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Evaluating the Urban Expansion of Silifke (Mersin) District with a Focus on Green Spaces: The 2050 Projection

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Abstract

The aim of this study is to provide a framework for spatial planning aimed at creating resilient cities through land change trends from the past to the future (1990-2020-2050). Additionally, it aims to guide planning strategies by highlighting the current and future status of urban green areas. In this context, the trends for 2050 were evaluated in terms of green area requirements, using the Silifke example. Most of the development areas in Adana-Mersin RegionalPlan are expected to be built. All of these areas consist of agricultural (202 ha) and bare lands (46 ha). It is estimated that by 2050, the populations of Silifke-Taşucu-Kum Neighborhood will be 102,923 and 24,815, respectively. According to spatial planning regulations, the minimum green area within the 2050 urban plan boundaries should be 1,029,230 m² and 248,150 m², respectively. Consequently, decision-makers are expected to determine green area strategies guided by these findings in spatial planning studies.

Keywords: *Land change trend, urbanisation, urban ecosystem services, urban green space.*

Silifke (Mersin) İlçesi Kentsel Yayılımının Yeşil Alanlar Odağında Değerlendirilmesi: 2050 Yılı Projeksiyonu

Öz

Bu çalışmanın amacı, geçmişten geleceğe (1990-2020-2050) uzanan arazi değişimi eğilimleri ile dirençli kentler yaratmayı amaçlayan mekânsal planlama çalışmalarına bir çerçeve sunmaktır. Ayrıca kentsel ekosistem hizmetleri sağlayan kentsel yeşil alanların mevcut ve gelecekteki durumu ortaya konarak sonuçların mekânsal planlama stratejilerine rehberlik etmesi amaçlanmaktadır. Bu kapsamda, Silifke ilçesi örneğinde, 2050 yılı arazi değişimi eğilimleri ortaya konarak sonuçlar kentsel yeşil alan ihtiyaçları açısından değerlendirilmiştir. Adana-Mersin Çevre Düzeni Planında belirtilen gelişim alanlarının çoğunda yapılaşma beklendiği görülmüştür. Bu alanların tamamı sırasıyla tarımsal alanlardan (202 ha) ve çıplak alanlardan (46 ha) oluşmaktadır. 2050 yılı nüfusuna göre Silifke ve Taşucu-Kum Mahallesi imar sınırlarındaki yerleşimlerde sırasıyla yaklaşık 102.923 ve 24.815 kişinin bulunacağı tahmin edilmektedir. Mekânsal plan mevzuatına göre 2050 yılı imar planı sınırlarındaki kentsel yeşil alan miktarının sırasıyla en az 1.029.230m² ve 248.150 m² olması gerekmektedir. Sonuç olarak, mekânsal planlama çalışmalarını yapacak karar vericilerin, kentsel yeşil alan stratejilerini bu bulgular rehberliğinde belirlemeleri beklenmektedir.

Anahtar kelimeler: *Arazi değişim eğilimi, kentleşme, kentsel ekosistem servisleri, kentsel yeşil alan.*

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1. Introduction

The current era, known as the "Anthropocene," is also recognized as the "Urban Age," in which humans are considered a dominant geological force. With more than half of humanity now residing in towns and cities, this proportion is expected to exceed 60% by 2030 (Elmqvist et al., 2013). The quality of urban environments, comprising both natural and cultural components, is estimated to determine the quality of life for approximately five billion people by 2030 (Firehock & Walker, 2015). Urban areas are among the most affected by environmental issues stemming from extreme weather events, prominent indicators of global climate change. Challenges such as urban heat islands, unsustainable resource use, inadequate planning, and food and water scarcity are increasingly emerging due to urbanization. Additionally, factors such as population growth, vertical and horizontal urbanization, the inadequacy of open and green spaces in terms of both quality and quantity, environmental pollution, noise pollution, incorrect land use planning, and management policies have contributed to unhealthy and unfavourable urban development trends (Akın & Gül, 2020). Therefore, a key challenge for contemporary societies will be the creation of healthy and livable urban spaces.

Land change analysis is crucial for understanding how human activities and natural processes alter landscapes over time. These changes enable researchers to assess environmental impacts, biodiversity loss, and habitat fragmentation. Such analysis informs decisions regarding land management, urban planning, and conservation efforts, helping to mitigate negative effects on ecosystems and maintain ecological balance. It also aids in monitoring climate change impacts and supports sustainable development initiatives (Lambin et al., 2003; Alphan & Derse, 2013; Alphan et al., 2022).

Understanding land change trends along with urban development trends is crucial for effective land management, sustainable urban planning, and environmental conservation. These trends offer valuable insights into how human activities shape landscapes, influence biodiversity, and impact ecosystems. Studying these trends enables policymakers, urban planners, and environmentalists to make informed decisions to address challenges such as habitat loss, urban sprawl, and environmental degradation. Analyzing land change trends allows us to assess the spatial patterns of urbanization, agricultural expansion, and deforestation. This information helps identify areas at risk of habitat fragmentation, loss of biodiversity, and ecosystem degradation (Lambin et al., 2003).

Land change trends and urban development models offer insights into the drivers of environmental change. Various urban models, including compact and sprawled cities, have varying impacts on transportation systems, energy consumption, air quality, and public health. Studying these models enables policymakers to design urban areas fostering social equity, economic prosperity, and environmental sustainability. Furthermore, land change trends and urban development models offer insights into the drivers of environmental change. This knowledge enables stakeholders to develop strategies for mitigating negative impacts and enhancing ecosystem services (Seto et al., 2012).

In conclusion, the study of land change trends and urban development models is essential for promoting sustainable land management, resilient urban planning, and environmental conservation. The quality of life in urban areas correlates with how urban landscapes, which serve as the primary determinants of essential elements such as clean air, water, and food, are managed (Firehock & Walker, 2015). However, societies often overlook the significance of natural resources such as clean air, water, and agricultural lands in sustaining life. Urbanization also exerts pressure on ecosystems, leading to increased sensitivity to invasive species, loss and fragmentation of local habitats, and changes in the quantity, timing, and quality of precipitation (Mell, 2010).

The main focus of ecosystem service studies is the benefits people derive from nature. Thus, in these studies, the sustainability of natural areas is ensured by considering human activities in conjunction with maintaining them. The benefits that humans derive from ecosystems' functioning are collectively referred to as "Ecosystem Services" (MEA, 2005). These services include provisioning services such as food and water supply, regulating services that affect climate, diseases, and water quality, cultural services providing spiritual and cultural benefits, and supporting services maintaining conditions for life such as soil formation, photosynthesis, and nutrient cycling (MEA, 2003). Progress towards human well-being and sustainable development depends critically on improving the management of these services to conserve and sustainably utilize ecosystems (MEA, 2003). Terms like "urban ecosystems" are often used in studies such as Action 5 and MAES (2015) to represent areas where the majority of the human population resides. These ecosystems, which host important areas for synanthropic species associated with urban living areas, significantly influence other ecosystem types and include urban and industrial areas, commercial and transportation areas, urban green spaces, mines, landfills, and construction areas (MAES, 2016). Various titles, such as Urban Green Infrastructure, Urban Green, Green Urban Spaces, or Urban Green Spaces, are used to specify "Urban Ecosystems," although these terms sometimes refer to the same concept but target different audiences (MAES, 2015).

For instance, under the heading of Urban Green Spaces, numerous ecosystem services are provided for urban ecosystems, including reducing the heat island effect, storing carbon dioxide, enriching soil, providing food and habitat for wildlife, preventing stormwater runoff, and offering recreational and educational opportunities to users (Hepcan & Hepcan, 2017). While it may not always be possible to make clear distinctions among these concepts, it is essential to remember that urban ecosystems, green urban areas, or urban green spaces constitute a structural component, whereas green infrastructure implies a functional implication (MAES, 2015). Green Infrastructure is defined as a network of high-quality green spaces and other environmental features strategically planned to support human well-being and quality of life (EEA, 2014; LI, 2009; Benedict & McMahon, 2002; Ahern, 2007; EC, 2013). When developed and maintained systematically as part of rational development and conservation planning, Green Infrastructure has the potential to serve as a good model for a city's land use and spatial development (Chang et al., 2012).

Due to its coastal location on the Mediterranean, Silifke is under pressure from various sectors such as tourism and construction, transportation with ports, and agriculture, particularly the fertile agricultural lands in the Göksu Delta. Especially along the coast, it hosts numerous species and is home to internationally protected wetlands such as the Göksu Special Protection Area. Given the presence of many natural features, continuous monitoring of these areas' changes and tracking of their potential implications are necessary. This is essential for understanding the consequences of these changes and ensuring the preservation of the region's ecological balance and biodiversity.

The aim of this study is to delineate land change trends toward urban areas, specifically in Silifke (Mersin), from the past to the present (between 1990-2020) and from the present to the future (to 2050), in order to create more resilient cities against the impacts of global climate change. Thus, it will provide a framework for future research. Furthermore, the aim is to guide future studies by delineating the current and future status of urban green areas, the fundamental component of urban green infrastructure providing urban ecosystem services, along with the current and future state of the population.

In this context, the study area boundaries were defined to encompass the central settlements of Silifke through a micro-watershed study. The areas to be developed by the year 2050 were determined through a land change trend analysis, considering the existing urban development zones in the 1/100,000 scale Adana-Mersin Regional Plan. Subsequently, the population projection for the year 2050 was determined for settlements within the zoning planning boundaries of Silifke Center and Taşucu - Kum neighborhood. The urban green space, which constitutes a fundamental component of urban green infrastructure providing urban ecosystem services, requirements of the developing areas, were evaluated in the context of the population status projected for the year 2050. Furthermore, the findings of a study conducted by Derse (2023) concerning the study area (urban green areas and population status in 2020), were re-evaluated in conjunction with the results of this study for the year 2050.

2. Material and Method

2.1. Material

2.1.1. Study area

A micro-watershed study was conducted to define the research area boundary using the boundaries of the Silifke district located within the Eastern Mediterranean Basin Kayraktepe Sub-Basin. For this study, ALOS World 3D data with a spatial resolution of 30 m was utilized. As a result of the micro-watershed study, the boundaries of the research area were determined. The study area is located within the borders of Silifke (Mersin) district on the Mediterranean coast of Türkiye (Figure 1).

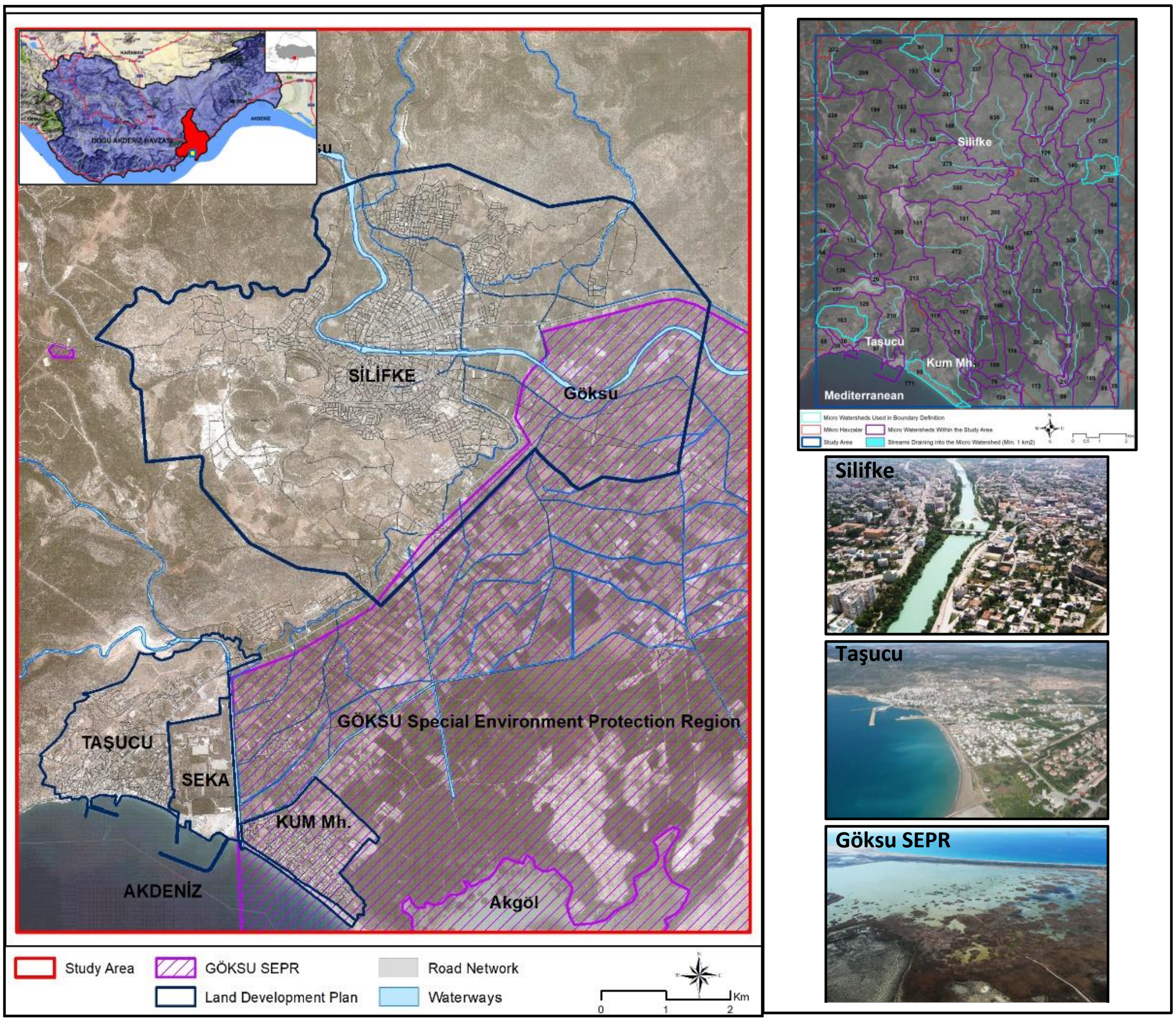


Figure 1. Location of the study area in Turkiye (Photos SB, 2019)

The study area has a total size of 15.845 ha. The Mediterranean Sea is located on the southern border of the study area. The study area is separated from the Central Anatolia by the Taurus Mountains in the north. While the average annual temperature of the area is 19,2 °C, the average temperature in the winter varies between 14,9-23,4°C and the total annual rainfall of the area is approximately 56 mm (MGM, 2022). The study area has a typical Mediterranean climate and the rainiest month is December and the driest month is August. One of the important geomorphological units in the study area is valleys. Mediterranean climate characteristics extend from these valleys extending from south to north to the interior of the Taurus Mountains. Rivers are buried in these deep valleys. Göksu River is one of these rivers Göksu Delta (Silifke Plain), which has fertile agricultural lands, is located on the slopes of the valleys through which the Göksu River flows. Göksu Delta also has Special Environmental Protection Region (SEPR) status and is a Ramsar site protected by the international agreement to which Turkey is a party. Silifke district, to which the study area is located, is surrounded by Erdemli in the east, Mut and Gülnar districts in the west, Karaman province in the north and the Mediterranean Sea in the south. Founded on both banks of the Göksu River, Silifke is at the junction of the highway network connecting Southeastern Anatolia, Eastern and Western Mediterranean, and Central and Western Anatolia, and is 80 km away from Mersin.

The altitudes within the borders of Silifke district, which covers the study area, vary between 0 and 2509 m. While gently sloping terrain is rarely encountered along the coastal zone, the topography becomes more dynamic towards the north, characterized by valleys and steep slopes with high inclinations. The predominant land use within the study area is agricultural activities, constituting the most significant aspect of the working landscape. Intensive agricultural activities are predominantly conducted in the expansive plains of the Göksu Delta (Silifke Plain), particularly along the coastal zone, characterized by extensive flatlands. The Göksu Delta (Silifke Plain) is divided into eastern and western shores by the Göksu River. The soil structure and climate, which play a role in determining agricultural potential, lead to the diversification of production patterns and an increase in production quantity. The structure of the Göksu Delta enables the cultivation of both temperate climate and warm climate crops, thereby creating a highly diverse agricultural landscape, with the potential for the cultivation of a rich variety of crops.

2.1.2. Land use and land cover (LUC) maps

LUC maps are indispensable tools for assessing landscape changes and urbanization patterns. They aid in environmental planning, resource management, and policy formulation (USGS, 2006; EEA, 2018). CORINE LUC maps are vital tools for understanding LUC dynamics. They offer valuable insights into environmental changes, facilitating sustainable land management and policy development (EEA, 2019).

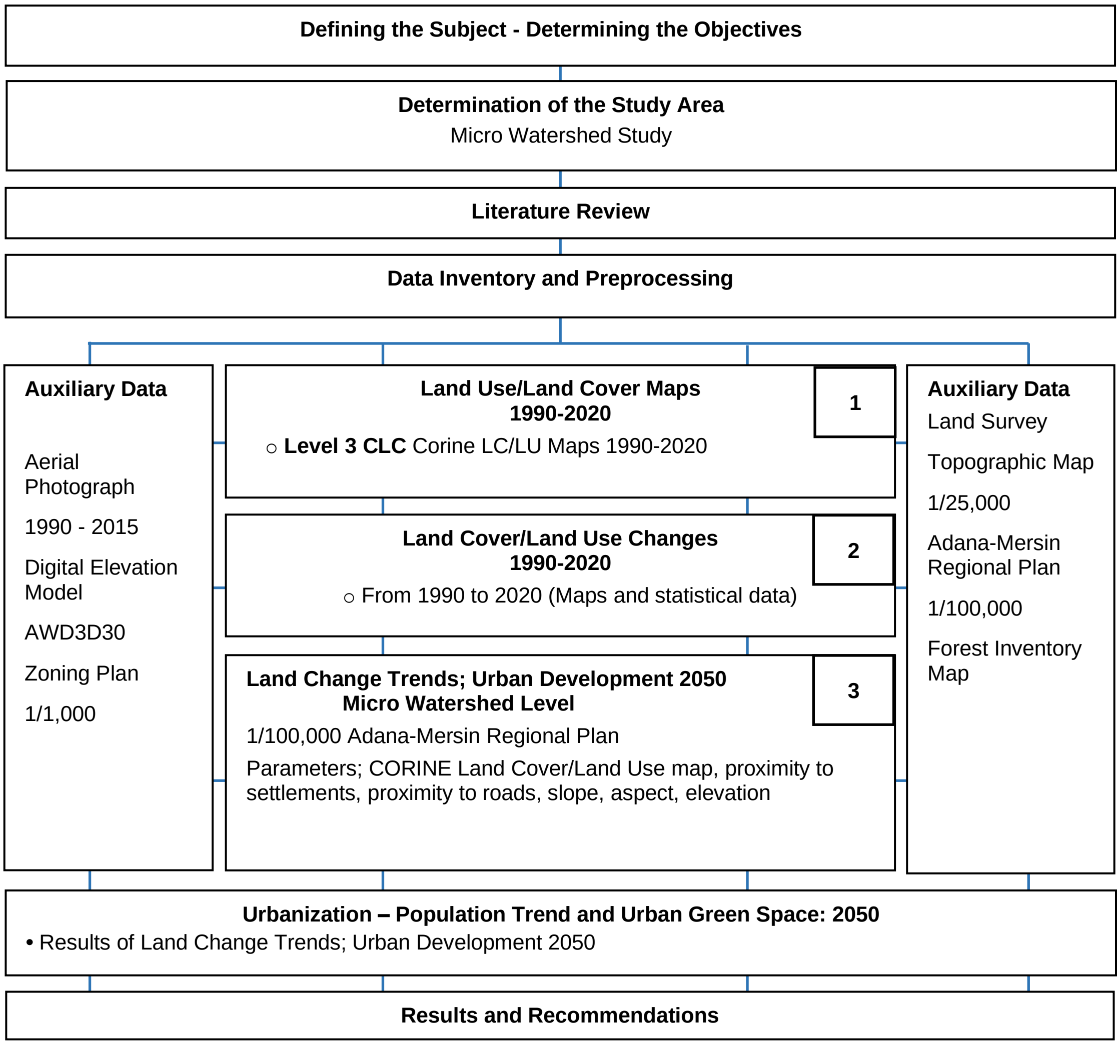
The CLC classification system is a standardized framework developed by the European Environment Agency (EEA) for mapping LUC across Europe. It categorizes land into 3 levels and 44 classes such as forests, urban areas, wetlands, and agricultural land, providing valuable data for environmental monitoring and policy-making (EEA, 2017). CLC 1990 and 2020 LUC maps, which are the main component of this study, were produced by revising the data obtained from the Copernicus Land Monitoring Service (CLC 1990 and CLC 2018) (LMS, 2020). The LUC maps were revised based on aerial photographs taken in 1990 and 2015, acquired for this study. Additionally, the 2020 LUC map was rerevised based on current status information, including data from other supplementary sources such as Google Earth, forest inventory maps, topographic maps, and field surveys.

The LUC maps for 1990 and 2020 were included in the land change model to determine the land change trends for the research area in 2050.

2.2. Method

As mentioned above, the boundaries of the research area were determined on the basis of the micro-watershed study. Considering the defined research area boundary, subsequent studies were conducted at both the micro-watershed level and the scale of urban planning to ensure compatibility with the scales of the research. After defining the boundaries of the research area, the studies were primarily divided into two main parts. In the first stage, LUC changes occurring between 1990 and 2020 were identified. Based on these changes, along with other parameters, land change trends for urbanization in 2050 were determined. In the second stage, land change trends in the study area were re-evaluated at the existing urban planning level. Thus, the status of urban development areas within the relevant urban planning boundaries outlined in the Adana-Mersin Regional Plan for 2050 was elucidated. Additionally, the population projection for 2050 was determined, and an assessment was conducted regarding the urban green space needs of these areas. The basis of this study is formed by urban areas. Therefore, the study was conducted taking spatial plans into account. Zoning boundaries were obtained from Silifke Municipality as three separate data sets (Silifke Center and Taşucu - Kum Neighborhood). In this study, zoning boundaries are discussed in two parts. These are the Silifke Center zoning boundary and the Taşucu – Kum Neighborhood zoning boundary located on the coastline. The purpose of this study is to make an evaluation based on the results of the study using the current spatial plans and to integrate these results into the plans. In other words, in this study, no evaluation has been made on the correctness or incorrectness of the plans or decisions produced and implemented so far. In terms of the essence of this study, an evaluation was made based on the current situation. As a result, it has been revealed how the urban development trend within the zoning boundaries of Silifke and Taşucu-Kum Neighborhood will be in 2050. Based on these results, evaluations were made and suggestions were presented. The flow diagram is given in Table 1.

Table 1. Flow diagram of the study



2.2.1. Land change trend

Land change trend analysis is vital for understanding patterns of urbanization, deforestation, and habitat loss. It helps identify drivers of landscape change and informs sustainable land management practices (Lambin et al., 2003). "Land Change Trend" method analyzes historical LUC changes to identify trends and drivers of landscape transformation. It aids in land management and conservation planning (TerrSet, 2016). This study elucidates land change trends for the study area in terms of future urban development through a 2050 projection, aiming to delineate prospective land transformation tendencies. In this context, using the Land Change Modeler module of the TerrSet software, the changes in LUC between the years 1990 and 2020 within the micro-watershed level of the study area have been identified. The process of change prediction within the Land Change Modeler progresses sequentially through change analysis, transition potential modeling, and ultimately change prediction, constituting a step-by-step and experimentally guided procedure.

Projecting future scenarios for land change prediction relies on historical changes observed in LUC maps over the period from the first to the second time step (TerrSet, 2016). The initial step in the change prediction process consists of change analysis. The Transition Potentials tab categorizes transitions between two LUC maps into a series of sub-models, each defined by a set of drivers or explanatory variables. The Change Prediction tab provides controls for a dynamic LUC change prediction process. Once the end date is determined, the amount of change at each transition is modeled either through a Markov Chain analysis or by determining a transition probability matrix from an external model (TerrSet, 2016).

3. Research Findings and Discussion

3.1. Land Change Trend for Urban Development: Projection 2050

Within the scope of spatial planning, projections made based on the current state are crucial tools for identifying potential disruptions or issues that may arise in the event of the continuity of ongoing processes, and for taking necessary actions against them.

In this section of the study, land change trends related to urban development in the research area for the year 2050 have been identified. Thus, by determining the direction and magnitude of changes, an assessment can be made based on the current situation. Additionally, population estimates for the year 2050 have been determined. This is because it is aimed to identify the green areas needed based on population estimates for the areas that will be urbanized by 2050.

In this context, LUC changes between the years 1990 and 2020 within the research area were determined using the Land Change Modeler module of the TerrSet software. Based on these changes and in conjunction with other parameters known to be significant for spatial development, land change trends for the year 2050 were delineated. LUC maps at Level 3 of the CLC classification system for the years 1990 and 2020 were prepared for use by cutting them according to the boundaries of the research area for the identification of changes between 1990 and 2020 (Figure 2 and Table 2).

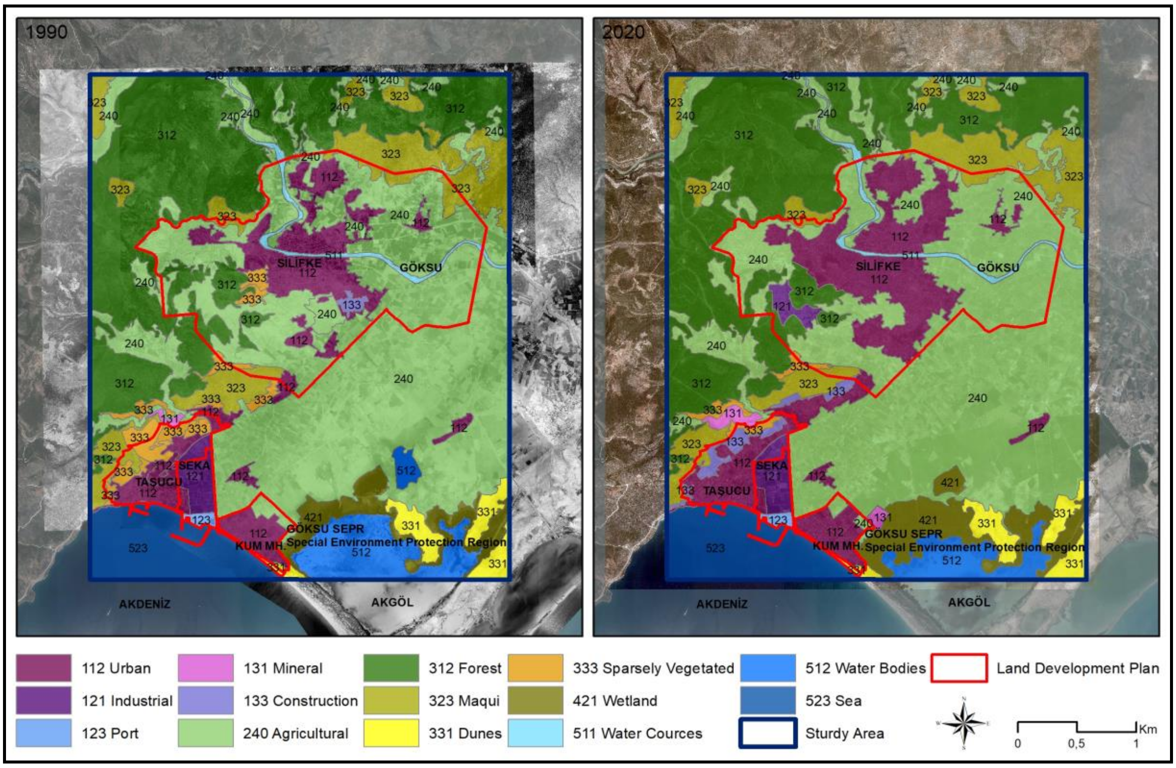


Figure 2. CLC LUC maps for the years 1990-2020

Table 2. Statistical information for the CLC LUC maps for the years 1990 and 2020

CLC	CLC Name	1990	2020	CLC	CLC Name	1990 (ha)	2020 (ha)
112	Urban Fabric	1362	1901	323	Maquis	1266	1140
121	Industrial Units	167	245	331	Dune	323	314
123	Port Areas	32	32	333	Sparsely Vegetated	349	96
131	Mineral Extracrion Site	19	75	421	Wetlands	448	629
133	Construction Sites	28	130	511	Water Cources	132	131
240	Agricultural Areaa	6589	6431	512	Water Bodies	656	364
312	Forest	3699	3583	523	Sea	775	774
					Total	15845	15845

3.1.1. Changes in LU/LC (CORINE LUC 3rd level) between 1990 and 2020

When examining the LUC maps at the micro-watershed level for the years 1990 and 2020, along with their associated statistical data, it is observed that urban areas have increased by approximately 600 hectares. Upon inspection of the LUC map for the year 2020, it is evident that a significant portion of this urban expansion is attributed to the enlargement of the Silifke urban center. Industrial areas, on the other hand, have experienced an increase of around 80 hectares from 1990 to 2020. The construction sites in the process of being developed have shown approximately a fivefold increase over the course of 30 years. Construction areas, which had an approximate spatial extent of 30 hectares in 1990, have expanded to 130 hectares by the year 2020. This situation presents very concrete indicators regarding the rate of increase in construction activities.

When examining the current situation in rural-inclined areas, it is observed that agricultural areas have decreased by approximately 150 hectares. Similarly, there is a decrease of approximately 120 hectares in forested and shrubland areas, which constitute natural and semi-natural areas. Bare areas, which had an approximate spatial extent of 350 hectares in 1990, have receded to approximately 100 hectares by 2020. One reason for the increase in wetlands is the transformation of the water surface, located southeast of the 1990 LUC map in a patchy shape, into a saline marshland classified under the wetlands class. The other reason is the expansion of reed beds, also classified under the wetlands class, on the shores of the lagoon within the Göksu SEPR. The decrease in water surfaces is again depends on the expansion of reed marsh areas in the Akgöl lagoon. In 1990, the size of the mining area located only north of the Taşucu settlement center was 19 hectares, whereas by 2020, the size of the mining areas increased fourfold to reach 75 hectares. This is due to both the expansion of the existing mining area and the opening of new mining areas in the Göksu SEPR for salt extraction purposes.

The 3. level CLC LUC map classes have been generalized for the land change trend study. Under the category of artificial areas, urban texture, industrial areas, construction sites, and port areas have been generalized as "urban." Water-related classes such as wetlands, waterways, and water surfaces have been generalized as "water." Additionally, changes occurring within the water class have been thoroughly examined, and the direction of changes at the subclass level is specified in the following section. Bare areas, dunes, shrubs, forests, agricultural areas, and mining sites have been considered as separate classes. As a result of the generalization, a total of 8 classes have been identified, and these classes have been used to determine land change trends for the research area with the 2050 projection. In change studies, determining not only the magnitude but also the direction of changes is of great importance. This enables a concrete demonstration of the quantities and orientations of changes, facilitating evaluation regarding transitions between classes. Consequently, such assessments lay the groundwork for actions to be taken in line with identified needs. The LUC changes between 1990 and 2020 are presented in Table 3.

Table 3. Direction and statistical information of changes between 1990 and 2020

CLC Code			
1990	**2020**	**LUC Change Directions from 1990 to 2020**	**Amount of Change (ha)**
240	112	From Agricultural to Urban	431
312	112	From Forest to Urban	19
323	112	From Maquis to Urban	75
333	112	From Sparsely Vegetated to Urban	191
240	131	From Agricultural to Mineral Extracrion	28
421	131	From Wetland to Mineral Extraction	15
312	240	From Forest to Agricultural	123
323	240	From Maquis to Agricultural	75
331	240	From Dune to to Agricultural	11
421	240	From Wetland to Agricultural	94
333	312	From Sparsely Vegetated to Forest	26
333	323	From Sparsely Vegetated to Maquis	34
		Total	1122

Upon examining the direction and statistical data provided in Table 3 regarding the changes between 1990 and 2020, it is evident that the predominant trend has been towards urban areas. A significant area totaling 993 hectares, comprising 431 hectares of agricultural land, 191 hectares of bare land, 75 hectares of shrubland, and 19 hectares of forested area, has transitioned into urban areas over the 30-year period from 1990 to 2020. During this timeframe, approximately 30 hectares of agricultural land have been converted into mining areas, resulting in the expansion of the existing mining site. The areas transformed from wetlands to mining areas constitute locations where salt production takes place within the Göksu SEPR. Furthermore, over the 30-year period, a total of 303 hectares of land, including 123 hectares of forested area, 75 hectares of shrubland, 11 hectares of dune area, and 94 hectares of wetland area, have been converted into agricultural land. Areas transitioning from bare land to shrubland and forest predominantly consist of rejuvenated areas resulting from afforestation or cutting activities within the scope of forestry operations. During the period from 1990 to 2020, the majority of the built-up areas in Taşucu were formed by the transformation of the bare areas in the immediate vicinity of the existing settlement into urban areas. Similarly, in Silifke, most of the built-up areas were formed by the conversion of agricultural areas adjacent to the existing urban settlement into urban areas. The spatial distribution of LUC changes between 1990 and 2020 is provided in Figure 3.

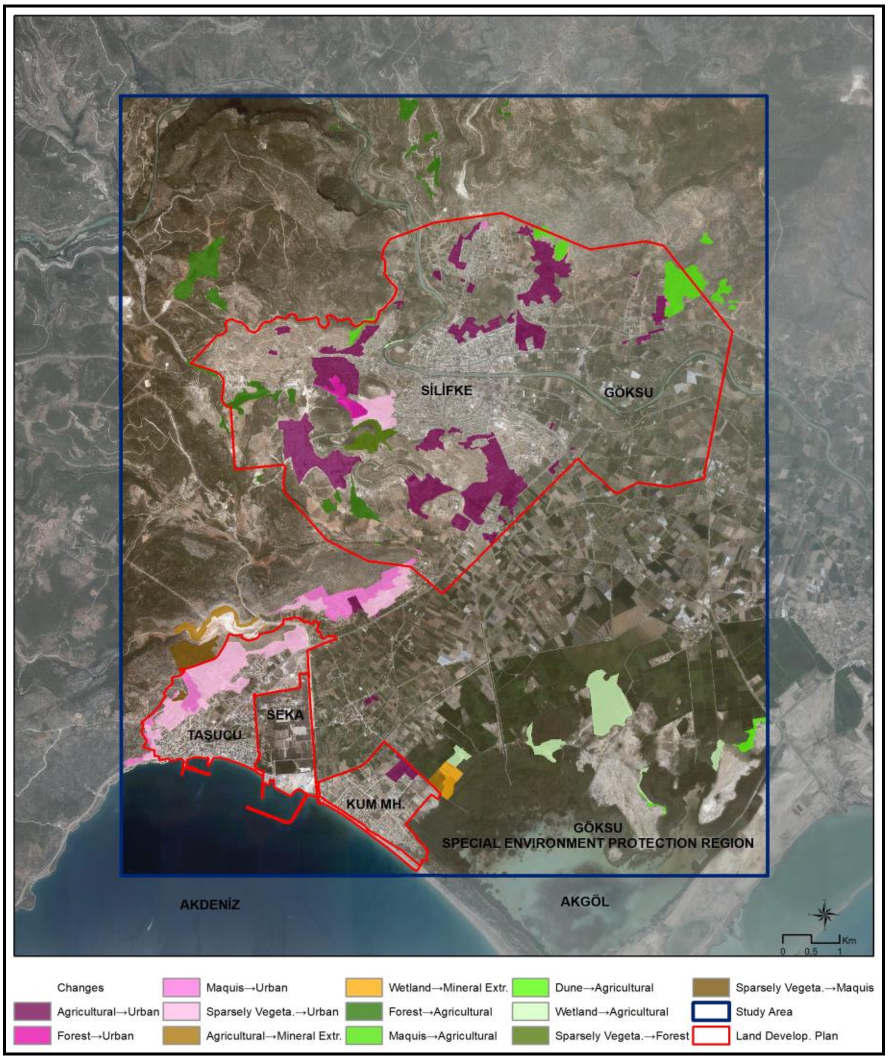


Figure 3. The spatial distribution of LUC change between 1990 and 2020

3.1.2. 2050 LUC changes: urbanization trend

Especially concerning physical spaces, estimations about the future based on current conditions serve as crucial tools for identifying potential disruptions or issues that may arise if ongoing processes persist, and for taking necessary actions to address them. In this section of the study, an attempt has been made to elucidate land change trends for the research area in terms of future urban development, focusing on the projection for the year 2050.

The basis of this study is formed by urbanized areas. Therefore, when discussing the land change trends for the year 2050, the areas transitioning from bare lands, agricultural lands, shrublands, and forests to urban fabric are referred to. When determining the trend of transformation into urban areas from the specified classes, certain parameters have been defined. These parameters are determinants and constraints that need to be included in the assessment phase in terms of suitability for settlement. These include the CLC LUC map, proximity to settlements, proximity to roads, slope, aspect, and elevation maps. The parameters of input data values used in land change trend analysis are essential for understanding and predicting LUC changes. CLC LUC maps provide information on the spatial distribution of different LUC categories, serving as a foundational dataset for land change analysis (EEA, 2020).

Proximity of Settlement measures the distance of land parcels or pixels to urban or built-up areas, indicating the degree of urbanization and potential expansion (Yuan et al., 2007). Proximity of Road, it evaluates the distance of land features to road networks, which influences accessibility, transportation infrastructure, and patterns of urban development (Yang et al., 2018). Slope represents the inclination or steepness of the terrain, affecting land suitability for various uses, erosion susceptibility, and the potential for infrastructure development (Fan et al., 2020). Aspect refers to the compass direction that a slope faces, influencing factors such as solar radiation exposure, vegetation distribution, and microclimate conditions (Masek et al., 2008). Elevation represents the height of the land surface above sea level, affecting temperature gradients, precipitation patterns, and land use suitability. All maps prepared based on the scoring information provided in Table 4 are presented in Figure 4.

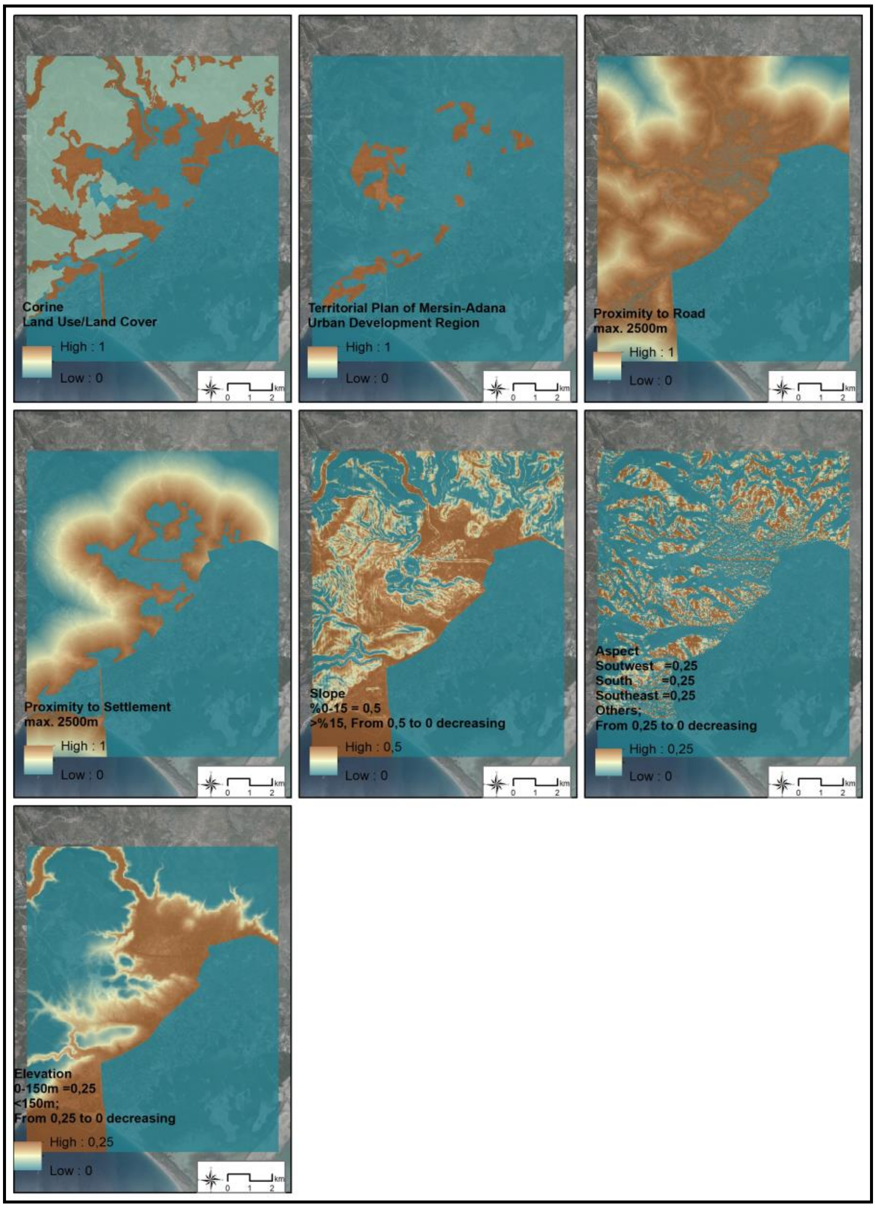


Figure 4. The input data used in land change trend analysis

These parameters, when integrated into land change models and analyses, provide valuable insights into the dynamics and drivers of LUC changes, supporting sustainable land management and planning efforts.

The parameters have been scored according to suitability for settlement. Similar parameters used in previous studies were examined for scoring, and determined according to the nature of this study (Feng et al., 2011; Silva & Clarke, 2002; Li et al., 2018). Additionally, when determining parameter values which used distance units, the distance from the center of the zoning plan to the boundary of the zoning plan was also taken into account. The impact levels of parameters have been normalized according to their maximum values. If the numerical sum of maximum values is assumed to be 5, which corresponds to one hundred percent, then the parameter with a maximum value of 1 will have a 20 percent effect, the parameter with a value of 0.5 will have a 10 percent effect, and the parameter with a value of 0.25 will have a 5 percent effect. Additionally, in this study, considering the current situation, the urban development areas specified in the 1/100,000 scale Adana-Mersin Regional Plan have been utilized to filter the study area boundary. The boundaries of the Göksu SEPR indicated in the same plan have also been evaluated as areas unsuitable for urban development. For this purpose, the lowest score has been assigned to the locations corresponding to the boundaries of the Göksu SEPA in the data used in the land change trend analysis. The information regarding the scoring used in the production of the maps presented in Figure 4 is provided in Table 4.

Table 4. The parameters of the input data used in land change trend analysis

Data Name	Impact	Max.	Min.	Description	Assigned Value
CORINE 3th Level LUC Map	% 20	1	0	Urban	0
				Water	0
				Sparsely Veg.	1
				Agricultural	1
				Maquis	0,25
				Forest	0,25
Urban Development Regions	% 20	1	0	According to 1/100,000 scale Mersin-Adana territorial plan	
Proximity of Settlement	% 20	1	0	Evaluated for a max. distance of 2500m.	
Proximity of Road	% 20	1	0	Evaluated for a max. distance of 2500m.	
Slope	% 10	0,5	0	Slope Degree values; %0-15=0,5, ≥%15=	
Aspect	% 5	0,25	0	Aspect values; South, soutwest/east = 0,25,	
Elevation	% 5	0,25	0	Elevation values; 0-150m = 0,25, ≥150m =	

To determine land change trend, used in many studies the Multi-Layer Perceptron (MLP) Neural Network model within The Transition Potentials Tab of the TerrSet Land Change Modeler was utilized (Sahaa et al., 2022; Symeonakis, 2016; Sankarrao et al., 2021). The MLP Neural Network is extensively developed to offer an automatic mode that does not require user intervention and provides valuable insights into the contributions of explanatory variables (Eastman et al., 2005). The accuracy rate of the MLP Neural Network model result should be at least 50%, and if a result lower than this value is obtained, necessary checks should be performed, and the model should be rerun (TerrSet, 2016). In this study, a relatively high accuracy rate of 79.3% was achieved. The map showing the areas with the probability of urban transformation for the year 2050 is presented in Figure 5, while the statistical information regarding this map is provided in Table 5.

When examining the urbanization expectation for the year 2050 through the land trend study, it is observed that almost all of the urban development areas specified in the 1/100,000 Adana-Mersin Regional Plan are expected to be urbanized. In only some parts of the urban development areas located to the west and north of the Silifke settlement center, there is no expectation of urbanization until 2050. All of the areas expected to be urbanized within the Silifke zoning plan boundaries consist of agricultural lands (202 ha). All of the areas expected to be urbanized within the zoning plan boundaries of Taşucu-Kum District consist of bare lands (46 ha). These areas are located within the boundaries of areas designated as urban development zones without being included in any protection class in the Environmental Plan. As mentioned in previous sections, rather than claiming to evaluate based on what should be, this study has conducted an assessment in line with its objectives focusing on the current situation and the existing conditions outlined in approved plans.

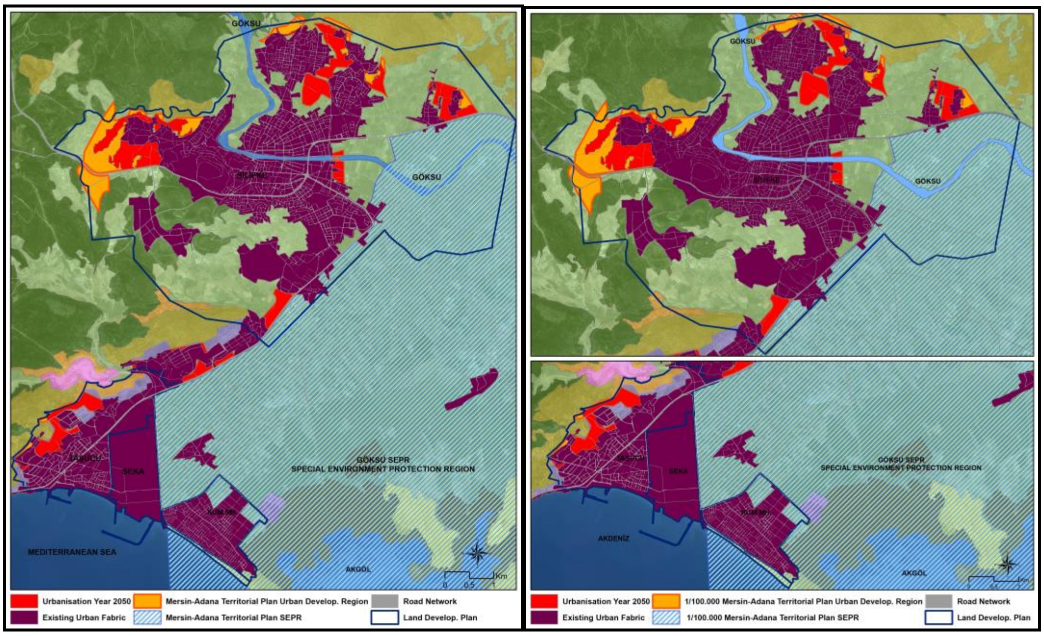


Figure 5. Urbanization projection for land change tendency in 2050

Table 5. Statistical information on urbanization projection for land change tendency in 2050.

The Classes that expected to transform into the urban fabric	Silifke	Taşucu	Between Silifke and Taşucu	Total
From Sparsely Vegetated Areas to Urban Fabric	-	46 ha	2 ha	48 ha
From Agricultural Areas to Urban Fabric	202 ha	-	12 ha	214 ha
	Total			262 ha

3.2. Population Trend

Evaluating the land change trend results for urban development in 2050 while considering population trends will provide valuable data for determining the per capita green area requirement in areas expected to urbanize. For this purpose, a population trend study for the year 2050 was conducted, taking into account the current population status of the neighborhoods within the zoning boundaries of Silifke and Taşucu-Kum District. As a result of the study conducted in 2013, the names and boundaries of certain neighborhoods have been changed, and some new neighborhoods have been added. Therefore, Taşucu has been named as the "Taşucu neighborhood" as the sole neighborhood. Current population statistics for the neighborhoods within the zoning boundaries are provided in Table 6.

Table 6. Population census results for Silifke and Taşucu Neighborhoods. (TÜİK, 2021)

Silifke			
Neighborhood Name	**Population (People)**	**Neighborhood Name**	**Population (People)**
Gazi Mh.	15.428	Pazarkaşı Mh.	1.640
Göksu Mh.	14.396	Tosmurlu Mh.	1.237
Mukaddem Mh.	6.675	Bucaklı Mh.	1598
Sarıcalar Mh.	6.056	Ulugöz Mh.	1.160
Sayağzı Mh.	5.208	Kabasakallı Mh.	956
Yeni Mh.	3.563	Say Mh.	954
Toros Mh.	3.452	Camiikebir Mh.	910
Atik Mh.	2.990	Burunucu Mh.	826
Saray Mh.	1.762	Total	68.811
Taşucu			
Neighborhood Name			**Population (People)**
Continued from Table 6			
Taşucu Mh.			13.215
		Total	82.026

The total population in the neighborhoods within the Silifke zoning plan boundaries is 68,801 people, while the population census of Taşucu Neighborhood, the only neighborhood within the Taşucu zoning plan boundary, is 13,215 people. The current population census in both zoning plan boundaries is 82,206 people. The results of the population projection for the year 2050 using the linear trend analysis model based on the address-based population registration system results for the year 2021 are presented in Table 7. The Linear trend analysis model, also known as time series analysis, aims to determine the best-fitting line to the observed values in past years in the form of the model *'y = a + bx'* using the 'Least Squares' method, which minimizes the sum of squared deviations. Then, assuming that the linear trend (tendency) will continue in the future, predictions are made (Hess et al., 2001).

Table 7. Silifke and Taşucu population: projection of 2050

Years	Silifke (People)	Taşucu (People)	Years	Silifke (People)	Taşucu (People)
2020	68007	11383	2035	85141	18085
2021	68811	11815	2036	86326	18534
2022	69729	12253	2037	87512	18983
2023	70915	12701	2038	88697	19431
2024	72100	13150	2039	89883	19880
2025	73286	13599	2040	91068	20329
2026	74471	14047	2041	92254	20777
2027	75657	14496	2042	93439	21226
2028	76842	14945	2043	94625	21675
2029	78027	15393	2044	95810	22123
2030	79213	15842	2045	96996	22572
2031	80399	16291	2046	98181	23021
2032	81584	16739	2047	99367	23469
2033	82770	17188	2048	100552	23918
2034	83955	17637	2049	101738	24367
			2050	102.923 People	24.815 People

According to the projection results, the expected population in 2050 is estimated to be 102,923 for Silifke and 24,815 for Taşucu. In this study, a linear trend analysis model was used, and the MAPE (Mean Absolute Percentage Error) value remained below 10%. The claim that the MAPE value below 10% in trend analysis is considered high accuracy is commonly considered in the literature (Tatlıdil, 1992) (Figure 6).

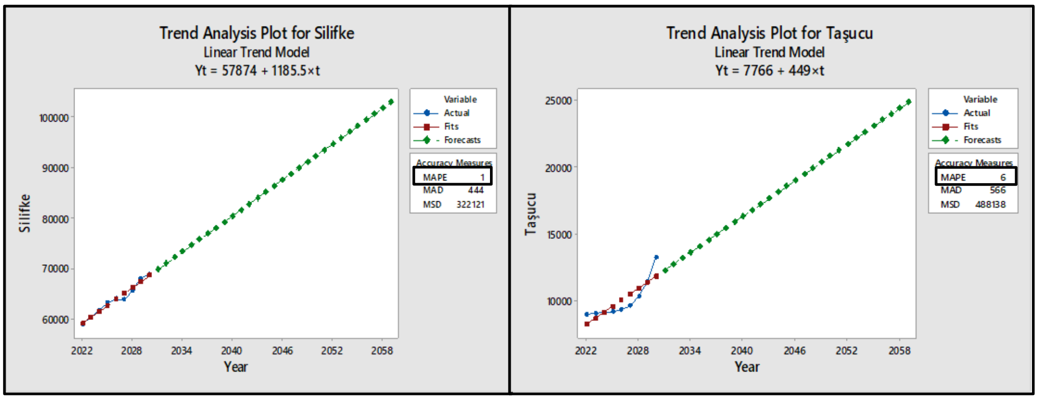


Figure 6. Accuracy values for trend analysis

According to the population projection for the year 2050, it is estimated that there will be approximately 102,923 people residing within the zoning boundaries of Silifke. According to the current spatial planning and construction regulations, the minimum green area per capita should be 10 m². Therefore, by 2050, within the zoning planning boundaries of Silifke, the green area should cover at least 1,029,230 m². In Taşucu Neighborhood, it is estimated that there will be approximately 24,815 people residing within the urban boundaries. According to the current spatial plans and construction regulations, by the year 2050, within the urban planning boundaries of Taşucu Neighborhood, the green area should cover at least 248,150 m².

3.3. Urbanization - Population Trend and Urban Green Space Status: 2020 and 2050

The assessment of urban ecosystem services requires a definition based on existing indicators and data, and the status of urban green infrastructure is crucial in defining the status of these services. Before initiating the classification study to produce maps serving the identified spatial scale, it is necessary to clarify the spatial boundaries of urban ecosystem services and determine the typology of urban green infrastructure (MAES, 2016). Gezer & Gül (2009) classify urban open and green spaces based on their usage into three groups: Public (General) Open and Green Spaces, which are generally accessible to urban residents and cater to their recreational needs (e.g., city and neighborhood parks, urban forests, cemeteries, botanical and zoological gardens, fairgrounds, sports facilities); Semi-Private Open and Green Spaces, accessible only to employees and their families or specific groups under certain conditions (e.g., schoolyards, military areas, public institution and factory campuses); and Private Open and Green Spaces, exclusively for use by owners or residents of single or multi-storey private properties (Gezer & Gül, 2009). In the Urban Atlas (UA) classification, classes relevant to urban ecosystem services consist of 14100 urban green areas and 14200 sports and leisure facilities. Urban green areas represented by code 14100 include publicly accessible green spaces primarily for recreational use, suburban natural areas transformed into city parks, and forests or green areas extending from the surroundings to urban areas bordered by structures. Sports and leisure facilities represented by code 14200 encompass all sports facilities, whether managed publicly or commercially, along with associated green spaces, parking lots, etc., for public use in various sports activities (EU, 2016). The Spatial Plans Preparation Regulation, which came into effect in 2014 and is currently in force, defines "Social infrastructure areas" in its "Definitions" section as "the general term for open and green spaces such as playgrounds, parks, squares, neighborhood sports areas, botanical parks, recreation areas, which are designed by the public or private sector for meeting the cultural, social, and recreational needs of individuals and society and for enhancing quality of life in a healthy environment" (MBS, 2014). According to Appendix-2 Table titled "Standards and Minimum Area Sizes of Minimum Social and Technical Infrastructure Areas in Different Population Groups" of the same regulation, open and green spaces in planning within district boundaries should consist of playgrounds, parks, squares, neighborhood sports areas, botanical parks, picnic areas, and recreation areas, and the minimum area per capita of open and green spaces should be at least 10m² (MBS, 2014). Green areas defined in the "Definitions" section of the Planned Areas Zoning Regulation, prepared based on the provisions of the Zoning Law No. 3194 dated 3/5/1985 and the Law Decree on the Organization and Duties of the Ministry of Environment, Urbanisation and Climate Change No 644 dated 9/6/2011, currently in force as of 3/7/2017, are described as follows: "The total of playgrounds, children's gardens, resting, walking, picnicking, entertainment, recreation, and recreational areas allocated for the benefit of the society (Metropolitan-scale fairs, botanical and zoological gardens, and regional parks fall within these areas.), including the functions and building conditions specified in the 19th article" (MBS, 2017).

In this stage of the study, based on all these definitions, the results of Derse's (2023) production of 4th level Corine Urban Atlas maps were utilized to identify urban green areas providing urban ecosystem services within both Silifke and Taşucu-Kum Districts' zoning boundaries. In Derse's (2023) study, the current per capita green area amounts were evaluated by considering both the classifications indicated in the classification system used and the definitions specified in the current legislation, the Spatial Plans Construction Regulation. The findings from Derse (2023)'s study were considered together with the results generated in this study. Table 8 presents the population of Silifke center and Taşucu-Kum neighborhood within the municipal boundaries in 2020, the status of urban green areas according to different definitions, the population projection for 2050, the required quantity of urban green space and the anticipated amount of urbanized areas.

Table 8. Population and urban green space situation according to Urban Atlas and Spatial Plans Construction Regulation (SPCR): Between 2020 and 2050 (Revised using the data from Derse (2023)

	Population		**According to Urban Atlas**		**According to SPCR**		**Size of the Area expected to transform into the urban fabric in 2050**
	Year	**People**	**Urban Green Space Quantity**	**Per Capita Urban Green Space Quantity**	**Urban Green Space Quantity**	**Per Capita Urban Green Space Quantity**	
Silifke	**2020**	68.811	533.000m²	7,75 m²	265.000 m²	3,85 m²	
	2050	102.923	1.029.230m²	10m²	1.029.230m²	10m²	2.020.000m²
	The size of UGS needed		496.230 m²	25% of the area expected to be built in 2050	764.230 m²	%38 of the area expected to be built in 2050	
Taşucu - Kum mh	**2020**	13.125	233.000m²	17,8m²	163.000 m²	12,3 m²	
	2050	24.815	248.150m²	10m²	248.150m²	10m²	460.000m²
	The size of UGS needed		15.150m²	%3 of the area expected to be built in 2050	85.150m²	%18 of the area expected to be built in 2050	
SPCR: Spatial Plans Construction Regulation		UGS: Urban Green Space					

As seen in Table 8, it is evident that for the central settlement of Silifke, neither the urban green space quantity determined according to the Urban Atlas classification system nor those defined in the Spatial Plans Implementation Regulation meet the minimum requirement of 10m² of green space per capita stipulated in the current legal regulations.

For the central settlement of Silifke, according to the Urban Atlas, the per capita urban green space quantity remains at 7.75 m², while according to the spatial planning regulation, it stands at a significantly insufficient with 3.85 m². Based on population projection studies conducted for 2050, it is estimated that the population will reach 102,923 individuals. Considering the required green space stipulated in the regulations, it is concluded that by 2050, the minimum urban green space within the urban planning boundaries of Silifke should be at least 1,029,230 m². With the urban green space in Silifke central area in 2020 being 533,000 m² according to the Urban Atlas classifications, at least 496,230 m² of new urban green space facilities need to be constructed within the planning boundaries by 2050.

This implies that at least 25% of the anticipated 2,020,000 m² (202 ha) area to be developed by 2050 should be designated as urban green space. However, the situation is more unfavorable when considering the urban green space quantity calculated based on the current regulations. The urban green space area defined in the SPCR for 2020 is 265,000 m². To meet the minimum per capita green space requirement, at least 764,230 m² of new urban green space facilities need to be constructed within the planning boundaries by 2050. This suggests that at least 38% of the anticipated developed area in Silifke central area by 2050 should be allocated as urban green space.

Unlike the central settlement of Silifke, for Taşucu-Kum neighborhood, both the urban green space quantity determined according to the Urban Atlas and The spatial planning regulation comply with the legal requirement of at least 10 m² of green space per capita. According to the Urban Atlas classifications, the per capita urban green space quantity is determined as 17.8 m², while according to the spatial planning regulation, it is calculated as 12.3 m².

For the year 2050, it is estimated that the population will be 24,815 individuals. According to the minimum per capita green space requirement stipulated in the regulations, the urban green space area within the Taşucu-Kum neighborhood planning boundaries should be at least 248,150 m² by 2050.

Considering the classifications in the Urban Atlas, the urban green space area in 2020 is 233,000 m², indicating the need for the construction of 15,150 m² of new urban green space facilities by 2050. Thus, at least 3% of the anticipated 460,000 m² (46ha) area to be developed by 2050 should be allocated as urban green space. Overall, while Taşucu-Kum neighborhood appears to be relatively well-off in terms of existing urban green space quantity, the situation of urban green spaces determined according to the current regulations is more unfavorable. The urban green space area defined in the SPCR for 2020 is 163,000 m². To meet the minimum per capita green space requirement, at least 85,150 m² of new urban green space facilities need to be constructed within the Taşucu-Kum neighborhood planning boundaries by 2050. This implies that at least 18% of the anticipated developed area in the Taşucu-Kum neighborhood planning by 2050 should be allocated as urban green space.

3.4. Discussions

Several studies have examined the per capita urban green space quantity in various cities across Turkey, highlighting both the current status and the need for improvement in urban planning and management strategies.

In a study conducted by Gül and Küçük (2001) in Isparta, it was found that the existing regulated active open-green areas, including city and neighborhood parks, playgrounds, and recreational areas, averaged at 3m² per capita. However, when considering additional potential green spaces such as roads, cemeteries, urban forests, and groves, this figure was estimated to rise to 14.6 m² per capita. The authors underscored the significance of meticulously planning, designing, and managing open-green spaces from scientific, ecological, and technical standpoints to foster the development of a contemporary, and habitable urban environment.

Similarly, Türker and Gül (2022) analyzed 29 green areas at the neighborhood scale in Uşak city center and determined the per capita green space quantity to be 8.50 m², with a playground area of 3.37 m² per child. However, they noted that this fell below the legal standard of 10 m² per capita, indicating an inadequate, uneven, and fragmented distribution of green spaces in terms of numerical and areal sizes within the neighborhoods.

In Selçuklu district, Önder et al. (2011) utilized GIS to assess the adequacy of active green areas in terms of spatial quantity and accessibility. They found that the existing active urban green areas covered 57,632.75 m², resulting in a per capita ratio of 12.53 m², which was higher than the legal requirement. However, they highlighted disparities, particularly noting that areas outside city parks fell below established standards. Despite plans for additional green spaces, implementation remained limited, indicating a lack of sufficient contribution to urban life.

Hepcan & Hepcan (2018) focused on Bornova's urban landscape, identifying natural and vegetated components using land-use maps. They determined that only 45% of the urban development area comprised potential components for an urban open-green space system. Their findings underscored the need for a comprehensive green infrastructure plan, revealing insufficient quantities and low landscape continuity within urban areas.

In conclusion, these studies collectively emphasize the importance of adequate per capita urban green space for fostering sustainable and livable urban environments in Turkish cities, while also highlighting the necessity for improved planning, management, and implementation strategies.

4. Conclusion and Suggestions

Urban areas are among the most affected places by the environmental issues caused by the globally recognized problem of climate change. Additionally, the issues stemming from urbanization itself are quite comprehensive and diverse. Consequently, one of the most defining challenges of our time will be creating healthy and livable urban spaces for societies. The objective of this research is to analyze land change trends in Silifke (Mersin) over time, spanning from 1990 to 2020 and projecting to 2050, with a focus on enhancing urban resilience to global climate change impacts.

In this study, the study area was delineated to encompass Silifke's central settlements using micro-watershed analysis. Land change trend analysis determined areas slated for development by 2050, based on existing urban development zones in the 1/100,000 scale Adana-Mersin Regional Plan. Population projections for 2050 were made for Silifke Center and Taşucu and Kum Neighborhood. Urban green spaces were assessed in relation to projected 2050 population, and findings were compared with Derse's (2023) study.

In the examination of land change trends conducted at the micro-watershed level for the years 1990 and 2020, a notable increase in urban areas by approximately 600 hectares is observed. Particularly, the LUC map for the year 2020 highlights a substantial expansion of the Silifke center contributing significantly to this growth. Over the same period, industrial areas have also experienced an increase of around 80 hectares. Moreover, there has been a remarkable surge in construction sites under development, indicating a fivefold increase over the span of 30 years. For instance, the spatial extent of construction areas, which encompassed roughly 30 hectares in 1990, has expanded to 130 hectares by 2020, underscoring the rapid pace of construction activities. These findings provide concrete evidence of the escalating trend in urbanization and construction endeavors within the study area. Such insights gleaned from the analysis of LUC maps serve to elucidate the dynamic changes in land use patterns and underscore the need for comprehensive planning strategies to manage and mitigate the impacts of urban expansion.

When the urbanization expectations for the year 2050 were examined, it was observed that nearly all of the urban development areas specified in the 1/100,000 Adana-Mersin Regional Plan are expected to be developed. Additionally, within the boundaries of the Silifke zoning plan, it was noted that all areas expected to undergo urbanization are comprised entirely of agricultural lands.

The analysis revealed that the central settlement of Silifke falls short of meeting the minimum requirement of 10m² of green space per capita as mandated by current legal regulations. According to the Urban Atlas, the per capita urban green space quantity stands at 7.75 m², while spatial planning regulations estimate it at a significantly insufficient 3.85 m².

Considering population projections for 2050, with an estimated population of 102,923 individuals, it is concluded that by 2050, the minimum urban green space within the urban planning boundaries of Silifke should be at least 1,029,230 m². However, existing urban green space in Silifke's central area in 2020, totaling 533,000 m² according to the Urban Atlas classifications, falls short. At least 496,230 m² of new urban green space facilities need to be developed within the planning boundaries by 2050, implying that at least 25% of the anticipated 2,020,000 m² area to be developed by 2050 should be designated as urban green space.

The situation is even more unfavorable when considering the urban green space quantity calculated based on current regulations. The urban green space area defined in the SPCR for 2020 is 265,000 m². To meet the minimum per capita green space requirement, at least 764,230 m² of new urban green space facilities need to be constructed within the planning boundaries by 2050, suggesting that at least 38% of the anticipated developed area in Silifke central area by 2050 should be allocated as urban green space.

In contrast, for the Taşucu-Kum neighborhood, both the Urban Atlas and spatial planning regulations comply with the legal requirement of at least 10 m² of green space per capita. The per capita urban green space quantity is determined as 17.8 m² according to the Urban Atlas and 12.3 m² according to spatial planning regulations. With an estimated population of 24,815 individuals by 2050, the urban green space area within the Taşucu-Kum neighborhood planning boundaries should be at least 248,150 m² by 2050. However, existing urban green space in 2020 is 233,000 m², indicating the need for the construction of 15,150 m² of new urban green space facilities by 2050. Thus, at least 3% of the anticipated 460,000 m² area to be developed by 2050 should be allocated as urban green space in Taşucu-Kum neighborhood.

Overall, while Taşucu-Kum neighborhood appears to be relatively well-off in terms of existing urban green space quantity, the situation of urban green spaces determined according to the current regulations is more unfavorable. The urban green space area defined in the SPCR for 2020 is 163,000 m². To meet the minimum per capita green space requirement, at least 85,150 m² of new urban green space facilities need to be constructed within the Taşucu-Kum neighborhood planning boundaries by 2050. This implies that at least 18% of the anticipated developed area in the Taşucu-Kum neighborhood planning by 2050 should be allocated as urban green space.

In conclusion, while the Taşucu-Kum neighborhood seems relatively well-off in terms of existing urban green space quantity, the situation of urban green spaces in Silifke's central area is more unfavorable, highlighting the urgent need for strategic planning and investment in urban green infrastructure to ensure sustainable urban development and enhance the quality of life for residents.

Understanding land change trends, especially the conversion of agricultural land into urban areas, is crucial for sustainable urban planning and mitigating the adverse effects of urbanization on ecosystems and biodiversity.

Urban green spaces play a vital role in enhancing urban resilience, mitigating climate change impacts, improving air and water quality, and providing recreational and aesthetic benefits to urban residents. Thus, recognizing the importance of urban green spaces is essential for promoting healthy cities.

Based on the findings of this study, it is recommended that urban planning authorities prioritize the preservation and expansion of urban green spaces within Silifke (Mersin) and other urban areas. This can be achieved through policies and initiatives aimed at conserving existing green areas, integrating green infrastructure into urban development projects, and promoting community engagement in urban greening efforts.

Furthermore, promoting sustainable land management practices and incorporating nature-based solutions into urban planning processes can help enhance the resilience of cities to climate change while improving the overall quality of urban life.

Collaborative efforts between government agencies, local communities, and environmental organizations are essential for achieving these goals and creating healthier and more sustainable urban environments for current and future generations.

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