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Regenerative Design - Climate Adaptation & Mitigation - Circular Economy - Citizen Agency - Urban Livability

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The impact of Land Use and Land Cover (LULC) changes on coastal dynamics through landscape structure

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Abstract

Coastal areas are dynamic environments shaped by the interaction between natural processes and human activities. Rapid urbanization and land use transformations increasingly threaten the ecological integrity and spatial structure of coastal landscapes. In this context, this study aims to examine the impacts of land use and land cover (LULC) changes on coastal landscape structure and user perception through a comparative analysis of two adjacent beach areas in Budva, Montenegro—one affected by LULC change and another largely preserving its natural structure. The research integrates a multi-criteria decision-making framework and perception-based analysis. The Analytic Hierarchy Process (AHP) was employed to evaluate the relative importance of ecological and functional landscape criteria, including coastal protection capacity, biodiversity contribution, aesthetic value, and public usability. In addition, user perception data were analyzed using SPSS statistical methods, including correlation analysis and one-sample t-tests. The findings reveal that coastal areas maintaining their natural characteristics perform better in terms of ecological functionality and user satisfaction. Criteria related to coastal protection and biodiversity received the highest importance in the AHP evaluation, while statistical analyses indicated strong relationships between ecological attributes and user perception variables. Overall, the results highlight the importance of integrating ecological indicators and user perception into coastal landscape planning. The study emphasizes the role of nature-based solutions and multi-criteria evaluation approaches in supporting sustainable coastal management and improving the resilience of coastal environments.

Keywords

Climate action; Sustainable development; Coastal dynamics; LULC

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1. Introduction

Throughout the twentieth century, significant urban developments have altered land use and land cover (LULC) through various human activities (Moniruzzaman et al., 2021), making LULC one of the most influential factors affecting human life (Zarin & Esraz-Ul-Zannat, 2023). LULC refers not only to how a given area is utilized for purposes such as agriculture, conservation, development, recreation, wildlife habitats, and urban uses, but also to the outcomes of human-environment interactions influenced by socioeconomic dynamics and climate change processes (Anand et al., 2024). Today, a large portion of the global population resides in urban areas, and this proportion is expected to increase further by 2050. As a result, urbanization has become a critical issue that must be addressed on a global scale (Kumar et al., 2025). Existing studies have examined the response to climate change and LULC changes (Gao & Ruan, 2018), revealing that urban expansion—particularly the rapid transformation of rural areas into commercial and residential land—is accelerating (Tariq & Shu, 2020). Changes in land use and land cover (LULC) are of vital importance for urban planning, environmental management, and sustainable development (Waleed & Sajjad, 2022; Farhan et al., 2024; Nuthammachot & Ali, 2025). A better understanding of LULC changes paves the way for analyzing the dynamics of urban growth (Gaur & Singhr, 2023). Therefore, knowledge of past, present, and future patterns of LULC significantly contributes to achieving sustainable development by informing urban planning, policy-making, and resilience-building strategies (Kumar et al., 2025). Recent studies also highlight that ecological landscape components and vegetation-based planning strategies play a critical role in improving environmental performance and ecosystem resilience in urban areas (Gulpinar Sekban, 2026). Recent research demonstrates that LULC dynamics are shaped by a diverse set of socioeconomic, institutional, and environmental drivers; for instance, studies conducted in Ethiopia and Iran reveal that land conversions from agricultural to forest or urban uses are largely governed by income expectations, land size, and local policy frameworks (Kebede et al., 2024; Ziari et al., 2025).

Today, with rapidly increasing population, urbanization trends, and evolving user needs, urban areas are under intense pressure from dense construction and functional transformation. This pressure accelerates the transformation of natural spaces and is particularly evident in sensitive ecosystems such as coastal regions. In this context, Land Use and Land Cover (LULC) changes emerge as a significant analytical technique for monitoring and evaluating these spatial transformation processes (Kumar et al., 2018). In addition to these pressures, the ecological structure of coastal environments can be significantly influenced by vegetation patterns and habitat structures, which regulate microclimatic conditions and environmental stability in urban landscapes (Onur & Gulpinar Sekban, 2026). Coastal environments are under considerable stress due to negative impacts such as climate change, infrastructure development, and human activities, which lead to coastal erosion, seawater intrusion, sea level rise, disruption of nutrient balance, and degradation of natural resources (Anand et al., 2024). In this regard, the integration of urban green spaces into spatial planning frameworks has been highlighted as a critical adaptation strategy; global city experiences indicate that green infrastructure not only mitigates urban heat but also contributes to energy savings and climate resilience (Ascione et al., 2025).

LULC (Land Use and Land Cover) analyses provide the ability to observe spatial-temporal changes, thereby offering critical data for environmental sustainability. At the root of these changes lie largely anthropogenic activities. Human-induced factors such as industrialization, tourism pressure, infrastructure investments, and urban sprawl cause significant and often irreversible physical and ecological impacts on the natural coastline. Beaches, in particular, are among the areas where this transformation is most acutely felt, due to their inherent natural structure and high level of interaction with human activities. From an ecosystem services perspective, urban green spaces and natural landscape components contribute to biodiversity conservation, climate regulation, and the overall environmental quality of cities (Gulpinar Sekban, 2025). Changes occurring along coastal routes lead to environmental problems such as erosion, habitat loss, and shoreline retreat, while simultaneously affecting the recreational, aesthetic, and social functionality of the region. Therefore, regular monitoring of LULC changes in coastal areas and analyzing the anthropogenic drivers behind these changes are of great importance for the development of sustainable coastal management policies. In this context, detailed spatial analyses will allow for the identification of current pressures and support the establishment of a balanced approach between conservation and use for the future. Evidence from urban functional areas further confirms that carbon sequestration and storage exhibit strong synergies with other regulating ecosystem services such as flood retention, local temperature regulation, and habitat quality, underscoring the value of integrating these services into coastal and urban land use planning (Lai & Zoppi, 2025).

1.2 State of research aim

Coastal landscapes are among the most dynamic environments, constantly shaped by natural processes and human interventions. In this context, understanding the implications of Land Use and Land Cover (LULC) changes on both ecological functions and social perceptions has become a central challenge for sustainable coastal management. While many studies focus separately on either the physical or social dimensions, there is still a lack of integrative approaches that combine expert knowledge, spatial analysis, and user perception within a unified framework.

The primary aim of this study is to evaluate how LULC changes affect the ecological integrity and perceptual quality of coastal areas, taking the Budva coastline in Montenegro as a representative case. The research seeks to bridge the gap between measurable landscape transformations and subjective user experiences by adopting a multidisciplinary methodology that combines spatial, environmental, and social data. Specifically, the objectives of the study are to:

1. identify and quantify spatial and temporal patterns of LULC changes along the Budva coastal zone using geospatial datasets and field observations;
2. assess expert evaluations on the environmental and visual impacts of these changes through a multi-criteria decision-making model based on the Analytic Hierarchy Process (AHP);
3. examine user perceptions regarding the aesthetic, functional, and recreational qualities of coastal areas using SPSS-supported statistical analysis of survey data;
4. determine the correlations between ecological parameters (such as coastal protection capacity, biodiversity potential, and carbon sequestration) and user-based variables (including awareness, preference, and satisfaction);
5. develop an integrated evaluation framework that combines expert judgments and user perceptions to support evidence-based coastal management and planning.

By combining the analytical precision of AHP with the interpretive depth of perception analysis, this study aims to contribute a comprehensive model for assessing coastal sustainability. The findings are expected to inform local authorities, planners, and researchers in designing strategies that balance ecological preservation with social well-being, ensuring that coastal development aligns with both environmental resilience and community values.

2. Methodology

2.1 Study area

The main material of this study is a beach located in Budva, situated along the Adriatic coast of Montenegro (Fig.1). Kotor, with its natural harbor and well-preserved medieval urban fabric, is a notable settlement both geographically and culturally. The Bay of Kotor, where Budva is located, stands out with its stunning natural landscapes, sea, and coastline. This natural allure attracts the interest of tourists (Radenovic, Tripkovic-Markovic, 2016). Budva is one of the largest and most popular holiday destinations on Montenegro's Adriatic coast. The unique geographical setting where the sea meets the mountains not only gives the city a striking natural beauty but also draws the attention of tourists. Having been under the rule of many civilizations throughout history, Budva has a rich cultural heritage as a result. It experienced significant development particularly during the Venetian period, and architectural structures from that era have survived to the present day. With its historical texture, natural beauty, and vibrant tourism scene, Budva continues to be one of the most prominent cities on the Adriatic (Hryniewicz et al., 2022).

Budva's landscape offers great visual richness through the striking contrast between exotic greenery and historical structures. The city's lively beaches, restaurants, sports facilities, and various entertainment venues blend modern living with natural beauty. Green spaces adorned with palm trees and tropical plants give the city a refreshing and vibrant Mediterranean atmosphere. These features make Budva stand out not only for its historical significance but also as a tourism destination renowned for its natural beauty (Hryniewicz et al., 2022).

The study area consists of two adjacent beaches. The first site is a beach that has not undergone any LULC (Land Use and Land Cover) changes. The second site, on the other hand, is a beach that has experienced LULC changes. These two contrasting sites form the primary material of the study. The contrasting characteristics of the areas are among the reasons for their selection as study sites. Both locations are actively functioning as beach facilities (Fig.1,2).

The classification of the two selected coastal areas as LULC-affected and non-affected was established through a rigorous combination of field observations and systematic spatial interpretation of high-resolution satellite imagery sourced from Google Earth Pro. Land use patterns, vegetation cover density, built-up surface extent, and overall landscape structure were carefully examined and comparatively evaluated across both adjacent beach sites. This dual-method approach ensured that the classification was grounded in both empirical on-site evidence and verifiable remote sensing data, thereby minimizing subjectivity in the delineation of study conditions. The two selected sites consequently represent clearly contrasting spatial conditions: one area largely retaining its natural coastal morphology, native vegetation, and ecological integrity, and another that has undergone measurable transformation through construction activities, impervious surface expansion, and land use intensification. This well-justified spatial differentiation forms the comparative foundation of the study and directly supports the validity of the subsequent AHP and SPSS analyses conducted across the two contrasting coastal landscapes.

Fig.1 Study area (Google Earth Pro)

Fig.2 Non LULC Area (1) and LULC Area

2.2 Methodology

The methodology of the study involves the use of AHP and SPSS analysis methods. The main objective of using AHP is to evaluate *which criteria and to what extent landscape elements in beaches that have not undergone LULC changes affect coastal dynamics and users*.

First stage: determination of objectives and criteria

In the first phase of the study, the main objective of the research was clearly defined. In line with this objective, a hierarchical criteria matrix was constructed in accordance with the Analytic Hierarchy Process (AHP) method. In the matrix, the top level represents the "goal," while the criteria aimed at achieving this goal are positioned at the lower levels. At this stage, the central research question of the study was defined as: *Which landscape combination contributes most positively to coastal dynamics?* To address this question, four alternatives representing different landscape forms were created for use in the AHP analysis. These alternatives are defined as follows: *Alternative 1: No LULC Change, Alternative 2: With LULC Change.*The perception survey was administered to a total of 211 participants who were visiting the study area at the time of data collection, representing a cross-section of active coastal users with direct experiential familiarity with the evaluated environments. Participants were selected through a purposive sampling approach, targeting individuals with firsthand exposure to both the LULC-affected and non-affected beach areas, thereby ensuring the contextual relevance and site-specificity of the collected perception data. The structured questionnaire comprised seven statements designed to capture respondents' environmental awareness, attitudes toward natural beach conservation, and dispositions regarding the implementation of nature-based solutions in coastal landscape management. Each statement was evaluated by participants using a five-point Likert scale, ranging from 1 — "strongly agree" to 5 — "strongly disagree", enabling the quantification of subjective perceptual responses into an ordinal measurement framework suitable for statistical analysis.

The collected data were subsequently processed and analyzed using SPSS statistical software. Pearson correlation analysis was applied to examine the strength and direction of relationships between the evaluated environmental perception variables, identifying statistically significant associations among respondents' attitudes toward ecological, aesthetic, and functional coastal attributes. In addition, a one-sample t-test was conducted to determine whether the mean perception scores of the respondents differed significantly from a predefined reference value, thereby allowing for an objective assessment of the overall direction and magnitude of user attitudes. A significance threshold of $p < 0.05$ was adopted throughout all statistical procedures. The combination of correlation analysis and hypothesis testing provides a robust and methodologically transparent basis for interpreting the quantitative dimensions of user perception within the broader analytical framework of the study.

In line with the multi-criteria decision-making structure of the AHP method, an initial pool of criteria was identified through a systematic literature review and expert consultations. Following a screening process to eliminate redundant and low-relevance criteria, 10 criteria were retained and integrated into the hierarchical AHP structure. These 10 criteria — spanning both ecological and socio-functional dimensions — were selected to ensure analytical focus and comparability across the two study sites (Fig.2, Tab.2). The relative importance of each criterion was evaluated using weights calculated through the AHP method. These weights revealed that it would be appropriate to group certain criteria under similar thematic categories (Fig.2). To more accurately analyze expert opinions, a specially designed comparison matrix was prepared for the experts. This matrix enabled the comparison of the relative importance levels between the criteria and enhanced the reliability of the study's findings (Fig.3).

A total of 20 domain experts participated in the AHP pairwise comparison process. The expert panel was composed of professionals from disciplines directly relevant to the research topic, including landscape architecture, urban planning, environmental engineering, and coastal ecology. All participants had a minimum of five years of professional or academic experience in their respective fields. The composition of the expert panel is summarized in Tab.1 below.

Expert Code	Field of Expertise	Academic/Professional Background	Years of Experience
E1	Landscape Architecture	Academic	10+
E2	Urban Planning	Practitioner	8+
E3	Coastal Ecology	Academic	12+

Tab.1 Expert panel

The Analytic Hierarchy Process (AHP) was employed as the primary multi-criteria decision-making method in this study, following the procedural framework originally established by Saaty (1980) and subsequently refined in later methodological contributions (Saaty, 2004). To determine the relative importance of each evaluated criterion, pairwise comparison matrices were systematically constructed on the basis of structured expert evaluations, in which domain specialists were asked to compare each criterion against all others with respect to its contribution to coastal landscape assessment. These comparisons were performed using Saaty's fundamental nine-point scale, where a value of 1 denotes equal importance between two criteria and a value of 9 indicates that one criterion is considered extremely more important than the other, with intermediate values representing proportional gradations of relative preference. The priority weights of the criteria were subsequently derived by computing the normalized principal eigenvector of each pairwise comparison matrix, a procedure that translates the relative judgments of experts into quantifiable and comparable weighting scores. To rigorously evaluate the internal reliability and logical consistency of the expert judgments, the Consistency Ratio (CR) was calculated for each comparison matrix.

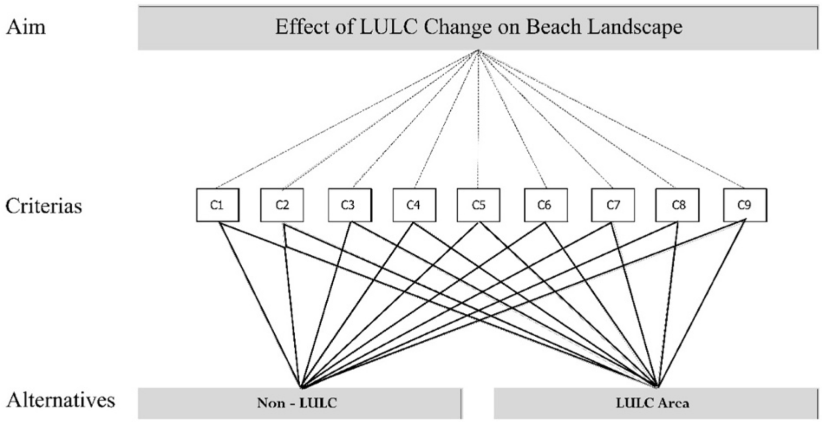


Fig.3 AHP Modelling

In accordance with the threshold established by Saaty (2004), a CR value below 0.10 is considered indicative of acceptable consistency, meaning that the expert comparisons do not contain contradictory or unreliable judgments that would compromise the validity of the derived weights. In the present study, the calculated inconsistency rate of 0.00075 falls substantially below this threshold, demonstrating an exceptionally high level of consistency among expert evaluations and thereby confirming the methodological soundness and reproducibility of the AHP-based weighting procedure applied throughout the analysis.

After determining the alternatives and objectives, the study proceeded to the next stage of the multi-criteria decision-making process. At this stage, a criteria matrix based on pairwise comparisons was developed within the framework of the Analytic Hierarchy Process (AHP) method. In the AHP analysis, comparisons of the criteria were carried out both among the criteria themselves (criterion-to-criterion comparison) and between all the defined alternatives for each criterion (alternative-to-criterion comparison) (Benítez et al., 2011; Yang et al., 2022; Chaube et al., 2024).

In the constructed comparison matrix, numerical scales were used based on expert opinions. On these scales: a value of 1 (Equal Importance) indicates that "both elements contribute equally to the objective," a value of 3 (Moderately More Important) means "one element is slightly preferred over the other," a value of 5 (Strongly More Important) indicates "one element is clearly preferred over the other," a value of 7 (Very Strongly More Important) suggests "one element is significantly more preferred," and a value of 9 (Extremely More Important) reflects "one element is overwhelmingly and indispensably preferred over the other." Intermediate values of 2, 4, 6, and 8 are used to express relative preferences between two successive fundamental values. This scaling method allows for the quantification of subjective expert evaluations, enabling systematic comparisons in the decision-making process (Saaty, 2003; Saaty, 2004) (Tab.2).

Alternative 1,2	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1. Coastal protection capacity	1									
C2. Contribution to biodiversity		1								
C3. Ecological compatibility			1							
C4. Low maintenance requirement				1						
C5. Aesthetic impact					1					
C6. Water filtration						1				
C7. Ease of public use							1			
C8. Microclimate effect								1		
C9. Carbon sequestration potential									1	
C10. Enhancing human-nature interaction										1

Tab.2 Criteria matrix table

Second stage: statistical analysis

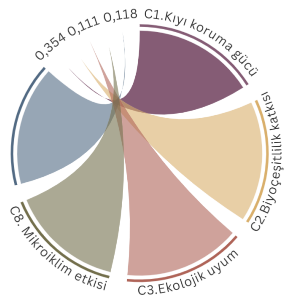
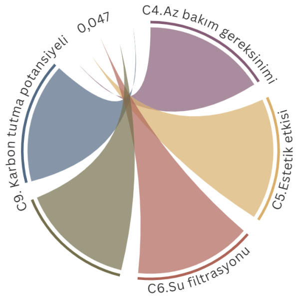
In the second phase of the study, calculations were performed using the Analytic Hierarchy Process (AHP) method with 20 experts, 10 criteria, and 2 alternatives. For these calculations, a specific area within the Budva region was selected as the study area. In this phase, a total of 7 questions were posed to the experts. These questions were designed to evaluate the criteria identified in the first phase of the method, specifically for the selected study area. Each question was structured to assess the impact of a criterion on the area. The criteria were examined through 7 different parameters, which were then transformed into survey questions for the experts. The questions in the survey were evaluated using a 5-point Likert scale: strongly agree, agree, neutral, disagree, and strongly disagree. This method allowed for the collection of quantitative data based on expert opinions, making the multi-criteria decision-making process for the study area more objective.

3. Findings

3.1. Evaluation of AHP (Analytical Hierarchy Process) results

In the AHP results for parameters classified as not undergoing LULC changes, the "Coastal protection power" (C1) criterion holds the highest priority with a weight of 35.4%, indicating that coastal protection functions are the most critical factor from the decision-makers' perspective among the criteria assessed in the context of ecosystem services. The "Biodiversity contribution" (C2) criterion ranks second with 30.7%, providing significant input for the preservation of ecological balance and habitat diversity. The "Ecological adaptation" (C3), "Microclimate effect" (C4), and "Carbon sequestration potential" (C5) criteria have weight values of 11.1%, 11.0%, and 11.8%, respectively. This shows that while these criteria are relatively lower in priority, they still make meaningful contributions to the decision-making process. Overall, it is evident that within environmental criteria, protective and biodiversity-supporting characteristics are prioritized over adaptive and climate-related features. In the case of parameters that have undergone LULC changes, the "Aesthetic effect"

(C7) criterion holds a very high weight of 51.7%, highlighting that aesthetic values are a determining factor in the planning of public spaces. Visual perception and user satisfaction are further emphasized by the "Low maintenance requirement" (C6) and "Ease of public use" (C9) criteria, which are ranked second and third with weights of 22.6% and 21.0%, respectively. These data indicate that sustainability and accessibility are taken into account in the decision-making process. On the other hand, "Water filtration" (C8) has a relatively low weight of 4.7%, suggesting that ecosystem services related to water quality are considered lower in priority compared to other socio-functional criteria, and that user satisfaction, the area's perceptibility, and social acceptance are key influencing factors.

Main criterias	Weighting score	Sub-criterias	Weighting score
NON-LULC	 0.654 - %65	C1. Coastal protection power	0.354
		C2.Biodiversity contribution	0.307
		C3.Ecological adaptation	0.111
		C4. Microclimate effect	0.110
		C5. Carbon sequestration potential	0.118
LULC Applications	 0.358 - %35	C6. Low maintenance requirement	0.226
		C7. Aesthetic effect	0.517
		C8.Water filtration	0.047
		C9. Ease of public use	0.210

Tab.3 Criterias weighting score

The obtained AHP weights show that decision-makers prioritize both ecosystem services (particularly coastal protection and biodiversity) and user-focused values (particularly aesthetic contributions) during the evaluation process. In the planning of coastal areas, physical protection and visual aesthetics emerge as the highest priority criteria. This indicates that nature-based solutions are addressed within an ecological and user-centered multi-criteria framework, aligning with sustainable planning approaches (Tab.3, Fig.4).

Throughout Section 3, all reported findings are systematically and explicitly linked to their corresponding analytical methods as established in Section 2, ensuring full methodological coherence across the manuscript. Section 3.1 presents the AHP-derived weighting scores and priority rankings for both LULC-affected and non-affected coastal parameters, revealing the relative importance assigned to ecological and user-oriented criteria by domain experts within the multi-criteria decision-making framework. Building on this foundation, Section 3.2 reports the SPSS-based statistical outputs, encompassing Pearson correlation analyses and one-sample t-test results, which rigorously quantify the interrelationships among ecological variables and user perception parameters. The integration of these two complementary analytical approaches — quantitative priority weighting through AHP and inferential statistical analysis through SPSS — not only strengthens the interpretive validity of the findings but also provides a robust, interdisciplinary evidential basis for the study's conclusions on coastal landscape dynamics.

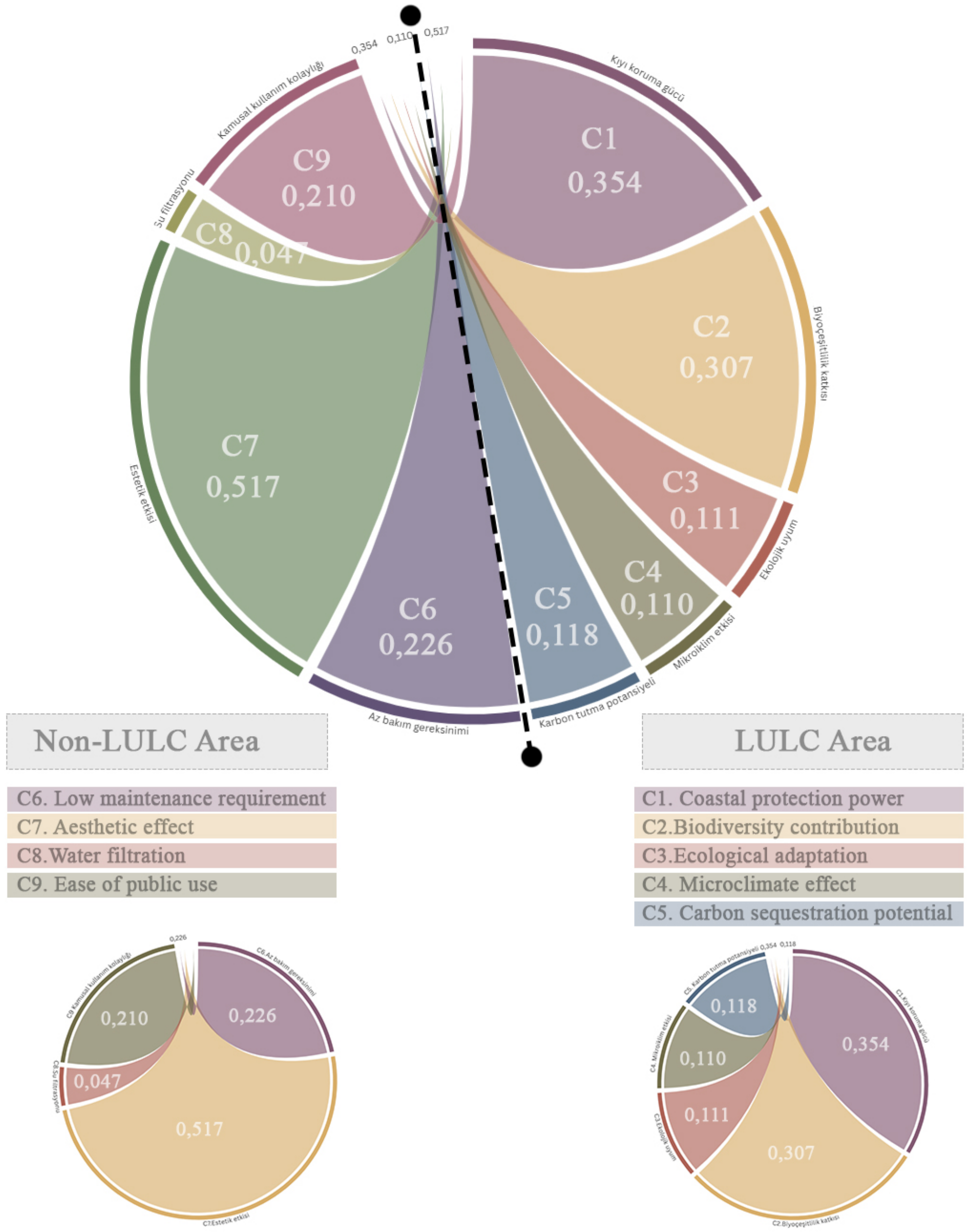


Fig.4 Distribution of criteria and scores

Within the scope of this study, the nine sub-criteria identified are grouped under two main categories: Non-LULC criteria and Land Use and Land Cover (LULC) criteria. These criterion groups were weighted 65 per cent and 35 per cent, respectively, according to the importance level of decision makers. Non-LULC Criteria Group (65% weight) This group consists of five sub-criteria focusing on ecological and environmental functions: C1. Coastal protection capacity: 0.024 C2. Contribution to biodiversity: 0.018 C3. Ecological adaptation: 0.021 C4. Microclimate impact: 0.041 C5. Carbon sequestration potential: 0.017. For example, criterion C4 has a relatively high level of importance, accounting for a significant portion of the 65 per cent weight. LULC Criteria Group (35% weight) This group includes criteria related to space utilisation such as ease of use and visual/functional value: C6. Low maintenance: 0.019 C7. Aesthetic impact: 0.017 C8. Water filtration: 0.034 C9. Suitability for public use: 0.041. Especially criterion C9 stands out as the criterion with the highest importance in this group. The score weights obtained by the alternatives for each criterion were normalised in line with the decision makers' priorities. These values reflect the relative superiority of each alternative in terms of the criterion in question. For example; C1. In terms of coastal protection capacity, the highest weight was given to Non-LULC areas with 0.354. C7. In the aesthetic impact criterion, the highest weight belongs to

LULC areas with 0.517. This shows that decision makers evaluate the aesthetic value depending on land use. According to the AHP results, factors such as microclimate effect (C4) and suitability for public use (C9) stand out with relatively higher weights among the criteria. In addition, the superiority of LULC and Non-LULC areas in terms of different criteria differs. This shows how complex and multidimensional multi-criteria decision-making processes are in areas such as land planning or landscape design (Tab.4).

Applications	Total weights	Sub-criterias	Score weights of alternatives		
			Score weights	Non-LULC	LULC Area
	Non-LULC %65	C1. Coastal protection power	0.024	0.354	0.646
		C2. Biodiversity contribution	0.018	0.307	0.693
		C3. Ecological adaptation	0.021	0.111	0.889
		C4. Microclimate effect	0.041	0.110	0.890
		C5. Carbon sequestration potential	0.017	0.118	0.882
	LULC Area %35	C6. Low maintenance requirement	0.019	0.774	0.226
		C7. Aesthetic effect	0.017	0.483	0.517
		C8. Water filtration	0.034	0.953	0.047
		C9. Ease of public use	0.041	0.982	0.210
Note: Inconsistency rate is calculated as 0.00075					

Tab.4 Grouping results according to AHP weights

3.2 Statistical analysis of parameters

The variable C1 - Coastal protection power shows the highest positive correlation with C2 - Contribution to biodiversity (r = 0.754). This finding indicates that landscape elements with high coastal protection capacity also tend to support biodiversity. This relationship is significant and indicates that ecosystem services are provided together. C3 - Ecological Adaptation shows very strong positive correlations with C4 - Microclimate Effect (r = 0.839) and C5 - Carbon Sequestration Potential (r = 0.760). This suggests that ecologically well-adapted areas are also effective in improving microclimate and sequestering carbon. These high correlations support the multifunctionality of ecosystem services. The relationship between C4 - Microclimate Impact and C5 - Carbon Sequestration Potential is also very strong (r = 0.828). This finding suggests that these two ecological services are often provided together and should be considered together in landscape management. C6 - Low Maintenance Requirement has strong correlations with both C4 (r = 0.693) and C5 (r = 0.724). This suggests that more ecologically sustainable sites can also be maintenance efficient. Moderate positive correlations were found between C7 - Aesthetic Impact and C8 - Water Filtration (r = 0.493) and C9 - Ease of Public Use (r = 0.461). This indicates that aesthetically pleasing areas are also functionally user-friendly and environmentally contributing areas. There is a high positive correlation (r = 0.649) between C8 - Water Filtration and C9 - Ease of Public Use. This relationship indicates that environmental services provide higher benefits when they are accessible and usable by the public. Low or weak correlations were observed between some variables (e.g. r = 0.152 between C3 and C9). This suggests that there is no direct relationship between these two attributes or that this relationship is influenced by other factors (Tab.5).

The Results section explicitly presents the numerical outcomes of both the AHP and SPSS analyses. The weighting scores derived from the Analytic Hierarchy Process (AHP) model are reported in Tab.2 and 3, including the grouping of criteria according to their priority rankings. In addition, the statistical relationships among the evaluated parameters are examined through Pearson correlation analyses (Tab. 5 and 6) and a one-sample t-test (Tab.6).

These analyses provide quantitative evidence for the relationships between ecological criteria and user perception variables, strengthening the data-driven interpretation of coastal landscape dynamics.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1	0.754	0.263	0.333	0.222	0.346	0.418	0.490	0.410
C2	0.754**	1	0.232	0.244	0.226	0.353	0.266	0.470	0.443
C3	0.263	0.232	1	0.839	0.760	0.662	0.398	0.367	0.152
C4	0.333	0.244	0.839**	1	0.828	0.693	0.408	0.347	0.163
C5	0.222	0.226	0.760**	0.828**	1	0.724	0.335	0.300	0.200
C6	0.346	0.353	0.662	0.693	0.724**	1	0.323	0.399	0.387
C7	0.418	0.266	0.398	0.408	0.335	0.323	1	0.493	0.461
C8	0.490	0.470	0.367	0.347	0.300	0.399	0.493	1	0.649
C9	0.410	0.443	0.152	0.163	0.200	0.387	0.461	0.649	1

C1. Coastal protection power, C2.Biodiversity contribution, C3.Ecological adaptation, C4. Microclimate effect C5. Carbon sequestration potential, C6. Low maintenance requirement, C7. Aesthetic effect, C8.Water filtration, C9. Ease of public use

Correlation Values and Symbols

Symbol	Symbol description	Value range	
	Very strong correlation	0.600 and above	** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)
	Strong correlation	0.450 – 0.600	
	Mid-level correlation	0.300 – 0.450	
	Low correlation	0.150 – 0.300	
	Very low correlation	0.000 – 0.150	

Tab.5 Correlation results

	C1	C2	C3	C4	C5	C6	C7
C1	1	0.766	0.722	0.310	0.392	0.236	0.201
C2	0.766**	1	0.793	0.275	0.252	0.197	0.133
C3	0.722**	0.793**	1	0.342	0.339	0.297	0.292
C4	0.310	0.275	0.342	1	0.329	0.445	0.323
C5	0.392	0.252	0.339	0.329	1	0.765	0.568
C6	0.236	0.197	0.297	0.445	0.765**	1	0.660
C7	0.201	0.133	0.292	0.323	0.568	0.660**	1

C1 Do you think it is important to keep the beach natural and why?
C2 Do you have information about the protection of the beach ecosystem?
C3 What threats do you think the beach ecosystem faces?
C4 What measures should be taken to protect natural beaches?
C5 What do you think about nature-based solutions in landscape design?
C6 Would it be better to preserve the beach in its natural state or to introduce certain landscaping measures?
C7 What are the aesthetic, social or ecological advantages of preserving the beach in its natural state?

Correlation Values and Symbols

Symbol	Symbol description	Value range	
	Very strong correlation	0.600 and above	**Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)
	Strong correlation	0.450 – 0.600	
	Mid-level correlation	0.300 – 0.450	
	Low correlation	0.150 – 0.300	
	Very low correlation	0.000 – 0.150	

Tab.6 Correlation results

This correlation analysis reveals the relationships between attitudes, knowledge level and perceptions towards the protection of the natural structure of beaches. According to the results of the analysis, there is a high and statistically significant (**, $p < 0.01$) positive correlation at the level of 0.766 between the variables 'Do you find it important to keep the beach natural?' (C1) and 'Do you have information about the protection of the beach ecosystem?' (C2). This shows that individuals who attach importance to the protection of the natural structure of beaches are also more knowledgeable about the protection of beach ecosystems. Similarly, a very strong correlation of 0.793 was observed between C2 and the variable 'What threats does the beach ecosystem face?' (C3). This shows that as the level of knowledge increases, the threat perception also increases. Moderate positive correlations were also observed between C3 and some other variables. For example, a correlation of 0.342 was found between C3 and 'What measures should be taken to protect natural beaches?' (C4) and 0.339 with 'What do you think about nature-based solutions in landscape design?' (C5). These results show that individuals who are aware of beach threats are more inclined to produce solutions and evaluate nature-based solutions in landscape design more positively. Especially the high correlations between C5, C6 and C7 are noteworthy. There are significant correlations at the level of 0.765 between C5 and C6 and 0.660 between C6 and C7. This indicates that individuals who have a positive attitude towards nature-based solutions in landscape design are more aware of the aesthetic, social or ecological benefits of the beach and prefer the preservation of the beach in its natural state to landscaping. In general, positive and statistically significant relationships were found between the variables in the analysis.

These findings reveal that individuals' knowledge levels and environmental awareness have an impact on their attitudes and preferences towards beach protection. Such relationships emphasise the importance of environmental education programmes and awareness raising activities and can be instructive for policy makers and environmental planners (Tab.6).

The one-sample t-test conducted within the scope of this study aims to assess whether respondents' attitudes and perceptions towards the conservation of the natural structure of beaches are significantly different from a given reference value (possibly a neutral or average attitude value).

					95% Confidence Interval of the Difference			
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper	Std. Deviation	Std. Error Mean
C1	25.000	210	0.000	1.67299	1.5411	1.8049	0.97208	0.06692
C2	26.503	210	0.000	1.85782	1.7196	1.9960	1.01825	0.07010
C3	27.823	210	0.000	1.89573	1.7614	2.0301	0.98972	0.06814
C4	31.640	210	0.000	1.97630	1.8532	2.0994	0.90733	0.06246
C5	23.550	210	0.000	2.13744	1.9585	2.3164	1.31839	0.09076
C6	25.235	210	0.000	2.44550	2.2545	2.6365	1.40767	0.09691
C7	25.228	210	0.000	2.55924	2.3593	2.7592	1.47359	0.10145

Tab.7 Results of One Sample T-Test

The results of the analyses show that the p-value for all variables (C1-C7) is 0.000 and these results are statistically significant ($p < 0.05$). These findings reveal that the respondents gave significantly different and higher responses than the reference value on each relevant issue. For example, the mean of the answers to the question 'Do you find it important to keep the beach natural?' (C1) is 1.67, while the means of the questions related to knowledge and awareness such as 'Do you have information about the protection of the beach ecosystem?' (C2) and 'What threats does the beach ecosystem face?' (C3) are 1.86 and 1.89, respectively. This shows that the participants are not only sensitive to environmental issues, but also have knowledge about them.

When we move on to more practical and evaluative questions, it is seen that the mean values increase even more. For example, the mean values for the questions 'What do you think about nature-based solutions in landscape design?' (C5), 'Would it be better to preserve the beach in its natural state or to make certain landscape arrangements?' (C6) and 'What are the aesthetic, social or ecological advantages of preserving the beach in its natural state?' (C7) are 2.14, 2.44 and 2.56 respectively (Tab.6). This shows that the participants are not only limited to environmental awareness, but also find nature-based solutions more aesthetically, socially and ecologically beneficial and support these solutions.

In general, the results of the one-sample t-test scientifically support that there is a high level of social awareness and a positive attitude towards the protection of the natural structure of beaches. These data provide strong evidence to guide environmental sustainability, nature-based planning and public awareness studies.

4. Conclusion

This study aims to analyse the effects of coastal landscape elements on user perception and coastal dynamics by comparing two different coastal areas in Budva, Montenegro. Within the scope of the research, a beach with a largely preserved natural structure and a beach affected by construction and land use changes were analysed. The findings obtained using the Analytical Hierarchy Process (AHP) method and SPSS analyses showed that criteria such as biodiversity, coastal protection capacity, aesthetic value and public usability are determinant in user perception. By combining quantitative evaluation (AHP) and statistical perception analysis (SPSS), this study provides an interdisciplinary framework that bridges ecological assessment and social perception, offering a more comprehensive understanding of how users experience and evaluate coastal landscapes. The convergence of AHP-based priority weights and SPSS-derived statistical outputs across both study sites reinforces the internal consistency of the findings and validates the interdisciplinary methodological approach adopted in this study.

The results obtained reveal that the protection of natural landscape elements is important not only in terms of ecological but also social and visual quality. On the other hand, intensive construction and LULC (Land Use/Land Cover) changes in coastal areas negatively affect user satisfaction and landscape integrity. In this direction, it is emphasised that interventions should be made by considering sustainable planning and ecological balance in coastal areas. This emphasizes that the sustainability of coastal environments depends on harmonizing physical integrity with user perception — a balance that can only be maintained through integrated coastal management and the inclusion of public awareness in policy-making.

According to the results obtained from AHP analyses, coastal protection is the most important criterion for users when evaluating coastal areas. According to the AHP results, coastal protection capacity (C1) was identified as the highest priority criterion among the non-LULC parameters, with a local weight of 35.4%, followed by biodiversity contribution (C2) at 30.7%, carbon sequestration potential (C5) at 11.8%, ecological adaptation (C3) at 11.1%, and microclimate effect (C4) at 11.0%. Among the LULC-affected parameters, aesthetic effect (C7) emerged as the dominant criterion with a local weight of 51.7%, followed by low maintenance requirement (C6) at 22.6% and ease of public use (C9) at 21.0%. These distributions, as reported in Tab.2, confirm that decision-makers prioritize both ecological protection functions and user-oriented values in the assessment of coastal landscapes. This was followed by biodiversity (27.5%), aesthetic impact (22.1%) and public usability (16.2%). This distribution reveals that users primarily expect environmental protection and naturalness in coastal areas, followed by visual and social use features. This prioritization not only highlights users' sensitivity to ecological values but also suggests that public expectations align closely with scientific principles of sustainability. In this sense, the AHP framework proves to be a reliable tool for translating subjective perceptions into measurable planning criteria. It is also noteworthy that the AHP consistency ratio of 0.00075 — well below the accepted threshold of 0.10 — confirms that the expert evaluations were logically coherent and free from contradictory judgments, thereby ensuring the reliability of the derived weighting scores.

The one-sample t-test results presented in Tab.6 demonstrate statistically significant differences across all perception variables at the $p < 0.05$ level, confirming that participants expressed consistently positive attitudes toward the preservation of natural coastal structures. In particular, the coastal area that retained its natural morphology received more favorable evaluations across all ecological and aesthetic criteria.

In particular, the coastal area that preserved its natural structure received more positive evaluations by the users. This coastal area was found to be more qualified in terms of both physical preservation and landscape integrity; in terms of biodiversity, it was stated that the diversity of flora and fauna was more perceptible. This area, which visually leaves a calmer, natural and aesthetic impression, is also considered more satisfying in terms of user experience. These findings reveal that natural coastal environments contribute simultaneously to ecological stability and psychological well-being. Therefore, user perception can be considered an indirect indicator of ecological health, functioning as a social reflection of environmental quality.

According to the correlation analysis, a very strong positive relationship ($r=0.754$) was found between coastal protection capacity and biodiversity contribution. Similarly, ecological adaptation was highly correlated with microclimate effect ($r=0.839$) and carbon sequestration potential ($r=0.760$). This indicates that natural areas support each other in terms of ecological functions. Additionally, the strong relationship ($r=0.828$) between microclimate effect and carbon sequestration potential suggests that these two services should be considered together. The positive correlation of the low maintenance requirement variable with these services is also significant in terms of sustainable design. The moderate correlations between aesthetic effect and water filtration ($r=0.493$) and suitability for public use ($r=0.461$) indicate that visually appreciated areas also provide functional and environmental benefits. On the other hand, the correlation analysis regarding individual attitudes and perceptions towards the preservation of the natural structure of beaches revealed that as environmental knowledge and awareness increase, perceptions of threats and preferences for nature-based solutions also increase. In particular, the very strong relationship ($r=0.793$) between C2 (knowledge level) and C3 (threat perception) and the high correlation ($r=0.765$) between C5 (nature-based solution assessment) and C6 (preference for natural conservation) underline the connection between environmental awareness and attitudes. One-sample t-test results also showed significant differences for all variables at $p < 0.05$ level, scientifically supporting that participants demonstrated high awareness and positive attitudes towards preserving the natural state of beaches. These findings suggest that nature-based planning and environmental education efforts are well-received in society, and that there is strong public support for sustainable coastal management. This connection between awareness and perception also implies that environmental education can play a crucial role in fostering community-driven coastal conservation. Promoting knowledge-based engagement ensures that users become active participants rather than passive observers in maintaining coastal integrity. These statistically significant results, obtained from a sample of 211 coastal users, provide a sufficiently robust empirical basis for drawing conclusions about general user attitudes toward natural coastal environments and the perceived impacts of LULC-driven landscape transformation.

From a planning and management perspective, the findings of this study underscore the critical importance of integrating ecological indicators alongside user perception data into coastal landscape evaluation frameworks and evidence-based decision-making processes. The results convincingly demonstrate that preserving the natural structure and morphological integrity of coastal areas contributes simultaneously and measurably to ecological stability, visual quality, and overall user satisfaction — reinforcing the interdependence of environmental and socio-functional dimensions in coastal systems. Notably, the AHP-derived priority weights reveal that both ecosystem service criteria, particularly coastal protection and biodiversity contribution, and user-oriented criteria, particularly aesthetic value and ease of public use, are consistently ranked as high-priority determinants by domain experts, reflecting a broadly shared recognition of the multi-dimensional value of natural coastal environments.

In light of these findings, coastal planning strategies should deliberately prioritize nature-based solutions, ecological restoration practices, and soft coastal engineering approaches as primary instruments of intervention, rather than relying solely on conventional hard infrastructure measures that may compromise long-term ecological resilience. Furthermore, the systematic incorporation of user perception assessments into environmental impact evaluations and landscape performance analyses can substantially support the formulation of more balanced, inclusive, and sustainable coastal management policies. By explicitly aligning ecological protection objectives with documented social expectations, recreational needs, and aesthetic preferences, planners and policymakers can develop adaptive management frameworks that are both scientifically grounded and responsive to the evolving demands of coastal communities. Ultimately, the interdisciplinary approach adopted in this study — combining quantitative multi-criteria analysis with statistical perception evaluation — offers a transferable methodological model for sustainable coastal governance in similarly dynamic and vulnerable coastal environments.

In contrast, the coastal area affected by LULC changes has been described by users as a less preferred, less impressive, and lower-quality environment due to factors such as increased hard surface ratio, intensified urbanization, and loss of natural vegetation. This clearly demonstrates that as coastal areas deviate from natural integrity in landscape planning, both user satisfaction and ecological quality tend to decrease. These findings confirm that over-urbanization in coastal zones leads not only to ecological degradation but also to a perceptual decline that diminishes the overall landscape experience. Thus, unsustainable development practices result in both physical and cultural losses in coastal identity.

In light of all these data, it can be emphasized that for the sustainable management of coastal areas, the preservation of naturalness and the minimization of landscape interventions are essential. This multi-criteria analysis, based on users' perceptions, demonstrates that coastal areas should be addressed not only physically but also in terms of social perception and ecological functionality. Through the systematic prioritization provided by the AHP analysis and the statistical validation offered by SPSS, this study makes a significant contribution to the need for science-based decision-making in coastal planning processes. The integration of analytical hierarchy with perception-based evaluation introduces a novel methodological synthesis that strengthens the reliability of coastal assessment. It provides planners with measurable indicators grounded in both expert analysis and community experience, bridging the gap between scientific objectivity and human subjectivity.

As a result, this comparative evaluation conducted using the Budva example highlights that the preservation of the natural structure in coastal areas is indispensable in terms of user satisfaction, aesthetic quality, and ecological sustainability. Implementing nature-based solutions in coastal management, supported by multi-criteria analyses based on local user perception, is of great importance for long-term coastal protection strategies. In addition to these empirical results, this research contributes to the academic discourse on coastal sustainability by proposing an integrated methodological framework that unites expert-based evaluation and user-centered perception analysis. This dual approach advances beyond conventional spatial or visual assessments, enabling a more comprehensive understanding of how LULC dynamics influence both ecological functions and human experiences.

The study also demonstrates the applicability of multi-criteria decision-making methods such as AHP as effective tools for translating subjective user evaluations into quantifiable indicators of environmental quality. This methodological synthesis reinforces the value of combining quantitative and perceptual data in landscape research, ensuring that scientific findings remain context-sensitive and socially relevant.

From a policy perspective, the results underscore the importance of embedding participatory and perception-based indicators into coastal planning frameworks. Local governments and urban planners are encouraged to adopt evidence-driven strategies that integrate nature-based solutions, soft engineering techniques, and ecological restoration to enhance coastal resilience.

Furthermore, the Budva case study reveals that landscape perception acts as a diagnostic tool for detecting ecological degradation and urbanization pressure. As user perceptions decline, it signals an underlying loss of environmental integrity, highlighting the need for early intervention and adaptive management.

Future research should extend this analytical framework to larger spatial and temporal scales, integrating multi-temporal remote sensing, participatory GIS, and socio-ecological modeling to explore how land use dynamics interact with climate variability and cultural values in coastal systems. By incorporating both expert and community-based knowledge, future studies can help develop more inclusive, resilient, and adaptive coastal management strategies across the Mediterranean and beyond.

Taken together, the empirical evidence generated through this study contributes to the growing body of literature advocating for perception-inclusive, ecologically grounded coastal governance, and offers a replicable analytical template for assessing landscape quality in other Mediterranean and globally comparable coastal settings.The present study acknowledges several methodological limitations that should be considered when interpreting the findings. First, the criterion weighting procedure within the AHP model is inherently grounded in expert judgments, which — despite the application of consistency ratio checks to ensure reliability — may introduce a degree of subjectivity into the priority rankings. The composition and size of the expert panel, as well as the disciplinary backgrounds of its members, may influence the resulting weight distributions and should therefore be taken into account when generalizing the findings to other coastal contexts. Second, the user perception analysis is based on structured survey responses, which are susceptible to individual variability in environmental awareness, personal experience, and aesthetic sensitivity. Response biases inherent to self-reported data, including social desirability effects and varying levels of familiarity with the study area, may partially affect the representativeness of the perception outcomes. Third, the delineation of LULC-affected and non-affected conditions relied primarily on visual spatial interpretation of satellite imagery and systematic field observations, rather than on a fully automated or supervised remote sensing classification procedure, which may limit the precision and reproducibility of the spatial differentiation. Future research should address these limitations by integrating multi-temporal, high-resolution remote sensing datasets and applying rigorous land cover classification algorithms to enhance the accuracy and objectivity of LULC change detection. Additionally, expanding the expert panel diversity and increasing survey sample sizes across varied demographic groups would further strengthen the robustness, transferability, and scientific credibility of the proposed analytical framework in comparative coastal landscape studies.

Ethics statement

This study was conducted in accordance with the ethical principles of research involving human participants. Survey participants were informed about the purpose of the study and provided voluntary consent prior to participation. No personally identifiable information was collected or retained.

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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