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Monitoring of Land Use/Land Cover Change and Statistical Analysis of Change within the Scope of Urban Sprawl; North Cyprus Case

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Abstract

Monitoring land use and land cover (LULC) change is one of the main methods used in assessing landscape dynamics and defining environmental health at different spatio-temporal scales. In this study, the LULC changes between 2013 and 2021 in some centers (Lefkoşa, Girne, Gazimağusa, and Lapta) located in the Northern Cyprus Island were monitored through UA and GIS technologies, and a projection for the year 2050 was created within the scope of the settlements. The results showed that, specifically for settlements, there was an increase of 65.59% in the Girne region, 33.60% in the Lapta region, 66.87% in the Lefkoşa region, and 83.50% in the Gazimağusa region, and this increase was mostly in the north and west directions. As a result of statistical analysis, the 2050 projection reveals that settlement centers will spread significantly. It is anticipated that the results of this study will be a reference for decision-makers within the scope of land management and urban settlement planning in Northern Cyprus.

Keywords: *Land use and land cover, change detection, urban sprawl, Landsat 8 OLI, supervised classification.*

Arazi Kullanımı/Arazi Örtüsü Değişiminin İzlenmesi ve Kentsel Yayılma Kapsamında Değişimin İstatistiksel Analizi; Kuzey Kıbrıs Örneği

Öz

Arazi kullanımı ve arazi örtüsü (AKAÖ) değişiminin izlenmesi, peyzaj dinamiklerinin değerlendirilmesinde ve farklı mekânsal-zamansal ölçeklerde çevre sağlığının tanımlanmasında kullanılan temel yöntemlerden biridir. Bu çalışmada da uzaktan algılama (UA) ve coğrafi bilgi sistemleri (CBS) teknolojileri vasıtasıyla Kıbrıs Adası'nın kuzeyinde yer alan bazı merkezlerdeki (Lefkoşa, Girne, Gazimağusa ve Lapta) 2013-2021 yılları arasındaki AKAÖ değişimi izlenmiş ve yerleşimler kapsamında 2050 yılına yönelik projeksiyon oluşturulmuştur Sonuçlar, yerleşim yerleri özelinde Girne bölgesinde %65,59, Lapta bölgesinde %33,60, Lefkoşa bölgesinde %66,87 ve Gazimağusa bölgesinde %83,50 artış olduğunu ve bu artışın çoğunlukla kuzey ve batı yönlü olduğunu göstermiştir. İstatistiksel analizler sonucu 2050 yılı projeksiyonu, yerleşim merkezlerinin önemli oranda yayılım göstereceğini ortaya koymaktadır. Bu çalışma sonuçlarının, Kuzey Kıbrıs özelinde arazi yönetimi ve kentsel yerleşim planlaması kapsamında karar vericilere referans olacağı öngörülmektedir.

Anahtar kelimeler: *Arazi kullanımı ve arazi örtüsü, değişim tespiti, kentsel yayılma, Landsat 8 OLI, kontrollü sınıflandırma.*

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1. Introduction

Global social and economic developments increase urbanization within the world ecosystem, and urbanization creates pressure on natural areas, causing significant changes in ecosystems, environment, landscape, and biodiversity (Rahman et al., 2019; Kafy et al., 2020; Türker & Akten , 2023). Although urbanization is an indicator of economic development and prosperity, it also creates negative consequences, especially on natural ecosystems, in the short and long term (Maimaitiyiming et al., 2014; Nathaniel et al., 2021). Land use/land cover (LULC) change within the scope of urban expansion brings with it many ecological problems such as climate change, air pollution, biodiversity loss, etc. in the long term (Selim & Demir, 2018; Wang et al., 2020; Zhang et al., 2022). Land use and land cover pattern is a distinctive element of the landscape that has direct and indirect connections with various socio-economic and socio-cultural processes (Foley et al., 2005). This pattern represents the rate of human activities on the land surface, mostly in the form of LULC change, and this change affects land use systems (Wang et al., 2021). The speed and order in the change of LULC depends mainly on the economic, social, and political characteristics of people and the regional policies of central and local governments (Sleeter et al., 2018; Gomes et al., 2020). Therefore, detecting the LULC change temporally and spatially has become one of the priority issues in order to take the necessary precautions by determining the control, limits, speed and possible effects of this change (Li et al., 2023; Alawamy et al., 2020; Lunetta et al., 2022).). The assessment of LULC change has become central to various aspects of the human and natural environment and the interaction between them (Hu et al., 2019; Baig et al., 2022). Assessment of LULC is essential to solve a number of environmental problems at the regional level, such as unregulated urbanization, loss of productive agricultural lands, destruction of wetlands, degradation of wildlife habitat and pressures on ecosystem services (Hussain et al., 2020a; Aghsaei et al., 2020; Aneseyee et al., 2020; Taiwo et al., 2023). In addition, LULC change has become more important in land use planning and land management due to its negative effects on the state and integrity of ecosystem functioning (Duan et al., 2023; Li et al., 2023).

Determining LULC change is a spatial phenomenon and requires a spatial strategic approach (Kafy et al., 2020). Remote sensing (RS) and geographic information systems (GIS) technologies are mostly used in the literature to simulate the current and future forms of land use change (Hussain et al., 2020b; MohanRajan et al., 2020; Bagwan et al., 2023). Nowadays, we can detect spatio-temporal LULC changes using satellite data. These data appear as one of the most reliable tools in monitoring the wide spatial range of the earth (Chamling & Bera, 2020). Remotely sensed wide spectrum range satellite data have been proven in the literature to be highly reliable and cost-effective for measuring various dimensions of LULC variation, saving time and providing accurate results (Abdullah et al., 2019; Shah 2012; Zhai et al., 2021). A comprehensive scientific perspective is offered to get historical, present, and future LULC characteristics by combining several descriptive remote sensing models with variable, multi-temporal, high-resolution satellite images (Li et al., 2014; Chamling and Bera, 2020; Selim et al., 2023). Monitoring LULC change is also very feasible and easy using satellite data, and therefore it is widely preferred among researchers from an operational perspective (Attri et al., 2015; Vivekananda et al., 2021; Ghute et al., 2023).

Determining the LULC change and incorporating the results obtained in this context into spatial planning in the relevant area has become even more important, especially in terms of socio-economic and geo-political regions where urban development is accelerated. In this context, the Island of Cyprus is an important region in terms of monitoring the LULC change and creating future projections due to its location, economic, cultural and social structure. Although the economy of Northern Cyprus is mostly dependent on the service sector, it shows significant growth due to its climate characteristics and tourism activities. Although the economic structure is less diverse like other small island economies, the construction sector has become one of the locomotive sectors of the Northern Cyprus economy due to the increase in foreign demand (Şafakli, 2011). Settlements, especially tourism facilities, are spreading rapidly on the island and especially in the coastal areas. Therefore, land uses differ and land cover changes. Within the scope of sustainability, detecting this LULC change, obtaining information about its momentum from past to present and its potential status in the future is of great importance for spatial planning decisions of the region. The fact that no comprehensive LULC change study has been found in the literature for Northern Cyprus throughout the region increases the importance of this study.

In this study, it was aimed to determine the LULC change of Lefkoşa (Nicosia), Girne (Kyrenia), Gazimağusa (Famagusta), from now on it will be called Mağusa, and Lapta, which are the 4 major cities of Northern Cyprus that are important in terms of tourism, between 2013 and 2021, and to estimate the potential settlement spread for the future. The main data set consists of Landsat 7 ETM+ and Landsat 8 OLI/TIRS satellite images. Satellite images of each region in the relevant years were provided with open access, image pre-processing and classification were carried out, and accuracy analyzes were applied. The numerical data obtained was used to create future projections with the help of statistical analysis. It is envisaged that the results of the study can benefit the central and local governments of the region and affect spatial planning decisions.

2. Material and Method

2.1.Material

The main material of the study consists of the city centers and their immediate surroundings of Lefkoşa, Girne, Mağusa and Lapta, which are the four largest settlements of Northern Cyprus (Figure 1).

Figure 1. Study area

Cyprus, the third-largest island in the Mediterranean, behind Sardinia and Sicily in Italy, is 71 km away from Turkey and is located at 34°33' and 35°42' north latitudes and 32°16' east longitudes. While the Turkish Republic of Northern Cyprus (KKTC) is located in the northern part of the island, which has a surface area of 9,251 km^2, there is the Greek Administration of Southern Cyprus (GASC) in the southern part. The KKTC surface area is 3241 km^2, accounting for 35.04% of the island, the Greek Cypriot Administration's surface area is 5509 km^2 (59.56%), and the British military zone is 256.01 km^2. The buffer zone covers an area of 244.04 km^2 (TCDB, 2024). The region is defined as "semi-arid" according to the macro climate classification. In winter, the average temperature ranges from 5 to 15 °C, while in summer, it can reach 40 °C. The average precipitation is approximately 500 mm per year, the lowest precipitation is 182 mm and the highest precipitation is 759 mm (Payab &Türker, 2019).

The data set of the study consists of Landsat 7 ETM+ and Landsat 8 OLI/TIRS satellite images. These images were provided open access through the EarthExplorer (EE) user interface developed by the United States Geological Survey (USGS) (Table 1).

Table 1. Satellite images features preferred in the study

Landsat 7	Wavelength (Mikrometer)	Landsat 8	Wavelength (Mikrometer)	Resolution (meter)
Blue	0.45-0.52	Blue	0.45-0.51	30
Green	0.52-0.60	Green	0.53-0.59	30
Red	0.63-0.69	Red	0.64-0.67	30
Near Infrared (NIR)	0.77-0.90	Near Infrared (NIR)	0.85-0.88	30

In the study, open source QGIS 3.6.3 software was used to perform pre-processing (band merge, subset, mosaic, image enhancement) of satellite data. ArcGIS 10.4.1 software, which is in our faculty's inventory, was used for image classification processes.

2.2.Method

The study method was carried out in 6 stages: data acquisition, pre-processing of satellite images, classification processes, statistical projection analyses, assessment and results/suggestions (Figure 2).

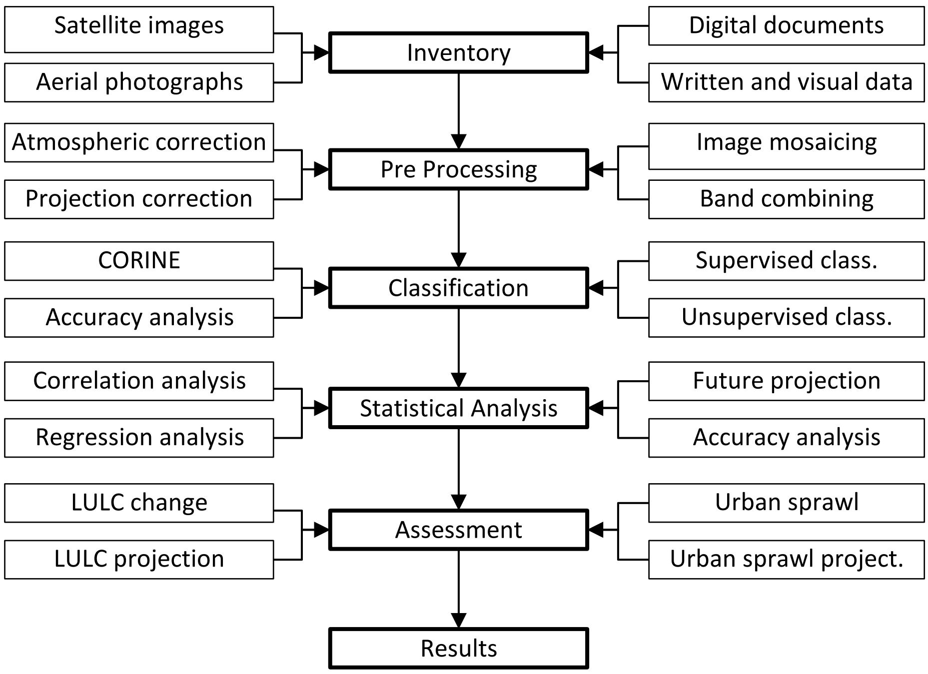


Figure 2. Method flowchart

During the inventory phase, satellite images for June of each year between 2013 and 2021 were obtained. Aerial photographs of the region from past years and today were provided for use in the evaluation phase. A database was created in GIS software by providing written, visual and numerical data to be used in the classification and evaluation phase. In the created database, in the 9-year period, including 2013 and 2021, data for this year were ignored due to the high cloudiness level in the satellite images of June 2015. Then, atmospheric and projection correction operations were carried out with QGIS software over the relevant database, and mosaicing and band combining process steps were applied.

During the classification phase, CORINE (Coordination of Information on the Environment) 1st level settlement, agriculture, forest, water surface and other class values were assigned for supervised and unsupervised classification processes. A minimum of 500 sample points were selected for each class. 500 sample points taken from open access Google Earth Pro on the same date and from the same regions were transferred to ArcGIS and compared with the classifications produced. The image processing phase continued with supervised classification, which produced higher accuracy.

Correlation and regression analyzes were applied in the statistical analysis part of the study, and it was seen that the best statistical analysis technique representing the data obtained specifically for settlements was the linear regression model (formula 1). Therefore, linear regression analysis was applied to the change in the residential areas of each region over the years.

$y = \beta_0 + \beta_1 x + \varepsilon$ (James et al., 2023)

formula 1

- y is the dependent variable
- x is the independent variable
- β_0 is the costant or intercept
- β_1 is x's slope or coefficient
- ε is the error term

In the evaluation, conclusion and recommendations stages, the trends in the spread of settlements and potential development projections for 2050 were interpreted within the scope of LULC and specifically for each region. In this context, suggestions that can guide spatial planning are presented.

3. Findings and Discussion

3.1. Findings

In this study, carried out in 4 district centers in the Northern Cyprus, which has strategic and geopolitical importance, supervised classification was carried out to determine LULC classes and reveal their changes according to years, and the average classification accuracies for all years are presented in Table 2.

Table 2. Classification accuracies of regions

Regions	Accuracy (%)	Error ratio (%)
Girne	87,57	12,43
Lefkoşa	87,10	12,90
Mağusa	85,50	14,50
Lapta	88,01	11,99

Supervised classification results reached over 85% user accuracy in all regions. Error rates are generally due to the fact that roofless buildings and vacant lands give similar reflectance values, and the mixing of agricultural lands and forest areas that border each other. Reaching a similar accuracy value in images of a region from all years allows accurate evaluation of LULC change and especially the spread of urbanization. In this context, each region has been examined separately and is presented below as Girne Region, Lefkoşa Region, Mağusa Region and Lapta Region.

3.1.1. Girne region

The urban settlement of Girne District, which has a coast to the Mediterranean, generally spreads in an east-west direction along the coastline. Agricultural areas have a fragmented and scattered appearance within the urban settlement. Urban settlement and agricultural areas are surrounded by forest class, and it is understood that urbanization has spread to the inner regions up to the slopes of the mountains. It is seen that urbanization is in an increasing trend every year from 2013 to 2021 (Figure 3).

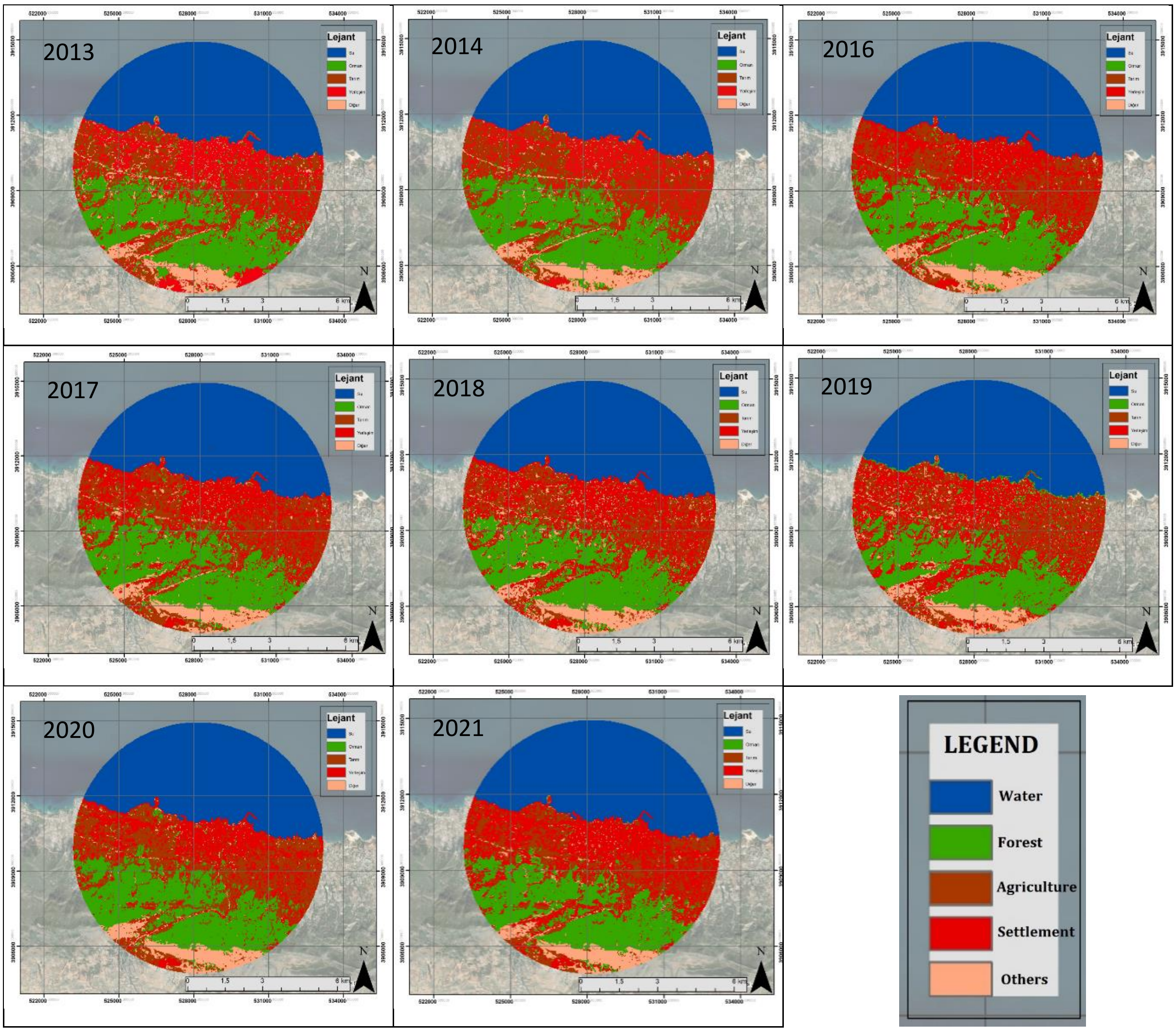


Figure 3. Classified images of Girne urban settlement by years

Girne urban settlement, 7800 ha of which was selected as the study area, showed a steady increase in the classified residential areas from 1186 ha in 2013 to 1964 ha in 2021. Although there is no significant increase or decrease in forest areas, it is seen that settlements increase mostly on agricultural areas and vacant lands (Table 3).

Table 3. Area distribution of LULC classes in Girne region by years (ha)

Girne	Water	Forest	Agriculture	Settlement	Others	Total
2013	2780	1661	1385	1186	788	7800
2014	2775	1799	1440	1402	385	7800
2016	2791	1729	1173	1568	538	7800
2017	2786	1750	1333	1584	347	7800
2018	2799	1706	1168	1676	451	7800
2019	2794	1632	1063	1754	557	7800
2020	2816	1659	1090	1885	350	7800
2021	2812	1653	1029	1964	342	7800

It is understood that some of the urban agricultural areas have been converted into settlements and that settlements are increasing, especially in coastal areas. Girne population increased by 10.7% between 2006-2011 and this rate will be 38.8% between 2011-2020 has been reported (DPÖ, 2020). This confirms that the increase in urbanization is due to the population growth and the need for housing.

3.1.2. Lefkoşa region

Lefkoşa, located in the central part of the island and the capital of the Turkish Republic of Northern Cyprus, is the most populous city in the region in terms of population. There are wetlands and fragmented forest areas in the city. The settlements are densely spread within the study borders (Figure 4).

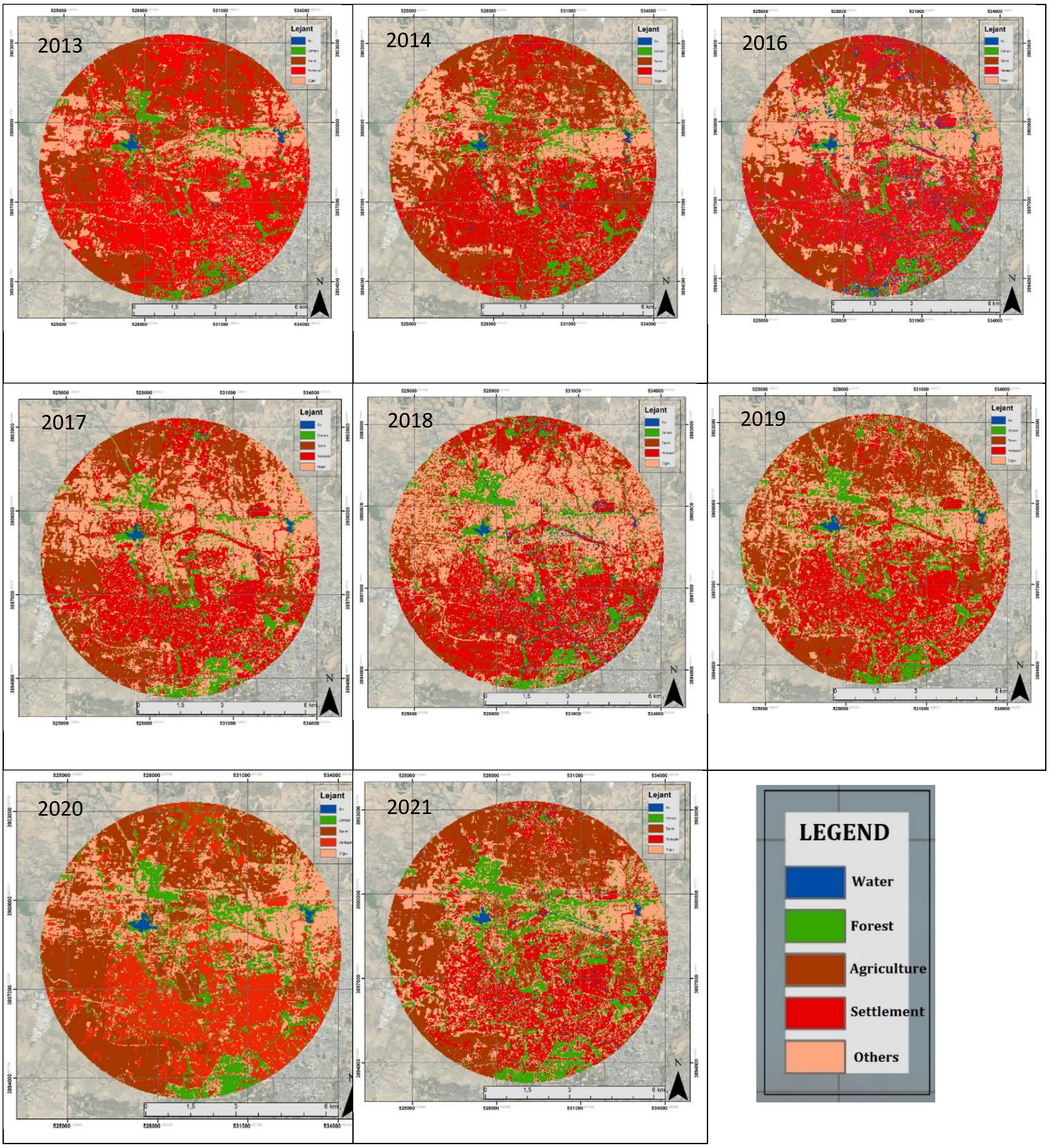


Figure 4. Classified images of Lefkoşa urban settlement by years

In the capital Lefkoşa, the settlement areas classified within the boundaries of the 7800 ha study area in 2013 were 2095 ha, reaching 3496 ha in 2021, an increase of approximately 67%. Likewise, an increase was observed in forest area and water surfaces within the city (Table 4). It is understood that the "KKTC Water Supply Project", which became operational in 2015, positively affected the green areas and water availability in the cities of the region.

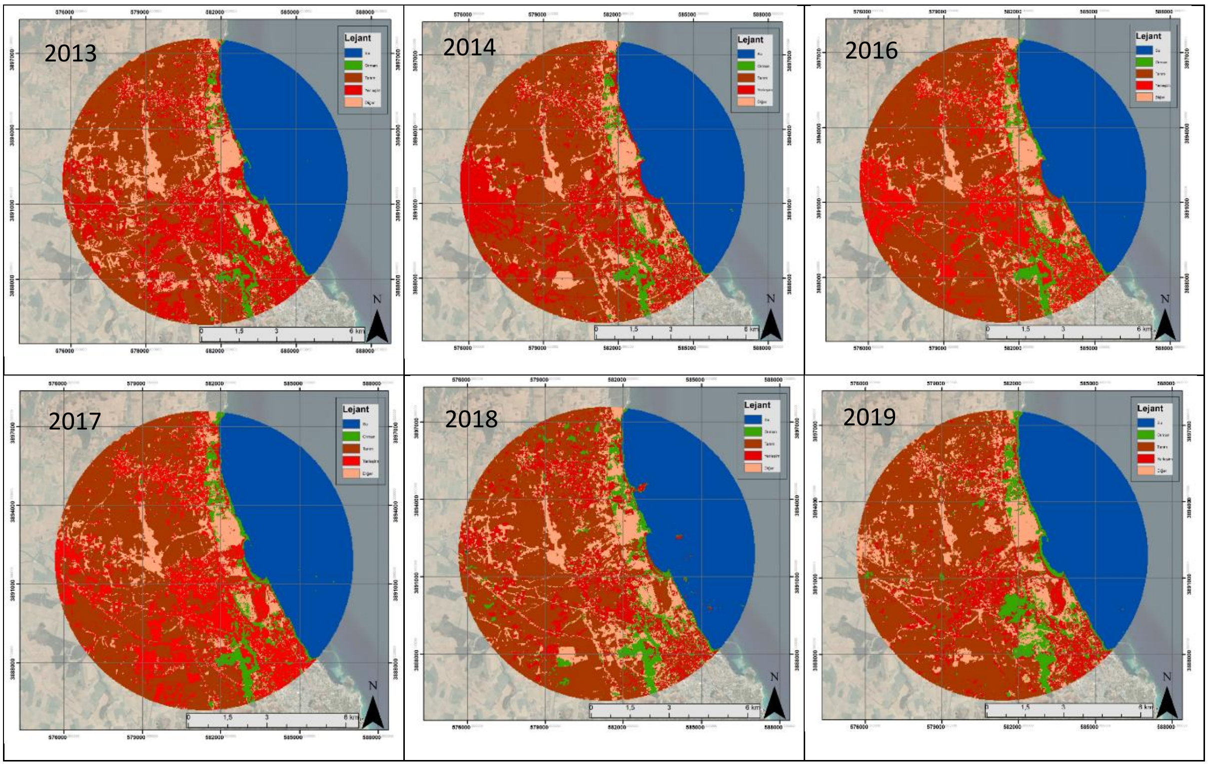
Table 4. Area distribution of LULC classes in Lefkoşa region by years (ha)

Lefkoşa	Water	Forest	Agriculture	Settlement	Others	Total
2013	45	618	2585	2095	2456	7800
2014	61	710	2467	2253	2309	7800
2016	55	603	2500	2295	2346	7800
2017	50	784	2325	2433	2208	7800
2018	43	974	2245	2692	1846	7800
2019	36	1082	2278	2725	1678	7800
2020	38	1019	2255	2832	1656	7800
2021	81	1249	1564	3496	1410	7800

According to DPÖ (2020), it was reported that there was a 32.1% increase in the projection population of Lefkoşa in 2020, which was based on the population censuses of 2006 and 2011. Lefkoşa's capital status, the increase in population over the years and the development of tourism activities have increased the need for housing, and the construction in the city center has developed on urban agricultural lands. The results obtained show that vacant lands in the city are being replaced by residences.

3.1.3. Mağusa region

In Mağusa, which is one of the most important port cities of the KKTC and the Mediterranean and also an important tourism and education center, settlements lie along the coast and spread towards the inner regions due to the suitable land structure. In the 2011 image, it is understood that the building density is distributed in the north-south direction of the city, and in 2023, this density has spread and developed significantly towards the western part (Figure 5).



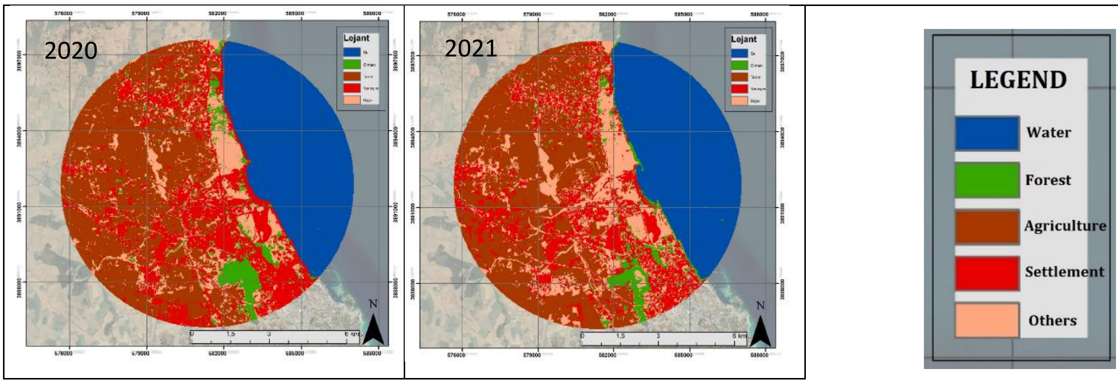


Figure 5. Classified images of Mağusa urban settlement by years

In Mağusa, which is a tourism and port city, the residential areas classified within the boundaries of the study area in 2013 were 1194 ha, reaching 2191 ha in 2021, an increase of approximately 83%. Vacant lands within the city have shrunk under the pressure of urbanization, and the unsloping land structure has been effective in the speed of urbanization. It is understood that tourism construction has increased along the coastal area and the structures have spread throughout the city center (Table 5).

Table 5. Area distribution of LULC classes in Mağusa region by years (ha)

Mağusa	Water	Forest	Agriculture	Settlement	Others	Total
2013	2837	318	3912	1194	1740	10000
2014	2841	366	3893	1274	1626	10000
2016	2837	447	3850	1747	1119	10000
2017	2835	467	3841	1767	1090	10000
2018	2818	571	3752	1878	981	10000
2019	2812	648	3625	1983	933	10000
2020	2835	408	3783	2117	857	10000
2021	2822	369	3648	2191	970	10000

According to DPÖ (2020), it was reported that there was a 36.5% increase in the projection population of Mağusa between 2011-2020. The partial decrease in urban agricultural areas, the stability of the forest class within the city and the approximately 79% decrease in vacant lands in an 8-year period show that the urbanization pressure is developing in this direction.

3.1.4. Lapta region

Located in the Girne region of KKTC and on the seashore, Lapta is a tourism region that serves the tourism sector 12 months a year. Many tourism facilities are located in this region. In addition to the local population, a significant proportion of British and German populations reside in this region. It is mostly covered with tourism facilities in the coastal region, urban settlements with secondary residences in the inner parts, and forest areas towards the slopes of the mountains (Figure 6). The fact that the Girne-Güzelyurt highway passes through this region has caused the settlement density to concentrate around this highway next to the coastline.

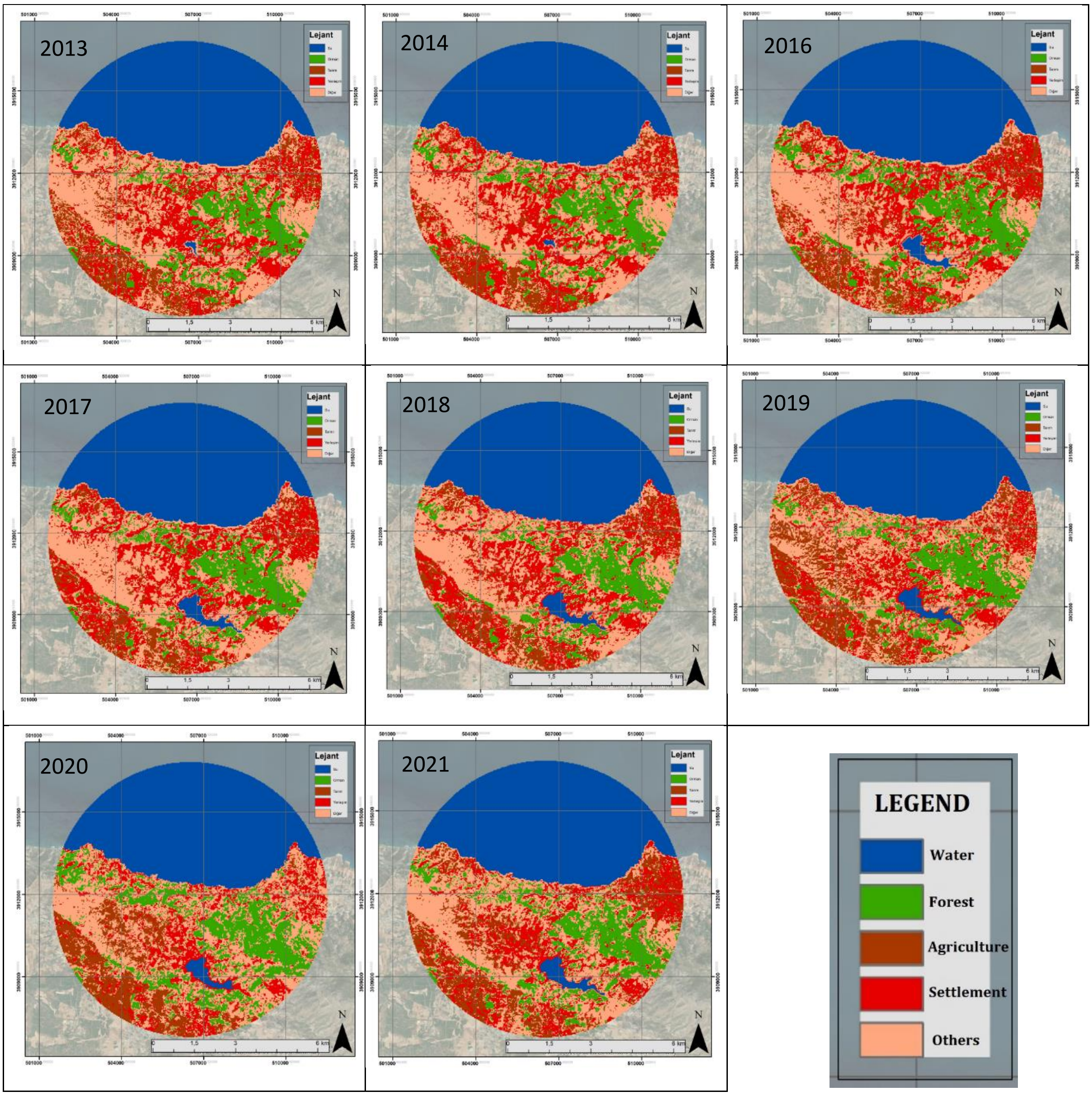


Figure 6. Classified images of Lapta urban settlement by years

Lapta, a tourist town, is more advantageous than other regions in the study in terms of urban forest areas. While the residential areas classified in 2013 were 1110 ha, they reached 1483 ha in 2021, an increase of approximately 34% (Table 6). Geçitköy Dam is located in this region and this supports agricultural activities and irrigation systems in the region. The increase in water surfaces is due to the increase in the amount of water in the Geçitköy Dam with the KKTC Water Supply Project, which came into operation in 2015.

Table 6. Area distribution of LULC classes in Lapta region by years (ha)

Lapta	Water	Forest	Agriculture	Settlement	Others	Total
2013	2830	777	672	1110	2411	7800
2014	2844	872	650	1146	2888	7800
2016	2886	971	620	1183	2140	7800
2017	2914	857	608	1767	1346	7800
2018	2906	817	613	1358	2016	7800
2019	2906	894	638	1394	1967	7800
2020	2919	880	624	1426	1951	7800
2021	2898	866	612	1483	1941	7800

According to DPÖ (2020), it was reported that there was a 23.7% increase in the projection population of Lapta between 2011-2020. This increase is parallel to the 34% increase in urban areas within the scope of the study. Especially with the introduction of the water supply project, an increase in forest areas has been observed since 2016, and settlements have generally spread over vacant lands and agricultural areas.

3.1.5. Statistical analysis of urban change and future projection

In this study conducted specifically for 4 important regions of Northern Cyprus, the LULC change between 2013 and 2021 was determined and this change was calculated in area and percentage. From these change data, regression analysis was applied for the settlement class and correlation curves were created. The mathematical relationship between two variables was produced by "Regression Analysis", and the direction and degree of the relationship was produced by "Correlation Analysis" (Figure 7). Linear regression analysis was used because there is a linear relationship between two sets of numbers (location and time) that may be related to each other. Linear regression, which was applied to create a future projection about the relationship between time, an independent variable, and location, a dependent variable, was preferred because it is the model that best represents the data produced.

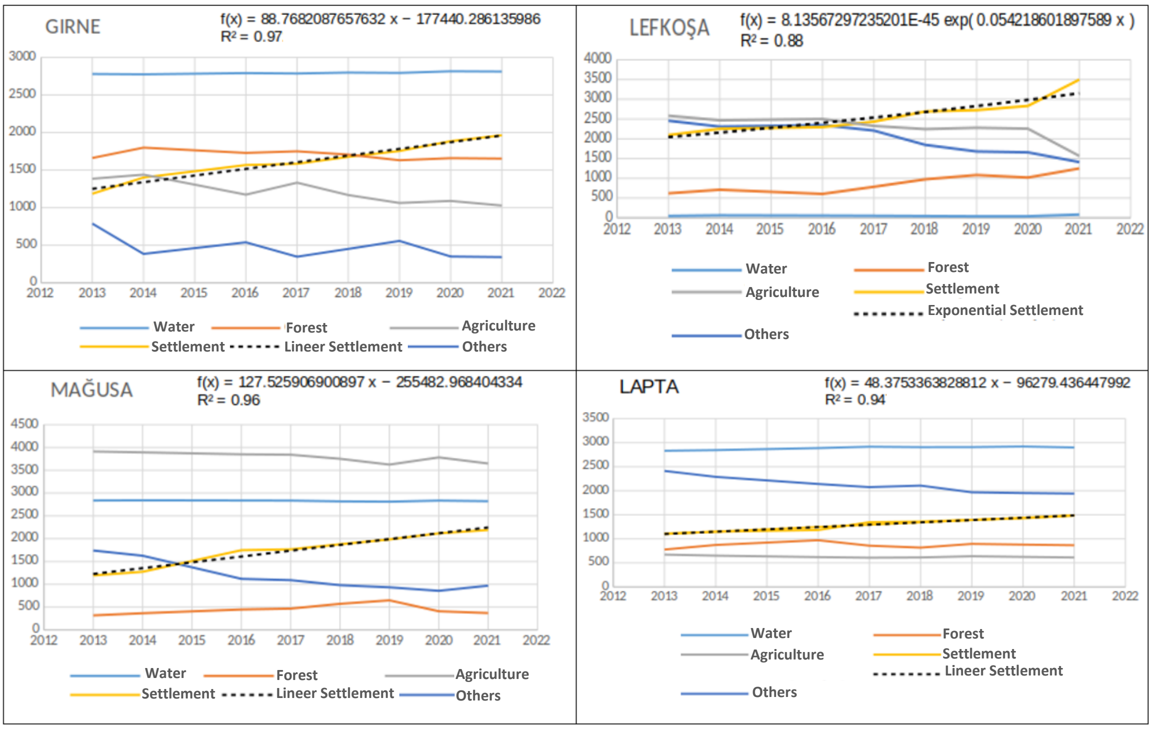


Figure 7. Correlation curves for regions

The r^2 values obtained from the regression analysis are close to 1, as seen in the figure above. The positive linear relationship between settlement and time confirms that settlements are increasing year by year. Within the scope of statistical analysis, a forecast table for 2030-2040 and 2050 was created for the areal values of the increases in the settlements of 4 regions (Table 7).

Table 7. Future projection of areal changes of settlements (ha)

Years	Girne	Lefkoşa	Mağusa	Lapta
2013	1249.98	1934.57	1215.41	1099.88
2021	1960.13	2984.65	233597	1486.88
2030	2759.04	4861.19	3484.10	1922.25
2040	3646.72	8358.53	4759.80	2406.00
2050	4534.40	14372.01	6035.50	2889.75

According to Table 7, when looking at the spread of settlement areas of the regions in 2050, it is understood that the urban settlement spread of the capital Lefkoşa is quite large. It is seen that there may be a large increase if there is no intervention within the current plans and developments. Nicosia is followed by Mağusa, Girne and Lapta, respectively. It is understood that the current acceleration of settlement expansion is quite rapid for Northern Cyprus, an island country.

3.2.Discussions

This study, which covers the important settlement centers in terms of tourism and trade in the northern part of Cyprus, the 3rd largest island of the Mediterranean, aims to determine the change of LULC in central settlements from 2013 to 2021 and to estimate the possible projection for the future based on this change. In this context, meaningful results were obtained in line with the data produced. According to these results, it is estimated that the central settlements of Girne will cover an area of approximately 4534 ha in 2050, the central settlements of Lefkoşa will cover 14372 ha, Mağusa 6035 ha and Lapta 2890 ha. In the case of Girne, while urban expansion was at a minimum level before 2002, it was reported that a serious urban expansion started with the UN Peace Plan of 2002 and there were significant increases in the construction sector (Oktay & Bala, 2015). The projection produced shows that urban sprawl will increase with population growth. It was predicted that the expansion in Girne would increase along the coast, creating pressure on the natural structure (Warner, 1999). Lefkoşa, which is the trade and economic center of the region, has increased greatly both in terms of population and urban expansion, and it has been reported that the old buildings in the city were demolished and replaced with more modern and tall buildings (Oktay, 2005). According to the results of the LULC between 2013 and 2021, it was observed that construction increased. Nikoofam & Mobaraki (2020) emphasized that Mağusa is facing rapid and unplanned urbanization and stated that the quality of life in the region will be affected by this inappropriate settlement spread. Kara & Dolatlı (2021), with their sustainable urban development scenarios studies covering the years 2002–2011, revealed that the Mağusa region will move away from sustainability if no precautions are taken. As a matter of fact, the LULC change covering the years 2013-2021 confirms that this region is under urban expansion pressure. The Lapta region, on the other hand, stands out as a tourism resort where urban expansion is increasing, especially under the pressure of secondary residences (Wagner, 1999b).

In all four regions discussed in the study, urban expansion develops on green areas, productive agricultural areas and vacant lands. In particular, the potential to transform urban open green space into residential areas puts urban sustainability under pressure. In order to benefit from the various ecological and functional features of urban green spaces such as carbon storage, CO_2 emission reduction, sustainable biodiversity etc., the growth of urbanization on these areas should be limited and directed (Selim et al., 2015; Tuğluer & Çakır, 2019; Gül et al., 2021). The resilience of cities can be strengthened if there are sufficient open and green spaces and these areas are integrated into the daily life of the society (Şahin et al., 2024). In order to ensure urban sustainability, spatial-functional developments and future conservation-development potentials need to be taken into account. In addition, it is necessary to protect the original local values and to consider holistic approaches with the historical information of the cities and their surroundings (Ardahanlıoğlu et al., 2020; Erdoğan and Öztürk, 2019). In order to direct and classify the spread of cities in urban planning, urban green spaces should be included in the green infrastructure system and a holistic planning approach should be applied (Gül et al., 2020; Selim, 2021). The increase in urbanization spread, especially in coastal areas, is a result of transportation routes built with hotels and secondary residences in these regions (Oni, 2013; Fuladlu et al., 2021). These activities lead to the transformation of coastal landforms, flora and fauna (Oni, 2013), and cause the deterioration of micro ecosystems in the coastal area due to economic concerns. The absence of a regional master plan and weak zoning regulations (Fuladlu et al., 2021) have led to an increase in unplanned urban sprawl. Past and current studies on the region support the LULC change produced at the end of this study and confirm that urban sprawl has increased significantly (Oktay, 2005; Oktay & Conteh, 2007; Fuladlu et al., 2018; Kara & Dolatlı, 2021; Geddes et al. , 2023).

4. Conclusion and Suggestions

The increase in population causes an increase in the demand for settlements. Therefore, the urban pattern spreads horizontally and vertically to respond to this population. Urban sprawl is a complex phenomenon that varies from place to place and has a detrimental impact on the sustainability of urban growth. Researchers also explore in detail the monitoring of LULC change in urban sprawl, developing and implementing a number of studies and methodologies. These methods are mostly based on measurements and analysis with tools such as RS and GIS. This study focuses on monitoring the LULC change in 4 important settlement centers in Northern Cyprus, detecting urban sprawl and estimating the future projection by using RS and GIS technologies. According to the research results, settlements have increased significantly in the relevant field of study between the last years 2013-2021. An increase of 65.59% in the Girne region, 33.60% in the Lapta region, 66.87% in the Lefkoşa region and 83.50% in the Mağusa region was detected. This increase is mostly concentrated on agricultural areas, green areas and vacant lands within the city. It is understood from the future projections that if there is no urban development action plan or zoning plan intervention that will allow controlled development, this urban expansion will increase much faster in 2050 and may reach irreparable levels. Since the obtained LULC change covers only the selected study area, this change should be developed to cover all Northern Cyprus settlements, especially in order to monitor urban development more accurately and take the necessary precautions. Additionally, in order to evaluate the different dimensions of LULC change, precise determinations must be made using satellite images at resolutions that will allow monitoring and evaluation analyzes from the regional scale to the neighborhood scale. It is necessary to monitor the development and change of the entire region, especially since the 2000s, and to determine this change with RS and GIS techniques. In this context, sustainable spatial plans must be urgently produced, implemented, and supervised. Only in this way can unplanned development that is likely to be encountered in the future be prevented. In addition, according to the results obtained within the scope of the study, the LULC change in the relevant years mostly showed a tendency towards construction, and this construction created pressure on the natural structure of the island.

The GIS-based methodology preferred in the study can also be applied to other settlements in the region to determine the potential urban sprawl trend. The results of the study can be used by researchers, policy makers, and decision makers to guide the creation of spatial planning strategies. In addition, with the projection created for the future, the effects of potential environmental problems can be reduced and opportunities for sustainable development can be created. This research is one of the most comprehensive studies to date, estimating the future projection of urban sprawl by monitoring the LULC change of 4 large urban settlements in Northern Cyprus.

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Author Contribution and Conflict of Interest Declaration Information

All authors contributed equally to the article. Material preparation, data collection and analysis were performed by [Çiğdem Esendağlı] and [Serdar Selim]. The first draft of the manuscript was written by [Serdar Selim] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript. There is no conflict of interest.

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