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Floristic Similarity Status of Manavgat Sorgun Forest, Titreyengöl and Boğaz Forest

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ABSTRACT: Today, population growth has increased anthropological pressure on natural areas. Natural areas have been destroyed, degraded, or fragmented as a result of anthropological pressure. This has led to the fragmentation of habitats and their diversification or eventual disappearance over time. This study investigated the floristic similarities between Manavgat Sorgun Forest, Titreyen Göl, and Boğaz Forest. The floristic structure of the three areas was determined, and the plants in the floristic findings were coded. Coding was done according to plant type, endemism status, IUCN status, angiosperm or gymnosperm status, medicinal and commercial plant status, and class. Using this coding, the three areas were compared using Modified Discriminant Analysis with SPSS 20.0 IBM COP program. Historical (1985) and current (2022) Landsat satellite images of the areas were examined. The median pixel values of all available images from 1985 and 2022 were calculated, and the median images from 1985 and 2022 were used. Thus, since the prevailing sky over Antalya is cloudless throughout the year, cloudless images and images free from other noise were produced. In addition, Google Earth images of the areas from 1985 and 2025 were also examined.

Keywords: Sorgun Forest, Titreyengöl Lake, Boğaz Forest, Modified Discriminant Analysis.

INTRODUCTION

Our planet is undergoing constant change and transformation. Approximately 17% of the land on the earth's surface has been converted to urbanisation and agriculture, and 56% is characterised by rural, urban, and suburban use. Only approximately only 26% can be defined as large wild areas. Although these three usage types are considered separately from another, they all require ecological connections within and between them (Sütün, 2021). 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. 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 (Tonyaloğlu and Atal, 2025).

Increasing urbanization and the accompanying urban sprawl have been cited as a major cause of landscape change in many countries around the world. Recent decades show a steady shift of urban populations to the suburbs and the expansion of cities towards forested areas. This change has led to an increase in urban fringe areas that are either in contact with or mixed with forest and rural areas. Especially in the coastal and tourist areas of the European Mediterranean countries, many small towns and resorts have been built in or around natural and forest areas, mainly for their recreational attractions and scenic beauty (Peker, 2021). Turkey is a country with high biodiversity and habitat diversity. To protect habitats, which are a vital component of nature, it is necessary to define, inventory, and map them, just as it is necessary to protect species. The effects of habitat destruction pose a significant threat to biodiversity. It is predicted that biodiversity loss will continue to increase in the coming years as a result of growing environmental problems and negative changes in habitats. Habitat conservation is one of the most effective and rational ways to prevent and/or slow down biodiversity loss. To achieve this, it is first necessary to define, identify, and map habitats with their unique characteristics. Determining habitats at both micro and macro scales is of great importance in developing both local and global conservation strategies (Çakmak and Aytaç, 2021). The greatest negative impact on natural resources is human-induced. Due to the rapid population increase in Antalya in recent years, the city has needed new buildings, new roads, and new living spaces. As a result, existing green areas in the city have disappeared or become constricted (Ünal and Gökoğlu, 2022). Some areas are also experiencing habitat fragmentation due to anthropological pressure.

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The Manavgat Basin is located in the western part of the Taurus Mountains, within the Taurus Karst Belt, in an area where deep and surface karst is intensely developed (Doğan, 2002). Manavgat, a district of Antalya, is situated between 36° 38° 22' 11" and 37° 25° 45' 11" north latitudes and 31° 0° 2' 25' 11" and 31° 44° 35' 11" east longitudes. The district's area is 2,283 km². Manavgat, one of the places in Turkey that experienced a tourism boom in the 1980s, has benefited greatly from its waterfalls, beaches, caves, streams, plateaus, and numerous plant and wild animal species, all of which have contributed to its development as an alternative tourism destination (Akış and Kaya, 2018). The rapid development and change in coastal areas, coupled with the increase in problems, has led to a search for new planning and management approaches. Antalya is the province with the longest coastline on the Mediterranean in Turkey. The Side and Manavgat coasts are a privileged coastal area with significant historical and natural riches, including natural dune beaches, coastal dune forests, rivers, and protected areas. Since the beginning of tourism in the 1980s, physical land-use changes have been observed along the Side and Manavgat coasts, and a number of problems stemming from a lack of planning and management exist in the region. The fundamental reasons for these problems include the insufficient consideration of coastal identity and coastal ecosystems during the planning phase, the long delay in preparing an environmental planning scheme for the region, and the increase in building density through plan revisions (Ortaçeşme and Alpaslan 2009). The industrial revolution and technological advancements have accelerated landscape changes worldwide. This change has resulted in habitat fragmentation and decreased biodiversity. In the Manavgat River basin, the most significant changes are the conversion of forested areas into agricultural land, and vice versa (Yıldırım and Ortaçeşme, 2016). Manavgat Sorgun Forest (Figure 1) holds a significant position among the dune forests located along the Mediterranean coastline. The forest is situated 90 km east of Antalya and west of where the Manavgat River flows into the sea (between 36°46´16.5" N and 31°26´56.5" E latitudes). Located within the Manavgat district, the forest is 1.5 km south of the district center. The forested area extends 250-350 m inland from the coastline, covering an area 6 km long and 1.5-2 km wide. Sorgun Forest covers an area of 637.8 hectares, of which 310.0 hectares is a First Degree Natural Site Area. To the east of the forest lies the Manavgat River, to the north are the agricultural lands and Sorgun neighborhood (formerly Sorgun Village) belonging to the Manavgat district, to the west is the Ayıgözü neighborhood and agricultural lands, and to the south is the beach and the Mediterranean Sea (Erdoğan et al., 2009). Manavgat Gorge Forest (Figure 1) is located between Titreyengöl Lake and the Akçasaz area where the Manavgat River flows into the Mediterranean Sea, at 36°45´19.65" north longitude and 31°27´28.5" east latitude. Situated 85 km east of Antalya city and 3 km south of the district center, this forested area extends 200 m inland from the coast, covering an area 1.5 km long and 200-500 m wide. The forest covers an area of 54 hectares. It is bordered by the Manavgat River to the east, agricultural lands and the Manavgat River to the north, Titreyengöl Lake to the west, and the beach and the Mediterranean Sea to the south. Located between the lake, the river, and the sea, the Gorge Forest is an islet surrounded by water on all four sides (Erdoğan et al., 2010).

Manavgat Titreyengöl (Figure 1) is located 78 km southeast of Antalya province, within the borders of Manavgat district and 2.5 km south of the district center. The lake is situated west of where the Manavgat River flows into the sea, between 36°45'20.2" north and 31°27''15.9" east latitudes. A small wetland formed as a result of the Manavgat River changing its course, the lake was previously connected to the sea, but this connection has disappeared over time. Located between the sea and the Manavgat River, Titreyengöl is 200 m from the sea and 390 m north of the river. Connected to the Manavgat River by a small canal, the lake is situated at an average elevation of 2-4 m above sea level. The depth of the lake is decreasing day by day due to the accumulation of silt at the bottom. Titreyengöl is surrounded by roads to the north and east, and by hotels and holiday resorts to the south and west. The lake has a surface area of 8.2 hectares and a circumference of 8.7 hectares (Erdoğan et al., 2010).

Figure1. *Sorgun Forest, Boğaz Forest and Titreyengöl*

Discriminant analysis is a type of multivariate analysis that is an extension of the single-factor multivariate analysis of variance (MANOVA). After rejecting the Ho hypothesis, which implies no difference between groups, it is concluded that there is a difference between groups. The main reasons for this difference are revealed through discriminant analysis. Discriminant functions obtained through discriminant analysis. i. Discriminant functions consist of the linear components of predictor variables. Discriminant functions reveal which predictor variables influence the difference between groups. These variables that influence the difference between groups are called discriminant variables. Another function of discriminant analysis is to determine, with minimal error, the group to which a unit belongs if it belongs to one of the groups but whose origin is unknown (Ünsal, 2000).

MATERIALS AND METHODS

During the studies titled "Sorgun Forest Nature and Outdoor Sports Park Project Evaluation Report" (Erdoğan et al., 2009), "Determination of the Flora and Fauna of Titreyengöl and its Surroundings and the Determination of Titreyengöl Water Quality" (Erdoğan et al., 2010), and "Evaluation Report on the Wildlife Constituting the Flora and Fauna of Boğaz Forest" (Erdoğan et al. 2010) conducted in 2009-2010, the floristic structure of the areas was examined in detail and flora lists were compiled by me. The flora lists were updated and changes were identified through field studies conducted in 2024-2025. Various sources were used for the identification of plants, primarily the flora of Turkey (Davis, 1965-1982; Davis et al., 1988; Güner et al., 2000), as well as other sources (Ekim, 2005; Ekim et al., 2000; Göktürk and Sümbül, 1997; Ünal, 1996; Ünal and Gökceoğlu, 2003; Heywood et al., 1964-1981; Pignatti, 1982). Modified Discriminant Analysis was performed to determine the similarity between the three areas. For this purpose, the plants in the floristic findings obtained from each area were coded. The coding was done according to the plant, endemism status, IUCN status, Angiosperm or Gymnosperm status, Medicinal and Commercial Plant Status, and class. Thanks to this coding, the 3 areas were compared by performing Modified Discriminant Analysis with SPSS 20.0 IBM COP program. Historical (1985) and current (2022) Landsat satellite images of the areas were examined (https://developers.google.com/earth-engine/datasets/catalog/landsat). The median pixel values of all available images from 1985 and 2022 were calculated, and the median images from 1985 and 2022 were used. Thus, since the prevailing sky over Antalya is cloudless throughout the year, cloudless images and images free from other noise were produced. Google Earth images of the areas from 1985 and 2025 were also examined.

Table 1. *Plant coding statuses*

Endemic Status	Endemic 1 Not endemic 2
Angiosperm/Gymnosperm	Angiosperm 1 Gymnosperm 2
Medicinal	Medical 1 Non-medical 2
Commercial	Commercial 3 Non-commercial 4
Danger Situation	EN 1 VU 2 DD 3 CR 4 LR 5 NT 6 CD 7
Mushroom/Fern/Gymnosperm/ Monocotyl/Dicotyl	Mushroom 1 Fern 2 Gymnosperm 3 Monocotyl 4 Dicotyl 5

RESULTS AND DISCUSSION

Located within the Mediterranean Ecological Region, the Sorgun Forests represent pine forest ecosystems situated on sand dunes. The forest ecosystem contains four different habitats: forest habitat, maquis habitat, maquis-forest habitat, and herbaceous

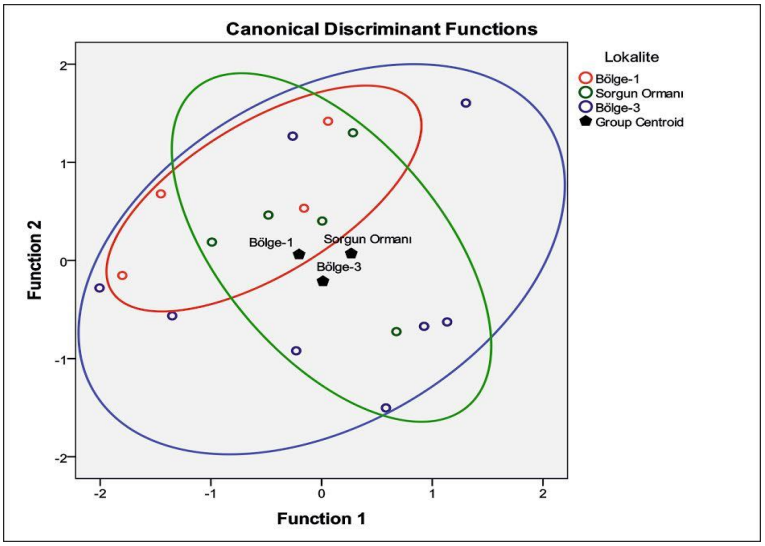
habitat. 404 plant species (302 species, 63 subspecies, and 39 varieties) belonging to 69 families have been identified in the Sorgun Forest. Of these, 4 are endemic, 1 is a rare species, and 11 are in the IUCN category (8 are critically endangered, 2 are critically endangered, and 1 is not yet fully understood). Eight plant species are covered by the Convention on International Trade in Endangered Species of Wild Animals and Plants (CITES). Of the identified plant species, 26 are commercially valuable, 21 are medicinal, and 14 have both medicinal and commercial value. 279 plants are found in herbaceous habitats, 363 in maquis habitats, 43 in forest habitats, and 202 in maquis-forest habitats (some plants prefer more than one habitat). Herbaceous species are widespread throughout the area, primarily in forest and maquis habitats. The presence of herbaceous species prevents dune movement and stabilizes the sand, and is also an indispensable factor in the shelter and feeding of the animals that make up the wildlife. Sorgun Forest is a dune forest that has developed on dunes formed over thousands or even millions of years and has a total area of 637 hectares.. Within the Mediterranean Phytogeographic Region, the Boğaz Forest, located in the Manavgat district of Antalya province, contains four different habitats: Forest, Maquis, Herbaceous, and Dune. These habitats house 70 families, 427 plants, 323 species, 65 subspecies, 39 varieties, and 6 endemic species (Table 2). The thickness of the material (=clay + mud + organic mud) on the bottom of Titreyengöl Lake increases towards the north, i.e., towards the freshwater pumping station, varying between 0.55 m and 2.00 m. The blackening and putrefaction in the lake sediment indicate decomposition in an oxygen-free environment. As a result of the research, it was observed that the lake is very densely covered with submerged (underwater) and emersed (above water) aquatic plants. Especially in the inner parts of the lake, species belonging to the families Ceratophyllaceae (Hornwort family), Haloragidaceae (Water yarrow family), Characeae (Water chandeliers), Potamogetonaceae (Water hyacinth family), and Zannicheliaceae are found, and in the coastal areas; Species belonging to the Poaceae (Gramineae) (Grass family), Thyphaceae (Reed and rush family), Juncaceae (Roughwood family), Butomaceae (Roughwood family), and Cyperaceae (Sedge family) families have been found to be abundant. There are 10 species belonging to 10 families. Located within the Mediterranean Phytogeographic Region, Lake Titreyengöl and its immediate surroundings lie between the Sorgun Forests, composed of Aleppo pine and pistachio pine trees on sand dunes, and the Manavgat River. Situated within a forest and wetland ecosystem, the area boasts a vegetation cover that includes forest trees, maquis elements, dune and hydromorphic alluvial soil types, and aquatic plant species. The Sorgun Forest, located west of Lake Titreyengöl and designated a First Degree Natural Site, is interrupted in the hotel area before continuing again after the lake to the Akçasaz location where the Manavgat River flows into the sea. The Aleppo pine forest on the sand dunes east of the lake extends to the shoreline. Within the degraded Aleppo pine forest, there are individual Aleppo pine trees and, in the undergrowth, maquis elements such as kermes oak, myrtle, mastic, terebinth, and thistle, as well as climbing plants such as hawthorn, blackberry, and vine. Further north, in a small area, there is a plantation of Cypriot acacia. Titreyengöl has four different habitats: Forest, Maquis, Herbaceous, and Seasonal Wetland. In these four habitats, 382 plant species belonging to 66 families have been identified naturally growing in Titreyengöl. Of these identified plants, 289 are species, 56 are subspecies, and 37 are varieties, 2 of which are endemic (Table 2).

Table 2. *Habitat and taxonomic information of Sorgun Forest, Titreyen Lake, and Boğaz Forest*

Area	Habitat	Family/Taxon Number	Species, Subspecies, Variety	Endemic
Sorgun Forest	Forest Maquis Maquis-Forest Herbaceous	69 Family 404 Taxon	302 Species 63 Subspecies 39 Variety	4
Titreyen Lake	Forest Maquis Herbaceous Seasonal Wetland	66 Family 382 Taxon	289 Species 56 Subspecies 37 Variety	2
Boğaz Forest	Forest Maquis Herbaceous Dune	70 Family 427 Taxon	323 Species 65 Subspecies 39 Variety	6

Plants in the floristic findings obtained from each area were coded according to their endemism status, IUCN status, Angiosperm or Gymnosperm status, Medicinal and Commercial Plant status, and class. Thanks to this coding, the 3 areas were compared using Modified Discriminant Analysis with SPSS 20.0 IBM COP program. Accordingly, Boğaz Forest is completely similar to Titreyen Lake. Sorgun Forest and Boğaz Forest are much less similar. On the other hand, Sorgun Forest is partially similar to both regions. However, it is more similar to Boğaz Forest (Figure 2).

Floristic Similarity Status



Eigenvalues				
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	,456[a]	75,0	75,0	,209
2	,152[a]	25,0	100,0	,122
a. First 2 canonical discriminant functions were used in the analysis.				

Figure 2. *Modified Discriminant Analysis of Fields.*

Examination of Landsat satellite images of the areas from 1985 and 2022 reveals that the areas were once a single, unified whole, but over time they have become separated due to habitat fragmentation caused by anthropological pressure (Figures 3 and 4). The primary reasons for this are believed to be increasing population and related construction, as well as anthropological pressure from tourism.

Figure 3. *Landsat Satellite Image 1985.*

Figure 4. *Landsat Satellite Image 2022.*

Examination of Google Earth satellite images of the areas from 1985 and 2025 reveals that the area was once a single, unified whole, but habitats have fragmented over time. Floristic studies and comparisons of similarities show that although Boğaz Forest is completely similar to Titreyen Göl, Sorgun Forest and Boğaz Forest are much less similar, Sorgun Forest partially resembles both areas, and is more similar to Boğaz Forest, the similarities between the areas have gradually decreased and they have diverged over time.

Figure 5. *Google Earth satellite images from 1985 and 2025.*

Rapid development and change in coastal areas driven by population growth have resulted in the destruction of habitats and vegetation. In Antalya, economic growth and restructuring based on tourism since the 1980s have led to significant population and workforce increases. Between 1985 and 2015, the population grew by 257%. During the same period, Antalya had the highest proportion of residents born in other provinces. The tourism workforce increased by 524% between 1980 and 2000. Tourism also impacted the settled foreign population in Antalya. By 2016, the number of foreigners registered in ADNKS (Address-Based Population Registration System) exceeded 60,000 due to residence or work permits, making Antalya the province with the highest foreign population proportion at 2.6% (Işık and Zoğal, 2017). Rapid population growth has raised concerns about natural protected areas. Vuruşkan and Ortaçeşme's 2009 study found that natural protected areas in Antalya are confined within urban fabric due to intensive construction and urbanization and are heavily influenced by urban developments. In recent years, land use has increased along with population growth. Sünbül and Tonyaloğlu (2021) investigated changes and transformations in land use/land cover (LULC) in Antalya Province's Kaş District between 2000 and 2020, reporting a 2.5- fold increase in urbanization and greenhouse activities in coastal areas. The tourism sector in Turkey has developed significantly since the early 1980s, particularly along the Aegean and Mediterranean coasts, thanks to investments and incentives (Akengin and Dinç, 2020).

CONCLUSION

In their 2020 study on changes in the Kundu and Belek tourism regions of Antalya province, Ünal et al. found that construction has predominantly occurred in coastal areas since 1985. They specifically noted an increase in land use and occupation from 1985 to 2022. For the Kundu Tourism Region, the Park-Recreation area was determined to be 74.74 hectares (10.61%) in 2022, while for the Belek Tourism Region it was 8.93 hectares (0.51%). This indicates that there has been intense construction in both Kundu and Belek tourism regions since 1985, with the most significant development observed in the Kundu Tourism Region. In the coastal area east of Antalya, stretching from the Lara Sand Dunes to Manavgat, the areas that have remained preserved with their existing natural structure are the Lara Sand Dunes Natural Site and the Aksu Stream-Beşgöz Creek Natural Site. While the entire coastal strip outside these areas, excluding the ancient city of Side, has undergone significant changes due to various uses, the coastal dune belt area known as Sorgun Forest, Titreyen Lake, and Boğaz Forest has survived to the present day with its natural structure and balance largely undisturbed. Due to the ecological characteristics of this forest

area, it should be designated as an "Absolute Protection Forest Area" and an "Absolute Protection Wetland Area," and all necessary measures should be taken by the relevant institutions to protect the area.

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CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

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