NICHES

Nature's integration in cities' hydrologies, ecologies and societies

D3.2 Ecosystem service value assessment and mapping under NBS scenarios

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1 Introduction

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 (Calvin et al., 2023). These pressures not only threaten the ecological integrity of cities but also exacerbate social inequalities, as economically and socially vulnerable groups often bear a disproportionate share of climate-related burdens (Camacho-Caballero et al., 2024). The combined effects of inadequate infrastructure, limited access to resources, and marginalization can amplify vulnerabilities, leading to heightened risks across urban populations. Moreover, incremental shifts in everyday conditions—such as rising average temperatures or recurrent minor floods—accumulate over time, damaging ecosystems and eroding urban quality of life. These dynamics highlight the urgent need to embed equity considerations into climate adaptation planning.

Nature-based solutions (NBS) are increasingly recognized as promising strategies for enhancing urban resilience, biodiversity, and well-being (European Commission. Directorate General for the Environment., 2016). Examples such as green roofs, rain gardens, and multifunctional green corridors offer environmental benefits like flood mitigation and microclimate regulation, while also delivering cultural and recreational value (Frantzeskaki, 2019).

Empirical evidence has demonstrated that the implementation of green roofs can significantly mitigate urban heat through reductions in surface temperatures of up to 15°C, as well as substantially improve stormwater management by retaining over 70% of rainfall during intense precipitation events (Berardi, 2016; Speak et al., 2013). Similarly, rain gardens have been shown to effectively decrease peak stormwater runoff by 30–90% and simultaneously enhance water quality through the filtration of pollutants, including nitrogen compounds and suspended solids (Davis & Naumann, 2017; Eckart et al., 2017). Additionally, urban parks and vegetated areas are associated with reductions in local ambient air temperatures ranging from approximately 0.5 to 2.0°C, contingent upon specific climatic and contextual variables (Bowler et al., 2010; Zölch et al., 2016). Nevertheless, recent literature underscores the context-dependent nature of the efficacy of nature-based solutions, emphasizing that their outcomes vary substantially according to design characteristics, spatial configurations, and socio-economic contexts (Kabisch et al., 2017; Sekulova et al., 2021).

Despite growing evidence on the environmental efficacy of NBS, their implementation often overlooks local preferences, knowledge, and values—particularly among socially marginalized groups. This disconnect can limit the relevance, uptake, and long-term success of such interventions.

Recent scholarship emphasizes the role of recognition justice in environmental governance, arguing that beyond equitable distribution, effective policy must acknowledge diverse identities, needs, and experiences (Langemeyer & Connolly, 2020; Wolch et al., 2014). Public acceptance of climate and environmental interventions often hinges on perceptions of fairness, transparency, and responsiveness. For example, studies on carbon pricing have shown that policies gain support when people understand them, see them as just, and observe that benefits are allocated to vulnerable groups and environmental goals. These findings align with justice-oriented urban planning frameworks that advocate for inclusive and participatory approaches to increase legitimacy and acceptance (Cason et al., 2025).

Despite growing awareness of these justice dimensions, practical methods for incorporating local perspectives into spatial planning remain limited (Rall et al., 2019; Wolch et al., 2014).

Especially in cities, where spatial and social inequalities intersect, interventions designed at a metropolitan scale may conflict with localized needs. Therefore, scholars call for planning frameworks that make recognition justice spatially explicit—identifying not only which services people prioritize, but also where they want them implemented and why (Brown & Fagerholm, 2015; Brown & Weber, 2013).

This study responds to these challenges by developing a spatially explicit, participatory methodology that integrates a Discrete Choice Experiment (DCE) with a Participatory Public Geographic Information System (PPGIS). The DCE captures which attributes of NBS—represented by specific ecosystem services—are most valued by residents. Simultaneously, PPGIS enables respondents to map where they would prefer to see these benefits delivered. This dual framework allows researchers to link preference strength with spatial context, offering a more nuanced understanding of how NBS can be tailored to both societal priorities and place-specific needs.

The primary objective of this study is to apply an integrated DCE–PPGIS methodology to explore ecosystem service preferences related to urban NBS within the Barcelona Metropolitan Area (AMB), emphasizing spatial expressions of recognition justice. The research addresses the following questions:

1. Which ecosystem services provided by NBS do residents prefer, compared to the status quo?
2. How do socio-demographic variables influence residents' preferences of these ecosystem services?
3. In which urban areas do residents identify the greatest need for implementing ecosystem services associated with NBS?

By answering these questions, the study offers both methodological and practical contributions: enhancing recognition justice in urban planning and advancing spatially explicit, citizen-informed sustainability strategies.

The next section introduces the case study of the Barcelona Metropolitan Area, followed by a presentation of the integrated DCE–PPGIS methodology. Results are then reported, before a discussion of implications in light of recognition justice and urban policy. The final section concludes with reflections on broader applications and future research directions.

2 Case Study: Barcelona Metropolitan Area

Barcelona was chosen as a relevant urban context due to its documented environmental challenges. The city experiences frequent heatwaves, with projections indicating a worsening of heat-related risks in coming decades (Ballester et al., 2023). Flooding also presents a recurrent threat, exacerbated by impermeable urban surfaces and increasing extreme rainfall events. Moreover, green space availability is limited in several neighborhoods. Although the city has made progress through tree planting campaigns and biodiversity strategies, disparities in access to green infrastructure persist. For instance, Baró et al. (Baró et al., 2019) argue that while Barcelona has relatively high tree coverage, this often compensates for a lack of public green areas.

The city is actively integrating nature-based approaches into its planning framework, particularly through the Green Infrastructure and Biodiversity Plan 2020 and the Climate Emergency Declaration. These efforts aim to enhance ecological connectivity and resilience, yet debates continue over whose needs are prioritized and which areas benefit most. As such, Barcelona presents a complex socio-ecological landscape where environmental pressure, spatial inequality, and political momentum for NBS converge.

In particular, the Barcelona Metropolitan Area (AMB) is a compelling context for investigating spatial and socio-demographic dimensions of ecosystem service preferences due to its extensive diversity in land use, population density, and socio-economic characteristics. Encompassing 36 municipalities and hosting over 3.3 million residents, the AMB represents a coherent functional and ecological unit that offers a comprehensive setting to examine heterogeneous preferences and needs regarding urban nature-based solutions. This aligns with prior research and urban planning initiatives that highlight the AMB's suitability for analyzing the interplay between urban form, social diversity, and ecological functions (Baró et al., 2017; Camacho-Caballero et al., 2024; Khromova et al., 2025; Vasconcelos et al., 2024), thereby providing valuable insights into spatially explicit planning of NBS.

All demographic and socio-economic data used for spatial and statistical analysis were sourced from official AMB datasets and the Statistical Institute of Catalonia ((IDESCAT, 2025).

3 Methodology

This study employs a place-based, mixed-method approach integrating a structured survey, DCE, and PPGIS tools to understand citizens' spatially explicit preferences for NBS and associated ES. The following sections describe survey creation, sampling, statistical stratification, DCE setup, integration of PPGIS, ethical considerations, and case study selection.

3.1 Survey and PPGIS Design

3.1.1 Survey Design

Our choice experiment is grounded in Lancaster's theory of value (Lancaster, 1966), which posits that utility from goods or services arises from their attributes rather than the goods themselves. In this framework, respondents' NBS preferences derive from specific ES provided rather than intervention labels.

Each respondent evaluated twelve hypothetical choice scenarios, each comprising three alternatives: Options A and B (generalized NBS), characterized by the presence or absence of six ES attributes, and Option C, representing the status quo (no intervention). The attributes were heat mitigation, flood prevention, recreational opportunities, water storage, habitat provision, and aesthetic quality, each taking binary values (0: absent, 1: present).

The ES attributes included in the survey were selected through a transdisciplinary process that combined expert interviews, literature review, and empirical insights from the URBAG project—an interdisciplinary research initiative focused on urban sustainability and nature-based solutions in the Barcelona Metropolitan Area, among other cities. This process ensured that the selected attributes reflected both scientific relevance and local planning priorities. The final design resulted in 378 hypothetical choice scenarios, structured as follows: each respondent was presented with 12 choice sets, each containing two alternative NBS options, described by the six ES attributes listed above, along with a status quo option representing no change. The survey was administered in Spanish to ensure accessibility for local participants.

Respondents received simplified explanations of ES (as “benefits of green infrastructure”) to avoid technical jargon. Fig.1 shows an example choice set.

Opción A	Opción B	Opción C
Reduce la temperatura	No reduce la temperatura	No implementar ninguna infraestructura verde (permanece como está)
No muy eficaz en la prevención de inundaciones	Eficaz en la prevención de inundaciones	
Ofrece oportunidades de recreación	No ofrece oportunidades de recreación	
Almacena agua,aumentando las reservas de agua	No almacena agua	
No proporciona hábitat para las especies	Proporciona hábitat para las especies	
Es estéticamente agradable	No es estéticamente agradable	

Figure 1-Example of choice set in the DCE, one of twelve

By varying these attributes across different hypothetical scenarios, we can observe how changes in each ecosystem service affect individuals’ choices and, therefore, their utility (Hoyos, 2010; Pearce et al., 2002). This would allow to plan, instead of for specific NBS, for NBS that can provide specific ES.
The survey began with socio-demographic questions (gender, age, income, education, transport preferences, life satisfaction). Post-DCE questions explored reasons behind choices, with additional open-ended questions about preferred benefits, ensuring insights into public acceptance of NBS.
An efficient design guided choice scenario allocations following Troncoso (Troncoso, 2022). Supporting images depicting NBS were provided. The survey, including the Discrete Choice Experiment and spatial mapping tasks, was implemented using the Maptionnaire platform, which allowed for an integrated, interactive presentation of choice sets and mapping activities.

3.1.2 Statistical Representation of Respondents and Survey Distribution

We distributed the survey within the AMB through Netquest, a survey distribution company, applying stratified sampling theory (Cochran, 1977)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.

3.1.3 PPGIS integration in the DCE

A PPGIS module, integrated within the Maptionnaire platform, anchored preference data spatially. Participants marked their residence (point) and delineated a polygon around the

urban area they knew best. This allowed linking respondents' DCE preferences to specific urban locations, identifying spatial patterns of ES valuation and highlighting recognition justice and equity(Brown & Kyttä, 2014; Raymond et al., 2010; Wolch et al., 2014).
The integrated survey (Maptionnaire and Netquest) complied with EU GDPR guidelines, and the Autonomous University of Barcelona's ethics committee approved the study.

3.2 Analysis

3.2.1 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 modeling. 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.

3.2.2 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 (McFadden, D., 1974). 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:

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

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 (Train, 2009).
To capture multiple ecosystem services and a status quo (SQ) option, each service 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 (Hensher et al., 2015). 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 ecosystem service in alternative *j*, while SQ_j is a dummy variable taking the value of 1 if alternative j is the status quo (Louviere et al., 2000). 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 (Hauber et al., 2016; Hoyos, 2010). Among these, effects and dummy-variable coding are most commonly used for modeling categorical attribute levels (Bech & Gyrd-Hansen, 2005). 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 modeling strategy to progressively capture increasing complexity in respondents' choices. 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 ecosystem service, 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 (Hoyos, 2010; Revelt & Train, 1997). This allows for the possibility that different individuals assign different levels of importance to specific ecosystem services. The Mixed Logit 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 ecosystem service preferences (Hole, 2007).

3.2.3 Interdependencies of preferences with socio-demographic parameters

To examine whether socio-demographic characteristics influence preferences for ecosystem services, we tested interaction effects between respondents' attributes and the ecosystem service variables in the utility model. This approach allows us to detect whether specific population groups systematically prioritize certain ecosystem services 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 (Ballester et al., 2023), 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 (Geneletti et al., 2020b, 2020a), supporting interactions like Education × Habitat. Gender-based differences in public space usage (Krenichyn, 2006; Wolch et al., 2014) encouraged us to test Gender × Recreation, while mobility behaviors and lifestyle patterns—

such as reliance on public transport (Kamruzzaman et al., 2016) or frequency of outdoor activities (Brown & Kyttä, 2014)—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 $ES1_j$ × Age_i or ES_4 × $Income_i$. These interaction variables were generated by adding socio-demographic columns to the dataset and computing cross-products with each binary-coded ecosystem service 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 ecosystem service valuation.

3.2.4 Spatial analysis of Ecosystem Service Preferences

To spatially analyse ecosystem service preferences, we integrated respondents' DCE responses with participatory spatial data collected through polygons drawn on a digital map. Each participant was asked to indicate, via a free-form polygon, the area within the metropolitan region where they would most like their preferred NBS option to be implemented. This approach allowed for spatial localization of preferences beyond abstract or generalized choices.
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, we decomposed the selected DCE profiles into binary indicators (0 = absent, 1 = present) for each ES and assigned them to the corresponding polygon. This decoding step generated a spatial attribute table, where each mapped area carried information on the ecosystem services preferred by the respondent.
We adopted polygons as the mapping tool because they allow respondents to express both the location and the spatial extent of their preferences, capturing the inherent flexibility in how individuals perceive relevant areas for intervention. This method avoids the artificial constraints imposed by fixed-point or pre-defined zone selection and has been shown to enhance the validity of participatory spatial data in urban and environmental planning.
To visualize and quantify spatial patterns of preference, we overlaid a uniform hexagonal grid (100×100 m cells) over the entire study area, building on established approaches in spatial social-ecological research (Birch et al., 2007; Brown & Pullar, 2011; McFadden, D., 1974) a uniform hexagonal grid (100×100 m cells) over the entire study area. Each response polygon was spatially intersected with all overlapping hexagons using the sf package in (Pebesma, 2018). For each hexagon, we calculated:

1. The total number of overlapping polygons (i.e., response density)
2. The number of times each ES was selected in those polygons

To control for spatial clustering (e.g., over-representation of city-center areas), we normalized the ES counts by the total number of responses per hexagon. This yielded a relative preference index ranging from 0 to 1, indicating the proportion of participants in each cell expressing a preference for a given ES.
These results were exported as spatial layers in QGIS (version 3.34.12) and R (version 4.4.2) for visualization and further analysis. This approach enabled us to produce high-resolution

maps showing where specific ecosystem services are most desired, informing spatially targeted NBS planning strategies. Spatial joins and normalization were performed in R (sf package; Pebesma, 2018) and QGIS (version 3.34.12).

4 Results

4.1 Descriptive Statistics

The demographic profile of the survey respondents broadly reflects the diversity of the Barcelona Metropolitan Area (AMB), with some variation across age and education categories. The gender distribution is closely aligned with the general population—with 48.7% identifying as male and 51.1% as female—while 5% of participants identified with a gender other than male or female, a category not captured in the census.

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 and was closed after a prolonged decline in response rate, which had slowed to approximately three respondents per week in the final phase. 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.

Age-wise, younger adults (20–44) are more present in the survey sample, while older age groups, particularly those aged 65 and above, are less represented. This pattern is consistent with common challenges in recruiting older populations through online survey panels.

In terms of education, the sample shows a higher proportion of respondents with tertiary education (52.9%) compared to the AMB population (37.6%). Respondents with only primary or lower secondary education are less represented. This trend is often observed in online surveys, where participants with higher education levels are more likely to take part.

These trends reflect typical limitations of online, panel-based sampling methods, despite the use of stratified sampling to improve representativeness. They should be considered when interpreting the generalizability of the results.

Table 1 - Descriptive statistics

	AMB Census [%]	Survey Sample [%]	Difference [%]
Age			
20-24	6,7	0,4	7,6
25-29	7,3	0,4	8,8
30-34	7,9	0,5	9,5
35-39	8,3	0,5	10,4
40-44	9,7	0,5	11,8
45-49	10,6	0,6	11,0
50-54	9,5	0,5	9,5
55-59	8,6	0,5	7,8
60-64	7,3	0,4	15,3
>=65	24,0	1,4	98,6
Gender			
Hombre	48,7	48,7	0,0
Mujer	51,4	51,1	0,3
Otro	-	5,0	-
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 education and similar	23,6	36,7	-13,1
Tertiary education	37,6	52,9	-15,4

4.2 Model Estimates

Fig. 3 displays the estimated coefficients from the Conditional Logit model alongside their standard errors. The opt-out option (status quo) shows a strongly negative coefficient, confirming respondents' aversion to scenarios without new NBS implementation. All six ecosystem service attributes yield positive and statistically significant coefficients ($p < 0.001$), reflecting their positive contribution to respondents' utility.

Among these, Heat Mitigation stands out with the highest coefficient, followed by Flood Prevention and Water Storage, suggesting that services related to climate adaptation and hydrological regulation are highly valued. Aesthetic Enhancements, Habitat Provision, and Recreational Opportunities show more moderate but still clearly positive effects. The narrow confidence intervals around all bars (in orange) illustrate the statistical reliability of the estimates.

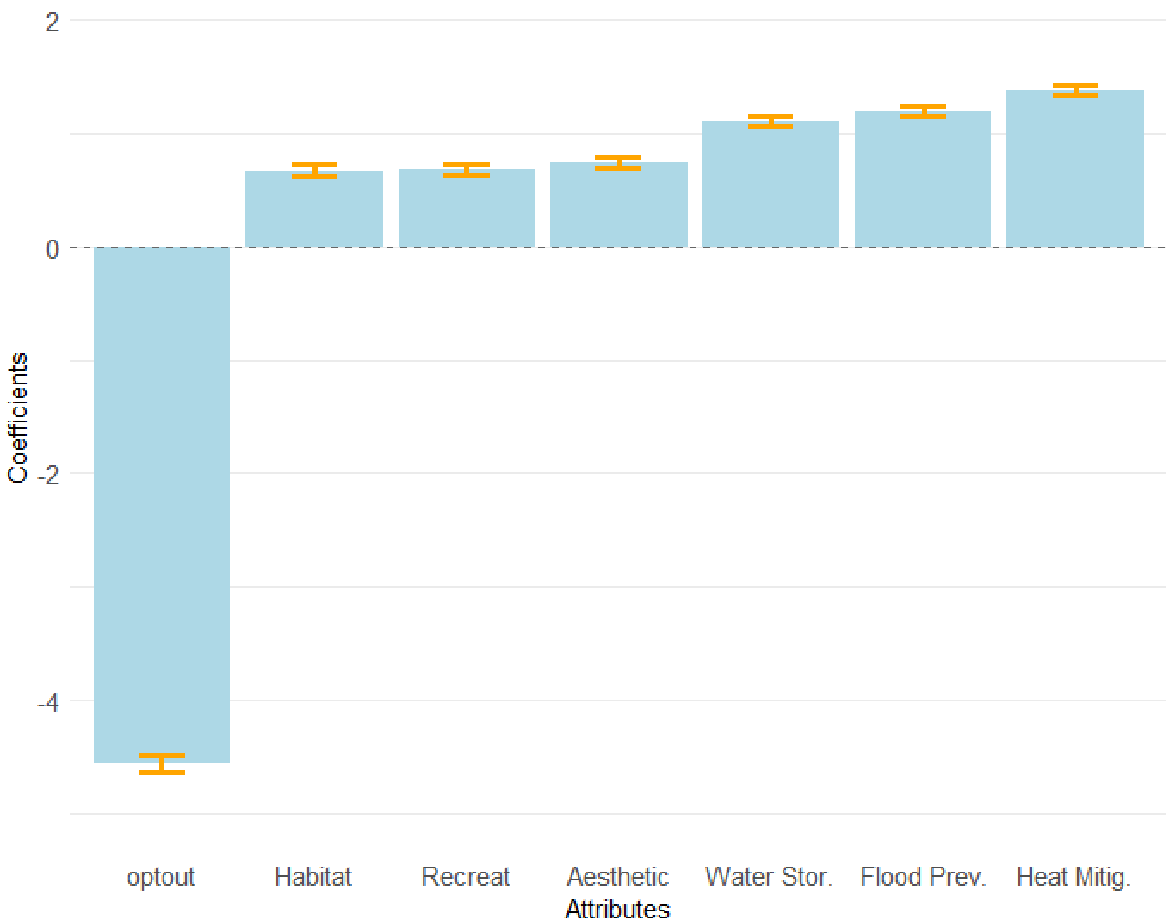


Figure 3 - Conditional Logit Model Coefficient, with Standard Errors. p<0.001 for all coefficients

We analyzed the collected responses using a two-step discrete choice modeling approach. First, a Conditional Logit (CL) model was estimated to identify how each binary ecosystem service attribute—as well as the opt-out (status quo) option—influences utility at the population level. This model provides estimates of the average effects of each attribute and captures the general preference for implementing new nature-based solutions (NBS) rather than maintaining the current situation.

Next, we employed a Mixed Logit (MXL) model to account for unobserved preference heterogeneity. Unlike the CL model, the MXL allows coefficients to vary randomly across individuals, enabling a more flexible estimation of how different respondents value specific attributes. This approach provides a more nuanced understanding of both central tendencies and distributional variation in preferences.

All models were estimated via maximum likelihood procedures (Hoyos, 2010), and the outputs include coefficients, standard errors, z-values, and p-values. Table 1 summarizes the main results from both CL and MXL models. In both models, the opt-out option has a significantly negative coefficient, indicating that respondents, on average, strongly prefer any new NBS over doing nothing. In contrast, all six ecosystem service attributes—Heat Mitigation, Flood Prevention, Recreational Opportunities, Water Storage, Habitat Provision, and Aesthetic Enhancements—show positive and significant coefficients, suggesting that each contributes positively to the utility derived from a proposed intervention.

Among the services, Heat Mitigation emerges as the most valued, with the largest positive coefficient in both models. Water Storage and Flood Prevention also score highly, emphasizing that resilience to heat and water-related risks are key concerns. Recreational Opportunities, Habitat Provision, and Aesthetic Enhancements, while smaller in magnitude, are still statistically significant ($p < 0.001$), confirming that they are meaningful contributors to perceived intervention value.

The strong negative coefficient for the opt-out alternative ($\beta = -4.562$ in the CL model) further reinforces the general opposition to the status quo. Model fit indicators support the robustness of both models, with highly significant likelihood ratio statistics and satisfactory convergence parameters. The exponentiated coefficients ($\exp(\beta)$) indicate that including services like heat mitigation, water storage, or flood prevention substantially increases the likelihood of an option being chosen.

Table 2 *** p<0.001 . CL Stats: n=63,396, Concord.=0.829, LR=21903 (df=7), p<2e-16. MXL Stats: n=63,396, LogLik=-15979, R=100, bfgs(88 iter)

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)

The Mixed Logit model offers additional insight by showing how preferences vary across the sample. As shown in Table 2, standard deviations for some parameters (e.g., opt-out, Habitat Provision) are significantly different from zero, indicating meaningful heterogeneity. This means that although the average respondent values these services, some place considerably more (or less) emphasis on them. For example, while Habitat Provision has a positive average effect, the large standard deviation suggests that a subset of respondents either highly prioritize biodiversity or consider it less important than others.

These findings emphasize the value of combining CL and MXL models. While the former captures aggregate trends, the latter reveals underlying diversity in preference structures. This dual approach supports more targeted policy design, helping urban planners align NBS interventions with community expectations. Overall, results confirm that citizens prioritize ecosystem services that enhance climate resilience and urban quality of life, with particularly strong support for solutions addressing heat and water management.

4.3 Interdependencies of preferences with socio-demographic parameters

In terms of socio-demographic factors, individuals with mid-range incomes (20,200€–60,000€) show a modestly higher likelihood of supporting new NBS interventions, with coefficients around $\beta \approx +0.076$. No clear pattern emerges among respondents in the highest income bracket.

Educational attainment follows a similar pattern: respondents with tertiary education demonstrate a stronger preference for adopting ecosystem services, while those with only primary or no formal education exhibit greater status quo bias—possibly due to lower perceived or actual benefits from NBS interventions.

Mobility-related variables and outdoor activity frequency play a more limited role. A minor positive effect was observed for respondents who commute by public transport or walk, which may suggest a slight preference for interventions that improve shading or urban aesthetics along common travel routes.

Importantly, interactions with optout reveals that mid-income brackets and highly educated groups display significantly larger negative coefficients in combination with the status quo, confirming that they are *particularly* unwilling to remain without any new service. In contrast, those with only primary or no schooling are likelier to tolerate doing nothing.

Taken together, these results suggest that planning efforts should prioritize Heat Mitigation and Flood Prevention, as they yield the largest gains in public acceptance, while also focusing outreach and incentives on lower-education cohorts—who exhibit notable status quo bias—so that all segments of the population appreciate the benefits of NBS.

These results reinforce the importance of prioritizing Heat Mitigation and Flood Prevention, which generate the greatest public support. Additionally, they highlight the need for targeted outreach and tailored incentives for less-educated groups, who are more hesitant to embrace change. Increasing awareness and demonstrating tangible benefits could help broaden acceptance and ensure more equitable implementation of NBS across all population segments.

4.4 Spatial analysis results

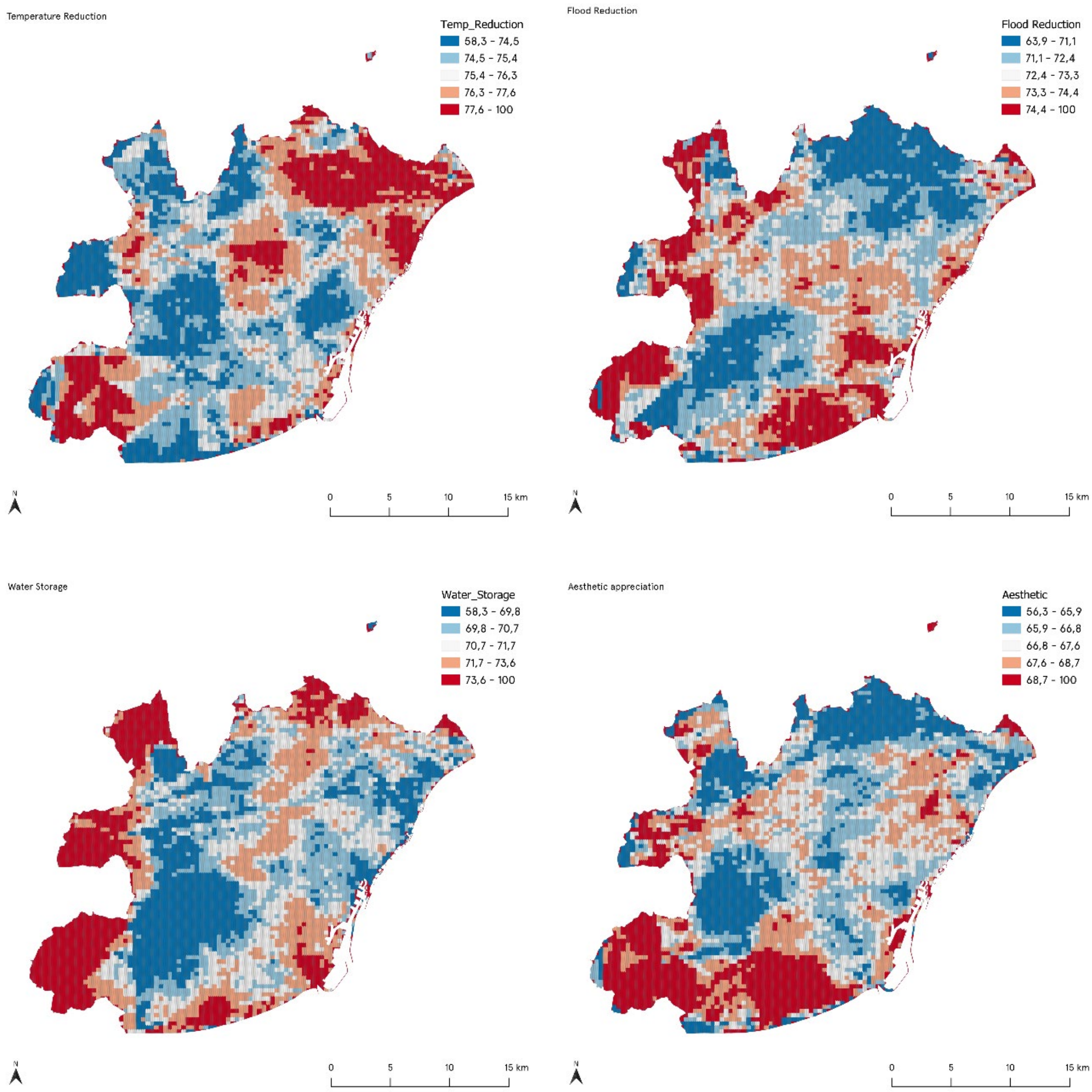
The spatial distribution of citizens' preferences for ES reveals notable geographic variability across the metropolitan area. By linking respondents' discrete choice experiment responses to the specific polygons they drew in the PPGIS survey, we generated relative preference indices for each ES attribute and mapped them using a hexagonal grid.

The resulting maps show that preferences are not uniformly distributed. Heat Mitigation, Water Storage, and Flood Reduction services tend to receive stronger support in central and western areas of the AMB, where exposure to urban heat and flood risk may be more strongly perceived. For example, preference for Heat Mitigation is particularly high in the north-eastern and south-western areas, possibly reflecting heightened vulnerability or awareness of climate-related risks.

Water Storage and Flood Reduction services show a similar pattern, with higher preference values concentrated in more urbanized or flood-prone areas. These findings align with the high coefficients observed for these services in the model estimates, confirming their relevance in both abstract preferences and spatially grounded expectations.

In contrast, preferences for Habitat Provision, Recreation, and Aesthetic Appreciation appear more spatially dispersed. Habitat-related preferences are more prominent in peri-urban and transitional zones, possibly linked to residents' proximity to green edges or ecological corridors. Recreational value is highest in areas where formal parks or natural areas may already exist or be lacking, suggesting demand for enhanced access or multifunctional green space. Aesthetic preferences follow a more diffuse pattern, though some concentrations are observed in northern and coastal areas.

Overall, the spatial analysis highlights a complex interplay between location-specific environmental conditions and residents’ expectations for NBS. These insights support the development of place-based planning strategies, ensuring that investments in green infrastructure respond to locally relevant needs and perceptions. Spatial patterns of preference can also inform targeted communication and co-design efforts in areas where support for certain ES may be lower or more contested.



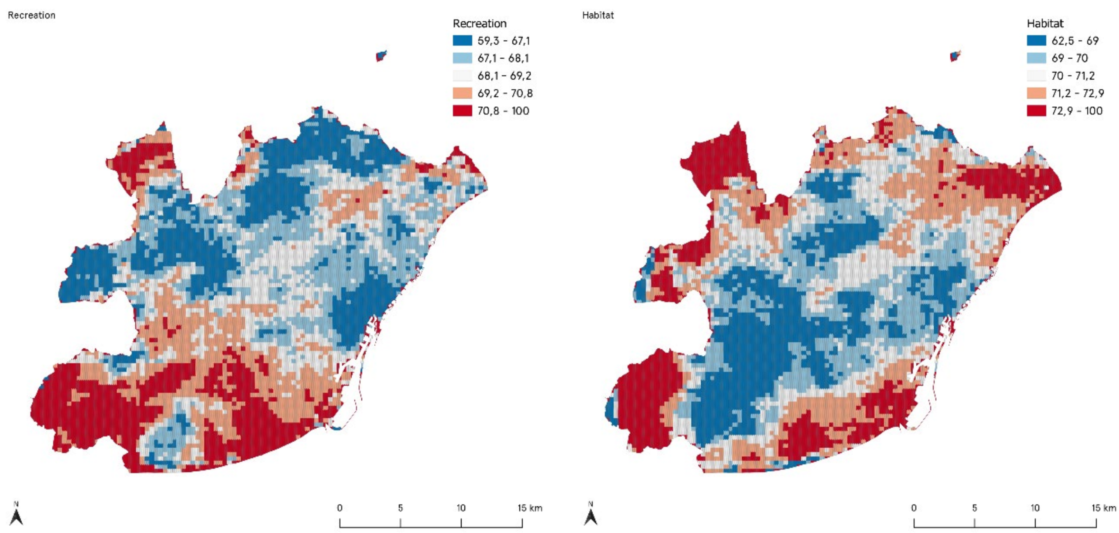


Figure 4 - Each map displays, using normalized values ranging from 0 (blue) to 100 (red), the spatial distribution of citizens' preferences for one of the six assessed ecosystem services: temperature reduction, flood reduction, water storage, habitat provision, recreation, and aesthetic quality.

5 Discussion

5.1 Preferences for Nature-Based Solutions and Implications for Urban Planning

This study confirms a strong public preference for Nature-Based Solutions (NBS) over the status quo across the Barcelona Metropolitan Area (AMB), reflecting a broad desire for interventions that enhance climate resilience and urban livability. The substantial and highly significant negative coefficient associated with the opt-out option demonstrates widespread dissatisfaction with existing urban conditions and a pronounced demand for change—echoing previous research on the perceived urgency of addressing climate-related risks in cities (Kabisch et al., 2016; Raymond et al., 2017).

Among the ecosystem services (ES) provided by NBS, heat mitigation emerged as the highest priority, followed closely by flood prevention and water storage. These results align with the specific vulnerabilities of the Barcelona context, which faces intensifying urban heat and increasing exposure to extreme precipitation (Ballester et al., 2023). They also resonate with broader findings that urban populations are particularly responsive to solutions addressing acute environmental stressors such as heatwaves and flooding (Harlan et al., 2006).

Recreational benefits, biodiversity support (habitat provision), and aesthetic enhancements also received strong support, albeit with relatively smaller coefficients. These attributes appear to be perceived as secondary, complementary gains rather than essential components of urban climate adaptation. Nevertheless, their consistent statistical significance confirms their importance in shaping public acceptance and perceived co-benefits of NBS, suggesting that multidimensional strategies integrating both regulating and cultural ecosystem services are likely to garner stronger support.

The spatial results further reinforce these findings, revealing clear geographical patterns of demand: preferences for flood and water management are concentrated in low-lying and more flood-prone areas, while heat mitigation and recreational services are often prioritized in densely built neighborhoods with limited green infrastructure. These spatialized patterns of demand should guide site selection and design, reinforcing calls for adaptive, context-sensitive planning in line with both ecological and social priorities.

5.2 Socio-Demographic Influences and Recognition Justice

As highlighted in recognition justice literature, addressing inequality in environmental planning requires acknowledging the differentiated needs and voices of urban residents (Wolch et al., 2014; Langemeyer & Connolly, 2020). Our findings confirm that socio-demographic variables—particularly income and education—significantly shape preferences for NBS and ecosystem services.

Middle-income respondents and individuals with higher levels of education were more likely to support interventions and reject the status quo, while those with lower educational attainment or lower income were more inclined to accept inaction. These differences may reflect disparities in environmental literacy, institutional trust, perceived personal benefit, or general policy engagement—factors that often correlate with educational attainment and class position (Geneletti et al., 2020).

Importantly, the mixed logit 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, habitat provision exhibited significant variation, suggesting that while biodiversity is broadly appreciated, its relative importance diverges based on background and possibly geographic context.

Such findings emphasize that one-size-fits-all planning risks neglecting the preferences of those who are already underserved. To address this, urban planners must adopt participatory and redistributive strategies that enhance recognition and procedural justice. However, participation should not be assumed to guarantee effective or risk-responsive outcomes on its own. Co-design processes must be complemented by targeted communication and educational efforts to ensure that underrepresented communities are aware of actual environmental risks and threats they may face. Without this, there is a risk that participatory outputs may reflect aesthetic preferences or symbolic inclusion, rather than generate interventions that effectively address vulnerability—whether human or ecological. These integrated strategies should include outreach to marginalized populations, co-creation efforts in underserved neighborhoods, and communication tools that translate the benefits of NBS into everyday concerns, such as thermal comfort, flood safety, and place attachment (Maestre et al., 2022).

5.3 Methodological Contributions and Limitations

This study makes a novel methodological contribution by combining Discrete Choice Experiments (DCE) with Participatory Public Geographic Information Systems (PPGIS) to analyze both the drivers and spatial dimensions of ecosystem service preferences. The integrated approach enables not only the identification of which services are most valued but also where interventions are desired. This spatially explicit framing of recognition justice advances previous work by grounding abstract preferences in concrete locations, thereby enhancing the relevance and applicability of results to real-world planning decisions.

Unlike many DCE-based studies that analyse preferences in isolation from geography, the spatial layer of this research helps reveal how environmental priorities intersect with lived urban realities. For example, the preference for heat mitigation in highly built-up districts or for habitat provision in peri-urban areas can inform more precise and context-sensitive NBS implementation.

Nonetheless, certain limitations should be acknowledged. The sampling strategy—while extensive—did not perfectly match the demographic profile of the AMB. Older adults and residents with lower formal education were underrepresented, which may have influenced the overall results and underestimated certain types of vulnerability or acceptance thresholds. 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.

Additionally, while the DCE effectively quantifies preferences, it cannot fully capture the underlying reasons behind those choices. 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 recognition justice must not only acknowledge diverse voices but also map them—translating preferences into spatial priorities to ensure that nature-based solutions are implemented in ways that are both ecologically meaningful and socially legitimate.

6 Conclusions

This study demonstrates that residents of the AMB support the implementation of NBS over maintaining the status quo, particularly those aimed at mitigating heat, preventing flooding, and enhancing urban water storage. These preferences indicate an urgent demand for interventions that address immediate climate-related risks and contribute to long-term urban resilience (Ballester et al., 2022; Harlan et al., 2006).

Crucially, socio-demographic characteristics—especially education and income—emerge as significant factors shaping the perceived value of ecosystem services. These findings reinforce the importance of embedding recognition justice into urban planning, ensuring that diverse population groups are not only represented in decision-making but also see their needs and perspectives acknowledged (Langemeyer & Connolly, 2020). Equity-oriented planning efforts should therefore prioritize inclusive outreach, tailored communication, and participatory engagement mechanisms to enhance legitimacy and policy support (Maestre-Andrés et al., 2019).

On a methodological level, the integration of DCE with PPGIS offers a novel, spatially explicit framework for aligning NBS with local knowledge. This approach allows for a nuanced understanding of what kinds of ecosystem services are valued, by whom, and where. By combining quantitative preference modeling with geospatial insight, this methodology advances the field of urban environmental planning in both theory and practice.

As urban areas confront escalating climate pressures, frameworks that integrate public values and spatial justice will be increasingly essential. The evidence presented in this paper lays a foundation for urban planners and policymakers to design NBS that are not only ecologically effective but also socially equitable and context-responsive. Future applications of this approach can support adaptive, community-informed planning processes across cities seeking to bridge sustainability goals with democratic legitimacy.

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