*Corresponding Author's Email: enkela.begu@fhf.edu.al
Proceedings of the International Conference on Advanced Research in Social Sciences
Vol. 2, Issue. 1, 2025, pp. 1-10
DOI: https://doi.org/10.33422/icarss.v2i1.1036
Copyright © 2025 Author(s)
ISSN: 3030-0967 online

The use of MCDA in forest health risk assessment for an effective geoenvironmental management of Divjake Karavasta National Park

Enkela BEGU[*1], Sonila SINJARI[2], Romeo HANXHARI [3], Xhulia BYGJYMI[4], D ritan PRIFTI[5]

[1*] PhD, University of Tirana, Faculty of History and Philology, Department of Geography, Albania.

[2] Assoc. Professor, University of Tirana, Faculty of History and Philology, Department of Geography, Albania

[3] Professor, University of Tirana, Faculty of History and Philology, Department of Geography, Albania

[4] PhD candidate, University of Tirana, Faculty of History and Philology, Department of Geography, Albania

[5] Director at the Remote Sensing Data Processing Department, State Authority for Geospatial Information, Albania

Abstract

Forest health refers to the overall ecological and functional condition of a forest, which affects its ability to support biodiversity, regulate the climate and provide natural resources for people and the surrounding environment. Since healthy forests are essential for maintaining ecosystems and combating climate change, continuing monitoring of their health status is crucial for an effective geo-environmental management process. Therefore, identifying risk factors and providing adequate information on potential problematic areas becomes an important task for protected areas managers at local and national level. This requires finding and obtaining a large amount of data from different sources and methods, a situation that can become complex in terms of spatial decision making because all the contributing factors need to be evaluated simultaneously. Nowadays, with development of geo-information technology these difficulties can be easily overcome by using Multi-Criteria Decision Analysis (MCDA) techniques. In this study, the adaptation of GIS/RS-based MCDA techniques in Divjake-Karavasta National Park is examined and explained. 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 reveals indicate that the majority of forest area in Divjake-Karavasta National Park resides in an adequate environment under supportive health factors.

Keywords: Forest health, National Park, MCDA, satellite images, vegetation indices

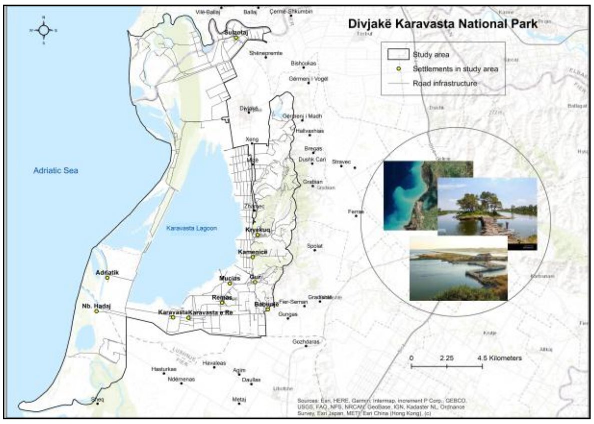
1. Introduction

Forests are crucial for maintaining biodiversity, regulating climate, and providing ecosystem services, such as carbon sequestration and water regulation. Forest health is a term used to describe the condition of a forest that directly depends on nature and human activities. It is determined by the various components including plant growth, organism, climate, insects and human. The Society of American Forests defines forest health as ‘the perceived condition of a forest derived from concerns about such factors as its age, structure, composition, function, vigor, presence of unusual (S. Dutta et al.,2020). Forest health risk assessment plays a vital role in geo-environmental management, as it helps identify potential threats to forest ecosystems, predict their impacts, and establish mitigation measures to protect forest health. A comprehensive risk assessment focuses on several factors that can threaten the health of forests, which can be categorized into both natural and anthropogenic threats.Some of the key components of forest health risk assessment would include:a) identification of risk factors that that may negatively affect forest health such as pollution,climate change,fires,land use change,soild degradation,pets and deseases,illegal activities; b)vulnerability assessment which focus on understanding how different forest species and ecosystems respond to risk factors. This is crucial for identifying vulnerable areas in order to assist planning operation; c) use of GIS/RS for hazard identification, continous monitoring and mapping which nowadays are proven to be essential tools for assessing and visualizing risks patterns;d) performing impact analysis in order to assess the potential impacts of identified risks.This includes evaluation of: 1)ecological impacts in terms of risks that pests or diseases will have on forest biodiversity, forest cover, and ecological functions;2)economic impacts by estimating the economic costs of forest damage, including loss of timber, non-timber products, tourism revenue, and ecosystem services; 3)social impacts by identiying communities that dependent on forests for livelihoods (e.g., indigenous peoples, farmers, or tourism operators) that can experience profound social consequences.Great forestry management includes knowing the resources the forest contains, calculating potential value and planning operations.Traditional forest surveys are effective but are limited by the area of coverage. Therefore, assessing stress caused by biotic and abiotic factor using remote sensing to complement field survey is vital for maintaining healthy and productive forests over large areas. All the above discussed issues are especially important with regards to a National Park area. Forest health risk assessment in national parks is a complex but essential task to ensure the long-term ecological integrity of these protected areas. By identifying risks, assessing vulnerabilities, and implementing adaptive management strategies, park managers can protect forests from threats such as invasive species, climate change, wildfires, and human activities. Ongoing monitoring and early warning systems also play a critical role in responding to emerging risks and ensuring that national parks remain resilient and sustainable for future generations. In this context, the main focus of this study is the use of GIS/RS technologies to provide insights on park’s forest health status in support of forest management decision-making. To achieve this goal important indices such as Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), Land Cover (LC) and Road infrastructure were chosen to examine the risk factors on forest health. Their patterns of spatial distribution were analyzed using satellite images as input data and MCDA approach in a GIS environment.

1.1 Study area

The Divjakë-Karavasta National Park lies on the Adriatic coast of Albania with a territory of 22,389 ha, at a distance of 90 km from Tirana city and 60 km from the Port of Durrës. It is a complex ecosystem combining several habitats with a diversity of wild flora and fauna and an amazing landscape[1]. Among the largest in the Mediterranean Sea, the lagoon of Karavasta has been recognised as a wetland of international importance by designation under the Ramsar Convention (N. Pano et al.,2018). The forests and woodlands are ascertained by a mixture of varied species of deciduous, coniferous and mixed trees, due to the lower river valleys and sea coast (J. Dhimitri et al.,2015). The area hosts the ecoregion of Illyrian deciduous forests, which is part of a larger biome called the Palearctic Mediterranean forests. The forest ecosystem in this park also includes dense pine forests located along the coastline, playing a vital role in protecting the inland ecosystems from erosion and saltwater intrusion. In 1966, the Divjaka Pine Forest was designated as a Strictly Protected Reserve, spanning 7 km. Recognizing its unique qualities, the Albanian government took the step in 1994 to proclaim the entire Karavasta - Divjaka wetland complex, which covers an area of 145 sq. km, as a specially protected natural ecosystem[2].

Figure 1: Study area



Source: ESRI World Topographic base map; ASIG data

Fig.2 Forest distribution in study area

Source: ESRI World Topographic base map; ASIG data

2. Database and Methodology

This study focus on assessing and identifying a set of risk factors in forest health by making use of GIS/RS technology. In order to achieve these objectives satellite images from SN32-Satellite Nusat 32 (Albania 1) and SN33-Satellite Nusat 33 (Albania 2) are utilized. They were provided by State Authority for Geospatial Information in Albania (ASIG)[3] and are part of NuSat 33, an Earth Observation satellite. In total there is a number of 30 images with high resolution - 70 cm pixel size - used to calculate indices needed for this study. Their time spam

[1] https://akzm.gov.al

[2] https://peakvisor.com/park/divjaka-karavasta-national-park.html

[3] https://geoportal.asig.gov.al

is between May-July 2024. In order to fulfil the objectives for forest health risk assessment first vegetation indices like NDVI, NDWI and GNDVI were generated applying NDVI function and Raster Calculator tool in ArcGIS Desktop 10.8.2. In addition, two more data layers - Land Cover and road infrastructure were created by using Deep Learning functions in ArcGIS Pro 3.0. All the indices were categorized into five classes i.e. very high, high, moderate, low and very low based on Quantile classification method. A GIS based multi-criteria decision method (MCDA) was then applied resulting in identification of vulnerable areas that are at risk with regards to forest health.

2.2 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). The NDVI is computed as the difference between near-infrared (NIR) and red (RED) reflectance divided by their sum. $NDVI_i$ represents smoothed NDVI (sNDVI) observed at time step i and their ratio yields a measure of photosynthetic activity within values between − 1 and 1. Thus, the high values of this index strongly indicates the presence of vegetation in that particular area. In this study area NDVI values range from -0.88 to 0.99 (Figure 4) and based on Quantiles classification they will form five classes respectively: -0.88 to -0.099 (very low), > -0.099 to - 0.10 (low), > 0.10 to - 0.35 (moderate), >0.35 to - 0.51 (high) and >0.51 to - 0.99 (very high). As it can be seen in the map (Fig.4) very low and low NDVI values represents mainly water surfaces while high and very high ones are related to forest areas located in the north, east and south eastern part of the park. It is interesting to notice that numerous patches of very low values of this index can be found also inside the forest area.

2.3 Green Normalized Difference Vegetation Index (GNDVI)

The Green Normalized Difference Vegetation Index (GNDVI) is a vegetation index used to determine water and nitrogen uptake into the plant canopy. GNDVI values range from -1 to 1, with higher values indicating dense and healthy vegetation cover. Values between -1 and 0: are associated with the presence of water or bare soil. It is used mainly in the crop cycle’s intermediate and final stages. GNDVI is more sensitive to chlorophyll variation in the crop than NDVI and has a higher saturation point. It can be used in crops with dense canopies or in more advanced stages of development, while NDVI is suitable for estimating crop vigor during the early stages. As for how it is calculated, the GNDVI is the green vegetation index that uses the near-infrared (NIR) and green band (GREEN) of the electromagnetic spectrum. In this study area GNDVI values (Figure 5) range from -0.94 -0.99. Using the same methodology based on Quantiles classification we obtained five classes for this index as follows: -0.94 to -0.22 (very low),> -0.22 to - 0.061 (low), >0.061 to - 0.31 (moderate), >0.31 to - 0.43 (high) and >0.43 to - 0.99 (very high). The spatial distribution patterns of this index indicate high values located on the north, east and south east part of the park. The slight difference on the value range with NDVI values can also be noticed in the area coverage with regards to forest distribution.

2.4 Normalized Difference Water Index (NDWI)

The Normalized Difference Water Index (NDWI) known to be strongly related to the plant water content, NDWI is a very good proxy for plant water stress. It is a satellite-derived index from the Near-Infrared (NIR) and Short Wave Infrared (SWIR) channels. The SWIR reflectance reflects changes in both the vegetation water content and the spongy mesophyll structure in vegetation canopies, while the NIR reflectance is affected by leaf internal structure and leaf dry matter content but not by water content (European Commission, 2011).

It is particularly useful for monitoring droughts, irrigated lands, and wetlands. NDWI is calculated using the near-infrared (NIR) and short-wave infrared (SWIR) bands of satellite imagery to highlight water features and enhance the presence of water in the study area. This index is sensitive to changes in the water content of leaves. Thus, by assessing vegetation moisture content where higher positive values indicate healthier vegetation with higher water content while lower positive or negative values suggest vegetation under water stress or with lower moisture content makes this index an invaluable tool in environmental monitoring. Values of NDWI > 0.3 typically indicates open water bodies, those between 0 to < 0.3 may represent mixed pixels of water and vegetation or soil with high moisture content and values < 0.0 generally, represents non-water features like vegetation, soil, or built-up areas. In this study area NDWI values (Figure 6) range from -0.99-0.99. Based on Quantiles classification these values are classified as follows: -0.99 to -0.45 (low water content), >0.45 to -0.32 (moderate water content), >0.32 to -0.061 (high water content), >0.061 - 0.20 (very high water content), >0.20 - 0.94 (water body). The patterns of spatial distribution that this index creates indicates that the forest areas have a low moisture content which can compromise in turn forest health.

2.5 Land Cover Index (LC)

The term "land cover" refers to the physical coverage of the Earth's surface. Generally, its index includes various biophysical categories such as as: areas of vegetation (trees, bushes, crops, grasses, herbs); artificial land (buildings, roads); bare soil (rock, sand); wet areas and bodies of water (sheets of water and watercourses, wetland). 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 4: NDVI index

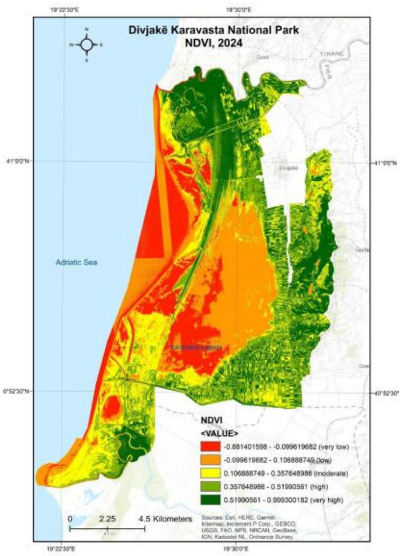


Figure 5: GNDVI index

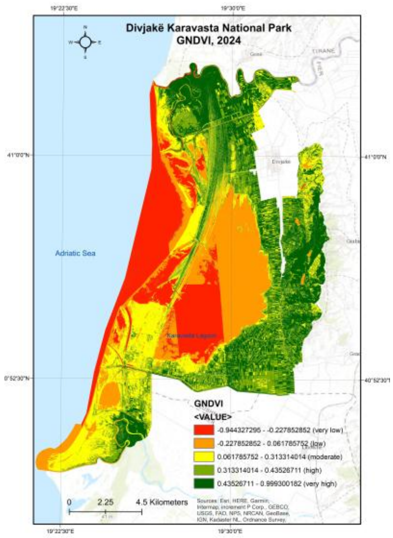


Figure 6: NDWI index

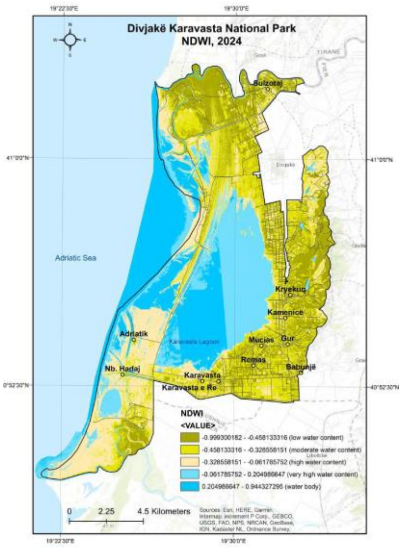
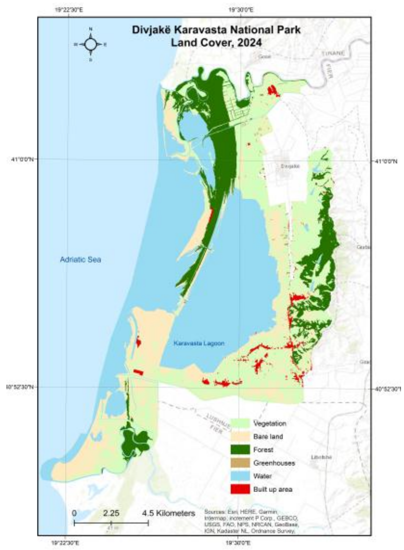


Figure 7: Land Cover index



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

2.6 Road Infrastructure and forest areas

Forest roads are a necessary element for accessing forestry resources, but their impact on the environment can be significant. Forest roads can cause a variety of negative impacts on forest areas such as: facilitating the spread of invasive organisms; creating improved access to forests, which in turn can increase predation rates from hunters; polluting the soil and water primarily because of the sediment. On the other hand, a well-planned, designed, constructed, and maintained forest road can be a valuable asset to park managers. Access to extractive resources is the first step in the forestry supply chain, eventually allowing forest products to be transported around the world (Boston,2016). 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 8/Table 2).

Figure 8: Road infrastructure and forest areas

Source: ESRI World Topographic base map;

SN32-Satellite Nusat 32(Albania 1)/ SN33-Satellite Nusat 33(Albania 2

Table 2: Road location

Road location	%
Inside forest area (forest roads)	1.15
Outside forest area (park roads)	98.85

Source: Authors' calculation on road infrastructure data

3 Multi-criteria Decision Analysis (MCDA)

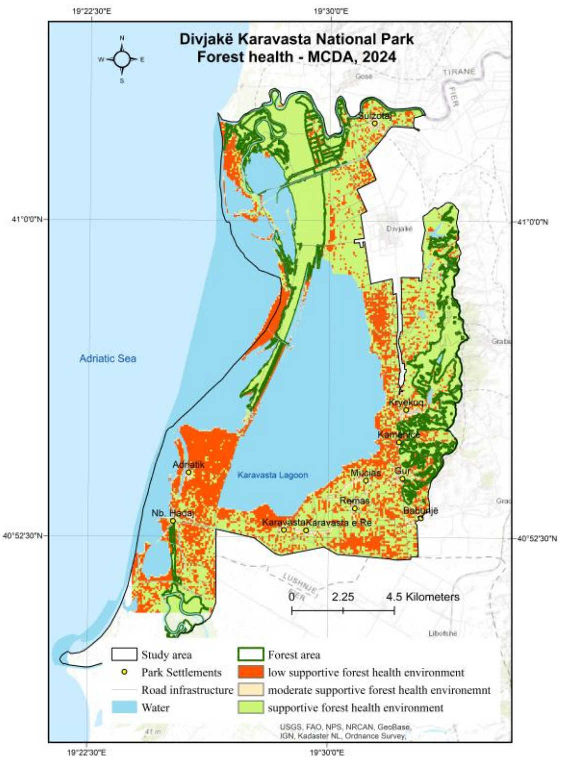
A GIS- MCDA based approach was used in this study to derive and analyze spatial patterns and relations of 5 (five) indices taken in consideration. These indices are: Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), Land Cover (LC) and Road infrastructure. A common scale factor was then applied to their values in order to create a pair wise relation with risk health factors in terms of their positivly supportive environment and vice versa (Table 3). The MCDA revelas areas that vary from low to supportive forest health environment (Figure 9). Most of the forest areas in Divjakë Karavasta National Park resides on a supportive environment.

Table 3: Common Scale factor

Indices	Assigned weight in a common scale factor (1= risk health factors/5=supportive health factors)				
	1	2	3	4	5
NDVI	very low	low	moderate	high	very high
GNDVI	very low	low	moderate	high	very high
NDWI	low water content	n/a	moderate water content	high water content	very high water content
Land Cover	Built up area, bare land, greenhouses	n/a	water	n/a	forest, vegetation
Road infrastructure	forest roads (inside forest area)	n/a	park roads (outside forest area)	n/a	n/a

Source: Authors' calculation

Figure 9: MCDA



Source: ESRI World Topographic base map; Authors' calculation/design

4 Conclusions

The study has used satellite image data to obtain information on spatial distribution of 5 indices with regards to forest health risk factor assessment in Divjakë Karavasta National

Park. These indices are: NDVI, GNDVI, NDWI, LC and Road infrastructure. All the indices were found effective in examining the forest health in the study area and have shown high degree of positive spatially correlation between them. The results of MCDA analysis used in a GIS environment provide useful information on forest areas that are under positively supportive environmental health factors. Therefore, findings of this study will contribute on increasing the understanding of forest health status among all the stakeholders involved in park's management to continue forest protection policies in support of long term forest health.
The study also emphasizes the importance of efficiency of Remote Sensing as an innovative technology that provides decision-makers with complex data at a fine spatial resolution. These data in a raster format can be easily combined with other thematic information in a GIS environment creating the foundation for operational forest inventory and monitoring programs in local and national level.

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 auxilary data needed to complete this study.

References

Bostoni, K. (October 2016). The Potential Effects of Forest Roads on the Environment and Mitigating their Impacts. Springer International Publishing AG 2016. [Online]. Available: https://link.springer.com/article/10.1007/s40725-016-0044-x

Dhimitri,J., Sinani, A., Todi, J., (December 2025). The Landscape of Divjakë-Karavasta National Park in Information among Youth. Agriculture and Agricultural Science Procedia. [Online].

Available: https://www.researchgate.net/publication/275589622_The_Landscape_of_Divjake-Karavasta_National_Park_in_Information_among_Youth

Pano,N.,Simeoni,U.,Frasheri,A.,Abdyli,B.,(2018). The principal aspects of the limniological of Karavasta Lagoon system.

Available: https://en.wikipedia.org/wiki/Divjak%C3%AB-Karavasta_National_Park

Dutta,Sh., Sahana,M.,Rehman,S.,Sajjad,H., (August,2020). Assessing Forest Health Using

Geographical Information System Based Analytical Hierarchy Process: Evidences from Southern West Bengal, India. In book: Spatial Modeling in Forest Resources Management: Rural Livelihood and Sustainable Development Publisher: Springer International Publishing. [Online].

Available:https://www.researchgate.net/publication/343601253_Assessing_Forest_Health_Using_Geographical_Information_System_Based_Analytical_Hierarchy_Process_Evidences_from_Southern_West_Bengal_India

European Commission. NDWI: Normalized Difference Water Index. 2011. Version 1.

DESERT Action - LMNH Unit. Accessed March 13, 2019 [Online].

Available: http://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_ndwi.pdf

Fassnacht, F et.al, Remote sensing in forestry: current challenges, considerations and directions Forestry: An International Journal of Forest Research, 2024, 97, 11–37. https://doi.org/10.1093/forestry/cpad024

Websites

https://geoportal.asig.gov.al

https://akzm.gov.al

https://peakvisor.com/park/divjaka-karavasta-national-park.html