UDC: 911.372.7:502/504
doi:10.5379/urbani-izziv-en-2024-35-01-06

Received: 5 April 2024
Accepted: 27 May 2024

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Assessing cultural ecosystem service potential for green infrastructure planning in a peri-urban landscape: An expert-based matrix approach

With the encroachment of urban areas into peri-urban landscapes, the requirement for effective green infrastructure (GI) planning has become increasingly important for maintaining ecological integrity and human wellbeing. An expert-based matrix approach is proposed as a method for evaluating the potential of cultural ecosystem services (CES) in making informed GI planning decisions in a peri-urban landscape. Experts from various disciplines and areas of work were consulted to systematically evaluate various types of land-use and land-cover classes, as well as protection regimes characteristic of a peri-urban landscape across the CES categories. In addition to CES provision potential, experts also evaluated the possible potential to cause cultural ecosystem disservices. These scores are aggregated to generate spatially explicit maps that highlight areas with high CES provision potential and those with the potential to cause disservices. This approach was then applied to three case study areas, demonstrating its effectiveness in identifying priority areas for GI planning and management interventions. The results highlight the importance of integrating CES considerations into GI planning processes to enhance landscape resilience, social wellbeing, and cultural heritage preservation in dynamic peri-urban environments. Using scoring, validation exercises, and spatially explicit presentation on case studies, the utility and applicability of the expert-based matrix approach as a valuable tool for sustainable GI planning on a landscape scale is demonstrated.

Keywords: peri-urban landscape, spatial planning, ecosystem services, green infrastructure, matrix

1 Introduction

Recently, ecosystem services (ES) have attracted considerable attention in the realm of environmental science and policy-making, and they are serving as a fundamental framework for determining the intricate linkages between natural systems and human wellbeing. ES encompass the diverse benefits that ecosystems provide to society, ranging from the provisioning of clean water and food to the regulation of climate and disease (MEA, 2005; TEEB, 2008). Thus, the understanding and value of ES have become imperative for sustainable development and effective decision-making (Fürst et al., 2017). Land-use decisions have considerable implications for ecosystem functioning, biodiversity conservation, and human wellbeing. Historically, however, land-use planning has been sectoral and fragmented, failing to account for the multifunctionality and interconnectedness of ecosystems. Many researchers have been focusing on the importance of understanding, acknowledging, and mapping the spatial distribution of ES offered by landscapes for adaptive land-use management and ensuring a holistic and integrative approach to decision-making (De Groot et al., 2010; Haines-Young & Potschin, 2018; Müller et al., 2020). Therefore, decisionmakers can better assess trade-offs, identify synergies, and promote more sustainable land-use practices (Turner et al., 2007).

Furthermore, for effective planning and management, the spatial dimension of ES is important. ES are inherently spatially explicit, with their distribution influenced by factors such as land cover, land use, topography, and hydrology. Spatially explicit mapping and modelling of ES enable planners to identify priority areas for conservation, restoration, and sustainable development, thereby optimizing the delivery of ES across landscapes (Maes et al., 2012). In terms of the spatial explicitness of ES, however, the problem particularly arises in addressing the category of cultural ecosystem services (CES). CES are the non-material benefits that people obtain from ecosystems, including recreational, aesthetic, spiritual, and educational values. These services are extensively intertwined with human cultures, traditions, and identities, playing a crucial role in shaping social values and behaviours (MEA, 2005). CES are often intangible and difficult to quantify, which makes them susceptible to undervaluation and neglect in decision-making processes. Hernández-Morcillo et al. (2013) reported that only 23% of CES studies included an explicit spatial representation. It is especially worrying that the incorporation of ES issues into landscape planning and decision-making focuses on explicit quantification and mapping (Casado-Arzuaga et al., 2014). Such incorporation of CES fails because of their perceived intangible or subjective nature, or because they are challenging to quantify (MEA, 2005; De Groot et al., 2010; Chan et al., 2011; La Rosa et al., 2018). Despite the growing recognition of CES, challenges remain in effectively incorporating these services into land-use management and spatial planning frameworks. Similarly, in Slovenia, although the significance of CES is acknowledged in certain national and regional documents and has been a topic of a few recent studies (e.g., Ribeiro & Hribar, 2019; Kostanjšek & Golobič, 2023), they are not explicitly accounted for in any national, regional, or local regulations, potentially leading to inappropriate planning decisions (Žlender, 2021b). Therefore, it is essential to explore methods of quantifying and validating CES to capture issues that cannot be easily mapped. The mapping of CES has been strongly encouraged by many EU policies (European Environmental Agency, 2014; European Commission, 2013, 2020).

This study focuses on a peri-urban landscape, a transitional zone between urban and rural areas characterized by dynamic land-cover patterns and multifunctional areas (Žlender, 2021a, 2021b). In a peri-urban context, CES often manifest through the presence of green infrastructure (GI), comprising natural and semi-natural elements such as parks, forests, wetlands, and green corridors, which contribute to the local identity, sense of place, and community cohesion (Daniel et al., 2012). The European Commission (2013) has recognized GI as a smart solution for providing people and societies with a broad range of goods and services. Therefore, there is growing recognition of the requirement for more integrative and ecosystem-based approaches for land-use management and spatial planning in a peri-urban landscape, with a particular emphasis on maximizing the potential of GI to deliver multiple (C)ESs.

Amid urban expansion and land development pressure, the challenge is in effectively mapping and quantifying CES for informed decision-making and ensuring GI preservation. By integrating CES mapping into planning processes, decision-makers can identify priority areas for conservation, design culturally sensitive interventions, and engage stakeholders in collaborative decision-making (La Rosa et al., 2016; Spyra et al., 2020). Furthermore, to determine policy interventions and investment priorities, CES mapping can facilitate the development of innovative planning tools, such as CES indicators and valuation methods. Consequently, there is a pressing need to develop robust methodologies for characterizing and evaluating peri-urban landscapes, particularly in terms of their CES, as reported by Geneletti et al. (2017). Recently, there has been considerable interest in advancing the understanding of CES in a peri-urban landscape, and the number of CES mapping methods has increased (see, e.g., Plieninger et al., 2013; Roy et al., 2014; Zhang & Muñoz Ramírez, 2019). Moreover, the land cover-based approach is widely used; it is a quantitative assessment of the supply capacity of ES in a specific land-cover type, as proposed by Burkhard et al. (2009). This may be attributed

to its rapid assessment procedure with clear benefits for the decision-making process and low requirements for input data (Zhang & Muñoz Ramírez, 2019). Therefore, this approach is used to assess CES provision potential.

Using an expert participatory approach, the aim is 1) to systematically assess the CES potential associated with different land-cover types and protection regimes in selected peri-urban areas of Slovenia and 2) to provide certain insights into assessing GI based on the CES provision potential. In terms of the method, its usefulness is assessed in achieving the aims and present advantages, challenges, and possibilities for improving the method. The research aims are addressed based on the following research question: How can the expert-based matrix approach support GI planning in a multifunctional peri-urban landscape to provide and sustain CES?

The following sections of this article elaborate the methodology employed for data collection, analysis, and interpretation, in addition to discussing the implications of the results for urban planning and landscape management. This study is part of a larger research project aiming to set up a valuation framework for landscape planning and policy for CES in a peri-urban landscape.

2 Materials and methods

2.1 Study areas

Ljubljana, Kranj, and Koper were selected because they have all been previously identified as having experienced peri-urbanization. Ljubljana, the capital and largest city of Slovenia, has been facing peri-urbanization owing to inward migration, resulting in a demand for new housing and the expansion of economic activities and infrastructure on the city's urban edge. The city region has been at risk of extensive development and other negative consequences of urbanization and peri-urbanization because of a lack of comprehensive planning (Pichler-Milanović, 2002). To some extent, this has been curbed after Slovenia joined the European Union and adopted its planning programmes and, specifically for the municipality of Ljubljana, since it was adopted a comprehensive spatial plan of the Municipality of Ljubljana (Šašek Divjak, 2008; Sviršić Gotovac et al., 2021). Kranj and Koper, both medium-sized Slovenian towns with historical city centres, experienced (sub) urban growth after the mid-twentieth century. Although considerably smaller than Ljubljana, they are regional hubs and important economic, cultural, and social centres. Both Kranj and Koper are encountering pressures for housing and infrastructure development because agricultural land is primarily impacted (Nilsson et al., 2013; Spyra et al., 2021). Moreover, all three cities have been the focus of many projects investigating peri-urban issues (for further details, see Piorr et al., 2011; Žlender, 2021a; Interreg Europe, 2023).

A distinct methodology was used to define the borders of a peri-urban landscape for each case study. More information on this and on the characteristics of the areas can be found in Žlender and Brišnik (2023). Figure 1 shows the designation of the current land-use and land-cover distribution and protection regimes.

2.2 Selection of CES

Recognizing the importance of CES in shaping human interactions with the landscape and being central to the overall wellbeing of humans, many classification systems have been proposed to categorize these services, notably the Millennium Ecosystem Assessment (MEA 2005), the Common International Classification of Ecosystem Services (CICES) (Haines-Young & Potschin, 2018), and The Economics of Ecosystems and Biodiversity initiative (TEEB, 2008). However, the lack of uniformity across these classification systems is a challenge, leading to the fragmentation and non-unitary categorization of CES, which is also reflected in the policy guidance (Hirons et al., 2016). While selecting the distinctive categories of CES for this study, many important considerations were made to ensure comprehensive coverage and relevance to peri-urban contexts. In addition to alignment with the methodological purpose of this study, the characteristics of a peri-urban landscape were considered as an interface between urban and rural settings, which led to unique cultural dynamics, necessitating a more refined understanding of CES that reflects the specific contexts and requirements of these environments. Table 1 shows the reasons for selecting the distinctive categories.

Ecosystems yield benefits but also incur inconveniences, such as pests, infrastructure degradation, diseases, and allergens, termed ecosystem disservices. These include human-induced degradation and negative effects from intact ecosystems that impact human wellbeing. Cultural ecosystem disservices are responsible for non-material harm from ecosystems, whether natural (e.g., discomfort from wildlife) or anthropogenic (e.g., ecosystem damage; Plieninger et al., 2013). Assessment of disservices is an intricate issue because a function may be considered both a service and a disservice based on the context and value. Owing to the diverse peri-urban landscapes, three disservices were included in this study (Table 1).

2.3 Defining themes

In the method proposed by Burkhard et al. (2009), the division of land-use and land-cover classes serves as a fundamental step

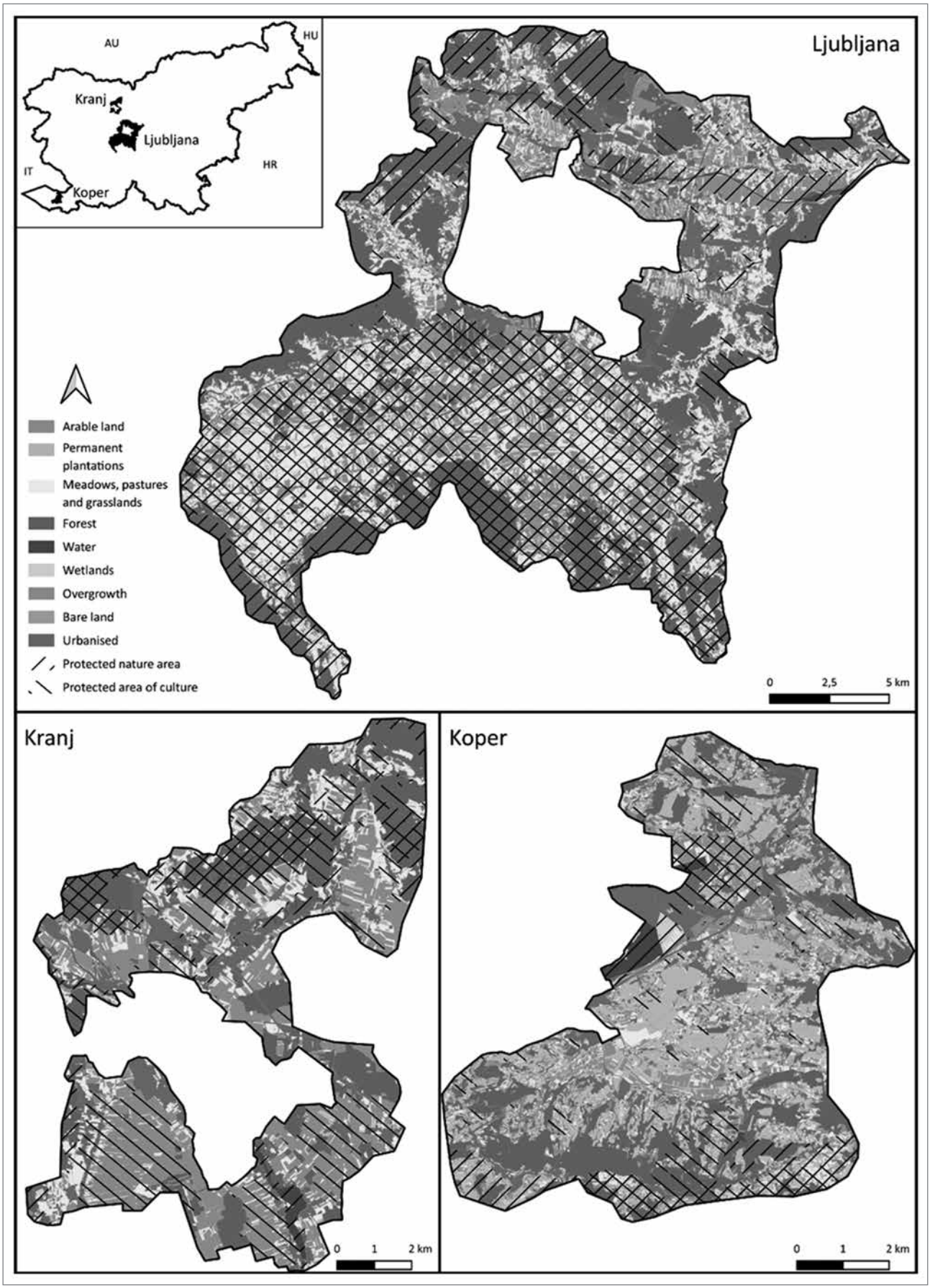

Figure 1: Land-use, land-cover, and protection regimes in the peri-urban landscape of the cases studied (illustration: Rok Brišnik, based on official and open-source databases).

Table 1: Information on CES used in this study.

No.	Category	Description	Reason for selection
Cultural ecosystem services (CES)			
1	Leisure and recreation activities	Such activities refer to walking, hiking, cycling, climbing, relaxing, enjoying attractive views, and escaping from stress in the peri-urban landscape.	Peri-urban landscapes often serve as vital recreational spaces for nearby urban populations. This category acknowledges the importance of leisure activities in enhancing human wellbeing and fostering a connection to nature in a peri-urban landscape.
2	Sense of place and identity	Sense of place (*genius loci*) refers to natural and built elements that are part of the ecosystem and encourage a complex emotional bond between people and place such as attachment, belonging, and identity.	A peri-urban landscape typically exhibits a unique blend of urban and rural characteristics, contributing to a distinct sense of place and local identity. Exploring this category allows for an understanding of how individuals perceive and relate to their surroundings, thereby influencing community cohesion and attachment to the landscape.
3	Aesthetic value	Aesthetic value is the interaction of people with the environment in relation to natural beauty based on human perceptions and evaluations.	The aesthetic qualities of peri-urban landscapes shape public perceptions and preferences; examining these values helps identify visual aspects that enhance landscape appreciation.
4	Source of inspiration	A source of inspiration for providing new thoughts, ideas, and creative expression	Understanding the inspirational qualities of peri-urban landscapes can provide insights into the cultural significance and symbolic meanings attributed to them by different social groups.
5	Social relations	Providing a place to hang out with friends and family, and facilitating social interactions and community engagement	This category emphasizes the role of the landscape in fostering social cohesion, recreational gatherings, and cultural events, thereby promoting social wellbeing and inclusivity.
6	Spiritual and religious services	These are spiritual experiences, religious ceremonies, and religious community events.	Investigating this category sheds light on the spiritual connections and cultural practices associated with peri-urban landscapes, underscoring their importance beyond ecological and recreational values.
7	Educational resource	Refers to the acquisition of various types of knowledge developed by various cultures; for example, traditional and expert knowledge that comes from living in a certain area.	Peri-urban landscapes provide educational opportunities in ecology, agriculture, history, and traditional land uses, serve as outdoor classrooms for experiential learning, and thus foster environmental literacy for children and adults.
8	Research resource	Providing biodiversity research about the flora and fauna of the area	Peri-urban landscapes offer research opportunities in ecological processes, land-use dynamics, and human-environment interactions. Viewing them as research resources highlights their scientific value.
9	Cultural significance	Refers to the contribution to the diversity of the landscape (cultural landscape) or to landscape-specific plant and animal species.	Peri-urban landscapes hold cultural heritage, stories, and traditions. Recognizing their cultural significance is key to promoting conservation amid urbanization pressures.
Cultural ecosystem disservices			
10	Noise	Refers to noise of any origin (e.g., traffic noise, industrial activities, agricultural machinery, wildlife calls).	Excessive noise pollution negatively impacts health, wellbeing, and quality of life. Studying noise as a disservice reveals its sources, impacts, and mitigation strategies. Effective noise management in peri-urban areas promotes a healthier acoustic environment for residents.
11	Danger	The source of danger can be nature (e.g., the presence of certain animals or plants) or human activity (e.g., neglect or degradation of ecosystems).	Assessing danger in these areas offers insights into risk perception and management strategies. Understanding danger is crucial for public safety and accident prevention.
12	Unpleasantness	The source of the unpleasant feeling can be nature (e.g., the presence of certain animals or plants) or human activity (e.g. neglect or degradation of ecosystems).	Unpleasantness affects sensory experiences and detracts from peri-urban landscape enjoyment. Identifying sources of unpleasantness is key to landscape enhancement and beautification. Addressing unpleasantness can lead to sensory restoration and a more positive environment. Improved landscapes enhance satisfaction and wellbeing for residents and visitors.

Table 2: List of themes and their descriptions.

No.	Theme	Description
1	Arable land	Areas for agriculture, constantly tilled surface without permanent plantations (e.g., fields)
2	Permanent plantations	Areas covered by perennial crops such as greenhouses, vineyards, orchards, olive groves
3	Meadows, pastures, grasslands	Areas used for mowing and grazing
4	Forest	Areas covered by forest
5	Water	Natural and artificial surface waters (rivers, lakes, sea)
6	Wetlands	Bogs, wetlands, salt marshes
7	Overgrowth	Areas overgrown with forest trees
8	Bare land	Undeveloped mostly natural land with little or no vegetation (beaches, dunes, gravel areas, scree)
9	Transport infrastructure	Roads (highways, main roads, parking), railways, airports, ports
10	Public infrastructure	Energy production areas (power plants of all kinds), waste management areas, power lines, etc.
11	Brownfield	Degraded, abandoned, and anthropogenically exposed areas (sand pits, mines)
12	Exclusive use	Non-residential large built-up areas for exclusive use (industrial, logistics, military areas)
13	Wider use	Non-residential large built-up areas for wider use (campuses, shopping centres, hospitals)
14	Green space	Maintained green areas and associated infrastructure for public use (parks, children's playgrounds, leisure facilities, hiking/cycle paths)
15	Sport and tourism	Maintained green areas and associated infrastructure for sports and tourism (stadiums, golf courses, racecourses, camp sites)
16	Residential	Areas of predominantly residential houses and/or residential-agricultural compounds
17	Mixed-use areas	Areas of predominately mixed-use (housing, public services, shops, tourism, etc.)
18	Nature conservation	Areas under nature protection of national or wider importance (Natura 2000, landscape parks, etc.)
19	Cultural landscapes	Historically and culturally important landscapes and their parts, such as archaeological sites, heritage, monuments, outstanding landscapes
20	Cultural heritage settlements	Culturally valuable settlements and their parts (historical village cores, traditional village patterns)

in a land cover-based approach for the quantitative assessment of the (C)ES provision capacity. However, because the objective was to assess GI based on the CES provision potential and due to the spatial scale of the study, additional categories were included to focus on areas that are high in biodiversity and enhance CES provision for people's benefit (Kopperoinen et al., 2014). In addition to land-use and land-cover classes, nature and cultural protection regimes were also included, and urban land use was divided into various subclasses.

This classification provided insights into the spatial distribution and composition of various landscape elements, identifying areas of ecological significance, connectivity, and potential GI opportunities. In addition, in the selection of datasets, an attempt was made to capture the specific characteristics of the peri-urban landscape, such as the mix of urban and rural land uses, intermingling of built and unbuilt areas, and the presence of specific land uses, such as waste and sewage treatment plants and logistic centres.

While selecting GIS datasets, focus was placed on the most recent and openly accessible spatial data. For selecting data sources, there was an effort to use formally valid datasets; however, due to the lack of some information, data from OpenStreetMap (2023) were also used. A combination of various GIS datasets representing related geographic features or phenomena was then grouped into themes (Kopperoinen et al., 2014) (e.g., all hydrological layers were combined into a single "Water" layer), which made it possible to consolidate data from different sources, simplified the complexity of the datasets, and facilitated the spatial analysis of similar data. The expression *theme* is used hereafter. The classification of themes was first tested by a few experts. Based on their feedback, the number of categories and their descriptions with examples was adjusted to create a final list of twenty themes, which were considered representative for describing various aspects of CES provision potential (Table 2). The complete list of data used for each theme is available from the author.

2.4 Scoring methodology and expert selection

A matrix of themes and CES was created, for which respondents had to evaluate 240 attributions by answering the following questions: *How does a theme contribute to the creation of spatial conditions for provision of a CES in the peri-urban landscape? How does a theme contribute to creating the spatial conditions for causing a disservice in the peri-urban landscape?* The scoring system for CES was then adapted from Kopperoinen et al. (2014), who proposed a scale assessing the effect of each theme on the prerequisites for the provision potential of each CES: 3 = very favourable, 2 = favourable, 1 = slightly favourable, 0 = no or neutral effect, −1 = slightly harmful, −2 = harmful, and −3 = very harmful. A scale was developed for disservices to measure the effect of each theme on a cultural ecosystem disservice: 3 = greatly prevents, 2 = prevents, 1 = slightly prevents, 0 = no effect or neutral, −1 = somewhat contributes, −2 = contributes, −3 = greatly contributes. Assessing the contribution to the creation of spatial conditions for the provision of each CES category in the peri-urban landscape rather than the ES supply is extremely important for planning, management, and research because they are hypothetically conceptualized for a long time period (Syrbe et al., 2017). In this manner, the hypothetical maximum, rather than the actual supply of a given CES, is measured. Following the advice of Campagne and Roche (2018), the matrix also included the scoring of confidence on a three-level scale: "I feel confident with my score," "I feel fairly confident with my score," and "I don't feel confident with my score." Contact was established with experts from various subject areas in dealing with space in different ways, such as planning, protection, management, and decision-making. They were informed about the intentions and asked for consent to send them an online questionnaire with a valuation matrix and five additional questions to answer.

2.5 Processing and analysing the data

We determined for each theme its provision potential for each CES by computing the weighted mean of experts' scores. Weights have been assigned according to the experts' declared confidence level (weight=1 if the expert selected 'I feel confident with my score', 0.75 for 'I feel fairly confident with my score' and 0.5 for 'I don't feel confident with my score')

The resulting values were, together with themes, applied as attribute values on a 100 m × 100 m grid (for more details on the procedure, see Žlender & Brišnik, 2023). A spatial aggregation analysis was performed using QGIS Desktop version 3.28. Maps were produced showing the potential for providing CES and causing disservices. Then, the cell values were normalized at intervals of 0.85 on a scale from −3 to 3 to treat each CES or disservice as equally important when aggregating them into joint layers for CES provision potential and potential to cause disservices. To determine the similarity between the cultural ecosystem service or disservice and themes, hierarchical cluster analysis (HCA) was performed along with heatmap and dendrogram visualizations. To define the similarity between clusters, the average linkage and Euclidean distance were applied. A statistical analysis was then conducted using SPSS 29.0 and Python with Seaborn.

3 Results

3.1 General overview of the data analysed

Twenty-five experts completed the matrix: of these, nineteen worked in research, nine in spatial planning practice, six in higher education, three in decision-making, three in land management, and one in implementation. They were highly educated in landscape architecture and spatial planning (n = 12), architecture and urban planning (n = 3), forestry (n = 3), agronomy and natural resources (n = 2), nature protection (n = 2), geography (n = 2), and biology (n = 1). Their current areas of work varied extensively and included environmental, infrastructure, traffic, urban and spatial planning, remote sensing, forest hydrology, landscape architecture, nature protection, paedology, regional development, strategic spatial planning, landscape typology, landscape assessment, urban forestry, and landscape valuation and management. Eighteen of these experts had already used the concept of ES in their work, and most of them (n = 13) became familiar with ES between 2011 and 2019. Three experts were familiar with the concept before this period, five after 2019, and four of them were not familiar with the concept.

At the end of the questionnaire, the experts provided additional comments. Most of them commented that the matrix was too long and the scoring was too subjective. They considered that the CES and especially the disservices did not allow an unequivocal answer for scoring. In scoring disservices, many inconsistencies were detected when analysing the data. There were uncertainties about whether they were supposed to score the themes per se or their influence on people. The opinions for scoring confidence levels were split, along with the opinions on whether there should be a greater or fewer number of themes. One expert suggested that an option to select "I don't know" should be provided. All comments were considered for the final evaluation of the approach.

3.2 CES provision potential based on evaluated themes

First, the means for the CES-theme and disservice-theme pairs were examined. In this section, for better understanding of the

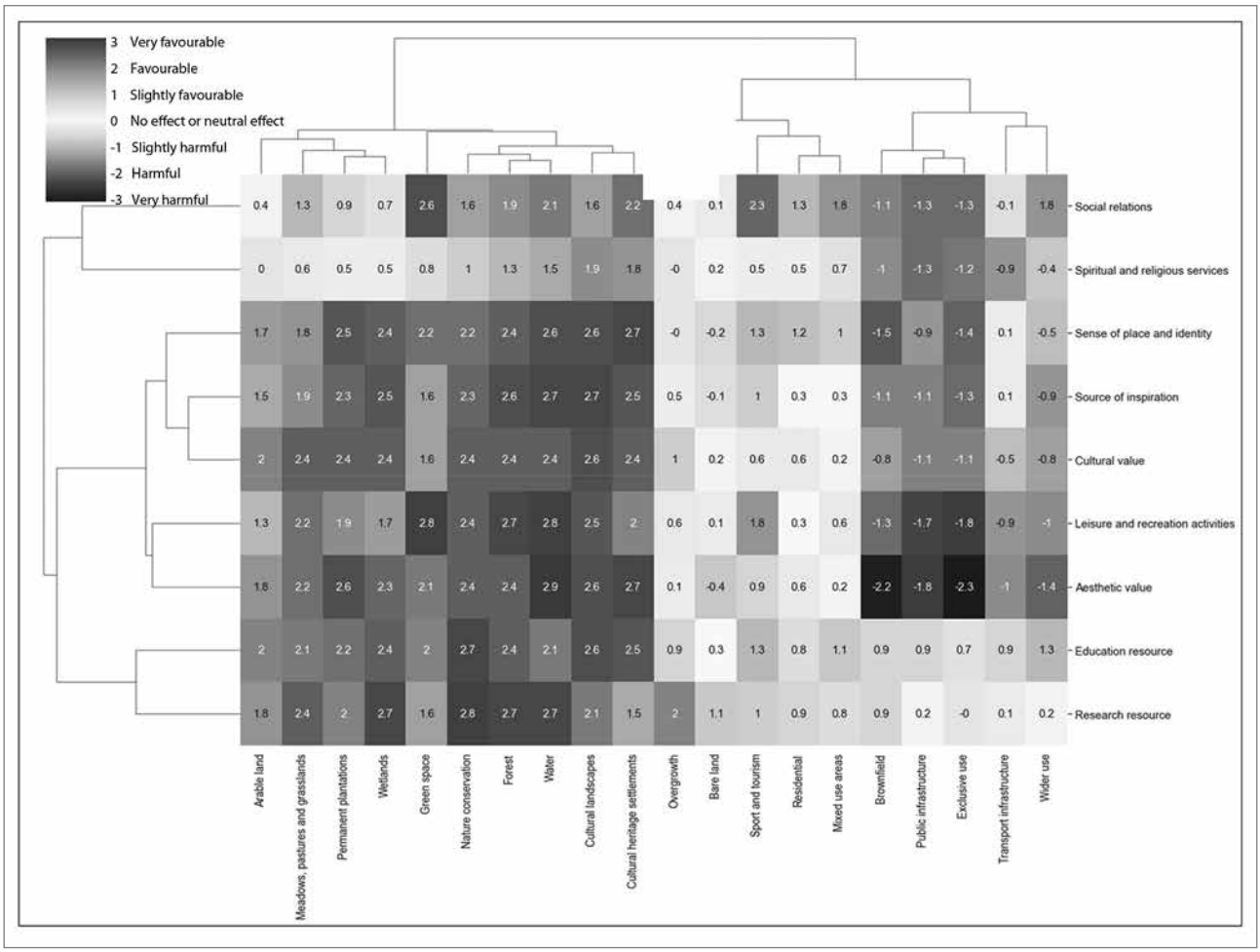

Figure 2: HCA with heatmap and dendrogram visualizations, illustrating clustering of themes in columns and CES in rows. Each cell presents the aggregated mean score of the experts, weighted with their confidence level and coloured according to the scale (illustration: Vita Žlender and Stefano Gemin).

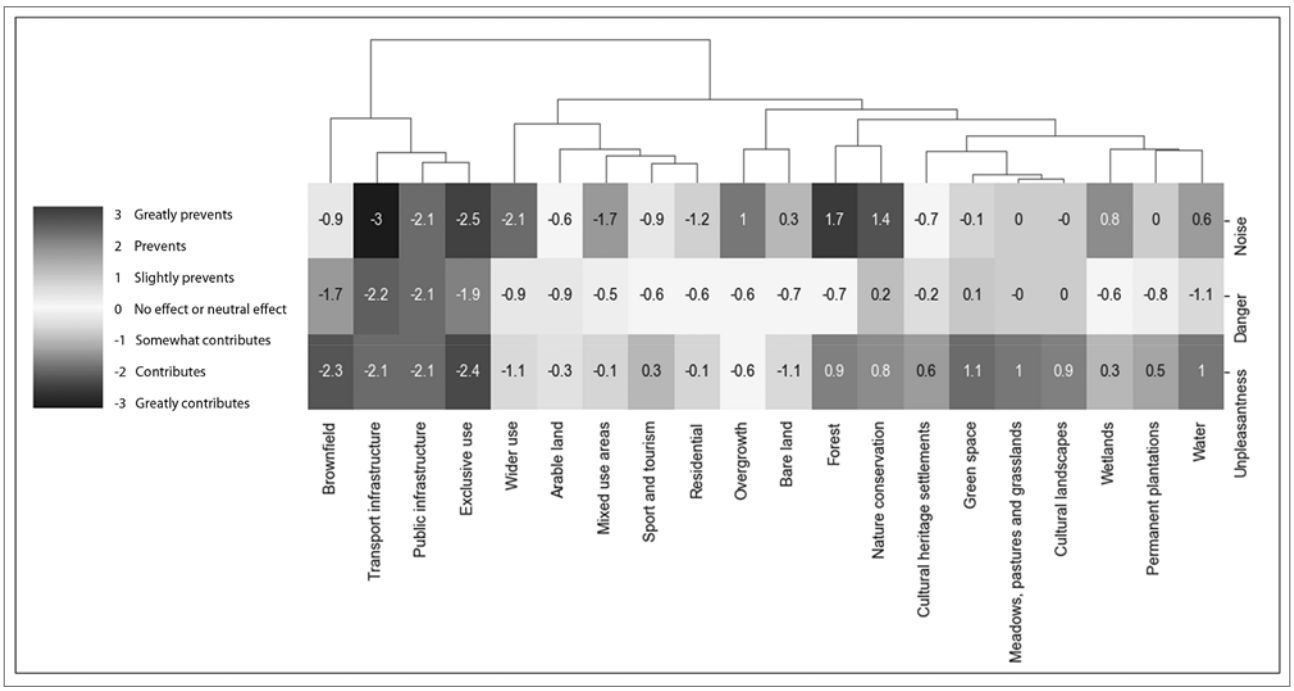

Figure 3: HCA with heatmap and dendrogram visualizations illustrating clustering of themes for each disservice. Each cell presents the aggregated mean score of experts, weighted with their confidence level and coloured according to the scale (illustration: Vita Žlender and Stefano Gemin).

theme, they are written in italics, while "CES" and "disservices" are in quotation marks. When rounding the means to 0.5, the inspected themes proved to be insufficient for assessing the provision potential of "spiritual and religious services". The most relevant themes were *water* for five CES and *cultural landscape and cultural heritage settlements* for three CES. "Spiritual and religious services" were not assigned any theme with high relevance, and "social relations" were assigned only to *green space*. No theme for any CES was assigned as very harmful. The lowest score of −2.3 was attributed to the contribution of *exclusive use* to "aesthetic value". In terms of disservices, five themes were assigned to "noise" with no effect and two with the greatest contribution (i.e., *transport infrastructure* and *exclusive use*). Five themes were assigned to "danger" and five to "unpleasantness", with a score of less than 0.5. No theme was assigned as greatly preventing for disservices. *Transport infrastructure* scored as greatly contributing to "noise"; however, most themes exhibited no effect scores.

Figures 2 and 3 show the HCA along with the heatmap and dendrogram visualization, in addition to the aggregated mean scores of experts, weighted using confidence levels. The dendrogram presents many pair clusters of CES. The cluster "source of inspiration" and "cultural significance" was found to be the strongest in assigning similar scores to themes in terms of providing or not providing potential for these two CES. Furthermore, the clustering of "leisure and recreational activities" and "aesthetic value", as well as that of "education" and "research resources", was demonstrated. Moreover, "sense of place and identity" was added to the extended clustering of "inspiration" and "cultural significance". In general, these clusters demonstrated medium to high relevance of unbuilt land uses and land cover, such as *arable land, wetlands, and forest*, except for *overgrowth* and *bare land*. The dendrogram presents also pair clusters of themes. Among them, two medium- to high-relevance clusters of predominantly unbuilt land uses were demonstrated; however, in between them, *green space* formed its own cluster, indicating the special role of this land use. The additional two clusters included several urban land uses, of which one cluster demonstrated themes without any effect for CES and one theme that was potentially harmful. In terms of the cause potential of themes for disservices, a harmful to very harmful cluster was formed by *transport infrastructure*, *public infrastructure*, *exclusive use*, and *brownfield*. Most themes characterizing unbuilt land uses were rather dispersed; only smaller clusters could be defined. These included *forest* and *nature conservation* with slightly favourable to favourable effects, or *cultural landscapes*, *green space*, *meadows*, *pastures and grasslands,* and *cultural heritage settlements* with mostly no effect on disservices.

To analyse the dispersion of experts' answers from the mean, the *SD* was determined. The *SD* ranged between 0.28 and 2.01 for CES and between 0.22 and 1.83 for disservices. The analysis demonstrated that the highest agreement ($SD < 0.5$) was present for the contribution of *forest*, *water*, and *green space* to providing spatial conditions for the provision of "recreation", *cultural heritage settlements* for "sense of place" and "identity", *water* and *cultural heritage settlements* for "aesthetics", and *forest*, *water*, *wetlands*, and *nature conservation* as "research resources". In terms of disservices, such a *SD* was present for the effect of *bare land* and *transport infrastructure* on causing "noise". To understand the discrepancies in the answers, *SD*s of more than 1.5 were measured, which were present for the contribution of *transport infrastructure*, *public infrastructure*, and *brownfield* for provision of "inspiration", *transport infrastructure* for "social relations", *transport infrastructure*, *public infrastructure*, *brownfield*, *exclusive and wider use*, and *green space* for "research", and *overgrowth* for "cultural significance". In terms of disservices, a *SD* of more than 1.5 was present for the effects of *water* on "noise", *forest* on "danger", and *forest* and *green space* on "unpleasantness".

3.3 Spatial distribution of the CES provision potential and the potential to cause disservices

Based on the matrix, individual maps (Figures 4 and 5) and synthesis maps (Figure 6) for the CES provision potential and the potential to cause disservices were developed. The spatial distribution characteristics of CES in the three study areas demonstrate that predominately seminatural areas have the most favourable spatial conditions, such as forested areas in Koper along ridged hills and on the Karst Rim as well as the Škocjan Lagoon nature reserve. In Kranj, such patches are seen in the forest around the town, the forested part of the Brdo Estate, and Lake Trboje; in Ljubljana, these patches are seen in the fringes of marshland to the south, the two forested green wedges to the east and west, and a few isolated hills to the north. These areas are important supports for cities' GI. There were negative effects of artificial areas with strong human intervention, such as transportation infrastructure, dump sites, and industrial or logistics units, with the most notable examples being business zones; for example, Brnčič Street (*Brnčičeva ulica*) in Ljubljana; Labore, Šenčur, and Naklo in and near Kranj; and Bivje and Sermin in Koper. The CES-providing capacity of these areas is weak; it is even more problematic because they have become isolated owing to a lack of significant connections with high-capacity provisioning areas. Figure 7 shows an example of an area in Kranj with predominantly harmful spatial conditions to provide CES. The maps for the potential to cause disservices demonstrate that it is exactly these areas

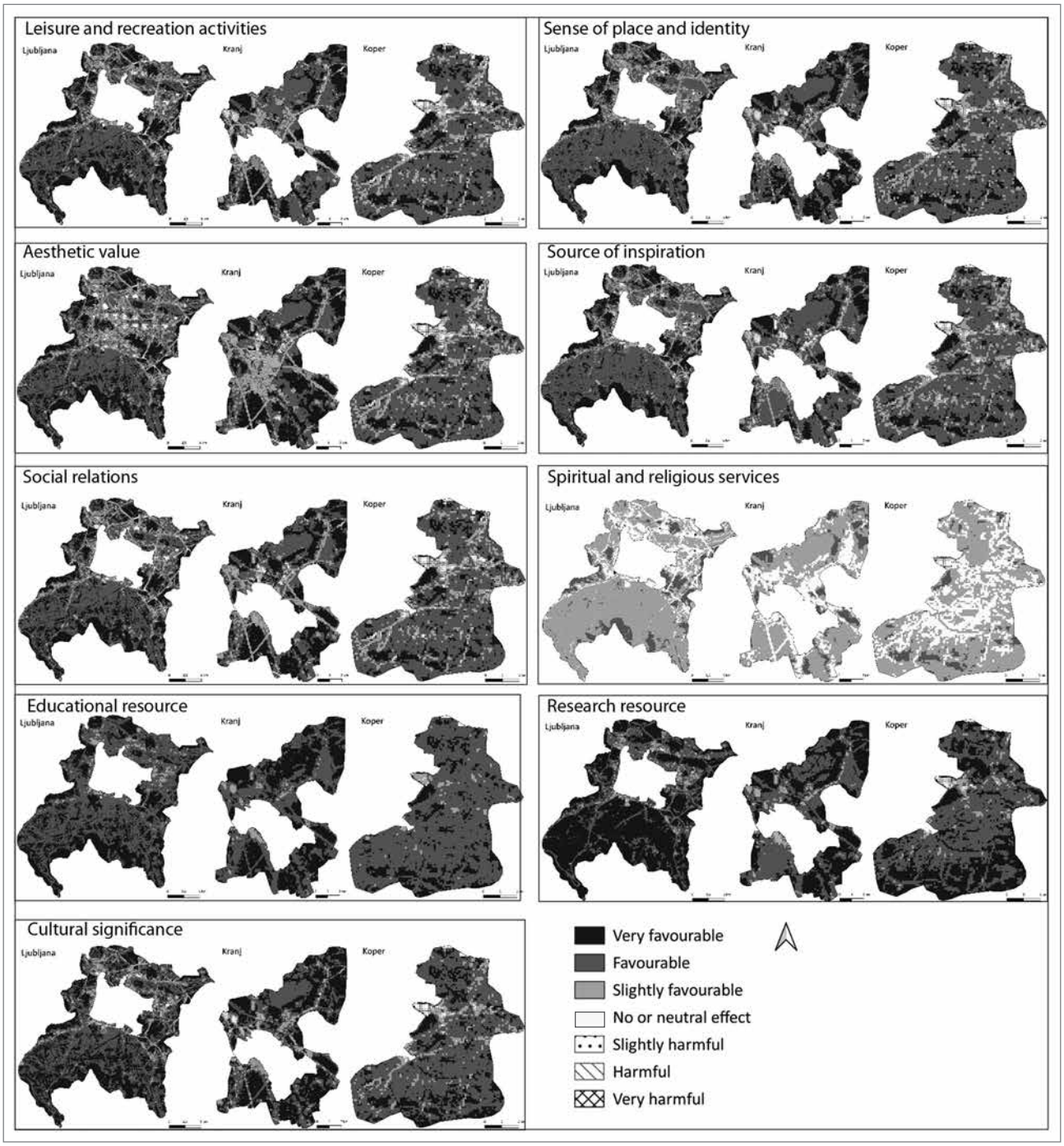

Figure 4: Maps for the three study areas showing the provision potential for individual CES categories, based on expert scores (illustration: Vita Žlender and Rok Brišnik).

that considerably contribute to the disservice inspected. Surprisingly, Kranj and Koper have larger patches of areas with harmful spatial conditions for providing CES than Ljubljana, which is a large city. However, note that in Ljubljana several such areas are located in the city's core area (Figure 7). These areas lack GI and consequently the potential to provide CES.

The results were compared with the depiction of different use areas in municipal spatial plans (OPNs; Figure 6). In Ljubljana, spatial patterns of favourable and very favourable spatial conditions to provide CES mostly occur on open green land, indicating generally positive environmental characteristics. This evaluation agrees with the area in OPNs defined as a "green system hinterland" (note: not indicated on the map). However, in the area described in the OPN as a "peri-urban area" (Figure 6), there is ample need for enhancing the current state, especially in areas to the north and northeast. In Kranj, the area described in the OPN as "multifunctional peri-urban

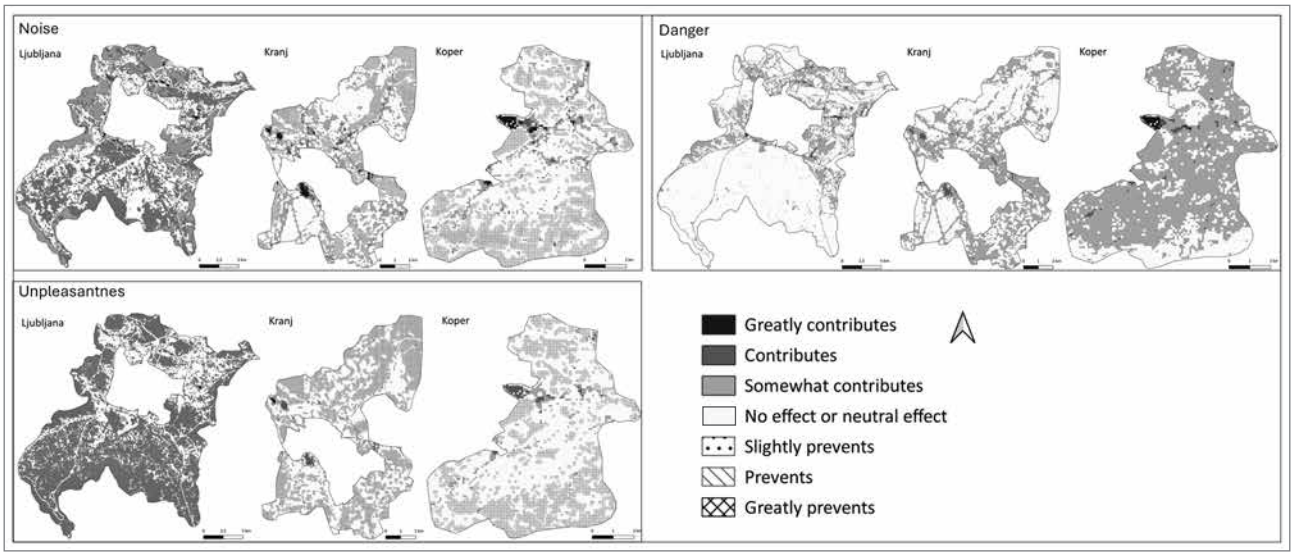

Figure 5: Maps for the three study areas showing the potential to cause individual cultural ecosystem disservice, based on expert scores (illustration: Vita Žlender and Rok Brišnik).

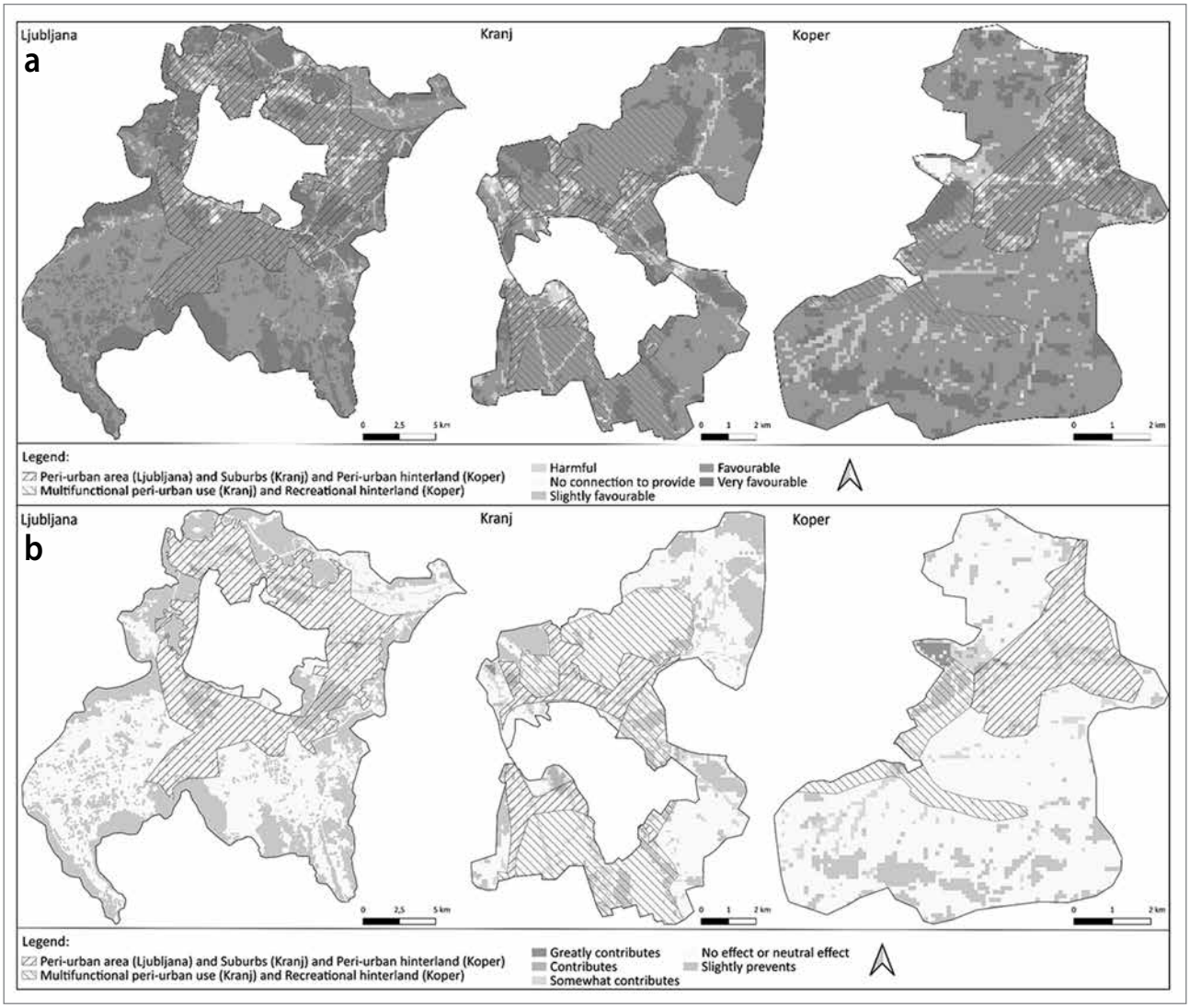

Figure 6: a) top maps show an aggregate of nine normalized CES layers for the three study areas depicting the spatial variation in provision potential based on expert scores and GIS data. b) Bottom maps show an aggregate of the three normalized disservice layers (illustration: Vita Žlender and Rok Brišnik, and Odlok … Koper, 2022; Odlok … Ljubljana, 2010; Odlok … Kranj, 2014).

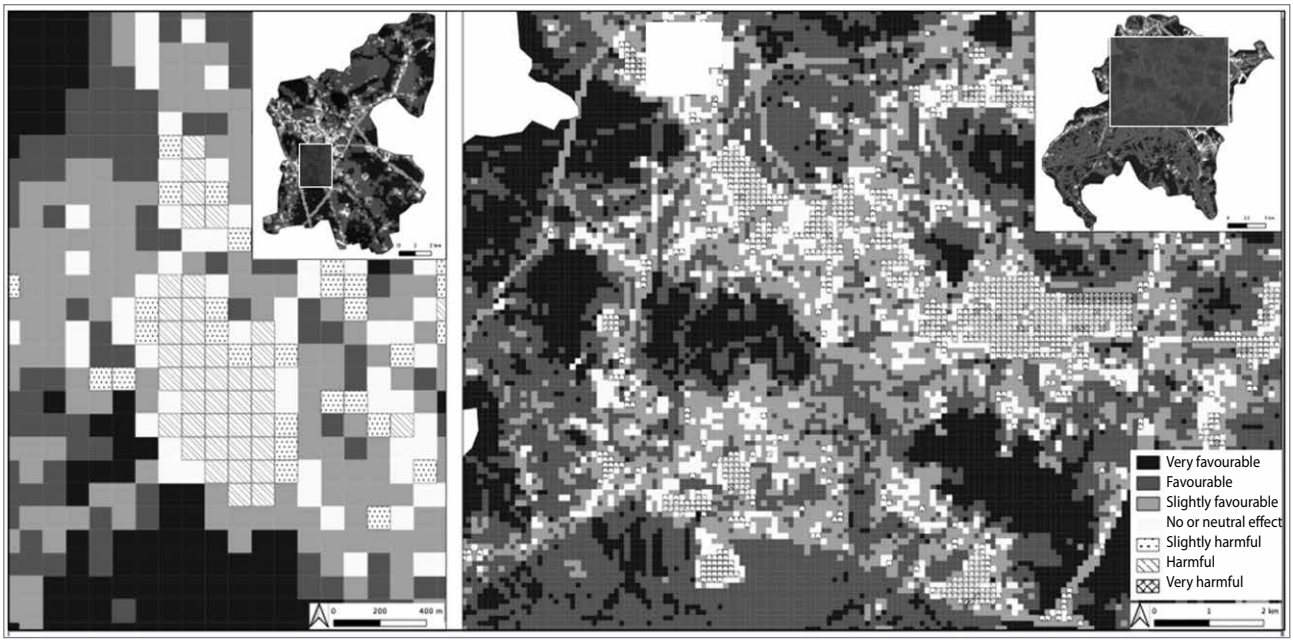

Figure 7: a) detail of an area in Kranj's peri-urban landscape with harmful CES provision potential with a perimeter of approximately 500 m; b): detail of an area in Ljubljana, showing that most of the areas with harmful spatial conditions are in the city core (illustration: Vita Žlender and Rok Brišnik).

use" has a predominantly favourable or even extremely favourable spatial conditions for CES provision. The area described in the OPN as "suburbs" exhibits mixed potential with patches of favourable and very favourable spatial conditions for CES provision; however, there are harmful conditions toward the north and southeast. In Koper, the "recreational hinterland" exhibits favourable and very favourable conditions for CES provision, whereas "peri-urban hinterland" encompasses patches of land with certain harmful conditions for CES provision. Improvements (possibly in the form of GI) are required to increase the provision potential for CES.

4 Discussion

4.1 Ecosystem-based support for GI planning in the peri-urban landscape

The peri-urban landscape has a complex, often ambiguous, character that blends various land uses and land covers that demonstrate a dynamic interplay between urbanization pressures and the imprints of nature. GI plays an important role in enhancing the ecological, social, and economic resilience of a peri-urban landscape (O'Brien et al., 2017). This article presents a method that helps identify and spatially locate various elements of GI based on the provision potential of CES at the landscape scale. Based on the predefined classification of CES and themes integrating land use, land cover, and protection regime classes, spatial data with the knowledge of various experts are discussed.

This assessment generated novel insights into the spatial distribution of areas regarding their potential to provide the CES and cause the disservices studied, respectively, in three case study cities. The results demonstrated spatial patches of low provision potential, where improvements are required to strengthen the GI network and thus enhance the multifunctionality of the peri-urban landscape. This was particularly relevant for Kranj and Koper. The CES mapping demonstrated the low CES provision potential of large patches of urbanized land, particularly land earmarked for exclusive use, such as industry, logistics, transportation infrastructure, and public infrastructure. The results showed that, to support GI planning and peri-urban multifunctionality and to avoid land-use conflicts caused by social demands for (C)ES, the establishment of mosaic landscapes combining different land uses on a small scale may strengthen the provision of CES in peri-urban landscapes, as discussed by Stürck and Verburg (2017). Note that the patchwork of cultural landscapes, including interwoven land uses and land covers such as arable fields, meadows, and forest patches, is widely acknowledged to be valuable and emblematic of Slovenian national identity (Golobič & Lestan, 2016). This sentiment is also reiterated in the OPNs of all three case studies.

Favourable potential provision was most frequently assigned to green and blue spaces, such as forests, water, and designated green spaces, which was also confirmed by Navara and Vedamuthu (2022) and creates the possibility to form archetypes for land-use evaluations (Karrasch et al., 2019). These spaces often have a multifunctional role in the peri-urban landscape.

The preservation and enhancement of forested and water areas should be promoted, owing to their high potential for CES provision. For this purpose, unitary policies and integrated tools and regulations that go beyond sectoral decisions are required (Filyushkina et al., 2022; Gottero et al., 2023). Only then can the development of multifunctional areas be made possible and support for GI planning be integrated to reduce competition over space and resources.

This study provides important insights for designing future policies with a direct impact on CES to enhance sustainable management of areas with high CES provision potential and improve areas with low relevance to providing CES. In particular, the municipal spatial plans and forthcoming regional spatial plans, as foreseen by the national Spatial Management Act (Sln. *Zakon o urejanju prostora*, Ur. l. RS, no. 199/2021), are particularly important. The results indicate that areas of low CES potential can be explored for peri-urban development with due concern for other planning requirements and demands. In particular, the peri-urban landscape, characterized by its high multifunctionality, requires not only conservation efforts but also strategic allocation for future urban expansion. The study is a foundational resource for broader assessments of ecosystems and their services, facilitating the identification of land suitable for future development based on its ES potential, which has already been tested in certain studies (e.g., Zhang & Muñoz Ramírez, 2019; Navara & Vedamuthu, 2022). The diverse array of themes offers spatially explicit indicators of meaningful locations for various CES. Spatial planners and managers play a pivotal role in shaping and nurturing these meaningful places by enhancing accessibility and permitting specific uses, thereby improving their development potential and promoting pro-environmental behaviour (Žlender & Gemin, 2020, 2023; Gottwald et al., 2021). They should thus work closely with local departments and the public to avoid isolated planning and implementation decisions, as has already been proposed by certain scholars (e.g., McDonald et al., 2005; Zhang & Muñoz Ramírez, 2019; Spyra et al., 2021).

4.2 Evaluation of the method

One important advantage of the expert-based scoring approach is its ability to incorporate diverse perspectives and knowledge domains in the assessment process. By involving experts from various fields, it was possible to capture a comprehensive understanding of the potential CES associated with different themes. This multidisciplinary approach improved the robustness of the assessment and ensured that a wide range of factors influencing CES provision were considered. Furthermore, this approach makes possible a systematic and transparent evaluation of various CES, allowing a comparison of different land-use options in terms of their potential to deliver cultural benefits. This approach also facilitated evidence-based decision-making in GI planning because stakeholders can weigh the relative importance of CES when prioritizing land-use strategies. Moreover, the method offers flexibility in adapting to local contexts and priorities, making it suitable for application in diverse subregional settings. By tailoring the set of themes to specific geographic, socioeconomic, and cultural conditions, the method can provide tailored insights that resonate with local stakeholders and decisionmakers. The innovation lies in the fact that the spatial analysis was based on a grid and allowed the presence of multiple themes in one grid cell. The summed value indicates the interrelation of individual themes. Owing to the complexity of spatial patterns in a peri-urban landscape of Slovenia, such an approach was considered more relevant in assessing CES and disservices in the peri-urban landscape than the assessment of individual land uses and land covers, as suggested by Burkhard et al. (2009). However, their method widely relies on the use of the CORINE database, which has been criticized for its lack of complexity (Zhang & Muñoz Ramírez, 2019). Focusing on landscape complexity is particularly important not only because peri-urban landscapes were inspected in this study but also for the whole of Slovenia, given the finely structured land uses and land covers across the entire territory of the country.

Furthermore, this approach is extremely useful for acquiring rapid overviews in complex systems, such as in peri-urban landscapes. In particular, there is potential for using this method in spatial planning for providing quick and objective insights into the state of the inspected peri-urban landscape in terms of its cultural ecosystem (dis)service distribution, as well as the monitoring phase of landscape management. This is a transparent method such that all score matrices and map layers based on them can be examined both together and separately; moreover, the assessments behind the results can always be tracked back. However, only the first identification of various spaces is provided, and additional research might determine the types of GI that should be planned and designed in different areas and investigate how to best provide an approach to sustainable development and the management of land resources. To make the research more comprehensive, combining quantitative and qualitative data is recommended, in addition to including various views in the assessment process. This approach can also be combined with other approaches common to spatial planning, such as suitability assessments, as shown in Martínez-Martínez et al.'s (2022) study. This combination of methods can be implemented in the initial stage of a planning project to identify areas with the highest suitability for a desired activity with lower intervention in CES.

Although the expert-based scoring approach has clear advantages, it is not without limitations. The subjective nature of

expert judgement and the potential for bias must be acknowledged (Müller et al., 2020); moreover, efforts should be made to reduce these risks through a transparent methodology and rigorous validation processes. In the case at hand, the group was biased because most experts were researchers in spatial planning or environmental studies, and decisionmakers at the local level and representatives of the general public were not asked to participate in the survey owing to the nature of the research project. The inclusion of locals is particularly relevant when working on a small scale, where people are more directly impacted by planning decisions (Kopperoinen et al., 2014; Navara & Vedamuthu, 2022). Furthermore, the datasets used for compiling the themes may be selected differently, and the reliability is always questionable. Moreover, the scores always remain somewhat subjective because they draw on broad theoretical principles rather than precise quantitative associations within the given context (Zhang & Muñoz Ramírez, 2019). In this evaluation of the method, the categorization of themes with the experts and, in repeating the method, needs to be completed before scoring. This may reveal additional themes characteristic of peri-urban landscapes. Not all themes equally support the CES categories investigated. However, by incorporating more detailed assessments of specific land-cover types, management regimes, landscape features, points of interest, and other elements, the evaluation of CES can be improved (Karrasch et al., 2019). However, this evaluation underscores the capacity of the expert-based scoring approach to capture evidence of CES potential and causes of disservices.

5 Conclusion

The proposed expert-based scoring approach proved to be a valuable tool for assessing the potential provision of CES and the potential to cause disservices across different themes. This method offers practical benefits for informed GI planning at the landscape level, not only relative to designated green spaces, such as urban parks or natural reserves, but also to potential areas, such as bare or brownfield sites. It thus aids in evaluating the advantages and disadvantages involved in the assessment and planning of GI. By harnessing experts' knowledge and providing a systematic framework for assessment, this method can contribute to more informed and inclusive decision-making processes for landscape planning and management.

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Acknowledgements

The author would like to thank Rok Brišnik, Stefano Gemin, and Simon Koblar for their technical assistance. This research was made possible with financial support from the Slovenian Research and Innovation Agency (grant numbers Z5-4589 and V5-2232).

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