



The use of GIS/RS technology in assessing abiotic influencing factors on Forest Health: a Case Study, Divjakë-Karavasta National Park

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Abstract

Geographic Information Systems (GIS) are an important tool in the environmental management of protected areas, offering advanced technological methods for biodiversity protection and spatial planning.

In the Divjakë-Karavasta National Park, the integration of GIS technology has significantly improved the monitoring and management of its rich ecosystems. The use of GIS in this park has enabled a detailed inventory of the health of vegetation, enabling the creation of accurate maps of the distribution of biodiversity.

These maps are essential for identifying areas of special ecological importance and for determining appropriate conservation measures. GIS and RS technology provides a solid methodology used to evaluate and analyze different factors that influence a decision with regards to forest health. It helps assess risk to forest health by considering various ecological, climatic and environmental factors (temperatures, humidity, the spread of fires, air pollution etc.) affecting forest health, thus enabling improved management of the forest environment.

A set of satellite images from SN32-Satellite Nusat 32 (Albania 1)/SN33-Satellite Nusat 33 (Albania 2), year 2024 are used as main data source to analyze risk factors in forest health of the park. Important indices namely Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), Land Cover (LC) and Road infrastructure have been calculated in a GIS environment using ArcGIS Desktop 10.8.2/Pro 3.2. The spatial patterns that study reveal indicate that the majority of forest areas in Divjake-Karavasta National Park resides in an adequate environment under supportive health factors. Moreover, GIS enables real-time monitoring of environmental changes, such as the appearance of invasive species or habitat degradation, providing valuable data for quick and

effective interventions. The integration of GIS in the management of the Divjakë-Karavasta National Park has brought many benefits, but it has also encountered various challenges. One of the main challenges is the need for staff training in the use of advanced GIS technology and the provision of the necessary equipment. However, the benefits of this integration are obvious, including improved efficiency in natural resource management and increased capacity to respond to environmental threats.

Keywords: Geographic Information System, remote sensing, biodiversity, mapping, national Park

1. Introduction

The continuous monitoring of forest ecosystems through Remote Sensing (RS) and Geographic Information System (GIS) technologies, along with their geo-environmental management, particularly when these ecosystems are part of protected areas, poses a significant challenge for developing countries like Albania. Over recent decades, the quality and availability of satellite imagery and aerial photographs have improved substantially, providing valuable resources for both research and education in geography (Williams et al., 2017). In the past decade, Albania has made commendable progress in offering geospatial data through the National Geoportal, developed by the State Authority for Geospatial Information. This represents a significant step toward Open Governance, enabling researchers and professionals to access and utilize geospatial data more effectively. Forest health risk assessment plays a vital role in geo-environmental management by identifying potential threats to forest ecosystems, predicting their impacts, and implementing mitigation measures to safeguard forest health. A comprehensive risk assessment addresses various factors that may endanger forest ecosystems, including both natural and anthropogenic threats.

The assessment of forest health threat factors using GIS and Remote Sensing (RS), along with the implementation of Precision Forestry by institutions responsible for Forests and Protected Areas, supports specialists, researchers, and decision-makers in monitoring and identifying key areas for conservation. It also aids in predicting ecological changes and optimizing forestry operations while mitigating environmental risks that threaten forest ecosystems.

The results of this study can further inform reforestation efforts by guiding the planning of planting activities and ensuring the adoption of sustainable practices that promote long-term forest regeneration.

Study area

Protected areas in Albania represent a vital component of national policies aimed at conserving biodiversity and preserving the country's natural heritage. According to the National Agency of Protected Areas (AKZM), currently, approximately 21.3% of Albania's total territory has been designated as protected, marking a significant increase compared to previous decades (National Agency of Protected Areas, 2025; www.akzm.gov.al).

This network includes a total of 799,991.95 hectares, encompassing 12 national parks, 22 protected landscapes, 5 managed nature reserves, and numerous other areas designated for the conservation of special biodiversity values (National Agency of Protected Areas, www.akzm.gov.al).

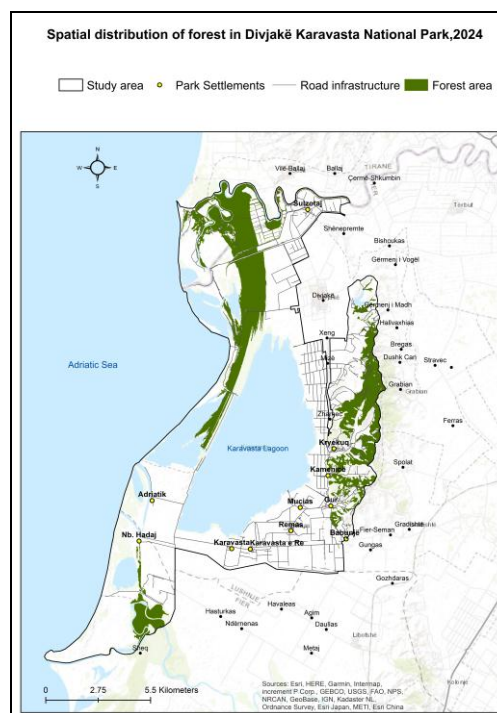
Among the most important protected areas is the Divjakë-Karavasta National Park, which also illustrates the role of forests as both ecological assets and economic resources, contributing to sustainable rural development and nature-based tourism.

Divjakë-Karavasta National Park is distinguished by its diverse natural habitats, ranging from wetlands and lagoons to forest ecosystems. Located along Albania's western coastline, the park covers an area of approximately 22,389 hectares, including coastal zones, lagoons, wetland systems, and forested areas (National Agency of Protected Areas, www.akzm.gov.al). It is recognized as one of Albania's most important biodiversity hotspots and is part of the Ramsar Convention for the protection of wetlands of international importance.

The park is composed of several key ecosystems, including forests, lagoons, and coastal meadows. The landscape is predominantly covered by pine forests and oak woodlands, while the Karavasta Lagoon—one of the largest in Albania—serves as a crucial site for coastal biodiversity and migratory bird species (National Agency of Protected Areas, www.akzm.gov.al). Within the park, forests form a significant component of the natural landscape, covering an area of 2,321.11 hectares, which accounts for approximately 10.37% of the park's total area. These forested zones are primarily composed of stone pines (*Pinus pinea*) and characteristic Mediterranean vegetation, playing an essential role in soil erosion prevention, microclimate regulation, and local biodiversity conservation.

The forest ecosystems also provide habitat for a wide variety of fauna, including several protected and endemic species. The role of forests in Divjakë-Karavasta National Park is multifaceted—ecological, economic, and recreational. Therefore, the sustainable management of these forest resources is critical to preserving the integrity of the park as one of Albania's most valuable natural assets. The conservation of the park's forested areas is a key priority in national strategies aimed at nature protection and the promotion of sustainable tourism in coastal regions.

Figure.1: Forest distribution in study area



Source: ESRI World Topographic base map; ASIG data

The physical-geographical and topographical characteristics of Divjakë-Karavasta National Park create a unique and diverse environment, serving as a valuable natural and cultural resource for Albania. The park not only offers numerous opportunities for ecotourism but also plays a crucial role in preserving regional ecosystems and biodiversity.

2. Database and Methodology

This study focuses on assessing and identifying a set of risk factors affecting forest health by utilizing GIS and Remote Sensing (RS) technologies. To achieve these objectives, satellite images from SN32–Satellite NuSat 32 (Albania 1) and SN33–Satellite NuSat 33 (Albania 2) were used. These images were provided by the State Authority for Geospatial Information in Albania (ASIG) and are part of the NuSat 33 Earth Observation satellite program (<https://geoportal.asig.gov.al>). In total, **30 high-resolution satellite images** with a **70 cm pixel size** were analyzed to calculate the indices required for this study. The images cover the period between **May and July 2024**. To meet the objectives of forest health risk assessment, key vegetation indices such as **NDVI (Normalized Difference Vegetation Index)**, **NDWI (Normalized Difference Water Index)**, and **GNDVI (Green Normalized Difference Vegetation Index)** were generated using the NDVI function and the **Raster Calculator tool** in **ArcGIS Desktop 10.8.2**.

Healthy green vegetation canopies have a distinct interaction with electromagnetic energy, particularly in the visible and near-infrared (NIR) regions of the spectrum. In the visible range, plant pigments—especially chlorophyll—strongly absorb energy, primarily for photosynthesis. This absorption is most pronounced in the red and blue wavelengths, resulting in the characteristic green appearance of leaves due to higher reflectance in the green portion of the spectrum.

3. An overview of natural and anthropogenic factors influencing forest health

Forest health is a crucial focus for the preservation and sustainable development of forest ecosystems and protected areas. This includes evaluating the potential of implementing innovative technologies for forest health assessment, which serve as mechanisms to facilitate monitoring and support informed decision-making for effective geo-environmental management.

Climate change, fragmentation, invasive species, over-exploitation, and deforestation are the main causes of the loss of forest ecosystems. (Dar, Shahid & Nabi, Masarat & Dar, Sajad & Ahmad, Wani Suhail, 2022).

This study, which is closely linked to the impacts of climate change on forested areas, examines several abiotic factors that may threaten forest health. These include both natural and anthropogenic sources such as topographic conditions, topographic moisture, soil salinity, extreme climatic events (e.g., erosion risk, wildfire risk, flood risk, storms), as well as physical infrastructure, urban development, and pollution from human activities.

Many researchers associate forest health assessment with the presence of chlorophyll in leaves, which can be monitored through Remote Sensing (RS) technology. This approach

allows for the detection of vegetation stress in forests by evaluating a range of factors that influence vegetation vitality and plant development.

3.1. Topographic conditions

Divjakë-Karavasta National Park is located in a predominantly flat area with low relief. Its low elevation above sea level contributes to a soft and level landscape, typical of coastal and lagoon environments. Lower elevation zones are generally more vulnerable to anthropogenic disturbances compared to higher elevation areas. In this study, indicators such as elevation and slope were derived from a Digital Elevation Model (DEM), prepared using the Shuttle Radar Topography Mission (SRTM) DEM data from the USGS Earth Explorer platform (<https://earthexplorer.usgs.gov/>).

The geological structure of Divjakë-Karavasta National Park is closely linked to its sedimentary and alluvial formations, which are characteristic of Albania's western coastal and lagoon regions. The area consists primarily of recent geological formations created through the deposition of materials transported by rivers and the sea. This region remains geologically and sedimentologically active due to the continuous deposition processes, influenced by both fluvial and marine dynamics. Periodic flooding and erosion contribute to the formation and regeneration of sedimentary structures, making the landscape dynamic and constantly evolving.

The morphology of Divjakë-Karavasta National Park is distinguished by a diverse combination of relief features, resulting in a complex and unique landscape that includes lagoons, sand dunes, coastal forests, river deltas, and wetlands.

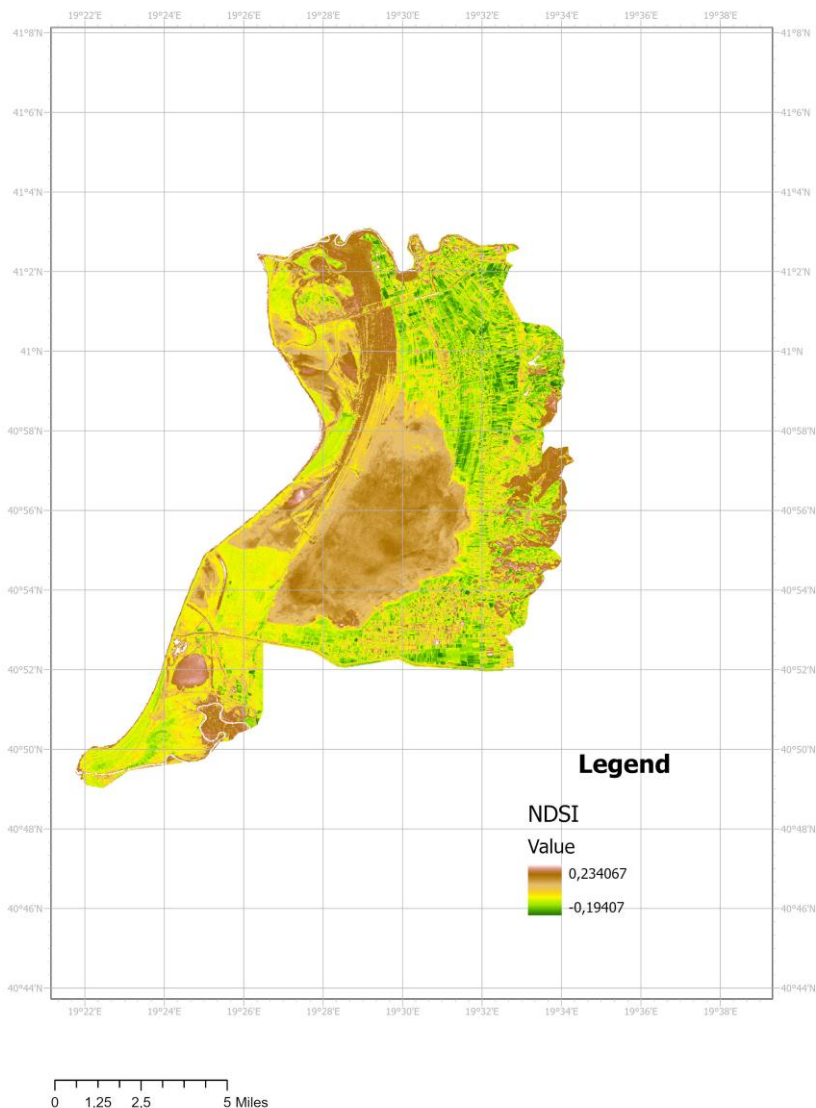
3.2. Soil Salinity

Water flow during the lagoon–sea exchange process, and vice versa, reaches an average rate of 20–30 m³/sec. Over the course of a year, the lagoon surface experiences average evaporation equivalent to a 1,100 mm layer of water. The average monthly water temperature in the lagoon during winter drops to approximately 6°C.

In winter, due to rainfall directly on the lagoon surface and runoff from surrounding land, salinity levels vary between 10 to 25‰, while near the estuary of the communication channels, salinity can range from 30 to 40‰.

The Normalized Difference Salinity Index (NDSI) is a remote sensing method used to estimate soil salinity through satellite imagery. It utilizes specific spectral bands to quantify salinity levels in soil and vegetation. Higher NDSI values (approaching +1) indicate increased salinity, while lower values (closer to 0 or negative) suggest lower salinity or healthier vegetation conditions.

Figure 2:



Here are gray brown soils, according to the national classification; saline soils (around the Karavasta lagoon), alluvial soils (flooded by the deltas of the Shkumbini and Seman rivers), uncultivated sandy land and parts of old sand dunes. We have a concentration of soluble salts, where the chlorine content is at high levels, endangering the cultivation of plants (AKM 2015).

3.3. Hydrometeorological Conditions

The climate of Divjakë-Karavasta National Park is typical of Albania's coastal zones and is classified as Mediterranean. It is strongly influenced by the park's proximity to the Adriatic Sea and the presence of the Karavasta Lagoon. This climate supports a wide variety of vegetation types and ecosystems, including coastal forests, wetlands, and lagoon habitats, contributing to the park's rich biodiversity.

The park falls within the Mediterranean Plain Climatic Zone, specifically its central sub-zone, which is characterized by hot summers and mild winters. The average annual temperature is

approximately 17.1°C, with average temperatures of 24°C in July and 8.1°C in January. The average annual temperature amplitude is 15.5°C.

Rainfall is most abundant from November to March, with an annual average precipitation of 1,000 to 1,200 mm. Humidity levels remain high throughout the year, particularly during the rainy season, helping to sustain the lagoon and forest ecosystems.

3.3.1. Damage from Extreme Temperatures

Late spring frosts tend to be more damaging to coniferous species than early autumn frosts. Frost can cause deciduous wood to dry out, especially when gangrenous tissue surrounds it. A major concern is the formation of frost cracks, which may allow the entry of pathogens and lead to disease.

Frost cracks are common, especially in beech trees and other hardwood species with heart-shaped cross-sections. Sudden increases in air temperature can also cause leaf scorch, where the edges of leaves appear wilted or burned. In conifers, foliage may turn from healthy green to red, indicating stress or damage.

Larger trees may suffer from crown dieback (peripheral drying) due to sustained high summer and autumn temperatures, particularly when soil moisture is low.

3.4. Wind Damage

Periodic exposure to strong winds can significantly affect tree structure and health by reducing crown quality, stem straightness, and overall growth. Common signs of wind damage include:

- Uprooted trees with attached root systems
- Splintered or broken branches, especially in the upper canopy
- Leaning or tilted tree trunks

3.4.1. Drought Risk

To monitor vegetation moisture and drought conditions, the Normalized Difference Moisture Index (NDMI) is used. NDMI is particularly effective for tracking droughts, irrigated land, and wetland dynamics. It is derived from satellite imagery using reflectance values in the Near-Infrared (NIR) and Short-Wave Infrared (SWIR) bands.

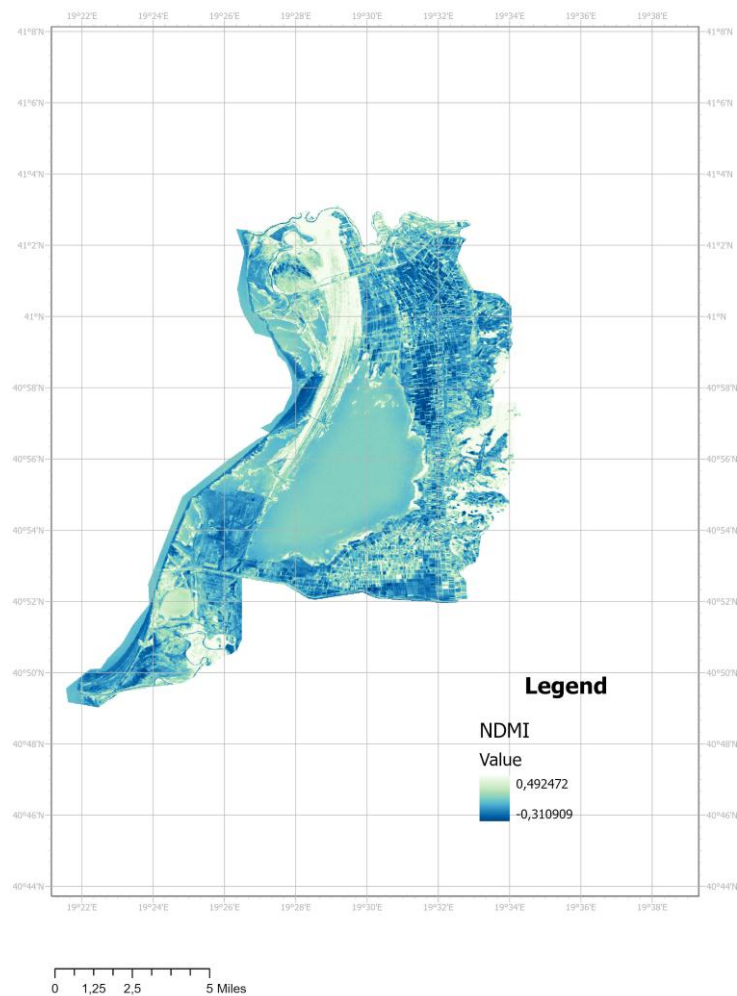
Soil moisture (SM) is a critical factor in influencing vegetation leaf water potential and production under drought stress (Konings and Gentine, 2017; Liu et al., 2020), and has been used as a drought indicator for vegetation response studies (Bastos et al., 2020).

NDMI values range from -1 to +1:

- Negative values (approaching -1): Indicate barren soil or severe drought.
- Values near zero (approximately -0.2 to 0.4): Indicate vegetation under water stress.
- Positive values (approximately 0.4 to 1): Reflect healthy vegetation with adequate water content.

Similarly, the Normalized Difference Water Index (NDWI) is another widely used metric for assessing plant water stress and drought impact, particularly effective in wetland and agricultural monitoring.

Figure 3:



3.5 Anthropogenic disturbances

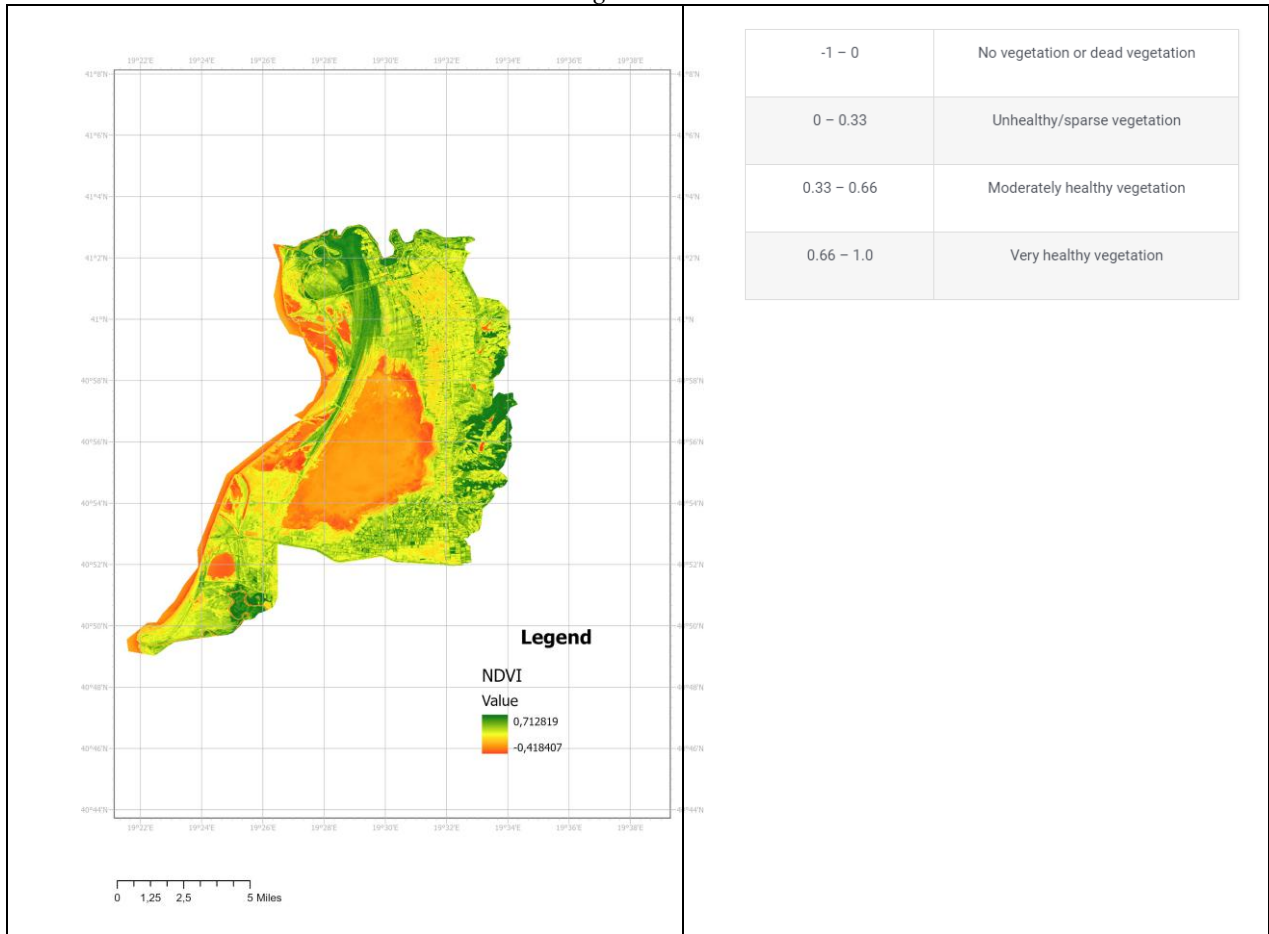
Anthropogenic disturbances, such as settlements, infrastructure development (e.g., roads), and land use/land cover (LULC) changes, can significantly alter ecological systems by modifying the natural landscape configuration and increasing the vulnerability of ecosystems.

One of the most commonly used vegetation indices in forest classification and land cover change studies is the Normalized Difference Vegetation Index (NDVI).

NDVI is an important index used to measure the various aspects of vegetation at spatio-temporal scale (S. Dutta et al., 2020)

NDVI is widely applied to monitor vegetation vigor by analyzing reflectance in the near-infrared (NIR) and red (RED) spectral bands. This index serves as a measure of vegetation health and greenness, with values ranging from -1 to +1. Higher values indicate dense, healthy vegetation, while lower or negative values indicate sparse or stressed vegetation, bare soil, or water bodies.

Figure 4:



As shown on the map (Fig. 4), very low and low NDVI values mainly correspond to water surfaces, whereas high and very high values are associated with forest areas located in the northern, eastern, and southeastern parts of the park. Interestingly, several patches with very low NDVI values are also found within forested zones, indicating areas of possible vegetation stress or disturbances.

The Normalized Difference Built-up Index (NDBI) is a remote sensing index particularly useful for identifying and monitoring built-up areas in urban and peri-urban environments. NDBI values range from -1 to +1, where higher values typically indicate a greater presence of urban or built-up land, while lower values reflect vegetated or natural land covers.

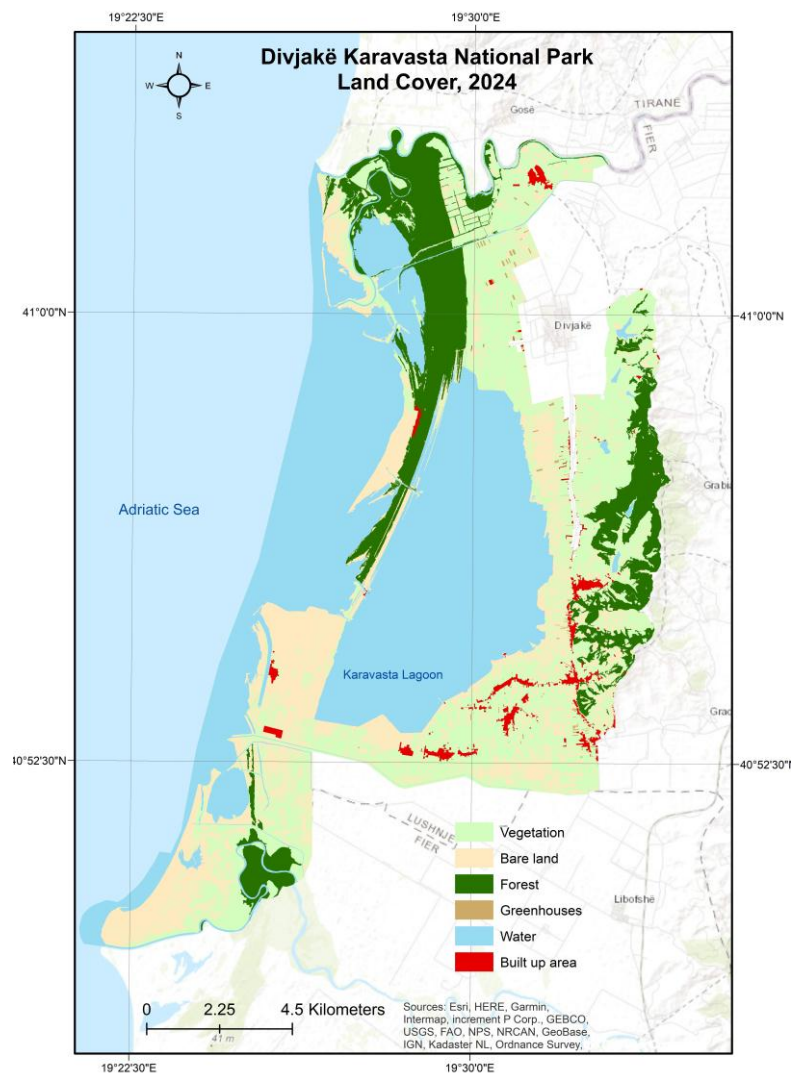
The land cover index in Divjakë Karavasta National Park (Figure 7) is categorized in 6 classes (Table 1) as follows: 1) vegetation, 2) bare land, 3) forest, 4) greenhouses, 5) water, 6) built up area.

Table 1

Land cover classes	%	Ha
1. Vegetation	27	6500
2. Bare land	19.25	4504
3. Forest	13	3265
4. Greenhouses	0.15	38
5. Water	38	9189
6. Built up area	2.6	618

Source: Authors' calculation on LC data

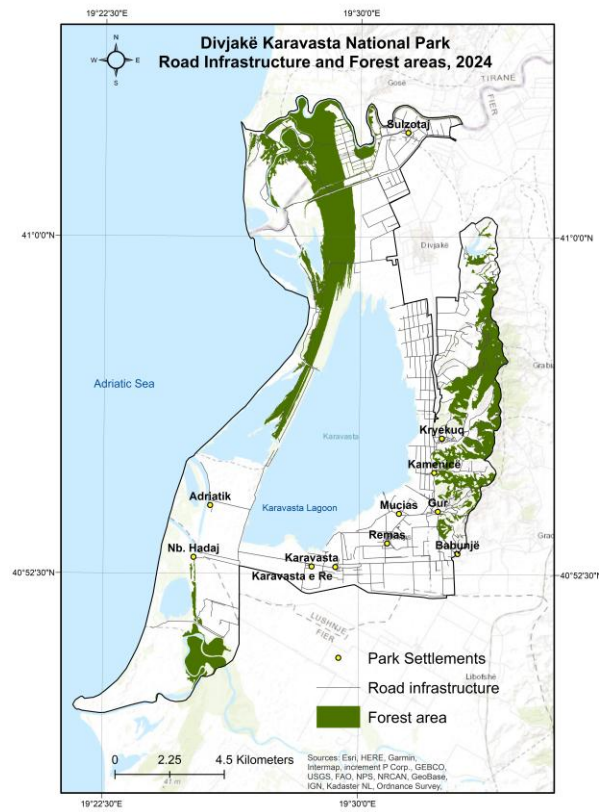
Figure 5:



Road infrastructure within Albania's protected areas represents a vital component for enabling access, fostering sustainable tourism development, and promoting the natural and cultural values of these territories. However, interventions in the form of road construction or improvement can have significant environmental consequences, particularly for forest ecosystems. Negative impacts include habitat fragmentation, land degradation through erosion, disruption of ecological corridors for wildlife, the spread of invasive species, and increased pollution (acoustic, atmospheric, and hydrological). Therefore, the planning and development of road networks in these ecologically sensitive areas must align with the principles of sustainable development and integrated land management, ensuring the long-term preservation of their environmental integrity.

In this study the extent of road infrastructure in the park is used as an additional indicator that provides insights on the interaction of human activities with forest area in Divjakë Karavasta National Park.

Figure 6: Road infrastructure and forest areas



Source: ESRI World Topographic base map; SN32-Satellite Nusat 32(Albania 1)/ SN33-Satellite Nusat 33(Albania 2)

3.5.1 Forest fires

1.1 Fire is a major disturbance factor. Fire often gets out of control and destroys forest vegetation and biomass. Forest fires pose a serious threat to the sustainable use of natural resources. Both the uncontrolled expansion of agricultural land and the increased use of forests for recreational purposes and tourism increase the risk of forest fires.

The main causes of forest fires in this area include:

- Natural factors, such as high temperatures and dry climatic conditions.
- Human activities, including negligence during picnics, the burning of agricultural waste, and intentional arson.

These fires have severe consequences on the park's ecosystem, including:

- Loss of biodiversity, through the destruction of rare plant and animal species.
- Habitat degradation, negatively affecting the ecosystem services the park provides.
- Increased soil erosion, which can lead to flooding and further environmental degradation.

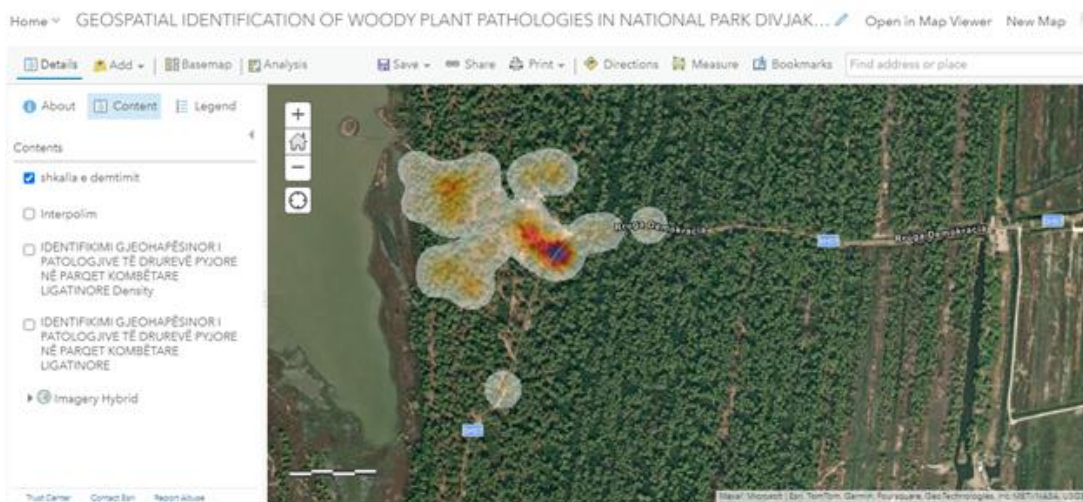
To address this problem, immediate and long-term measures are necessary, such as:

- Strengthening the capacity of firefighting services, by providing modern equipment and specialized training.
- Raising awareness among local communities about fire risks and prevention strategies.
- Strict enforcement of environmental laws, particularly targeting illegal burning and other harmful activities that elevate wildfire risk, is essential. The ecological value and vulnerability of Divjakë-Karavasta to fire necessitate integrated strategies for fire prevention, monitoring, and sustainable land management. These strategies are vital for ensuring its protection and resilience amid climate change and escalating human pressures.

Figure 7: Reporting through arc gis survey 123 of damage to forest areas by natural and human factors



Overlay of geoinformation generated by UAV/GIS SURVEY 123/technologies and interpretation of results



Acknowledgment

This paper is an output of the science project conducted within the framework of the *National Program for Technology and Innovation (PTI), 2024*, funded by the **National Agency for Scientific Research and Innovation (AKKSHI)**. Project's title is "*The Use of GIS/RS in Risk Assessment and Forest Health Forecasting for Effective Geo-Environmental Management in the Divjakë – Karavasta National Park*".

We would like to express our warmest gratitude to State Authority for Geospatial Information in Albania (ASIG) for providing us with the satellite images and other auxiliary data needed to complete this study.

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