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Landscape Units for Ecological Infrastructure Planning in Urban and Peri-Urban Areas: A Case Study of a Medium-Sized Latin American City

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ABSTRACT

Planning an ecological infrastructure (EI) network requires defining its components and assessing the ecosystem services (ES) it provides. In this context, classifying the landscape into units facilitates information integration and serves as a spatial reference framework for analyzing its structure, organization, and functioning. This study aims to delineate landscape units in the urban and peri-urban areas of a medium-sized Latin American city to support EI planning and the conservation of ES, with a particular focus on cultural services. Using Mar del Plata, Argentina, as a case study—where cultural ES have been previously analyzed from different perspectives—this research identifies landscape units based on an assessment of EI and its components, evaluating each unit's status concerning cultural ES. The results indicate that landscape units differ in the cultural ES they provide, as well as in user activities and perceived needs, such as vegetation, safety, and accessibility. The integration of spatial data from multiple sources supports the development of guidelines and recommendations to enhance EI across different landscape units. These findings are expected to provide valuable information for local decision making, while the proposed approach can be transferred to other cities.

1. INTRODUCTION

In contemporary urban planning, the concept of landscape is becoming increasingly relevant as a framework for addressing complex environmental challenges through the integration of ecological processes and functions. Within this context, the ecological systems that encompass urban areas and their surroundings are conceptualized as ecological infrastructure (EI), providing multiple benefits to inhabitants.

Understanding these elements as a form of infrastructure—analogous to other urban infrastructures—means recognizing them as planning entities and essential assets that must be strategically designed and maintained. It highlights the importance of designing green spaces as an interconnected network rather than as isolated units within the urban fabric. It also emphasizes their role as providers of ecosystem services (ES), defined as the benefits people obtain from ecosystems (MEA, 2005).

Building on this idea, Calaza Martínez (2019) argues that planning an EI network first requires defining its components and identifying and assessing the ES it provides. Secondly, it involves conducting a detailed analysis to assess the needs, demands, and opportunities for the system's overall functioning and determining the necessary interventions for each space and element. In short, a comprehensive diagnosis integrating various sources of territorial information is essential.

The classification of landscapes into units provides a structured approach to integrating territorial information while also offering a spatial reference framework for analyzing the components, organization, and functioning of landscapes (Pérez-Chacón, 1999).

In Latin America, the urbanization process that accelerated in the second half of the twentieth century particularly drove the growth of medium-sized cities with populations ranging from 100,000 to 2,000,000 inhabitants (Crespo et al., 2016). Today, the region is considered the most urbanized in the developing world. However, urban growth is occurring at a pace that exceeds the capacity to implement planning policies, including those focused on EI, which could help mitigate some of the challenges these cities face.

In this context, the present study aims to contribute to the planning and conservation of EI and the ES it provides, with a particular focus on cultural ES. These services are defined as the non-material benefits ecosystems offer, such as spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences (MEA, 2005). The city of Mar del Plata (Argentina) is selected as the case study, as cultural ES have previously been examined there from multiple perspectives (Karis, 2019; Mujica et al., 2022). Previous studies have assessed these services using indicators that reflect specific characteristics of the EI delivering them. Advances have also been made in identifying and classifying services and exploring their social valuation. However, a research gap remains in the comprehensive assessment of ES provided by EI. Building

on previous findings, this study aims to integrate results from various sources and methodologies to deepen the understanding of this relationship. To that end, it examines how landscape classification into units can serve as a framework to integrate territorial information.

The research addresses the following questions: What are the main attributes of EI across different landscape units? Which cultural EI are associated with the EI components identified in each sector? Do the attributes of EI influence both the provision of cultural ES and the ways in which the population uses and perceives them?

To address these questions, the study delineates landscape units within the urban and peri-urban areas of Mar del Plata, based on an assessment of EI and its components. It then analyzes the cultural services within these units, first through expert knowledge and subsequently through a survey of public green space users. Based on the integration of results obtained at each stage, strategies and guidelines for intervention in each landscape unit are proposed.

The structure of the paper is as follows: it begins with a literature review outlining key concepts related to EI, ES, and landscape units. This is followed by a description of the study area and a detailed explanation of the materials and methods employed. The results are presented in four subsections: the delimitation of landscape units; the identification of cultural ES based on expert knowledge; the evaluation of these services as perceived by the local population; and the development of guidelines and recommendations derived from the integration of findings. Finally, the discussion and conclusions synthesize the main insights of the study, emphasizing both the strengths and limitations of using landscape units as a framework for EI planning.

It is expected that the results of this research will provide a valuable foundation for decision-making related to the landscape of the study area. Moreover, the methods and findings presented here are applicable and transferable to other urban contexts.

2. LITERATURE REVIEW

2.1. Ecological infrastructure and ecosystem services at the urban scale

Ecological infrastructure (EI), also known as green infrastructure, refers to a strategically planned and managed network of natural and semi-natural areas, along with other environmental elements, designed to provide a wide range of ecosystem services (European Commission, 2014). This network includes green and blue spaces—such as parks, gardens, rivers, and wetlands—as well as other physical components of terrestrial and aquatic environments.

At the urban scale, EI comprises a network of parks of various sizes, gardens, and urban nature reserves, all interconnected through tree-lined streets, rivers, roads,

railway corridors, and other components. Given the high degree of landscape transformation in cities, interactions among natural and built systems—comprising green (vegetation), blue (water), and gray (built infrastructure) components—are essential for maintaining ecological functions and enhancing urban quality of life (Romero-Duque et al., 2020). In this context, EI plays a key role in delivering environmental, social, and economic benefits, while supporting urban sustainability and resilience.

The benefits provided by these systems are framed within the concept of urban ES (Gómez-Baggethun & Barton, 2013), a framework that facilitates their incorporation into planning and management processes across urban and peri-urban areas. Various tools and methods have been developed to identify, classify, assess, and even estimate the economic value of these services.

This study adopts the Common International Classification of Ecosystem Services (CICES) (Haines-Young & Potschin, 2018), which organizes ES into three main categories: provisioning services, which supply material and energy resources such as food, water, and raw materials; regulating and maintenance services, which support environmental processes like climate regulation, air purification, and flood control; and cultural services, which provide non-material benefits such as recreation, aesthetic value, and cultural heritage.

Cultural ES arise from the interaction between social and ecological systems, since they depend on the human interpretation of the biophysical environment through sensory, emotional, and cognitive experiences. Unlike provisioning or regulating services, cultural ES exist only through human perception. In urban environments, their availability and quality are also shaped by urban planning decisions and management practices. For example, recreational services are influenced by the presence of infrastructure elements such as benches, pathways, sports areas, and accessibility features.

2.2. Landscape units in the study and planning of EI

The concept of landscape is complex and encompasses multiple interpretations. It refers not only to the external and visible physiognomy of a specific portion of the Earth's surface, but also to the individual and collective perceptions it generates—that is, both the tangible geographical features and their intangible interpretations (Nogué et al., 2019).

In this sense, the landscape provides a valuable framework for understanding the interactions among ecological, economic, and cultural dimensions (Potschin & Haines-Young, 2006). From a planning perspective, it provides tools for organizing and analyzing territorial elements, land uses, and the systems that structure them.

Zoido (2002) emphasizes the value of the landscape approach in territorial diagnosis, as it enables the identification of land uses and conflicts, as well as the processes driving landscape transformation. Similarly, Mazzoni (2014) notes the growing adoption of landscape as a unit of analysis, particularly in land-use planning and territorial assessments, over the past two decades.

This approach is particularly relevant for regional and urban planning (Forman, 2010), where defining landscape units serves as a bridge between landscape characterization and decision-making in territorial planning (Rotger, 2018). These units not only facilitate the understanding and description of a landscape's character but also function as fundamental territorial divisions where specific policies can be implemented, ultimately becoming integral to territorial, urban, and sectoral planning.

Landscape units represent the spatial expressions of ecosystems and are particularly useful for analyzing ES in a given territory. They provide a foundational framework for organizing territorial data and assessing the composition, structure, and ecological functioning of the landscape in relation to service provision.

Grounded in the principles of landscape ecology, this approach enables integrated analysis and planning. Scholars have highlighted the relevance of landscape ecology in promoting sustainable development (Ndubisi, 2002; Termorshuizen & Opdam, 2009; Ahern, 2013; Dale et al., 2013), while Helfenstein et al. (2014) emphasize its interdisciplinary nature and its critical role in planning.

The delineation of landscape units involves identifying areas of relative homogeneity and assigning them specific functions within a broader mosaic. These units may be defined based on a single variable or a combination of characteristics, forming patches of varying shapes, sizes, and configurations (Farina, 2006). While there is no single method for identifying such units, a crucial step is identifying the most relevant landscape discontinuities according to the selected criteria.

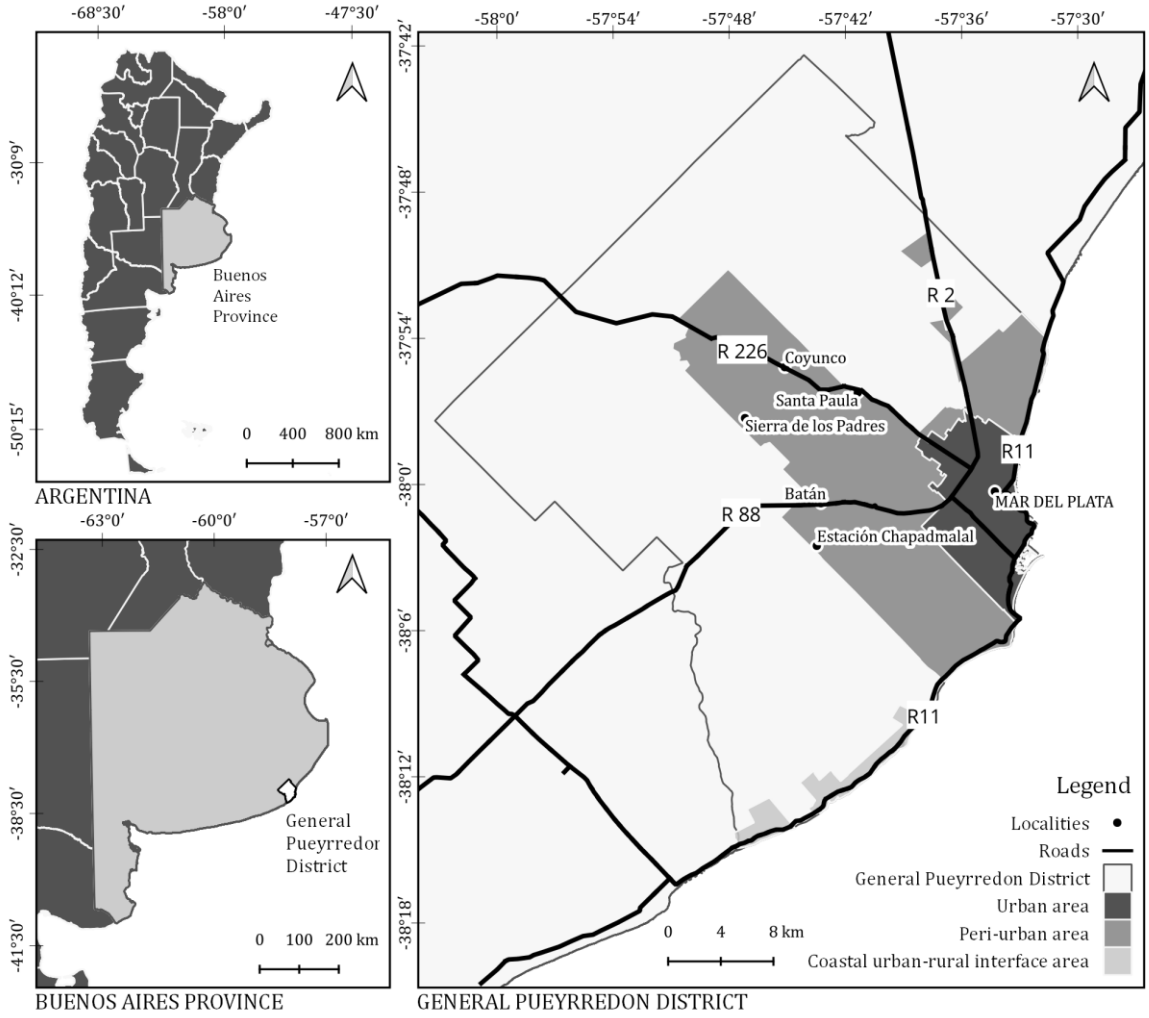
Nogué et al. (2018) describe two complementary approaches to this process. The synthetic approach involves grouping or subdividing territorial sectors based on internal differentiation or shared traits. The analytical approach, by contrast, involves overlaying thematic maps that represent different landscape elements. The integration of these layers allows for the delineation of spatial units based on the synthesis of ecological and cultural dimensions.

Ultimately, this process results in the identification of landscape units characterized by distinct natural and cultural attributes—whether visible or intangible— which distinguish one landscape from another and provide a meaningful basis for planning and intervention.

3. STUDY AREA

The study area (Figure 1) corresponds to the city of Mar del Plata (Argentina), its peri-urban area, and a recently expanding coastal urban-rural interface sector.

Figure 1 - Study area



Source: Authors' Elaboration

Mar del Plata is located on the Atlantic coast and serves as the administrative center of the General Pueyrredon District[1], in the southeastern region of Buenos Aires province (Argentina). The city concentrates the majority of the district's population,

[1] *Buenos Aires Province (Argentina) is legally divided into districts, which function as local government entities (municipalities). Each district encompasses a continuous territorial area that includes one or more localities, one of which serves as the seat of the municipal government.*

totaling 667,082 inhabitants, according to the outcomes of the 2022 National Census of Population, Households and Housing (INDEC, 2023).

From a biophysical perspective, the territory is characterized by the presence of the Northern *Sierras of Buenos Aires* Province, part of the *Tandilia* System, which extend mainly across the southwestern, eastern, and western sectors. In contrast, the southern area is defined by an undulating plain. The coastline features cliffs interspersed with beaches, often located in bays between headlands. While some beaches maintain natural stability, others have formed or persist due to anthropogenic interventions (Fernández, 2018).

The urban-rural interface, which develops discontinuously on the outskirts of Mar del Plata, includes expanding residential areas that coexist with productive zones focused on intensive agriculture. However, this urban expansion has not been accompanied by urban consolidation processes, such as the extension of basic sanitation infrastructure or urban densification (Zulaica & Ferraro, 2015). As a result, this interface exhibits pronounced socio-territorial contrasts and environmental challenges, particularly regarding the management of ecological infrastructure (EI).

With respect to EI components, the study area includes public green spaces (PGS), which are open-access areas dominated by vegetation and natural elements, primarily serving recreational, ecological, and social interaction purposes. Among the largest PGS are *Camet* Park, Local Sports Centre Park, and *Punta Mogotes* Linear Park. Smaller parks and squares can be grouped into two categories: larger ones, generally occupying an area equivalent to four urban blocks and located in the central urban zone; and smaller neighborhood squares, typically covering a single block.

Additionally, the area includes two officially designated nature reserves: *Laguna de Los Padres* Nature Reserve and the *Puerto de Mar del Plata* Nature Reserve. In addition, other protected areas exist under different legal designations. For instance, the southern coastal strip under municipal jurisdiction, located along Route 11 from *Punta Mogotes* to the *Las Brusquitas* stream, has been designated a Tourist and Forest Reserve. Moreover, several neighborhoods in the district have been declared Forest Reserves, due to the quality and quantity of their tree species, which justify their conservation.

Finally, the area includes both regional and urban green corridors. Regional corridors connect the urban fabric with surrounding ecosystems and often align with the roads linking Mar del Plata to nearby towns. In contrast, urban green corridors interconnect existing green spaces within the city. However, urban green corridors in Mar del Plata are still in the early stages of planning and implementation.

4. MATERIALS AND METHODS

This section outlines the methodological approach adopted in the research. A mixed-methods strategy was implemented, integrating spatial analysis, expert knowledge, and a population survey. The process was structured into three stages, as detailed below. Finally, the results from the previous stages were compared for each landscape unit, informing the development of specific guidelines and recommendations. These were derived from various sources, including Karis (2024), Calaza Martínez (2019), the European Environment Agency (2011), and Salbitano et al. (2016).

4.1. Delimitation of landscape units

To define landscape units, the existing neighborhood boundaries in the study area (Municipalidad de General Pueyrredon, 2022) were used as a reference. These neighborhoods were then grouped based on various EI variables using QGIS software. The selected variables were defined based on previous studies (Karis, 2019; Rodríguez and Vázquez Brust, 2022) and included the following:

- Tree and vegetation status, assessed through the Normalized Difference Vegetation Index (NDVI), following Karis (2019).
- Presence of EI components that contribute to the distinctive character of each unit, as identified by Karis (2019):
    - Nature reserve areas
    - Beaches
    - Surface water bodies and courses
    - Areas predominantly used for agricultural activities
    - Green corridors at urban and regional scales
    - Neighborhoods within forest reserves
    - Public green spaces (PGSs) of different sizes:
        - Neighborhood squares: less than 3.5 ha
        - Urban squares or parks: between 3.5 and 10 ha
        - Large parks: more than 10 ha
- Characteristics of PGSs, based on Rodríguez and Vázquez Brust (2022):
    - Maintenance status
    - Diversity, considering different land uses surrounding the PGS, as well as the variety of urban furniture and functional areas within the space (e.g., children's play areas, sports courts or equipment, areas for monuments, fairs, etc.)
    - Accessibility, evaluated based on the materiality of perimeter streets, sidewalks, internal pathways, and the presence of pedestrian ramps at intersections

- Vegetation cover, analyzed in relation to the proportion of green areas versus other functional areas, tree coverage extent, and the percentage of tree-lined perimeters
- Population density according to data from the National Census of Population, Households and Housing (INDEC, 2010).

The boundaries of the landscape units were adjusted according to census radii[2] to ensure compatibility with population data from the National Census of Population, Households, and Housing (INDEC, 2010) in unit characterization.

4.2. Identification of cultural ES in landscape units based on local expert knowledge

This study builds upon previous research by Mujica et al. (2022), which identified the ES provided by EI components in the study area and assessed the extent to which each EI component contributes to these services. The study employed a panel of local experts using the Delphi technique and applied the CICES V5.1 classification system (Haines-Young & Potschin, 2018).

Regarding cultural ES, CICES V5.1 differentiates between services derived from direct, in-situ, and outdoor interactions with living systems—requiring presence in the environmental setting—and those resulting from indirect, remote, often indoor interactions with living systems, which do not require physical presence. The former category is further divided into physical and experiential interactions with the natural environment and intellectual and representative interactions with the natural environment. In contrast, indirect interactions encompass spiritual, symbolic, and other interactions with nature, as well as biotic characteristics with non-use values, such as existence and legacy values for future generations.

In the previous study, seven cultural ES were identified (Table 1):

- Physical and experiential interactions with nature:
  1. Tourism
  2. Recreation
  3. Social encounters and interaction
  4. Nature observation and aesthetic values
- Intellectual and representative interactions with nature:
  5. Scientific research and educational values
  6. Local identity
- Biotic characteristics with non-use value:
  7. Existence value

[2] *Census radii are geographical units within the census survey structure. In urban areas, each census radius typically includes an average of 300 households, while in rural or mixed areas, this number is generally lower.*

For this study, the identification of cultural ES provided by EI in each landscape unit was carried out by comparing the findings from the previous research with the spatial distribution of EI components within the delineated units. A map was then created to visually represent these results, incorporating the spatial location of the identified services.

4.3. Cultural ES provided by PGS according to the local population

To analyze cultural ES based on the uses and preferences of the local population, data were drawn from a face-to-face survey conducted in November 2021. The survey included 471 individuals over 18 years of age who were users of PGSs.

Regarding the methodological design, a non-probabilistic quota sampling approach was applied, considering the landscape units delineated in the study area. The total population at the time of the survey was 603,054 inhabitants, according to the latest available data (INDEC, 2010). The survey responses were analyzed using SPSS Statistics 21 software (IBM).

Partial results of the survey were previously published in Karis & Zulaica (2024). This study focuses on responses to two specific questions regarding the uses and opinions of respondents about PGS.

First, responses to a question about the activities being performed in PGS were analyzed. The reported activities were grouped according to the cultural ES categories defined by CICES V5.1, as shown in Table 1. Since participants were asked about ongoing activities, no responses were associated with indirect interactions under the CICES classification.

The second aspect analyzed corresponds to responses to an open-ended question in which respondents were asked what they felt was lacking in the PGS they visited. The answers were categorized into the following groups:

- Maintenance
- Equipment and furniture (e.g., areas for physical activity, benches, drinking fountains)
- Safety
- Vegetation (e.g., trees, flowers, grass)
- Restrooms
- Lighting
- Universal accessibility (e.g., ramps, accessible restrooms, inclusive playgrounds)

For the analysis, descriptive statistics were applied to examine response frequencies. Additionally, the distribution of responses was evaluated across three sectors of the study area, which group landscape units (LU) with similar characteristics in terms of PGS:

- Central urban area: LU1 and LU2
- Urban ring: LU3, LU4, LU5 and LU6
- Peri-urban and coastal rural-urban interface area LU7, LU8, LU9, LU10, LU11 and LU12

Table 1 – Activities carried out by the survey respondents and their correspondence with the classification of cultural ecosystem services

<table>
<tr><th>Activities carried out by the respondents (Karis & Zulaica, 2024)</th><th>Ecosystem Services (Mujica et al., 2022)</th><th>Class (CICES V5.1)</th><th>Group (CICES V5.1)</th><th>Division (CICES V5.1)</th></tr>
<tr><td>Accompany children. Go for a walk. Walk the dog. Sports activities. Spend the day</td><td>Recreation</td><td rowspan="2">Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions</td><td rowspan="3">Physical and experiential interactions with natural environment</td><td rowspan="3">Direct, in-situ and outdoor interactions with living systems that depend on the presence in the environmental setting</td></tr>
<tr><td>Meet with people. Shop at fairs. Attend outdoor shows</td><td>Social encounter and interaction</td></tr>
<tr><td>Contemplate the landscape</td><td>Nature observation. Aesthetic values.</td><td rowspan="2">Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions</td></tr>
<tr><td>Rest. Relaxation activities. Read.</td><td>Other</td><td></td><td></td></tr>
</table>

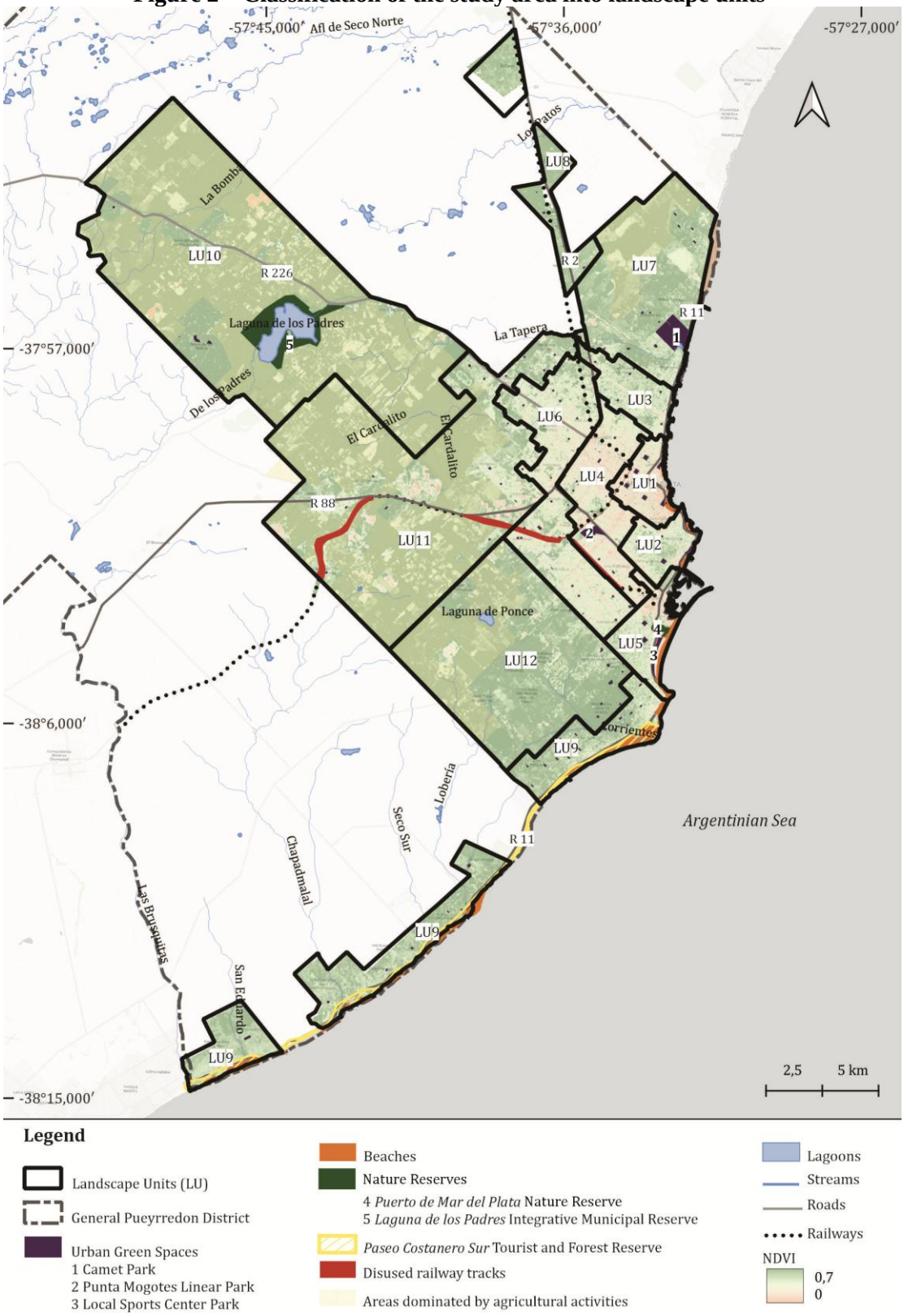
Source: Author(s)

5. RESULTS

5.1. Delimitation of landscape units

A total of twelve landscape units were identified: six in the urban area and six in the urban-rural interface zone, which includes both the peri-urban sector and the southern coastal area. As previously mentioned, these units were defined by grouping neighborhoods (Municipalidad de General Pueyrredon, 2022) based on the analysis of multiple data sources. The character of each unit emerges from the interaction between the analyzed variables. Figure 2 illustrates the spatial delimitation of the landscape units, whereas Table 2 details their main characteristics.

Figure 2 – Classification of the study area into landscape units



Source: Authors' Elaboration

Table 2 – Main characteristics of the defined landscape units

Landscape Unit	Main characteristics
LU1 Urban center	This unit contains urban green corridors and squares with vegetation in good condition, scoring high in diversity, condition, accessibility, and naturalness. Beaches extend along most of the coastline, and there are sections of disused railway tracks. Beyond these designated spaces, vegetation is scarce. No additional land is available for new PGSs.
LU2 Southern Garden city.	Characterized by abundant trees and vegetation in the gardens of residential neighborhoods. The PGSs include neighborhood squares and urban parks, all in good condition regarding accessibility, diversity, and maintenance. However, coastal PGSs have lower tree cover, leading to intermediate naturalness values. The unit also features beaches and green spaces along the coastal promenade. There is no vacant land for additional PGSs.
LU3 Northern Garden city	This unit has abundant vegetation in residential gardens. The PGSs consist of neighborhood squares with varying values for accessibility, diversity, maintenance, and naturalness. It includes a section of the *La Tapera* Stream, which marks the boundary of the city's urban commons, and beaches along the coastal promenade.
LU4 Inner urban unit	Vegetation is primarily concentrated in the gardens of some residential neighborhoods. The PGSs include the Local Sports Centre Park and neighborhood squares which exhibit varying values in the evaluated indices. Some vacant plots and sections of a disused railway line are also present.
LU5 Port	Distinguished by the *Puerto de Mar del Plata* Nature Reserve, a Linear Park, and the *Punta Mogotes* beaches. Vegetation is well-preserved in some neighborhoods. The unit includes neighborhood and urban squares with varying values for accessibility, diversity, and maintenance.
LU6 Western urban unit	This unit contains vacant land, streams, and sections of disused railway tracks. The PGSs are scattered neighborhood squares with varying accessibility scores and intermediate values for diversity and maintenance. In terms of naturalness, squares in the southern sector exhibit high values, whereas those in the west show lower scores.
LU7 Coastal peri-urban	Characterized by abundant trees and vegetation, with key features including *Camet* Park, *La Tapera* Stream, and several neighborhood squares, which generally score low in accessibility, diversity, and maintenance but moderate to high in naturalness. The unit also includes beaches and vegetation along Highway 11, which serves as a regional green corridor.
LU8 Inner Northern peri-urban	This unit has significant vegetation in residential areas. Its PGSs include neighborhood squares with high diversity and naturalness values but medium to low accessibility and maintenance scores. It is intersected by *La Tapera* and *Los Patos* streams, and its neighborhoods are aligned along Highway 2, which could function as a regional-scale green corridor.
LU9 Coastal Southern peri-urban	Rich in vegetation, this unit features numerous neighborhood squares that generally exhibit low scores in accessibility, diversity, maintenance, and naturalness. The neighborhoods are situated along Highway 11, designated as the *Paseo Costanero Sur* Tourist and Forest Reserve, which could function as a green corridor. The area includes streams such as *Lobería*, *Chapadmalal*, and *Las Brusquitas*, as well as beaches.
LU10 Hills peri-urban	This unit contains abundant vegetation. Its PGSs include neighborhood squares and urban parks, with high diversity and naturalness values but medium to low accessibility and maintenance scores. It is also defined by the *Laguna de los Padres* Nature Reserve and Highway 226, which serves as a regional green corridor, alongside areas dominated by agricultural activities.

LU11 Western peri-urban	Vegetation is scarce in the more urbanized areas. The PGSs consist of a few neighborhood squares that generally score low in accessibility, diversity, naturalness, and maintenance. The unit includes agricultural and mining areas, streams, and disused railway tracks.
LU12 Inner Southern peri-urban	This unit has abundant trees and vegetation in residential neighborhoods, including private communities that lack PGSs. Outside these areas, there are a few neighborhood squares with medium to low scores across evaluated indices.

Source: Author(s)

5.2. Cultural ES in landscape units according to local expert knowledge

Figure 3 illustrates the interaction between the delineated landscape units and the capacity of EI components to provide cultural ES, as assessed by the panel of local experts (Mujica et al., 2022).

In the urban area, the units characterized by the presence of urban squares and beaches (LU1, LU2, LU5, and the coastal sector of LU3) offer multiple cultural ES simultaneously, with recreation and tourism being particularly prominent. Additionally, the residential neighborhoods within LU2 feature gardens of significant landscape value, enhancing their appeal for tourism and strengthening their association with local identity.

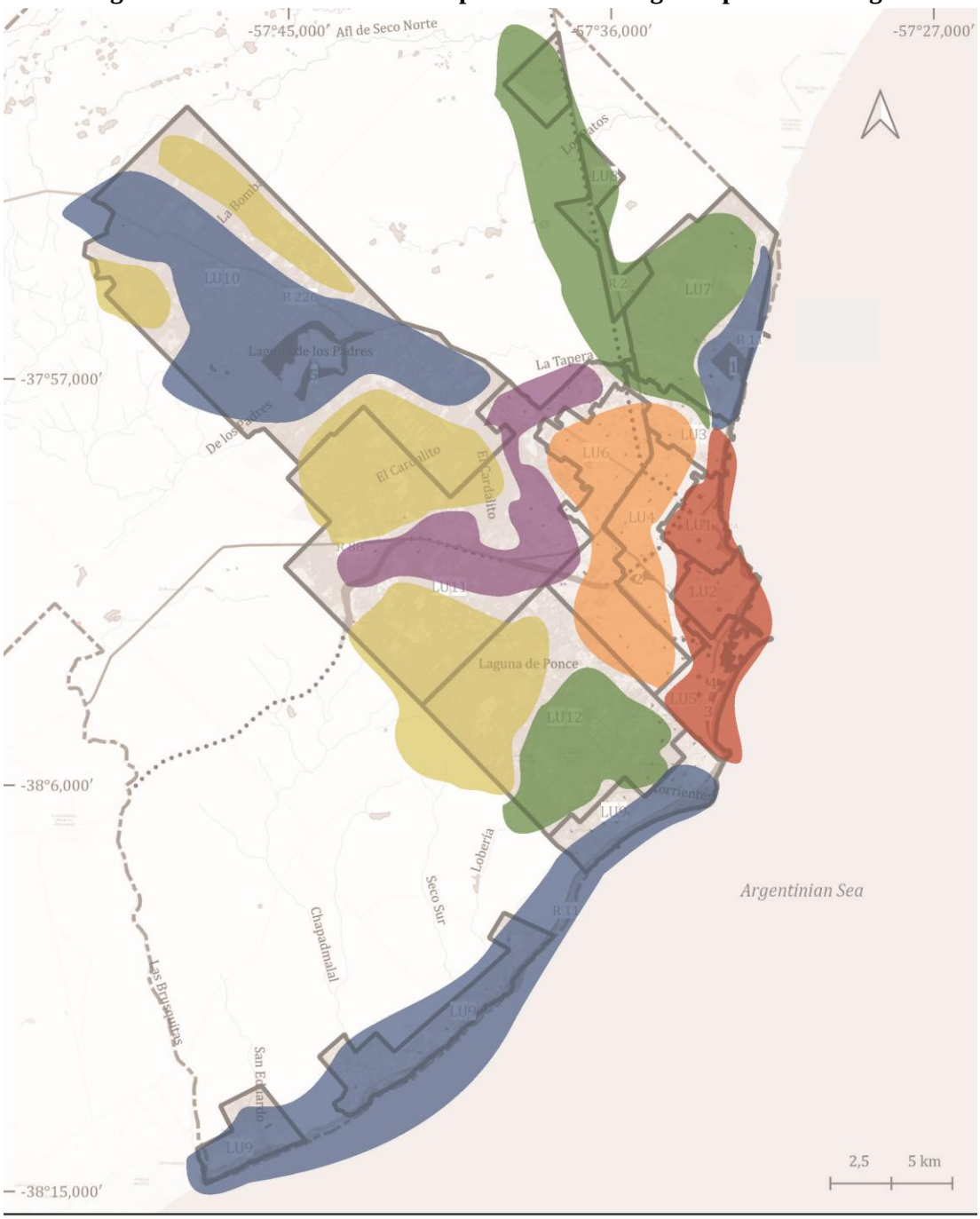
Conversely, in units where the defining elements are neighborhood squares or the vegetation in residential gardens (LU3, LU4, and LU6), the most relevant services are recreation, social encounter, and local identity, rather than tourism. It is important to note that these spaces differ in terms of infrastructure and amenities required for specific activities. As a result, not all residents of these neighborhoods can access the same benefits from these services.

In the peri-urban and urban-rural interface areas, the units along the coastline (LU7 and LU9) or in the hills (LU10) provide the widest range of cultural ES simultaneously, offering abundant opportunities for recreation and contemplation.

Meanwhile, areas dominated by agricultural activities primarily contribute to local identity, research and education, and aesthetic appreciation. LU8 and LU12, where gardens and tree-lined streets in residential areas predominate, mainly provide aesthetic benefits and environmental education services.

Finally, the most urbanized sectors of LU11, including *Batán* and the neighborhoods adjacent to the urban area, primarily support recreation, social encounter and interaction through neighborhood squares, following a pattern similar to LU6.

Figure 3 – Cultural ES in landscape units according to expert knowledge



Legend

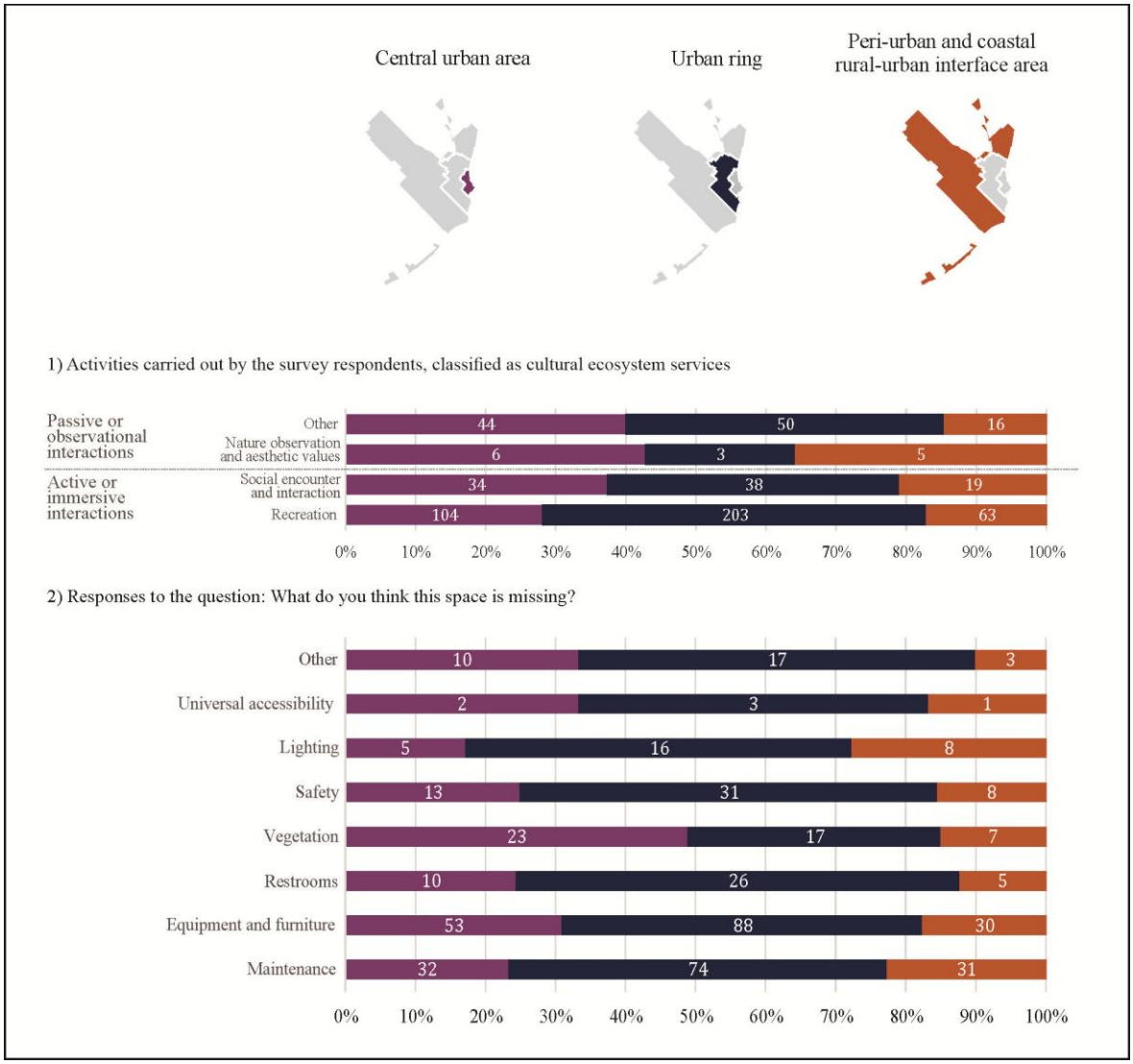
- Urban area sectors with simultaneous provision of multiple cultural ES.
- Urban area sectors with moderate provision of cultural ES, mainly recreation, social encounter and interaction and local identity.
- Peri-urban sectors with simultaneous provision of multiple cultural ES, with emphasis on tourism, recreation, nature observation, aesthetic values and local identity.
- Peri-urban sectors with moderate provision of cultural ES, mainly recreation, scientific research and educational values.
- Peri-urban sectors with moderate provision of cultural ES, mainly recreation, social encounter and interaction and local identity.
- Peri-urban sectors dominated by agricultural activities and provision of cultural ES derived from these activities, mainly nature observation, aesthetic values, local identity, scientific research and educational values.

Source: Authors' Elaboration

5.3. Cultural ES provided by the PGSs, according to the local population

Firstly, by categorizing the activities carried out by respondents in PGSs based on their associated cultural ES and in relation to CICES V5.1 (Figure 4), it is evident that activities involving active interactions related to recreation are more common in the urban ring. In contrast, activities involving passive or observational interactions are more prevalent in both the central urban area and the peri-urban area.

Figure 4 – Distribution of responses across the study area



Source: Authors' Elaboration

Regarding what respondents felt was lacking in the PGS they visited, responses categorized under vegetation (trees, flowers, grass) were more prominent in the PGSs of the central urban area compared to other sectors of the study area. Conversely, concerns

about security and the lack of public restrooms were more pronounced in the urban ring. Additionally, issues related to lighting were particularly relevant in PGSs located in the peri-urban and coastal urban-rural interface areas.

5.4. Guidelines and recommendations based on the integration of the results

Based on the findings, five key guidelines are proposed:

1. Enhance cultural ES in PGSs
2. Increase the green area
3. Improve EI connectivity
4. Preserve EI
5. Monitor EI and ES

For each guideline, specific recommendations are provided, applicable to one or more landscape units (Table 3). The spatial distribution of these guidelines and recommendations is illustrated in Figure 5.

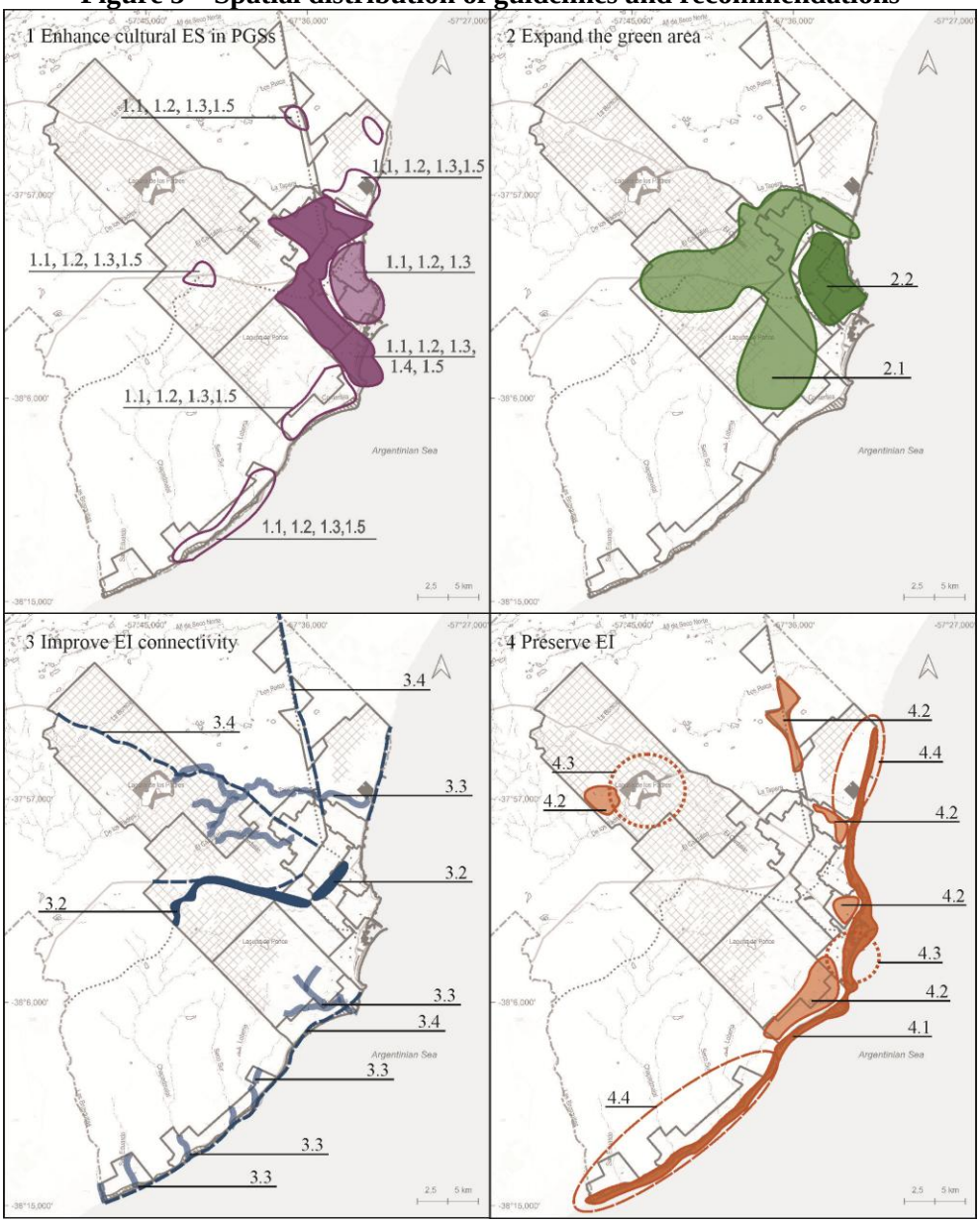
Table 4 – Guidelines and recommendations for landscape units

Guidelines	**Recommendations**	**Applicable or Priority LUs**
1. Enhance cultural ES in PGSs	1.1. Increase tree cover and vegetation in PGSs.	Applicable to all units.
	1.2. Implement maintenance programs for PGSs.	
	1.3. Install specific urban furniture and equipment based on user needs.	
	1.4. Improve accessibility by upgrading perimeter streets, sidewalks, internal pathways, and installing ramps at corners.	
	1.5. Improve safety and lighting in PGSs.	
2. Expand the green area	2.1. Develop new recreational green spaces in vacant lots within the consolidated urban fabric.	LU3, LU6. LU8, LU9, LU11, LU12.
	2.2. Identify opportunities to incorporate vegetation in areas without available land for new PGSs, such as green roofs or walls.	LU1, LU2, LU4.
3. Improve EI connectivity	3.1. Increase tree-lined streets to enhance connectivity.	Applicable to all units.
	3.2. Convert unused railway sections into urban green corridors, integrating rest areas and pedestrian routes into residents' daily paths.	LU1, LU4, LU6, LU11.
	3.3. Transform streams into green corridors with rest areas and pedestrian routes.	LU3, LU7, LU9, LU10.
	3.4. Strengthen existing regional green corridors, promoting alternative tourist and recreational circuits that connect rural areas and smaller towns in the General Pueyrredon District.	LU7, LU9. LU8, LU10, LU11.
4. Preserve EI	4.1. Protect beaches and coastal landscapes, considering their cultural and aesthetic value.	LU1, LU2, LU3, LU5, LU7, LU9.
	4.2. Preserve the historical and identity-related values of gardens, enhancing their role in tourism and local identity.	LU2.

	4.3. Promote landscape and ecosystem conservation to preserve cultural ES provided by Nature Reserves.	LU5, LU9, LU10.
	4.4. Identify EI components that can guide urban expansion while conserving peri-urban and rural landscapes, as well as EI elements with symbolic, historical, and identity value. Use EI as a conservation strategy to mitigate the ecological and social impacts of urban expansion, preventing ecosystem fragmentation.	LU7, LU9
5) Monitor EI and ES	Maintain an updated database to monitor EI and cultural ES dynamics, supporting the prioritization of intervention strategies.	Applicable to all units.

Source: Author(s)

Figure 5 – Spatial distribution of guidelines and recommendations



Source: Authors' Elaboration

6. DISCUSSION AND CONCLUSIONS

This study aimed to delineate landscape units in the urban and peri-urban areas of a medium-sized Latin American city based on EI, to support the planning and conservation of the ES it provides. Methodologically, these units serve as a spatial framework for understanding and describing the landscape characteristics of the study area. Additionally, they function as territorial components for analyzing cultural ES. In this regard, the classification enabled the integration of findings from previous studies, incorporating various EI indices and information layers. Subsequently, this delineation facilitated a re-evaluation of the ES assessment conducted by experts and an analysis of survey results based on the location of PGSs.

Regarding the character of the units within the urban area, it is clearly defined in some cases by the presence of significant PGSs and, in others, by the vegetation in residential gardens or vacant lots on the urban periphery. Conversely, in peri-urban and coastal urban-rural interface areas, the units are primarily characterized by regional green corridors, large PGSs and nature reserves. In general, the delineation of these units aligns with the road axes along which the city is expanding (Zulaica et al., 2023).

The availability and characteristics of EI, which were considered in the delineation of these units, influence both the cultural ES they provide and how the population uses and perceives them (Scholte et al., 2015). The results indicate that, within the urban area, units containing well-maintained PGS—particularly those that also include other EI components such as beaches and urban green corridors—are more significant in providing cultural ES.

However, in peri-urban and coastal urban-rural interface areas, certain units offer a wide range of services through beaches, large parks, nature reserves, or regional green corridors, regardless of the condition of the PGSs. In these cases, EI plays a crucial role in the provision of services such as tourism, recreation, nature contemplation, and local identity. Meanwhile, the survey results, which focused on PGSs, highlight that ES involving passive or observational interactions are particularly relevant in these units.

The integration of these findings led to the development of guidelines and recommendations for EI management across different landscape units. However, beyond the specific recommendations for each unit, emphasis is placed on the importance of maintaining an updated database to monitor EI dynamics and cultural ES, ensuring that intervention strategies align with community needs and demands.

Furthermore, given the differences observed between urban and peri-urban areas, incorporating indicators that reflect these spatial distinctions would enhance the analysis. Additionally, it is recommended to monitor EI across different seasons to account for temporal variations and develop targeted proposals that address real and evolving needs.

Regarding the strengths and weaknesses of using landscape units for EI planning, a key advantage is the ability to integrate complementary sources of information in the assessment of ES, thereby supporting both diagnostic and planning processes in urban landscape management. This study combined diverse types of data—both quantitative and qualitative—which could be further enriched by incorporating additional perspectives.

Moreover, since landscape units are delineated based on neighborhood boundaries, planning processes could benefit from the active participation of local neighborhood associations or community-based organizations. Neighborhoods provide opportunities for integrated urban planning at a smaller, more manageable scale than the city as a whole, enabling flexible, people-centered approaches (SHIFT – Platform for Sustainable and Inclusive Cities, n.d.). This approach has proven effective in urban governance across Latin America (Brakarz et al., 2011).

As for limitations, a key challenge lies in the availability and compatibility of spatial data at the required scale and level of detail. Additionally, while this approach allows for the spatial integration of various datasets, it also requires continuous methodological refinement to ensure that the delineation of units reflects the complex and dynamic nature of urban landscapes.

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