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Landscape Indicators—An Inventive Approach for the Sustainability of Landscapes

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Abstract: Despite the prerequisite tools of sustainability, there is an arising need to particularly assess landscape sustainability (LS). In this regard, no quantitative approach was identified, neither locally nor internationally. The main objective of this current study is to design a new set of Landscape Indicators (LIs) and a new scheme of LS assessment. Accordingly, an inventive mixed research method was adopted, including different techniques, diverse data categories, and extensive analysis. 15 potential tools were examined, and 51 indicators were prioritized based on an inventive four-dimensional approach to LS. Diverse landscape experts and local stakeholders were consulted to justify the choice of LIs. Site visits and the different aspects of international and local policies were also considered. The new identified set of LIs was applied at Tannourine Cedar Forest Nature Reserve, North Lebanon. While some LIs showed a need for further attention, transformative management was proposed to actively present the unique identity of the reserve and make it a true sustainable Lebanese landscape. Remarkably, this research led to the establishment, for the first time, of an educational tool for landscape sustainability assessment, the LSA tool, that will help decision-makers towards landscape correction, conservation, or even protection.

Keywords: tools of assessment; inventive approach; parameters and indicators; holistic assessment; Lebanese landscape; Tannourine Cedar Forest Nature Reserve

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1. Introduction

Searching for landscape indicators (LIs) that would help transformative action toward landscape sustainability is a necessity, since sustainable indicators used nowadays in the landscape field are either qualitative or ecological [1]. Even though some can be adapted into the mentioned field, it remains difficult to truly translate—quantitatively—the concept of landscape sustainability.

Defined in the European Landscape Convention since 2000 and addressed within the Sustainable Development Goals (SDGs), the assessment of landscape sustainability is an opportunity to accurately create policies [2], introduce the protection of quality landscapes [3], and implement holistic planning and management [4,5] of an entire landscape, not only a particular territory [6]. From another point of view, sustainable landscape development has great potential as a framework for achieving most of the SDGs [7,8] and provides the setting to enable the unfolding of many difficult problems [9] and associated solutions in relation to the SDGs [10].

This article first recalls the main concepts underlying a system of sustainability indicators, then raises the replacement of existing indicators and designs new LIs to address

landscape sustainability. It also enhances the view towards guiding policies in favor of the landscape and evaluating them. LIs were afterwards used in the context of the Landscape Sustainability Assessment LSA tool [1], which was established in the first place, to be able to quantify the sustainability of landscapes. This approach raises awareness among reserves and landscape systems about the conception of landscape sustainability through reflection on their own management and practices. Therefore, it aims to evaluate the sustainability of landscape implementation, knowing that the evaluation is not a control measure. It could relate to the verification of the application of a regulation (landscape quality), compliance with a set of requirements (LEED, SDGs), or the justification of aid (urban and rural greening). Hence, it would imply having verifiable information (direct measurements, surveys, etc.).

On the other hand, an evaluation aims at estimating the degree of achievement of previously set objectives. Through the LSA method, the assessment is made for the manager or tenants of a landscape to serve as a diagnosis and monitoring tool or as a decision-making tool. The information has no need to be verifiable, and the data used to establish it is provided voluntarily and anonymously by the interested party.

Knowing That LSA is an educational tool, it also eases the understanding to analyze the different perspectives and take the convenient decision in supporting landscape sustainability.

1.1. Conceptual Framework

Since "Landscape" is the interdisciplinary communication between landscape status, human activities, and natural processes, the landscape is thus the result of driving forces (societal activities, economical revenues and naturel processes) over relevant pressure (exploitation, urban expansion, agricultural production. . .), creating a slight, medium, or severe impact [11].

But with the uncontrolled interventions and overexploitation [12] over the Lebanese landscapes [1], the qualities of Lebanese landscapes are continuously threatened and sometimes lost. In this perspective, we urge us to consider landscape at the core of any intervention, on the corrective level as well as protective measures. This led to an increasing need for a new set of indicators, the LIs.

In this matter, we have first examined fifteen different tools in (i) general sustainability and (ii) landscape sustainability. Then, we identified the expansion needs of LIs, their roles and their typologies.

1.2. Predecessors

Yet, most of them were either (i) qualitative, (ii) ecological indicators-based, or (iii) not specific to the landscape [1]. The interest in landscape assessment approaches mainly targeted European concepts [1], where landscape diversity is similar to the Lebanese landscapes. Yet, most of them were based on either qualitative or ecological indicators [1]. We will briefly mention hereafter four of the predecessor tools that were most inspirational to this current research (Table 1).

1. Strategic Environmental Assessment SEA consists of a range of analytical and participatory approaches [8]. We selected SEA since it adopts indicators to prevent territorial trespassing and impacts the landscape [1,9,13]. It also focuses on territorial and landscape programs with an effect on the environment [1,14], but unfortunately, it is mostly voluntary for the landscape approach [1,15] and qualitative. Most importantly, SEA takes the visual dimension into account.
2. Sustainability Assessment at Farms (known in French by Indicateurs de Durabilité des Exploitations Agricoles) is a quantitative method [1,10], based on agro-ecological indicators [16], but not specific to the landscape [17]. Covering the three dimensions of sustainability, SAF is a 41 indicator-based method used by farmers in a self-assessment process. Also recommended in pedagogic situations [1,18,19], SAF is a decision-making tool for possible progress in sustainability [18].

3. The Landscape Performance Series LPS, purposed towards sustainable landscapes, most particularly helps landscape designers and agencies quantitatively estimate performance [1,20]. Unfortunately, it is used only to transform the landscape design and not the visual dimension.
4. Management Effectiveness Tracking Tool METT is a scorecard questionnaire [1,11] on adaptive management, particularly concerning protected areas [21]. It is an optional evaluation tool [11,21] that helps suggest rapid adaptation.

Table 1. A brief comparative table showcasing predecessors and relevance to landscape sustainability.

Tools of Assessment Selected		Tool Characteristics and Scale	Reasons for Adopting This Research				
			Landscape Relevance	Indicator Type		Indicator Dimension	
				Qualitative	Quantitative	Agro-Ecological	Landscape Specificity
SEA	Strategic Environmental Assessment	1. participatory approach 2. territorial & landscape focused 3. site scaled	☑	☑		☑	☑
SAF	Sustainability at Farms	1. three dimensional; 41 indicators; decision making 2. educational 3. farm scale	☑		☑	☑	
LPS	Landscape Performance Series	1. Transformative approach 2. design development focused 3. site scaled	☑		☑		☑
METT	Management Effectiveness Tracking Tool	1. Scorecard questionnaire 2. proposes rapid adaptation 3. protected area scaled	☑	☑			

1.3. The Expansion Need for Landscape Indicators

Landscape indicators are indices at the service of landscape policies [22], with the active implementation of which some European nations have demanded indicators [23,24] to effectively represent many aspects of the landscape [24,25].

We can indicate the current status of the landscape [26], its evolution, the societal attitudes towards it [27], and the level of awareness and appreciation of the landscape among the population [28]. LIs are representative, variables that allow us to "measure" (when quantitative, as in our case) or describe a specific phenomenon (when qualitative as the case of prerequisite indicators) in a simple and clear way [24].

The use of LIs in evaluation was adopted in different fields and scapes, either associated with parameters as in the matter of green open spaces [29] or independently for a wider assessment by means of landscape quality [30,31] and contingent upon our case.

Institutions are also aware of the expansion need for LIs [32,33], while stakeholders and policymakers can benefit from knowing and adapting their assessments, and communicating the critical facets.

Though we must stress the fact that there is not just one landscape sustainability model, the LIs must be adapted to local landscapes before using the LSA method.

1.4. Role and Types of Landscape Indicators

According to Phondani et al. (2016) [24], the role of indicators for sustainable landscaping is as tools that can be used in the conceptualization, implementation, and monitoring of nationwide progress. Landscape indicators have three main roles:

1. recognition function (monitoring and measuring conditions and processes);
2. evaluation function (judgement of the value of the condition, the process, and the human action in relation to these);
3. orientation function (supplying indications on the ways in which human action should be implemented) [34].

They must describe, in a simple yet rigorous way, the reality of the landscapes, particularly the Lebanese landscapes-, fully contributing to (i) the identification of problems, (ii) furthering the knowledge of existing challenges in relation to landscape conservation, (iii) management and planning, and thus (iv) enabling research and the finding of suitable and flexible solutions.

Also, LIs must be purposed to evaluate the effectiveness of the actions of the various levels of the administration in the area of landscape, providing clear signs of the success or failure of those policies adopted and guiding decision-makers towards issues of priority in the area of landscape.

The types of indicators used in key international and particularly in sustainability landscape studies emphasize systems of social, economic, and ecological indicators [4,33]. Therefore, several LIs can be used as a starting point in the current study. However, the perceptual (visual) dimension that remains absent in the prerequisite tool is taken into account in this current research and will be discussed in the following section.

1.5. Quantifying Landscape Indicators

The conceptual framework illustrated the relationship between the identified indicators and the overall concept of landscape sustainability. However, despite the increasing need for landscape indicators and in order to reach the main objective of this research, which is creating a holistic tool for landscape sustainability, there remains a notable gap in our understanding of:

i. a fourth dimension, the perceptual dimension, not previously mentioned in the context of the current study.
ii. quantitatively assess the sustainability of landscapes, unlike any predecessor.

2. Materials and Methods

The Lebanese landscapes show variability in characteristics, in physical aspects, and in functional requirements, and they present a unique visual identity and genuine natural and built landscapes [1]. They are an exceptional scenic reprieve in an integrative community, worthy of not only management and design but also conservation.

The need for a new adaptive set of indicators (LIs) arises from the necessity to objectively and quantitatively assess the landscape sustainability. Therefore, LIs must communicate clearly and precisely about the features of landscape to the citizens of Lebanon, particularly in order to facilitate and improve their understanding. Moreover, they contribute towards raising awareness and educating the population [17]. This readability will favor a good level of participation.

Some of the large sets of indicators can be adopted, but an adaptive method should be applied. That is why what has been offered so far in terms of LIs can be a good example for Lebanese Landscape Indicators (Le-LIs) and provide clear signs of the success or failure of proposed projects and policies. That means they will guide decision-makers to prioritize the landscape and identify the weaknesses and discrimination of strengths in the landscape.

2.1. Developing a System of Sustainable Landscape Indicators

Sustainable indicators are anticipated to be objective, methodically established, relevant to the original problem, easy to get, and immediately understandable [17]. The concept of sustainability suggests the establishment of indicators combining three dimensions [35], simultaneously involving the understanding of the economic, environmental, and social aspects [36].

This systemic aspect of sustainability, well adopted worldwide, is complemented by three other aspects [17]: (i) the temporal aspect; (ii) the spatial aspect that evaluates the effects in the long term; and (iii) the ethical aspect, clarifying that sustainability is based on a system of values.

Yet, these three dimensions are not completely satisfactory to describe the LIs [37]. A fourth dimension is added to this research. Accordingly, a four-key concept can cap-

ture the interdisciplinary relation of LIs through a transformative approach from a three-dimensional methodology as conventionally known in sustainable development towards a four-dimensional method describing the proposed inventive landscape indicators in Landscape Sustainability Assessment (Figure 1).

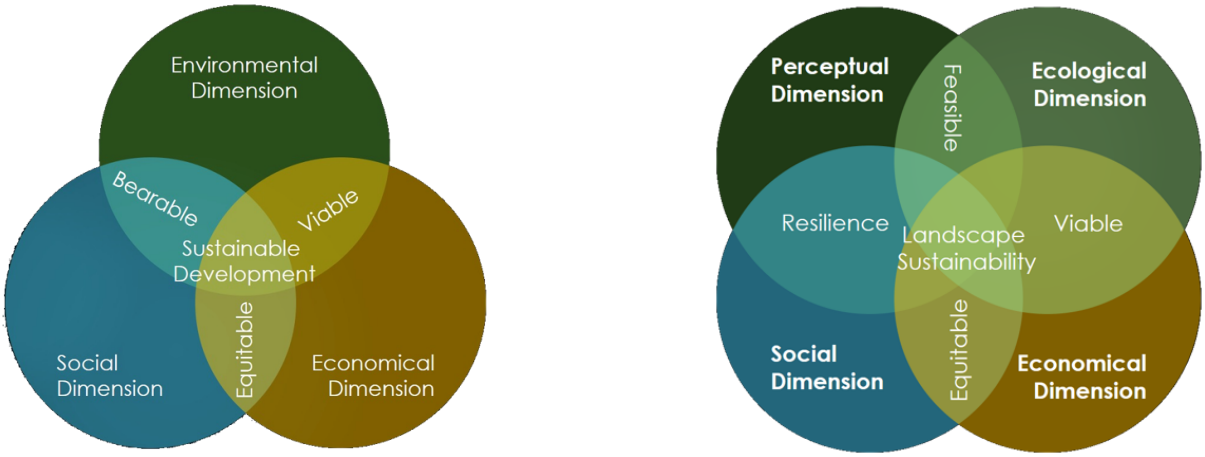

Figure 1. Transformative approach from a three-dimensional methodology in sustainable development towards a four-dimensional method describing the proposed inventive landscape indicators in Landscape Sustainability Assessment.

Four inter-relations are thus proposed to describe the proposed LIs. We first mentioned viability, which implies, as per sustainable development, securing the sources of income of the agro-ecological production system in the face of the market and uncertainties weighing on direct aid [35]. Equitability in the context of sustainability refers to the idea that all people throughout a community have the same rights and opportunities to maintain an acceptable quality of life [38].

Landscape Resilience is the interrelationship between social awareness, livability, and the landscape dimension. It hereafter represents human well-being, community cohesion, and the aesthetic appeal of the landscape [4]. It captures the combination of perceptual beauty in a landscape and its overall livability. The LIs of this section underline the well-being and engagement of the communities toward the landscape. They will be able to situate the citizens in relation to certain social references, such as the income from the landscape or working time, and will also be able to address more subjective aspects, such as participation in conservation of the landscape or other initiatives.

Feasibility is the inter-sectorial dimension between the ecological and environmental dimensions and the landscape dimension. It encompasses the practicality, perceptual acceptability, and conceptual acceptability of a project or action on the considered landscape [27,31]. It suggests not only the possibility or unfeasibility in a tangible manner but also if it is considered sensible, reasonable, acceptable, or unacceptable from a perceptual or conceptual point of view.

2.2. Adopting a Mixed Methodology

Following the establishment of a well-defined framework and highlighting the need for inventive LIs and their advantages, it is important to describe their (i) selection, (ii) mode of calculation, and (iii) implementation method.

To do so, a mixed methodology was adopted, consisting of merging diverse research techniques, data types, and outcomes as presented in Table 2.

Table 2. Mixed methodology, including research techniques, data types, indicator types, and outcomes used in the study.

Technics	Data Type	Indicator Type			Outcomes
		New Indicators	Relevant Indicators	Existing Indicators	
GIS techniques and Google mapping	Spatial	☑			Selecting LIs, Scoring, and Maxima
Landscape visual studies	Landscape scenes, Photographs, drawings	☑			Selecting LIs, categorization, Scoring, and Maxima
Citations and readings	Descriptive		☑	☑	Selecting LIs, categorization
Social perception and surveys		☑			Selecting LIs, categorization
Documents analysis	Descriptive and statistical	☑	☑	☑	Selecting LIs, categorization, Scoring, and Maxima
Interviews and questionnaires		☑			Selecting Lis

New indicators were identified through the different techniques except for the citations and reading techniques since, as previously mentioned, they were inventive through this research. Accordingly, different data types (spatial data, landscape readings, and photography) were used to first select and categorize LIs and then establish scoring and maxima.

As for the relevant indicators and existing indicators, they were detected through readings and prerequisites. For example, we identified the indicators from Lebanese Law 130 (the only Lebanese law related to landscape and protected areas in Lebanon) and others that were previously developed from existing landscape sustainably tools or nominated by observatories and will be clarified in the coming sections.

However, to tackle the real needs around the landscape indicators, we identified first the stakeholders engaged in LIs and interviewed landscape managers of different reserves as well as experts (Table 3), visitors, and local residents of the Tannourine Cedar Nature Reserve, the site selected for the elaboration of LIs.

Table 3. Some details about the interviews conducted with different managers and experts.

Interviewees	Total Number of Interviewees	Type of Reserve			Types of Expertise	
		Cedar Reserve	Cedar and Pine Reserve	Others	Landscape Design and/or Management	Tools and/or Value Chain
Reserve managers	8	4 ☑			☑	☑
		1	☑		☑	
		3		☑	☑	
		5			☑	
Experts	15	5			☑	
		5				☑

Accordingly, we interviewed five managers of eight well-known cedar forests in Lebanon and three managers of other reserve types. Also consulted were fifteen experts in landscape (design and management) and tools (and value chains).

At the selected site, we also conducted landscape observations and visual assessments (landscape visual reading, social perception, diagnosis. . .) and collected more data, such as visitors (age, number, time of visits, season of visits), activities held (number, type, availability), social implementation, revenues, paid services, and others.

All the collected data—from research, interviews, imagery, and on-site—were supported by GIS (Geographic Information System) mapping and imagery, compiled and analyzed, to come up with the new LIs, the development cycle of which is shown in Figure 2.

Yet, the most important and challenging phase of the research was to elaborate a scoring system for each landscape indicator, and later test and monitor the elaborated LIs at the selected site. They will guide investments and adaptive management.

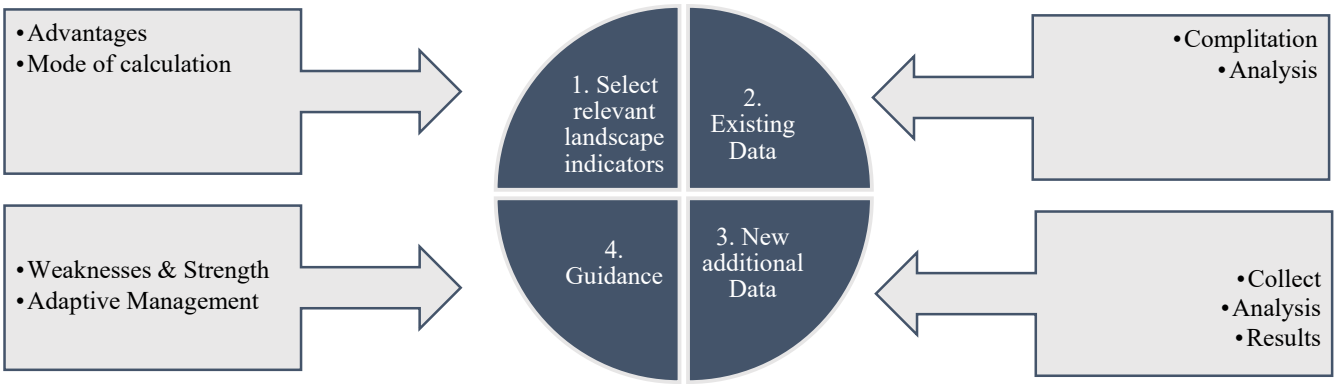

Figure 2. LIs development cycle.

2.3. Identifying Relevant Stakeholder Involvement and Engagement

Effective landscape management often requires collaboration and engagement with a diverse set of stakeholders to ensure that various perspectives and interests are considered [39] in decision-making processes. Stakeholder involvement can contribute to more sustainable and well-balanced landscape planning and management initiatives [40].

Landscape architects, environmentalists, and landscape tenants; reserve or protected areas managers; public authorities and policymakers; NGOs, cooperatives, and local communities; higher education institutes are all potential users of LIs . . ., etc. We considered five main groups of users:

1. Government and regulatory bodies that are responsible for land use planning, environmental protection, regulatory compliance, and policymakers. They can be local, regional, or national government agencies.
2. International and non-governmental organizations that have an interest in landscape sustainability, landscape conservation, and advocacy for sustainable practices, biodiversity conservation, and protection of natural resources.
3. Local communities are defined as residents, community organizations, local businesses, and private landowners (individuals, corporations, or entities) with a direct interest in the quality of life, cultural heritage, and economic well-being of the landscape site.
4. Cultural and touristic groups that often support unique perspectives on conservation and land management.
5. Research, Planning, and Development groups include (i) academic and research institutions such as universities, research organizations, and scholars conducting studies related to landscape ecology, and sustainable development; (ii) environmental consultants and planners, i.e., professionals providing expertise in impact assessments, landscape architecture, and sustainable land management practices and (iii) infrastructure and development agencies, i.e., organizations involved in infrastructure development, urban planning, and transportation that may impact the landscape.

In addition, businesses and industries operating within or adjacent to the landscape, including agriculture, forestry, tourism, and other sectors that impact land use, as well as media and communication outlets such as journalists, media organizations, and communication platforms that influence public perception and awareness of landscape issues, were identified.

These landscape stakeholders often play a role in decision-making processes that affect the landscape's development, conservation, or transformation. They encompass a broad range of individuals, groups, and organizations that have an interest, influence, or involvement in the planning, management, and use of a landscape. Their engagement fosters inclusivity, brings in the insights of local communities, businesses, and organizations, and ensures a more holistic understanding of the landscape.

2.4. Establishing Key Landscape Indicators

Based on a literature review, a landscape visual study, interviews, and stakeholders' engagement, key indicators (inventive) were identified and established.

Firstly, the literature reveals available landscape indicator sets, summarized in Table 4. Their number is limitless [41], and only a few studies explain how they can be used [33] and whether the measurement is quantitative or qualitative, with a stress on the choice of appropriate landscape indicators [23,31]. In our study, we adopted many of these indicators, transformed those qualitative into quantitative, compiled those with the existing and additional data, and validate them with experts and managers as previously mentioned.

Table 4. Categorization of relevant Landscape Indicators according to countries.

Country of Origin	Methodology	Relevant Landscape Indicators	Uses
Europe	Policies establishment	Landscape diversity Landscape quality Landscape character	Landscape-related concepts
Asia	Four sets of indicators of performance	Improved landscape livelihoods Improved ecosystem services Improved resource efficiency in land use Supply of food and other products	Landscape at different scales; landscape sustainability management
Catalonia	Ten indicators	Transformation of the landscape Landscape diversity Landscape fragmentation Economic value of the landscape Knowledge of the landscape Landscape satisfaction Landscape sociability Landscape and communication Public and private action in the field of conservation Application of instruments of the landscape legislation	Landscape quality
Netherland	Landscape perception and assessment	Unity Functional organization Possibility of using the landscape for your own activities Historical character Natural character Spatial dimensions Sense impressions	Landscape appreciation Landscape perception
Italy	European landscape character	Coherence Openness Diversity	Landscape character landscape policy
United Kingdom	Emerging indicators	Land cover Cultural pattern	Future monitoring at landscape scale

Accordingly, we identified three initial categories of LIs shown in Table 5. The first category represents the "antecedent research-based indicators" that were selected from previous research, either from other tools or nominated by observatories. We can mention, for example, the space organization, dependencies, ecological diversity, etc. [1].

The second category of LIs represents those mentioned in the new Lebanese Law, and was specified through official government announcements, legal databases, and by contacting relevant government authorities. These LIs refer to various sectors, such as environmental protection, social welfare, and economic development.

Table 5. Categories of indicators as per literature review and non-conventional thinking.

An Example of Antecedent Research-Based Indicators	Indicators Mentioned in the New Lebanese Law	Some Inventive Indicators to Be Taken into Consideration
Ecological diversity	Types of protected areas	Accessibility and dimension of the site
Space organization	Buffer zone	Number and age of visitors
Specificity	Limitation	Entrance fees and paid services
Dependencies	Presence inside a private area	Neighboring urban agglomerations
Revenues	Endemism	Territorial and landscape diversity
Dynamism	Rare species	Built heritage and cultural landscape
Well-being	Biodiversity	Landscape resources management
Social diversity	Urban pressure	Social contribution and event hosting
		Agroforestry and agricultural activities

The third category is relevant to inventive LIs, selected either from stakeholders' engagement or from new data analysis. The objective of these LIs is to go beyond conventional indicators and address landscape challenges.

While the data and mapping captured throughout the latest years will help understand the landscape changes and anticipate the impact of various interventions, the inventive indicators empower decision-makers to make more informed and agile choices. They offer a real-time and adaptive framework for assessing the effectiveness of sustainability initiatives, identifying emerging trends, and proactively addressing potential challenges. Mentioned here below in Table 4, the first proposal of inventive LIs. Their elaboration, scoring, maxima, and implementation will be discussed in later sections of this research.

This approach not only enhances the accuracy of landscape sustainability assessments but also promotes a more responsive and collaborative approach to landscape management, aligning with the principles of adaptive governance and resilience. Ultimately, inventive indicators derived from stakeholders' engagement and new data analysis contribute to a more dynamic, inclusive, and effective paradigm for sustainable landscape management.

2.5. Scoring and Weighting

A scoring system for each indicator was established. The weighting of different indicators was determined based mainly on their relative importance to overall landscape sustainability, and in close collaboration and validation with experts and stakeholders.

The overall landscape sustainability score, calculated by summing the scores across all LIs and landscape dimensions, provides a comprehensive assessment [42] that considers the impact of a «change» on the environment [43], society, its economic viability, and landscape perception [44].

After testing and based on regional considerations and stakeholder input, the LIs and scoring levels should be adjusted to align with the goals of the assessment and the characteristics of the landscape under consideration.

We have selected the Tannourine Cedar Forest Nature Reserve (TCFNR) for the LIs implementation since it shows consideration for factors such as accessibility, ecological diversity, cultural significance, and many others.

3. Results

After examining around 15 existing sustainability tools (in general sustainability and landscape sustainability) and after settling all the interviews, surveys, and site visits for diagnosis and analysis, 51 inventive landscape indicators were suggested.

This set of LIs falls within a four-dimensional methodology (ecological, economic, social, and perceptual landscape sustainability dimensions), as shown in Figure 1, complementing 12 components of landscape sustainability LS (Table 6).

Each of the components accounts for the same weight, which is 33 or 34 units of the total scoring (also shown in Tables below) and entails several landscape indicators.

Table 6. Reading grid using 51 landscape indicators.

4 Dimensions	12 Components	51 Landscape Indicators
landscape sustainability ecological dimension grade/100	Ecological Diversity	5 LIs
	Space organization	5 LIs
	Practices effectiveness	5 LIs
landscape sustainability economical dimension grade/100	Viability	4 LIs
	Independency	4 LIs
	Efficiency	3 LIs
landscape sustainability social dimension grade/100	Living environment	4 LIs
	Esthetic value	4 LIs
	Dynamism	4 LIs
landscape sustainability perceptual dimension grade/100	Perceptual Diversity	4 LIs
	Perceptual features	4 LIs
	Perceptual components	5 LIs

In the following, we will elaborate on the four dimensions, relevant components, and corresponding landscape indicators. We will also explain the principles of each dimension in relation to the landscape.

Subsequently, the new set of LIs is implemented at the selected site, and the results of scores and calculations are also presented.

3.1. Sustainable Landscape Ecological Indicators SLEI

The ecological dimension consists of three components (ecological diversity, space organization, and practices effectiveness) and 15 landscape indicators (Table 7). Each of the components accounts for the same weight, which is 33 or 34 units of the total scoring (which is 100). This dimension refers to ecological principles in relation to landscape. It examines the rigidity of the ecological system to make efficient use of the ecology at lower landscape costs. The indicators illustrate the ability of a landscape system or project to be more or less autonomous in their use of natural resources and generate fewer pollutants through their ecological activities.

Table 7. The 15 landscape indicators of the landscape sustainability ecological dimension.

3 Components	15 Indicators		Maxima Value	Total Score
Ecological Diversity	I.1.	Territorial diversity	13	33 units	100
	I.2.	Land cover diversity	13		
	I.3.	Regional breeds	5		
	I.4.	Endemic species	5		
	I.5.	Habitat quality	13		

Table 7. *Cont.*

3 Components	15 Indicators	Maxima Value		Total Score
Space organization	I.6. Accessibility	10	33 units	100
	I.7. Site dimension	6		
	I.8. Ecological regulating zone	6		
	I.9. Urban pressure	6		
	I.10. Favor of the natural or built heritage	12		
Practices effectiveness	I.11. Local practices	6	34 units	
	I.12. Integrative activities	6		
	I.13. Soil resource protection	10		
	I.14. Energy dependency	10		
	I.15. Water resources management	3		

3.2. Sustainable Landscape Economic Indicators SLEcI

The economical dimension consists of three components (viability, independence, and efficiency) and 11 landscape indicators (Table 8). This dimension refers to economic practices and principles in accordance with the landscape. It examines competencies and autonomy.

Table 8. Landscape indicators of the landscape sustainability economic dimension.

3 Components	11 Indicators	Maxima Value		Total Score
Viability	I.16. Productive resources	15	33 units	100
	I.17. Specialty	5		
	I.18. Landscape resources	15		
	I.19. Local markets	10		
Independency	I.20. Tourism and activities	15	33 units	
	I.21. Artisanal and goods	10		
	I.22. Museum and educational	10		
	I.23. External dependency	10		
Efficiency	I.24. Competitiveness	15	34 units	
	I.25. Public/private shares	10		
	I.26. Revenues	15		

The indicators illustrate the ability of landscape to return on investment while at the same time safeguarding its resources. This dimension helps with investing in the landscape and balancing economic activities. It emphasizes responsible resource management to ensure continued economic opportunities without landscape degradation.

3.3. Sustainable Landscape Social Indicators SLSI

The socio-territorial dimension consists of three components (living environment, esthetic value, and dynamism) and 12 landscape indicators (Table 9). This dimension refers to economic practices and principles in accordance with the landscape. It examines competencies and autonomy.

Table 9. Landscape indicators of the landscape sustainability social dimension.

3 Components	12 Indicators	Maxima Value		Total Score
Living environment	I.27. Well-being	12	33 units	100
	I.28. Landscape policies	7		
	I.29. Societal participation	6		
	I.30. Local job creation	4		
Esthetic value	I.31. Local reference	5	33 units	
	I.32. Cultural and historical reference	5		
	I.33. National reference	11		
	I.34. Patrimonial reference	9		
Dynamism	I.35. Event hosting	7	34 units	
	I.36. Societal/population evolution	7		
	I.37. Societal typology/diversity	6		
	I.38. Parties involved diversity	3		

3.4. Sustainable Landscape Visual Indicators SLVI

The visual or perceptual dimension consists of three components (diversity, features, and components) and 13 indicators (Table 10). This dimension refers to landscape principles. It examines the qualifications of the landscape along with the interventions on the landscape and opportunities for advancement.

Table 10. Landscape indicators of the landscape sustainability visual (perceptual) dimension.

3 Components	13 Indicators	Maxima Value		Total Score
Perceptual Diversity	I.39. Landscape character	7	33 units	100
	I.40. Landscape quality	13		
	I.41. Landscape coherence	13		
	I.42. Landscape cover	13		
Perceptual features	I.43. Composition	10	33 units	
	I.44. Configuration	6		
	I.45. Appreciated/depreciated	10		
	I.46. Fragmentation	6		
Perceptual components	I.47. Anthropogenic intervention	12	34 units	
	I.48. Landscape elements	10		
	I.49. Landscape integration	10		
	I.50. Recreational opportunities	10		
	I.51. Local identity	3		

The indicators illustrate the ability of a landscape to positively impact its surroundings. This dimension helps invent the landscape and create transformative action to re-evaluate or integrate a project within a landscape.

3.5. Implementing Sustainable Landscape Indicators at Tannourine Cedar Forest Nature Reserve

Pilot tests were recently conducted at the selected site to evaluate the LIs effectiveness, feasibility, and reliability. The selected landscape for this study is located in the north of

Lebanon, between the villages of Tannourine el-Tahta and Hadath el-Jebbeh. Tannourine Cedar Forest Nature Reserve (TCFNR) is a protected area in Lebanon, dedicated to the conservation and preservation of the Lebanese iconic cedar trees, the *Cedrus libani*.

Nestled within a picturesque landscape, the nature reserve stands as a testament to its unique biodiversity rich natural and cultural heritage. Inlaid with outstanding hiking trails, limestone caves, and local community engagement, it encourages the preservation of traditional practices and promotes sustainable tourism.

The landscape indicators were applied at the nature reserve to assess and evaluate the sustainability of the landscape. Scores and calculations are presented below through the graphical representations from Figures 3–10.

Firstly, to be able to identify which dimension would be the limiting factor, we went through the four dimensions of landscape sustainability illustrated in Figure 3. Comparing the four dimension values to maxima and within each other, we identified the landscape socio-territorial dimension as the limiting factor, having the lowest value (44/100). The landscape economic dimension is not very promising either (value = 48/100), since the value is lower than average. The ecological and perceptual dimensions of the landscape are satisfactory.

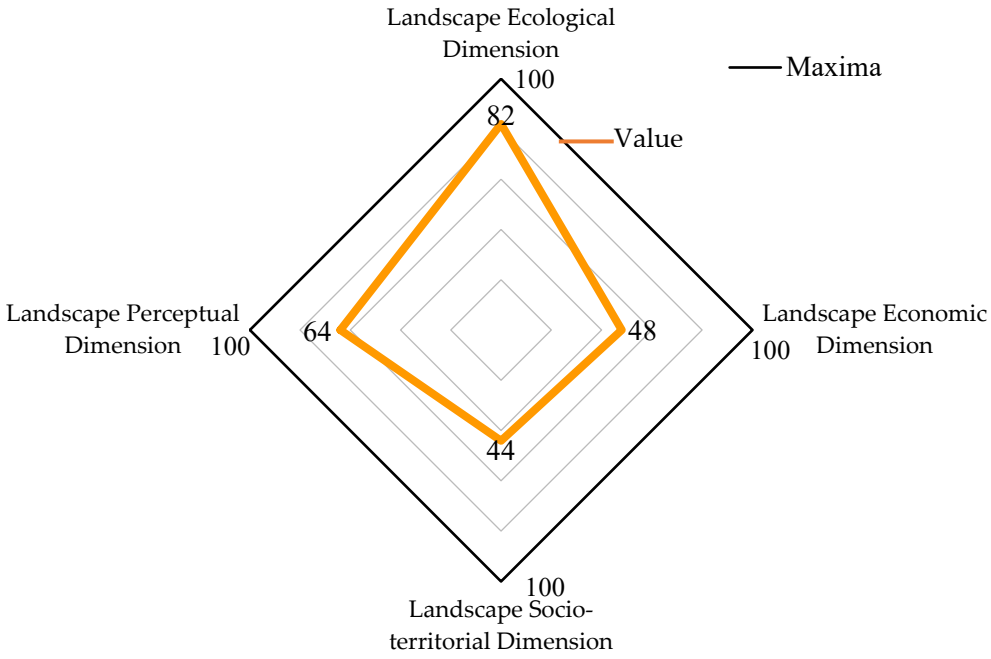

Figure 3. The four dimensions of LS and the limiting factor (socio-territorial dimension).

Secondly, in order to highlight the most sustainable components of the landscape and those whose sustainability would be desirable to improve, weaknesses and strengths of components are observed (Figure 4). In this case, a chart, of the radar type is ideal to observe the multivariate nature of landscape sustainability.

This radar, illustrated in Figure 4, helps compare each component to the other and its distribution towards the maxima. We can observe that the space organization, perceptual features, and ecological diversity show the highest grades since they are the closest to the maxima (highlighted in orange).

While viability, efficiency, and dynamism show the lowest scores, when zooming into the sustainable landscape indicators (SLIs), we can recognize the effective development for each component, and thus propose further actions.

In Figures 5 and 6, for example, are shown, respectively, the results of some indicators in the ecological and economical components. Even though they present better results than the socio-territorial dimension (the limiting factor), further understanding is possible.

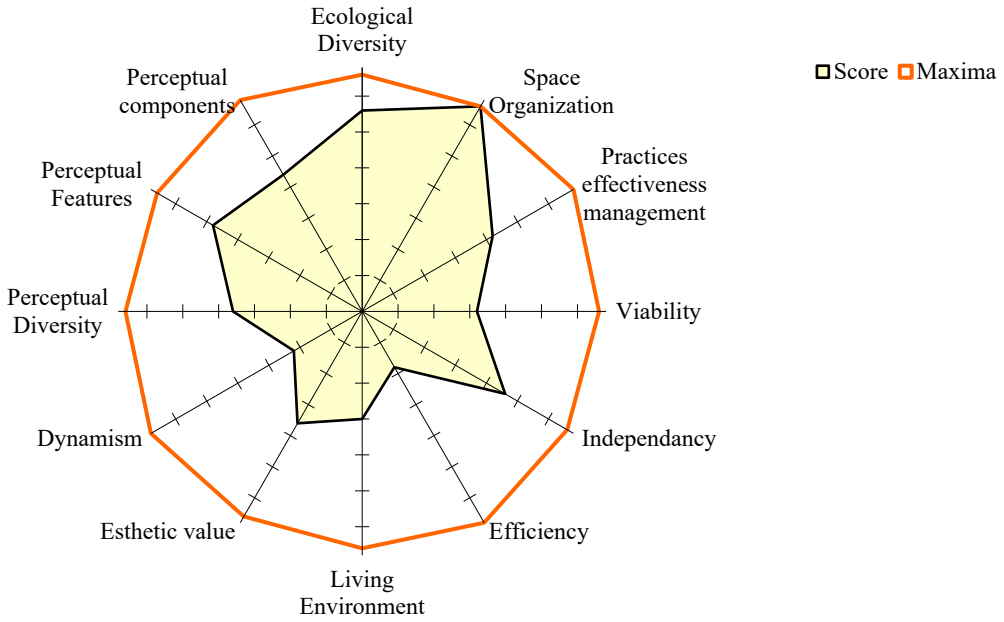

Figure 4. The twelve components of LS: weaknesses and strengths.

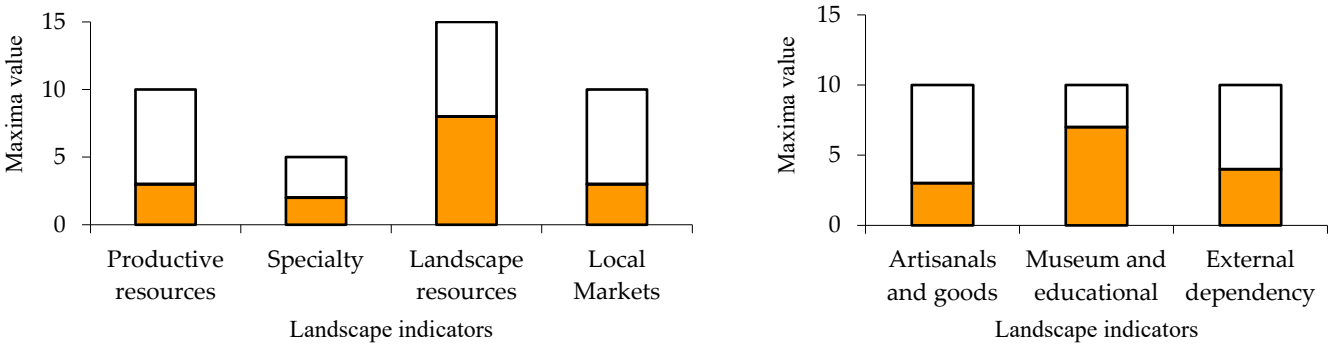

Figure 5. Zoom to Viability and Independence Economical Components.

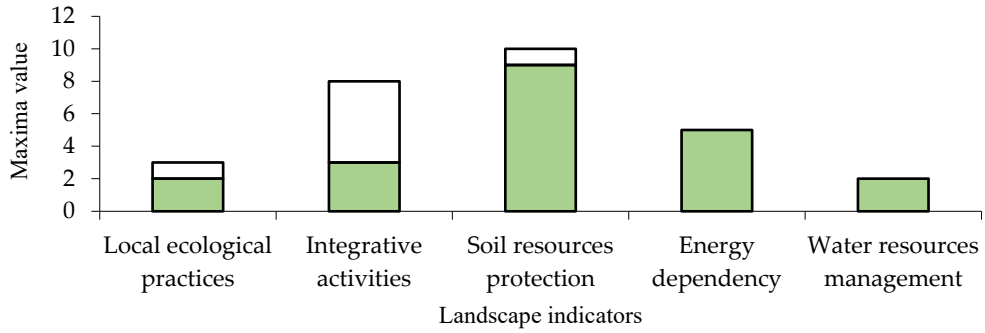

Figure 6. Zoom to Practices Effectiveness Management Ecological Component.

Figure 5 particularly shows viability & independency. When digging further, we can observe that landscape resources, museums, and educational institutions have higher values. What is already accomplished to this extent at the reserve must be preserved; however, more needs to be done here. Same for other indicators.

While in the case of practices effectiveness management illustrated in Figure 6, energy dependency and water resources have reached their maxima, better maintain their sustainability, and must work on integrative activities.

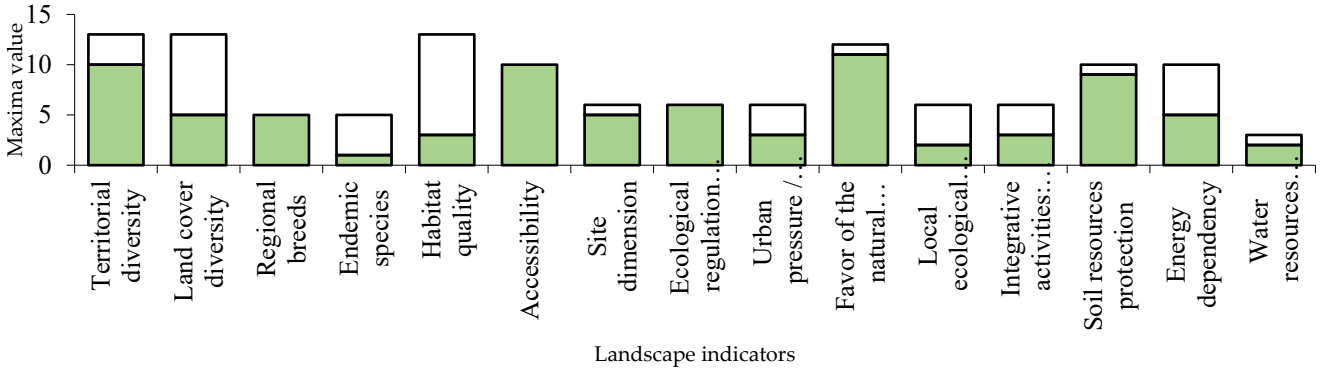

Figure 7. Landscape Ecological Dimension, Scores, and Maxima.

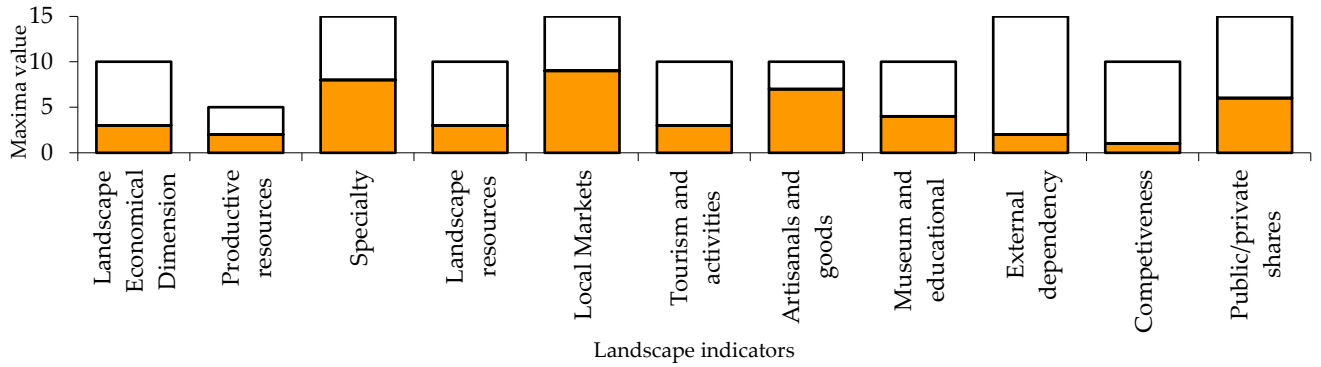

Figure 8. Landscape Economic Dimension, Scores, and Maxima.

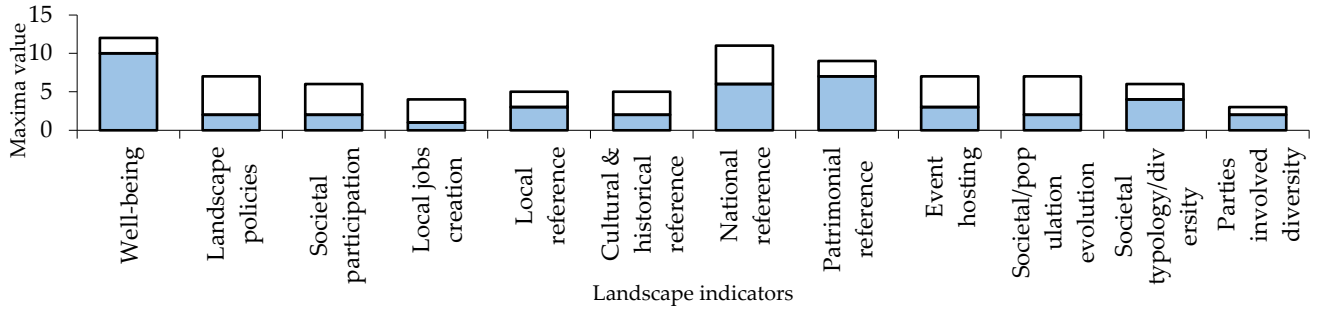

Figure 9. Landscape Socio-territorial Dimension, Scores, and Maxima.

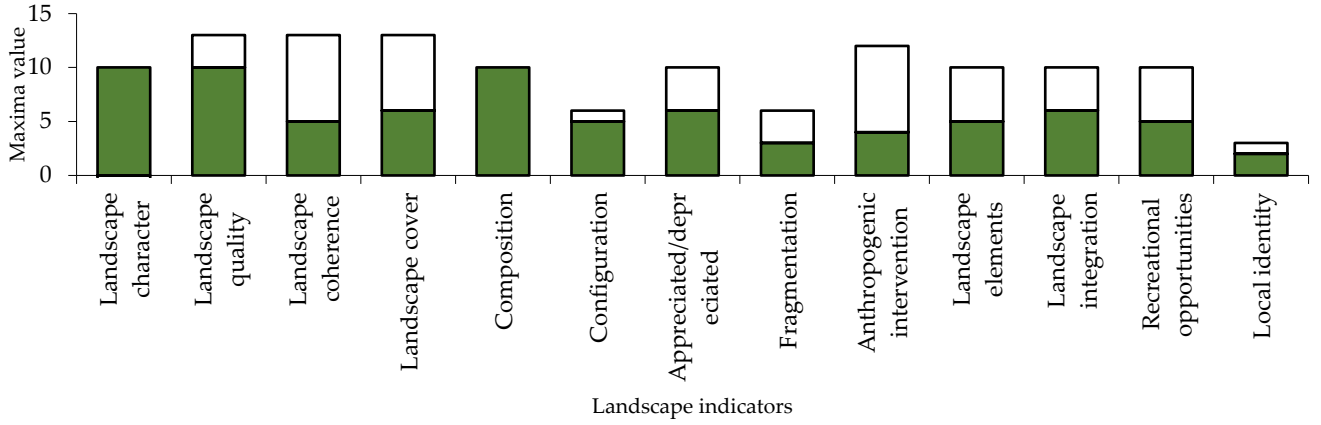

Figure 10. Landscape Perceptual Dimension, Scores, and Maxima.

Furthermore, a holistic overview of the SLIs of the overall landscape dimensions is seen in the histograms below (Figures 7–10). While ecological and perceptual dimensions reached interesting values, when zooming into LIs, we could see that many still needed improvements.

To mention here, for example: endemic species, habitat quality, local ecological practices, landscape coherence, landscape cover, anthropogenic intervention, etc.

Economic and socio-territorial indicators are less satisfying. Most of them need further attention.

4. Discussion

Following the identification, design, and categorization of the new set of landscape indicators, a new scheme of assessment is now defined [45]. Landscape indicators will thus replace ecological indicators, and landscape sustainability is becoming quantifiable. Through this research, we were able to create a new four-dimensional approach that takes into consideration the ecological, economical, socio-territorial, and perceptual facets of the landscape.

As implemented on TCFNR, landscape indicators newly identified were calculated and graphically represented. This will ease the understanding of the landscape system by first examining the general situation, and then elaborating on the strengths and weaknesses of the studied landscape to later be able to recommend conservation, elaborate management, propose correction, or, on the contrary, offer protection.

4.1. Assessment of the General Situation: The Four Dimensions

Two dimensions showed promising results. It is the landscape ecology dimension and the perceptual dimension that reached interesting values, with a respective score of 82/100 and 64/100. While both socio-territorial and economic dimensions showed values less than the average, the landscape socio-territorial dimension was found to be the least satisfying. Thus, the later dimensions must be improved. To do so, we need to first identify where his weaknesses stan, and then propose the action(s) to be adopted.

4.2. Zoom-in to Landscape Components

Now zooming-in on the four dimensions and focusing on the twelve landscape components identified and comparing them to the maxima, we can reinforce and accentuate the strong components and on the other hand, interfere with or correct the weak components. These strengths and weaknesses are identified on the charts generated from the calculation of LIs, either radar type or histogram type. In both cases, the more values are separated from the maxima, the less the component sustainability.

In the case studies here in this research, efficiency and dynamism showed lower values. At the same time, perceptual features and practice management showed good results, while space organization reached the highest value. To further elaborate, we need to recognize other relevance, most particularly concentrate on LIs, in accordance with their components.

4.3. Zoom-in to Landscape Indicators

When going deeper towards the landscape indicators (second zoom-in), we can recognize the effective development for each. Knowing that we identified 51 landscape indicators, their implementation at TCFNR showed variability in results, where some LIs were satisfying and explained good management and practices of the landscape, while others showed the exact opposite.

For example, the LESD showed the best values, mostly due to the promising ecological diversity and space organization. However, when zooming in on LIs, we mostly recognize mostly a lack of indicators related to endemic species, habitat quality, and urban pressure. Even though trespassing is limited, or visible (according to site observations and reserve management team), the reserve lacks nature-based solutions [24] and shows some degradation.

While indicators related to accessibility, ecological regulating zones and regional breeds were important. This being due to the site being submissive to the law, respect for limits and zoning at the site are well defined.

On the economic level, the external dependency and competitiveness indicators are particularly noticeable. Regardless of the important landscape resources available at TCFNR and the remarkable museum and educational activities, the reserve appeared sensitive to aid [12]. It is dependent mostly on external aid, despite the diverse activities held at the site and in the surroundings. So far, the reserve is not yet self-sufficient economically. Additional action must be taken for financial autonomy [46].

Also, if the TCFNR is considered a hub for landscape sustainability, this can encourage competitiveness in the region, create more jobs and opportunities, and thus enhance the landscape socio-territorial component. More activities can be proposed for TCFNR. For instance, creating connectivity with the cultural surroundings [8,47] can attract more visitors and build new exploration opportunities. In this case, landscape policies and societal participation require great attention. The reserve needs further purposes and contributions from local initiatives [8].

Last but not least, the results for the perceptual dimension were acceptable; however, further enhancements are possible. This is especially the case of the perceptual diversity component, where the landscape character is strong and the reserve is a habitat for the Lebanese iconic cedar trees, the *Cedrus libani*. However, landscape coherence and landscape cover require supplementary evaluation and stability [28,48]. It is also the case of the perceptual component, where anthropogenic interventions need further regulatory actions [31], recreational opportunities [28,48] to be emphasized, and regenerative.

5. Conclusions

The establishment of this new framework for assessing the sustainability of landscapes highlighted (i) a clear description of the landscape sustainability system, (ii) a normative framework to assess sustainable landscapes, and (iii) a proposal for evaluating the overall sustainability of the landscape.

The implementation of landscape indicators using the LSA method to assess the overall performance at Tannourine Cedar Forest Nature Reserve was promising. It showed good results, mostly concerning ecological and landscape management. Also, it actively presented the unique identity of the reserve. Though further societal integration and autonomous actions are needed to meet enhanced outcomes at social and economic scales [44].

However, it is vital to additionally test, apply, and validate the tool on first other reserves and then on different types of landscapes, locally and then internationally. This can, on the one hand, help assess its reliability and adaptability to various typologies of landscapes (nationally and internationally). On the other hand, validation can ensure that the tool produces consistent and meaningful results across different contexts [28,44,46].

Few to no prerequisite studies were made on this particular part of the landscape, since, as mentioned previously, most existing tools were qualitative and ecological indicators-based.

We proposed in this study, for the first time, a quantitative approach to landscape indicators by either transforming the predecessors that can be adaptable to landscape sustainability or by integrating new inventive landscape indicators that consider the local landscape law in addition to international landscape measures.

However, it wasn't really easy to settle on maxima and calculation modes. They became feasible and tangible with the many interviews, field visits, observations, and validations. Our prospect is to make these landscape indicators accessible to all users and integrate a participatory approach to reach our aspiration.

Most importantly, landscape indicators inventively defined (i) an indicative baseline and maxima and (ii) a new dimension, the perceptual dimension, added to the conventional sustainability approach—that is, environmental, socio-territorial, and economical—creating a wider comprehension of the landscape and its interaction with the society within.

Furthermore, the landscape indicators will support landscape consultancies, management, and/or education to respond to their increasing interest in landscape-related concepts and answer the need to adopt them in territorial and management policies.

Yet, this is only the beginning, the main objective of this study was to lay the froundwork for the Landscape Sustainability Assessment. Even though some training might be needed for implementing this method, it can accept a large flow of data, and evolve until a holistic approach is reached.

Last but not least, further studies must be conducted to test LIs at different sites, achieve necessary adjustments and refinements to reach the holistic tool, and meet our aspirations in supporting landscape consultancies and/or educational institutes.

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