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Investigation of Land Use/Land Cover change in Mersin using geographical object-based image analysis (GEOBIA)

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Abstract

In a rapidly changing and developing world, progressive urbanization with a growing population is inevitable. With the migration of people from rural areas to urban areas, both in Turkey and in the world, growth is continuously occurring even in small cities. Remote Sensing technologies provide fast and reliable data and methods for the examination of urban areas, and with these methods, it allows to produce highly accurate Land Use/ Land Cover (LU/LC) maps to examine the temporal changes of urban areas. This study aimed to interpret the changes in Mersin province in the last six years by using LU/LC maps. In this context, Sentinel-2 images of the years 2015 and 2021 with 10 m spatial resolution, including Mersin city center, were obtained. Highly accurate LULC maps of two different years were produced using geographic object-based image analysis (GEOBIA). During the object-based classification, Level 2 of the CORINE project terminology was used for the LU/LC classes. In this process, open-source geographic data (Open Street Map, Wikimapia) were also included in the classification. The LU/LC changes that were occurred in the study area in the last six years were evaluated by comparing the classification results, the areas of the detailed LU/LC classes were examined and the changes were put forward objectively.

1. Introduction

The increasing population in our country as well as all over the world lead to significant changes in urban areas. It is important to observe the past and current status of urban areas for the design of rapidly expanding cities. Remote sensing techniques are widely used to detect and monitor the change in urban areas [1, 2]. Satellite images with medium resolution optical satellite images such as Sentinel-2, and Landsat are widely used to produce Land Use/ Land Cover (LU/LC) maps. The maps are an important resource for accessing Earth Observation information and understanding the dynamics of urbanization and allow for analysis of developments over the years in urban [3]. Monitoring and mapping of LU/LC change and detailed analysis of these changes provide useful information to planners and decision-makers [3-5]. There are several methods of generating LC/LU maps. Geographic Object-Oriented Image Analysis (GEOBIA) is a widely used approach recently. GEOBIA is a technique that uses the analysis of image objects while traditional pixel-based classification uses pixels. It is possible to take into account topological relationships and use different functions and indexes, other than just spectral information with GEOBIA. Since different geographical data sources obtained from different platforms can be integrated into the GEOBIA classification, the method allows for obtaining detailed thematic classes with high accuracy [3, 6-8].

In this research, LU/LC maps were created from Sentinel-2 images of the 2015 and 2021 years of Tarsus, Toroslar, Mezitli, Yenişehir, and Mersin Central districts, and their changes in the last 6 years were analyzed. Sentinel-2 images were chosen because they were open-source data with 10-m spatial resolution in the RGB and

NIR bands. Furthermore, there were no recent studies investigating LU/LC change in Mersin by using Sentinel-2 images. In this study, the GEOBIA approach was used, rule sets were determined based on functions, indexes, and topological relations, and 2015 and 2021 LU/LC maps were created. During the classification, Open Street Map (OSM) and Wikimapia open-source geographic data were also used. Totally 14 classes in the second CORINE level were used to create LU/LC maps.

2. Study Area

Mersin province is located between 36-37° north latitude and 33-35° east longitude and the mid-south region of the Anatolian Peninsula. This province, which is one of the important cities in Turkey, has 13 districts in total and trade is highly developed due to being a port city [9,10].

Tarsus, Toroslar, Mezitli, Yenişehir, and Mersin Central districts, which are among the important districts of Mersin and constantly developing, were chosen as the study area. This District is located in the eastern part of Mersin, Turkey, and has approximately 3.880 km^2 surface area and various landscape characteristics including forest, agricultural areas, urban areas, and water bodies (Figure 1).

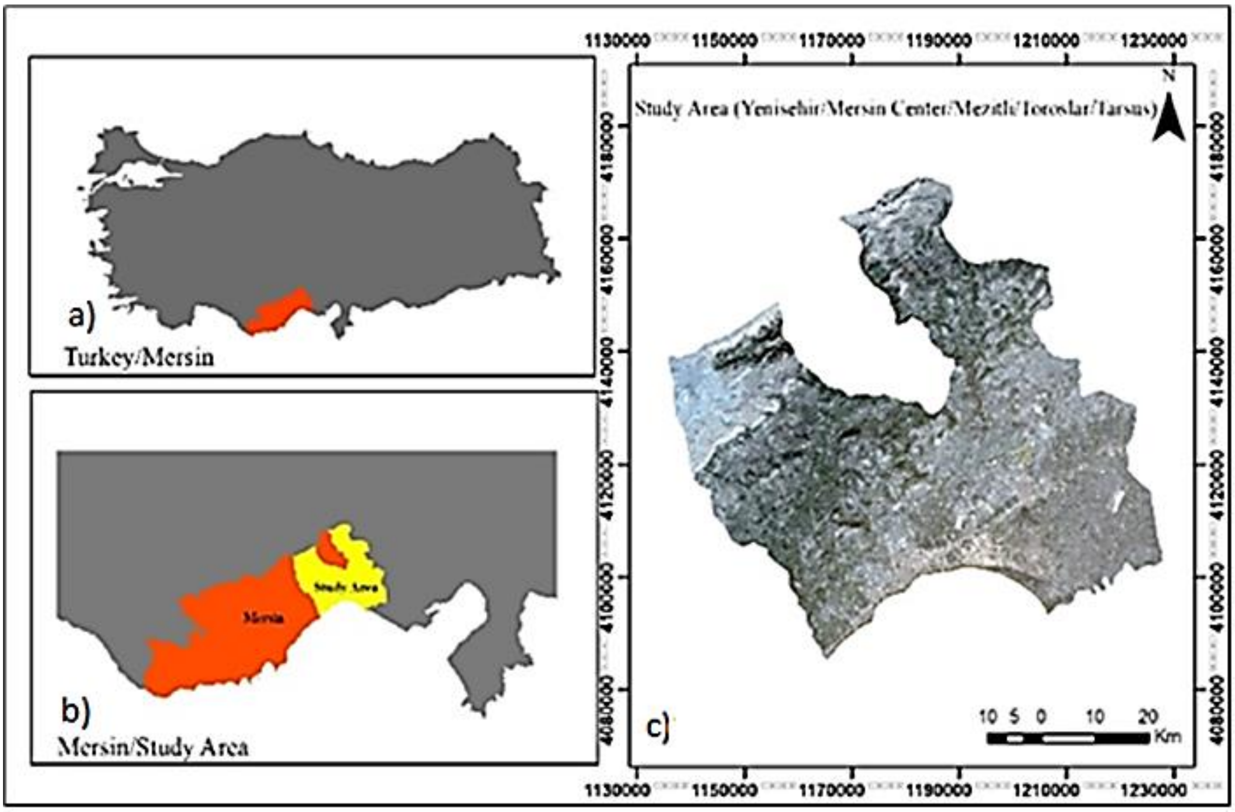

Figure 1. Location of the Study Area **(a)** Turkey (grey)/Mersin (orange); **(b)** Mersin(orange)/Study Area(yellow); **(c)** Tarsus, Toroslar, Mezitli, Yenişehir, and Mersin Central districts (Sentinel-2)

3.Method

3.1. Data

Four Sentinel-2 Level 2A images acquired on 02 September 2015 and 21 October 2021 are used. Sentinel-2 has 13 spectral bands with 10, 20, and 60-meter spatial resolution [11]. In this study, only the 10-meter spectral bands which are Red (665 nm), Green (560 nm), Blue (497 nm), and Near-Infrared (835 nm) are used. The images were ortho-rectified tiles of 100 km x 100 km in UTM WGS84 projections.

Open-source vector data were used to determine a more detailed class and increase accuracy. Open Street Map (OSM) and Wikimapia were used for extraction of land-use classes such as transport units and industrial areas and mine, dump, and construction sites. In addition, Imperviousness maps which are obtained from the Copernicus website were used to control the determined urban fabric classes. In this study, second-level CORINE classes for defining LU/LC classes.

Figure 2 illustrates the flowchart of the process chain. GEOBIA was performed using various indices, and features to create CORINE-based Level 2 LU/LC maps of the study area. Finally, an accuracy assessment was conducted to determine the accuracy of these two maps and evaluated change between 2015 and 2021.

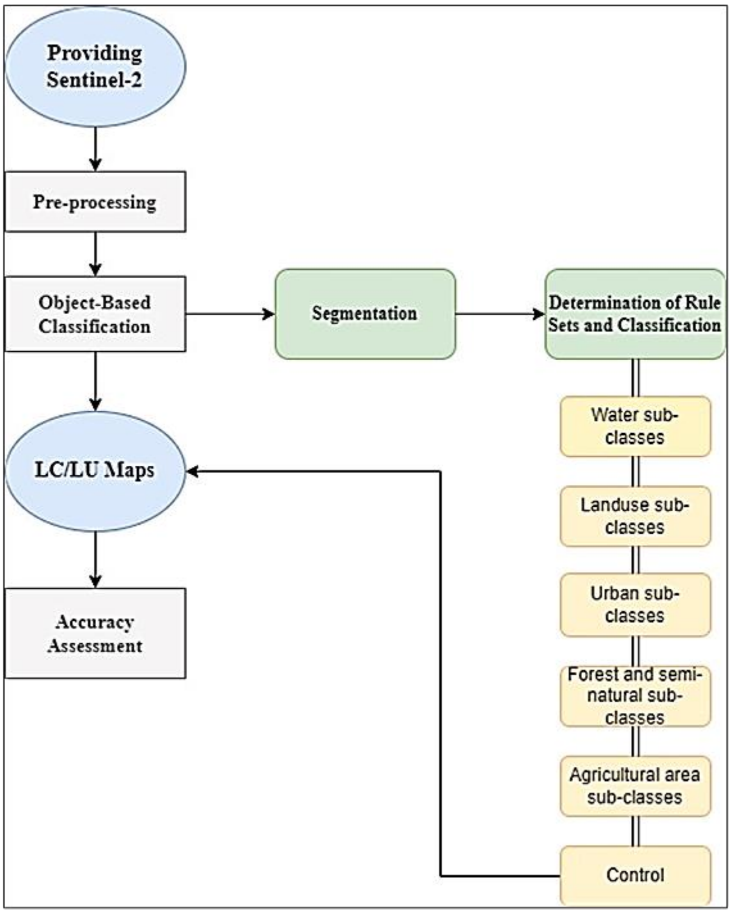

Figure 2. Flowchart of this study

3.2. Image Preprocessing

Sentinel images were obtained at the 2A level which constitutes ToA reflectance values. This shows that there is no need for geometric correction. 4 full frames that cover the study area were downloaded and RGB and NIR bands were layers stacked. Then, mosaic satellite images were created using the histogram matching method for the 2 frames of 2015, 2021 and both images were separately subsetted according to the study area borders.

A total of 14 classes were created according to the 2nd level CORINE nomenclatures and Figure 3 shows these classes.

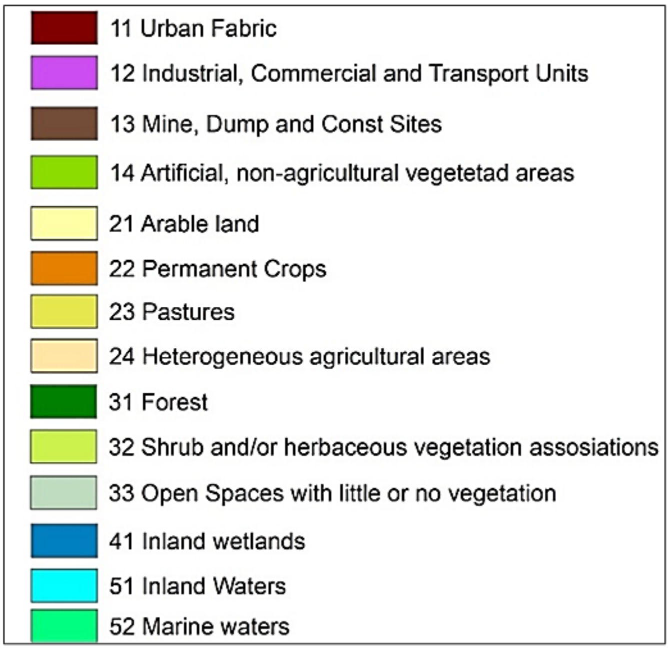

Figure 3. LU/LC classes used

3.3. Classification

The GEOBIA approach was used in the classification phase. The most important and first stage of Classification is the segmentation stage to obtain high accuracy classification results. There are many segmentation methods in the literature, the most used is multiresolution segmentation. Scale, shape, color, compactness, and smoothness, which are the control parameters of the method, should be chosen carefully considering the spatial resolution of the satellite image used [8,12,13]. In this study, the multiresolution segmentation method was used and the appropriate parameters were carefully selected. While the scale parameter varied between 700 and 100, the shape and compactness parameters differed between 0.9 and 0.4 for each LU/LC.

During the segmentation and classification phase, 3 open-source data were used to obtain better results for some of the LU/LC classes. These data were first checked for compatibility with the images and then included in the process. Some vectors were manually fixed since considering the image resolution some parts of the data were too detailed to be used. OSM for Road and Industrial Areas (12) (land use sub-class), Imperviousness Maps for urban fabric (11) class, and Wikimapia for other land-use classes (12,13, and 14) were used as supplementary open-source geo-information. Roads were used with a 10-meter buffer, as suggested in the Urban Atlas Mapping Guide [14]. The supplementary data were integrated into the recognition project as thematic layers and used in the GEOBIA procedure.

Different indices and functions that are defined in the recognition software were used in the classification step and explained in Table 1.

The classification phase was started with vegetated and artificial surface areas for two periods via NDVI and water sub-classes (41,51,52) were determined using Normalized Difference Water Index (NDWI) and Area and Distance to and Texture after Haralick functions.

Table 1. Indices and features used in this study [3,8,15]

Features/Indices	Explanations
NDVI	Normalized difference vegetation index; NDVI = (Layer 4 - Layer 1)/ (Layer 4 + Layer 1)
NDWI	Normalized difference water index; NDWI = (Layer 2 - Layer 4)/ (Layer 2 + Layer 4)
Brightness	Mean of the brightness values in an image
Maximum difference	Calculates the mean difference between the feature value of an image object and its neighbors of a selected class
Standard deviation of NIR	The standard deviation of the NIR band is derived from the intensity values of all pixels in this channel
Shape index	The measure of overall shape complexity
Border index	Describes how jagged an image object is; the more jagged, the higher its border index
Asymmetry	Compares an image object with an approximated ellipse around the given image object
Density	The distribution in space of the pixels of an image object
Area	The total number of pixels in the object
Length/Width	The length-to-width ratio of the mainline of an object
Coordinate (X, Y Center)	X-position and Y-position of the center of an image object. The calculation is based on the center of gravity (geometric center) of the image object in the internal map.
Related border to	Determines the relative border length an object shares with neighbor objects of a certain class
Distance to	The distance (in pixels) of the image object's center concerned to the closest image object's center assigned to a defined class
Texture after Haralick (GLCM)	Texture features are used to evaluate the texture of image objects. Texture after Haralick features is calculated from the gray level co-occurrence matrix.

Secondly, Industrial, commercial, and transport units (12) were determined using Open Street Map (OSM) and Wikimapia vector data and the geometric functions Asymmetry, Length /Width, Brightness, Related border to and Border Index, Shape index, Coordinate, and Maximum difference were used in addition to these vector data. Then the other step, the other land use sub-classes Mine, dump, and construction sites (13) and Artificial, non-agricultural vegetated areas (14) were identified using Wikimapia vector data including Border Index, Shape index, Coordinate (X, Y Center) and Maximum difference and Area functions.

In the third step, Urban fabric (11) was determined between unclassified areas in artificial surfaces with the help of imperviousness vector data and Brightness" and "Area function values.

In the next step, after applying a bigger scale segmentation to the unclassified areas, the classification of Forest (31) was classified by using NDVI, Texture after Haralick (GLCM), Standard deviation, and Maximum difference. Then, Scrub and/or herbaceous vegetation associations (32) and Open spaces with little or no vegetation fields were identified with a smaller scale factor and with the help of NDVI, Coordinate, Area, Maximum Difference, Density, and Standard Deviation functions.

In order to define agricultural sub-classes (21,22,23,24) Texture after Haralick (GLCM) functions were used. Firstly NDVI, Related border to, Standard deviation, Coordinate, Maximum difference feature, and indices, were used to obtain the Arable Land. In addition to the NDVI index, Permanent Agriculture, Pastures, and Heterogeneous agricultural areas were recognized with the use of various Texture after Haralick. After the classification was completed and was controlled in all LU/LC classes, some areas were corrected by manual editing.

After classification processes, an error matrix was created by using 160 randomly selected reference points for each year. Results were evaluated based on the producer's and user's accuracies.

4. Results and Discussion

4.1. LU/LC Maps

In this study, LU/LC maps of Mersin metropolitan city were produced according to 2nd level CORINE nomenclature using the GEOBIA technique on Sentinel-2 dated 2015 and 2021 images. Classification results are shown in Figure 4. Totally 14 LU/LC classes each year were created. The class areas are represented in Table 2.

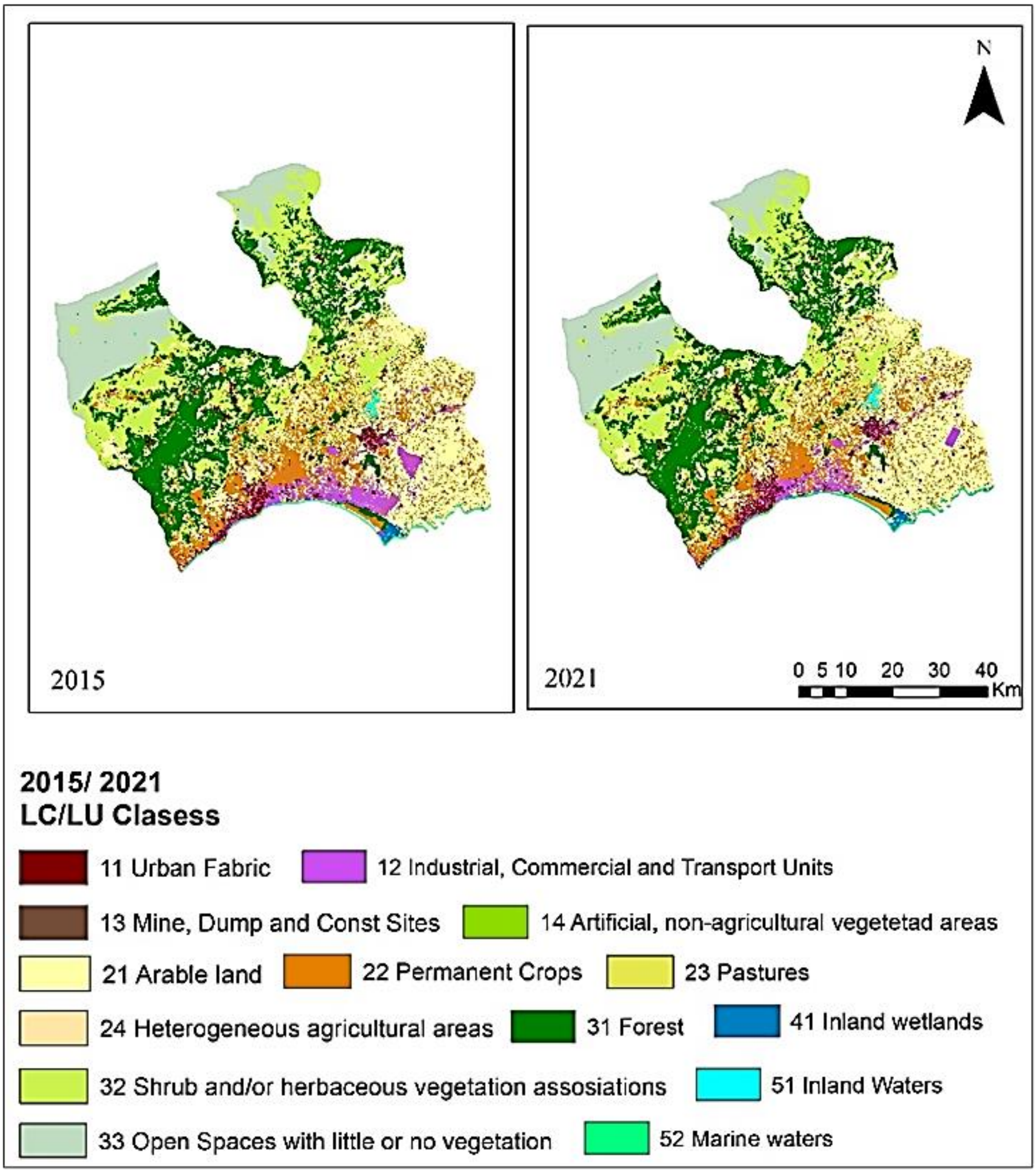

Figure 4. LU/LC maps of two years

According to the results, it is seen that there is an increase in urban fabric (11) in 2021 compared to 2015. In addition, the increase in other artificial areas (12,13,14) also shows that there is urbanization in the districts. Despite the increase in urban areas, the increase in agricultural areas (21,22) indicates that agriculture is also effective in 2021 among the livelihoods of the districts.

The decrease in the shrub and/or herbaceous vegetation associations (32) together with the increase in the open spaces with little or no vegetation (33) may mean that thinning has occurred in some native classes.

A decrease in the total area of wetland and water-related (expect 52) (41,51) classes in 2021 may indicate that there is a slight drought.

Table 2. Class areas in classified images

Class Code	Classes	2015 (km²)	2021 (km²)
11	Urban fabric	107,07	115,37
12	Industrial, commercial and transport units	161,12	180,49
13	Mine, dump and construction sites	19,78	20,18
14	Artificial, non-agricultural vegetated areas	6,94	7,79
21	Arable land	940,07	962,34
22	Permanent crops	466,04	470,24
23	Pastures	11,78	9,57
24	Heterogeneous agricultural areas	1,86	0,23
31	Forest	851,32	851,19
32	Shrub and/or herbaceous vegetation associations	799,54	748,54
33	Open spaces with little or no vegetation	448,83	452,28
41	Inland wetlands	11,34	9,81
51	Inland waters	32,89	30,28
52	Marine water	20,88	21,15
	Total	3879,46	3879,46

4.2. Accuracy Assessment

A point-based accuracy assessment was applied to determine the thematic accuracies of 14 LC/LU classes. To generate reference polygons, open-source geospatial data such as Google Earth, and Yandex Maps were used each year. 160 randomly selected points according to proportionally the class area in the study area were used in this phase. The accuracy assessment was completed and error matrixes were produced using ArcGIS software. Table 3 shows the overall and class level accuracy values. The overall accuracy of the 2015 and 2021 LU/LC maps were found as 80.63% and 82.50 %, respectively.

Table 3. Accuracy assessment results of LU/LC maps

Class Code	Producer's Accuracy (%)	User's Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)
	2015		2021	
11	80.00	72.73	75.00	81.82
12	75.00	75.00	75.00	75.00
13	75.00	75.00	80.00	72.73
14	77.78	70.00	77.78	70.00
21	82.35	87.50	87.50	93.33
22	81.25	76.47	82.35	82.35
23	85.71	75.00	85.71	75.00
24	66.67	80.00	71.43	83.33
31	84.21	88.89	87.50	87.50
32	82.35	77.78	82.35	77.78
33	83.33	83.33	83.33	83.33
41	77.78	87.50	80.00	88.89
51	87.50	87.50	87.50	87.50
52	100.00	100.00	100.00	100.00
Overall Accuracy	80.63		82.50	
Kappa Statistics	0.7890		0.8100	

5. Conclusion

LC/LU maps provide accurate, reliable, and up-to-date geographic information important for the current status, change, effective management, and future planning of cities. To produce an efficient LC/LU map with accurate and detailed LU/LC classes, it is necessary to prefer the GEOBIA approach.

In this study, thanks to the use of Sentinel-2 images together with open-source geo-information, which can be obtained free of charge, detailed LU/LC maps were produced and the change in the study area were examined. In addition, detailed identification of agricultural areas was made possible by the GEOBIA approach. Thanks to the Texture of Haralick (GLCM) functions, many green areas can be distinguished.

The importance of using open-source data for the determination of land use classes is demonstrated by the ability to produce high accuracy from data with 10 m spatial resolution. However, it is extremely important to be able to analyze the satellite image and vector data compatibility well before proceeding to the classification stage.

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Conflicts of interest

The authors declare no conflicts of interest.

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