

Enabling new informational landscapes for resolving nature-based solutions literacy and planning in Barcelona Metropolitan Area

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ABSTRACT

This paper builds upon the necessity of developing sound informational landscapes to enable NBS planning in metropolitan areas. Information literacy was enhanced through a complex participatory process in Barcelona Metropolitan Area, aimed at detecting existing knowledge, potential barriers for implementing NBS and identifying opportunities for action. Communication and storytelling as a transversal process accompanied the whole process from the beginning. Participatory informational maps were produced, as the core of the co-design and co-learning dynamics. Results showed gaps mainly related to NBS literacy, biodiversity and cultural ecosystem services. Furthermore, actors with different interests shared dissimilar NBS knowledge, interests and priorities over territory. We conclude highlighting the importance of the evidence-based planning, information generators and NBS literacy to enforce the NBS understanding, preservation and implementation in metropolitan areas. **Keywords** Participatory process; Information; Communication; Knowledge; Mapping; Actors; Nature-based solutions literacy.

1. Introduction

Adapting the metropolitan territories to global change has emerged as one of the greatest challenges for the spatial planning debate. Green spaces within metropolitan areas are recognized to halt biodiversity loss, foster ecosystem functioning and generate multidimensional **nature-based solutions** (hereafter NBS). NBS have significant potential to advance landscape restoration, to decrease the vulnerability and to enhance urban resilience. A growing body of literature has provided sound reference and knowledge on the potential of NBS (Kabisch et al., 2016; Pauleit et al., 2017; Gulsrud et al., 2018; Konijnendijk, 2021; Kabisch et al., 2022). However, **conceptualising, planning and implementing** NBS is particularly challenging given the complex spatial configuration, fragmented and changing landscape context in metropolitan areas (Kabisch et al., 2022). Moreover, the relationship between urban society and urban nature is changing, giving rise to new societal values, interests and conflicts in this context (Konijnendijk, 2000).

Participatory approaches (i.e. co-design and participatory

mapping) have been used to help planners and policy makers design green infrastructure that not only addresses ecological priorities, but also incorporates user demands and needs in green infrastructure design, planning and management (Basnou et al., 2020). Co-design describes the active collaboration among stakeholders in designing solutions to a problem (Vargas et al., 2022). Co-design as a “learning alliance” (Van der Jagt et al., 2019) encourages and empowers NBS knowledge in planning. Participatory mapping (i.e. PPGIS - public participation geographic information system) is a powerful tool to add place-specificity, local knowledge and evidence-base to ecosystem services assessment, urban design, land use planning and green infrastructure management (Brown and Kytä, 2014; De Vreese et al., 2016a).

However, while the European Commission (Harrak and Lemaitre, 2023) urges that design and implementation of NBS should be co-produced with multiple institutional and civil stakeholders and lessons learnt should be widely shared, the **uptake of co-produced NBS into planning and practice** has been limited (Roitsch et al., 2024). At the same time, the lack of relevant and contextualized information derived from and feeding participatory approaches has been an

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Box 1

Key ideas framing the nexus NBS literacy and informational landscapes in metropolitan areas.

We use the concept of "information landscape" over metropolitan territories to refer to the ways in which information flows, is managed, and is used within a wide territory, including various municipalities and administrative hierarchies. This concept is overlaid upon the classical definition of landscape ecology (Forman, 1983), which refers to: (1) the spatial relationships among landscape elements, or ecosystems, (2) the flows of energy, mineral nutrients, and species among the elements, and (3) the ecological dynamics of the landscape mosaic through time.

In this case, we added the social perspective and encompassed various sources, types, and flows of information that exist and interact, to understand how information related to NBS is understood, generated and shared within a metropolitan area.

Therefore, by integrating the NBS literacy concept, we demonstrate the multiple benefits of the informational landscapes, to enforce the socio-ecological flow and address inclusion in urban planning. This approach enables:

- Data transparency, integrating, organizing and making geospatial data available for everybody
- Community Engagement and Public Participation (i.e. involving citizens in decision-making and participatory mapping)
- Transparent Data Sharing, Public Access to Knowledge, Capacity-Building and Education and citizens science initiatives (i.e. Citizens as sensors of territorial interests and demands)

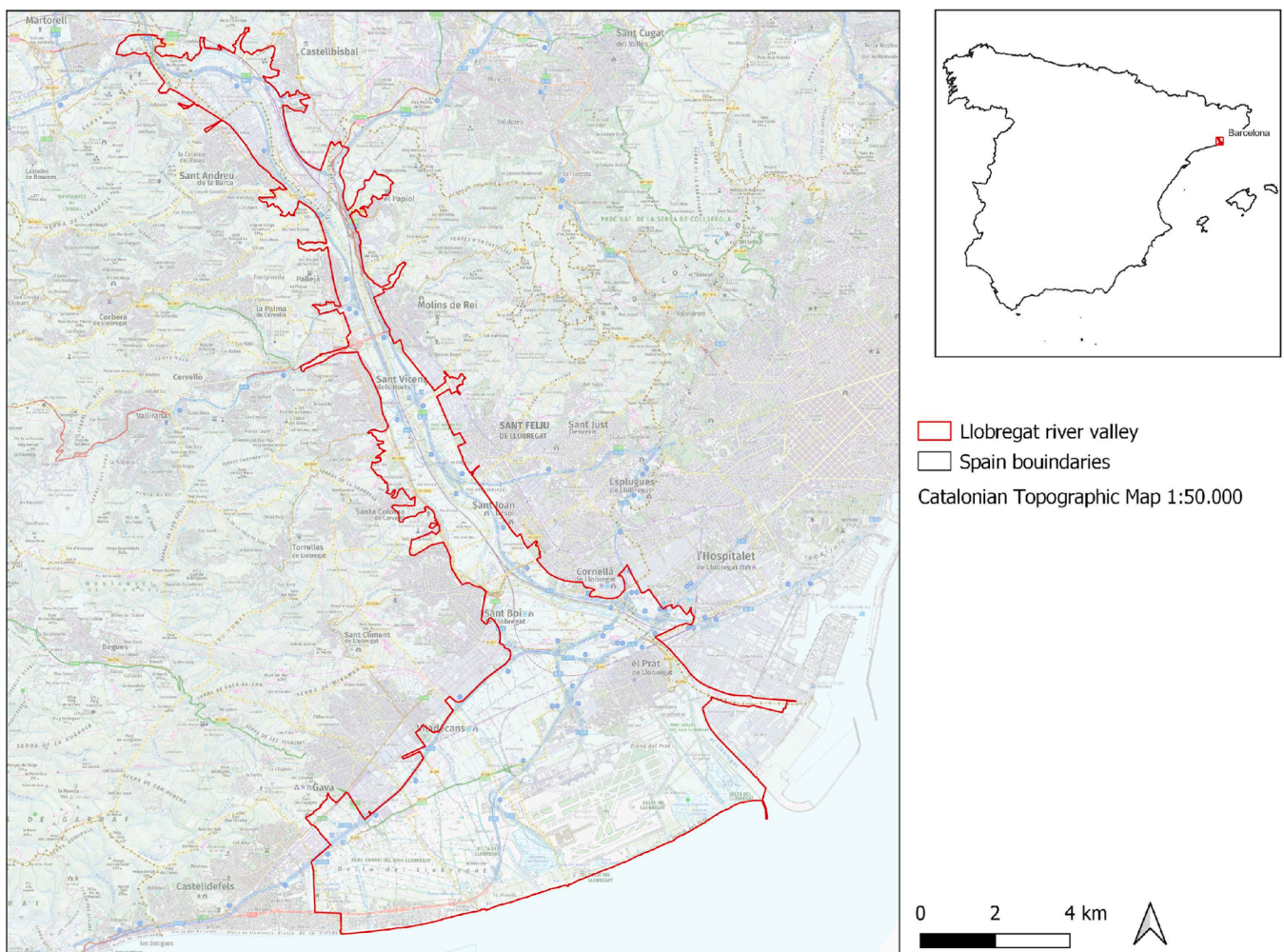


Fig. 1. The location of study area, along the metropolitan section of the Llobregat river Valley (Spain).

important barrier for putting NBS into practice (Van Der Jagt et al., 2023), especially in metropolitan areas.

In this study, we argue that sound informational landscapes can support researchers, planners and policymakers in NBS conceptualization, planning and implementation at complex metropolitan scales (for example the Llobregat River Valley in the Barcelona Metropolitan

Area). We define the **informational landscape** as the relevant and contextualized data on the geographic area and the topic under discussion, informing multidisciplinary actors and aligned with territorial challenges, planning strategies and policy agendas. Although informational landscapes are supportive for including co-design approach into practice, their potential remains insufficiently explored. A solid

informational landscape contributes to information literacy (Warschauer, 2004) with the stakeholders and helps them to deal with misinformation. Information literacy includes the capacity and skills to understand and use information on a certain topic, and as such, informational literacy is critical to social inclusion. Moreover, information literacy also helps stakeholders dealing with misinformation, disparities in accessing information, data complexity or specific jargon. Through mutual learning in social networks, co-design and participatory mapping facilitate informational literacy. We use the concept of informational landscapes to generate, understand and use data related to a complex territory and a complex topic; with the people who live, work, know and depend on the studied landscapes acting as information facilitators in a co-production process. The informational landscape is place-based and it implies many informational levels, perceptions and knowledge from various fields (the concept is framed in Box 1).

In order to generate meaningful data and support an evidence-based approach for planning context-adapted NBS in metropolitan landscapes, our research focused on the following **objectives**: (a) enabling the informational landscape around NBS through a multi-actor perspective; (b) detecting and understanding the potential role of informational landscapes to capture and process local knowledge and stakeholders' perceptions, and (c) identifying opportunities for actionable and supportive informational landscapes to implement NBS.

2. Methods

2.1. Study area

The focus of this study is the landscape of the lower part of the Llobregat River Valley, near Barcelona, Spain (Fig. 1). The Llobregat River is one of the main axes of the green infrastructure in the Barcelona Metropolitan Area and it is a strategic corridor for the implementation of large infrastructures. It is also one of the most important river systems in Catalonia, in a territory dominated by intense land-use changes in the last decades. The total length of the Llobregat River is 170 km, of which the last 30 km (before joining the Mediterranean Sea) is situated in the Barcelona Metropolitan Area, spreading along 16 municipalities, from Martorell to Prat de Llobregat.

The Lower Valley of Llobregat River is part of various protected areas (especially belonging to the Agricultural Park of Baix Llobregat, an important reservoir of ecosystem services in the metropolitan area, such as food provision). This section also includes the Llobregat Delta, listed as part of the European Natura 2000 network, a hotspot of biodiversity and ecosystems services in the Barcelona Metropolitan Area. The metropolitan section of the Llobregat River is canalised for the most part and the typical meandering and natural vegetation (i.e., riparian forest) has been lost due to straightening the river. Few small, well-preserved riparian forest patches have been identified along the river.

This area has a complex institutional framework, with multiple levels of government. The main administrations with territorial planning competences in the Llobregat Valley are the Generalitat (Government of Catalonia), the Barcelona Metropolitan Area government (AMB) and the municipal councils. Additionally, two public consortia have competencies in this area (the Consortium of the Agrarian Park of Baix Llobregat and the Consortium of Natural Areas of Llobregat Delta); these public consortia are governed by the municipal councils, the Barcelona Metropolitan Area, the Generalitat and the Diputació de Barcelona (Barcelona Provincial Council). The main planning document governing the planning and development of the Barcelona Metropolitan Area is the recently adopted metropolitan PDUM (Pla Director Urbanístic Metropolità; Metropolitan Urban Master Plan; AMB, 2023), but given the recent approval of the PDUM (2023), part of the territorial planning still follows the older Metropolitan Plan (dating from 1976).

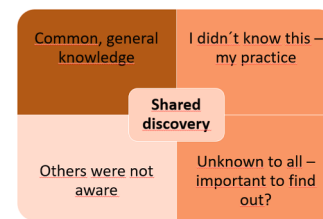


Fig. 2. Main ideas of the co-design sessions to share, generate knowledge and enable stakeholders learning.

2.2. Co-design and co-learning process

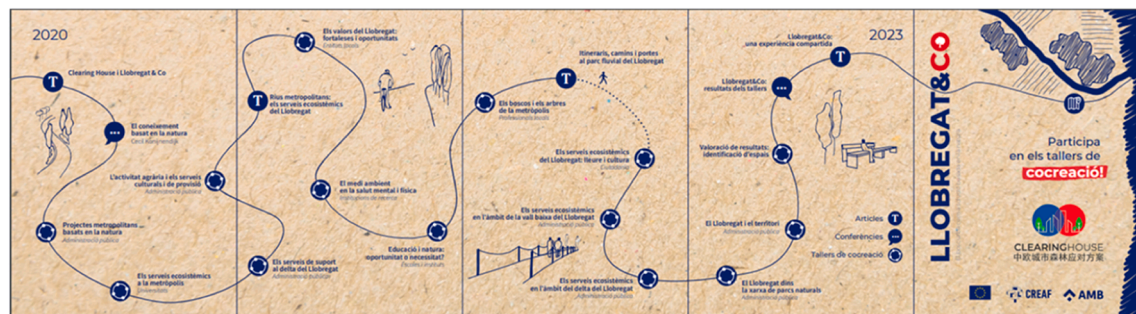
Our participatory approach was mainly based on co-design, co-learning and participatory mapping, supported by various communication actions and channels (see Section 2.3), to enable and motivate a community around the informational landscape. Co-learning enabled an open and collaborative process of knowledge sharing between the partners in charge of research on NBS and local stakeholders. It also allowed local stakeholders to complement and provide feedback on this research through group discussions. Therefore, participatory approaches are a prerequisite for integrating local knowledge and stakeholders' experiences and perceptions (Adams et al., 2023; Kabisch et al., 2016) and include it in the informational landscape.

Between 2020 and 2022, a metropolitan administration (the Barcelona Metropolitan Area, AMB) and a research institution (CREAF) organised and designed the dynamics of six co-design workshops (see ANNEX I) related to the Llobregat River Valley, in the framework of CLEARING HOUSE H2020 project (Fu et al., 2020). Following stakeholder mapping and stakeholder onboarding, a co-design process was implemented to integrate and exchange between local actors from research, academia, planning, policy and society in the fields of urban planning, landscape design, architecture, biology, ecology, health and urban sociology. Policy was represented by municipal, metropolitan and regional administrations. Local NGOs and community groups represented the societal actors. A facilitator helped to deliver related knowledge and to favour discussion and consensus.

A workshop-based co-learning process was developed, following the Johari window approach (Fig. 2), a communication model to build relationships between team members (Brown and Harvey, 2006). The Johari window centres on a common and shared discovery of knowledge building and knowledge sharing, including (1) discovering the context (general knowledge), (2) learning from participants' previous knowledge and awareness (I didn't know this/Others were not aware/Unknown to all), and (3) deploying pathways and making decisions based on the shared discovery (represented mainly by participatory mapping). This framework allowed to better tailor the workshops and participatory mapping, and to understand the knowledge gaps and participants' demands related to NBS along the Llobregat River landscape.

2.3. Communication and storytelling

The communication approach accompanying the co-design process primarily targeted the actors living, studying and working in the study area, and aimed to enlarge the outreach and impact of the informational landscape beyond the participants in the co-design workshops. The basis of our communication actions relied on storytelling and community creation. The first event was designed as an introductory webinar, with a top expert, to raise awareness and motivation about the workshops and set the background of the future activities. Storytelling helped us to bring clear messages, as an inspiration to reconnect people with Llobregat River landscapes. In this line, we named and created the community Llobregat&Co (<https://clearinghouse.amb.cat/en/>), to raise awareness and engage the participants. A visual participation itinerary



a.



b.



c.

Fig. 3. Material produced around the concept of Llobregat&Co for the co-design sessions. a) Activity circuit for Llobregat&Co community of Llobregat River landscape b) Fragment of the Ecosystem Services card game: introductory cards c) Final trip along the Llobregat River Valley, which closed the co-design itinerary (Photo credit: C. Basnou).

(guidance on how the participation process is organised) was settled, together with various materials (for both communication and learning, see Fig. 3a). The “Ecosystem Services Card Game” was produced in the form of a honeycomb pattern for one of the workshop’s dynamics, and given as a gift for participants (Fig. 3b). A communication task force was responsible for various communication actions (see ANNEX II), contacting and sending feed-back to the participants. A final trip along the Llobregat River Valley was planned as an outdoor educational experience for all ages, with the aim of raising awareness about the open-access PPGIS tool developed for this approach (Fig. 3c).

2.4. Mapping and analysing the informational landscape

During the co-learning sessions, various actors identified key factors or issues locally relevant for NBS, using a legend with stickers marked in blue or red on a paper map (blue for *Identifying biodiversity, ecosystem services or ancillary infrastructure* and red stickers for *Barriers, Challenges and Proposals for NBS actions*). The classification used for the legend was built in line with some of the main targets of **Nature Restoration Regulation** (EC https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law_en) and the **EU Biodiversity Strategy for 2030**, considering specific habitats, biodiversity, ecosystem services and functions. Concretely, participants were asked (a – blue stickers) to locate points where existing actions or related infrastructure are already in place (i.e. related to biodiversity areas, provision of ecosystem services, natural habitats or citizens initiatives regarding nature) and (b – red stickers) to propose new NBS related actions and areas, and identify the barriers and socio-ecological challenges along the study area (such as fragmented habitats, vulnerable areas to be restored). A detailed cadastral map provided the base for this activity in

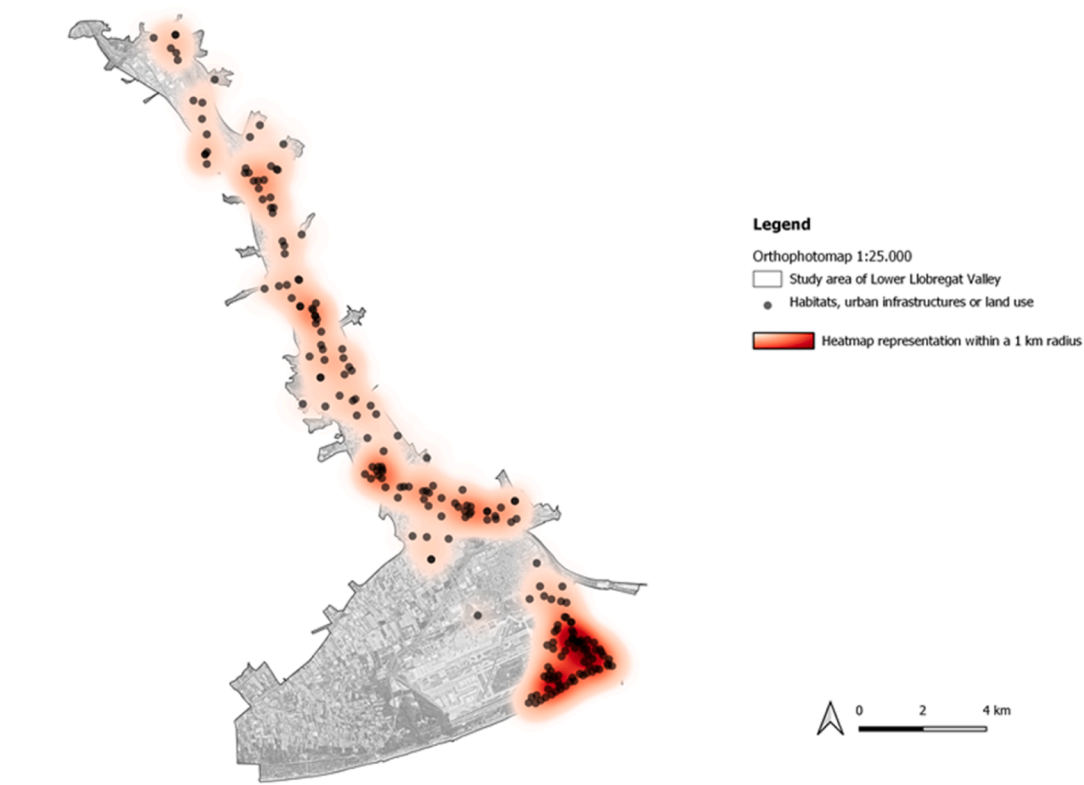
each co-design session (1:25.000 scale).

The locations were georeferenced, documented (i.e. layered according to date and stakeholder type) and introduced in an in-house developed PPGIS (<https://ide.amb.cat/LlobregatCo/index.html>). Based on this information, the following **informational maps** were produced, using the geographical information system QGIS (QGIS Development Team, version 3.28.11):

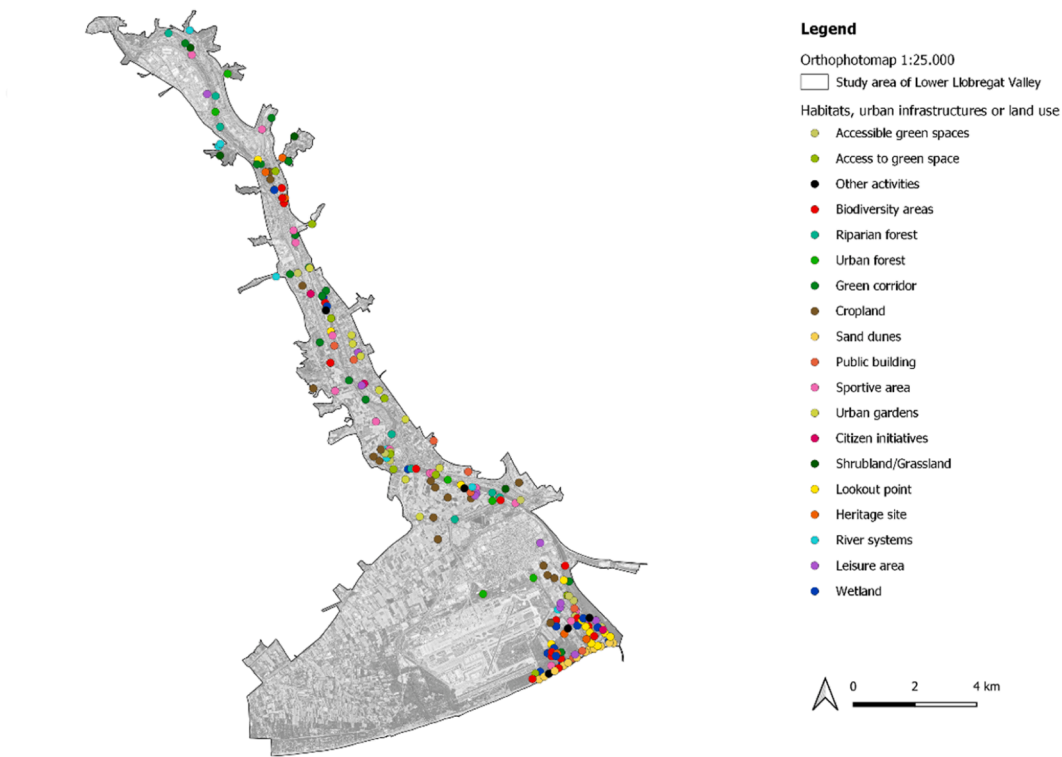
- Heat map with spatial informational hotspots (raster, based on the blue stickers)
- Heat map representing all the barriers, challenges and proposals (raster, based on the red stickers)
- Knowledge on habitats, infrastructure and citizens initiatives (vector, based on blue stickers)
- NBS barriers, challenges and proposals per main actor group (vector, based on the red stickers)

The spatial values were mapped using a 1 km buffer to drive informational heat maps, in order to visualise and quickly show the data (knowledge) density over the territory. Heat maps are based on a calculation of the density of points around each output raster cell, applying the quadratic kernel function (Silverman, 1986). This technique has been widely used to visualise the spatial patterns of PPGIS-based ecosystem service indicators (e.g. Brown and Kyttä, 2014; De Vreese et al., 2016a). The radius selected was 1 km and considered two map typologies: (a) knowledge related to the existing data and (b) barriers, challenges and proposals for opportunity areas and future NBS planning.

The spatial informational hotspots were mapped according to locations of data abundance on biodiversity, ecosystem services and



a. Spatial informational hotspots



b. Identifying habitats, infrastructures and citizens initiatives

Fig. 4. The distribution of the informational landscape across the Llobregat river Valley (resulting from the co-design sessions).

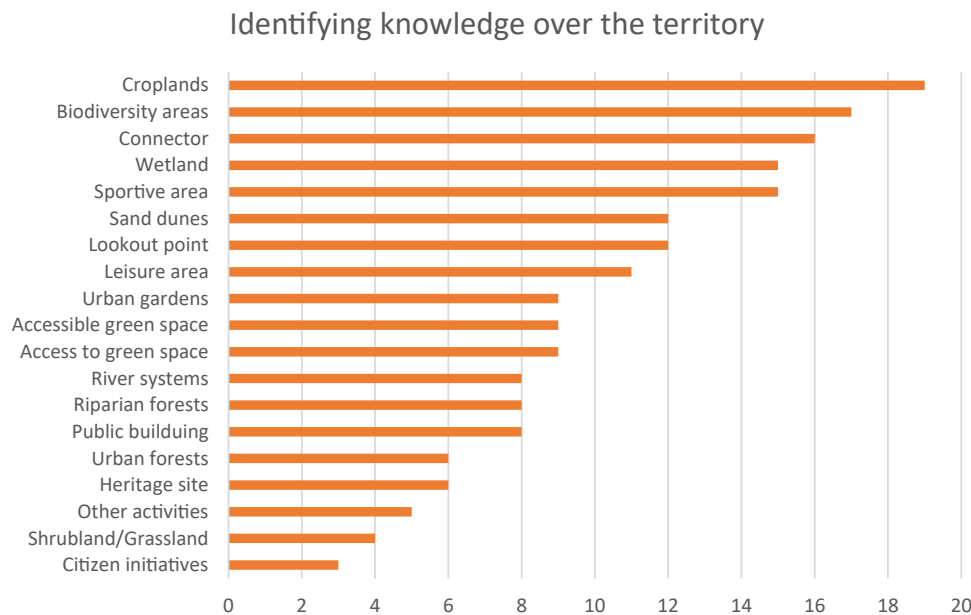


Fig. 5. Number of identified habitats, infrastructure and citizens initiatives across the map.

ancillary infrastructure considered important by different user groups. The informational landscape related to knowledge gaps was assessed through identifying keywords addressed (and their use frequency) during co-design dynamics (such as the ecosystem services game and the final discussion). This approach was completed by analysing the transcripts, pictures and recordings of the workshops and observation methods of the informational “coldspots” (locations with data gaps and data scarcity) identified by the facilitators during the participatory mapping exercise.

Additionally, the point layers were included in a multivariate analysis (RDA) to address stakeholders’ different views and perception when mapping certain aspects (i.e. NBS) (similar, for example, to De Vreese et al., 2016a).

3. Results and discussions

3.1. Mapping the informational landscape

The results of the participatory mapping were spatially processed and graphically presented. These results provide a landscape perspective, which enables the inclusion of biodiversity, natural processes and functions, within the NBS planning process.

Fig. 4a presents the general informational heatmap of the Llobregat Valley area, identifying 192 spatial elements along the study area (identifying biodiversity, ecosystem services or ancillary infrastructure). The mapping exercise revealed a good knowledge over the territory by the participants in the co-design workshops, with certain spatial patterns and informational hotspots.

The map reveals that most of the information is concentrated around a protected area, the Llobregat Delta, with homogenous knowledge distributed along the river, which corresponds to an area with diverse land-uses. The informational coldspots (with less information provision by stakeholders) are situated in areas corresponding to croplands, the airport, and the south-western part of the coastal area. Interestingly, this coastal area shelters a few vegetation patches of special interest (i.e. Mediterranean coastal pine forests).

Fig. 4b shows the location and the information and their classification (biodiversity areas, ecosystem services provision, main habitats, related infrastructure, citizens’ initiatives etc). In this study area, the results reflected that most knowledge ($n = 19$) was related to the area corresponding to the protected Parc Agrari of Baix Llobregat,

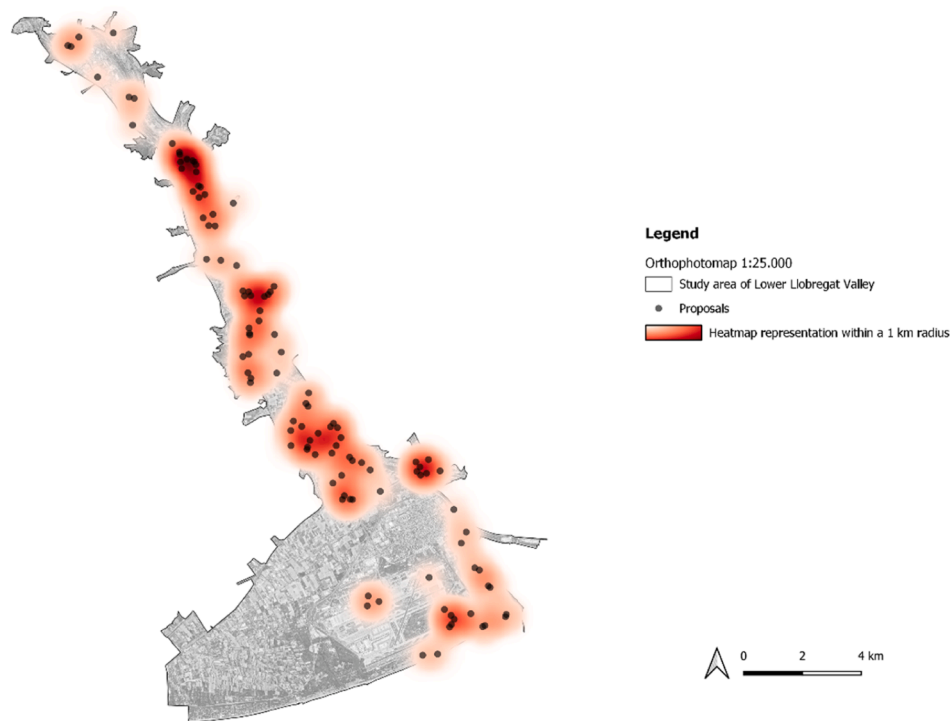
biodiversity area ($n = 17$) and landscape connectors ($n = 16$) (Fig. 5). Urban forests (i.e. street trees, parks, peri-urban parks or riparian forests) were identified to a lesser extent ($n = 6$); the reasons can be both less knowledge on their location and less representation in the area. Actually, apart from some urban parks, urban forests are underrepresented in the area. And finally, less knowledge on the citizens initiatives was noted overall in the study area ($n = 3$).

These results should be explored with caution, as they don’t represent the real ecosystem services delivery, but they assess the local knowledge and perceived ecosystem service delivery over the territory. However, the level of detail of this information enables further exploration (i.e. for territorial planning) and strengthens the understanding of multidimensional aspects of NBS, linking them to other territorial and societal needs and processes.

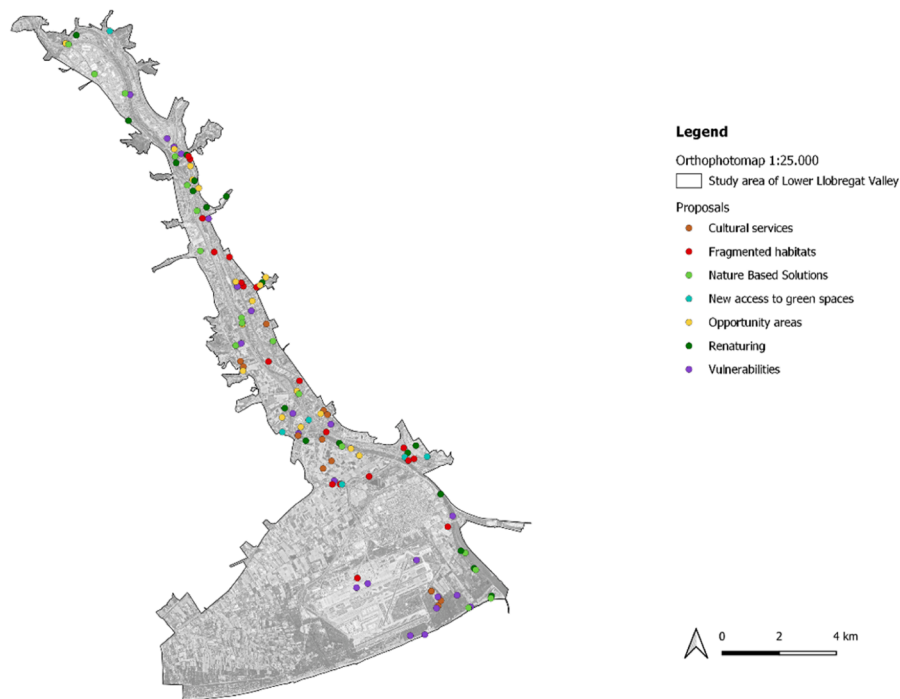
The maps in Fig. 6(a and b) represent the “Barriers, Challenges and Proposals” along the Llobregat River Valley, this includes proposals for new NBS interventions (including suggested locations for these), and barriers and socio-ecological challenges for new NBS actions. This map reveals the ecosystem services demands, interests, needs and challenges related to landscape and NBS planning. As indicated in Fig. 7, highest interest was related to identifying vulnerable areas ($n = 23$ locations on the map), fragmented habitats ($n = 19$) and renaturing ($n = 17$, e.g. ecological restoration through planting). Opportunity areas and areas for further implementation of NBS were also identified. Spaces related to cultural values and ecosystem services ($n = 11$) or opportunities to increase accessibility to green spaces were identified to a lesser extent ($n = 6$).

When the information for implementing NBS is stratified per actor group, the results show an interesting spatial configuration, which can be explored in Figs. 8 and 9. A multivariate analysis (RDA) shows a clear separation (both spatial and per land-cover), especially related to the main administration bodies on one side, and research, nature conservation and health actors on the other side (Fig. 9). It has emerged that researchers prioritise and propose new NBS along the river, whereas administrations focus especially on the urban and road area, but also on shrublands. Nature conservation groups and NGOs mostly propose new NBS along the beaches and industrial area, and experts from health prioritise NBS mostly in relation to woody crops.

Similar findings were stated elsewhere: actors with different environmental, economic, and social interests may not share similar land-management preferences (Brown & Kyttä, 2014). Such an analysis can



a. Heat map representing the proposals (including interests around territorial priorities and opportunities for future actions related to landscape and NBS planning)



b. The proposals by category

Fig. 6. Proposals for future actions related to landscape and NBS planning.

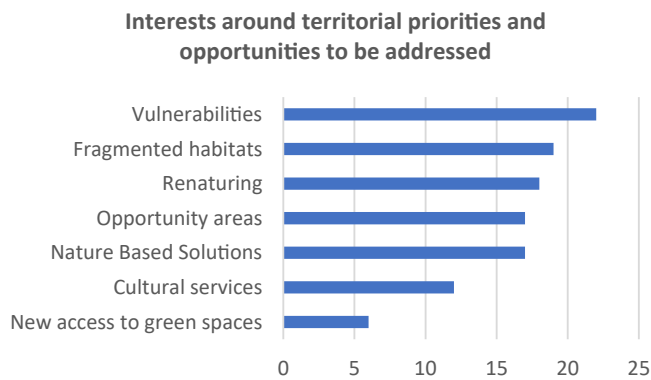


Fig. 7. Interests around territorial priorities mapped by all the participants.

represent useful guidance for local administrations in determining the perception of various stakeholders in relation to NBS. Moreover, data obtained from this participatory process adds important insights for the existing studies of ecosystem services assessment, territorial connectivity or biodiversity conservation.

3.2. Knowledge gaps

Our study identified various knowledge gaps related to NBS (Fig. 10). These gaps mainly relate to: landscape, design, planning and governance, and implementation. Knowledge gaps related to the social landscape mainly focused on strengthening social inclusion, and how to deal with conflict management and effective communication of key concepts. For designing better NBS, there is a need for a better understanding of the evidence-base and multifunctionality. Planning and

governance remain an important gap, especially related to the territorial complexity and spatial scale. Knowledge gaps concerning NBS implementation include concerns about the lack of tools and a missing clear legal framework. An overall concern was how to increase green space connectivity, given the existing territorial pressures. Concerns on how to include cultural ecosystem services into planning have been raised by various actors. Cultural ecosystem services (such as recreation, social and educational opportunities, cultural heritage or knowledge systems) are underrepresented among the priorities identified during the participatory mapping sessions (Fig. 6). However, cultural ecosystem services play a significant role in well-being and urban quality of life. Generally, they are more directly experienced and intuitively appreciated by people compared to other ecosystem services (Plieninger et al., 2015; De Vreese et al., 2016b), even if they often go unmeasured. As reflected by other studies, cultural ecosystem services have been poorly integrated into NBS or green infrastructure planning (Milcu et al., 2013; O'Brien et al., 2017). Strengthening cultural ecosystem services is key in highly populated areas (such as the metropolitan areas), where the open spaces are relevant for citizens' health and well-being (i.e. opportunities for recreation, such as leisure, trekking, sport, or educational activities, outdoor teaching etc.).

Biodiversity monitoring and conservation was mostly seen as a transversal, but key concept insufficiently integrated into NBS planning overall, mostly highlighted by specific actor types (i.e. research and academia). They also reflected on the opportunities of understanding which NBS can benefit both people and biodiversity, revealing the importance of strategic choices of particular ecosystem services to include in NBS and conservation planning (Chan et al., 2006; Jacobs et al., 2016).

Overall, these knowledge gaps reflect the gap in spatially-based social valuation methods, and the need to integrate this information to the

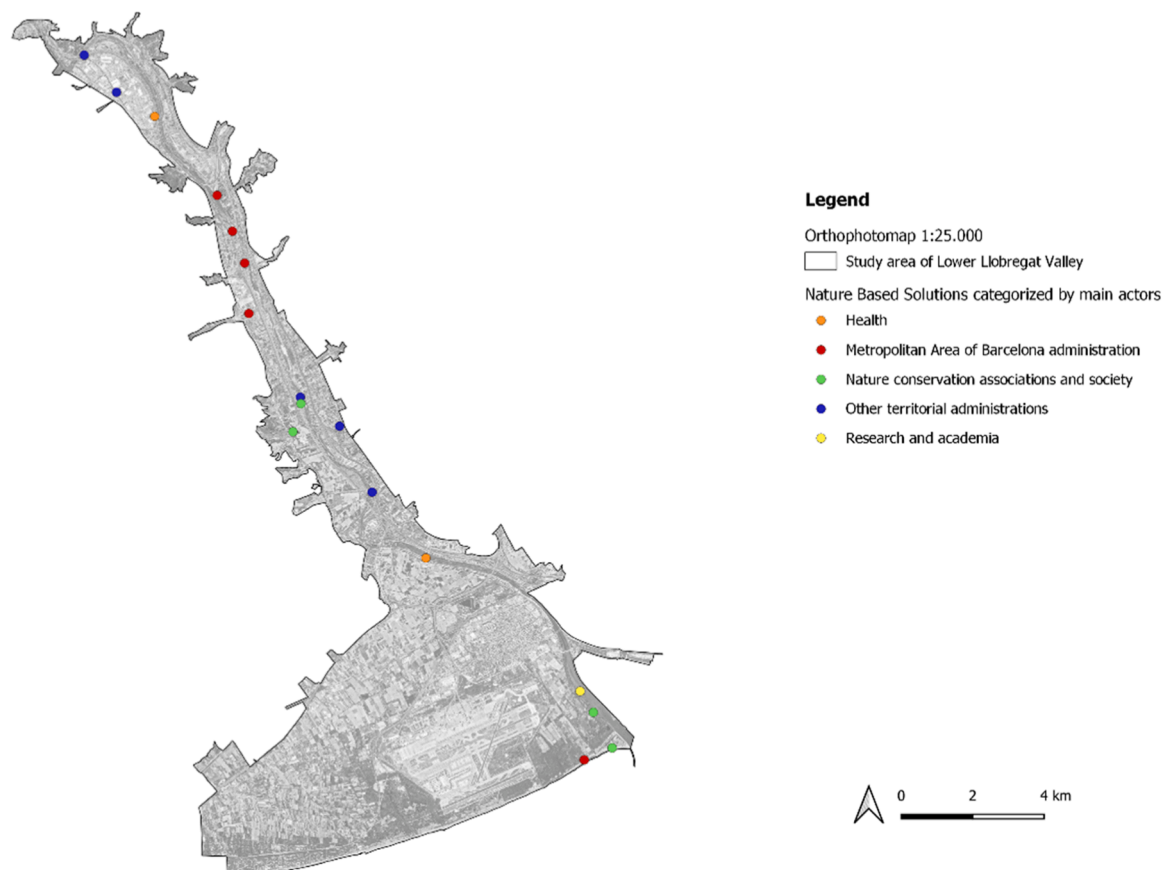


Fig. 8. Spaces for NBS opportunities that emerge according to each actors' typology.

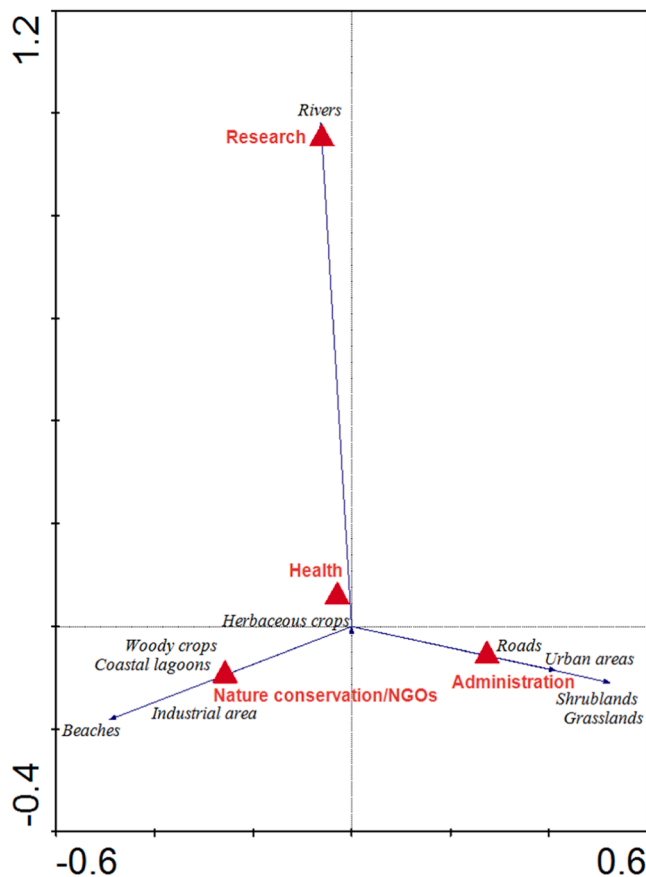


Fig. 9. RDA analysis showing the relationships between actors' typology and land-covers preferences for implementing new NBS proposals.

existing ecological and infrastructural information, already at planners' disposal in this area. As suggested by previous studies (De Vreese et al., 2016a), spatially-based social valuation methods (i.e. individual's perceptions and preferences for certain environmental features or NBS typologies), enriches the informational landscape through bringing valuable information for long-range, strategic NBS and green infrastructure planning, which maximises the functional performance of green space and it also incorporates citizens' preferences and their view on opportunities and challenges. Moreover, this approach allowed advancing on identifying key multi-actor interdependencies, people's perceptions and mainstreaming governance to address NBS implementation not only identifying, but also addressing knowledge gaps for NBS implementation.

3.3. Informational landscapes and NBS literacy

The concept of "information" has been used in other fields (Cohen, 2006; Whitworth, 2020), while various literacy concepts (i.e. academic literacy, species literacy, botanical literacy etc.) have been developed in social and pedagogy studies (Stroud et al., 2022; Warschauer et al., 2004). Informational landscapes enable literacy, but also the community's access to various layers of knowledge (including the lack of knowledge) across a territory. A landscape *with* information is more than just naming the data: it's about understanding other key ecological details, connections and concepts that can help framing and implementing a realistic vision for territorial planning and decision-making.

Information literacy and related skills enable citizens to access, understand information and to critically evaluate and use it. For NBS planning and implementation, the lack of what we called "NBS literacy" (insufficient knowledge related to NBS, misconceptions, confusions or

lack of mainstreaming of biodiversity, environmental, social and economic benefits) is challenging for both the informational landscape as a resource and for social inclusion. Information as a fundamental resource and the lack of information literacy practices and related skills are rarely mentioned in relation to planning, designing and managing NBS and green infrastructure. The spatial NBS catalogue in the Barcelona Metropolitan Area delivered by our study (<https://ide.amb.cat/LlobregatCo/index.html>), generates at the same time a common understanding and a common language to strengthen NBS literacy across a large spectrum of actors.

Our study also identified disconnections between two specific layers in the informational landscape: the scientific NBS discourse, and the debate in practice (see also Roitsch et al., 2024). At the same time, the existence of other approaches that also manage the environment in a way that benefits both nature and society (i.e. the concepts of "ecosystem approach" and "ecosystem services") can also lead to informational gaps related to NBS (as also observed by Escobedo et al., 2019). For some stakeholders NBS generates confusions (i.e. consider certain grey infrastructure as NBS). For others, the integration of biodiversity protection and conservation was unclear (see also Alva, 2022), or NBS was seen as only addressing certain challenges. Even if the NBS concept does not explicitly address actions directed towards biodiversity conservation, as a goal or prerequisite (Schneiders et al., 2012; Nesshöver et al., 2017), the integration of this concept into NBS planning is key, especially in metropolitan landscapes experiencing intense socio-environmental and economic pressures, with well-documented consequences for biodiversity, ecosystems functions (i.e. ecological connectivity) or services. This has also been a concern with the European Commission, who in 2020 revised its NBS definition, to stress the importance for NBS to contribute to biodiversity and ecosystem service delivery; without such a contribution, an intervention does not comply with the EC definition for NBS.

The co-design sessions demonstrated that some actors were not familiar with the concept of ecosystem services and therefore, their ability to understand the informational landscape, and more specifically, the term of NBS was lower. The need for better science communication to enforce the interface of science-society has been emphasised by various authors (Janse and Konijnendijk, 2007; Ugolini et al., 2015). As pointed out by other studies, insufficient knowledge weaving between several layers of the informational landscape and between stakeholders (Basnou et al., 2020; Tengö et al., 2017) can be a serious drawback, present at various levels and different stages of the participatory process. For example, a successful co-design process (mapping, interpreting and processing the informational landscape) should translate the knowledge into terms and language that can be understood by all actors (Boeraeve et al., 2018; Roitsch et al., 2024).

As stated elsewhere, a successful implementation of NBS also requires innovative participatory planning and "engaging multiple types and systems of knowledge" (Raymond et al., 2017) to enable place thinking (Albert et al., 2021; Frantzeskaki et al., 2021). This is the core of the informational landscape concept: the co-design materials and storytelling developed along the participatory approach helped to create a place-based narrative for all (i.e. around the Llobregat&Co community) and to enhance NBS literacy from a multidisciplinary point of view. NBS literacy complements the informational landscape, which goes further than PPGIS in mainstreaming NBS, sparking social innovation and fostering innovative planning.

Moreover, we demonstrated that integrating the concept of information literacy into the informational landscape for NBS planning has various benefits: it assures multi-level knowledge repositories, a better organisation and integration of data (i.e. for urban planning and governance), avoids data ambiguity, synonymy or changes in terminology (for example, two similar proposals known under different names or belonging to different administrative hierarchies), which in turn enables a correct geoparsing (that is, transforming an unstructured free text prior to geocoding, to avoid location disambiguation, *sensu*

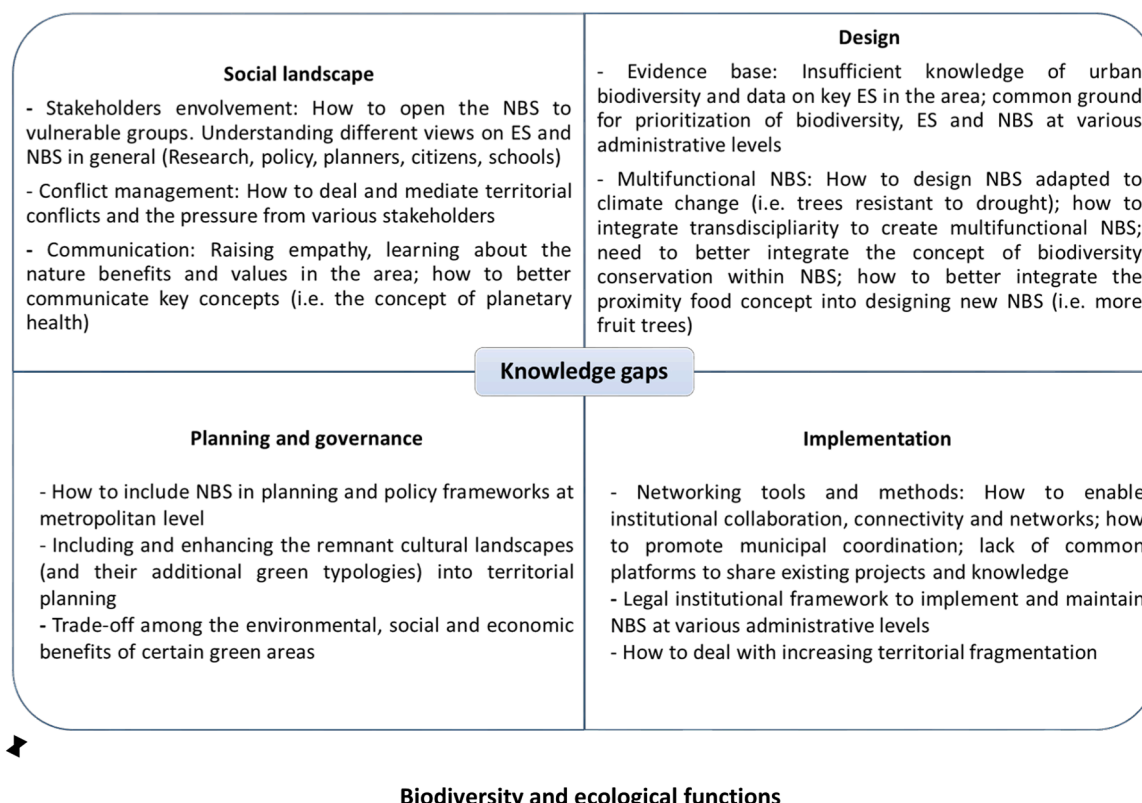


Fig. 10. Knowledge gaps reported for various dimensions of NBS in the study area.

Scharl and Tochtermann, 2009)

3.4. Informational landscapes as a tool to integrate co-design and NBS into the Metropolitan Planning and Governance

One of the main challenges for spatial planning and governance in this metropolitan landscape is the complex territorial jurisdiction, which impacts the development and implementation of NBS. Limited coordination among various public agencies, along with development pressure, and the complex interplay between the social and ecological values of green infrastructure, pose significant barriers to NBS planning (see also Roitsch et al., 2024).

In our case study, an informational landscape has been developed based on ecosystem services (both supply and demand) and biodiversity, as a basis for future NBS planning, while promoting synergistic ecosystem service delivery. It complements other studies in the Barcelona Metropolitan Area that have assessed ecosystem service provision and demand through cartographic indicators. Furthermore, it encourages the inclusion of collective and local knowledge to identify potential areas for NBS development and implementation. The data retrieved also help planners and researchers to understand where and how to enhance or create new NBS. Thus, our informational landscape supports decisions on where NBS could be implemented, restored or should be safeguarded. The new PDUM (Plan Director Urbanístico Metropolitano) emphasises the strategic integration of green infrastructure at the local scale. In this context, the informational landscape offers essential information and insights for future planning, particularly in relation to urban corridors along the Llobregat River valley.

The inclusion of participatory methods allowed offering alternative solutions to various challenges, and deploying different mechanisms to connect, and share decision-making with diverse stakeholders based on the informational landscape. Involving people in the planning process can increase public support and increase citizens' awareness on biodiversity and ecosystem services loss (Boeraeve et al., 2018; Derkzen et al.,

2017). Moreover, participatory planning supports sharing of skills. The knowledge and skills of various participants, as well as the expertise of professionals, benefits the planning process (Buchy and Hoverman, 2000).

Sipilä and Tyrväinen (2005) and De Vreese et al. (2016a) mentioned some drawbacks related to participatory approaches, which are equally relevant for working with informational landscapes. They are complex and more demanding with respect to time and resources than conventional planning and sometimes with limited representativeness. Another challenging task is the planning of the informational landscape process, in line with strategic projects' timeframe and scale (metropolitan or city level). Unexpected events (i.e. pandemics) and the posterior changes in people's behaviours are also very demanding and require flexibility and quick adaptation from the organisation teams (see also Roitsch et al., 2024). Despite this, participatory processes are of great interest to feed informational landscapes with knowledge and data and to stimulate collaborative planning, design and decision-making. In the case of applying informational landscapes for NBS, that include a strong social dimension, participation (i.e. participatory mapping) and social learning in the framework of informational landscapes leads to a "common language", and common goals, with beneficial results for neighbourhoods and cities. Integrating participatory processes is a prerequisite for including local knowledge and informational landscapes.

Furthermore, multi-actor interdependencies, people's perceptions, governance complexity and knowledge gaps are other challenges to NBS implementation, with various dimensions affecting stakeholders' involvement (Kabisch et al., 2016).

4. Conclusions

Metropolitan areas need additional solutions and support to tackle global change and implement NBS, in order to operationalize the concept of ecosystem services. This research developed an informational landscape that facilitates collaborative NBS planning, design and

management in the Llobregat River valley. Applying the informational landscape for NBS planning, demonstrated that the NBS concept is associated with several knowledge gaps, particularly in relation to planning and governance. In this regard, establishing a locally-adapted and place-based knowledge for planning in the form of an informational landscape is crucial for mainstreaming and implementing NBS within a specific landscape context (Albert et al., 2021).

The informational landscape approach developed in this study allowed to address various challenges in metropolitan areas, to better connect people with territory and possibly address future NBS “targets” and territorial “features”. Participatory approaches enable the integration of spatial and place-based information, addressing multiple ecological and social dimensions. Through this approach, technologies such as PPGIS can be valuable tools for connecting various stakeholders and locating knowledge evidence across the territory, thereby supporting informed and collaborative decision-making. To support this process, guidance and storytelling are essential for helping to understand and learn about key concepts, such as multifunctional NBS, ecosystem services, and territorial planning. Therefore, generating a common language and a NBS literacy are crucial for advancing the NBS concept (Nesshöver et al., 2007).

A limitation of the present study is the insufficient focus on other actors (i.e. from public health or education), to enrich the informational landscape with more specific knowledge regarding the barriers, opportunities and benefits of NBS for vulnerable groups. Inclusion of more transboundary actors, also known as change agents or knowledge brokers (*sensu* Ershad Sarabi et al., 2019) would be also relevant for the uptake and implementation of NBS. Despite these limitations, the availability of the open online informational landscape offers a significant opportunity to overcome these challenges and provide future opportunities for a more inclusive approach to NBS planning. New tools for stakeholder analysis, such as social network analysis or interconnected clusters (Van der Jagt et al., 2019), can complement this approach and provide deeper insights in the informational landscape and further inform NBS planning and implementation in metropolitan areas.

CRedit authorship contribution statement

Corina Basnou: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Rik de Vreese:** Writing – review & editing, Resources, Project administration, Methodology. **Helena Sanz:** Visualization, Methodology. **Marta Pérez:** Visualization, Software, Resources. **Javier Gordillo:** Visualization, Software, Resources. **Patricia García:** Visualization, Software, Resources. **Sandra Caldúch Fernández:** Visualization, Formal analysis, Data curation. **Joan Pino:** Resources, Methodology, Data curation. **Laura Cid:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Eugènia Vidal-Casasnovas:** Writing – review & editing, Methodology, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2025.128719.

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