Spatial Analysis of Infrastructure Types in Kızıldağ National Park Using Remote Sensing and GIS

E. Seda Arslan[1,*], *Ömer K. Örücü*[1]

[1] Department of Landscape Architecture, Suleyman Demirel University, Isparta, Türkiye, sedaarslan@sdu.edu.tr, omerorucu@sdu.edu.tr

* corresponding author

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Abstract: Protected areas are pivotal in sustaining life and enhancing human well-being. A comprehensive comprehension of such areas' ecological and natural attributes is imperative for delineating infrastructure modalities aimed at fostering sustainability. In this vein, an analytical methodology was employed to scrutinize land utilization patterns, topographical features, slope gradients, and aspects within the confines of Kızıldağ National Park (KNP). Given the presence of rural settlements surrounding KNP, a spatial analysis of land use and land cover, within the framework of an infrastructure-centric approach, emerges as a viable avenue for discerning prospective challenges and conflicts. The study delineates infrastructure types into four categories – namely green, blue, gray, and yellow –illustrated spatially within the study area. Remote sensing techniques utilizing Sentinel-2A satellite imagery were deployed for data acquisition. Indices such as NDVI, NDWI, and SAVI were scrutinized to identify infrastructure systems and quantified in hectares. The findings reveal that green infrastructure predominates over other infrastructure types within the study area.

Keywords: infrastructure; Sentinel-2A; remote sensing; Kızıldağ National Park; GIS.

1 Introduction

Understanding land use and land cover plays a pivotal role in ecological planning research (Musetsho et al. 2021, Wang et al. 2021). The preferred method in scientific research for comprehending natural resource distributions and their utilization patterns is through the spatial representation of current land cover (Luo et al. 2008, Vizzari 2011, Song et al. 2018, Kiliç and Arslan 2022). Considering the holistic perspective with which landscapes are currently comprehended, owing to the intersection of their numerous dimensions, a thorough assessment of infrastructure types necessitates a more expansive analysis of the structure and interrelations among various landscape components (Degerickx et al. 2020, Arslan et al. 2021).

The utilization of land cover data is frequently observed in determining the relationship between landscape due to its close association with the ecosystem it represents (Burkhard et al. 2012, Koschke et al. 2012, Kandziora et al. 2013). This study aims to identify different land cover types based on the assumption of their potential in landscape. In this study, green infrastructure represents a strategically planned network consisting of natural and semi-natural areas (European Union 2013). Blue infrastructure encompasses all water elements such as rivers, channels, lakes, and wetlands (Bioveins 2017). Yellow infrastructure comprises cultivable areas, pastures, and mixed agricultural lands (Arslan et al. 2021). Grey infrastructure represents all structures, roads, and other urban constructions (Bioveins 2017).

In this context, an analytical methodology was employed to examine land utilization patterns, topographic features, slope gradients, and aspects within the confines of Kızıldağ National Park (KNP). Considering the presence of rural settlements surrounding KNP, a spatial analysis of land use and land cover, within an infrastructure-centric framework, emerges as a promising approach for identifying potential challenges and conflicts. The research categorizes infrastructure types into four groups—green, blue, gray, and yellow—illustrated spatially within the study area. Remote sensing techniques utilizing Sentinel-2A satellite imagery were used for data acquisition. Indices such as Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Soil Adjusted Vegetation Index (SAVI) were analyzed to identify infrastructure systems and quantified in hectares.

Accordingly, the research questions addressed in the study are as follows:

1. What is the relationship between the identified infrastructure systems in the study area and the slope, aspect, elevation, and climatic characteristics?
2. What is the potential of NDVI, NDWI, and SAVI indices obtained from satellite images in detecting infrastructure systems?
3. Which infrastructure type (blue, green, yellow, gray) dominates in terms of area size in the study area?

2 Materials and methods

2.1 Study area

Kızıldağ National Park established on May 19, 1969, is a national park in southern Türkiye. It is in the Yenişarbademli-Şarkikaraağaç-Aksu districts of Isparta Province. Situated in the southwestern region of Turkey amid the lakes district, Kızıldağ National Park (KNP) ranks among the largest national parks in the country covering 80,427.48 hectares. Esteemed for its natural splendor, it serves as a prominent destination for outdoor recreation and nature-based tourism (Figure 1).

2.2 Data preparation and analysis

Sentinel 2A satellite images were used to identify infrastructure types in the study area. The Multi-Spectral Imager (MSI) of Sentinel 2A encompasses a spectral range spanning 443 to 2190 nanometres (nm), offering a swath width of 290 kilometers and achieving spatial resolutions

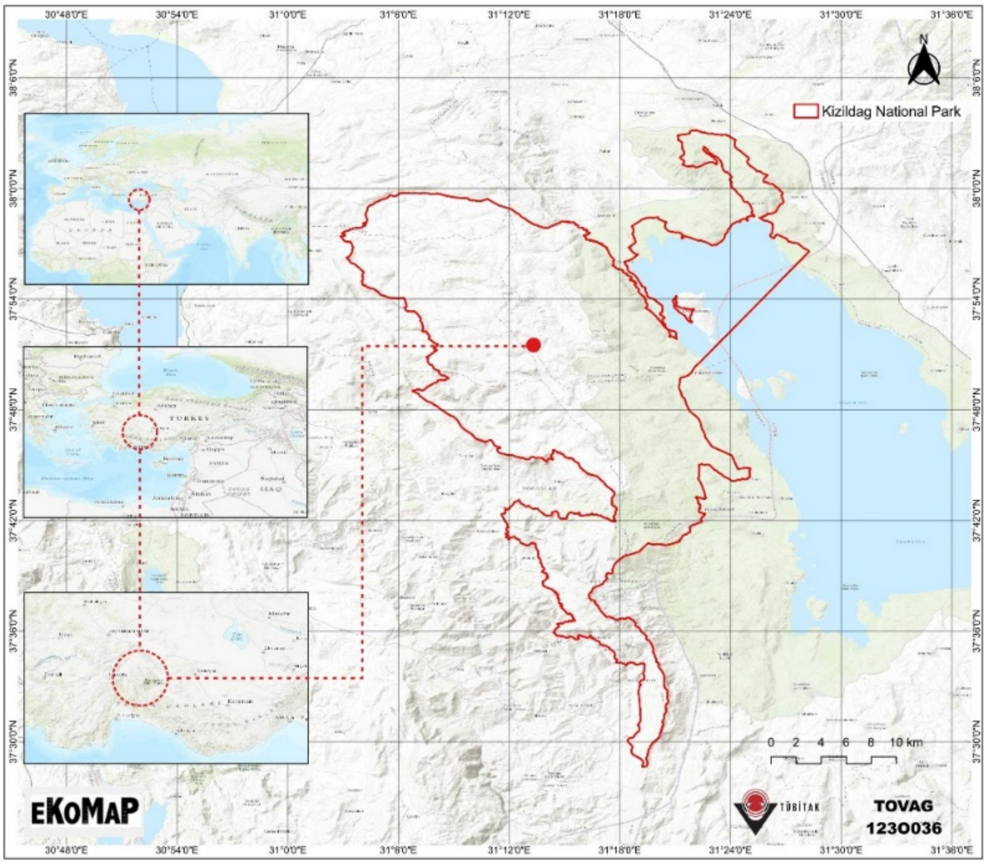

Figure 1. Study area.

of 10 meters for four visible and near-infrared bands, 20 meters for six red edge and shortwave infrared bands, and 60 meters for three atmospheric correction bands. Images dated June 25, 2023, during the most distinct vegetation period, were obtained from https://scihub.copernicus.eu/ and subjected to preprocessing, supervised classification, and validation analyses using QGIS software. Two satellite images have been downloaded. The merging of the bands of the two downloaded satellite images was conducted using the Layer Stack tool under the Raster menu of ERDAS Imagine 2015 software. Radiometric corrections of the satellite images were performed using the semi-automatic classification plugin (SCP) of QGIS 3.34.4 software, and they were saved in the WGS-84-UTM-Zone-36N coordinate system. NDVI, NDWI, EVI (Enhanced Vegetation Index), SAVI, and NDBI (Normalized Difference Built-up Index) indices were generated for the study area. In addition, a Digital Elevation Model (DEM) obtained from the ALOS PALSAR (Advanced Land Observing Satellite) satellite with a resolution of 12.5x12.5 meters was used for surface analysis (slope, aspect, elevation) in the study.

NDVI, SAVI, and EVI indices were utilized to identify green and yellow infrastructures, NDBI index for identifying gray, and NDWI index for identifying blue infrastructures.

NDWI is used for the detection and analysis of water bodies. This Index was used to determine blue infrastructure in the study area. NDVI represents the difference in spectral values reflected by plants depending on the presence of chlorophyll, and it is used to determine the vitality and health status of plants. This Index was used to determine green infrastructure in the study area. NDBI (Normalized Difference Built-up Index) is used to detect built-up areas and is typically employed to identify urban development. This Index was used to determine gray infrastructure in the study area. Another index used in the study is SAVI (Soil Adjusted Vegetation Index). This Index was used to determine yellow infrastructure in the study area.

In the study, a pixel-based supervised classification method was used on the 8-4-2 band combination. Sample areas (training pixels) were selected in locations characterizing four types of infrastructure. These include blue infrastructure (water surfaces), green infrastructure (forest areas and plant communities), yellow infrastructure (agricultural areas and cultivated fields), and grey infrastructure (settlement areas, roads, bare rocky areas, etc.). This technique classifies each pixel in the image based on its spectral value and the groups of example pixels provided during the training phase, thereby assigning the pixels in the image to the defined sub-classes. Subsequently, the Accuracy Assessment command in the ERDAS IMAGINE 15 software was employed to determine the accuracy of the obtained classification data. For the classification accuracy analysis, 135 randomly selected ground control points were used. The ground control data were obtained from field studies and CORINE 2018 Land cover data.

3 Results

The mean elevation within the research domain is recorded at 1347 meters. Elevation demonstrates a declining gradient from west to east. Dedegöl Mountain, situated south of the KMP border, marks the apex in elevation, while

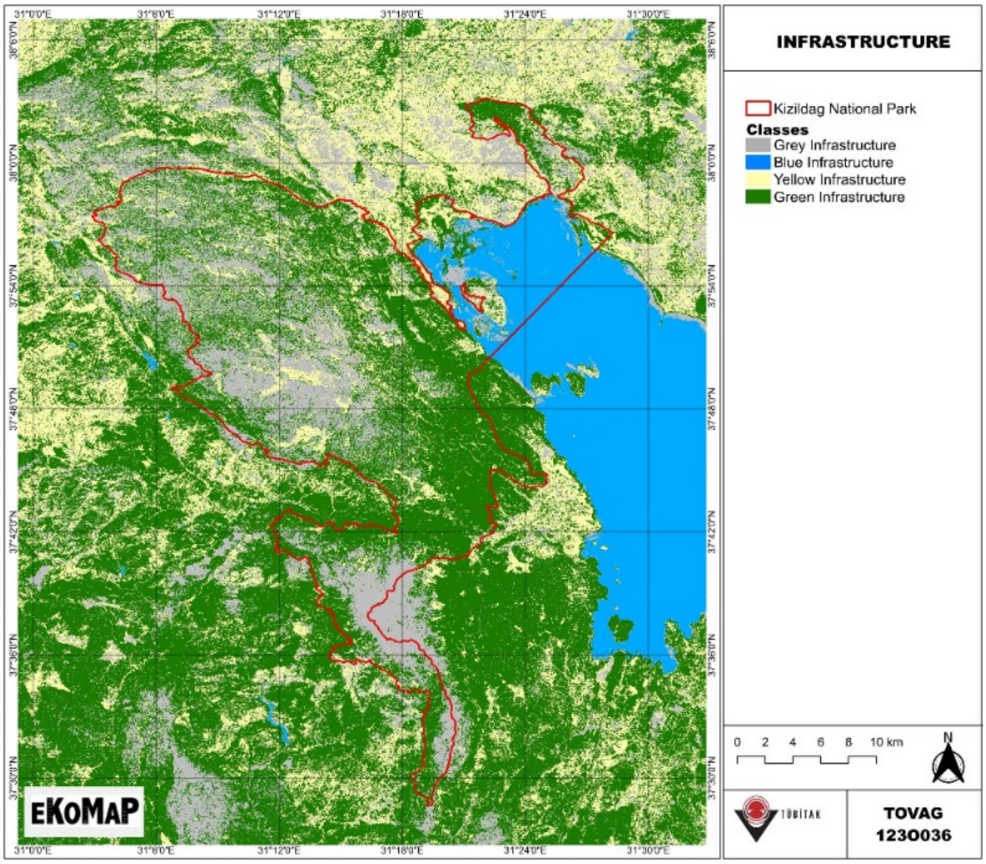

Figure 2. Infrastructure types in the study area.

Beyşehir Lake represents the lowest region. The slope gradients within the study area have been examined across 7 classes. Flat areas and those with slopes close to flat (0–2%) constitute 2.2% of the area. Approximately 55% of the area falls within the 6–24° slope range. The average slope is at approximately 11°. The prevailing aspect in the region is northeast-southwest.

Utilizing data from Sentinel 2A satellite imagery, maps have been generated for normalized vegetation index, normalized water index, soil-adjusted vegetation index, and enhanced vegetation index. The analysis of NDVI indicates that values between –1 and –0.1, corresponding to water-covered areas, account for 6591.74 hectares. Conversely, regions with NDVI values greater than the 0.2 threshold, indicating vegetative cover are represented at 50,880.18 hectares. Similarly, NDWI analysis shows that values within the 0–1 range represent water surfaces, which have been recalculated to cover 8,140.27 hectares following reclassification.

The map illustrating landscape infrastructure types within the study area is presented in Figure 2. Based on Figure 2, it has been calculated that 48% of the study area consists of green infrastructure, 8% comprises blue infrastructure, 30% is composed of grey infrastructure, and 14% is attributed to yellow infrastructure.

'Overall classification accuracy' was calculated as 85.19% and 'overall Kappa statistics' = 0.7782 according to the result of the accuracy assessment.

4 Conclusions

In this study, infrastructure systems are evaluated based on the area they cover and the topographical characteristics of these areas. The potential of determining the infrastructures of the indices used in the study is associated with it. When infrastructures are correlated with the topography of the area, it is determined that the dominant infrastructure type in the area is green infrastructure. The green infrastructure approach has gained visibility for planning landscapes and understanding the features of the land in recent years. It is expected that the results of this study will contribute to the development of methods for the spatial analysis of infrastructure systems and assist in the development of strategies for the sustainability and management of these systems. Consequently, an ecological point of view can contribute to the technology to provide a comprehensive planning approach.

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