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ELEMENTARY OR COMPLEX? EVALUATING LANDSCAPE SERVICES ACROSS TWO SPATIAL SCALES IN STRUNJAN LANDSCAPE PARK

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ABSTRACT

This study assesses landscape services (LSs) in Strunjan Landscape Park, Slovenia, comparing the applicability of elementary (landscape features and land cover) versus complex (landscape patterns) spatial units for evaluation. The assessment of two types of service-providing units (SPUs) is performed through a two-tiered process combining qualitative and descriptive evaluation with quantitative/numerical LS evaluation. Whereas elementary SPUs provide a straightforward basis for evaluation, their contributions often depend on spatial context. A descriptive and numerical assessment of 28 elementary SPUs reveals that heterogeneous units, such as extensive orchards, gardens, forests and olive groves, provide the broadest range of services. By contrast, small or homogeneous units contribute less. Complex SPUs, represented by eight landscape patterns, capture the complex character of the landscape and provide more comprehensive LSs. Patterns such as mosaics of agricultural land, forested slopes and coastal lagoons deliver provisioning, regulating and cultural services across all categories. The evaluation confirms that landscape patterns better represent LS provision than features and land cover do, as they integrate structure, function and perception. The study concludes that complex SPUs are more suitable for LS mapping and planning because they better encompass the complexity of landscape character (LC) while allowing a certain level of standardisation.

Keywords: Landscape services, landscape features, landscape patterns, landscape character, evaluation

INTRODUCTION

Problem definition and literature review

The increasing recognition of the role that landscapes play in supporting both ecological processes and human well-being has led to the development of frameworks that go beyond the ecological scope of ecosystem services (ESs). One such framework is the concept of

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landscape services (LSs), which explicitly integrates ecological functions, landscape structure and human perception in assessing the benefits that people obtain from landscapes (Vallés-Planells *et al*., 2014). Unlike the concept of ESs, which primarily focuses on the functional outputs of natural systems (Grunewald & Bastian, 2015; Haines-Young & Potschin, 2010), LSs offer a holistic perspective that also considers how spatial configuration, visual perception and sociocultural values shape the provision and experience of these services (Bastian *et al*., 2014; Termorshuizen & Opdam, 2009; Wang *et al*., 2025).

Vallés-Planells *et al*. (2014) defined LSs as the contributions of the landscape and its elements to human well-being, explicitly recognising the spatial structure of the landscape and its perception by people. This definition adds a crucial dimension to ESs; it incorporates landscape character (LC), spatial relationships and visual identity, all of which are vital for how services are produced, spatially distributed and experienced.

Several studies have emphasised the interdependence of LC and LSs and the importance of the physical and social dimensions of LC in providing LSs (Bastian *et al*., 2014; Hermann *et al*., 2014; Vallés-Planells *et al*., 2014; Wang *et al*., 2025). LSs are dependent not merely on landscapes' physical characteristics but also on the way these characteristics are combined and perceived.

LS classification has emerged mainly from ES classification. Vallés-Planells *et al*. (2014) proposed a three-tier typology—provisioning, regulating and cultural LSs—aligned with traditional ES categories (Haines-Young & Potschin, 2010; Haines-Young & Potschin-Young, 2018) but focused on the landscape scale (Table 1). Most LS categories are aligned with ESs, with two landscape-specific additions (support for daily activities and regulation of spatial structure) and a slightly different classification of cultural services.

Table 1: LS classification. LSs in bold were introduced by Vallés-Planells *et al*. (2014) as an addition to or substitution for the ESs proposed by Haines-Young & Potschin (2010).

Services' group	**Landscape services** (Vallés-Planells *et al*., 2014)
Provisioning	Nutrition, material, energy, **support for daily activities**
Regulation and maintenance	Regulation of wastes, flow, the physical environment, the biotic environment and **spatial structure**
Cultural and social	**Health, enjoyment, personal fulfilment, social fulfilment**

The diverse character of LSs calls for various approaches to their mapping. Whereas some LSs can be derived directly from land cover categories (e.g. provisioning and biomass), others are more complex and emerge from LC (e.g. cultural and aesthetic value; Gulickx *et al*., 2013), as well as from people's perceptions of that character (Plieninger *et al*., 2015). In addition, the differentiation between ESs and LSs is not always clear, since some services arise from ecosystems, others from individual landscape features and/or land use categories and from LC (Bastian *et al*., 2014).

Mapping the value of LSs is a significant methodological challenge. Whereas ESs can often be linked to biophysical indicators (e.g. forest cover and carbon storage), LSs require more nuanced spatial proxies, especially for aesthetic, identity-based or symbolic values. Common approaches include (1) participatory geographic information systems (GIS) and public participation GIS (Fagerholm *et al*., 2019; Ridding *et al*., 2018; Schmidt *et al*., 2019); (2) visual preference surveys and LC analysis (Tveit *et al*., 2006; Wang *et al*., 2025); and (3)

expert-based landscape assessments (Golobič *et al*., 2024; Kostanjšek & Golobič, 2023; van Berkel & Verburg, 2014).

A key challenge in LS mapping is linking LSs to the actual physical entities that provide them. Unlike provisioning services tied to biomass or yield, many LSs, especially cultural ones, depend on the integrity and coherence of the landscape as a whole. This makes them less location bound and more sensitive to contextual qualities, such as diversity, historic continuity and visual accessibility (Schaich *et al*., 2010; Swanwick, 2003). Many researchers emphasise the importance of addressing LSs at different spatial scales. As shown in Table 2, LS mapping is related to elementary spatial entities: (1) land cover or (2) landscape features; (3) more complex landscape characteristics, such as landform; or (4) the overall character of landscapes—embraced in landscape units, types or patterns. LSs are assessed using (1) various indicators, (2) public opinion or (3) expert assessments.

Table 2: Overview of LS research, spatial entities used for LS mapping and methods for service assessment.

	Spatial entities for LS mapping				Methods for LS assessment		
Study	**Land cover**	**Landscape features**	**Spatial characteristics**	**Land. char. units, types or patterns**	**Spatial/ecosystem indicators**	**Public opinion**	**Expert judgement**
Perennes *et al*. (2020)	x				x		x
Gulickx *et al*. (2013)	x		x		x		
Hermann *et al*. (2014)		x		x	x		
Wang *et al.* (2025)				x	x		x
Bastian *et al.* (2014)		x	x	x		x	
Nowak & Grunewald (2018)	x		x	x	x		x
Schmidt *et al*. (2019)	x	x	x			x	x
Agar *et al.* (2016)	x			x	x		x

Hypothesis and objectives

This study hypothesises that different types of landscape services (LSs) are generated by service-providing units (SPUs) that differ in their level of complexity. Some services come from categories of land cover or landscape features, whereas a more complex spatial context is important for the provision of others.

The aim of the study is to compare the applicability of two levels of SPUs for LS evaluation by:

- assessing LSs in relation to elementary SPUs, which include the basic entities in the landscape, such as categories of land cover and landscape features; and
- assessing LSs in relation to complex SPUs, which are landscape patterns representing the interplay of landscape characteristics, such as relief, land cover, climate characteristics and landscape features.

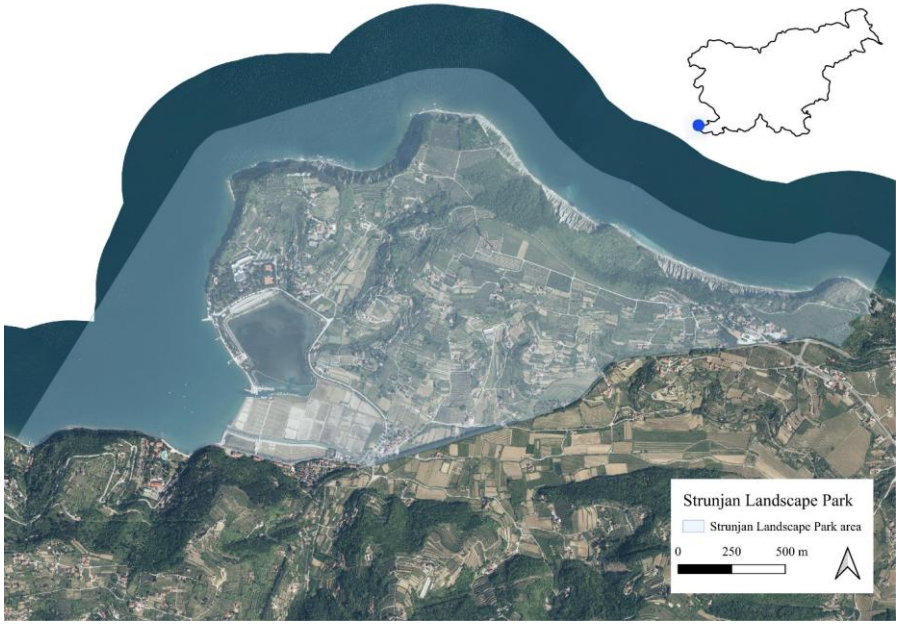
METHODOLOGY

To evaluate LSs, we first selected the study area and highlighted the key characteristics of Strunjan Landscape Park. Next, we identified the LSs to be evaluated and defined two levels of LS mapping—elementary SPUs (landscape features and land cover categories) and complex SPUs (landscape patterns)—which were assessed according to the degree of service provision. This was followed by desktop mapping of elementary and complex SPUs, subsequently verified in the field. All identified SPUs were then qualitatively and quantitatively evaluated in terms of LS provision.

Case study area

The study area is Strunjan Landscape Park (Krajinski park Strunjan) in southwest Slovenia. The focus of the study is on terrestrial part of Park, the salt pans and lagoon, covering approximately 160 hectares. The remaining part of the park, which together encompasses around 429 hectares, also includes a marine section, meaning that the park comprises both terrestrial and marine ecosystems. Strunjan Landscape Park is best known for the Strunjan Cliff (Strunjanski klif) and the Strunjan Salt pans (Strunjanske soline). The 80-meter-high flysch cliff rising above the sea is located in the northernmost part of the park and is protected as a natural monument. The steep cliff face gradually disintegrates and erodes due to sea and wind abrasion. Below the cliff lies the semicircular Moon Bay (Mesečev zaliv), shaped by natural erosion processes. The southern part of the park is the Strunjan Salt pans, one of the oldest preserved salt pans in the world, which serves today as an important cultural monument. Adjacent to the salt pans is Stjuža, the only Slovenian coastal lagoon, serving as an important habitat for birds and other animal species. The central part of the park is characterised by a mosaic cultural landscape with permanent crops and a coastal tourist area. The study area is shown in Fig. 1.

Fig. 1: Strunjan Landscape Park (Krajinski park Strunjan).



Landscape services

The list of LSs, which were mapped and evaluated in Strunjan Landscape Park, was adopted from Vallés-Planells *et al*. (2014) and Haines-Young & Potschin-Young (2018). For the purpose of this study, the LS included in the research were adapted to the character of the area studied with SPU types as units, so the LS inventory was adapted to be more comprehensively represented across all categories. Material provisioning services were assessed therefore at an aggregated level. The category "Material resources" combines biotic and abiotic material resources, following the higher-level "Material" class of Vallés-Planells *et al*. (2014). Although Haines-Young & Potschin-Young (2018) distinguish genetic material and mineral substances at lower hierarchical levels, they were aggregated here because the study focuses on comparing SPU types rather than on a fine-grained classification of provisioning services. The list of LS is presented in Table 3.

Table 3: Landscape services assessed in Strunjan Landscape Park.

Services' group	LSs mapped and evaluated in Strunjan	LSs' detailed interpretations
provisioning	Biomass/nutrition	Cultivation of wild plants and animals for food, materials or energy
	Water	Provision of surface and groundwater, including potable water and other outputs from aquatic ecosystems
	Material resources	Provision of biotic and abiotic material resources, including genetic resources from living organisms and mineral raw materials
	Support for daily activities	Provision of a high-quality and functional environment that supports everyday activities, including living, working, mobility, and access to services.
Regulation and maintenance	Regulation of wastes	Decomposition of waste and other harmful substances of human origin
	Regulation of the physical environment	Regulation of soil, water, material flows and extreme events, including maintenance of abiotic conditions
	Regulation of the biotic environment	Contribution to pollination, habitat protection, pests and disease control
	Regulation of spatial structure	Spatial connectivity and complexity (i.e. diversity and richness) and the presence of buffer zones
Cultural and social	Physical and mental health	Provision of space for recreation, sport and quiet retreat from daily routine
	Enjoyment	Visual attractiveness of the space and provision of space for active or passive relaxation
	Personal fulfilment	Provision of orientation, inspiration and scientific, educational, religious and spiritual significance
	Social fulfilment	Provision of identity and a sense of continuity through natural and cultural heritage, as well as communal spaces beyond home and workplace for socializing and working together

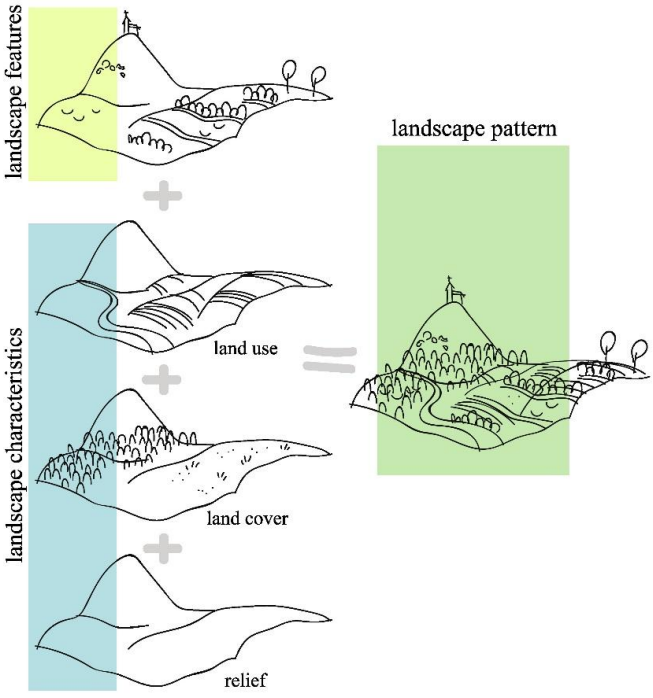
Elementary and complex landscape elements

Landscape is a complex system and a continuum. Therefore, when studying it, we must always define the scale of investigation by selecting a basic unit to which we attach information. A literature review (Table 2) shows that the mapping of LSs is linked to various spatial units. In the present study, we evaluated LSs using two spatial units: elementary units, which include landscape features and land cover categories, and complex units, which include landscape patterns.

Landscape features are defined as individual landscape components, such as drywalls, trees and drainage ditches (Golobič *et al*., 2024). In contrast to land cover categories, which represent broader, continuous surface types (e.g. forests and orchards), landscape features typically appear as point features, linear features or small-area features (e.g. a forest patch within an agricultural landscape). By mapping both land cover categories and landscape features, covering the entire area may be possible.

Landscape patterns are combinations of landscape characteristics, such as relief, land cover and landscape features. They can appear multiple times within a landscape (Golobič *et al*., 2024). Unlike the individual components that make up a pattern (e.g. land use, features and characteristics), patterns are complex spatial units because both their structures and their functions depend on which elements they consist of and how these components are distributed. An individual landscape pattern is distinguished from others by the specific combination and distribution of landscape characteristics and features. Therefore, considering the context of occurrence is an essential component of a landscape pattern. It is inseparably linked to the evaluation of LSs when using landscape patterns as the basis for assessment. Landscape features, characteristics and patterns are shown in Fig. 2.

Fig. 2: Relationship among landscape features, characteristics and patterns.



The mapping of LS value is based on the method developed in two previous studies (Kostanjšek, 2024; Penko Seidl *et al*., 2024). A GIS inventory of elementary and complex SPUs was first conducted throughout the study area using ArcGIS Pro software and later verified in the field. Several data layers were used for mapping (Table 4). Whereas each land use category and landscape feature was in most cases mapped based on one data layer (e.g. land use map or digital ortho-photo), landscape patterns were mapped using the combination of several data. Considering the layers that compose landscape character (Fig. 2), landscape patterns were delineated manually, considering terrain characteristics – e. g. slope, elevation (lidar), combined with land cover and land use (digital ortho-photo and land use map). Later on, the boundaries were verified in the field. Maps of identified landscape features, land cover categories and landscape patterns are presented in Appendices A, B and C.

Table 4: Spatial data, used for mapping of SPUs.

SPUs	Data used for mapping
Land use categories	land use map, habitats map
Landscape features	land use map, lidar, digital ortho-photo, nature protection regimes, water elements, drywalls inventory
Landscape patterns	lidar, digital ortho-photo, land use map

Evaluation of landscape services

The evaluation of LSs involved two key steps, with each step performed on both SPU levels (elementary and complex). First, a qualitative assessment of each SPU's contribution to an LS was performed. Second, the degree to which the SPU provides a certain LS was assessed. All SPUs were rated across three LS categories—regulating, provisioning and cultural (Vallés-Planells *et al*., 2014)—using a three-point ordinal scale (0-2). The scale numbers indicate: 0 indicates no or negligible contribution; 1 indicates a partial or indirect contribution; and 2 indicates that providing the service is a primary function of the SPU or that the SPU has an inherently high capacity to provide it. The ordinal scores provide a semi-quantitative approximation of relative LS provision and should not be interpreted as cardinal measurements. Numerical evaluation is the approximation of an SPU's contribution to a given LS, whereas descriptive evaluation is a contextual complement designed to understand the spatial context of a particular SPU. Descriptive evaluation also provides a thematic link and a starting point for management of the protected area.

RESULTS

Evaluation of elementary units' contributions to landscape services

Twenty-eight categories of elementary SPUs were identified within the study area, of which 13 can be classified as land cover categories, whereas 15 correspond to the definition of landscape features.

The descriptive evaluation of LSs allows us to systematically assess with expert judgment the contribution of each spatial unit to a particular LS. Based on the descriptive evaluation of elementary units, we can distinguish between units classified as land cover categories and landscape features in terms of their contributions to LSs. In most cases, land cover units are easier to evaluate in isolation. For example, the primary role of an intensive orchard is the production of biomass/food, which is directly tied to the orchard area itself and is largely

independent of the broader context. By contrast, the function of landscape features generally depends on the spatial context in which they occur. For instance, terraces supported by drywalls inherently regulate physical conditions (soil stabilisation), but when combined with the land cover on terraces (e.g. vineyards, olive groves), their role in providing services expands. They become important for regulating spatial structure, providing personal and social fulfilment and supporting recreational or aesthetic enjoyment. Similarly, tree lines always function as connecting elements in the landscape and contribute to regulating spatial structure; their other roles (e.g. regulating physical conditions and providing genetic material) depend on their composition (tree age, species, spacing and understorey) and location (cultural landscape, along roads and within settlements). Examples of descriptive evaluations for the selected categories are presented in Table 5.

Table 5: Descriptive/qualitative evaluations of the selected elementary SPUs.

Elementary SPUs	Value for landscape services
Olive groves	Olive groves, especially on slopes or in combination with terraces, stabilise the soil and retain water in the ground. They are sources of food and support the local economy while serving as a carbon sink. Additionally, they contribute to cultural ecosystem services, particularly by shaping the identity of coastal landscapes (LC, visual attractiveness and tourist amenity), preserving traditional olive cultivation practices and forming part of protected cultural landscapes.
Tree alleys	Tree-lined avenues contribute to improved air quality by absorbing CO_2 and pollutants. They reduce the urban heat island effect and provide shade, which lowers the need for cooling, especially when tree canopies are interconnected. Avenues also improve soil quality and help prevent erosion, particularly when located on slopes. In addition to their environmental functions, tree-lined avenues have aesthetic and cultural value. They are prominent landscape features and are often protected by regulations (e.g. avenues of stone pines). They help connect green spaces, create a pleasant living environment, support daily activities and recreation and thereby positively influence public health.
Salt pans	Salt pans provide naturally harvested salt, which also supports traditional production methods (a form of cultural services). They help regulate water quality, as salt pan ecosystems filter and remove pollutants. Culturally, they hold high value as part of the cultural heritage and tourism, providing opportunities for education and recreation and significantly contributing to the spatial structure. Salt pans help preserve traditional knowledge and are extremely important for LC and identity.

Numerical evaluation using a three-level scale further supports the descriptive findings by assessing the contribution of each SPU to each LS. SPUs that provide the greatest range of LSs include extensive orchards and gardens, olive groves, forests and forest patches, parks, the sea, salt fields and lagoons. These spatial units deliver services across all three categories and achieve the highest rating (score 2) for at least three services. Conversely, LSs receive the least contributions from intensive orchards, cultivated terraces, overgrown lands, individual trees, campsites, ponds, springs and wells, berths, artificial shorelines and chapels.

This group generally provides services from only one or two categories, with lower contributions to individual services (score 1). From this list, it is evident that most are either small landscape features that do not play a significant role in the landscape on their own (e.g. springs, chapels and ponds) or land cover categories that are highly monofunctional (e.g. intensive orchards and campsites) or have very specific roles (e.g. food production or recreation). The results of the evaluation are presented in Table 6.

Table 6: Numerical evaluation of elementary SPUs' contributions to landscape services

Elementary SPU	Biomass/nutrition	Water	Material resources	Support for daily activities	Regulation of wastes	Regulation of the physical env.	Regulation of the biotic env.	Regulation of spatial structure	Physical and mental health	Enjoyment	Personal fulfilment	Social fulfilment
Ext. orchards and gardens	2		2	2	1	2	2	1	1	2	1	1
Intensive orchards	2			1	1	1	1					
Vineyards	2		1	1	1	1	1		1	1		2
Olive groves	2		1	1	1	2	1		1	1	1	2
Terraces				1		1	1	1				1
Built-up terraces						1	1	1		1	1	2
Forests and forest patches	2	1	2		2	2	2	1	2	1	1	
Overgrowing areas			1		1	1	1					
Solitaire trees						1		1		2	1	
Groups of trees and bushes			1		1	2	1	1		1		
Hedgerows			2		1	2	1	2				
Riparian vegetation		1	1		2	2	1	2				
Campsites				1			1		2			2
Tree alleys				1		1	1	2	1		1	1
Park			1	1	2	1	1	1	2	2	1	2
River		2			1	1		2	1	2	1	
Ponds		1			2	1	1				1	
Springs		2			1	1				1	1	
Wells		2									1	
Sea	1	2	1	1	2	1	2	1	2	2	2	2
Salt pans	1		2		2	1	2	1	1		2	2

Elementary SPU	**Biomass/nutrition**	**Water**	**Material resources**	**Support for daily activities**	**Regulation of wastes**	**Regulation of the physical env.**	**Regulation of the biotic env.**	**Regulation of spatial structure**	**Physical and mental health**	**Enjoyment**	**Personal fulfilment**	**Social fulfilment**
Lagoon	1	1	2		2	2	1	1	1		1	1
Rocky/pebble beach			1			1			2	1	1	1
Cliff			1			1		1	2	2	2	2
Berths				1					1			
Artificial coast									1		1	1
Canal		1	1	1	1	1		1	1			
Chapels									1	1	2	

2	*The primary purpose of the SPU is to provide the landscape service in question, or it has an inherently high capacity to provide that service.*
1	*The SPU partly provides the service in question, or the contribution towards the service provision is indirect.*
No value	*The SPU does not provide the service in question, or the contribution is negligible.*

Evaluation of complex units' contributions to landscape services

We identified eight complex SPUs, or landscape patterns, in the study area (Fig. 4). They can be grouped into four categories based on shared characteristics:

- The first group includes the patterns of (1) the sea and (2) the salt pans with the lagoon.
- The second group includes (3) the steep cliff coast and (4) the forested slopes above the cliffs.
- The third group consists of (5) the patterns of an urbanised coastline with tourist complexes.
- The fourth group comprises three patterns of traditional cultural landscapes: (6) agricultural landscapes on flat terrain, (7) coastal valleys with mosaic agricultural use and (8) mosaic landscapes with permanent crops in hilly areas.

A descriptive evaluation of landscape patterns enables assessment of the complex interplay of features and characteristics that, due to the combinations in which they appear, can significantly contribute to LSs (e.g. a mosaic of olive groves, vineyards and orchards on terraced slopes with hedgerows provides more diverse LSs than its individual components alone). Examples of the descriptive evaluations of selected patterns are presented in Table 7.

Table 7: Descriptive evaluation of selected complex SPUs.

Complex SPUs	Value for landscape services
Salt pans and lagoon	Salt pans with lagoons supply naturally produced salt, which also supports traditional farming methods (cultural services). They regulate water quality together with the surrounding vegetation and the lagoon by filtering and removing pollutants and regulating surface and groundwater levels. Canals are also important for regulation. Culturally, they have high value as part of the cultural heritage and tourism offerings, especially with their fortified shorelines, which provide educational and recreational opportunities and make an important contribution to the spatial fabric. Salt pans contribute to the preservation of traditional knowledge and are an important component of landscape identity.
Forest above the cliff	The forested slopes above the cliff provide biomass and genetic material. They regulate the climate by absorbing CO_2, improving air and water quality, preventing soil erosion and retaining soil moisture. Culturally, they contribute to recreation, mental health and the aesthetic value of the landscape. Forest patches are also an important source of inspiration and connection with nature, supporting activities, especially recreation, and consequently contributing to health, personal fulfilment and satisfaction. Groups of trees and shrubs are particularly important in terms of regulating processes and spatial structure.
Mosaic agricultural hilly landscape	The landscape pattern provides a wide range of provisioning services due to the presence of permanent plantations and extensive orchards and gardens, except for water, which is absent. The diversity of uses also indirectly provides a wider range of regulating services and ensures a varied landscape structure. The presence of terraces (with or without drywalls) adds to the structural articulation of the landscape and reinforces the cultural importance of permanent crops, particularly in terms of social fulfilment. Forest patches, trees and shrubs add structure and help regulate processes in the landscape.

The results of the numerical evaluation also show that all patterns, except for (5) the urbanised coastline and (6) the agricultural landscape on flat terrain, make a significant contribution to the provision of LSs. The reason for this is their mosaic structure and the abundance and complex interconnection of various spatial forms. This combination provides more LSs compared to individual elements. All identified landscape patterns provide at least one service from each group. The evaluation is presented in Table 8.

Table 8: Numerical evaluation of complex SPUs' contributions to landscape services.

Complex SPUs	Biomass/nutrition	Water	Material resources	Support for daily activities	Regulation of wastes	Regulation of the physical env.	Regulation of the biotic env.	Regulation of spatial structure	Physical and mental health	Enjoyment	Personal fulfilment	Social fulfilment
Sea	2	2	1	1	2	1	2	1	2	2	2	2
Salt pans and lagoon	1	1	2	1	2	2	1	1	1	1	2	2
Steep coast with cliff		1	1			1		2	2	2	2	2
Forest above the cliff	1	1	2		2	2	2	1	2	2	1	
Urbanised coast with tourist facilities				2		1		1	2	2	1	2
Agricultural landscape on plateau	2		1	1	1	2	1		1	1		1
Coastal valleys with mosaic cultural landscape	2	2	1	1	2	1	2	2	1	1	1	2
Mosaic agricultural hilly landscape	2	1	1	2	1	2	2	2	1	1	2	2

2	*The primary purpose of the SPU is to provide the landscape service in question, or it has an inherently high capacity to provide that service.*
1	*The SPU partly provides the service in question, or the contribution towards the service provision is indirect.*
No value	*The SPU does not provide the service in question, or the contribution is negligible.*

DISCUSSION AND CONCLUSION

The SPUs used for LS assessment are critical for capturing LSs' spatial dynamics. Most commonly, land cover or land use categories have been used as basic mapping units. These include elements such as vegetation patches, water bodies, roads, buildings and meadows (Syrbe & Walz, 2012). Despite the fact that land cover categories provide straightforward and mappable units, they often fail to capture the relational and perceptual qualities of landscapes that enhance the provision of LSs. For example, a forest patch offers more recreational value if it is visually or physically connected to other landscape elements (Tveit *et al.*, 2006). Similarly, a vineyard holds greater identity value when embedded within

a traditional small-scale land mosaic, rather than being a part of intensive monocultures. In general, the contribution of landscape features to LSs depends on their spatial contexts.

This phenomenon has led to the growing recognition of landscape patterns as more suitable spatial units for landscape analysis. Patterns reflect not just what is present in the landscape but also how these elements are combined, related and perceived. This aligns directly with the LS framework in which perception and configuration matter as much as composition (Fagerholm *et al*., 2019; Vallés-Planells *et al*., 2014).

Using elementary SPUs, especially landscape features, as the basis for LS assessments has several drawbacks. First, features are often too small or fragmented to represent meaningful service units. This is especially true for regulating services that require larger areas for their provision, or for cultural services that depend on the scenic or symbolic coherence of an area (Albert *et al*., 2016).

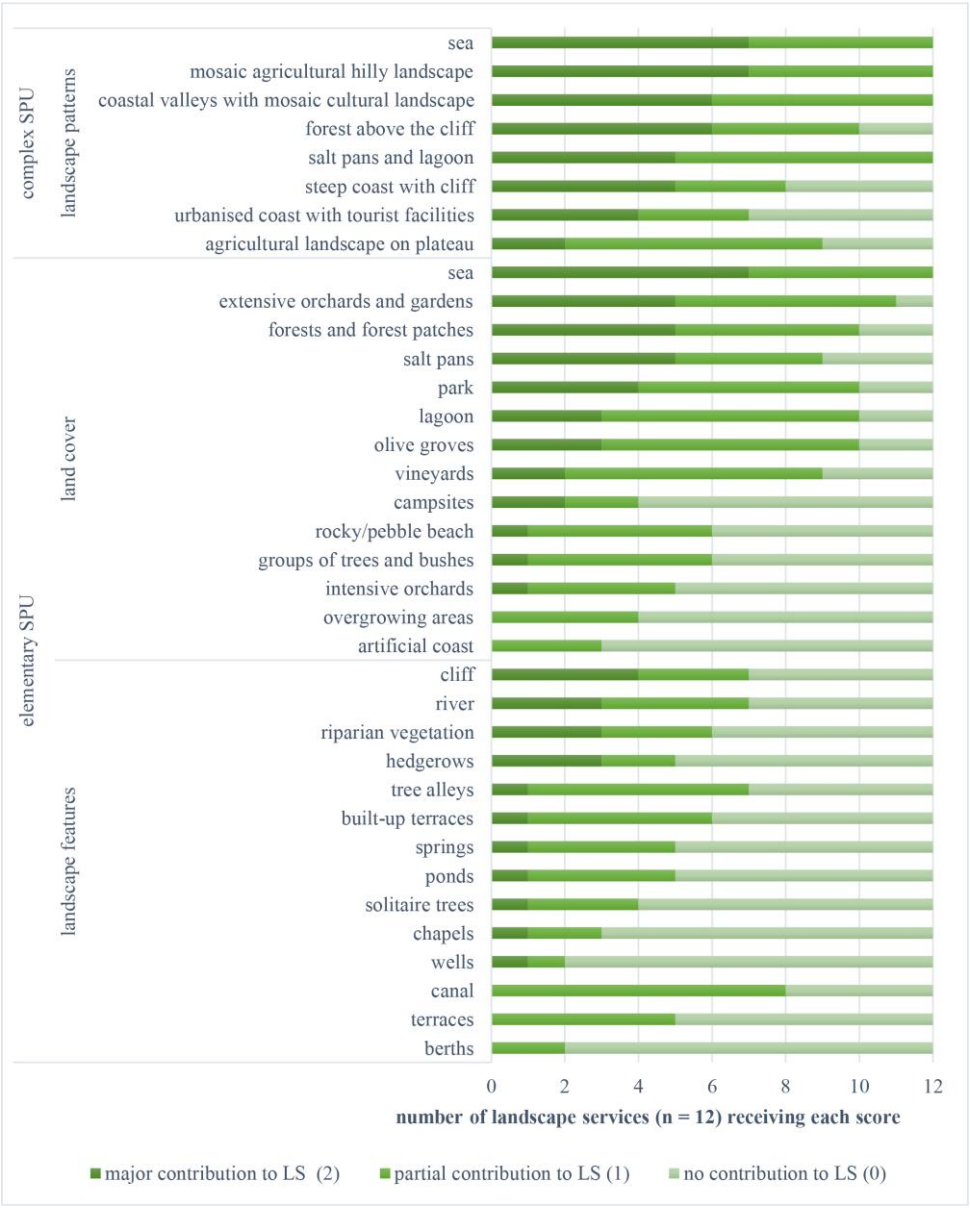
Second, many LS are highly context dependent. The same feature (e.g. a hedgerow or a vineyard) may support different levels of services depending on its surroundings, accessibility or landscape integration. This is particularly true for aesthetic and recreational services, in which scale, composition and contrast play a crucial role (Swanwick, 2003; Tveit *et al*., 2006). A vineyard within a traditional terraced landscape might offer strong identity and scenic value, whereas one embedded in a large-scale monoculture may not.

Both descriptive and numerical evaluations of elementary SPUs' contributions to LSs have shown that the inner homogeneity or small size of a unit and the degree of human influence are the main factors affecting an individual unit's contributions to LSs. As shown in Fig. 3, the lowest contributions to LSs come from landscape features that are small in scale or of anthropogenic origin (e.g. berths, terraces and canals), as well as from land cover categories that are internally homogeneous (e.g. artificial coast, overgrowing areas and intensive orchards). By contrast, the greatest contributions come from elementary SPUs that are internally heterogeneous (e.g. extensive orchards and gardens) and from complex SPUs under extensive use (e.g. coastal valleys with mosaic cultural landscape) or naturally preserved complex SPUs (e.g. forests abovethe cliff).

We must also be aware of the limitations of the presented evaluation method. Despite the use of available data (e.g. data on habitat types or the conservation importance of specific areas) and fieldwork, expert assessment is somehow subjective. On the other hand, particularly in the evaluation of cultural services, it is important to verify the needs and satisfaction of users with individual LSs.

Nevertheless, we believe that there are sufficient arguments to link the evaluation of LSs to complex SPUs or landscape patterns. The spatial occurrence of these patterns corresponds to the definition of landscape as stated in the Council of Europe Landscape Convention (2004): 'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors'. Therefore, it makes sense to evaluate LSs for individual landscape patterns. Landscape patterns integrate biophysical, visual and functional characteristics, which means that they better reflect the real conditions affecting the provision of LSs compared with isolated landscape elements. At the same time, these patterns represent the smallest typological units, as they appear in landscape repeatedly/across different locations and perform similar functions. Their repetitive nature enables comparison between units and facilitates the development of transferable evaluation criteria. This allows for a certain degree of standardisation and repeatability in the evaluation process. Such standardisation is essential for ensuring consistency, transparency and broader applicability of results in planning and management contexts.

Fig. 3: Numerical evaluation of the contributions of SPUs to LSs. For each SPU, the stacked bar shows how many of the 12 assessed landscape services received a score of 2 (major contribution), 1 (partial contribution) or 0 (no or negligible contribution).



The results of this research have confirmed the growing consensus in landscape planning and ecology that landscape patterns are a more appropriate unit for LS assessment. Patterns capture the complex interplay of structure, function and perception and are better suited for planning interventions aimed at enhancing or protecting service provision (Termorshuizen & Opdam, 2009; Walz *et al.*, 2019). Moreover, using patterns allows for the aggregation of

services across spatial scales, supporting integrative landscape governance that aligns with ecological networks, visual corridors and sociocultural zones (Bastian *et al.*, 2014).

In terms of recommendations for management of future landscapes, landscape patterns present much more suitable management unit compared to elementary units due to several reasons. First, their complex character embraces all individual components, as well as the relationships among them. Second, landscape patterns can be distinguished among each other based on (natural and cultural) characteristics, which call for tailor-made objectives and require different management approaches. Third, since landscape patterns represent a kind of basic typologic unit, the aforementioned tailor-made objectives and management approaches can be up to a point standardized and applied within areas with similar landscape patterns.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

REFERENCES

Agar, P.M. de, Ortega, M., & L. de Pablo, C. (2016). A procedure of landscape services assessment based on mosaics of patches and boundaries. *Journal of Environmental Management*, *180*, 214–227. https://doi.org/10.1016/j.jenvman.2016.05.020.

Albert, C., Galler, C., Hermes, J., Neuendorf, F., von Haaren, C., & Lovett, A. (2016). Applying ecosystem services indicators in landscape planning and management: The ES-in-Planning framework. *Ecological Indicators*, *61*, 100–113. https://doi.org/10.1016/j.ecolind.2015.03.029.

Bastian, O., Grunewald, K., Syrbe, R.-U., Walz, U., & Wende, W. (2014). Landscape services: The concept and its practical relevance. *Landscape Ecology*, *29*(9), 1463–1479. https://doi.org/10.1007/s10980-014-0064-5.

Council of Europe Landscape Convention (2004). *Council of Europe Landscape Convention*, Pub. L. No. ETS No. 176. https://www.coe.int/en/web/conventions/full-list.

Fagerholm, N., Torralba, M., Moreno, G., Girardello, M., Herzog, F., Aviron, S., Burgess, P., Crous-Duran, J., Ferreiro-Domínguez, N., Graves, A., Hartel, T., Măcicăsan, V., Kay, S., Pantera, A., Varga, A., & Plieninger, T. (2019). Cross-site analysis of perceived ecosystem service benefits in multifunctional landscapes. *Global Environmental Change*, *56*, 134–147. https://doi.org/10.1016/j.gloenvcha.2019.04.002.

Golobič, M., Penko Seidl, N., Bevk, T., Kostanjšek, B., Pipan, T., Ažman, T., Kržič, K., Hudoklin, J., Hočevar, I., Simič, S., Kokalj, Ž., & Gabrič, A. (2024). *Prenova regionalne razdelitve krajinskih tipov in izjemnih krajin v Sloveniji ter njihova digitalizacija* (p. 94) [Končno poročilo raziskovalne naloge]. Univerza v Ljubljani, Biotehniška fakulteta.

Grunewald, K., & Bastian, O. (Eds). (2015). *Ecosystem Services – Concept, Methods and Case Studies*. Springer. https://doi.org/10.1007/978-3-662-44143-5.

Gulickx, M.M.C., Verburg, P.H., Stoorvogel, J.J., Kok, K., & Veldkamp, A. (2013). Mapping landscape services: A case study in a multifunctional rural landscape in The Netherlands. *Ecological Indicators*, *24*, 273–283. https://doi.org/10.1016/j.ecolind.2012.07.005

Haines-Young, R., & Potschin, M. (2010). *Proposal for a common international classification of ecosystem goods and services (cices) for integrated environmental and economic accounting*. European Environment Agency.

Haines-Young, R., & Potschin-Young, M.B. (2018). Revision of the Common International Classification for Ecosystem Services (CICES V5.1): A Policy Brief. *One Ecosystem*, *3*, e27108. https://doi.org/10.3897/oneeco.3.e27108.

Hermann, A., Kuttner, M., Hainz-Renetzeder, C., Konkoly-Gyuró, É., Tirászi, Á., Brandenburg, C., Allex, B., Ziener, K., & Wrbka, T. (2014). Assessment framework for landscape services in European cultural landscapes: An Austrian Hungarian case study. *Ecological Indicators*, *37*, 229–240. https://doi.org/10.1016/j.ecolind.2013.01.019.

Kostanjšek, B. (2024). *Vrednotenje ekosistemskih storitev z vključevanjem krajinskih prvin in uporaba v prostorskem načrtovanju na primeru razvoja poslovnih con*.Thesis, Univerza v Ljubljani, Biotehniška fakulteta. https://repozitorij.uni-lj.si/IzpisGradiva.php?id=158807.

Kostanjšek, B., & Golobič, M. (2023). Cultural ecosystem services of landscape elements and their contribution to landscape identity: The case of Slovenia. *Ecological Indicators*, *157*, 111224. https://doi.org/10.1016/j.ecolind.2023.111224

Nowak, A., & Grunewald, K. (2018). Landscape sustainability in terms of landscape services in rural areas: Exemplified with a case study area in Poland. *Ecological Indicators*, *94*, 12–22. https://doi.org/10.1016/j.ecolind.2018.01.059

Penko Seidl, N., Kostanjšek, B., & Kržič, K. (2024). *Popis krajinskih prvin v KP Strunjan in vrednotenje njihovega pomena za biotsko raznovrstnost ter ekosistemske storitve* (p. 45). Univerza v Ljubljani, Biotehniška fakulteta.

Perennes, M., Campagne, C.S., Müller, F., Roche, P., & Burkhard, B. (2020). Refining the Tiered Approach for Mapping and Assessing Ecosystem Services at the Local Scale: A Case Study in a Rural Landscape in Northern Germany. *Land*, *9*(10), 348. https://doi.org/10.3390/land9100348.

Plieninger, T., Bieling, C., Fagerholm, N., Byg, A., Hartel, T., Hurley, P., López-Santiago, C.A., Nagabhatla, N., Oteros-Rozas, E., Raymond, C.M., Van Der Horst, D., & Huntsinger, L. (2015). The role of cultural ecosystem services in landscape management and planning. *Current Opinion in Environmental Sustainability*, *14*, 28–33. https://doi.org/10.1016/j.cosust.2015.02.006.

Ridding, L.E., Redhead, J.W., Oliver, T.H., Schmucki, R., McGinlay, J., Graves, A.R., Morris, J., Bradbury, R.B., King, H., & Bullock, J.M. (2018). The importance of landscape characteristics for the delivery of cultural ecosystem services. *Journal of Environmental Management*, *206*, 1145–1154. https://doi.org/10.1016/j.jenvman.2017.11.066.

Schaich, H., Bieling, C., & Plieninger, T. (2010). Linking Ecosystem Services with Cultural Landscape Research. *GAIA - Ecological Perspectives for Science and Society*, *19*(4), 269–277. https://doi.org/10.14512/gaia.19.4.9.

Schmidt, K., Martín-López, B., Phillips, P.M., Julius, E., Makan, N., & Walz, A. (2019). Key landscape features in the provision of ecosystem services: Insights for management. *Land Use Policy*, *82*, 353–366. https://doi.org/10.1016/j.landusepol.2018.12.022.

Swanwick, C. (2003). The Assessment of Countryside and Landscape Character in England: An Overview. In *Countryside Planning. New Approaches to Management and Conservation* (pp. 109–124). Routledge.

Syrbe, R.-U., & Walz, U. (2012). Spatial indicators for the assessment of ecosystem services: Providing, benefiting and connecting areas and landscape metrics. *Ecological Indicators*, *21*, 80–88. https://doi.org/10.1016/j.ecolind.2012.02.013.

Termorshuizen, J.W., & Opdam, P. (2009). Landscape services as a bridge between landscape ecology and sustainable development. *Landscape Ecology*, *24*(8), 1037–1052. https://doi.org/10.1007/s10980-008-9314-8.

Tveit, M., Ode, Å., & Fry, G. (2006). Key concepts in a framework for analysing visual landscape character. *Landscape Research*, *31*(3), 229–255. https://doi.org/10.1080/01426390600783269.

Vallés-Planells, M., Galiana, F., & Van Eetvelde, V. (2014). A Classification of Landscape Services to Support Local Landscape Planning. *Ecology and Society*, *19*(1). https://doi.org/10.5751/ES-06251-190144.

van Berkel, D.B., & Verburg, P.H. (2014). Spatial quantification and valuation of cultural ecosystem services in an agricultural landscape. *Ecological Indicators*, *37*, 163–174. https://doi.org/10.1016/j.ecolind.2012.06.025.

Walz, A., Schmidt, K., Ruiz-Frau, A., Nicholas, K., Bierry, A., De, A., Lentsch, V., Dyankov, A., Joyce, D., Liski, A., Marba, N., & Scholte, S. (2019). Sociocultural valuation of ecosystem services for operational ecosystem management: Mapping applications by decision contexts in Europe. *Regional Environmental Change*, *19*. https://doi.org/10.1007/s10113-019-01506-7.

Wang, Y., Yang ,Diechuan, Lu ,Yawen, & and Gao, C. (2025). A character-based conceptual framework to integrate landscape services into landscape planning. *Landscape Research*, *0*(0), 1–17. https://doi.org/10.1080/01426397.2025.2489973.

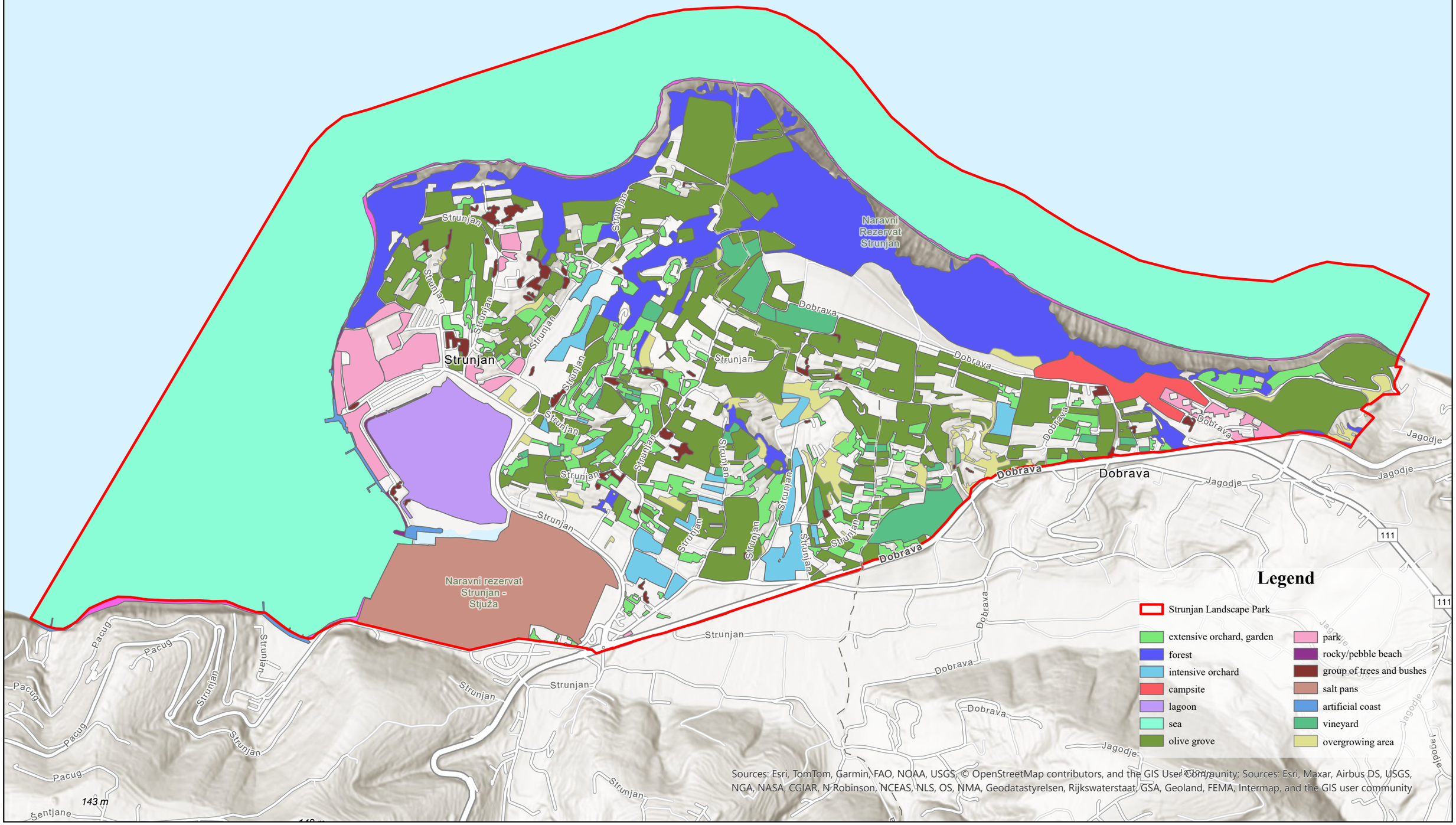
APENDIX

Appendix A: Land cover in Strunjan Landscape Park

Appendix B: Landscape features in Strunjan Landscape Park

Appendix C: Landscape patterns in Strunjan Landscape Park

Appendix A:
Land cover in Strunjan Landscape Park



Appendix B:
Landscape features in Strunjan Landscape Park



Appendix :
Landscape patterns in Strunjan Landscape Park



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