

REMOTE SENSING-BASED ASSESSMENT OF LAND USE DYNAMICS AND ECOSYSTEM SERVICES IN ALBANIAN COASTAL LAGOONS: IMPLICATIONS FOR SUSTAINABLE TOURISM DEVELOPMENT

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ABSTRACT

Coastal lagoons of Albania are multifunctional ecosystems that support biodiversity, regulate environmental processes, and sustain local economies through fisheries, agriculture, and tourism. In recent decades, urban expansion and tourism development have increased pressure on wetlands. The Kune-Vain wetlands, located between Shëngjin and Lezhë, are an important protected wetland on the northern Albanian coast and are increasingly affected by land transformation. This study investigates land use dynamics and vegetation changes in the Kune-Vain wetlands using remote sensing techniques and assesses their implications for ecosystem services and sustainable tourism development. The research covers the wetland ecosystem and adjacent coastal and urban areas influenced by the expansion of Shëngjin and Lezhë. Multi-temporal land use/land cover (LULC) datasets derived from Copernicus CORINE data were used to evaluate spatial changes. Vegetation dynamics were analyzed through the Normalized Difference Vegetation Index (NDVI) derived from satellite imagery representing historical conditions from the late 1980s–early 1990s and recent observations. GIS techniques were applied to identify patterns of urban growth, land transformation, and vegetation variability. Preliminary results indicate progressive land transformation around the wetlands, especially in areas affected by urbanization and tourism. Built-up areas expanded, surrounding landscapes were modified, and NDVI showed localized vegetation changes in sensitive wetland zones. Continuous spatial monitoring is essential for sustainable tourism planning and integrated coastal management.

Keywords: Kune-Vain Lagoon, LULC change, NDVI, ecosystem services, sustainable tourism, urban expansion

1. INTRODUCTION

Coastal wetlands are among the most productive and valuable ecosystems worldwide, providing essential ecological functions and ecosystem services such as habitat provision, water regulation, shoreline protection, nutrient retention, carbon storage, and support for fisheries and tourism-related activities [1, 2]. In the Mediterranean region, lagoon and wetland systems represent highly dynamic environments that are particularly sensitive to land-use change, hydrological alteration, and climate-related pressures [7]. Anthropogenic activities, including urban expansion, agricultural intensification, tourism development, and infrastructure growth, are widely recognized as major drivers of wetland transformation and habitat degradation in coastal regions [9]. In Albania, coastal lagoon ecosystems such as Kune–Vain, Karavasta, and Narta have been identified as areas of national and international ecological importance due to their biodiversity and ecological functions [3,4]. However, recent socio-economic development and land-use pressures have increased the vulnerability of these systems, particularly in areas influenced by settlement expansion and tourism-related

activities. Remote sensing and Geographic Information Systems (GIS) provide efficient tools for monitoring environmental changes in wetland ecosystems over extended time periods. Multi-temporal analysis of satellite imagery enables the identification of land-use and land-cover changes, while vegetation indices such as the Normalized Difference Vegetation Index (NDVI) are widely used to assess vegetation condition and ecosystem dynamics [5]. These techniques allow the detection of spatial and temporal changes that support environmental management and conservation planning.

Despite the recognized ecological importance of the Kune–Vain lagoon system, relatively limited studies have focused on long-term spatial analysis of vegetation dynamics and wetland transitions using multi-temporal satellite data. Therefore, the aim of this study is to assess vegetation dynamics and wetland extent changes in the Kune–Vain wetlands using remote sensing and GIS techniques. Specifically, the study evaluates: (i) long-term changes in NDVI-based vegetation density; (ii) vegetation dynamics between 1985 and 2024; and (iii) wetland extent changes between 2000 and 2018.

2. MATERIALS AND METHODS

2.1 Study Area

The Kune–Vain wetlands ecosystem is located along the northwestern coastal plain of Albania, near the mouth of the Drini River and in proximity to the city of Lezhë and the town of Shëngjin. The wetland complex consists of lagoons, marshes, agricultural lands, and transitional vegetation zones influenced by both marine and freshwater processes. The study area covers approximately 106.53 km², including wetland and surrounding land-use areas influencing wetland dynamics.

The ecosystem is recognized for its biodiversity and ecological importance but has experienced increasing pressure from land-use change, agricultural development, and urban expansion over recent decades [4,9] (Fig. 1).

2.2 Satellite Data and Image Processing

Multi-temporal satellite imagery from the Landsat program was used to analyze vegetation dynamics in the Kune–Vain wetlands. Landsat 5 Thematic Mapper (TM) images were used for the years 1985 and 2004, while Landsat 9 Operational Land Imager (OLI) imagery was used for 2024. All images were selected from similar seasonal periods to minimize seasonal variability and ensure comparability between years. Preprocessing steps included radiometric and atmospheric corrections using standard surface reflectance products. The imagery was processed within a GIS environment, and all datasets were projected to a common coordinate system to ensure spatial consistency across temporal datasets.

2.3 NDVI Calculation and Change Detection

Vegetation dynamics were assessed using the Normalized Difference Vegetation Index (NDVI), which is widely applied in vegetation monitoring and wetland studies [6,8]. NDVI was calculated using the red and near-infrared spectral bands of Landsat imagery. The resulting NDVI values were classified into vegetation density categories to support spatial comparison of vegetation conditions across different time periods. To evaluate long-term vegetation dynamics, NDVI difference analysis was performed between 1985 and 2024, allowing identification of areas with vegetation increase, decrease, or stability. This approach enabled the detection of spatial patterns of vegetation change across the wetland ecosystem.

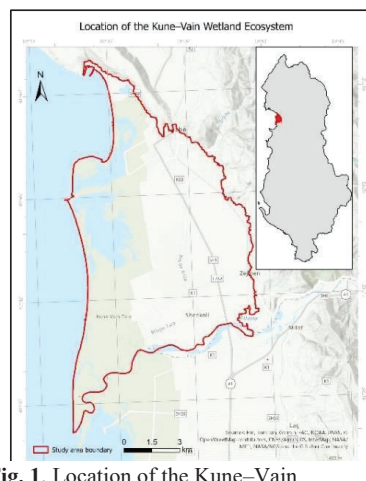


Fig. 1. Location of the Kune–Vain wetlands ecosystem

2.4 Land-Use Change and Wetland Transition Analysis

Land-use and wetland dynamics were analyzed using classified land-cover datasets representing wetland extent for the years 2000 and 2018. These datasets were used to evaluate wetland loss, conversion, and internal transformation processes. Spatial overlay analysis was applied to identify areas of wetland persistence, conversion to open water, and internal wetland transitions. Additionally, urban expansion patterns were assessed by comparing land-use classes between the selected years, allowing identification of areas where wetlands were affected by urban development. All spatial analyses were conducted using geographic information system (GIS) tools, enabling quantification of area changes and visualization of spatial transformation patterns.

3. RESULTS

The spatial distribution of NDVI-based vegetation density classes in the Kune–Vain wetlands for the years 1985, 2004, and 2024 is presented in Fig. 2, while the quantitative distribution of vegetation classes is summarized in Table 1.

In 1985, the study area was predominantly characterized by bare soil or very sparse vegetation, covering 75.29 km² (70.72%) of the total area. Areas classified as sparse to moderate vegetation occupied 24.64 km² (23.13%), while water bodies covered 6.53 km² (6.13%). Moderate to dense vegetation was nearly absent, accounting for only 0.01 km² (0.01%), indicating limited development of dense vegetation structures during this period.

By 2004, bare soil or very sparse vegetation decreased to 69.02 km² (64.83%), while sparse to moderate vegetation increased to 32.78 km² (30.79%). Water bodies declined to 4.67 km² (4.38%), indicating spatial redistribution of vegetation and surface water [5].

In 2024, bare soil or very sparse vegetation declined to 56.79 km² (53.33%), while sparse to moderate vegetation expanded to 40.38 km² (37.91%).

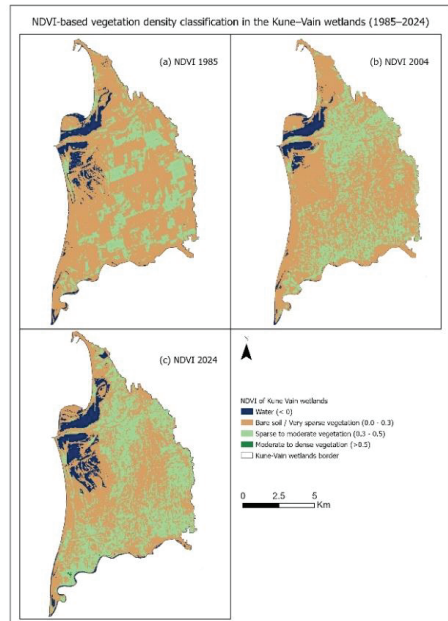


Fig. 2. Spatial distribution of NDVI-derived vegetation density classes in the Kune–Vain wetlands for (a) 1985, (b) 2004, and (c) 2024.

Table 1. Area (km²) and percentage (%) distribution of NDVI-based vegetation density classes in the Kune–Vain wetlands for the years 1985, 2004, and 2024.

NDVI Class	1985 Area (km ²)	1985 (%)	2004 Area (km ²)	2004 (%)	2024 Area (km ²)	2024 (%)
Water (<0.0)	6.53	6.13	4.67	4.38	9.22	8.66
Bare soil /very sparse vegetation (0.0–0.3)	75.29	70.72	69.02	64.83	56.79	53.33
Sparse to moderate vegetation (0.3–0.5)	24.64	23.13	32.78	30.79	40.38	37.91
Moderate to dense vegetation (>0.5)	0.01	0.01	0.00	0.00	0.08	0.07

Water coverage increased to 9.22 km² (8.66%), and moderate to dense vegetation slightly increased to 0.08 km² (0.07%), indicating localized vegetation densification [2]. Vegetation dynamics between 1985 and 2024 are illustrated in Fig. 3, and the corresponding spatial distribution of change categories is summarized in Table 2.

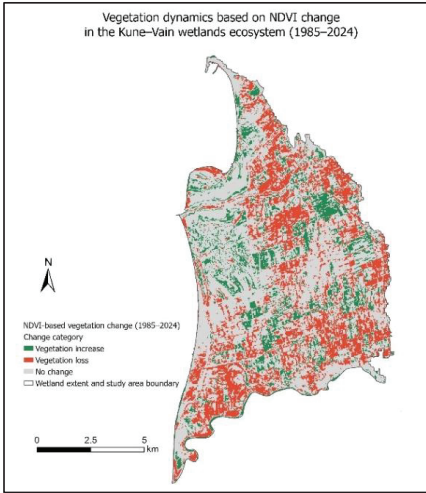


Fig. 3. Vegetation dynamics in the Kune-Vain wetlands ecosystem derived from NDVI change analysis between 1985 and 2024.

Table 2. NDVI change statistics

Change category	Area (km ²)	Percentage (%)
Vegetation decrease (-1)	15.09	14.17
No change (0)	63.23	59.37
Vegetation increase (1)	28.21	26.45
Total	106.53	100

The results indicate that 63.23 km² (59.37%) of the study area remained stable during the analysis period, representing the dominant category of vegetation persistence. Areas experiencing vegetation increase accounted for 28.21 km² (26.45%), while vegetation decrease was observed across 15.09 km² (14.17%). Vegetation increase was primarily distributed in inland transitional zones and areas characterized by gradual vegetation recovery, whereas vegetation decrease was mainly concentrated along coastal margins and selected zones affected by land-use intensification. Such

spatial patterns of vegetation stability combined with localized increase and decrease are commonly observed in coastal wetland ecosystems undergoing both natural and anthropogenic pressures [1,7]. Wetland extent changes between 2000 and 2018 are presented in Fig. 4, showing spatial patterns of wetland persistence and localized wetland loss.

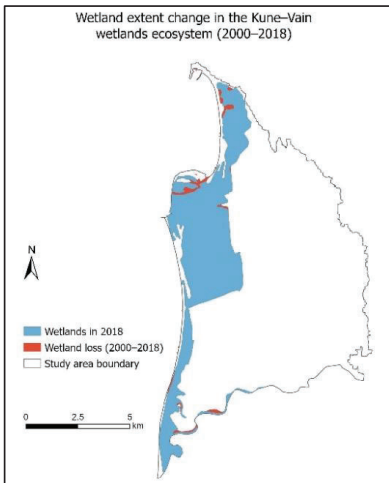


Fig. 4. Wetland extent change in the Kune-Vain wetlands ecosystem between 2000 and 2018.

The spatial analysis indicates that large portions of the wetland system remained stable during the observation period, while localized wetland loss occurred along lagoon margins and coastal sectors. These zones of wetland reduction were mainly concentrated along dynamic shoreline environments and transitional wetland boundaries, reflecting areas sensitive to hydrological variability and land-use pressures. Such localized wetland losses are consistent with patterns reported in Mediterranean coastal systems influenced by shoreline processes, water-level fluctuations, and human-induced landscape modification [9].

4. DISCUSSION

The results indicate clear spatial changes in vegetation distribution and wetland extent within the Kune-Vain wetland system. The reduction of sparsely vegetated surfaces and expansion of moderate vegetation zones suggest gradual vegetation development influenced by natural succession and land-use adjustments [2].

Localized vegetation decrease along coastal margins and wetland loss near lagoon boundaries highlight areas sensitive to shoreline dynamics and hydrological variability, consistent with observations from Mediterranean wetland environments [7].

The applied GIS and remote sensing approach proved effective for detecting vegetation and wetland dynamics; however, medium-resolution imagery may limit detection of small-scale features. Future studies may benefit from higher-resolution datasets and additional environmental indicators.

5. CONCLUSIONS

This study assessed vegetation dynamics and wetland extent changes in the Kune–Vain wetland ecosystem using multi-temporal satellite imagery and GIS-based analysis. The results indicate a gradual reduction in sparsely vegetated areas and localized wetland loss, while large portions of the system remained stable over time. NDVI-based change detection proved effective in identifying spatial vegetation trends and wetland dynamics. The applied methodology provides a practical framework for supporting wetland monitoring and environmental management in coastal ecosystems.

DECLARATIONS

Conflict of Interest Statement: The authors declare no conflict of interest.

Author Contributions: S.P. conceptualized the study, processed the data, prepared all maps and figures, drafted the manuscript, and finalized the paper. A.H. contributed to literature review and interpretation. V.P. contributed to methodology and revision. All authors approved the final manuscript.

Data Availability Statement: The data used in this study are available from the corresponding author upon reasonable request.

Ethics Statement: Not applicable.

Originality Statement: The authors confirm that this manuscript is original, has not been published previously, and is not under consideration elsewhere.

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