts of land use/land cover changes on ecosystem services in ecologically fragile regions. *Sci. Total Environ.* **2022**, *831*, 154967. [CrossRef]
31. Barranco, R.R.; Silva, F.B.E.; Herrera, M.M.; Lavalle, C. Integrating the MOLAND and the Urban Atlas Geo-databases to Analyze Urban Growth in European Cities. *J. Map Geogr. Libr.* **2014**, *10*, 305–328. [CrossRef]
32. Aksoy, T.; Dabanli, A.; Cetin, M.; Senyel Kurkcuoglu, M.A.; Cengiz, A.E.; Cabuk, S.N.; Agacsapan, B.; Cabuk, A. Evaluation of comparing urban area land use change with Urban Atlas and CORINE data. *Environ. Sci. Pollut. Res.* **2022**, *29*, 28995–29015. [CrossRef]
33. Büttner, G. CORINE land cover and land cover change products. In *Land Use and Land Cover Mapping in Europe*; Manakos, I., Braun, M., Eds.; Springer: Dordrecht, The Netherlands, 2014; Volume 18. [CrossRef]
34. Pazúr, R.; Feranec, J.; Štych, P.; Kopecká, M.; Holman, L. Changes of urbanised landscape identified and assessed by the Urban Atlas data: Case study of Prague and Bratislava. *Land Use Policy* **2017**, *61*, 135–146. [CrossRef]
35. Urban Atlas, Copernicus, Land Monitoring Services 2022. Urban Atlas. Available online: https://land.copernicus.eu/local/urban-atlas (accessed on 23 October 2023).
36. Corine Land Cover, Copernicus, Land Monitoring Services Corine Land Cover. Available online: https://land.copernicus.eu/pan-european/corine-land-cover (accessed on 23 October 2023).
37. TUIK. Statistic Data Protal. Available online: https://data.tuik.gov.tr/ (accessed on 23 October 2023).
38. Şehitkamil District Governorship. Our City: Gaziantep. The European Environment Agency. 2022. Available online: http://www.sehitkamil.gov.tr/ilimiz-gaziantep#:~:text=GAZ%C4%B0ANTEP%E2%80%99%C4%B0N%20CO%C4%9ERAF%C4%B0%20%C3%96ZELL%C4%B0KLER%C4%B0,Sar%C4%B1kaya%20Da%C4%9Flar%C4%B1%20da%20yer%20almaktad%C4%B1r (accessed on 1 October 2022).
39. The Ministry of Interior. Available online: https://www.icisleri.gov.tr/illeridaresi (accessed on 23 October 2023).
40. Boulougari, E. Geoland2. GMES Land Products Training. Available online: https://esdac.jrc.ec.europa.eu/projects/geoland2 (accessed on 23 December 2023).
41. Urban Atlas Mapping Guide. Available online: https://land.copernicus.eu/user-corner/technical-library/urban_atlas_2012_2018_mapping_guide (accessed on 23 October 2023).
42. Copernicus Land Monitoring Service-Urban Atlas. Available online: https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-urban-atlas (accessed on 23 October 2023).
43. *Trimble Documentation eCognition® Developer 8.64.1, Reference Book*; Trimble Germany GmbH: München, Germany, 2011.
44. Semi-Automatic Classification Plugin (SCP). Available online: https://fromgistors.blogspot.com/p/semi-automatic-classification-plugin.html (accessed on 23 December 2023).
45. Mishra, M.K.; Mathew, A. Investigating the spatio-temporal correlation between urban heat island and atmospheric pollution island interaction over Delhi, India using geospatial techniques. *Arab. J. Geosci.* **2022**, *15*, 1591. [CrossRef]
46. Ministry of Environment, Urbanization and Climate Change. National Air Quality Monitoring Network (UHKIA). Available online: https://sim.csb.gov.tr/STN/STN_Report/StationDataDownloadNew (accessed on 23 October 2023).
47. Li, S.; Cao, Y.; Liu, J.; Wang, S.; Zhou, W. Assessing Spatiotemporal Dynamics of Land Use and Cover Change and Carbon Storage in China's Ecological Conservation Pilot Zone: A Case Study in Fujian Province. *Remote Sens.* **2022**, *14*, 4111. [CrossRef]
48. Shi, G.; Ye, P.; Ding, L.; Quinones, A.; Li, Y.; Jiang, N. Spatio-Temporal Patterns of Land Use and Cover Change from 1990 to 2010: A Case Study of Jiangsu Province, China. *Int. J. Environ. Res. Public Health* **2019**, *16*, 907. [CrossRef] [PubMed]
49. Wang, L.; Han, X.; Zhang, Y.; Zhang, Q.; Wan, X.; Liang, T.; Song, H.; Bolan, N.; Shaheen, S.M.; White, J.R.; et al. Impacts of land uses on spatio-temporal variations of seasonal water quality in a regulated river basin, Huai River, China. *Sci. Total Environ.* **2023**, *857*, 159584. [CrossRef] [PubMed]

50. Zarin, T.; Esraz-Ul-Zannat, M. Assessing the potential impacts of LULC change on urban air quality in Dhaka city. *Ecol. Indic.* **2023**, *154*, 110746. [CrossRef]
51. Yang, D.; Ye, C.; Xu, J. Land-Use Change and Health Risks in the Process of Urbanization: A Spatiotemporal Interpretation of a Typical Case in Changzhou, China. *Land* **2021**, *10*, 820. [CrossRef]