Land Use and Land Cover Classification of Landsat (TM-TIRS) and Landscape Change Analysis: Iznik Case Study*

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Abstract

There are many methods to analyze rural landscapes, but a limited number of methodological procedures offer tangible solutions for understanding changes in the rural landscape. This study aims to analyse that change and present the results visually and statistically to inform safeguarding the cultural heritage. It focuses on analysing the changes in the rural landscape of Nikea (Iznik)/Turkey between 1985-2022. Nikea (Iznik) is an important historic city on the UNESCO World Heritage Tentative List (2014) together with its hinterland. It has preserved its identity as a rural landscape from the past to the present. In this study, land use and land cover (LULC) maps for 1985 and 2022 were obtained from Landsat images by using Geographic Information Systems (GIS) and Remote Sensing (RS) methods. Principally, a series of Landsat images from 1985 and 2022 with 30×30 m resolution (TM 1985 and TIRS 2022) was processed and trained through a pixel-based method: Supported Vector Machines (SVM) by using the ArcGIS Pro software. Finally, a confusion matrix created to measure the accuracy assessment of LULC maps. The classification accuracy of 1985 was determined as 85%, 2022 was determined as 83%. This study proves that the LULC maps of 1985 and 2022 obtained by using GIS and RS Methods have reliable classification accuracy. Thus, it creates a database that will serve its primary purposes such as examining the connections of the change in land use with the continuity of rural life and a further change detection study focused on the region.

Keywords

Rural landscape change, land cover change, image classification, Nikea(Iznik), conservation of the rural landscape

Introduction

There are numerous techniques such as Landscape Metrics and Spatial Analysis for analyzing rural landscapes, however there are only a limited number of procedural methods that provide practical solutions to analyse changes within rural landscapes. Considering the significant contributions of rural peoples to global heritage, it is crucial to adopt an approach that prioritizes the conservation of historic and cultural heritage in these areas that are prone to rapid changes.

Change in the rural landscape is examined in many different contexts but with similar methods in many studies (Wang et al., 2020, Fichera et al., 2012) recently conducted a study to draw city planners' attention to mainstream ecosystem-based adaptation and mitigation into urban plans by detecting LULC changes through the remote sensing and geographical information system in Kathmandu (Nepal), known for its rapid growth (Wang et al., 2020). Earlier, a similar study was completed in Italy. The land cover and its change in the Avellino area of Southern Italy was studied, using remote sensing data and techniques. It is revealed that land cover changes are linked to the consequences of natural and social processes, such as the disastrous Irpinia earthquake (1980), specific zoning laws, and urban plans (Fichera et al., 2012). These and similar studies, with their analyses and interpretations, impact the approaches of various other disciplines to rural areas, bringing a more comprehensive perspective.

The unique aspect of this study lies in its demonstration of the benefits of employing remote sensing data and Geographical Information Systems for assessing changes in rural landscapes. It emphasizes the need for wider utilization of these as their advantages may unlock access to heritage resources. This research was carried out considering there has yet to be a comprehensive study on the change and transformation of the rural landscape in Iznik, which is included in the UNESCO World Heritage Tentative List. The city's connection with the rural landscape around Lake Iznik and its surroundings is prominent. The importance of Iznik, a town with a history dating back to the Hellenistic Period, can only be fully understood when considering its connections to the rural area surrounding it, as the town has interacted with this region since prehistoric times (Alioğlu et al, 2012). Although the rural landscape has transformed into different uses over time, the town still maintains its rural character and interacts with it (Kap Yücel, 2018). However, recent research revealed the fact that rural landscapes, which have always high value, are vulnerable to change (Yu et al., 2016).

In this study, LULC maps of Iznik, which are created by the classification of images (aerial photographs and satellite images) (Cavur et al., 2019) for the years 1985 and 2022. Comparison of these two maps as a method was used to analyze the change and transformation in the rural landscape. The creation of LULC maps for these two years by processing Landsat images with 30x30 m resolution from 1985 and 2022 (TM 1985 and TIRS 2022) using ArcGIS Pro software. Because by utilizing the integration of RS and GIS techniques, it is possible to analyze and classify the structure of land cover change and to understand the changes in the area of interest (Fichera et al., 2012).

This study aims to undertake a preliminary study at the point of conservation of rural landscape after documenting a 37-year change in the rural landscape of Iznik by demonstrating that a comparison of the LULC maps of 1985 and 2022, which were created using RS and GIS-based visualizations, is a satisfactory means for detecting the change in the rural landscape of Iznik. This finding is parallel with the spatial transformation of the area due to political and social changes in the country that have impacted the area in the last decades.

Methodology

This study followed a research methodology with five steps: collecting data, pre-processing of data, training of data, classification (SVM), accuracy assessment, and post-processing of analysis *(Figure 1).*

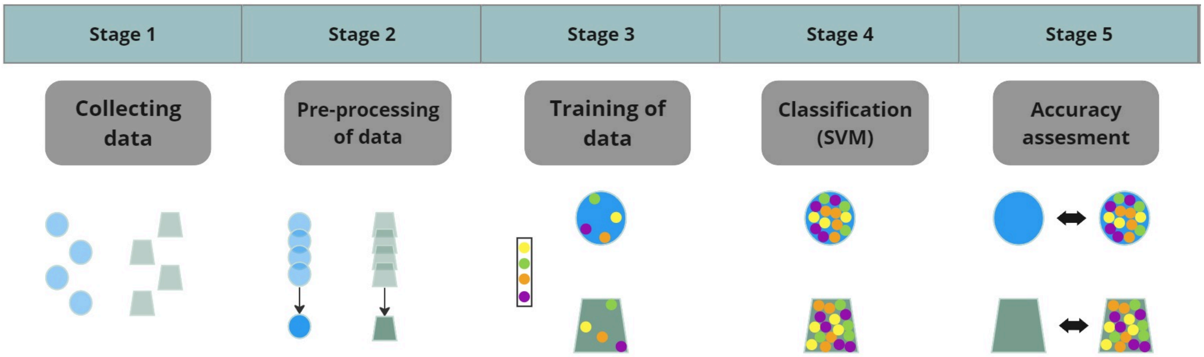

Figure 1. Research Methodology

In the data collecting stage, the USGS (https://earthexplorer.usgs.gov) online website was used as a source because it offers free and high-resolution data. Landsat images from 1985 and 2022 were used in this study, as the specific land change under investigation has taken place within the past three decades, and the oldest available data dates to 1985. After obtaining a Landsat TM image with 8 bands for 1985 and a Landsat TIRS image with 11 bands for 2022 of Iznik and its surroundings, the raw Landsat images from these two years were uploaded to ArcGIS Pro. In the stage of pre-processing data, the bands were made composite, and the boundaries of the study area were processed into the resulting composite images *(Figure 2).*

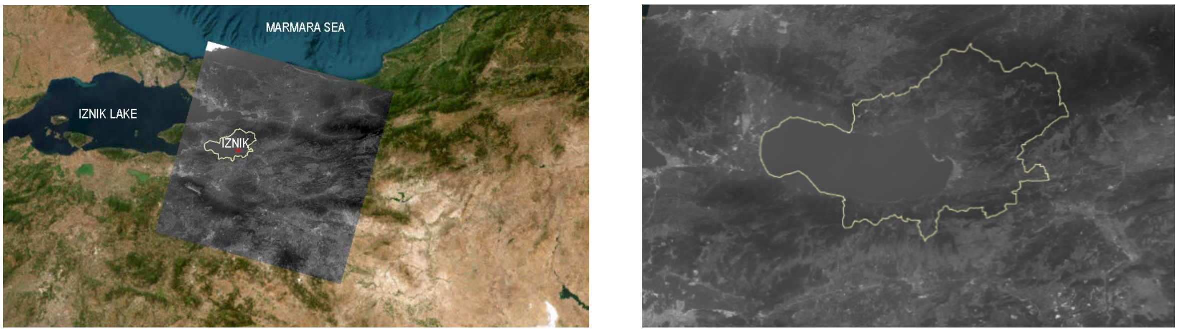

Figure 2. Composited landsat images in Arcgis Pro Software

Afterward, the 1985 and 2002 images were visualized in RGB bands in order to have true-band colors *(Figure 3,4).*

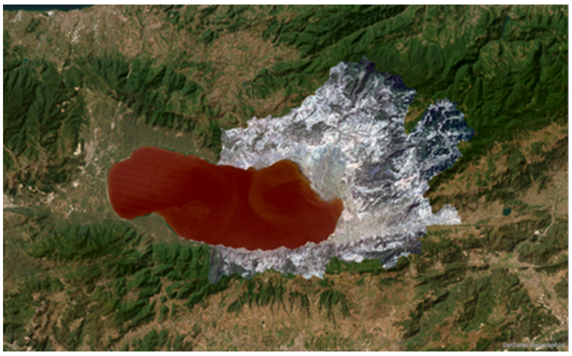

Figure 3. Aerial photo (1985)

Figure 4. Aerial photo (2022)

In the third step, images were trained to teach the software how to accurately classify changes in data. This process helps in identifying and distinguishing different types of changes from remotely sensed imagery. Firstly, seven classes were defined. These classes are water, built-up areas, open spaces with little or no vegetation, forests and the seminatural regions, agricultural/arable lands, agricultural permanent crops (such as olive groves), and inland marshes and reedbeds. After that, pieces of a minimum of 30 by 30 pixels were selected and they were assigned to the classes to collect enough samples for each class to get acceptable accuracy. Then pieces of a minimum of 30 by 30 pixels were selected and they were assigned to the classes (*Figure 5).*


Figure 5. Samples for data training excercise

In the classification phase, all pixels were assigned to the appropriate classes using the Supported Vector Machines (SVM) method in a pixel-based manner. It is a commonly-used classification method that determines the hyperplane in a high-dimensional space that most effectively separates the two classes. The SVM performs classification by converting the data into a higher-dimensional space using a kernel function and then finding the hyperplane that most effectively separates the two classes (Zhou, 2012).That method has two approaches, pixel-based and object-based, and there is yet to be consensus as to which is better for LULC classification. However, the pixel-based classification approach has advantages when creating LULC by classifying some natural and semi-natural areas (Tonyaloğlu et al., 2021). It is a more successful approach for classifying data whose resolution is not very high, and it also performs more successfully in classifying natural and semi-natural areas than others. In this study, the fact that the Landsat images used as the main data are free but not very high-resolution and the focus is a rural region consisting of natural and semi-natural areas causes this approach to be preferred. Thus, at the end of the classification stage, the LULC map for 1985 and 2022 was created *(Figure 6,7)*.

As a result of the classification process, it was determined that the most notable changes from 1985 to 2022 were in the water, built-up areas, and agricultural areas (arable lands and permanent crops). In the map of 1985, there were 5.391 pixels (428,76 hectares) assigned to built-up areas, increasing to 11.195 pixels (894,96 hectares) in the 2022 map. Similarly, while the class of agricultural areas contained 128,734 pixels on the map of 1985, this number increased to 200,590 in the 2022's map. In addition, in 1985, the water class consisted of only Iznik Lake and included any pixel in other parts of the study area. However, this pixel number increased to 258 pixels with the dams placed in various parts of the study area. On the other hand, another detection made after the classification process was that the algorithm assigned incorrect classes to some pixels due to confusing some classes. Especially since the two classes which were labeled forests and seminatural regions at the beginning were highly mixed up with each other. Because of that, these two classes were combined into a single class with the label forests and semi-natural regions. The failure to distinguish these classes from each other was because the data was not very high resolution. The Landsat images used were the best free data available, but their resolution was not high enough to avoid this error.

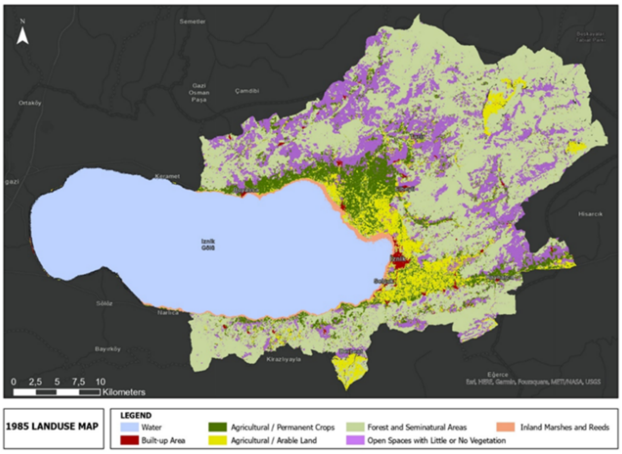

Figure 6. LULC map of 1985

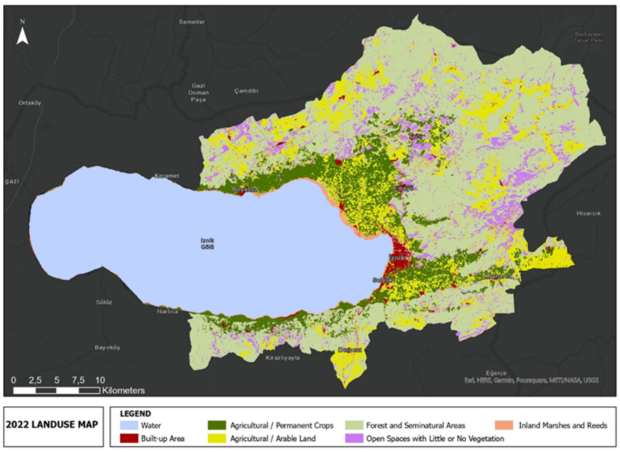

Figure 7. LULC map of 2022

In order to calculate the accuracy of these LULC maps and to understand whether this method can be used, 250 points were placed on the obtained maps in the accuracy assessment stage. *(Figure 8)* After that, a comparison was made between the corresponding points found in the LULC maps and aerial photographs from the relevant years. Thus, the classification accuracy for 1985 is calculated as 85%, while the classification accuracy for 2022 was calculated as 83%. In addition to these results, tables *(Table 1 and Table 2)* created as a result of the accuracy assessment process allow us to understand the classes that are confused with each other by the algorithm.

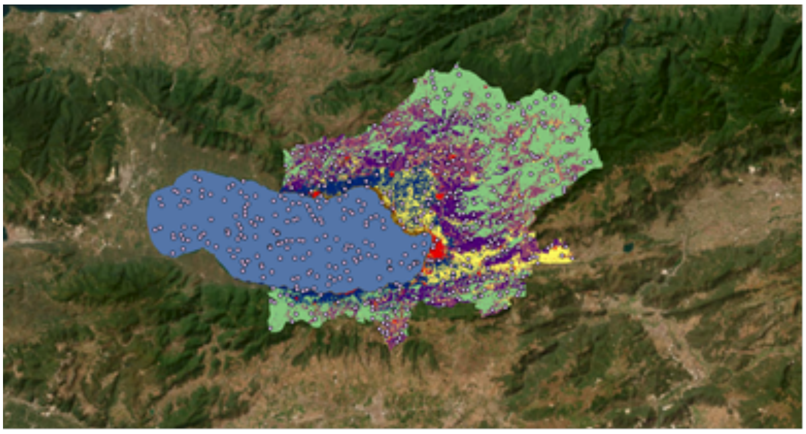

Figure 8. 250 points placed on the map for accuracy calculation

1985		1 WATER	2 FORESTS	3 PERM. CROPS	4 BUILT-UP	5 ARABLE LANDS	6 OPEN SPACES	7 REEDS	ACCURACY
1	WATER	15	0	0	0	0	0	3	%83,3
2	FORESTS	0	241	2	0	4	14	0	%92,3
3	PERM. CROPS	0	1	37	1	1	14	0	%68,5
4	BUILT-UP	0	0	0	6	0	0	0	%100
5	ARABLE LANDS	0	6	8	0	30	9	0	%56,6
6	OPEN SPACES	0	18	2	1	2	87	0	%79
7	REEDS	0	0	1	0	0	1	8	%80
TOTAL									%85

Table 1. Accuracy Assesment of 1985[1]

2022		1 WATER	2 BUILT-UP	3 OPEN SPACES	4 FORESTS	5 ARABLE LANDS	6 PERM. CROPS	7 REEDS	ACCURACY
1	WATER	20	0	0	0	0	0	0	%100
2	BUILT-UP	0	12	0	0	0	0	0	%100
3	OPEN SPACES	0	0	28	9	4	6	0	%59,50
4	FORESTS	0	0	11	233	18	1	0	%89
5	PERM. CROPS	0	0	0	0	77	5	0	%92,70
6	OPEN SPACES	0	0	13	2	4	59	0	%76
7	REEDS	0	0	2	2	0	0	6	%60
TOTAL									%83

Table 2. Accuracy Assesment of 2022[2]

[1] The legend (1985): 1-Water, 2-Forests and Seminatural Regions, 3-Agricultural/Permanent Crops, 4-Built-Up Areas, 5- Agricultural/Arable Lands, 6-Open Spaces with Little or No Vegetation, 7- Agricultural/Arable Lands

[2] The legend (2022): 1-Water, 2- Built-Up Areas, 3- Open Spaces with Little or No Vegetation, 4- Forests and Seminatural Regions, 5- Agricultural/Arable Lands, 6- Agrıcultural/Permanent Crops, 7- Agricultural/Arable Lands

Discussion

The tables created after the completion of the accuracy assessment, which is the last stage of the study, not only show that the LULC maps obtained have high accuracy rates such as 83% and 85%, but also include class-based accuracy rates. One of the greatest accuracy rates was achieved in 1985 and 2022 in the built-up class with %100. The reason for obtaining such a high accuracy rate is that the built-up class is very different from the other six classes based on pattern. Another class with the highest accuracy is water, with 100% in 2020 and %83,3 in 1985. The reason for the higher accuracy rate compared to these other classes is that water is also quite different from the majority as a pattern, and thus it can be recognized more accurately by the algorithm. The fact that the rate was not higher in 1985 is due to the intense inland marshes and reeds formation in the coastal area of Iznik Lake, which includes all the water class samples. The fact that the samples belonging to these two classes are very similar in pattern on the coasts prevented them from being separated better by the algorithm. Forest and the semi-natural regions class has a fairly high accuracy, with 92,3% in 1985 and 89% in 2022. This was made possible by combining the two classes by means of the algorithm and defining them as a single class. On the other hand, in open spaces with little or no vegetation, agricultural/arable lands, agricultural permanent crops, and inland marshes and reeds classes the accuracy rates for two years are relatively lower, except for agricultural arable lands with an accuracy of 92% in 2022. The reason for this is the pattern similarity and low data resolution, as in the previous class confusions. Despite being the most optimal freely accessible data, the resolution of the utilized Landsat images was inadequate to prevent this error.

It is understood at the end of the fifth step, that there were some advantages and disadvantages of this method applied by using remote sensing data and geographical information system to detect the change in the rural landscape change in Iznik. To able to analyze and understand such a large area can be seen as one of the biggest advantages, because, with this method, the transformation in a large area that people cannot perceive with the naked eye can be easily detected. The possibility of making determinations on high-accuracy results is another advantage. This way, the transformations of agricultural/arable lands and agricultural/permanent crops can be analyzed accurately.

Conclusion

The main objective of this study was to create comparable Land Use Land Cover (LULC) maps for 1985 and 2022 using remote sensing and GIS for better understanding the dynamics of the region and conservation of rural landscapes in Iznik. These maps are significant in tracing the historical continuity of agricultural production in the rural area in the Iznik hinterland. The methodology followed in the study for creating Land Use Land Cover (LULC) maps using Landsat scene data has effectively detected changes in Iznik's rural landscape over 37 years. This aspect of the study emphasizes the importance of utilizing remote sensing data and Geographical Information Systems to access heritage, particularly in today's digital era. The effective and reliable methodology of this study reveals that the outputs obtained at the end of the study are healthy and pave the way for these outputs to serve the various purposes of the study. These purposes can be outlined as investigating how changes in land use impact rural life and uncovering the impact of agricultural land changes on daily life and architectural patterns. This study also contributed to the literature used as a source study when making inferences about whether the built environment threatens the natural heritage areas that need to be protected and when making integrated conservation decisions at a larger scale. Further, the outputs obtained at the end of this study will be used in a following publication as data, where we will demonstrate the changes and from which class to which class the change occurred and at what rate in these 37 years in the region.

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