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Spatial Recognition Justice: Integrating Participatory Mapping and Discrete Choice Experiment to Elicit Ecosystem Service Values

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Abstract

Nature-based solutions (NBS) have become a central component of climate adaptation and sustainability agendas in many cities. Yet NBS implementation increasingly faces opposition from residents. As NBS fail to consider diverse needs, values, and priorities of different population segments, they fall short from a recognition justice perspective. This study provides a systematic assessment of residents' preferences for six ecosystem services associated with NBS based on a demographically and spatially representative sample of 1,700 respondents in the Barcelona Metropolitan Area, Spain. We employ a mixed-method approach that integrates a Discrete Choice Experiment with a Public Participation GIS approach to estimate ecosystem service preferences and map their spatial distribution across the study area. Results indicate strong public support for ecosystem services related to heat mitigation, flood prevention, and water storage. However, preferences display clear geographic variation and significant differences across income and education groups. A critical finding is that both the least and the most affluent residents, as well as those with the lowest level of education, tend to be less supportive of expanding ecosystem service provision through NBS. These findings highlight the importance of systematically addressing the needs and perspectives of these groups to strengthen recognition justice in NBS planning. Doing so is essential not only for a fairer distribution of nature's benefits but also for ensuring long-term public acceptance of NBS implementation and transformation strategies.

Keywords: Climate adaptation, Nature-based solutions, Ecosystem Services, Recognition Justice, PPGIS, Discrete Choice Experiment

Urban areas worldwide are increasingly challenged by the intensifying impacts of climate change, such as more frequent heavy rainfall events, urban heatwaves, and escalating environmental pressures [1–3]. These pressures not only threaten the ecological integrity of cities and human health [4,5] but also exacerbate social inequalities, as economically and socially vulnerable groups often bear a disproportionate share of climate-related burdens [6–8]. The combined effects of inadequate infrastructure, limited access to resources, and marginalization can compound existing vulnerabilities, increasing climate-related risks for urban populations. In response, nature-based solutions (NBS) have emerged as a key framework in global climate adaptation agendas [9,10].

NBS, defined as “actions to protect, conserve, restore, sustainably use and manage […] ecosystems, which address social, economic and environmental challenges” [11] encompass a broad range of interventions that integrate ecological processes into urban systems, from green roofs and rain gardens to urban forests and multifunctional green corridors. NBS interventions have the potential to offer multiple ecosystem services (ES), including flood mitigation, microclimate regulation, and opportunities for recreation and social interaction [12]. For instance, empirical studies have demonstrated that NBS, such as green roofs, can significantly mitigate urban heat by reducing surface temperatures by up to 70% under Mediterranean climatic conditions [13], as well as substantially improve stormwater management by retaining around 62% on average at the global level [14]. Similarly, urban parks and vegetated areas are associated with reductions in local ambient air temperatures of approximately 0.5 to 4.0°C, contingent on specific climatic and contextual variables [15,16]. However, the local implementation of NBS often embeds tensions between national or EU-level policy objectives and local, place-specific priorities [17–19]. Consequently, despite the proven ability to provide benefits, NBS initiatives often encounter local opposition [20–22]. The disconnection between larger-scale planning objectives and local priorities can limit NBS legitimacy, uptake, and long-term success; it may even undermine the transformative capacities often associated with NBS [23]. Research has shown that public acceptance of climate adaptation and environmental measures strongly depends on perceptions of fairness, transparency, and responsiveness [24,25]. For instance, studies on climate policies [26] have shown that support increases when policies are perceived as fair and as benefiting vulnerable groups and environmental goals [27,28]. Yet current NBS planning systematically overlooks local knowledge, preferences, and values; particularly, though not exclusively, those of socially marginalized groups [29].

In response, urban planning scholars have called for justice-oriented frameworks that promote inclusive and participatory approaches to enhance both legitimacy and social acceptance [6]. More specifically, scholars have emphasized the need to more strongly integrate recognition justice in NBS planning [29–31]. Recognition justice is understood as the acknowledgment of the pluralism of diverse identities, needs, values, and preferences within environmental decision-making [32–35]. Acknowledging such pluralism requires understanding local preferences and capturing the values and priorities that individuals and groups attach to different forms and functions of urban nature [36–38]. They may concern not only the types, locations, and attributes of NBS but also the choice to opt out of NBS interventions altogether. In the context of NBS planning, making such pluralism spatially explicit is essential. A systematic and spatially explicit assessment of plural preferences can therefore help render recognition justice operational for planning practice. By revealing whose perspectives are represented and where priorities are geographically concentrated, such an assessment can support the translation of fairness and inclusion into spatial NBS planning decisions.

Yet the systematic implementation of a spatially explicit assessment of plural preferences in the context of urban NBS planning is methodologically challenging. Participatory processes such as workshops or stakeholder consultations often involve only small groups of already engaged citizens, risking biases in representation and overlooking the needs of less vocal or marginalized groups (Rall et al., 2019; Stålhammar & Raymond, 2025). On the other hand, large-scale surveys, while more inclusive in scope, tend to neglect the spatial and localized dimension of preferences, focusing on *what* people value without specifying *where* they want nature-based interventions implemented (Wolch et al., 2014; García et al., 2024). While there is no space here to provide a comprehensive review of methodological shortcomings, we identify three persistent gaps for a more thorough assessment of spatial recognition justice in the context of urban NBS planning: (1) a lack of systematic frameworks for assessing residents' preferences consistently [39,40]; (2) limited representativeness of participants, often biased toward already engaged citizens [41–44]; and (3) insufficient spatial differentiation and explicitness in the assessment of people's plural preferences [45,46].

Bridging these gaps requires methodological approaches that are both spatially explicit and representative, capturing not only the types of benefits citizens prioritize but also the specific locations where they believe these benefits are most needed [47,48]. Among the most robust methods developed to assess public preferences, Discrete Choice Experiments (DCEs) are widely regarded as the "gold standard" for stated preference elicitation [49–51]. DCEs allow researchers to estimate the relative importance of specific configurations and simulate support for alternative planning options. DCEs have been successfully applied in both forest and urban contexts to inform planning and policy, including biodiversity-oriented forest management (Giergiczny et al., 2015), fire prevention strategies (Farreras & Mavsar, 2012), urban tree planting (Giergiczny & Kronenberg, 2014), coastal protection (Dario et al., 2024), and NBS prioritization across European cities (Pröbstl-Haider et al., 2024). Combined with a representative survey panel, DCEs can be used to systematically estimate preference structures. However, DCEs typically lack spatial explicitness, offering limited insight into where residents would prefer ES to be delivered.

In this study, we therefore present a novel approach that combines a representative DCE survey with participatory mapping. The participatory mapping approach has been used to facilitate spatial mapping of people's preferences [52,53] and to identify concrete locations for NBS intervention [54,55]. This place-based grounding makes participatory mapping particularly valuable for designing socially equitable and context-sensitive NBS strategies (Brown & Fagerholm, 2015). Through participatory mapping, planners can visualize the geographic distribution of perceived needs, highlight underserved areas, and integrate local knowledge into decision-making, which makes it a critical tool for supporting spatial recognition justice. However, while participatory mapping excels at assessing preferences and their spatial localisation, it lacks the capacity to evaluate structured trade-offs among ES attributes. Most applications rely on ranking or qualitative input, which, though rich in local insight, do not allow systematic comparison or the estimation of marginal values (Lampinen et al., 2023; Gierth & Haase, 2023).

In sum, DCE and participatory mapping provide complementary strengths and address different aspects of the three identified gaps: DCEs offer systematic and representative preference measurement, while participatory mapping introduces spatial explicitness and local grounding. Yet neither method alone captures the plurality of social-spatial preferences for NBS. This therefore integrates DCE and participatory mapping within a unified methodological framework. This approach allows us to capture both where residents want ES delivered and which type of ES they value most, producing spatially grounded, demographically representative, and systematically comparable insights. Specifically, we address the following research questions:

1. In which urban areas do residents identify the greatest preference for implementing ES associated with NBS?
2. Which ES provided by NBS do residents prefer, compared to the status quo?
3. How do socio-demographic variables influence these spatial and preference patterns?

In this study we focus on the Barcelona Metropolitan Area (AMB) as a case study. We combine a representative DCE with a participatory mapping module that anchors each respondent’s choices to mapped areas they know best, allowing us to estimate preference weights and translate them into spatial patterns of preferences for ES. By addressing the research questions, the study provides both methodological and practical contributions. Methodologically, it advances an integrated framework that systematically connects citizens’ preferences with spatially explicit patterns of preferences, bridging the gap between stated-preference methods and participatory mapping. Practically, it offers a scalable and replicable tool for urban planners, supporting spatial recognition justice in NBS planning by showing how social plurality and place-based priorities are distributed. By situating this mixed approach within the AMB, the study illustrates how globally circulating frameworks of NBS and resilience are reinterpreted through local social and spatial contexts. The following section presents the results derived from this integrated approach, beginning with model estimates of ES preferences and followed by their spatial expression across the AMB.

Results

This section presents the results of the integrated DCE and participatory mapping approach. We first describe how residents' preferences for ES are spatially distributed across the AMB. We then report the estimated preference coefficients from the DCE models. After that, we present socio-demographic determinants of preferences. The section concludes with an assessment of the sample's representativeness.

Spatial distribution of ecosystem service preferences

Residents' preferences for ES exhibit clear spatial differentiation across the AMB, as shown in Figure 1. These spatial patterns indicate where different ES are prioritised across the metropolitan landscape and how strongly they are valued relative to one another. These patterns are represented through spatial preference surfaces, which integrate the participatory mapping and DCE components of the survey. The participatory mapping component identifies where residents locate their priorities, while the DCE component provides information on the relative strength of preferences for each ES. Together, these components generate spatial preference surfaces that capture both the location and intensity of the stated preferences. To produce these surfaces, the polygons drawn by respondents were intersected with a uniform hexagonal grid, and the resulting indices were normalised by the number of responses per cell. The maps in Figure 1, therefore, describe relative preference intensities, rather than absolute counts.

The spatial preference surfaces show that preferences for temperature reduction are concentrated along the eastern coastal corridor and in several southern municipalities, while central districts of Barcelona exhibit lower relative intensities for this ES. Preferences for water storage display higher intensities in peri-urban and coastal zones, with lower values across a broad central and southwestern area. Flood reduction preferences are strongest in southern coastal areas and peri-urban sectors. Habitat provision preferences are more pronounced along the northern margins and in transitional peri-urban areas close to ecological corridors. Recreation-related preferences form clusters in southern coastal and western sectors, whereas aesthetic preferences are more diffusely distributed, with identifiable clusters in the south-western zones. Overall, the spatial preference surfaces reveal substantial variation in how residents locate and prioritise different ES preferences across the metropolitan landscape.

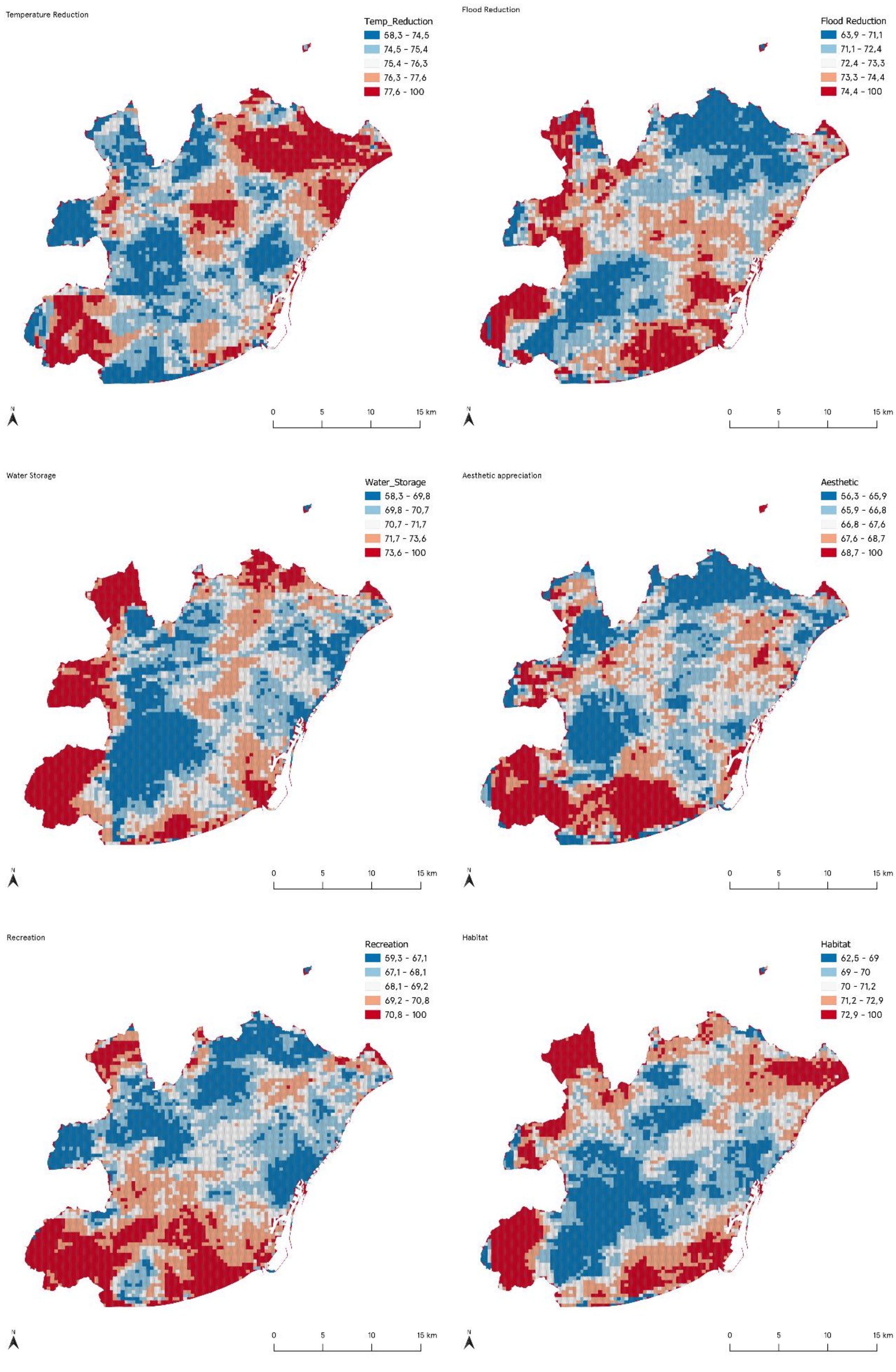

Figure 1 - Spatial distribution of citizens' preferences for the six assessed ecosystem services. Normalized values range from 0 (blue) to 100 (red).

Which ecosystem services matter most to residents

The Discrete Choice Experiment reveals clear differences in the strength of residents' preferences for ES associated with NBS. Across the sample, respondents consistently favoured alternatives that provide these services over the status quo, indicating broad support for expanding ES provision through NBS.

These patterns are derived from discrete choice models that estimate the relative importance residents assign to each ES. To quantify these preferences, we first estimated a Conditional Logit model, which captures average preferences across respondents, and then a Mixed Logit model, which allows preferences to vary across individuals. Both models show robust statistical performance, as indicated by highly significant likelihood ratio statistics and satisfactory convergence parameters. Figure 2 reports the utility coefficients estimated through the Conditional Logit model, together with their standard errors.

Across all six ES, preference coefficients are positive and statistically significant ($p < 0.001$), indicating that respondents are more likely to choose NBS options that provide these services than those that do not. The opt-out option, representing no additional NBS intervention, shows a strongly negative coefficient ($\beta = -4.562$), confirming a general preference for some form of NBS intervention over maintaining the status quo.

Among all ES, preferences for heat mitigation are strongest, followed by flood prevention and water storage. These services receive higher average utility coefficients than recreation, habitat provision, and aesthetic quality, which also show positive but more moderate preference levels. This ranking indicates that services directly related to climate adaptation and hydrological functioning are prioritised more strongly than other ES. The small standard errors around the estimates (Figure 2) indicate that these coefficients are estimated with high precision. The exponentiated coefficients reported in Table 1 further confirm that including services such as heat mitigation, flood prevention, or water storage substantially increases the likelihood that an NBS intervention is chosen.

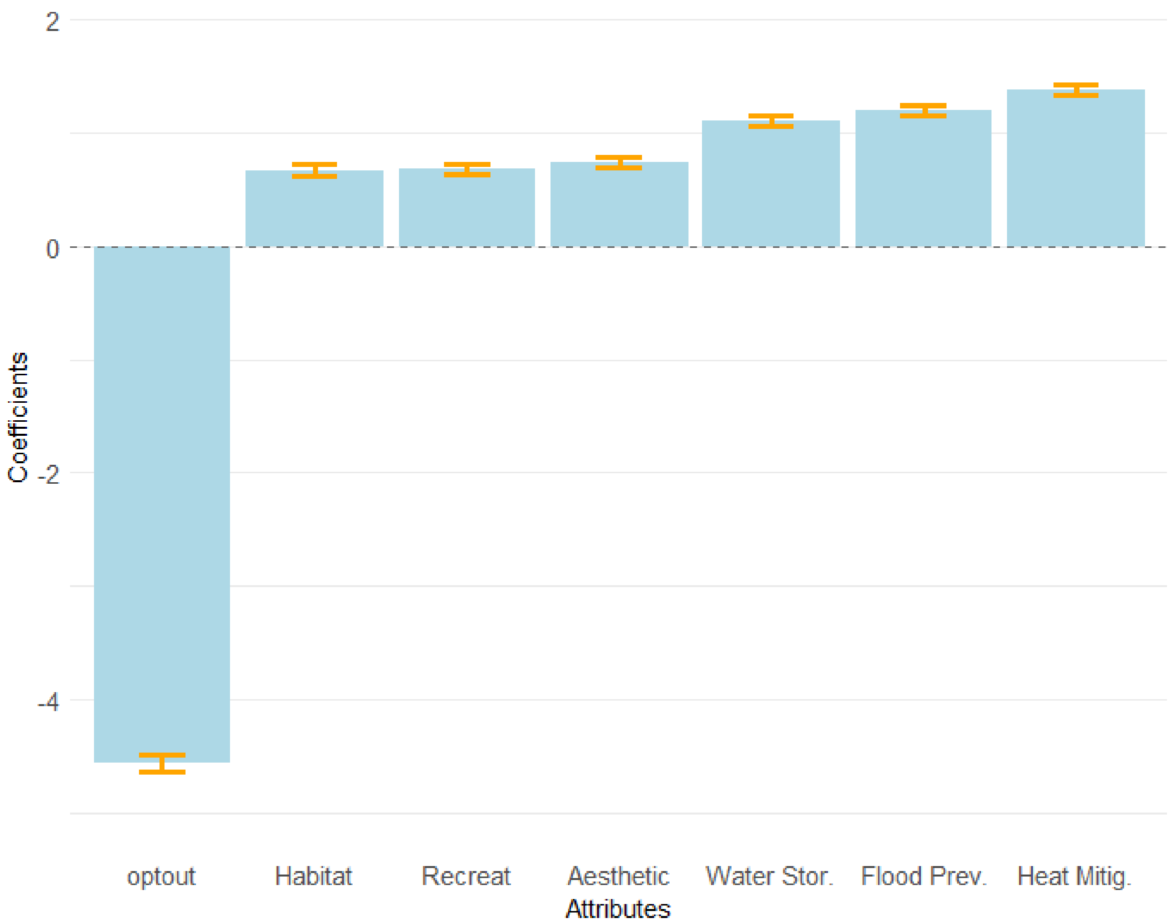

Figure 2 - Conditional Logit model coefficients for ecosystem service attributes. Bars show estimated utility coefficients (β) for the opt-out alternative (status quo: no intervention) and the six ecosystem services. Error bars represent ±1 standard error. All coefficients are statistically significant ($p < 0.001$).

To explore whether these preferences vary across individuals, we next estimated a Mixed Logit model. As in the Conditional Logit model, the opt-out option remains strongly negative, and all ES retain positive and statistically significant average coefficients (Table 1), confirming the robustness of the overall preference structure. However, the Mixed Logit model additionally captures unobserved heterogeneity in preferences, allowing the importance assigned to each service to differ across respondents.

Several ES show statistically significant standard deviations, indicating substantial variation in how strongly individuals prioritise specific benefits. For example, while habitat provision has a positive average effect, its large standard deviation suggests that some respondents place particularly high importance on biodiversity-related services, whereas others consider them less relevant. Heat mitigation, flood prevention, and water storage continue to show the strongest average effects, but the dispersion around these estimates confirms that preference strength is not uniform across the population. This heterogeneity highlights the presence of differentiated expectations regarding the role of NBS. The following section examines how heterogeneity in preferences relates to respondents' socio-demographic characteristics.

Table 1 - Preference estimates for ecosystem services from Conditional Logit (CL) and Mixed Logit (MXL) models

Parameter	CL Model		MXL Model	
	CL Coef (SE)	exp(coef)	MXL Coef (SE)	sd.
optout	-4.562*** (0.038)	0.010	-37.403*** (9.660)	25.912 *** (6.919)
A (Heat Mit.)	1.380*** (0.024)	0.252	3.980*** (0.943)	0.315 (0.628)
B (Flood Prev.)	1.207*** (0.023)	0.230	2.620*** (0.552)	0.116 (0.456)
C (Recreat.)	0.683*** (0.024)	0.505	1.914*** (0.442)	0.120 (0.521)
D (Water Stor.)	1.114*** (0.023)	0.328	2.176*** (0.449)	-0.230 (0.414)
E (Habitat)	0.675*** (0.025)	0.509	1.843*** (0.424)	6.795 *** (1.625)
F (Aesthetic)	0.750*** (0.024)	0.472	1.997*** (0.446)	0.407 (0.405)

*Note: *** p<0.001 . Conditional Logit Model Stats: n=63,396, Concord.=0.829, LR=21903 (df=7), p<2e-16. Mixed Logit Model Stats: n=63,396, LogLik=-15979, R=100, bfgs(88 iter)*

How socio-demographic characteristics shape support for NBS

Preferences for NBS and ES vary systematically across socio-demographic groups, indicating that support for environmental interventions is not evenly distributed within the population. In particular, income and educational attainment emerge as key factors shaping both overall support for NBS and the willingness to move beyond the status quo.

Respondents with mid-range incomes (20,200€–60,000€) show a slightly higher propensity to support new NBS interventions (β ≈ +0.076), whereas no clear preference pattern emerges among respondents in the highest or lowest income brackets. Educational attainment shows a clearer gradient: individuals with tertiary education display stronger support for NBS, while respondents with only primary or no formal education are more likely to favour maintaining current conditions.

When considering behavioural factors, mobility-related habits and outdoor activity frequency play a comparatively limited role in shaping preferences. A minor positive effect is observed for respondents who commute by public transport or walk, although these effects are small relative to those associated with income and education.

How representative is the survey sample of the metropolitan population

Overall, the survey sample reflects the main demographic structure of the AMB population, with a high degree of alignment for some characteristics and moderate deviations for others. Gender representation is particularly close to census distributions, while age and education groups show some differences in relative proportions.

Gender distribution closely mirrors that of the AMB population, with almost equal shares of male and female respondents. In addition, a small proportion of participants identified with a gender category not captured in official census statistics.

With respect to age, younger adults are somewhat more represented in the sample, whereas older age groups, particularly respondents aged 65 and above, are less frequent. Educational attainment also differs slightly from the population profile, with respondents holding tertiary education appearing more often in the sample and those with primary or lower secondary education being less represented.

These patterns are transparently documented in Table 2, which compares the survey sample with AMB census data across age, gender, and education categories.

Table 2- Representativeness of the survey sample for the AMB population.

	AMB Census [%]	Survey Sample [%]	Difference [%]
Age			
20-24	6.7	4.0	2.8
25-29	7.3	8.0	-0.6
30-34	7.9	9.3	-1.3
35-39	8.3	10.0	-1.7
40-44	9.7	10.9	-1.2
45-49	10.6	12.3	-1.7
50-54	9.5	11.6	-2.0
55-59	8.6	10.0	-1.4
60-64	7.3	8.3	-1.0
>=65	24.0	15.7	8.3
Gender			
Male	48.7	48.7	0.0
Female	51.4	51.1	0.3
Other	-	0.3	-
Education			
Primary or lower education	13.4	2.9	10.5
First stage of secondary education and similar	25.5	7.5	18.0
Second stage of secondary	23.6	36.7	-13.1

education and similar			
Tertiary education	37.6	52.9	-15.4

Discussion

In this discussion, we interpret the main implications of our integrated DCE-participatory mapping approach for recognition justice and NBS planning, considering their methodological and operational aspects. We then examine the local insights for the AMB, including the spatial and socio-demographic patterns that shape ES preferences, discuss the study's limitations, and outline avenues for future research and practice.

A first key implication of this study is that it advances the operationalisation of spatial recognition justice in urban planning through a methodological innovation. By integrating DCE with participatory mapping, the analysis foregrounds residents' differentiated preferences and lived priorities, links them to the specific places where environmental improvements are most desired, and thereby makes recognition justice empirically measurable in a spatially explicit way.

More specifically, this provides a robust way to understand how diverse groups perceive environmental benefits and how such differences can inform more just planning decisions. This directly responds to long-standing calls for actionable approaches to recognition justice [32,34,56]. The methodological contribution is therefore inseparable from the justice dimension it enables. By grounding stated choice trade-offs in spatial contexts, the integrated framework moves beyond the descriptive preference mapping common in place-based studies [53,57] and the non-spatial valuation characteristic of most DCE applications for planning [58–60], bridging two methodological strands that have typically evolved in parallel.

By combining both, the approach provides quantitative, attribute-specific preference estimates along with their spatial distribution, enabling a more nuanced identification of which ES matter most to whom and where.

From a planning perspective, the main added value of the approach is that it provides spatially explicit evidence on local priorities for NBS-related ES across a metropolitan area. This complements conventional decision-support tools based on biophysical or socio-demographic indicators by showing where residents prioritise specific benefits, and where different needs coexist or diverge. Importantly, the approach is replicable and scalable to other municipal, urban, or metropolitan contexts, while remaining adaptable to diverse social-ecological conditions. Such insights can help planners design and communicate NBS strategies that are both context-sensitive and socially legitimate.

A further implication is that focusing on ES attributes, rather than predefined NBS types, allows residents to express which functions they value without being constrained by existing designs or political framings. The DCE structure also offers advantages over direct or revealed preference approaches, since structured trade-offs reproduce realistic planning choices and generate statistically robust estimates that do not depend on existing opportunities for action [61–63].

The methodological strengths of the approach become visible in the local case study application. Applied to the AMB, the approach reveals a clear geography of expectations regarding NBS benefits. The strong negative coefficient associated with the opt-out option indicates widespread dissatisfaction with current conditions and broad support for NBS implementation, in line with current greening strategies in the AMB. It provides evidence that the AMB's population responds to acute environmental stressors [64] and indicates local awareness of climate change adaptation needs. For instance, heat mitigation and flood prevention emerged as the highest priority ES, which aligns with recent intensification of heat and extreme precipitation in the region (Ballester et al., 2023). The prominence of water storage, likely influenced by a prolonged drought the region faced in 2023, is also exemplary for this.

At the same time, the spatial differentiation of preferences, evident across all ES, also indicates the need for more spatially differentiated NBS strategies. Preferences for flood reduction are concentrated in southern coastal and peri-urban areas, a pattern that aligns with hydrometeorological evidence identifying southern coastal municipalities and catchment outlets as recurrent hotspots of flood exposure due to the combined effects of topography, high imperviousness, and intense short-duration rainfall events [65–67].

Similarly, preferences for temperature reduction show higher intensity along the eastern coastal corridor and in several southern municipalities, while other areas exhibit comparatively lower values. This divergence suggests that perceived needs for heat mitigation are not solely driven by objective heat exposure, but may also reflect broader social-ecological factors shaping local experience and awareness of thermal stress.

Preferences for recreation cluster in southern coastal and western sectors, which may reflect perceived gaps in accessible or multifunctional green spaces. Aesthetic preferences are more diffusely distributed, with identifiable clusters in the south-western zones. These areas may offer stronger landscape potential or clearer opportunities for visual improvement, shaping residents' prioritisation of aesthetic ES.

Beyond spatial patterns, our findings also highlight that support for environmental change varies across socio-demographic groups, which is central to recognition justice in planning. As highlighted in recognition justice literature, addressing inequality in environmental planning requires acknowledging the plural needs and voices of urban residents [34,68]. In our results, income and education are associated with differences not only in ES preferences but also in the overall acceptability of NBS. Middle-income respondents and individuals with higher levels of education were more likely to support NBS interventions, while those with lower educational attainment or lower income were more inclined to accept inaction and to maintain the status quo, possibly due to lower perceived or actual benefits from NBS interventions.

A minor positive effect associated with active and public transport-based mobility patterns may indicate a higher degree of environmental stewardship, consistent with previous research linking mobility behaviour and pro-environmental attitudes [69–72].

These differences echo findings on the correlation between education level and environmental stewardship [73–75]. The reasons for this stronger opposition to NBS remain speculative from our study; however, recent studies have indicated that NBS implementation, particularly when combined with other urban interventions, may trigger gentrification processes, which primarily affect lower-income populations [76]. Other potential reasons for the observed preference pattern include a lack of awareness about local vulnerabilities or limited awareness of the benefits offered by NBS, such as improved thermal comfort, drainage safety, or recreational opportunities, as well as a rejection of NBS due to different priorities or an increasing politicization of urban greening, which may constrain support for NBS interventions. While a minority in our sample, fostering urban transformation with NBS requires additional understanding of the reasons behind the pattern described to avoid overlooking local opposition to NBS policies.

Importantly, the Mixed Logit Model results show considerable heterogeneity even within socio-demographic groups, reinforcing that preferences are not uniformly distributed and that aggregate patterns can obscure important subgroup dynamics. For instance, preferences for habitat provision exhibited substantial variation. These findings have a clear implication for NBS planning beyond the AMB case study: approaches based on uniform assumptions risk overlooking groups whose needs or priorities diverge from the dominant pattern, potentially leading to interventions that do not fully reflect the plurality of local expectations [33]. In contrast, multifunctional NBS strategies that combine different ES may generate stronger public acceptance than interventions focused on a single service. Although the call for multifunctional NBS is by no means new [40,77,78], the potential for enhanced social acceptability adds an additional argument in its favour.

Finally, several limitations affect how these findings should be interpreted. The sampling strategy, while extensive, did not perfectly match the AMB's demographic profile.

Older adults and residents with lower formal education were underrepresented, a pattern consistent with well-documented challenges in recruiting older populations through online survey panels, thus representing an important bias in our study [79–81]. Similarly, the overrepresentation of respondents with tertiary education reflects a common trend in online surveys, where higher-educated individuals are more likely to participate [82–84]. These patterns reflect typical limitations of online, panel-based sampling methods and should be considered when interpreting the generalisability of the results.

While future studies could address this through post-stratification weighting or purposive oversampling, these challenges are emblematic of broader tensions in participatory research between inclusiveness and practical feasibility [85–87]. Additionally, while the DCE effectively quantifies preferences, it cannot fully capture the underlying reasons behind those choices, for instance, the stronger opposition to NBS among low education and income population segments, as discussed above. Integrating qualitative data, such as interviews or focus groups, could deepen the interpretation of heterogeneity and support more responsive policy recommendations.

Overall, the combination of spatial and choice-based methods represents a promising advance in participatory environmental planning. It reinforces that spatial recognition justice must not only acknowledge plural voices but also map them, translating preferences into spatial priorities to ensure that NBS are implemented in ways that are both ecologically meaningful and socially legitimate. Together, these steps can support more democratic, context-grounded, and resilient pathways for NBS implementation across diverse urban settings.

Methodology

This study adopts a place-based mixed-methods design that integrates a DCE with a participatory mapping approach to elicit residents' preferences for ES provided by NBS and to locate where these preferences apply within the AMB. The DCE captures the relative importance of ES attributes and reveals preference heterogeneity among population segments, while the participatory mapping anchors these preferences spatially by asking respondents to map the areas they know best and where they would prioritise interventions. Together, these elements address two recurring limitations of participatory and survey-based approaches, namely representativeness and spatial explicitness, and provide a practical way to operationalise recognition justice by linking diverse preferences to concrete locations.

Sampling followed a stratified strategy to ensure statistical representativeness of the AMB population. The survey instrument combined the DCE tasks, socio-demographic questions, and spatial mapping. The methodological framework is detailed in the following sections: Section 4.1 introduces the case study, Section 4.2 describes the survey and participatory mapping design, and Section 4.3 outlines the analytical procedures, including data preparation, econometric modelling, socio-demographic interactions, and the spatial aggregation of stated preferences into high-resolution maps of ES demand.

Case Study: Barcelona Metropolitan Area

The AMB, encompassing 36 municipalities and more than 3.3 million residents, provides a suitable context for analysing spatial and socio-demographic variation in ES preferences due to its marked heterogeneity in land use, environmental conditions, and social profiles [88–90].

Its relevance for examining the interplay between urban form, social diversity, and ecological functions is well established in previous research and planning initiatives [7,66,91,92], making it a strong case for spatially explicit analyses of NBS preferences.

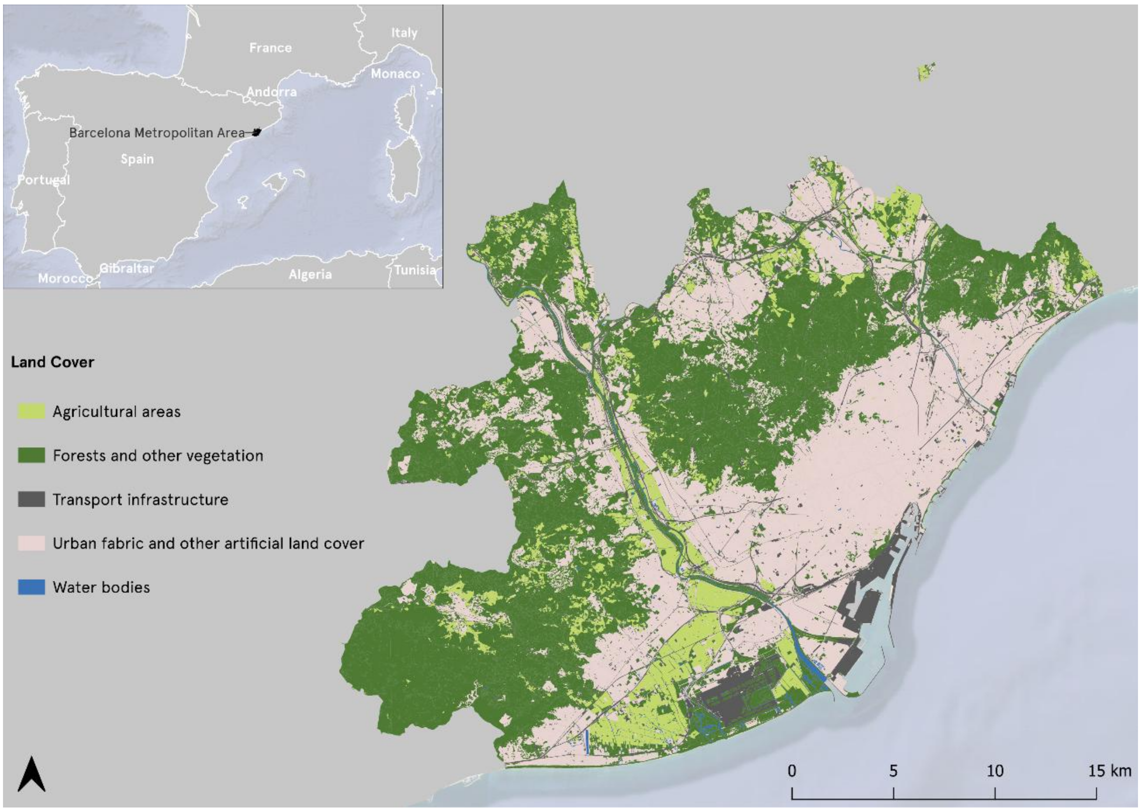

Figure 3 - Land-cover map of the Barcelona Metropolitan Area based on the MCSC v1.0 (2023) dataset (ICGC). Original level-2 classes were aggregated into level-1 categories for visualization

The AMB was also chosen due to its documented environmental challenges, not least in the context of climate change, and emerging trade-offs between ES provision [93]. The metropolitan area experiences frequent heatwaves, with projections indicating a worsening of heat-related risks in the coming decades [94–97]. Flooding is also a recurrent and significant risk [98], exacerbated by increasing extreme rainfall events and impervious artificial surfaces [65,67,99,100]. Remote sensing studies report that the mean imperviousness of urban sub-areas in Barcelona is approximately 70%, among the highest compared to other major European cities [101], and showing an increasing trend in time [102], hindering water infiltration, increasing runoff, and flood risk.

Despite recent efforts to expand green infrastructure [103,104], disparities in access to urban nature remain. Several studies have shown that public green spaces remain unevenly distributed across the city, resulting in unequal opportunities for wellbeing and environmental benefits [105–107]. The heterogeneity and inequalities of AMB's territory highlight the need for planning approaches that consider how residents from different neighbourhoods and with different socio-economic characteristics prioritise ES across the metropolitan area.

All demographic and socio-economic data used for spatial and statistical analysis were sourced from official AMB datasets and the Statistical Institute of Catalonia [108].

Survey and Participatory Mapping Design

In total, 7607 individuals accessed the survey, of whom 1761 submitted completed responses. The survey was open from 16 December 2024 to 3 March 2025. It was closed after a prolonged decline in response rate, with the final phase slowing to approximately 3 respondents per week. Although the initial target was 2000 responses, the final sample size of 1761 was deemed sufficient to support the planned statistical analyses, particularly given the richness of choice-task data per respondent and the stratified sampling approach employed.

Statistical Representation of Respondents and Survey Distribution

We distributed the survey within the AMB through Netquest, a survey distribution company, applying stratified sampling theory [109]across various characteristics, including municipality of residence, age, gender, and education level. By allocating respondents proportionally to each subgroup's share of the overall population, we aimed to minimise sampling error and enhance representativeness. To determine target quotas, we established population proportions for each stratum by dividing its population size by the total AMB population. For each stratum, we then multiplied its population proportion by the desired sample size of 2,000 respondents to identify theoretical targets that aligned with their relative weight in the AMB population. These proportions served as the baseline for deriving quotas that would ensure the final sample represented the complexity of the AMB's demographic and spatial distribution.

Survey Design

The choice experiment is grounded in Lancaster's theory of value [110], which holds that individuals evaluate an option through its attributes rather than as a whole. Applied to this study, this means that respondents assess an NBS based on the specific ES it provides. Each NBS alternative was therefore defined by six binary attributes: heat mitigation, flood prevention, recreational opportunities, water storage, habitat provision, and aesthetic enhancement. Attribute selection followed a transdisciplinary process informed by expert consultations, literature review, and findings from the ENABLE project, ensuring that the services included in the design reflected both scientific evidence and local planning priorities.[111].

Each respondent evaluated twelve hypothetical choice sets (Fig. 4 shows an example). In each set, two NBS alternatives (Options A and B) were described by the presence or absence of the six ES, while a third option represented the status quo (no intervention).

This structure enables the estimation of the relative importance assigned to each ES attribute and the identification of trade-offs among them [59,112]. To enhance accessibility, ES were described using clear, non-technical language.

The survey was implemented in Spanish through the Maptionnaire platform [113], which integrated the DCE with spatial mapping. Socio-demographic questions and post-choice items on motivations and perceived benefits were included to complement the quantitative data. The allocation of attribute combinations across scenarios followed an efficient design approach [114], allowing for robust estimation of main effects and heterogeneity.

The participatory mapping module asked participants to locate their place of residence and delineate a polygon representing the urban area they knew best and where they would prioritise NBS implementation. Using polygons offers flexibility in expressing both location and spatial extent of perceived needs and supports the interpretation of preference data within meaningful lived spaces (Brown & Pullar, 2011; Brown & Fagerholm, 2015).

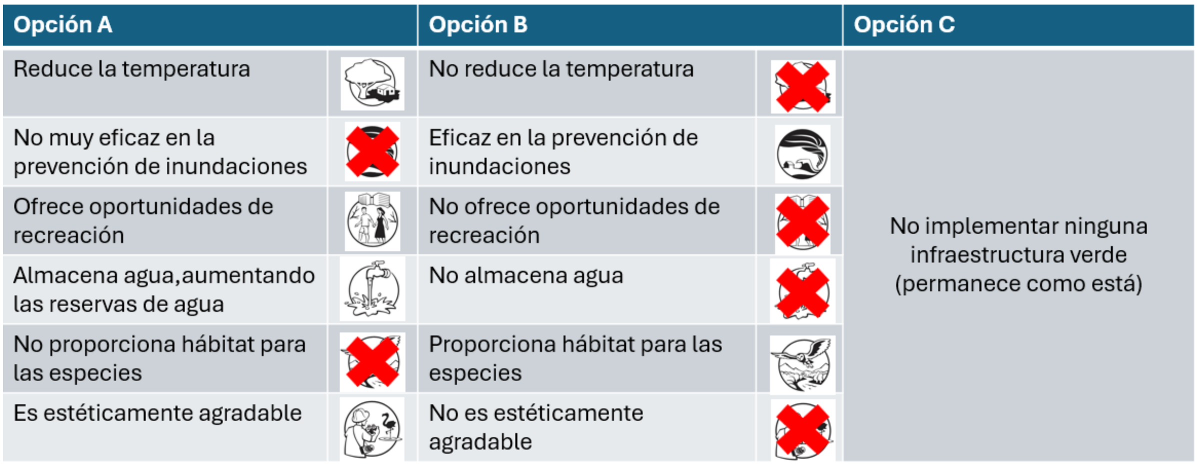

Figure 4 - Example of a choice set in the DCE (one of twelve)

Participatory mapping integration in the DCE

A participatory mapping module was integrated into the online survey through the Maptionnaire platform to spatially anchor individual preference data collected in the DCE. This integration enabled each respondent's stated preferences to be linked with the parts of the metropolitan territory they knew best, connecting attitudinal and spatial dimensions of environmental perception.

Participants were first asked to mark their place of residence and then to delineate a polygon representing the urban area they knew best. This polygon was later linked to their DCE responses, allowing the spatial localisation of the ES benefits implied by their preferred choice profiles. Importantly, respondents did not choose specific types of NBS. The mapping task focused instead on where the benefits associated with different ES configurations should be prioritised. This reflects the strategic aim of the study, which identifies priority areas for ES provision while leaving the concrete design of NBS interventions to later planning stages.

The polygons generated through the participatory mapping exercise were used to spatially aggregate respondents' choices, producing maps that illustrate where particular benefits, such as heat mitigation or flood prevention, are most desired. This integration made it possible to analyse spatial heterogeneity in preferences and to relate differences in stated choices to the physical and socio-ecological characteristics of the areas identified by participants.

The integrated survey, combining Maptionnaire for the spatial component and Netquest for sampling and questionnaire delivery, complied with the EU General Data Protection Regulation (GDPR). Ethical approval for the study was granted by the Ethics Committee of the Autonomous University of Barcelona (CEEAH-6119). All participants provided informed consent electronically at the start of the questionnaire on the Maptionnaire platform, prior to their participation in the study.

Analysis

Data Preparation

Data from the experimental design, survey responses, and metadata (e.g., response timestamps and completion status, etc.) were extracted and consolidated into a unified workspace. All records were standardized into a long data format suitable for discrete choice modelling. We carefully ensured alignment between individual responses and the corresponding DCE tasks. During this step, variable labels were cleaned (e.g., converted to lowercase), column names were harmonized, and row counts were verified for internal consistency. Categorical variables were recoded systematically, and any missing or anomalous entries were flagged. Outliers were identified based on consistency rules, such as mismatches between selected options and available alternatives, illogical response patterns, or incomplete choice tasks. These cases were reviewed and checked against the original survey files.Following these steps, the resulting clean and validated dataset was imported into R for subsequent model estimation.

Econometric Framework

Our analysis uses the Random Utility Model (RUM) to explain how individuals choose the option that maximises their utility among a set of alternatives [115]. Under this approach, the utility U_{ij} derived by individual i from choosing alternative j consists of a systematic (deterministic) part and a random term:

$$U_{ij} = \beta' \mathbf{X}_{ij} + \varepsilon_{ij},$$

Equation 1

Here, Xi_j is a set of explanatory variables characterising alternative *j*, *β* is the parameter vector, and ε_{ij} is an error term often assumed to be independently and identically distributed (iid) following a Gumbel distribution [116].

To capture multiple ES and a status quo (SQ) option, each ES was represented through dummy-coded variables, and an indicator variable was included for the status quo.

Furthermore, socio-demographic characteristics Zi were incorporated via interaction terms with the alternatives, acknowledging that individual traits may alter preferences [117]. Formally, the utility model can be written as:

$$U_{ij} = \beta_1 \,\mathrm{Heat}_{ij} + \beta_2 \,\mathrm{Flood}_{ij} + \beta_3 \,\mathrm{Rec}_{ij} + \beta_4 \,\mathrm{Water}_{ij} + \beta_5 \,\mathrm{Habitat}_{ij} +$$

$$+ \beta_6 \,\mathrm{Aesthetic}_{ij} + \alpha_i \,\mathrm{SQ}_j + \gamma \left(\mathbf{Z}_i \times \mathrm{Alternative}_j\right) + \varepsilon_{ij}$$

Equation 2

Here, $Heat_{ij}, Flood_{ij}$,… are binary variables indicating the presence of a particular ES in alternative *j*, while SQ_j is a dummy variable taking the value of 1 if alternative j is the status quo [118]. The interaction term *(Zi x Alternative$_j$)* allows for individual-specific influences on preferences (Hensher et al., 2015).

Three main approaches are available for coding categorical variables in DCE analysis: mean-centered coding, effects coding, and dummy-variable coding [59,119]. Among these, effects and dummy-variable coding are most commonly used for modeling categorical attribute levels [120]. For both, one attribute level is omitted (e.g., the first level in a three-level attribute), while present levels receive a value of 1, and absent levels are coded as 0 (dummy coding) or -1 (effects coding). We opted for dummy-variable coding due to its interpretability in estimating marginal effects relative to a baseline.

To estimate model parameters, we employed a two-step modelling strategy to capture increasing complexity in respondents' choices progressively. First, we used a Conditional Logit model, a standard application of the Multinomial Logit framework, which assumes that all individuals share the same preferences (i.e., homogeneous preferences) and that the assumption of Independence of Irrelevant Alternatives (IIA) holds (Train, 2009). This model allowed us to assess how the presence or absence of each ES, and the inclusion of a status quo option, influenced average utility across the entire sample.

Next, we implemented a Mixed Logit model to account for unobserved preference heterogeneity across individuals. In this specification, one or more coefficients β_k are treated as random variables with pre-specified probability distributions (e.g., normal or log-normal), rather than as fixed parameters [59,121]. This allows for the possibility that different individuals assign different levels of importance to specific ES. The model also relaxes the IIA assumption and can accommodate correlation across alternatives and repeated choices by the same individual. Furthermore, it provides richer insights into the variance and structure of individual-level preferences, helping to uncover sub-groups of respondents with distinct valuation patterns.

By comparing the Conditional Logit and Mixed Logit results, we were able to evaluate how well each model explained the observed choices and how much heterogeneity existed in ES preferences [122].

Interdependencies of preferences with socio-demographic parameters

To examine whether socio-demographic characteristics influence preferences for ES, we tested interaction effects between respondents' attributes and the ES variables in the utility model. This approach allows us to detect whether specific population groups systematically prioritize certain ES over others.

We selected socio-demographic variables based on theoretical and empirical literature showing their role in shaping environmental attitudes and risk perceptions. For instance, older individuals are often more vulnerable to extreme weather events [94], making Age × Heat Mitigation and Age × Flood Prevention logical interactions. Higher income has been associated with stronger preferences for non-material services such as aesthetics or biodiversity (Bateman et al., 2002; Hoyos, 2010), justifying Income × Aesthetic or Income × Habitat interactions. Similarly, educational attainment correlates with environmental awareness [123,124], supporting interactions like Education × Habitat. Gender-based differences in public space usage [68,125] encouraged us to test Gender ×

Recreation, while mobility behaviors and lifestyle patterns,such as reliance on public transport [126] or frequency of outdoor activities [127],were explored through interactions like PublicTransport × Aesthetic and ActivityFrequency × Recreation.

Technically, these interactions were implemented in R by including multiplicative terms in the utility specification, such as $ES1_j \times Age\_i$ or $ES_4 \times Income_i$. These interaction variables were generated by adding socio-demographic columns to the dataset and computing cross-products with each binary-coded ES attribute. We used the dplyr package for data manipulation and survival for estimating Conditional Logit models with interaction terms. For instance, the clogit() function from the survival package was employed to incorporate interaction effects using syntax such as attribute:Gender or attribute:Age. Including these terms enabled us to estimate whether, and how, the marginal utility of each ES varies across groups, revealing deeper heterogeneity in ES valuation.

Spatial analysis of Ecosystem Service Preferences

Spatial analysis was based on the polygons and preference data collected through the DCE-participatory mapping integration described in Section 5.1.3. The mapped polygons were converted into a uniform spatial grid and overlaid with socio-environmental data to detect clusters of high preference intensity for each ES attribute, allowing us to explore spatial variation in citizens' priorities across the AMB.

To translate DCE outcomes into spatial information, each participant's selected alternatives, characterized by a bundle of six binary ES attributes, were joined with their associated polygon. Using R (version 4.4.2), we decomposed the selected DCE profiles into binary indicators (0 = absent, 1 = present) for each ES and assigned them to the corresponding polygon. This process generated a spatial attribute table, where each mapped area carried information on the ES preferred by the respondent.

To visualize and quantify spatial patterns of preference, we overlaid a uniform hexagonal grid (100×100 m cells) over the entire study area, following established approaches in spatial social-ecological research [115,128,129]. Each response polygon was spatially intersected with all overlapping hexagons using the sf package in R [130]. For each hexagon, we calculated:

1. The total number of overlapping polygons (response density)
2. The number of times each ES was selected within those polygons

To account for spatial clustering, particularly the higher response density in central areas, we normalised ES counts by the total number of responses per hexagon. This yielded a relative preference index ranging from 0 to 1, representing the proportion of participants in each cell expressing a preference for a given ES.

The resulting outputs were exported as spatial layers in QGIS (version 3.34.12) for visualization and further analysis. This approach enabled us to produce high-resolution maps showing where specific ES are most desired, informing spatially targeted NBS planning strategies. Spatial joins and normalization were performed in R (sf package; Pebesma, 2018) and QGIS.

Data Availability

Socio-demographic and territorial data used for sampling and contextual analyses are available from the Barcelona Metropolitan Area (AMB) open data services and from the Statistical Institute of Catalonia (IDESCAT) (https://www.idescat.cat). All spatial data sources used for map production are reported in the corresponding figure captions. Survey data were collected via Netquest and administered through the Maptionnaire platform. Due to privacy and third-party restrictions, the raw survey microdata and participatory mapping geometries are not publicly available. High-resolution versions of the map figures shown in this study can be provided by the corresponding author upon reasonable request.

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Author contributions

G.B. contributed to the development of the methodological framework, led data preparation and cleaning, conducted all econometric and spatial analyses (R and QGIS), produced all maps, and wrote the manuscript. S.M. contributed to the survey design (R), including the participatory mapping module. J.L. conceived the original study idea and supervised the research and manuscript development. All authors discussed the results and approved the final version of the manuscript.

Code availability

Custom R scripts were developed for data cleaning, econometric modelling, and spatial analysis. The code is not publicly available.

Competing interests

The authors declare no competing interests.

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