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Spatial and temporal analysis of habitat quality

Habitat kalitesinin mekânsal ve zamansal analizi

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ABSTRACT

Objective: This study aims to analyze the spatio-temporal changes in habitat quality associated with land use/land cover (LULC) change and landscape characteristics in the Manisa province from 1995 to 2020.

Material and Methods: Open access LULC maps obtained from the European Space Agency (ESA) for the years 1995 and 2020 and Landsat satellite images of the same years were used in the study. After determining LULC changes for 1995 and 2020, habitat quality was modelled and evaluated for these years using the InVEST software's Habitat Quality Module.

Results: Between 1995 and 2020, Agricultural Land decreased, and Urban areas increased in the study area. The increase in Shrubland and Forests has improved the Habitat Quality, especially in and near upland areas. Despite these LULC changes, the average Habitat Quality increased very little, with high quality areas increasing and low-quality areas decreasing.

Conclusion: This study showed that Habitat Quality can be maintained by managing LULC changes, and that protecting and enhancing vegetation-rich areas would support high Habitat Quality.

Keywords: Habitat quality, hotspots, InVEST, LULC change, Manisa, NDVI

ÖZ

Amaç: Çalışmanın amacı, 1995-2020 yılları arasında Manisa ilinde arazi kullanımı/arazi örtüsü (AKAÖ) değişimi ve peyzaj özellikleri ile ilişkili Habitat Kalitesindeki yaşanan mekânsal-zamansal değişimlerin analiz edilmesidir.

Materyal ve Yöntem: Çalışmada, 1995 ve 2020 yıllarına ait Avrupa Uzay Ajansı'ndan (ESA) elde edilen açık erişimli AKAÖ haritaları ile aynı yıllara ait Landsat uydu görüntüleri kullanılmıştır. 1995 ve 2020 yılları için AKAÖ değişimleri belirlendikten sonra, bu yıllara ait habitat kalitesi InVEST yazılımının Habitat Kalitesi Modülü kullanılarak modellenmiş ve değerlendirilmiştir.

Araştırma Bulguları: 1995-2020 yılları arasında çalışma alanında Tarım Arazileri azalmış, Kentsel alanlar ise artmıştır. Çalılık ve Ormanlık alanların artışı özellikle yüksek bölgeler ve yakınlarında Habitat Kalitesini iyileştirmiştir. Bu AKAÖ değişimlerine rağmen, ortalama Habitat Kalitesi çok az artmış, yüksek kaliteli alanlar artarken düşük kaliteli alanlar azalmıştır.

Sonuç: Bu çalışma, AKAÖ değişimlerini yöneterek, bitki örtüsü zengin bölgelerin korunması ve artırılması yoluyla Habitat Kalitesinin korunabileceğini göstermiştir.

Anahtar sözcükler: Habitat kalitesi, sıcak noktalar, InVEST, AKAÖ değişimi, Manisa, NDVI

INTRODUCTION

Habitat quality ecosystem service is vital to support environmental sustainability, human well-being, and economic prosperity in rapidly growing cities. Habitat quality is an important indicator of the ecological environment. It refers to the ability of an ecosystem to provide suitable living conditions for sustainable individual and population-level development over a certain temporal and spatial range (Salata et al, 2017). In other words, habitat quality refers to the suitability of an environment to support a variety of life forms, including plants, animals and humans. Habitat quality, which is considered a fundamental component of ecosystem health, encompasses a variety of factors such as biodiversity, air and water quality, climate regulation and recreational opportunities. However, as the increase in industrial areas with urbanization continues to spread worldwide, the protection of natural ecosystems together with the balancing of development demands causes major problems in the deterioration of habitat quality. In this sense, one of the most important objectives of landscape planning is to protect and ensure the quality of habitats in and around the cities (Gomes et al., 2021; Wang et al., 2022; Li et al., 2023).

Today, many scientific studies increasingly emphasize the importance of habitat quality in sustaining urban ecosystems and supporting the welfare of urban dwellers. For example, numerous studies have demonstrated the positive relationship between habitat quality and biodiversity in urban environments (Grimm et al., 2008; McKinney, 2008), while urban green spaces such as parks, gardens and nature reserves play an important role in providing habitat for a variety of species, including pollinators, birds and small mammals (Gaston et al., 2013; Ersoy et al., 2019). Thus, maintaining habitat quality is required to conserve urban biodiversity and support ecosystem functions critical for human well-being.

On the other hand, urban ecosystems, which are heavily influenced by human activities, often have poor air and water quality (Francis & Chadwick, 2013; Semeraro et al., 2021). However, many studies have shown that green infrastructure components such as urban forests and vegetated corridors can significantly improve air quality by trapping pollutants and reducing the urban heat island effect (Nowak et al., 2006; Escobedo et al., 2011). Similarly, natural habitats contribute to water purification and flood mitigation, reducing the risk of flood-related diseases and property damage (Levin et al., 2001; Pataki et al., 2011; Kesgin Atak, 2020; Kurtşan & Nurlu, 2020). Therefore, protecting and enhancing habitat quality contributes positively to environmental quality and public health in rapidly growing cities.

Urbanization has an impact on the local climate, leading to an increase in temperatures and changes in precipitation regimes in the urban environment. In this context, green infrastructure components (e.g. open green spaces and natural habitats) provide ecosystem services necessary for climate regulation such as carbon sequestration, heat reduction and stormwater management (Cadenasso et al., 2007; McPherson et al., 2013). In this sense, maintaining habitat quality contributes to the sustainability of these natural climate regulation mechanisms and helps to mitigate the impacts of climate change.

Access to high-quality green spaces is associated with numerous physical and psychological benefits for urban residents (Bratman et al., 2015; Mears et al., 2019). Natural habitats contribute to improved mental health and well-being by providing opportunities for recreation, relaxation and social interaction. Furthermore, green spaces can enhance the overall liveability of fast-growing cities by acting as natural refuges from the stresses of urban life (Sandifer et al., 2015; Kolokotsa et al., 2020).

Finally, habitat quality also has an economic significance for fast-growing cities. Green spaces, and natural areas in particular, can attract tourists, increase property values, and support outdoor recreation opportunities (Luttik, 2000; Tzoulas et al., 2007). Furthermore, healthy and high-quality ecosystems provide essential ecosystem services that support various economic activities such as agriculture, fisheries and water supply (Bolund & Hunhammar, 1999; Millennium Ecosystem Assessment, 2005). In this sense, investigating and defining the economic value of habitat quality is important for informing decision-making processes and promoting sustainable urban development.

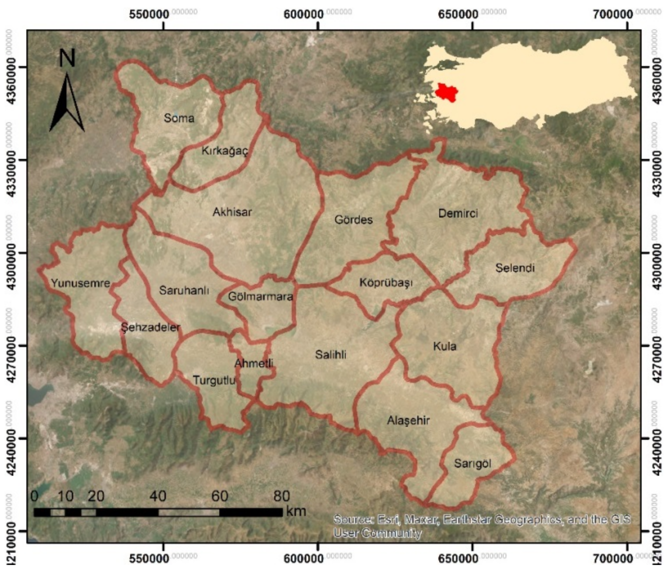
Modelling, determining, and detecting change in habitat quality is critical for environmental management and conservation strategies. These processes help us understand the factors that affect the health of ecosystems, biodiversity and human health. Modelling habitat quality supports us to assess the current state of ecosystems and to promote the sustainable use of natural resources. It also helps us to develop strategies to maintain the health of ecosystems by identifying changes in habitat quality and habitats in response to environmental changes. Therefore, modelling habitat quality and detecting its change is one of the fundamental steps to effectively manage natural resources and ensure a healthy environment for future generations (Terrado et al., 2016; Yohannes et al., 2021).

In this study, we evaluated habitat quality (HQ) in Manisa province, which is characterized by diverse natural features and historical importance in Türkiye. We utilized open-access land use/land cover (LULC) maps from the European Space Agency (ESA) and Landsat satellite images to generate Normalized Difference Vegetation Index (NDVI) data. HQ was modelled using the InVEST-HQ model based on LULC maps from 1995 and 2020, and the resulting HQ models were normalized with NDVI data for those years. Based on spatial analysis, high and low HQ clusters were identified using hotspot analysis. The results and evaluations enabled the formulation of recommendations for the conservation of habitats in the study area, to enhance their quality.

MATERIALS and METHODS

Material

The study area, Manisa Province, is located in the western part of Türkiye (27°08’-29°05’ E, 38°04’-39°58’ N), the second largest city in the Aegean Region, with a population of 1,400,000 and an area of 13,260 km² (Figure 1).



Şekil 1. Çalışma alanı lokasyonu.

Figure 1. *Location of the study area.*

Manisa province comprises seventeen districts. The fertile soil structure of the Gediz Plain has contributed to Manisa's status as one of Türkiye's top three provinces in terms of agricultural production, particularly in grape and olive cultivation. Additionally, its proximity to transportation routes such as ports and railways has led to the establishment of numerous industrial facilities (Vestel, Indesit and Bosch, etc.), favourable climatic conditions, well-developed transportation systems, and a diverse range of products, which have collectively contributed to the city's prominence in terms of industry. When the population growth and industrial development of the Manisa province are examined together, it becomes evident that a parallel relationship exists between the rise in urban population and the advances in the industrial sector.

The primary data set employed in this study is comprised of the European Space Agency Land Cover Maps for 1995 and 2020 with a spatial resolution of 300 meters (ESA, 2024), Landsat 5 TM, and Landsat 8 OLI satellite images (USGS, 2024). We employed the LC maps to model Habitat Quality (HQ) in InVEST 3.13.0, in conjunction with NDVI data derived from Landsat satellite images, to modify HQ and capture the environmental condition in our study area. In our study area, 20 LULC classes were identified by ESA. These were grouped under 7 LULC classes representing the basic LULC classes that will form the basis for the analyses (Table 1 & Figure 2).

Table 1. *Aggregated LULC classes, ESA LULC codes and class descriptions*

Çizelge 1. *Birleştirilmiş AKAÖ sınıfları, ESA AKAÖ kodları ve sınıf açıklamaları*

LULC	Codes	Class Descriptions
Cropland	10	Cropland, rainfed
	11	Herbaceous cover
	12	Tree or shrub cover
	20	Cropland, irrigated or post-flooding
	30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)
	40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)
Forest	60	Broadleaf Forest -Tree cover, broadleaved, deciduous, closed to open (>15%)
	70	Needleleaved Forest -Tree cover, needleleaved, evergreen, closed to open (>15%)
	90	Mixed Forest -Tree cover, mixed leaf type (broadleaved and needleleaved)
Shrubland	100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)
	110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)
	120	Shrubland
	122	Deciduous shrubland
Grassland	130	Grassland
	150	Sparse vegetation (tree, shrub, herbaceous cover) (<15%)
	153	Sparse herbaceous cover (<15%)
Urban	190	Urban areas including buildings, roads and other sealed surfaces
Bare Areas	200	Bare areas
	201	Consolidated bare areas
Water	210	Water bodies

The ArcMap 10.5.1 (ESRI, 2015) and InVEST 3.13.0 Workbench software (Natural Capital Project, 2022) (Habitat Quality Module) were employed to process and analyse the datasets and to model habitat quality in our study area, respectively. Furthermore, parameters suitable for the priori characteristics of the study area were identified through a literature-based research process.

Methods

As one of the key indicators of biodiversity, habitat quality refers to the potential of existing environmental conditions to provide suitable conditions for the survival, reproduction, and survival of individuals and populations of different species. Therefore, by examining the spatial and temporal changes in LULC as an important indicator of landscape pattern, it is possible to understand LULC change effects on biodiversity and the environment. Initially, the LULC maps of 1995 and 2020 obtained free of charge from the ESA website were cut according to the boundaries of the study area, and the resolution of LULC maps was resampled to 30 meters in ArcMap 10.5.1 software. Then the distribution, amount (total % and ha), and change in each LULC class (number of patches and mean patch area for each class) were calculated in ArcMap 10.5.1.

The model inputs employed in the InVEST Habitat Quality module are not species- or population-specific but rather applicable to all forms of biodiversity. The data required for this model comprises the following: (a) LULC map, (b) the threat file with a .csv extension, (c) the table of sensitivity to threats with a csv extension, (d) the semi-saturation constant and (e) the vector-based threat accessibility layer (Natural Capital Project, 2023). This study employed a literature review to ascertain the habitat characteristics, sensitivity to threats, semi-saturation constant, and distance to threats parameters of the LULC classes (Di Febbraro et al., 2018; Salata et al., 2020; Ouyang et al., 2021). The parameters employed to model habitat quality (HQ) for 1995 and 2020 in the study are given below in Table 2.

Table 2. *Parameters used in the Habitat Quality model*

Çizelge 2. *Habitat Kalitesi modelinde kullanılan parametreler*

		Sensitivity Values		
LULC category	**Habitat Suitability**	**Cropland**	**Urban**	**Bare Areas**
Urban (U)	0.09	0	0	0
Cropland (C)	0.39	0	0.5	0.4
Grassland (G)	0.86	0.5	1	0.4
Forest (F)	0.87	0.8	1	0.3
Shrubland (S)	0.81	0.7	0.6	0.3
Bare Areas (BA)	0.55	0	0	0
Water (W)	0.83	0.1	0.9	0.6
Threats	**Weights**	**Maximum distance**	**Decay**	
Cropland	0.42	0.6	linear	
Urban	0.79	1.7	exponential	
Bare Areas	0.35	5	linear	

Vegetation represents a significant environmental component with the potential to influence habitat selection and utilization intensity by species. In this context, satellite image-derived NDVI is a key index for assessing healthy and dense vegetation cover. In this regard, while NDVI has been identified as a potentially valuable indicator of biodiversity at large scales (Pettorelli et al., 2011; Barela et al., 2020), numerous studies have investigated the potential correlation between NDVI and species as well as its application for HQ estimation (Shen et al., 2013; Weber et al., 2018; Salata et al., 2020). Accordingly, this study integrated NDVI and the InVEST-HQ module to assess temporal and spatial changes in HQ over the last 25 years in Manisa, Türkiye. The NDVI index was incorporated into the Habitat Quality model with the formula below (1). Thus, the effect of vegetation cover on Habitat Quality was also included in the model.

$$NDVI*HQ \qquad (1)$$

In the next step, to make comparisons between 1995 and 2020, NDVI weighted Habitat Quality values were grouped into 5 groups using the Natural Breaks Classification method in ArcMap 5.1 software. Next, the Zonal Statistics tool in ArcMap 10.5.1 was used to evaluate the density and diversity of different LULC types, as well as their relative abundance within each Habitat Quality class. Finally, the Getis-Ord Gi spatial analysis was employed in ArcMap 10.5.1 to identify statistically significant clusters of high and low habitat quality ecosystem service values in the study area for the years 1995 and 2020.

RESULTS and DISCUSSION

LULC Change Results

Figure 2 represents the spatial distribution of 7 LULC classes in the study area for 1995 and 2020. As seen in Table 3 and Figure 2, the dominant LULC class in the study area is composed of Cropland in both years (73.01% and 68.00% of the total study area for 1995 and 2020, respectively). This is followed by Shrubland and Forest. On the other hand, Urban and Water LULC classes were the rarest categories in the study area both in 1995 and 2020. In terms of mean patch area, Cropland LULC category had the biggest patches across the study area with considerably lowest number of patches. This indicates that the patches of Cropland category are quite connected to each other. However, between 1995 and 2020, almost 5% of Cropland was lost and its pattern became more fragmented with smaller mean area and larger number of patches compared to 1995. Shrubland LULC class had smaller mean patch size with the highest number of patches, indicating that its patches are quite fragmented compared to Cropland LULC class. Upon examining the spatial characteristics of Forest LULC, it was obvious that its paths are more connected compared to Shrubland category with larger mean area and fewer number of patches. Grassland and Bare Areas LULC categories did not show an important change in terms of their spatial characteristics. However, whilst as one of the rarest LULC categories Urban LULC class increased its total area more than twice with more connected and clustered pattern across the study area (from 5658.75ha to 14156.91ha), Water category had more fragmented but increased total area (from 10875.87ha to 13471.83ha). The urban expansion and urbanization processes in our study area were less obvious compared to those observed in other regions of Türkiye and in other countries (Alberti, 2005; Groffman et al., 2017; Kesgin Atak & Ersoy Tonyaloğlu, 2020). Nevertheless, even at this relatively small scale, urban expansion had notable consequences, as will be discussed in further detail below.

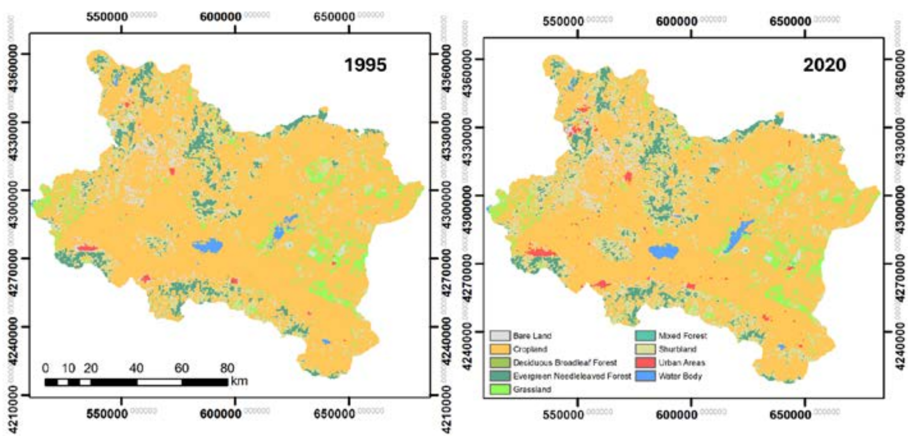


Figure 2. *Distribution of LULC classes in the study area in 1995 and 2020.*

Şekil 2. Çalışma alanında 1995 ve 2020 yıllarına ait AKAÖ sınıflarının dağılımı.

Table 3. *Landscape Metrics for LULC classes for the years 1995-2020*

Çizelge 3. *1995-2020 yılları AKAÖ sınıflarına ait Peyzaj metrikleri*

LULC Class	Years	Total Area (ha)	% Landscape	Number of Patches	Mean Area (ha)
C	1995	948675.24	73.01	356	2665.31
	2020	883488.96	68.00	515	1716.17
S	1995	152689.86	11.75	1363	112.09
	2020	206162.82	15.87	1149	179.56
F	1995	80008.11	6.16	551	236.62
	2020	83447.10	6.42	687	206.95
G	1995	60140.07	4.63	654	91.76
	2020	61197.75	4.71	727	84.00
U	1995	5658.75	0.44	75	74.17
	2020	14156.91	1.09	13	1039.75
BA	1995	41275.17	3.18	725	57.04
	2020	37397.70	2.88	763	49.01
W	1995	10875.87	0.84	19	572.63
	2020	13471.83	1.04	183	76.67

Table 4 reveals that the most significant transformation occurred in the Bare Areas category, with a change of 12.38% between 1995 and 2020. This conversion was experienced as a loss of area, manifesting as a conversion to other LULC classes. In particular, 8.06% of the Bare Areas LULC class was converted to Urban, 2.05% to Shrubland and 1.48% to Cropland. This was followed by an increase of 12% in the Forest LULC class. The highest conversion to forest was observed in the Shrubland (21.43%) and Cropland (15.01%) LULC classes. The Cropland LULC class exhibits a high degree of areal transformation, with a rate of -7.71%. Of this, 5.50% was transformed into the Shrubland class, 1.11% into the Forest class, and 0.47% into the Urban LULC class. A relatively small proportion of the Cropland LULC class (0.62%) was converted to the other three LULC classes. Although the area covered by the Urban LULC class is relatively small in comparison to the total study area (0.44% and 1.09% in 1995 and 2020, respectively), as previously stated, the total area has increased by more than twofold due to the conversion of other classes to urban (with a conversion rate of 0.91% from other LULC categories). All other LULC classes, in particular those classified as Forest and Cropland (2.37% and 2.02% of the total area, respectively), were transformed into Shrubland LULC class, resulting in an increase in the area covered by this LULC class (%4.73). As with the Shrubland LULC class, the Grassland LULC class also experienced a transformation from all other LULC categories, resulting in an increase of 3.21% in terms of its total area. Additionally, the Water LULC class experienced a minor degree of conversion from the Cropland, Grassland and Forest LULC classes, resulting in a 0.34% increase in the total area of the Water LULC class.

Table 4. *Change and transformation amounts of LULC between 1995 and 2020*

Çizelge 4. *1995-2020 yılları arasında AKAÖ değişim ve dönüşüm miktarları*

		1995							
	Area (%)	**S**	**G**	**B**	**C**	**F**	**U**	**W**	**Class Total**
2020	**S**	**95.27**	1.47	2.05	5.50	21.43	0.00	0.00	100
	G	0.06	**96.79**	0.01	0.30	0.01	0.00	0.05	100
	BA	0.16	0.01	**87.62**	0.09	0.21	0.18	0.00	100
	C	2.02	0.62	1.48	**92.29**	15.01	0.73	0.25	100
	F	2.37	0.00	0.11	1.11	**87.76**	0.00	0.04	100
	U	0.11	0.85	8.06	0.47	0.06	**99.09**	0.00	100
	W	0.01	0.26	0.67	0.23	0.00	0.00	**99.66**	100
	Class Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	
	Class Change (%)	4.73	3.21	-12.38	-7.71	12.24	0.91	0.34	

Habitat Quality Evaluation

Figure 3 illustrates the habitat quality maps, weighted by NDVI, for the years 1995 and 2020. On the NDVI maps, dark green areas indicate areas with high NDVI values due to the presence of healthy vegetation, while light green areas indicate areas with weak/poor vegetation cover or no vegetation cover (Figure 3). In 1995, the minimum and maximum NDVI values in the study area were -0.62 and 0.80, while the average NDVI value was 0.29. In 2020, these values were -0.99, 0.86 and 0.39, respectively. In 1995, high NDVI values were mostly concentrated in the southern parts of the study area, while in 2020, high NDVI values increased slightly, especially in the north-eastern direction, and spread throughout the study area. This is related to the increase in Shrubland and Forest areas. However, it was found that there was a decrease in NDVI values in 2020 in the south-west direction where healthy vegetation was dense (in the irrigated agriculture area), which was characterized by high NDVI values in 1995.

In the NDVI-weighted habitat quality maps, green areas indicate areas of high habitat quality and red areas indicate areas of poor habitat quality (Figure 3). When the NDVI-weighted values of the habitat quality were analysed, it was found that the mean value was 0.47 in the year 1995 and 0.48 in the year 2020. Although there is no significant increase in the average Habitat Quality value, when the distribution within the study area is analysed, it is seen that there are changes in areas with both high and low Habitat Quality. In 2020, there were areas in the west-central regions of the study area that experienced a degradation in Habitat Quality compared to 1995, while there were improvements in Habitat Quality in the surrounding areas and at the southern and northern borders of this area. So, despite the urbanization and human activities that have occurred in the study area, the increase in vegetation cover helped to mitigate the adverse effects of this process as indicated in the literature (Forman, 2014; Jiang et al., 2018; Tonyaloğlu, 2020).

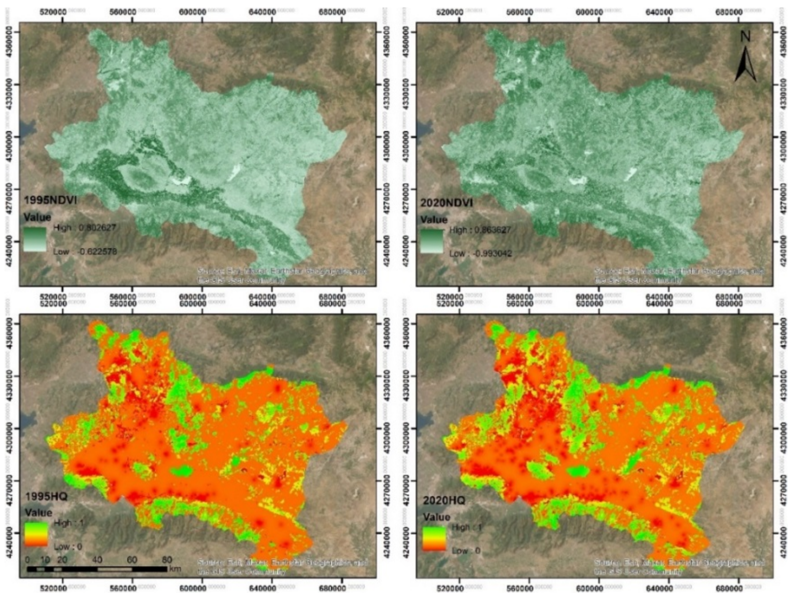


Figure 3. *NDVI and Habitat Quality Maps weighted by NDVI for 1995 and 2020 in the study area.*

Şekil 3. Çalışma alanında 1995 ve 2020 yıllarına ait NDVI ile NDVI ile ağırlıklandırılmış Habitat Kalitesi Haritaları.

Figure 4 shows the low, medium and high Habitat Quality regions in 1990 and 2020.

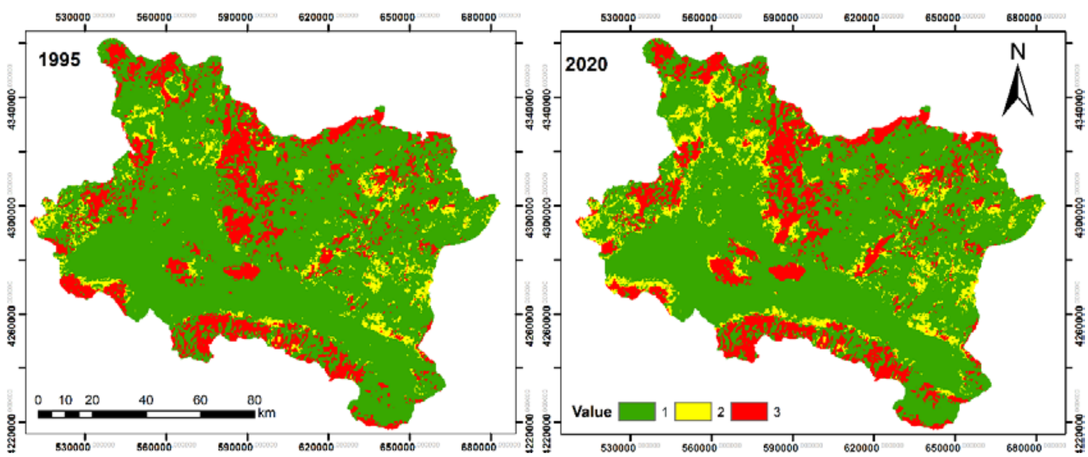


Figure 4. *Distribution of regions with low (1), medium (2) and high (3) Habitat Quality in 1995 and 2020.*

Şekil 4. 1995 ve 2020 yıllarında düşük (1), orta (2) ve yüksek (3) Habiat Kalitesine sahip bölgelerin dağılımı.

The role of vegetation cover in the formation of many ecosystem services has been demonstrated in numerous studies (Forman, 2014; Kesgin Atak & Ersoy Tonyaloğlu, 2020). The results of this study also support the literature. In 1995, the proportion of high Habitat Quality areas in the total area was

16.85%, while in 2020 this proportion increased to 17.89%. On the other hand, while in 1995 the proportion of low and medium Habitat Quality areas was 6.14% and 77.01% respectively, in 2020 there was a decrease in low Habitat Quality areas (down to 73.11%) and an increase in medium Habitat Quality areas (up to 8.99%). When the LULC classes of the regions classified as low, medium and high in terms of Habitat Quality were analysed, it was shown that the mixture of Forest, Shrubland, Water and Grassland was characterized by high values in terms of Habitat Quality on both dates. However, the intersections with Cropland and Bare Areas at the edges of the patches of these LULC classes were characterized by a lower, moderate level of Habitat Quality. On the other hand, Bare Areas and Cropland LULC classes, especially Urban LULC class, were characterized by poor Habitat Quality. In addition, it was determined that there are areas with low Habitat Quality, especially in the Urban LULC class and its immediate surroundings. This shows that compared to 1995, the expanding Urban LULC class had a negative impact on Habitat Quality in 2020, but the increasing Forest and Shrubland LULC class, which transformed from Copland and Bare Areas, had a positive impact on Habitat Quality.

Figure 5 shows the spatial clustering and dispersion of NDVI-weighted habitat quality in 1990 and 2020.

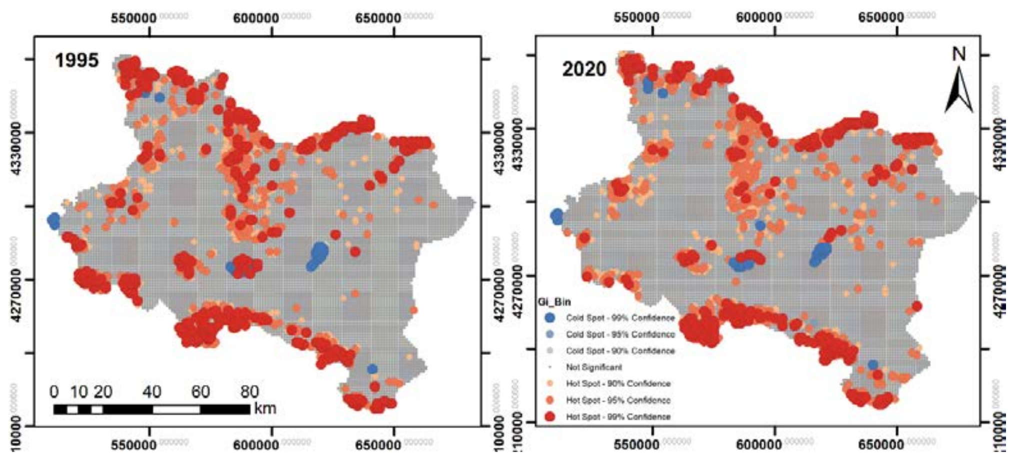


Figure 5. *1995 and 2020 results of the Habitat Quality Hotspot and Coldspot analyses.*

Şekil 5. 1995 ve 2020 yıllarına ait Habiat Kalitesi Hotspot ve Coldspot analizi sonuçları.

The significance of spatial patterns in land use and cover (LULC) in the development of effective conservation strategies for the maintenance and enhancement of habitat quality has been emphasized in the literature (Chaplin-Kramer et al., 2015; Salata et al., 2020; Ersoy Tonyaloğlu, 2024). Looking at the results of the Habitat Quality hotspot and cold spot analyses for 1995 and 2020, it was found that the Habitat Quality hotspots (99% confidence level) were concentrated in the high and mountainous areas with Forest and Shrubland patches in the border regions of the study area on both dates. Conversely, cold spots were mainly in lowland areas in particular around Water LULC class which was surrounded by Cropland and Grassland. On the other hand, near Akhisar district on the line from the central northern part of Manisa province to the south, conversions from Forest LULC class in 1995 to Cropland and Shrubland LULC classes in 2020 resulted in conversions from Habitat Quality 99% confidence level hotspots to 95% confidence level. The Urban LULC class had no effect on cold spots between 1995 and 2020 when the entire area of Manisa province is considered, as there was no significant increase in the urban LULC class.

CONCLUSIONS

The study area experienced important LULC changes from 1995 to 2020, including a reduction in Cropland and a substantial increase in Urban LULC classes. These changes resulted in a slight improvement in average Habitat Quality, with high-quality areas expanding and low-quality regions decreasing. The reduction in Cropland and the substantial increase in Urban areas from 1995 to 2020 highlighted the need for strategies to manage urban expansion and maintain agricultural productivity. The expansion of Shrubland and Forest LULC classes suggested opportunities for habitat restoration and conservation, which can further improve Habitat Quality. Hence, enhancing habitat quality in Manisa province through landscape planning and management should involve preserving and restoring natural habitats, promoting sustainable land-use practices, and improving landscape connectivity. Regular landscape assessments, such as those using the InVEST Habitat Quality model, can guide informed decisions on land use. Also, engaging local communities and raising awareness about habitat conservation are essential steps for sustainable planning efforts that would benefit both biodiversity and residents. Considering the study's findings, landscape planning and management should priorities the conservation and enhancement of high-quality habitats, particularly in expanding Shrublands and Forests. Strategies to sustainably manage urban expansion, such as creating green buffers and promoting infill development, are critical to reducing habitat fragmentation. Restoring degraded land, including previously converted Bare Areas and fragmented Cropland, can help to improve habitat connectivity. Adaptive management plans should be developed to address ongoing LULC changes and their impacts on Habitat Quality, to ensure that future development contributes positively to overall landscape health. Overall, a balanced approach to both urban development and ecological conservation is essential for sustainable landscape management in our study area. In this sense, integration of Habitat Quality metrics into land use planning and policy decisions would help us to maintain ecological resilience and sustainability.

Data Availability

Data will be made available upon reasonable request.

Author Contributions

Conception and design of the study: EET; acquisition of data: EET, BKA; analysis and interpretation of data: EET, BKA; statistical analysis: EET; visualization: EET, BKA; writing manuscript: EET, BKA.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that there is no need for an ethics committee for this research.

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