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Research Article

Challenges related to stakeholder involvement in the assessment of ecosystem services in protected areas in Slovenia

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Abstract

This study assesses the process of developing and testing a protocol that integrates a participatory approach for selecting, ranking and assessing ecosystem services (ES), to enhance their integration into the management of protected areas in Slovenia. Through five participatory workshops across ten pilot sites in both protected and non-protected areas, stakeholders have selected and ranked ES relevant to them. In parallel, we developed a typology of (sub)ecosystems and assessed the availability of their geospatial data with a panel of representatives from the participating protected areas and other nature conservation institutions. In assessing ES, we focused on three specific ES: forage provision, pollination and recreation and leisure, which we assessed using different methods. Our findings highlight the critical role of stakeholder involvement in the ES framework, particularly in accurate mapping and assessment processes facilitated by GIS technologies. A comparative analysis of three ES supply revealed generally higher capacities for pollination and recreation and leisure in protected areas, in contrast to provisioning services, such as forage provision, which did not show a similar pattern; however, exceptions were noted. A significant challenge identified was the scarcity of

relevant geospatial data, which reduces the potential of generating precise and reliable assessments and maps necessary for uptake into concrete management of protected areas.

Keywords

ecosystem services, participatory approach, mapping, assessment, protected areas, management

Introduction

Protected areas (PA; PAs for plural) are an important tool for nature conservation, where the motivation for biodiversity conservation traditionally encompasses both functional and intrinsic aspects of nature's value (Smrekar et al. 2023). It is increasingly recognised that the integration of ecosystem services (ES), benefits that people receive from ecosystems (Leemans and Groot 2003), into protected area management, can be useful in achieving sustainable conservation outcomes (Berghöfer and Dudley 2010; Doak et al. 2014; Hummel et al. 2019; Pu et al. 2023). However, the practical implementation of ES concepts within PA management remains limited (García-Llorente et al. 2018; Pu et al. 2023), which is at least partly due to a lack of standardised methods for ES identification, mapping and assessment (Hummel et al. 2019; Pu et al. 2023). Furthermore, there is often opposition amongst PAs managers and other nature conservation stakeholders to the concept of ES itself due to their disagreement with anthropocentric, utilitarian conceptions of nature (Norgaard 2010;Fisher and Brown 2014; Jax et al. 2018), particularly with regard to economic assessments (Costanza 2020). Finally, inclusion of ES into local decision-making processes and policies is often hampered by limited technical capabilities, lack of practical skills and knowledge, institutional shortcomings (Palomo et al. 2018; Šmid Hribar et al. 2021; Balvanera et al. 2022) or uncertainties, such as modelling and data uncertainties (Walther et al. 2025).

Many PAs face challenges stemming from competing interests of different stakeholders. This is also related to an often very top-down approach to their establishment and management, which fails to capture and balance these different interests (Nyaupane et al. 2022). Existing PA management is often based on general conservation principles that can be insensitive to the whole area and lack community support (cf. García-Llorente et al. (2018)). For this reason, participatory assessment approaches are increasingly being applied (Langemeyer et al. 2018; Burdon et al. 2019; Sagoe et al. 2021), which can help to gain political support and buy-in, as well as the relevance, accuracy and acceptance of conservation strategies by incorporating local knowledge, considering stakeholder needs and fostering community engagement in decision-making processes.

Furthermore, while PAs are often presumed to provide more ES than non-protected areas (NPA; NPAs for plural) due to their protection status, empirical data on these differences remain limited (e.g. Spanò et al. 2017; Marta-Pedroso et al. (2018)). This lack of

comparative analyses between PAs and NPAs represents a critical knowledge gap (Eastwood et al. 2016), as understanding these distinctions could better inform decisions on conservation priorities and management strategies. Such comparative assessments are necessary to demonstrate the benefits of protection with regard to ES. By identifying and addressing these gaps, this study aims to present a comprehensive process that not only standardises ES assessment in PAs, but also enables a direct comparison with comparable NPAs, offering a more nuanced understanding of the benefits derived from protection status. This process resulted in a protocol with detailed steps and guidelines for PAs managers that has been published in 2023 (Vurunić et al. 2023).

This research seeks to contribute a structured, replicable methodology tailored to Slovenia's PAs, focusing on a participatory approach to ES selection and ranking, assessment and mapping that recognises the challenge of comprehensively understanding the perceptions and needs of local communities regarding ES and going beyond solely biophysical assessments (e.g. Fagerholm et al. 2012; Villamor et al. (2014) ; Brown and Fagerholm (2015); Ramirez-Gomez et al. (2015); Damastuti and de Groot (2019)). It was thus orientated towards more practical solutions for fostering participation in selection, ranking, assessing and mapping ES. The process presented in this paper could also serve to assist conservationists and PAs managers in presenting the value of PAs to the general public. By comparing PAs and NPAs, research in the development of this process also aimed to gain more nuanced insights into the specific impacts of protection on ES and, ultimately, support a more evidence-based approach to PA management. An important attribute of this process lies in its participatory nature. Beyond its local relevance, this process has the potential to serve as a model for the integration of ES in PAs and neighbouring NPAs facing similar challenges in other regions.

In this paper, we present the full process of the stakeholders involvement in the assessment of ES in PAs and NPAs in Slovenia. We also discuss challenges encountered during this process and provide recommendations for improving the reliability of such assessments. By addressing these methodological and practical challenges, our work aims to advance a structured, evidence-based approach to PA management that integrates ES. We followed the following objectives:

1. to select and rank ES through participatory workshops;
2. to assess and map three selected ES in five PA and five NPA pilots in Slovenia;
3. to compare ES supply between PAs and NPAs.

Methods

Study area

Slovenia boasts well-preserved and beautiful nature. Through legal acts of protection, different categories of PAs have been established, depending on the conservation significance of the area and its management objectives. Based on their size, PAs are classified into broad and narrow categories. At the national level, over 13% of the territory

is covered by 50 broad PAs (one national, three regional and 46 landscape parks) and 1,218 more narrow PAs (one strict nature reserve, 56 nature reserves, 1,161 natural monuments) (ARSO 2021). Protected areas are also designated to implement internationally recognised forms of nature conservation, such as those defined by the International Union for Conservation of Nature (IUCN). In addition, Slovenia has a rich network of Natura 2000 sites, which cover 37% of the country's territory, putting it at the top of the EU countries in terms of proportion (Natura 2000 v Sloveniji 2024). These protection regimes overlap, so that a total of 40% of Slovenia falls under different forms of protection (ARSO 2023).

The research was carried out on five pilots in PAs and five pilots in nearby NPAs. The PAs included were the Triglav National Park (TNP), the Škocjan Caves Regional Park (PSJ), the Kozjansko Regional Park (KP), the Goričko Landscape Park (KPG) and the Logar Valley Landscape Park (KPLD). The criterion for selecting the PA was the ability of their managers to carry out ES research, based on an assessment by the Ministry of Natural Resources and Spatial Planning (MNVP), the co-financier of the research. We also considered a diverse array of PA types, including national (IUCN II and V), regional (IUCN III and/or V) and landscape parks (IUCN V). To provide a comparison of the supply of ES in NPAs, we asked the representatives of the above-mentioned PAs to choose a suitable reference area in the immediate vicinity that is as similar as possible in terms of natural conditions (topography, climate, vegetation etc.). Fig. 1 shows the geographical distribution of all 10 study pilots. By comparing PAs and NPAs, we wanted to address the third objective of this study, i.e. determining whether the supply of ES in PAs and NPAs differs.

TNP is the only national park in Slovenia. It is located in the north-west of the country and covers 83,982 ha. It has three protection zones, which define rules of behaviour with an emphasis on nature conservation and cultural heritage. This Alpine PA also hosts a wide range of economic, recreational and tourist activities, making it essential to reconcile the different and sometimes conflicting interests (Naravni parki Slovenije 2023). PSJ is a regional park in the south-eastern part of the Karst Region, comprising 401 ha of PA and 45,000 ha of impact area. The heart of the Park is the UNESCO site of Škocjan Caves. In addition to the rich underground natural heritage, such as subterranean geomorphological phenomena and endemic fauna, the Park preserves typical dry karst meadows and karst architecture, as well as many archaeological sites (Naravni parki Slovenije 2023). KP is a regional park in the east of Slovenia. It covers 20,650 ha and is characterised by a varied landscape, high level of biodiversity and rich cultural heritage, amongst which high herbaceous grassland orchards stand out (Naravni parki Slovenije 2023). KPG is a landscape park in the north-east of Slovenia, covering 46,200 ha. The diversity of habitats, including for endangered plant and animal species, reflects non-intensive land use, mainly agriculture, which has intensified in recent years. The fragmentation of land use has, thus, preserved a mosaic cultural landscape in this hilly region (Naravni parki Slovenije 2023). KPLD covers a glacial valley of the Kamnik-Savinja Alps in northern Slovenia and covers 2.4 ha. Unlike the previous parks (which were founded by the Republic of Slovenia), this one was established by a municipality.

As seen in Fig. 2, it contains a number of natural and cultural attractions that attract many visitors, which represents a key development challenge for the area (Naravni parki Slovenije 2023).

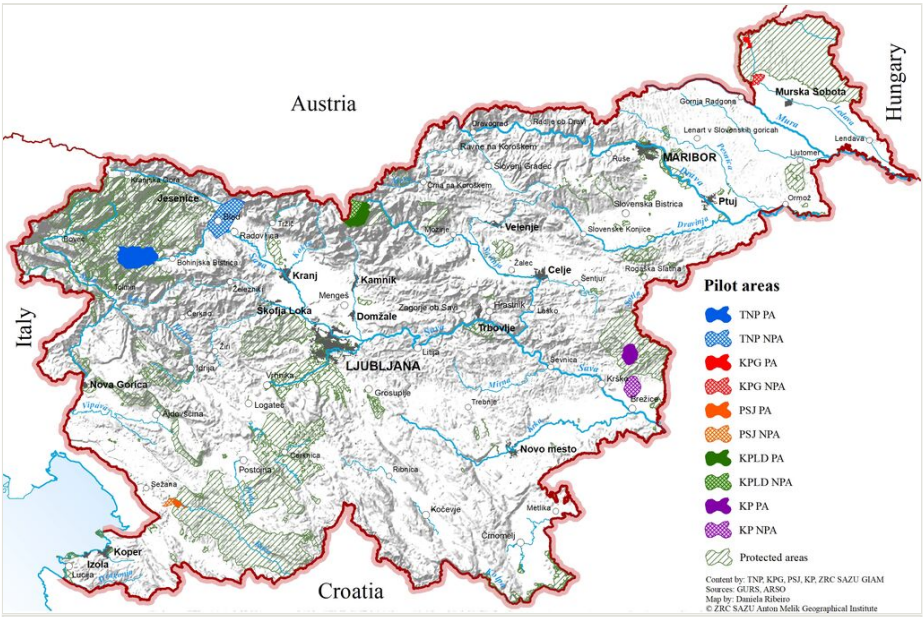

Figure 1.

Map of Slovenia with pilot areas marked.

Conceptual framework

In this study, we related to the cascade model of Haines-Young and Potschin (2010) in the sense that we addressed the supply of ES in PAs and NPAs. Thus, we were focusing on the potential of PAs and NPAs to supply ES and not on their actual use and/or demand. Moreover, we introduced the following elements to facilitate the assessment of differences in supply of ES within PAs and NPAs:

- participatory workshops with stakeholders;
- panel meetings with representatives of the participating PAs, the Institute of the Republic of Slovenia for Nature Conservation (ZRSVN) and a representative of the MNVP;
- ES indicators and virtual expert-based evaluation methods;
- comparison of ES in PAs and NPAs.

The workflow presented in Fig. 3 depicts the main steps of our research with key outcomes: (1) selection and ranking of ES; (2) the assessment of their supply; and (3)

addressing the difference between pairs of PAs and NPAs. Additionally, means for reaching the outcomes are defined as well, as are the objectives of research.

Figure 2.

Landscapes in the selected PAs.

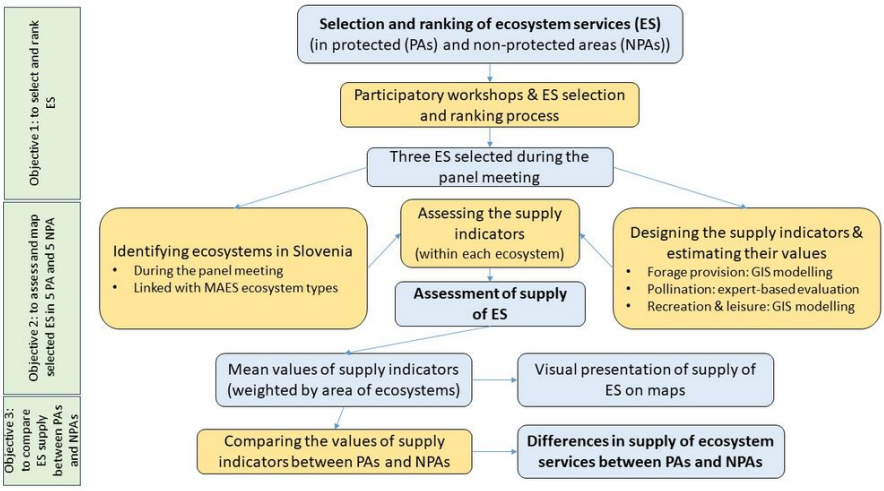

Figure 3.

A workflow diagram of methodological steps (green: objectives; blue: outputs; orange: methods/approaches).

Selecting, ranking, assessment and mapping ES

Selecting and ranking ES through participatory workshops

The selection of relevant ES was carried out in **five participatory workshops** with stakeholders: KPLD in October 2022, PSJ in January 2023, KPG in February 2023, KP in March 2023 and TNP in May 2023. With the exception of the KPLD workshop, which was organised by the authors, these participatory workshops were facilitated by representatives of the participating PAs. These representatives, knowledgeable about their regions, had the discretion to decide whom to invite and how to conduct the invitations. The participatory workshops started with a short introduction on what ES are, as the topic is still quite abstract for many stakeholders. During the workshops, stakeholders selected ES from an adapted list of ES, based on the international CICES classification (EEA 2018). The original list includes over 90 ES, which was deemed too complex for participatory engagement with stakeholders. To address this, we grouped related ES and produced a shorter list of 39 ES (Suppl. material 1). Each stakeholder was provided with 10 stickers to allocate to the ES they considered most relevant in terms of availability in both the PA and NPA, following a similar methodology as Palomo et al. (2013) and Palomo et al. (2014). Stakeholders were allowed to assign multiple stickers to a single ES. This process yielded lists of selected and ranked ES for each individual PA and NPA.

Stakeholders were actively involved in the selection and ranking of ES, based on their local knowledge. TNP did not prioritise the relevant ES in the NPA, as the NPA is geographically distant from other parts of the PA and the interests and priorities of the stakeholders are very different. This participatory ranking process, combined with the use of stickers to allocate importance, allowed us to capture a more nuanced understanding of stakeholder perceptions of ES availability and relevance in both the PA and NPA.

Using Jenks natural breaks in R programme, we classified ES importance by minimising within-class variance and maximising between-class differences. Final percentage values were computed as the **sum of partial percentages across individual PAs and NPAs** derived from stakeholder rankings. We then defined two classes, lower- and higher-importance ES, yielding homogeneous classes with clear separation.

The results of the five participatory workshops were subsequently discussed during a **panel meeting** in May 2023. We sought to reflect the participatory workshop rankings as far as possible. However, given the national context, where data are often scarce and formal ES assessments were essentially non-existent, the panel meeting agreed to select one ES from each group for further assessment, testing different methods and relying on the data and resources available within the project. Accordingly, we included the second-ranked ES (cultural) and the third-ranked ES (provisioning) as, for the first-ranked ES, not enough data were available. For the regulating group, after careful consideration, we selected an ES that did not appear in the stakeholder selection with higher importance. This was primarily due to feasibility and because the PAs representatives expressed interest in learning the expert-based evaluation method. The following ES were selected

on the panel meeting: rearing animals and their products for food (grazing) (Provisioning; according to CICES, a combination of 1.1.3.1 Animals reared for nutritional purposes and 1.1.3.2 Fibres and other materials from reared animals for direct use or processing (excluding genetic materials); hereby referred to as ‘forage provision’); pollination (Regulation and Maintenance; CICES 2.2.2.1 Pollination); and recreation and leisure (Cultural; according to CICES, a combination of 3.1.1.1 Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions and CICES 3.1.1.2 Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions).

ES assessment and mapping through indicators and expert-based data

Ecosystems are the basic spatial unit of ES. According to the Millenium Ecosystem Assessment (2005), one of the most prominent contributions to recognising society's dependence on ES and the functioning of ecosystems globally, healthy ecosystems are the key to securing ES. In this study, we used the MAES ecosystem typology (Maes et al. 2013), which we adapted to national circumstances during the panel meeting. We started from the ecosystems occurring in Slovenia, which were further subdivided into up to two lower levels (first more general, then more detailed, for example, meadow, then hummocky meadow, see Suppl. material 2). In this way, we were able to assess and map the ES more thoroughly, i.e. ensure greater relevance at national level. A prerequisite for the subdivision was the availability of geospatial data for each ecosystem type. During the development of the ecosystem typology, it became clear that, for lower-order ecosystems and some other land uses, the term ‘ecosystem’ was sometimes less appropriate than, for instance, landscape features (e.g. individual shrubs and trees, hedgerows, ponds, dry walls). However, to avoid terminological confusion, we have retained the generic term 'ecosystems' and, thus, maintained the link to the internationally established MAES typology. The table of ecosystem types in Slovenia could serve PAs managers as a basis for ecosystem inventories to identify and map ES.

The ES assessment is expressed through **indicators** selected on the basis of past research, but also taking into account their relevance in the context of the pilot areas and data availability. We also considered the diverse professional capacities of the pilot PA managers to participate in the calculation of the indicators and to use them independently in the future. Criteria for the ES indicators were that they:

- reflect the supply of the ES;
- reflect the biophysical aspect of ES supply;
- represent the current stock of the ES.

In this study, we did not address economic valuation, nor look at time trends. The indicators given in Table 1 were designed to enable covering all relevant ecosystems listed in Suppl. material 2.

Table 1.

Indicators for the ES selected in this study.

Ecosystem service	Indicator
Forage provision	Annual grassland biomass increment (t/ha/year) (Egger et al. 2004; Jäger 2017)
Pollination	Habitat suitability for pollinators (expert rating 1-5; 1 - minimum availability for pollination, 5 - maximum availability for pollination)
Recreation and leisure	Recreational attractiveness index (0-100) (Paracchini et al. 2014, Schirpke et al. 2017)

The provisioning and cultural ES were assessed using a GIS-based modelling protocol, while the regulating ES was, due to a lack of data, evaluated through a virtual expert-based evaluation. This approach introduced PAs representatives to two different ES assessment methods: one grounded in GIS modelling and the other in expert knowledge. The entire process of assessing and mapping ES was continuously coordinated through several panel meetings, which helped to refine and improve the ES assessment protocols (Vurunić et al. 2023).

The indicator for forage provision, **annual grassland biomass increment**, was estimated in two steps. First, the potential annual production of fresh grassland biomass was estimated using increment equations for different types of grassland (Table 2), where the key variable is the length of the growing season, which determines the number of days per year when the average daily temperature is at least 5°C (ARSO 2023).

Table 2.

Increment equations for different grassland types (Egger et al. 2004; Jäger 2017).

Types of grassland (as identified in Suppl. material 2)	**Growth equation [dt/ha/year]** (x = length of growing season in days)
Extensive (high tree) orchards Wet meadow Mountain pasture/mountain meadow	y= (0,0007*(x²))-(0,1513*x)+26,585
Permanent meadow	y = (0,0021*(x²))-(0,419*x)+93,774
Marshes and reedbeds	y = (0,0006*(x²))-(0,1613*x)+25,321
Heath and scrub	y = (-0,00007*(x²))+(0,1084*x)-4,7726

This estimate was then corrected for annual rainfall, slope and insolation. The corrections are described in Table 3.

The regulating ES **pollination** was assessed in a **virtual participatory expert evaluation** in July 2023.

The evaluation brought together two biologists (a pollinator specialist and a phytosociologist), the project team (4 members), representatives of the PAs (7), ZRSVN

(1) and MNVP (1). Scores were not assigned individually, but were instead generated through a group discussion in which all participants jointly deliberated and agreed on the final values.

Table 3.

Corrections to the potential grassland biomass increment.

Correction factor	Condition for correction: if the ...	Correction: the potential annual production of fresh grassland biomass is ...
Amount of precipitation	... annual rainfall [mm] less than the length of the growing season [n days]*3.33	... divided by 10
Slope of the terrain	... a slope of at least 10°	... reduced by (1 - (slope[°]/100)*production [t/ha/year]
Solar exposition	... exposure range 0-20%	... reduced by 20% for northern exposures and continuously by a decreasing % from northern to southern exposures where the correction is 0%

Ecosystems in PAs and NPAs were assessed and assigned a value from 0 to 5 according to their potential for pollination where supply for the ES pollination was understood as the **availability of an ecosystem to provide habitats or conditions for the existence of pollinators that depend on it for food production**. The assessment was carried out in two steps. First, we identified relevant ecosystems for pollination from the set of all ecosystems found in PAs and NPAs (Suppl. material 2). Second, we scored the identified ecosystems from 0 (no availability for pollination) to 5 (maximum availability for pollination), whereby the same ecosystem types in different PAs and NPAs did not necessarily always have the same score. For some ecosystem types (e.g. cultivated fields, forests), the scores may differ according to plant and tree species (a maize field has a score of 0, while a field of sunflowers, buckwheat, pumpkins, mixed crops etc. has a score of 3).

We assessed the ES recreation and leisure using a **recreational attractiveness index** (Paracchini et al. 2014; Schirpke et al. 2017). This is based on five elements hypothesised to influence recreational attractiveness:

- naturalness or degree of hemeroby;
- presence of waterbodies;
- diversity of land use;
- ruggedness of terrain
- presence of peaks.

All elements have the same impact on recreational attractiveness or the value of the index. Each element was evaluated on a scale of 0-100, where 0 means that the element does not contribute and 100 means that the element contributes extremely (maximally) to

recreational attractiveness. This was done through linear interpolation of the values between the extremes.

The naturalness or degree of hemeroby (1-7) was taken from Steinhardt et al. (1999) and assigned to land-use categories (LUCC), which is more detailed than ecosystem types originally used in the treatment of ES (Suppl. material 2). This was done because more detailed data on hemeroby could be used. The relationship between LUCC and ecosystem types (Suppl. material 2) is also shown in Table 4.

Rivers, lakes and streams enhance recreational attractiveness, but this effect is most pronounced in their immediate vicinity and then continuously subsides until 2000 m away, where it disappears completely (Paracchini et al. 2014). The effect of waterbodies is, therefore, expressed on a scale of 0-100, where 100 is attributed to the immediate surroundings (0 m away) and 0 to a place at least 2000 m from the water. The intermediate values are continuously distributed between the two extremes.

The intermingling of different types of ecosystems is more appealing than a single ecosystem. Spatial diversity in this sense was assessed by summing the different ecosystem types over a fixed area of 1000 x 1000 m. Areas with the highest number of different ecosystem types within each quadrant in the included PA and NPA pilots were assigned a value of 100 (maximum attractiveness), those with only one ecosystem type a value of 0 (minimum attractiveness) and the remaining areas with values between the two extremes.

Table 4.

Hemeroby degrees for different ecosystem types (Steinhardt et al. 1999), linking the more detailed ecosystem breakdown to the ecosystem types in Appendix 2 and its impact on recreational attractiveness.

Code	Land use (MKGP 2023)	Ecosystem types - level 1 (Suppl. material 2)	Hemeroby [1 (most natural)-7 (least natural)]	Impact on the recreational attractiveness of the landscape [0-100]
1	Cultivated field	fields	5	33
2	Permanent crops on arable land	permanent crops	4,5	42
3	Greenhouse		6	17
4	Vineyard		4.5	42
5	Intensive orchard		4.5	42
6	Extensive or grassland orchard		4	50
7	Permanent meadow	meadows	3	67
8	Agricultural land under overgrowth	heath and scrub	2	83
9	Forest tree plantation	permanent crops	4	50

Code	Land use (MKGP 2023)	Ecosystem types - level 1 (Suppl. material 2)	Hemeroby [1 (most natural)-7 (least natural)]	Impact on the recreational attractiveness of the landscape [0-100]
10	Trees and shrubs	heath and scrub	2.5	75
11	Uncultivated agricultural land	heath and scrub	3	67
12	Agricultural land with forest trees	mountain pastures/ mountain meadows	4	50
13	Forest	forest	2	83
14	Built-up and related land	urban	7	0
15	Reed	marshes and reedbeds	2	83
16	Other waterlogged land		2	83
17	Dry open land	bare surfaces	1	100
18	Open land		1	100
19	Water	watercourses, lakes, ponds, other standing waters	2	83

A more rugged landscape is more attractive than a flat one, as it is more dynamic and attractive for different types of recreational activities. Terrain ruggedness was assessed using the 'terrain ruggedness index' (TRI) (Riley et al. 1999), which is based on a digital elevation model and indicates the differences in elevation between adjacent raster cells. We assigned a maximum attractiveness value of 100 to the largest TRI values, 0 to flat areas and intermediate values between the two extremes to other areas.

The presence of elevations (mountains, hills etc.) was estimated using the frequency (presence) of their peaks in a 10 km^2 quadrant. Peaks are defined as typically concave landforms (TRI index of at least 162), with at least 600 m height relative to the lowest point in the 10 km^2 quadrant. Quadrants with the highest number of peaks were assigned an attractiveness score of 100, those without peaks a score of 0 and the rest intermediate scores relative to the two extremes.

The composite indicator of recreational attractiveness was calculated by combining all five elements of this ES by overlaying them in a GIS environment, summing the scores of the individual elements (0-100) for a predefined raster cell and again standardising the sum to a 0-100 scale.

Furthermore, **we mapped the capacity of the identified ecosystems to supply all three selected ecosystem services** using the ArcGIS 10.8.1 programme. Some ecosystems (e.g. hedgerows, gardens, ponds in ES pollination) were assessed in this way, but the geospatial data are not currently available and, therefore, cannot be represented on maps. The estimates can be used in future surveys when geospatial data are available for such specific ecosystems. Smaller features, such as individual trees on agricultural land, were not specifically included on the maps, as such trees usually grow in

grasslands, which were assigned a higher value than the trees themselves. For the same reason, individual shrubs, trees and tree islands were not included in the maps; such landscape features were only included if they grew on built-up areas. For dry walls, we have considered the length in kilometres.

Due to the different sizes of the pilot sites, the maps representing all sites appear at different scales to ensure clear visualisation. This different scale was necessary to accurately represent the spatial characteristics of the individual sites and, at the same time, to facilitate interpretation in the pilot areas.

Comparison of selected ES in protected and non-protected areas

The presence and size of ecosystems in each PA and NPA (i.e. landscape structure) was considered in the assessment of the three selected ES. The indicator values for the three ES were compared pairwise for the PAs and NPAs by calculating the weighted arithmetic mean for each site. The ES indicator values were grouped into classes and the class means were then weighted by the areas assigned to each class, based on the ES indicator values.

This was done sequentially: Kolmogorov-Smirnov test of normality for PAs and NPAs individually, Levene's test of equality of variances amongst the PAs and NPAs for each pair and finally either the t-test (parametric test) or the Mann-Whitney U test (non-parametric test).

In case of ES pollination, a non-parametric test was the obvious choice, as the assessment of ES supply was performed by ranking. Indicators for the ES forage provision and the ES recreation and leisure were continuous, but both tests of normality and tests of equality of variances indicated a violation of one or both assumptions needed to employ a parametric test. Thus Mann-Whitney U test was used in all cases.

Results

Selecting and ranking ES through participatory workshops

The participatory workshops were attended by a wide variety of local, sometimes regional and, in rare cases, national stakeholders (Table 5). The majority of stakeholders were from the local environment, which aligns with the 'bottom-up' aspiration of the ES evaluation. National stakeholders were present only at TNP and PSJ, which have more experience in organising this type of events. No national stakeholders other than researchers were present in the other PAs. The number of stakeholders also varied by PA, which is partly related to the organisers' ability to attract stakeholders, as well as to the specificities of the PA (size, past relationships, time of organisation etc.). The lowest number of stakeholders was in KPLD, where PA management struggles with institutional issues.

Table 5.
Workshop participants.

stakeholders/PA			TNP	PSJ	KP	KPG	KPLD
local	public	Protected area authority	-	-	-	-	-
		Local community	-	-	1	-	-
		Municipality	3	3	1	3	1
		Slovenian forest service	1	-	-	-	1
		Tourism organisation	1	-	1	-	-
	private	Land owner/farmer, forester	1	2	2	5	-
		Agrarian community	1	-	-	-	-
		Hunting club	-	1	-	1	-
		Fishery association	1	-	-	-	-
		Tourism provider	-	1	1	1	-
		Caving Association	-	1	-	-	-
		Local resident	-	-	3	-	-
		Beekeeper	-	-		1	-
regional	public	Protected area authority	-	6	1	-	-
		Organisation for nature conservation	1	1	1	-	-
		Organisation for cultural heritage conservation	1	-	1	-	-
		Development agency	-	1	-	-	-
	private	Heritage interpretator	-	1	-	-	1
		Archaeologist	1	-	-	-	-
		Land owner	1	-	-	-	-
national	public	Protected area authority	-	-	-	-	-
		Research institution	3	4	-	-	3
		Slovenian Environment Agency	1	-	-	-	-
		Slovenian Water Agency	1	-	-	-	-
		Chamber of Agriculture and Forestry of Slovenia	1	-	-	-	-
	private	Tourist association of Slovenia	-	-	1	-	-
Total			18	21	13	11	6

Overall, each ES was selected at least once, but Table 6 shows which ES were selected more frequently by the stakeholders in each PA and NPA and, thus, categorised in the higher importance class (see Suppl. material 3 for all ranked ES in PAs and NPAs). Of all PAs, ES1.15 Water for drinking, obtained the highest score, with 43.9% of the total score; the lowest ranked ES accounted for 0.5%. To be in the class of higher important ES amongst all PAs, at least 16% of the total had to be obtained. Ten ES from all three groups were included: the aforementioned Water for drinking (43.9%), Recreation and leisure (41.4%), Animal husbandry and products for food (36.8%), Agricultural crops for food (35.2%), Cultural heritage (25.6%), Wild animals for food (e.g. game) (24.4%), Educational ES (21.4%), Aesthetic ES (21.1%), Conservation of habitats (19.6%) and Control of soil erosion (19.2). The other ES ranked in the class of lesser importance.

Table 6.

ES that ranked in the upper half of relevant ES in the pilot PAs and NPAs.

ES (adopted and modified by CICES V5.1)	PA (%)					Sum (%)	NPA (%)					Suma (%)
	TNP PA (n=18)	PSJ PA (n=21)	KP PA (n=8)	KPG PA (n=11)	KPLD PA (n=6)	PAs	TNP NPA	PSJ NPA (n=21)	KP NPA (n=5)	KPG NPA (n=10)	KPLD NPA (n=6)	NPAs
ES1.15 Water for drinking	6.11	5.71	10.00	**15.45**	6.67	43.95	-	4.76	**10.00**	4.00	5.00	23.76
ES3.1 Recreation and leisure	8.89	6.19	7.50	5.45	**13.33**	41.37	-	7.14	6.00	8.00	**8.33**	29.48
ES1.4 Animal husbandry and products for food	**10.56**	4.76	7.50	7.27	6.67	36.76	-	1.90	4.00	5.00	**6.67**	17.57
ES1.1 Agricultural crops for food	4.44	3.81	**18.75**	8.8	0.00	35.19	-	1.90	10.00	**16.00**	0.00	27.90
ES3.4 Heritage, cultural	**7.22**	3.81	5.00	4.55	5.00	25.58	-	3.33	**10.00**	1.00	3.33	17.67
ES1.10 Wild animals for food	**17.22**	1.90	0.00	3.64	1.67	24.43	not ranked					
ES3.3 Educational ES	4.44	5.24	**6.25**	5.45	0.00	21.39	-	4.76	**12.00**	5.00	1.67	23.43

ES (adopted and modified by CICES V5.1)	PA (%)					Sum (%)	NPA (%)					Suma (%)
	TNP PA (n=18)	PSJ PA (n=21)	KP PA (n=8)	KPG PA (n=11)	KPLD PA (n=6)	PAs	TNP NPA	PSJ NPA (n=21)	KP NPA (n=5)	KPG NPA (n=10)	KPLD NPA (n=6)	NPAs
ES3.5 Aesthetic ES	3.33	5.24	2.50	0.00	**10.00**	21.07	not ranked					
ES2.10 Conservation of habitats	1.67	7.14	0.00	**9.09**	1.67	19.57	-	4.29	**6.00**	4.00	3.33	17.62
ES2.5 Control of soil erosion	5.00	1.90	1.25	2.73	**8.33**	19.22	not ranked					

In the NPAs, where data for the four pilot areas were considered, the highest ranked ES Recreation and leisure accounted 29.48% of the total, while the lowest ranked ES accounted barely 0.5%. The threshold amongst NPAs was 14.4%, slightly fewer ES were ranked as follows: Recreation and leisure (29.48%), Agricultural crops for food (27.9%), Water for drinking (23.76%), Educational ES (23.43%), Cultural heritage (17.67%), Conservation of habitats (17.62%) and Animal husbandry and products for food (17.57%).

An example of the selection and ranking of relevant ES for the KPLD PA (red polygon) and KPLD NPA (orange polygon) from the participatory workshop can be found in Fig. 4.

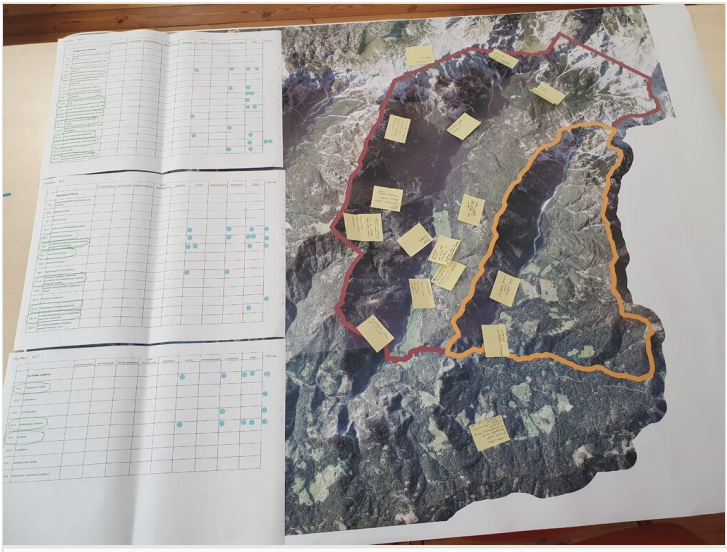

Figure 4.

Selection of relevant ES for the KPLD PA (red polygon) and KPLD NPA (orange polygon) and labelling of micro-locations with trade-offs and synergies.

Of the total of 10 ES ranked in the class of higher important ES in PAs, four are provisioning, four are cultural and two are regulating ES (see Table 6). While in NPAs, three are provisioning, three are cultural and only one is regulating ES. Fig. 5 shows the scores obtained by each ES in the pilot PAs and NPAs.

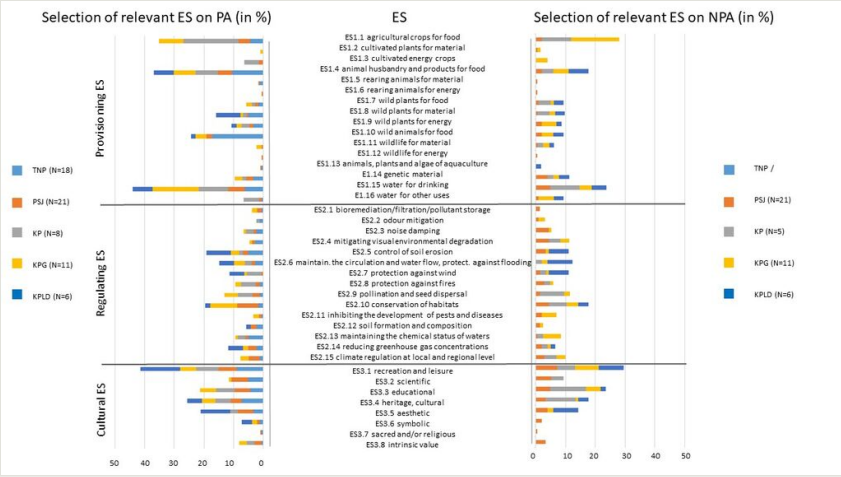

Figure 5.

Selection and ranking of ES in the PAs and NPAs pilots according to relevance for stakeholders.

Assessment and mapping of selected ES through indicators and expert-based data

Prior to the ES assessment, a participatory approach was used to prepare an overview of ecosystem types relevant to Slovenia and their geospatial data during the panel meeting (Suppl. material 2), which formed the basis for the assessment and mapping. The first column lists the internationally established MAES ecosystems (Maes et al. 2013); the second and third columns list the first- and second-level ecosystem types found in Slovenia. The fourth column refers to the source of the geospatial data in Slovenia. Most of the ecosystems were acquired from the Land Use Database from the Ministry of Agriculture, Forestry and Food (MKGP), captured in July 2023 (MKGP 2023). The rest are from individual cadastres (e.g. Water Cadastre), digital databases of the ZRSVN (e.g. dry walls) or obtained through personal correspondence (e.g. mountain pastures from the MKGP).

ES forage provision

The ES forage provision is considered as the capacity of grassland to provide feed for livestock. The mean values of the ES indicator (Fig. 6 and Table 7) are lower (statistically significantly) in PAs in the case of TNP, PSJ and KP, higher in case of KPLD and the same between the PA and NPA for KPG.

Table 7.

Descriptive statistics of the ES's supply indicator and results of testing the differences between PA and NPA (higher values of ES supply indicator are bolded). [1] Kolmogorov-Smirnov test; [2] Levene's test; [3] Mann-Whitney U test. * Kolmogorov-Smirnov test; 2 Levene's test; 3 Mann-Whitney U test.

Pilot area	TNP		PSJ		KP		KPG		KPLD	
	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA
Weighted mean [t/ha y.]	9.65	**11.43**	12.05	**13.54**	11.82	**12.64**	1.21	1.28	**9.96**	8.22
Std. dev.	2.93	1.46	3.14	2.83	1.90	1.69	1.49	1.44	1.58	1.29
K-S[1] test of normality [d-stat. (p-value)]	0.21 (0.00)	0.24 (0.00)	0.28 (0.00)	0.32 (0.00)	0.17 (0.00)	0.27 (0.00)	0.32 (0.00)	0.41 (0.00)	0.25 (0.00)	0.25 (0.00)
L.[2] test of equality of variances [F-stat. (p-value)]	378.67 (0.00)		0.74 (0.39)		15.40 (0.00)		3.85 (0.05)		3.10 (0.08)	
M-W[3] U test of means' differences [Z-stat. (p-value)]	-9.88 (0.00)		-4.30 (0.00)		-11.30 (0.00)		-0.48 (0.63)		7.32 (0.00)	

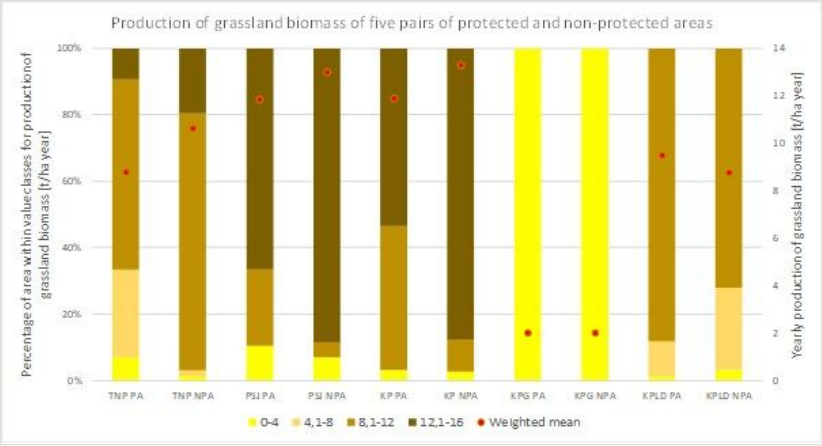

Figure 6.

Distribution of PA and NPA in relative proportions by class of ES indicator values for forage provision and calculated weighted arithmetic means (weights are relative proportions of area by class) of the ES indicator.

These ES estimates are also shown on maps (Fig. 7), which provide a spatial representation of, firstly, the presence of areas where grassland biomass production is even possible and, secondly, the spatial distribution of the production potential.

ES pollination

Pollination is a regulating ES, defined as pollination of crops by insects and other animals. Fig. 8 shows the estimates of the capacity of each ecosystem in the PAs and NPAs involved in providing pollination.

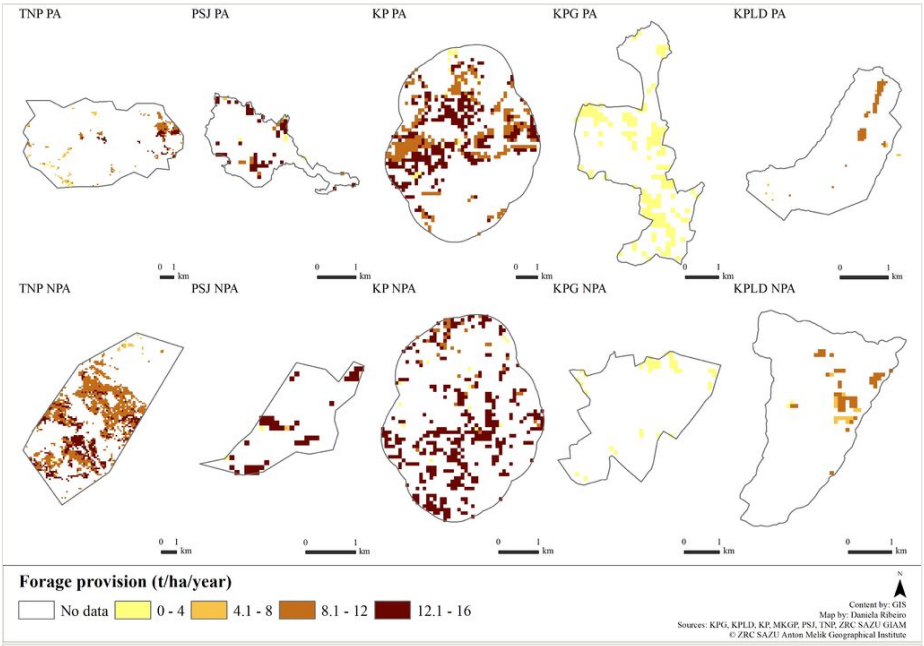

Figure 7.

Cartographic representation of the capacity for the ES forage provision in the pilot areas.

Ecosystems	score						pilots									
	0	1	2	3	4	5	TNP PA	TNP NPA	PSJ PA	PSJ NPA	KP PA	KP NPA	KPG PA	KPG NPA	KPLD PA	KPLD NPA
permanent meadow			2	3	4	5	4	3	5	5	4	2	4	2	4	4
mountain pasture					4		4	4	-	-	-	-	-	-	4	-
hummocky meadow						5	5	-	-	-	-	-	-	-	-	-
field		1	2	3			2	1	1	1	2	1	1	0	1	1
extensive (high tree) orchard						5	5	5	5	5	5	5	5	5	5	5
intensive orchard		1					1	1	1	-	1	1	1	-	-	-
vineyards		1					-	-	-	-	1	1	1	1	-	-
greenhouse	0						0	0	-	-	0	0	0	0	-	-
scrubland, overgrown land					4		4	4	4	4	4	4	4	4	4	4
forest		1	2	3	4		3	3	4	4	3	3	4	4	3	3
heath and scrub		1					1	1	1	1	-	-	-	-	1	1
gravel		1					1	1	1	-	-	-	-	-	1	1
scree (open land with low vegetation)		1					1	1	1	-	-	-	-	-	1	1
watercourse		1					1	1	1	-	1	1	1	1	1	1
spring	0						0	0	0	-	0	0	0	-	0	0
waterfall	0						0	0	0	-	-	0	-	-	0	0
sink	0						0	0	0	-	-	-	-	-	-	-
hedgerow					4	5	missing layer									
individual freestanding shrubs and trees		1	2	3			2	3	2	2	2	2	1	1	2	2
enclosed islands of shrubs or trees				3			3	3	3	3	3	3	3	3	3	3
riparian woodland				3			3	3	3	3	3	3	3	3	3	3
individual tree on agricultural land		1	2	3			-	2	-	-	2	-	-	-	2	2
tree avenue		1	2	3			-	-	-	-	3	-	-	-	-	-
vegetable (mixed) gardens			2	3	4		missing layer									
quarry		1					missing layer									
moor			2				2	2	-	-	-	-	-	-	-	-
marsh and reedbed			2				2	2	-	-	-	-	-	-	-	-
lake			2				2	2	-	-	-	2	-	-	-	-
pond (puddle)			2				2	-	2	-	-	-	2	-	-	-
built up		1					1	1	1	1	1	1	1	1	1	1
dry stone wall				3			-	-	3	3	-	-	-	-	-	-

Figure 8.

Estimates of the capacity for pollination in selected pilot PAs and NPAs (dash indicates absence of ecosystem in area; 0 - no capacity; 5 - maximum capacity).

For this ES, we observe differences both between the PAs and between PAs and NPAs (Table 8). Differences are statistically significant for all parks and, except in case of KPLD,

where the indicated supply of ES is higher in PAs than in NPAs. The KPLD NPA has a slightly higher capacity for this ES, as it has more grasslands on less favourable terrain. Large differences between the PA and NPA were found in KP and very pronounced in KPG, where there is only minimal capacity for pollination in the NPA. The highest capacity for pollination is in PSJ (both PA and NPA), followed by KP PA. KPLD and TNP also have a slightly lower, but still quite high capacity. KPG has the lowest capacity.

Table 8.

Descriptive statistics of the ES's supply indicator and results of testing the differences between PA and NPA (higher values of the ES supply indicator are in bold) [1] Kolmogorov-Smirnov test; [2] Levene's test; [3] Mann-Whitney U test.

Pilot area	TNP		PSJ		KP		KPG		KPLD	
	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA
Weighted mean [t/ha y.]	**2.62**	2.56	**3.97**	3.81	**3.18**	2.17	**2.39**	0.56	2.51	**2.79**
Std. dev.	0.91	0.95	0.82	0.96	0.69	0.98	1.53	1.22	0.92	0.73
K-S[1] test of normality [d-stat. (p-value)]	0.44 (0.00)	0.43 (0.00)	0.44 (0.00)	0.44 (0.00)	0.32 (0.00)	0.26 (0.00)	0.36 (0.00)	0.46 (0.00)	0.44 (0.00)	0.48 (0.00)
L.[2] test of equality of variances [F-stat. (p-value)]	37.03 (0.00)		13.27 (0.00)		647.38 (0.00)		269.28 (0.00)		338.30 (0.00)	
M-W[3] U test of means' differences [Z-stat. (p-value)]	3.82 (0.00)		2.43 (0.02)		29.87 (0.00)		22.84 (0.00)		-6.85 (0.00)	

In addition to this and the presentation in the graphs (Fig. 9), the results are also presented in maps (Fig. 10) showing the spatial distribution of capacity across the selected areas. In summary, the capacity for pollination is higher in most PA (the exception is KPLD), although the difference is only marginal in some places. However, we also note significant differences between PAs, with one PA (KPG) having very low supply for this ES.

ES recreation and leisure

The recreational attractiveness of the landscape reflects its quality of outdoor recreation. The results of the ES assessment are given below. The mean values of the ES indicator (Fig. 11 and Table 9) show that recreational attractiveness is quite similar in all pilots, with one exception - KPG, where the NPA values are significantly lower than in all other cases. The PA-NPA differences are statistically significant for all parks, though they are relatively small in TNP and KPLD (both in the Alpine area). TNP is also unique for actually having a higher indicator value for recreation and leisure in the NPA compared to the PA, as opposed to all the other parks.

The ES ratings are also shown on maps (Fig. 12), giving an insight into the spatial distribution of landscape attractiveness ratings for recreation and leisure.

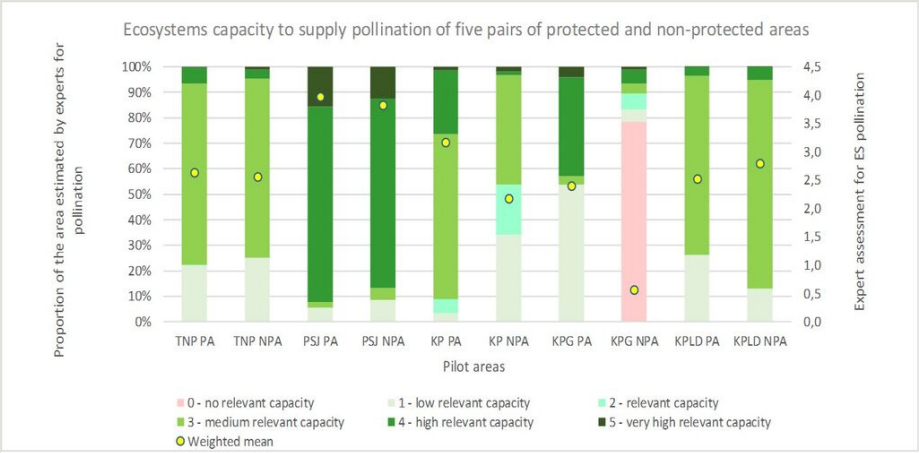

Figure 9.

Proportion of PAs and NPAs area with different estimates of ES pollination capacity (0 - no capacity, 5 - maximum capacity).

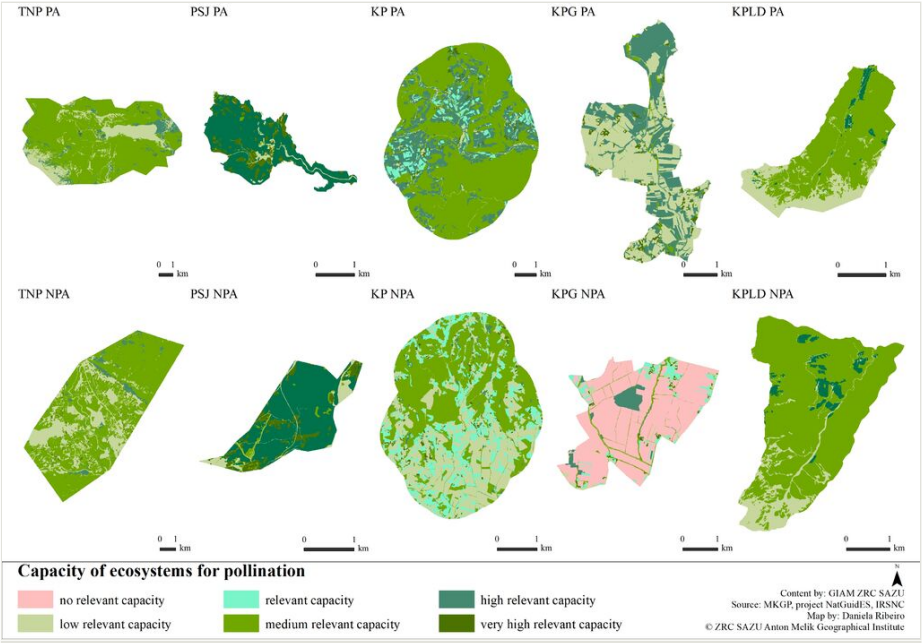

Figure 10.

Cartographic representation of the supply of ES pollination in the pilot areas.

Table 9.

Descriptive statistics of the ES's supply indicator and results of testing the differences between PA and NPA (higher values of the ES supply indicator are in bold) [1] Kolmogorov-Smirnov test; [2] Levene's test; [3] Mann-Whitney U test.

Pilot area	TNP		PSJ		KP		KPG		KPLD	
	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA
Weighted mean [t/ha y.]	49.85	**50.03**	**58.42**	42.29	**54.75**	49.14	**54.20**	28.37	**59.13**	57.68
Std. dev.	11.79	11.69	10.01	8.89	8.00	9.30	9.69	7.22	7.20	6.45
K-S[1] test of normality [d-stat. (p-value)]	0.04 (0.00)	0.06 (0.00)	0.09 (0.00)	0.13 (0.00)	0.03 (0.00)	0.06 (0.00)	0.08 (0.00)	0.11 (0.00)	0.07 (0.00)	0.07 (0.00)
L.[2] test of equality of variances [F-stat. (p-value)]	0.97 (0.32)		6.87 (0.01)		308.09 (0.00)		6542.66 (0.00)		28.38 (0.00)	
M-W[3] U test of means' differences [Z-stat. (p-value)]	-5.89 (0.00)		36.74 (0.00)		36.55 (0.00)		57.16 (0.00)		13.13 (0.00)	

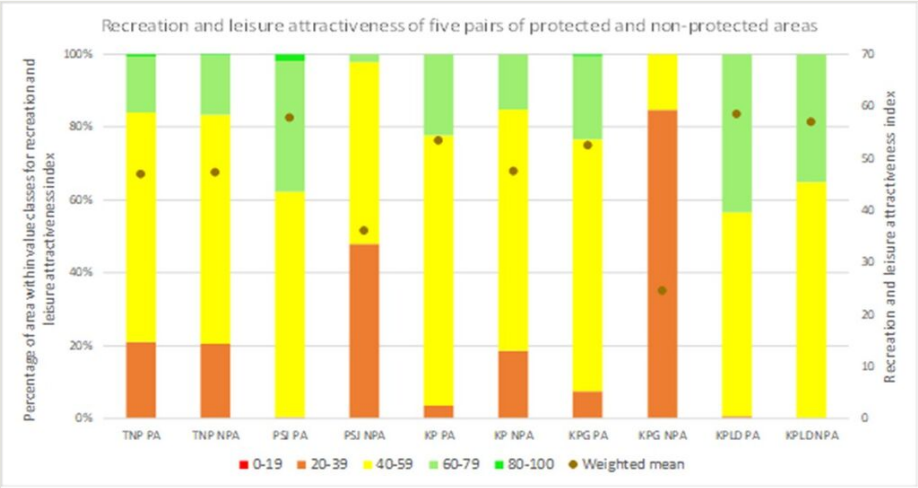

Figure 11.

Distribution of PAs and NPA areas in relative proportions by the ES Recreation and leisure indicator value class and calculated weighted arithmetic means (weights are relative proportions of areas by class) of the ES indicator.

Discussion

Public participation in ES research has gained significant attention in recent years (e.g. Fagerholm et al. (2012); Brown and Fagerholm (2015); Ramirez-Gomez et al. (2015);

Damastuti and de Groot (2019); Barnaud et al. (2023)). In this study, public participation played a central role, involving representatives from five PAs, the ZRSVN, the MNVP and general public stakeholders. This inclusive approach enriched the analysis by integrating diverse perspectives, aligning with the broader shift towards participatory ES research.

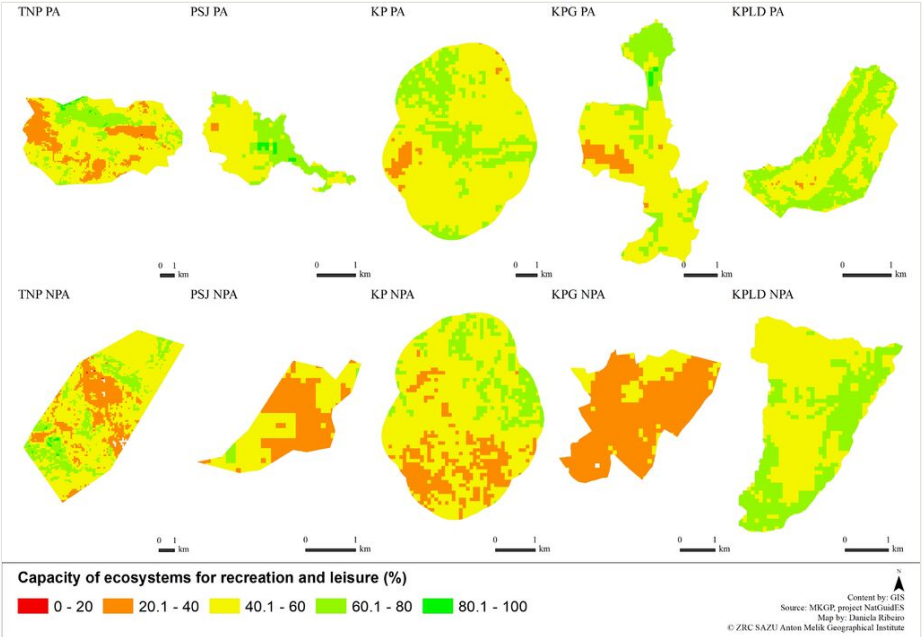

Figure 12.

Cartographic representation of recreation and leisure capacity in the selected pilot areas.

Participatory workshops and ES selecting and ranking

With the participatory workshops, we gained new insights into the local prioritisation of ES. The selection of the most relevant ES differs between PAs and NPAs, but less than expected. We expected that, due to their protected status and better-preserved nature, PAs would have a higher proportion of regulating and cultural ES amongst the ES of higher importance, while NPAs would have a higher proportion of provisioning ES. However, we found only slight differences between PAs and NPAs – stakeholders in the workshops considered provisioning and cultural ES to be more important than regulating ES regardless of protection status (Table 6). Only two regulating ES that fell into the higher-importance class were Conservation of habitats and Control of soil erosion. Of these, only Conservation of habitats was classified as higher importance in NPAs. Given the diverse representation of stakeholders at individual workshops, it is difficult to understand such a low proportion of regulating ES in the selection and ranking. It could be attributed to the high dispersion of the distributed stickers, i.e. scores per ES, which may be related to the desire to balance different ES, but it is likely more attributable to the awareness regarding different ES. This lack of selectivity poses a challenge for

prioritisation, as it reduces the ability to distinguish which ES are perceived as most critical for management and may dilute the focus of subsequent analyses. This was most evident in PSJ, which had the largest number of participants. This indicates a need for a well-facilitated participatory workshop with a clearly focused selection of ES. The facilitator should encourage stakeholders to focus on the most relevant ES in the area, either in terms of synergies or in terms of trade-offs, which will help them find common answers or solutions to specific conflicts. Otherwise, participation may be more of a crutch and may lead to dispersion in the selection and ranking process, as seen in the results of the participatory workshops in some areas (Fig. 5). It would, therefore, be best to carry out this exercise in two rounds: in the first round, participants should focus on selection and, in the second round, they should prioritise from a broader range a few (e.g. three to five) of the most relevant ES that are key for the management and development of the area. The ES from the shortlist would be assessed and mapped in detail at a later stage. Participant bias can also be avoided by enlarging the sample (more stakeholders) and possibly by weighting their votes so that the stakeholder groups are equal.

One of the difficulties in interpreting the workshop results was categorising the stakeholders. Stakeholders can identify with several different categories and there was some confusion due to different understandings of terms (e.g. who represents nature conservation or a local community). Therefore, one needs to be careful in interpreting the categories or offer stakeholders a limited (perhaps simplified) set of categories in which they can categorise themselves, with the option to select only one of them.

In short, even in the PAs (where conservation overarchingly relates to cultural landscapes rather than nature conservation), provisioning and cultural ES ranked higher than regulating ES. It appears that workshop stakeholders perceived both types of pilots (PA and NPA) as primarily providing space for food production and recreation and only secondarily as providing regulating ES. However, this result may be closely related to the type of stakeholders attending and a different set of stakeholders could have yielded different results (see, for example, Bidegain et al. (2019)).

Not all areas provide the same ES, but similarities are largely related to the actual use of space (Ribeiro and Šmid Hribar 2019) and probably to the set of stakeholders. The KPG PA and KP PA are the most similar, while KPLD stands out for its aesthetic ES (Žužek 2007). This is not surprising, as landowners in this PA, considered one of the most beautiful Alpine valleys, have been favouring tourism over food production for a relatively long time. All PAs prioritise a mix of provisioning/cultural ES, but each has a distinct signature (TNP - PA wild game and heritage; KP - PA agriculture; KPG - PA water and conservation; KPLD - PA recreation and leisure, aesthetic), while regulating services rarely achieve top rankings, except at the local level (e.g. TNP - PA control of soil erosion; KPG - PA and KP - PA habitat conservation).

An additional observation regarding expert participation in panel meetings is that working with ES is research-intensive and requires specific skills. In our study, experts participated up to and including the selection and ranking of relevant ES and in the virtual expert-based evaluation; however, the assessment using GIS modelling and mapping

was too complex for them. The latter two steps are likely to remain in the domain of researchers and practitioners familiar with the range of relevant and available indicators, modelling tools and other GIS tools. As the concept of ES deepens in terms of assessing ecosystem condition, understanding and differentiating indicators for ES and ecosystem condition, as well as environmental accounting, this will become even more challenging. It is very important that expert stakeholders are re-engaged in the process of interpreting the results, shaping the management of the selected site and communicating with the public, as their participation will greatly facilitate the understanding and uptake of results in PA management. This was highlighted in the Handbook for the identification and mapping of ecosystem services (Vurunić et al. 2023), which details six steps and explains the roles of each stakeholder in the identification, assessment and mapping of ES. This insight will need to be considered in future work with the professional community and emerging Communities of practice.

Opportunities for public participation are seen particularly in the aforementioned search for consensus on the management and development of PAs and in the field using citizen science to map specific landscape features (e.g. dry walls, ponds, hedgerows, gardens etc.) for which geospatial data are mostly unavailable.

Assessment and mapping of ES

The assessment and mapping of ES in PAs and NPAs was carried out using the ecosystem typology for Slovenia (Suppl. material 2), which is one of the outputs of this study. The table can be used by PAs managers in Slovenia as a basis for ecosystem inventories for the identification and mapping of ES and its specific content will be adapted to the natural characteristics of their PA. The presented table is not definitive, as it is quite likely that there will be other specific ecosystems in other (protected) areas in Slovenia. In the preparation of this table and the corresponding geospatial data, the lack of data proved to be a key issue, especially for more specific ecosystems, such as hedgerows and gardens. Such ecosystems (landscape features) play an important role in regulating ES, but cannot be considered because there are currently no data available. This gap also reflects the obstacles faced by researchers and policy-makers at European and global levels.

A shortcoming of the MAES ecosystem typology and CICES v.5.1 ES classification, namely the absence of karst features and their ES, was revealed during our study. Karst surface and underground ecosystems supply various ES, particularly clean water storage, special habitat provision and climate change mitigation. By providing connectivity between the surface and the underground, other karst phenomena, such as sinks and dolines, are also undoubtedly important and should be considered in terms of providing ES. Precisely due to this connectivity, karst ecosystems are uniquely vulnerable to human impact (Brinkmann and Garren 2011) and, therefore, require careful protection and management. However, to our knowledge, there is no specific inventory or assessment of karst ES; other than the tourist potential of specific features, the provision of ES by karst areas is often overlooked. This is of particular significance for countries

with extensive karst landscapes, such as Slovenia, where such landscapes occupy 44% of the territory (Gams 2003). To reflect this significance, we included caves and ice pits in our study.

Conversely, during the assessment and subsequent mapping, we found that the inclusion of point layers (e.g. points as natural values) was mostly unnecessary, except for the assessment of cultural ES (e.g. aesthetic, heritage, symbolic ES), so they were omitted from the ecosystem table.

Comparison of ES capacity by protected and non-protected areas

Indeed, differences were found between the supply of ES in PAs and NPAs, with PAs offering a markedly higher supply in the case of recreation and leisure - this was evident in four out of five PAs. The same held for pollination capacity, which was markedly higher in four PAs (TNP, PSJ, KP and KPG) and only lower in one (KLPD). Conversely, for forage provision, capacity was higher in only one PA compared to the NPA (KPLD), while it was lower in three out of five PAs (TNP, PSJ, KP) and not statistically significantly different in KPG. As there are relatively few studies explicitly comparing PAs and NPAs, it is quite difficult to compare our findings with those of other researchers. However, our findings were similar to those of Eastwood et al. (2016), who compared the delivery (not supply) of ES in PAs and similar NPAs using expert judgement and also found that the former generally deliver higher levels of ES, mainly cultural and regulating. Similarly, Spanò et al. (2017), who mapped the supply of ES in PAs and their surroundings, found that ES hotspots do tend to appear more in PAs, though trade-offs between different ES tend to occur. However, while it is possible to infer a positive relationship between protection status and ES supply (or delivery), it is difficult to assert that this is a result of protection and not the converse, without intertemporal comparison. In this respect, our findings are in line with some previous research like Yu et al. (2024), who indicate that PAs commonly enhance the provision of ES compared to NPAs. However, this is not always the case, as Buschke et al. (2023) show in their review of African studies. In line with our own findings, they demonstrated that opportunities for recreation and leisure are more frequent in PAs compared to NPAs.

Expert Attitudes and Policy Uptake: Challenges in Integrating the Ecosystem Services Concept for Protected Areas

Some stakeholders exhibited negative attitudes towards the concept of ES, revealing an understanding predominantly focused on species or habitats rather than on services provided by ecosystems. This divergence in perspectives suggests that certain stakeholders view ecosystems primarily through a conservation lens, potentially overlooking some ES.

Conservationists may be sceptical of the notion of ES due to value-based reservations regarding the commodification of nature (e.g. Berghöfer and Dudley (2010)). At the workshop presenting the study results, nature conservation practitioners pointed out that

the concept is already well-established in spatial management policies and is seen by decision-makers as a key link in balancing the needs of people and nature. However, they stressed the potential for misuse, underlining the need for nature conservationists to become acquainted with this communication tool and balance their misgivings with support for the ES concept. Furthermore, they did not consider their knowledge to be sufficient to address ES in a competent manner, but relied on the support of research institutions and ES specialists to implement ES in the context of nature conservation and to find its place in the nature conservation system.

Another point of contention for nature conservation experts was the consideration of different interests in land management, which is one of the most important elements of working with ES. They considered balancing different interests (especially those of 'capital') to be negative and believed most non-professionals to be ill-equipped to make decisions on land management due to a lack of knowledge about the importance of nature conservation. Conservationists, especially the PAs managers involved in the study, also often failed to see the utility of ES assessment and mapping for management, but rather perceived them as unnecessary additional work. However, their later testimonies showed that, having worked concretely with the ES concept in their PA, they had begun to better understand its rationale. They also acknowledged that work in this field is only nascent.

These findings largely coincide with explorations of attitudes of conservationists towards ES in the literature (e.g. Ainscough et al. (2019); Hermelingmeier and Nicholas 2017); Daněk et al. (2023)), which showed that conservation experts are often not familiar with the term, as well as concerns about potential misuse. However, the gradual increase in understanding and acceptance of the potential utility of ES demonstrates the concept's ability to act as a 'boundary object' for transdisciplinary communication (cf. Hermelingmeier and Nicholas (2017); Ainscough et al. (2019)).

Limitations

While the work presented in this paper is pioneering in terms of comparing ES in PAs and NPAs and engaging with PAs managers, it also has certain gaps. The first is related to the fact that, parallel to the work, we were developing and refining a process that was understood somewhat differently by different PAs. These different interpretations cause inconsistencies, such as the different sizes of the areas being selected for comparison, the lack of focused selection of pilot areas in the NPAs and, to some extent, the different stakeholders invited, possessing different interests, power and knowledge of ES. These inconsistencies were an entry point for bias, which is undoubtedly reflected later in the selection of relevant ES. It remains a challenge to avoid these biases and balance consistency with flexibility to account for local specificities. One way forward is undoubtedly a stricter, more specific protocol with clearer guidance and perhaps a reporting template as we tried to highlight in the published handbook for PAs managers (Vurunić et al. 2023). Another option to balance stakeholder voices is to weight different groups. On the other hand, participation of different groups across different areas is

always likely to be somewhat varied (e.g. certain groups such as cave explorers, hunters or fishermen may not appear at all in some areas) and such workshops are generally attended by those with the strongest interest. The best way forward is, therefore, probably ensuring a transparent process, preferably with several iterations.

Another limitation, which is related to ES assessment, is data scarcity. While this had already strongly influenced the choice of ES, we also had to resort to approximations and estimates. Furthermore, time constraints also affected our work, forcing us to limit ourselves to ES supply, while time was too short for a more comprehensive treatment of demand and use (flow) in the context of our study. The assessment of the three ES selected partly from the stakeholder rankings in the participatory workshops and partly, for reasons of data availability and feasibility, by mutual agreement at the panel meeting, provides only a partial picture of the ES in the PAs and NPAs. However, conducting the entire process as a 'proof of concept' was a major step forward for PAs and other participants in terms of understanding and better acceptance of the ES concept.

Conclusions

Based on the study presented here, three key conclusions can be drawn. **First**, we conclude that participation of the general and expert public in the selection, ranking, assessment and mapping of ES is possible and desirable, but not in all steps. Having worked with experts (representatives of PAs, the ZRSVN and the MNVP), we can conclude that the participation of such stakeholders is crucial for selecting and ranking relevant ES, for the expert assessment (knowledge of the specificities of their areas) and for the interpretation and implementation of results into the management of PA. However, the assessment itself through GIS modelling and mapping is too complex and will remain in the domain of researchers and GIS experts for the foreseeable future. This will become even more evident as we delve deeper into methods for assessing ES, analysing the condition of ecosystems and their capacity to provide ES and environmental accounting. In this context, we reiterate the need for a transparent and well-considered selection of stakeholders involved in the selection and assessment of ES and for investing effort in balancing the various biases that such work may entail.

Secondly, a comparison of the supply of the three assessed ES (forage provision, pollination, recreation and leisure) in PAs and NPAs showed that the capacity for ES provision is generally higher in PAs than in NPAs, with some exceptions that can be attributed to the specificities of the observed PAs/NPAs, but partly also to the research design and data/capacity limitations. Furthermore, these results might have been different if other or additional ES had been selected. This indicates the need for further research and refinement, but also underlines the need for better data and capacity in order to yield a fuller picture of differences in ES provision potential.

Thirdly, the lack of relevant indicators and geospatial data, especially for specific ecosystems (e.g. hedgerows), poses a major challenge for the assessment and mapping of ES. This lack makes it impossible to produce high quality and accurate assessments,

maps and other visualisation materials relevant for uptake into management. There is, therefore, a need to produce geospatial data for specific ecosystems. This is also related to the issue of the ES classification, which is both still evolving and too complex for most stakeholders to work with, necessitating simplifications for practical work, feasible indicators and standardisation.

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Conflicts of interest

The authors have declared that no competing interests exist.

References

- Ainscough J, Vries Lentsch A, Metzger M, Rounsevell M, Schröter M, Delbaere B, de Groot R, Staes J (2019) Navigating pluralism: Understanding perceptions of the ecosystem services concept. Ecosystem Services 36 https://doi.org/10.1016/j.ecoser.2019.01.004
- ARSO (2021) Okoljski kazalci - Zavarovana območja. https://kazalci.arso.gov.si/sl/content/zavarovana-obmocja-5
- ARSO (2023) Kazalci okolja v Sloveniji - Podatki o dnevnih povprečnih temperaturah. https://kazalci.arso.gov.si/sl
- Balvanera P, Pascual U, Christie M, González-Jiménez D (2022) Methodological assessment of the diverse values and valuation of nature of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Zenodo. https://doi.org/10.5281/ZENODO.6522522
- Barnaud C, De Longueville F, Gonella G, Antona M, Dendoncker N, Waylen KA (2023) Participatory research on ecosystem services in the face of disputed values and other uncertainties: A review. Ecosystem Services 63 https://doi.org/10.1016/j.ecoser.2023.101551

- Berghöfer A, Dudley N (2010) Chapter 7 Ecosystem services and protected areas. In: Ed. Wittmer H, et al. (Ed.) TEEB – The Economics of Ecosystems and Biodiversity for Local and Regional Policy Makers. URL: https://www.dffe.gov.za/sites/default/files/docs/economicsof_ecosystems_protectedareas.pdf
- Bidegain I, Cerda C, Catalán E, Tironi A, López-Santiago C (2019) Social preferences for ecosystem services in a biodiversity hotspot in South America. PLoS ONE 14 (4). https://doi.org/10.1371/journal.pone.0215715
- Brinkmann R, Garren SJ (2011) Karst and sustainability. Karst management361-378. https://doi.org/10.1007/978-94-007-1207-2_16
- Brown G, Fagerholm N (2015) Empirical PPGIS/PGIS mapping of ecosystem services: A review and evaluation. Ecosystem Services 13 https://doi.org/10.1016/j.ecoser.2014.10.007
- Burdon D, Potts T, McKinley E, Lew S, Shilland R, Gormley K, Thomson S, Forster R (2019) Expanding the role of participatory mapping to assess ecosystem service provision in local coastal environments. Ecosystem Services 39 https://doi.org/10.1016/j.ecoser.2019.101009.
- Buschke FT, Capitani C, Sow EH, Khaemba Y, Kaplin BA, Skowno A, Chiawo D, Hirsch T, Ellwood ER, Clements H, Child MF, Huber PR, Staden L, Hagenimana T, Killion AK, Mindje M, Mpakairi KS, Raymond M, Matlombe D, Mbeya D, Hase A (2023) Make global biodiversity information useful to national decision-makers. Nature Ecology Evolution 7 https://doi.org/10.1038/s41559-023-02226-2
- Costanza R (2020) Valuing natural capital and ecosystem services toward the goals of efficiency, fairness, and sustainability. Ecosystem Services 43 https://doi.org/10.1016/j.ecoser.2020.101096
- Damastuti E, de Groot R (2019) Participatory ecosystem service mapping to enhance community-based mangrove rehabilitation and management in Demak, Indonesia. Regional Environmental Change 19 https://doi.org/10.1007/s10113-018-1378-7
- Daněk J, Blättler L, Leventon J, Vačkářová D (2023) Beyond nature conservation? Perceived benefits and role of the ecosystem services framework in protected landscape areas in the Czech Republic. Ecosystem Services 59 https://doi.org/10.1016/j.ecoser.2022.101504
- Doak DF, Bakker VJ, Goldstein BE, Hale B (2014) What is the future of conservation? Trends in Ecology & Evolution 29 (2). https://doi.org/10.1016/j.tree.2013.10.013
- Eastwood A, Brooker R, Irvine RJ, Artz RR, Norton LR, Bullock JM, Ross L, Fielding D, Ramsay S, Roberts J, Anderson W, Dugan D, Cooksley S, Pakeman RJ (2016) Does nature conservation enhance ecosystem services delivery? Ecosystem Services 17 https://doi.org/10.1016/j.ecoser.2015.12.001
- EEA (2018) CICES - towards a common classification of ecosystem services (V5.1 ed.).
- Egger G, Angermann K, Aigner S, Buchgraber K (2004) GIS-gestützte Ertragsmodellierung zur Optimierung des Weidemanagements auf Almweiden. BAL-Bundesanst. für Alpenländ. Landwirtschaft Gumpenstein
- Fagerholm N, Käyhkö N, Ndumbaro F, Khamis M (2012) Community stakeholders' knowledge in landscape assessments–Mapping indicators for landscape services. Ecological Indicators 18 https://doi.org/10.1016/j.ecolind.2011.12.004
- Fisher J, Brown K (2014) Ecosystem services concepts and approaches in conservation: Just a rhetorical tool? Ecological Economics 108: 257-265. https://doi.org/10.1016/j.ecolecon.2014.11.004

- Gams I (2003) Kras v Sloveniji v prostoru in času [druga pregledana izdaja]. Založba ZRC
- García-Llorente M, Harrison PA, Berry P, Palomo I, Gómez-Baggethun E, Iniesta-Arandia I, Montes C, García Del Amo D, Martín-López B (2018) What can conservation strategies learn from the ecosystem services approach? Insights from ecosystem assessments in two Spanish protected areas. Biodiversity and Conservation 27 (7): 1575-1597. https://doi.org/10.1007/s10531-016-1152-4
- Haines-Young R, Potschin M (2010) The links between biodiversity, ecosystem services and human well-being. In: Eds: Raffaelli D, et al. (Ed.) Ecosystem Ecology: A New Synthesis. URL: https://www.cambridge.org/core/books/ecosystem-ecology/links-between-biodiversity-ecosystem-services-and-human-wellbeing/8F8375D46446640DB8216348A4BA296D [ISBN 978-0-521-51349-4].
- Hermelingmeier V, Nicholas KA (2017) Identifying Five Different Perspectives on the Ecosystem Services Concept Using Q Methodology. Ecological Economics 136 https://doi.org/10.1016/j.ecolecon.2017.01.006
- Hummel C, Poursanidis D, Orenstein D, Elliott M, Adamescu MC, Cazacu C, Ziv G, Chrysoulakis N, van der Meer J, Hummel H (2019) Protected Area management: Fusion and confusion with the ecosystem services approach. Science of the Total Environment 651: 2432-2443. https://doi.org/10.1016/j.scitotenv.2018.10.033
- Jäger H (2017) Mapping of supply and demand of biomass from alpine grassland. Technical University of Munich, Munich.
- Jax K, Furman E, Saarikoski H, Barton D, Delbaere B, Dick J, Duke G, Görg C, Gómez-Baggethun E, Harrison P, Maes J, Pérez-Soba M, Saarela S, Turkelboom F, van Dijk J, Watt A (2018) Handling a messy world: Lessons learned when trying to make the ecosystem services concept operational. Ecosystem Services 29: 415-427. https://doi.org/10.1016/j.ecoser.2017.08.001
- Langemeyer J, Palomo I, Baraibar S, Gómez-Baggethun E (2018) Participatory multi-criteria decision aid: Operationalizing an integrated assessment of ecosystem services. Ecosystem Services 30, Part A https://doi.org/10.1016/j.ecoser.2018.01.012.
- Leemans R, Groot R (2003) Millennium Ecosystem Assessment: Ecosystems and human well-being: A framework for assessment. Island press
- Maes J, Teller A, Erhard M, Liquete C, Braat L, Berry P, Egoh B, Puydarrieux P, Fiorina C, Santos F (2013) Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5: 1-58. https://doi.org/10.2779/12398
- Marta-Pedroso C, Laporta L, Gama I, Domingos T (2018) Economic valuation and mapping of Ecosystem Services in the context of protected area management (Natural Park of Serra de São Mamede, Portugal). One Ecosystem 3 https://doi.org/10.3897/oneeco.3.e26722
- Millenium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Synthesis. Island Press, Washington DC.
- MKGP (2023) Land Use Database. URL: https://podatki.gov.si/dataset/evidenca-
- Naravni parki Slovenije (2023) https://www.naravniparkislovenije.si/slo/naravni-parki
- Natura 2000 v Sloveniji (2024) https://natura2000.gov.si/natura-2000/natura-2000-v-sloveniji/

- Norgaard RB (2010) Ecosystem services: From eye-opening metaphor to complexity blinder. Ecological Economics 69 (6): 1219-1227. https://doi.org/10.1016/j.ecolecon.2009.11.009
- Nyaupane GP, Poudel S, York A (2022) Governance of protected areas: an institutional analysis of conservation, community livelihood, and tourism outcomes. Journal of Sustainable Tourism 30 (11): 2686-2705. https://doi.org/10.1080/09669582.2020.1858089
- Palomo I, Martín-López B, Potschin M, Haines-Young R, Montes C (2013) National Parks, buffer zones and surrounding lands: Mapping ecosystem service flows. Special Issue on Mapping and Modelling Ecosystem Services 4: 104-116. https://doi.org/10.1016/j.ecoser.2012.09.001
- Palomo I, Martin-Lopez B, Zorrilla-Miras P, Garcia Del Amo D, Montes C (2014) Deliberative mapping of ecosystem services within and around Donana National Park (SW Spain) in relation to land use change. REGIONAL ENVIRONMENTAL CHANGE 14 (1, SI): 237-251. https://doi.org/10.1007/s10113-013-0488-5
- Palomo I, Willemen L, Drakou E, Burkhard B, Crossman N, Bellamy C, Burkhard K, Campagne CS, Dangol A, Franke J (2018) Practical solutions for bottlenecks in ecosystem services mapping. One Ecosystem 3.
- Paracchini ML, Zulian G, Kopperoinen L, Maes J, Schägner JP, Termansen M, Zandersen M, Perez-Soba M, Scholefield P, Bidoglio G (2014) Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. Ecological Indicators 45: 371-385. https://doi.org/10.1016/j.ecolind.2014.04.018
- Pu X, Ding W, Ye W, Nan X, Lu R (2023) Ecosystem service research in protected areas: A systematic review of the literature on current practices and future prospects. Ecological Indicators 154: 110817. https://doi.org/10.1016/j.ecolind.2023.110817
- Ramirez-Gomez SI, Torres-Vitolas C, Schreckenberg K, Honzák M, Cruz-Garcia G, Willcock S, Palacios E, Pérez-Miñana E, Verweij P, Poppy G (2015) Analysis of ecosystem services provision in the Colombian Amazon using participatory research and mapping techniques. Ecosystem Services 13: 93-107. https://doi.org/10.1016/j.ecoser.2014.12.009
- Ribeiro D, Šmid Hribar M (2019) Assessment of land-use changes and their impacts on ecosystem services in two Slovenian rural landscapes. Acta geographica Slovenica 59 (2): 143-160.
- Riley SJ, DeGloria SD, Elliot R (1999) A terrain ruggedness index that quantifies topographic heterogeneity. intermountain Journal of sciences 5 (1-4): 23-27.
- Sagoe AA, Aheto DW, Okyere I, Adade R, Odoi J (2021) Community participation in assessment of fisheries related ecosystem services towards the establishment of marine protected area in the Greater Cape Three Points area in Ghana. Marine Policy 124 https://doi.org/10.1016/j.marpol.2020.104336
- Schirpke U, Marino D, Marucci A, Palmieri M, Scolozzi R (2017) Operationalising ecosystem services for effective management of protected areas: Experiences and challenges. Ecosystem Services 28: 105-114. https://doi.org/10.1016/j.ecoser.2017.10.009
- Šmid Hribar M, Japelj A, Vurunić S (2021) Systematic mapping of studies on ecosystem services in Slovenia. *Geographical Bulletin* 93 (1): 9-62. [In english, slovenian]. https://doi.org/10.3986/GV93101

- Smrekar A, Polajnar Horvat K, Ribeiro D (2023) Institucionalni okvir ohranjanja narave v Sloveniji = Institutional framework of nature conservation in Slovenia. Geografija v šoli 2 (3): 9-21. [In slovenian]. https://doi.org/10.59132/geo/2023/2-3/9-21
- Spanò M, Leronni V, Lafortezza R, Gentile F (2017) Are ecosystem service hotspots located in protected areas? Results from a study in Southern Italy. Environmental Science & Policy 73 https://doi.org/10.1016/j.envsci.2017.04.008
- Steinhardt U, Herzog F, Lausch A, Müller E, Lehmann S (1999) 16 The Hemeroby Index for Landscape Monitoring and Evaluation. Environmental indices: systems analysis approach.
- Villamor GB, Palomo I, Santiago CA, Oteros-Rozas E, Hill J (2014) Assessing stakeholders' perceptions and values towards social-ecological systems using participatory methods. Ecological Processes 3 (1). https://doi.org/10.1186/s13717-014-0022-9
- Vurunić S, Japelj A, Šmid Hribar M, Rac I (2023) Priročnik za identifikacijo in kartiranje ekosistemskih storitev: NatGuidES - identifikacija, ovrednotenje in kartiranje ekosistemskih storitev naravovarstveno pomembnejših območij v Sloveniji. 1. e-izd.. Založba ZRC, Ljubljana. https://doi.org/10.3986/9789610507987
- Walther F, Barton DN, Schwaab J, Kato-Huerta J, Immerzeel B, Adamescu M, Andersen E, Arámbula Coyote MV, Arany I, Balzan M, Bruggeman A, Carvalho-Santos C, Cazacu C, Geneletti D, Giuca R, Inácio M, Lagabrielle E, Lange S, Le Clec'h S, Lim ZYV, Mörtberg U, Nedkov S, Portela AP, Porucznik A, Racoviceanu T, Rendón P, Ribeiro D, Seguin J, Šmid Hribar M, Stoycheva V, Vejre H, Zoumides C, Grêt-Regamey A (2025) Uncertainties in ecosystem services assessments and their implications for decision support - A semi-systematic literature review. Ecosystem Services 73 https://doi.org/10.1016/j.ecoser.2025.101714.
- Yu C, Zhang z, Jeppesen E, Gao Y, Liu Y, Liu Y, Lu Q, Wang C, Sun X (2024) Assessment of the effectiveness of China's protected areas in enhancing ecosystem services. Ecosystem Services 65 https://doi.org/10.1016/j.ecoser.2023.101588.
- Žužek D (2007) Trajnostni razvoj turizma na Solčavskem: diplomska naloga. Univerza na Primorskem, Fakulteta za turistične študije-Turistica, Portorož.

Supplementary materials

Suppl. material 1: Appendix 1 doi

Authors: Japelj, A., Vurunic, S.
Data type: table
Brief description: Adapted and translated set of the CICES 5.1 classification and the original English version with codes.
Download file (26.39 kb)

Suppl. material 2: Appendix 2 doi

Authors: NatGuidES project
Data type: table
Brief description: Ecosystem types for identification, assessment and mapping of ES in Slovenia used in the NatGuidES project.
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Suppl. material 3: Stakeholder selection doi

Authors: Šmid Hribar, M.
Data type: 28. 8. 2025
Brief description: Stakeholder selection and ranking of ecosystem services (ES) in PAs and NPAs (participatory workshops).
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