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Original article

Co-evaluating the social benefits of urban biodiversity: A case study of the Botanical Gardens at Utrecht University, the Netherlands

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ABSTRACT

Green spaces, as a critical part of urban infrastructure, provide a wide range of social, cultural, and economic benefits through ecosystem services to humans. Human-nature relations and social values created by nature at the urban scale are unique to each context, and therefore, for a concise planning approach, it is essential to fully grasp the benefits through local social values. By addressing the gaps in the literature, this research aims to develop and apply an engaging, adaptable, and replicable monitoring methodology that focuses on co-evaluation, building upon experiential narratives of the social benefits of urban nature. Focusing on a local case study of Utrecht University Botanical Gardens, and relying on transdisciplinary methods such as public workshops, semi-structured interviews, and gamified ecosystem services benefits selection, this research emphasizes a co-evaluation that builds on experiential narratives of the social benefits of urban nature and biodiversity. The results initially identify narratives of urban biodiversity explicating how and what people recognize as urban biodiversity in the Botanical Gardens and the related social values using ecosystem services (ES) benefits. Secondly, alongside narratives, the social benefits of nature and biodiversity are explored through the benefits selected by participants, which indicate the perception of visitors and locals about the place. Ultimately, the results of co-evaluation are reflected in direct recommendations for improving the Botanical Gardens. This proposed methodology, as a replicable and engaging approach, provides a participatory framework that bridges the gap between ecological metrics and local social values when evaluating the recognized and perceived social-ecological benefits of urban nature.

1. Introduction

Green spaces in urban areas are a critical part of urban infrastructure as hotspots for biodiversity preservation (Wang et al., 2024). Biodiversity, as defined by McNeely (1988), is an "*umbrella term for the degree of nature's variety, including both the number and frequency of eco-systems, species or genes in a given assemblage*". In cities, urban biodiversity values are defined as plural, multiscale, and context-dependent ways of ascribing importance to the biodiversity that spans from the intrinsic value of non-human life, to the instrumental (e.g., economic) contributions to human well-being through ecosystem functions and services, to the relational meanings (e.g., cultural values) embedded in human-nature interactions, to recognized ecosystem disservices (e.g., pests in green areas) (Kowarik, 2023; Rega-Brodsky et al., 2022). Biodiversity, as an intrinsically valued part of nature (Morrow, 2024), provides direct and indirect benefits for human well-being, especially in densely populated urban areas (Gong et al., 2024). Beyond ecological functions, urban greenery provides benefits to citizens recognized as ecosystem services (ES)—benefits people obtain through ecosystems and their natural processes that contribute directly and indirectly to sustaining their health and well-being (Liquete et al., 2016; Santos-Martín et al., 2013). The social benefits of (being in, with) nature encompass the non-material benefits and meanings that people derive from nature and natural elements, which improve overall life quality and well-being, including cultural, spiritual, aesthetic, recreational, and sense-of-place values. These benefits are not only limited to tangible effects with direct utility for humans, such as cooling or food provision, but also include broader cultural benefits (Jabbar et al., 2022). The

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cultural benefits of nature in cities include individual and communal benefits, such as a sense of belonging and identity, aesthetic experiences, and immersion (Haines-Young & Potschin-Young, 2018; Smith et al., 2017).

Cultural benefits are integral components of a broader spectrum of nature's contributions to people that shape social values, encompassing both tangible and intangible aspects of human well-being (Díaz et al., 2018; Keniger et al., 2013). These social benefits (cultural, spiritual, aesthetic, and relational) are fundamentally shaped by social values of nature, defined as the meaningful relationships and shared principles that communities and individuals maintain with the natural environment (Pascual et al., 2023). Social values are reflected in how nature is experienced and perceived within society; they emerge from contextual factors that shape our perceptions of benefits and vary across communities. The recognition of social impacts nature—measurable changes in humans' relation and physical and mental well-being from exposure to and interaction with the natural environment—remains underrepresented, especially in urban planning and policy, while traditional evaluation methods often fall short in accounting for the full spectrum of social values at the local level.

To grasp the extent of nature's social benefits and to design interventions and urban plans to realize them, it is essential to systematically evaluate nature's social values (Pascual et al., 2023). In this research, the emphasis is on co-evaluating social values related to nature at the local urban scale. While there is no universally established definition of co-evaluation, it can be defined as a place-specific approach to integrating the participation of actors such as visitors, residents, stakeholders, and other relevant groups throughout the evaluation process. This process spans from data collection to analysis and evaluation, intending to inform the design of interventions or policies. Such interventions aim to enable and stimulate the delivery of social co-benefits of urban biodiversity and nature-based solutions (NbS). The co-benefits of nature are understood as secondary or complementary—and, in some cases, side-effects—positive outcomes of re-naturing measures in urban areas and beyond (Matsiliza, 2012; van der Jagt et al., 2023).

Human-nature relations and the related social values created by nature at the urban scale are unique to each context and vary based on local attributes such as ecological memory, ecological literacy, and the history of place (Soga & Gaston, 2020). Environmental, spatial, social, and biophysical factors influence how residents and actors experience and prioritize nature's benefits (Thiemann et al., 2022), highlighting the need for context-sensitive evaluation methods. Consequently, evaluating the social benefits of nature at the local urban scale requires a comprehensive yet replicable and flexible methodology that adapts to contextual differences (Raymond et al., 2017). Additionally, at a local scale, values and perceptions of benefits are shaped by citizens and various actors, including non-citizens such as tourists and visitors who may temporarily use urban green spaces as destinations, during short stays or single visits (Nóblega-Carriquiry et al., 2023). Consequently, their engagement in the evaluation process is fundamental.

Current methodologies fail to simultaneously capture three essential dimensions: 1. diverse social values beyond mono-dimensional metrics like monetary calculations, 2. the multifaceted local context through collaborative rather than top-down approaches, and 3. sensitivity to contextual differences, including spatial dimensions and users' characteristics. A methodology addressing these gaps must integrate all three elements (comprehensiveness in revealing diverse values, replicability across diverse case studies, and direct engagement of local actors and stakeholders throughout the evaluation process, including local experiences). This necessarily requires moving beyond one-dimensional evaluations, such as monetary calculations, to reveal the full spectrum of social values embedded in local contexts through collaborative approaches. Sensitivity to contextual differences (including environmental and site-specific elements, future orientation, and users' characteristics) is essential to understand how expectations and experiences shape value perception.

Current methodologies present a fundamental trade-off in evaluating social benefits at the local scale. Quantitative approaches such as remote sensing, cost-benefit analysis, and geospatial analysis are replicable and standardized, but as top-down methodologies, they fail to engage local actors in the evaluation process and cannot capture the full spectrum of social values beyond monetary or ecological metrics (Bekoe et al., 2021; de Araujo Barbosa et al., 2015; Gai et al., 2022; Haase et al., 2014; LaReaux & Watkins, 2025; Ma & Yang, 2025; Wegner & Pascual, 2011). Additionally, without the engagement of local actors and the identification of local values, quantitative measurements fail to address the full spectrum of social values and consequently fall short in their evaluations (Sharifi et al., 2021). In response to these shortcomings, hybrid methods (a combination of quantitative and qualitative ones) offer a flexible approach to engaging local communities, while complementary data is gathered through quantitative evaluations. The primary challenge of implementing hybrid methodologies is their inflexibility for replication. Hybrid approaches require both local participants in the co-evaluation process and the integration of data with possible quantitative data, which adds a layer of complexity in evaluations.

Using qualitative methods for evaluation at the local scale presents both advantages and disadvantages compared to conventional methods. Primarily, qualitative approaches offer more flexibility in the engagement of actors and stakeholders in the process of evaluation (Chrisman et al., 2002) and are less dependent on the availability of data or data sources for each specific case study (McCormack et al., 2010). Qualitative evaluations are more replicable than other evaluation methods at the local scale due to the simplicity of the methods used (such as interviews and surveys) and their versatility for data collection in the evaluation process. Despite the advantages, qualitative methods, which are built upon descriptive data and vary by contextual attributes, require concrete interpretation and narratives (Herranz-Pascual et al., 2023; van der Jagt et al., 2023). The literature on qualitative methodologies for evaluating the social benefits of local urban NbS that are at once comprehensive, replicable, and engaging remains limited (Mahmoud et al., 2021).

Additionally, social impact evaluation at local or neighborhood scales in urban areas is dependent on multiple contextual and social-ecological variables (Vanclay, 2024). Values, norms, and perceptions often differ in each context of study based on parameters shaped by social, economic, and cultural status (Soma et al., 2018). Social differences in each context lead to unique and distinct perceptions and interpretations of ecological effects on human lives. Several studies have investigated methodologies for evaluation at the local scale using quantitative approaches, with assessing social-ecological dynamics remaining as topics of discussion, rather than part of the evaluation itself (Ribeiro-Rodrigues & Bortoleto, 2024).

Top-down and quantitative approaches show shortcomings in reflecting these social values at a local scale (Sterling et al., 2017) and fail to adequately involve actors and stakeholders in the evaluation process. Another shortcoming in monetary interpretations is the mono-dimensionality in reflecting the benefits and, consequently, the lack of comprehensive coverage of social values (Menezes da Silva et al., 2023). As a result, moving beyond monetary evaluations at smaller scales seems necessary. At the local scale, bottom-up approaches are efficient in terms of involvement and coverage of stakeholders in evaluation (Kati & Jari, 2016), and consequently, considering social values. The challenge in collaborative evaluation mainly lies in reconciling diverse perspectives and rigorously interpreting heterogeneous data beyond monetary evaluations. Fig. 1 summarizes the dimensions and attributes of a co-evaluation approach at the local scale. By addressing the knowledge-to-practice gaps and in contrast to traditional methodologies, co-evaluation explicitly integrates social values and stakeholders' priorities into the assessment process, which is essential to the scope of this research.

This research seeks to answer the question of how the social benefits of biodiversity in urban areas can be evaluated through a co-evaluation

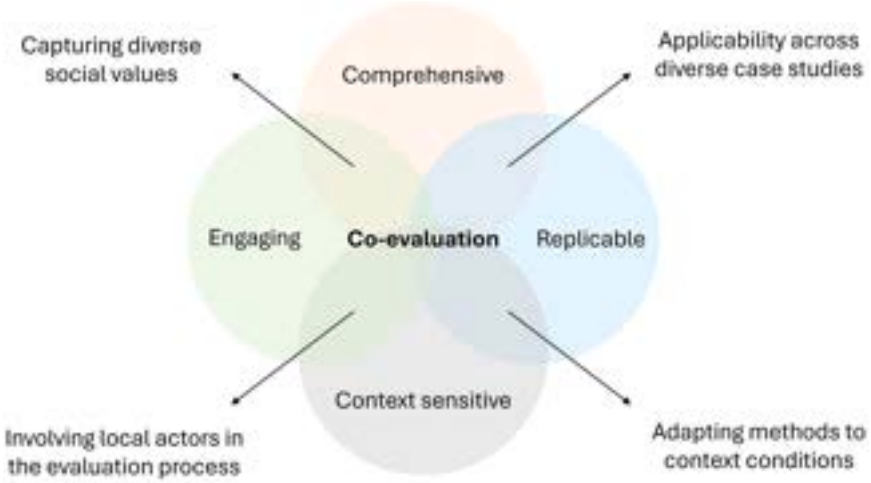

Fig. 1. Dimensions and attributes of social benefits co-evaluation of urban nature and biodiversity at local scale.

process that involves actors and citizens in general. This research aims to develop and apply an adaptable and replicable monitoring methodology that focuses on co-evaluation, building on experiential narratives of the social benefits of urban nature. This research engages citizens through workshops and interviews to create experiential narratives capturing local social values of nature. These narratives are then linked to social benefits of nature and biodiversity via a gamified ES benefits selection or targeted interview questions, illustrating how local values shape these benefits. Finally, based on these insights and participant consultation, tailored recommendations are developed to enhance human-nature interactions. This methodology provides an in-depth view of social values by engaging citizens throughout the evaluation process.

Fig. 2. Aerial view of the Utrecht University Botanical Gardens location at Utrecht Science Park.

2. Methodology

2.1. Case study

We explore this research question with a case study of Utrecht University's Botanical Gardens in the Netherlands. The Utrecht University Botanical Gardens are located southeast of Utrecht within the Science Park along the eastern green corridor of the town. Fig. 2 illustrates an aerial image of the location of the Botanical Gardens in Utrecht. Organized by Utrecht University, the botanical gardens cover 100,000 square meters and consist of nine thematic gardens focusing on immersive storytelling and discovery of different species, free walking paths, and open spaces equipped with benches and seating areas. Public entry to the Botanical Gardens is limited to a ten-euro fee and discounted rates for youths, senior citizens, and municipal or institutional pass holders. The entries to the garden consist of one main entry at the west of the Gardens and controlled entries for affiliated users at the north and east. Entry to the Gardens is free for affiliates of institutions located at Utrecht Science Park. Botanical Gardens are open from March to November, every day from morning to evening, with winter closure. As a functional, in-use urban green space, this evaluation views the Botanical Gardens as a case of co-evaluation, focusing on the results of having urban greenery and biodiversity for society.

The Botanical Gardens, due to their location at Utrecht Science Park and their established role in species preservation, education, and research, assume distinct meanings and functions for visitors. The Botanical Gardens are multifunctional places that are viewed as spaces for learning and education, restoration and health enhancement, and social interaction and community connection. The specific value of Botanical Gardens as a case study for co-evaluation lies in its social and ecological multifunctionality, as well as in the specific nexus between humans and nature. While the Botanical Gardens support learning and education by providing a variety of species, they also offer a biodiverse and distinct context for public interactions. The interactions between humans and nature in such a unique context, with opportunities for social benefits, make this case study suitable for investigating the social benefits of urban nature.

2.2. Collaborative activities and observation methodologies

The collaborative methodology employed in this research integrates multiple primary and complementary data collection methods to ensure a comprehensive and replicable co-evaluation approach. As illustrated in Fig. 4, the approach combines two primary activities (semi-structured interviews and collaborative sessions) with field observations as a complementary activity. Each method includes baseline replication guidelines, expansion criteria based on emerging patterns or data saturation, rebalancing strategies to address sampling limitations, and quality checks to validate findings. During collaborative sessions, participants select desired benefits through a gamified process using ES benefit cards (a replicable data-collection instrument designed to facilitate communication, with the option to use separately). This structured yet flexible framework enables adaptation to different contexts while maintaining methodological rigor.

2.2.1. Semi-structured interviews

Twelve semi-structured interviews were conducted during visiting hours at the botanical gardens, working days, and weekends between September and November 2024. The interviewees were selected using purposeful quota sampling from different age groups and genders among visitors to the Botanical Gardens. Quotas were set for broad age categories (younger adults, middle-aged adults, and older adults) and both genders, based on approximate visual assessment, with participants randomly recruited in the field to fill these quotas and minimize selection bias. Interviews were conducted in English. Five open questions were asked to each interviewee on three general themes: defining values of urban biodiversity and nature, the benefits of biodiversity on human lives, and ultimately, values and suggestions about improving the Botanical Gardens. The interviews lasted an average of 7–12 min and were conducted on different days and at various times (weekdays and weekends, mornings and evenings) to capture a diverse range of visitor profiles. Fig. 3 illustrates the structure of the questions used with the interviewees. Details on interview themes are available in Supplementary Material 1.

2.2.2. Field observations

In parallel with semi-structured interviews and collaborative sessions, direct user observations of total 50 h (30 h during weekends (morning to afternoon) and 20 h during the week (mornings, noon, and afternoons)) took place during the working hours of the botanical Gardens between September 2024 and February 2025 to capture visitors' behaviors and differences through different time frames. The field observation details and methods are available in Supplementary Material 1.

2.2.3. Workshops

Two open sessions with public invitation took place at Utrecht University, one in person in November 2024 and an online one in January 2025. In total, ten people participated in the sessions, which were conducted in English with a facilitator present. Participants openly answered and discussed four main questions on themes of the definition of urban biodiversity and its benefits, and suggestions for the Botanical Gardens. In both sessions, participants were asked to answer questions by writing in the designated areas and then elaborating and discussing their reflections with other participants. In this process, facilitators ensured reflexivity, avoided assumptions, and allowed participant narratives to emerge. The line of questions follows the same structure and aims as the question themes in the semi-structured interviews. Through a gamified procedure, participants selected the desired benefits from the botanical gardens by choosing ES benefit cards. To see the boards used during the workshops, see Supplementary Material 1. Despite an open public call for participation in the workshop, disseminated within the Science Park and its surrounding residential areas of Utrecht, most participants were affiliated with one of the academic institutions located in the Science Park. This was mainly due to the Botanical Gardens' location within Utrecht Science Park, as its frequent visitors are mainly students and academically affiliated staff who use the Gardens for day breaks or recreation, given their proximity and waived entry fee. An appraisal of the balance between the methods used in this research, aimed at supporting replication in co-evaluation processes, is presented in Fig. 4. For a list of responses in interviews, see Supplementary Material 3, and for responses in workshops, see Supplementary Material 4.

2.2.4. Ecosystem services cards for the participatory workshops

To facilitate communication with participants, 28 ES benefit cards were designed and proposed to participants, which were used and refined in previous studies (Morello et al., 2024). The cards in front contain information about the unique benefit of ES, accompanied by an AI-generated image that represents this benefit. Using AI-generated images rather than Botanical Garden images helps maintain neutrality and minimize potential bias in visual communication. Unlike photographs, which may emphasize specific landscapes or features and thereby unintentionally influence participant perceptions, AI-generated images provide a neutral and replicable representation of the diverse ES benefits. Furthermore, the available photographic material from the Botanical Garden was insufficient to represent all ES benefits, especially those that are abstract or not visually explicit. AI-generated imagery allows the creation of visualizations that cover the full range of benefits while avoiding unwanted contextual biases specific to local environments. The selected benefits on the cards are derived from a literature review on the benefits of nature and biodiversity for humans in urban areas, using ES based on Version 5.1 of the *Common International*

1. How do you define urban biodiversity? What comes to your mind? (open-ended response, responses will be categorized during the analysis)
2. What is the value of urban biodiversity to you?
    2.1. Why is it important to you, and how does it impact your daily life? (open-ended response, responses will be categorized during the analysis)
3. What are the benefits of urban biodiversity in your life? (open-ended response, responses will be matched and categorized during the analysis)
    3.1. Are there any drawbacks or disadvantages in your daily life? (open-ended response, responses will be matched and categorized during the analysis)
4. What does it mean to you to be in the Botanical Gardens? (open-ended response, responses will be categorized during the analysis)
    4.1. How do you describe your visiting experiences and feelings when in this place? (open-ended response, responses will be matched and categorized during the analysis)
5. Do you have any suggestions for improving the Botanical Gardens? (open-ended response, responses will be matched and categorized during the analysis)

Fig. 3. Structure of the questionnaire for interviews at the case study.

Collaborative sessions (primary activity)	Replication baseline: Plan 2-3 sessions with 4-8 participants, including gamified ES benefits, elected activity from 60-90 minutes (numbers vary based on case study size and visitors).
	Stop or expansions: Continue sessions until there is consensus across groups in answers or similar patterns emerging; otherwise, add 1-2 more sessions.
	Rebalancing criteria: If participation interest is very low, or if the results are too homogenous, assemble larger sessions with experts. Add a targeted session to focus on emerging themes. Split the sessions if there are more than 8 participants.
	Quality check: Presence of a subject expert and a facilitator in sessions, with debriefing sessions with experts to evaluate outputs. Summarize and validate the information with participants at the end of the sessions.
Interviews (primary activity)	Replication baseline: 10-20 semi-structured interviews with open-ended questions (numbers vary based on case study size and number of visitors). Ensure to engage with key stakeholders.
	Stop or expansions: Stop if consecutive interviews yield the same codes or no new information, and resume in different time frames and days.
	Rebalancing criteria: Increase interviews if any new stakeholder group is identified or after major changes in the case study (4-6 more). Expand the focus beyond hotspots or concentration points, and vary the days and times of interviews.
	Quality check: Match the outputs with the constructed codes and patterns through other methods. Ensure demographic diversity among interviewees.
Observations (complementary activity)	Replication baseline: Schedule at least six observation periods, each lasting at least 1 hour, on workdays and weekends, both morning and evening, to scan environmental and social elements and interactions between humans and nature.
	Stop or expansions: Expand observation periods during temporal activities, festivities, or peak times, or changing weather conditions.
	Rebalancing criteria: Add extra observation periods if off-peak or peak hours show different patterns in user behavior.
	Quality check: Match the information with elaborated codes from collaborative sessions or interviews. Consult with experts or administrative units to identify key areas. Predefine target areas and assign paired observers.

Fig. 4. Appraisal of the balance between the methods used in this research for replication in future co-evaluation processes.

Classification of Ecosystem Services (CICES) (Ayatollahi & Morello, 2025; European Environmental Agency, 2018). At the bottom of the benefits, a timeline indicates the possible waiting time in years to experience the benefit. This combination of information provides a simple yet informative message to participants regarding selection. At the back of the cards, information related to the corresponding ES, including the ES section, code, group, class, and an example, is mentioned. The cards come in three colors: yellow for provisional ES, green for regulating ES, and blue for cultural ES. The cards were designed to present a range of potential ecosystem service (ES) benefits, allowing participants to select

those most relevant to them. Some cards did not directly relate to the specific ES in the case study but were included to provide context and broaden the scope of choice.

This approach ensures the set is replicable across different case studies and helps to minimize potential bias by preventing participants from being steered toward specific topics. Fig. 5 shows a sample of cards. The complete set of cards is available in Supplementary Material 2. During both collaborative sessions, participants were introduced to a basic, conventional definition of ES before presenting the cards. They were also given a simple example for each of the three sections of ES to familiarize them with the activity's context. Participants discussed their selections and priorities with one another and the facilitator to clarify their motivations.

2.3. Analytical framework for qualitative information

This study used an inductive analytical framework, starting with edited transcripts of interviews and workshops conducted in accordance with standardized, ethics-approved protocols. The analysis proceeded with a first round of descriptive coding to summarize interview content, followed by structural coding to categorize emergent themes. Subsequently, pattern coding grouped similar excerpts under thematic categories. Coding was conducted by the workshop and interview facilitator-analyst, with discrepancies resolved during debriefing meetings with two experts, to ensure inter-coder reliability. After the initial thematic structuring, thematic analysis, and the final coded synthesis, two rounds of peer debriefing were held to enhance interpretive validity and reduce bias. These sessions provided critical feedback, improving the credibility and robustness of the findings. In this process, no specific software was used during the coding. In specific cases, such as the association between social benefits and specific categories of ES (e.g., "mental and physical well-being" and "recreational and restorative experiences"), the classifications were grounded in explicit operational definitions derived from participant narratives and literature on ES categorization, ensuring conceptual clarity and consistency. The classifications were grounded in explicit operational definitions derived from participant narratives and literature on ES categorization, ensuring conceptual clarity.

3. Results

The co-evaluation process takes place ex post at Utrecht University's Botanical Gardens, evaluating the social benefits of urban greenery and biodiversity. The co-evaluation identifies narratives of urban biodiversity (3.1, explicating what and how people recognize as urban biodiversity in the Botanical Gardens) and the related social values using ES benefits (3.2 and 3.3). Recommendations for improving the Botanical Gardens are also reported in 3.4.

3.1. Narratives of urban biodiversity

How people view and value urban biodiversity is captured by three distinct narratives that also represent how citizens perceive it and point to the underpinning values they attribute to it. These narratives present a distinct 'definition' of urban biodiversity and showcase a unique perspective on it in this locality. Overall, urban biodiversity is perceived as an essential component in urban areas, and participants recognize its intrinsic values. In all narratives, nature and biodiversity are used interchangeably.

3.1.1. Urban biodiversity as fauna and flora

The primary narrative defines urban biodiversity as flora or fauna species that are rarely observed in contemporary urban spaces. All participants in both sessions and interviews mentioned at least one species related to urban biodiversity. Participants describe urban biodiversity with animal species like "squirrels", "lizards", "butterflies", "hares", or with different trees or insects. Furthermore, "unique" or "rare" species, especially among animals, are other ways of describing biodiversity in this narrative. The distinguishable species are often related to special living environments (such as "woodlands"), which have a higher density of vegetation and greenery than urban environments. Species richness and diversity living in dense green spaces (especially including unique or symbolic animals), with the possibility of observation through daily activities, is defined as urban biodiversity for most participants.

3.1.2. Urban biodiversity as controlled wilderness

The second narrative encapsulates the nexus between biodiversity, nature, and wilderness in urban areas, with reflections on its spatiality. The concept of "controlled wilderness" or similar descriptions, such as "maintained wild nature", "different inhabitants of cities in different green environments", or "wild nature", highlight the definition of urban biodiversity by participants. In this narrative, urban biodiversity is perceived as closely associated with the presence of "green and blue spaces" either in the center or peripheral parts of the city. Differences in

Fig. 5. Sample of cards from each section of ES presented to participants of collaborative sessions for selection of priorities (source: authors).

biodiversity are visible to participants, especially between built environments where it is less visible, and outside city boundaries, where it is more visible. According to one participant, "nature/green is always willing to be, but it does not get enough space [in cities]".

3.1.3. Urban biodiversity for supporting living systems

The third narrative views urban biodiversity through the creation of social values and supporting living systems. Besides "intrinsic values that require recognition", "biodiversity supports services to people". Through this narrative, participants mentioned a broad range of services biodiversity provides, like "providing a food chain for living things" or "improving the appearance of the neighborhood" or examples that cover human well-being (mental and physical), like providing access to green, walkable areas and supporting walking experiences in cities. The narrative links the definition of urban biodiversity to the concept of ES and to how values of biodiversity are perceived differently across personal framings. The attributes and differences between the three narratives highlight the importance of contextual values and personal framing in perceiving and defining urban biodiversity. Acquiring such narratives is the first step in defining contextual variables and dynamics for evaluation.

3.2. Social benefits and values of urban biodiversity

Participants reflected on the educative role of Botanical Gardens through direct observation of nature, plants, and animal species, which is also stated directly as "it is more like a museum…" or by reading the provided informative panels or boards throughout the Gardens. Studying rare species and their interaction in a unique habitat is also categorized within the topic of learning and education, as two participants stated their intention to visit for such activities. As the Botanical Gardens include a variety of specialized gardens for education (e.g., evolution or discovery gardens and tropical greenhouses), this category of response, as expected, is indicated in almost all responses from participants. Despite the importance of the Botanical Gardens for education and learning, the most mentioned value and meaning of the Gardens for participants is within the category of recreation and health enhancement. Due to the vicinity of several institutions, especially between 11 AM and 2 PM, the Gardens are visited mainly by affiliated visitors of academic institutions at the Science Park.

Specifically, responses about perceived impacts of urban biodiversity on people cover a diverse range of both benefits and negative impacts at both personal and community scales. The social benefits mentioned cover a broad range of perceived effects, to synthesize the results, based on their attributes, benefits are divided into four main categories. According to responses from interviews and sessions, the categories are: 1. Mental and physical well-being, 2. Cultural and aesthetic appreciation, 3. Recreational and restorative experience, and 4. Social cohesion and community engagement. Among the responses, multiple respondents reflected on the intrinsic value of urban biodiversity and its role in supporting living systems (following the third narrative). Negative social impacts of urban biodiversity are generally perceived through the idea of community safety and well-being, which is elaborated in this section. A list of narratives and their corresponding overarching social benefits, based on participants' input, is observable in Table 1.

Among the categories of social benefits, mental and physical well-being have the most direct mentions from participants, while recreational and restorative benefits follow in order of preference. These two categories have a close relationship with each other, and most health benefits are perceived alongside recreational experiences. Reflections on health and being in nature for recreation, like "it boosts my immune system", "… emotionally, it is refreshing, and it encourages my health, both mental and physical", and "It gives me an escape from work—a break in the afternoon that really recharges me" are examples of this issue. Despite attention to physical health, urban biodiversity has major significance for participants' mental well-being. Managing stress through activities like observing nature and plants or finding a sense of relief and belonging in places with natural elements are examples of this case.

Table 1
Relation of narratives and their primary and secondary social benefits elaborated from collaborative sessions and interviews.

Narrative of urban biodiversity	Primary social benefits category	Secondary social benefit category
1. Urban biodiversity as fauna and flora	Cultural and aesthetic appreciation	Recreational and restorative experiences / Mental and physical well-being
2. Urban Biodiversity as Controlled Wilderness	Mental and physical well-being	Social cohesion and community engagement
3. Urban biodiversity as supporting living systems (values)	Social cohesion and community engagement	Mental and physical well-being

Another aspect that also closely connects with recreational and restorative benefits is the passive influence of nature and biodiversity in surroundings on mental well-being, which is described as "I have it passively influenced me … because I feel relaxed and enjoy seeing the seasonal changes presented by them, and they actually drive me to be more physically active". The effects of urban biodiversity on mental and physical well-being are constantly perceived through interaction with nature or passing the time in natural areas with distinct differences from dense urban fabric. These benefits correlate directly with the narrative of perceiving urban biodiversity as "controlled wildness", where people use such places to reduce their stress or escape work routines.

The benefits associated with the social cohesion and community engagement category highlight how urban biodiversity and nature foster human-human and human-nature interactions and how nature can reinforce collective human bonds. Through field observations and interviews, participants emphasized the value of green spaces and parks as a context for interacting with others or discussing daily life with friends or family. Quotes like "Nature in cities makes people come together more, especially in parks or community gardens" and "I enjoy being in nature because it is a place where people interact in a more relaxed way compared to the rest of the city" are examples of using green spaces as a context for social interactions. Besides, learning from nature through collective or individual actions is another perceived benefit by participants. For instance, two participants reflected on learning opportunities for the younger generation and community initiatives by mentioning, "People learn a lot just by being in nature together—someone always knows something about the plants or the birds and shares it". Social benefits in this category are mainly in line with the third defined narrative, which is that nature and biodiversity provide context for common value creation at the individual and community level.

The cultural and aesthetic appreciation benefits are principally based on valuing nature and its cultural heritage, regardless of any utility. This category has a strong connection with a sense of identity and belonging. This benefits category was often associated with the initial narrative of perceiving urban biodiversity through observing (symbolic or rare) species in or around urban green spaces, primarily via sensory activities. Observing squirrels, hearing birds, and learning about plants or flowers are examples of benefits mentioned through interviews and sessions. Like well-being benefits, this category is closely tied to recreational restorative experiences. Participants largely elaborated on how the beauty of nature, or specific green spaces like "open museum-like" places, resembles cultural value or significance for them. A general example of this category is observed in the following quote: "I think it was also nice just finding something beautiful, wanting to live together with other species".

Alongside the benefits of nature, participants pointed out examples of disservices, mainly around the lack of (sense of) safety in dense green areas and increased pest population. Lack of safety or sense of safety, especially with a lack of light or observing eyes in green areas, is also

often discussed in the literature (Hosseinalizadeh et al., 2022; van Rijswijk & Haans, 2018). For instance, a participant describes safety conditions as "I feel unsafe if it is too wild or very rural, especially at night".

The Botanical Gardens, as a place, is perceived as an opportunity for relaxation, recreation, and "relief from stress during working hours". Participants defined the use of the Botanical Gardens through phrases like "a short break from the office afternoon", "escape from academia for inspiration", and "a place for thinking and slowing down" to highlight this recreational and restorative aspect. The Botanical Gardens are perceived as a place for social interaction and community engagement. Based on observations and responses from participants, gardens are the context for "having a walk with friends or colleagues" or "participating in social activities and tours". The distinction of this category from

Fig. 6. Top five selections of ES benefits by participants in the first (in-person) session. Participants chose benefits that are associated with regulating (B) and cultural (G) ES (A detailed description of the methods, presentation of the cards, and results are given in Supplementary Material 2).

previous ones is its focus on human-human relations in the context of the Gardens. During weekends or morning visiting hours, the presence of families or small groups of visitors is more observable than during business days and working hours. The perception of using green spaces beyond their intended use is the main importance of this definition to participants, as highlighted by one participant: "The Botanical Gardens are not just for nature – they are social spaces where I connect with colleagues and friends".

3.3. Prevailing ecosystem benefits from the co-evaluation

This section presents the recognized ES benefits from the gamified ES cards during collaborative sessions and highlights the interviewees' responses. A complete list of responses is available in Supplementary Materials 3 and 4. The top selections of participants in collaborative sessions are mainly focused on cultural and regulating ES benefits, followed by provisional related benefits. The top ES benefits selections among participants are place for spiritual fulfilment, cognitive development, reflection (cultural), opportunity for more activities outdoors within nature (cultural), Improvement in biodiversity and better habitats for plants and pollinators (regulating), more sense of belonging and identity to the neighbor (cultural) and increase in area covered by greenery and heat reduction (provisional). Benefits such as opportunities for participation in local events and community formation (cultural), reduced depression and anxiety disorders (regulating), and increased interaction between neighbors, local cohesion, and identity (regulating) are frequently selected and mentioned by participants and interviewees. Fig. 6 presents the top selections by participants, ranked by priority and relative ES category.

The selected benefits show alignment with participants' perceptions and narratives of urban biodiversity. The selected cultural benefits align with the narrative of perceiving biodiversity through species in special environments, as they are associated with cultural and aesthetic appreciation. Furthermore, regulating ES benefits or benefits related to

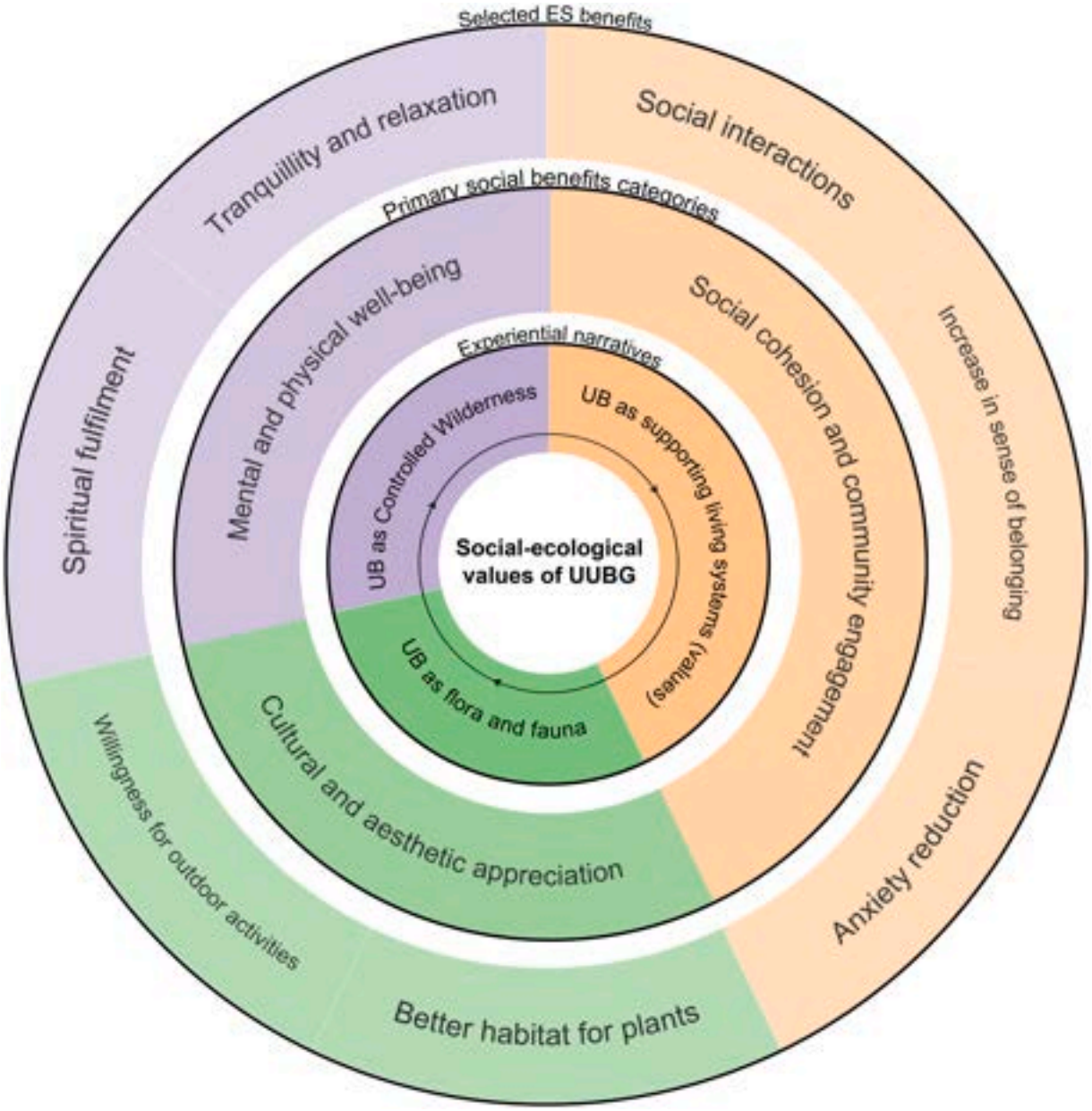

Fig. 7. Relation between social-ecological values of Utrecht University Botanical Gardens (UUBG) represented as narratives, social benefits, and selected ES benefits by participants. UB: Urban Biodiversity.

human well-being is associated with the second narrative of nature as controlled wilderness, as it provides indirect benefits. Fig. 7 shows the relation between social-ecological values at the Botanical Gardens. This figure's innermost circle presents three main urban biodiversity narratives defined by participants. While these narratives share social values of nature, they highlight different human perceptions of biodiversity in their surroundings. The second circle shows the social benefits linked to each narrative, illustrating their impact on visitors' experiences in the Botanical Gardens. The outermost layer links the previous two layers to examples of ecosystem service (ES) benefits identified in workshops and interviews. For example, observing diverse species, especially exotic and non-native ones, fosters understanding of urban biodiversity as a controlled wilderness, thereby enhancing mental and physical well-being through ES benefits like spiritual fulfillment and anxiety reduction by promoting relaxation in the Gardens.

3.4. *Recommendations for improving the botanical gardens*

Two key recommendations for improving the Botanical Gardens have been gathered from the interviews and participatory sessions: first, suggestions for improving the facilities required to enhance urban biodiversity, and second, suggestions for improving the experience in the Botanical Gardens. Regarding facilities or solutions to help urban biodiversity, the responses mainly focused on green infrastructure development, nature conservation, and community engagement. The green infrastructure category encompasses the development of walking paths separated from bike lanes, connecting nature with benches, reducing concrete usage in green open spaces, and incorporating vertical

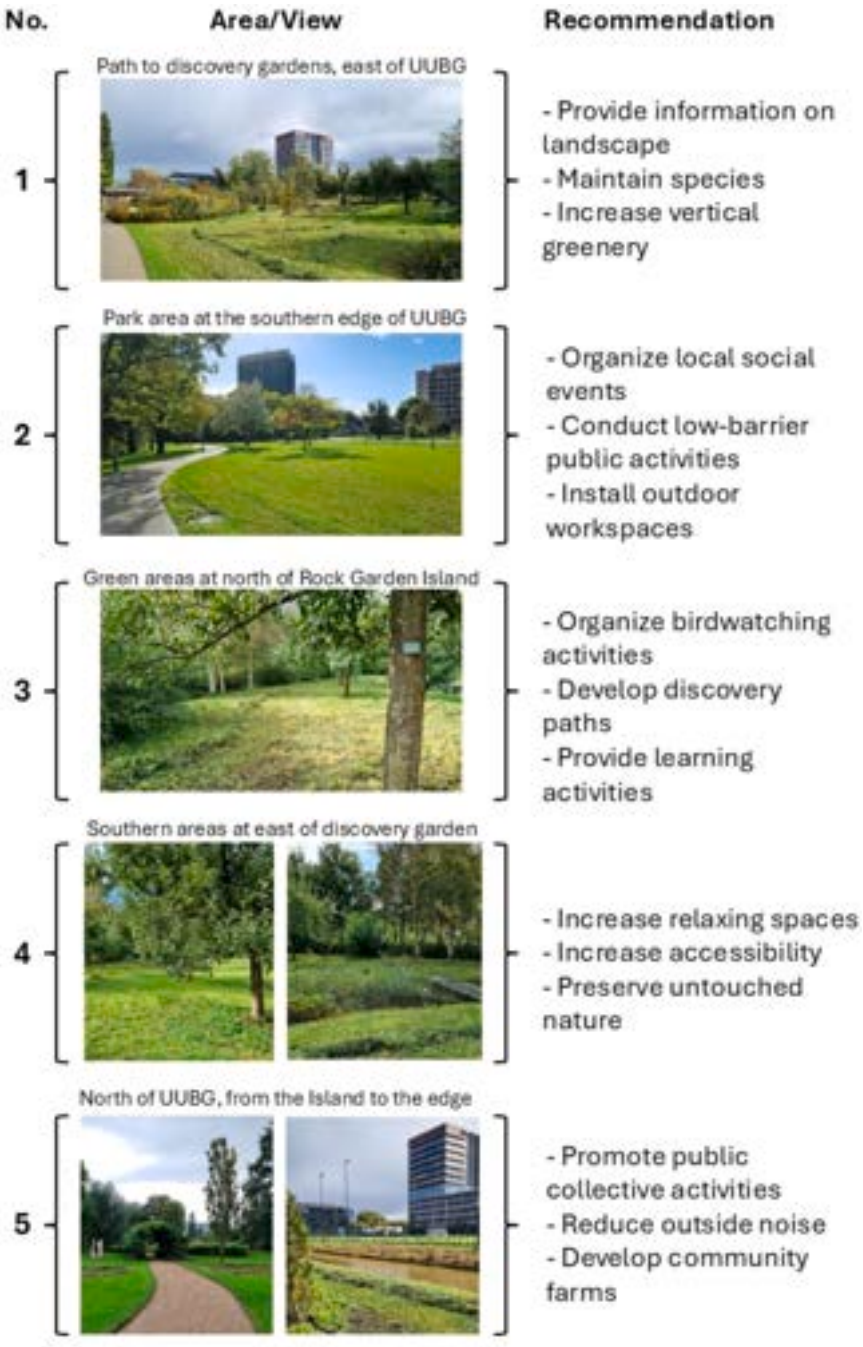

Fig. 8. A location-based list of recommendations suggested by participants in workshops.

green structures rooted in soil with varying heights, similar to urban furniture. Increasing safety around dense urban greenery and counting biodiversity as a separate layer are other suggestions in this category. Nature conservation suggestions include regularly removing invasive species, protecting animals from roadkill, and refraining from intervening in lush urban green spaces. Community engagement suggestions include developing family farms in neighborhoods, offering free entry to private or semi-private green spaces, and promoting community activities like bird watching.

Suggestions for Botanical Gardens focus on three improvement categories: accessibility, learning and education, and community engagement. Accessibility suggestions follow the general theme of making the Gardens more accessible to the public by increasing the number of entry gates, relocating the main entry near the main road, and enhancing the visibility and legibility of the main entrance. Participants highlighted the necessity of enhancing accessibility for visitors using wheelchairs or baby carriages. Learning and education suggestions focus on increasing workshops or public sessions by planning educational activities on plants, seeds, and plant exchange programs, and public exhibitions. The other focus in this category is improving signs and information on informative panels and increasing English interpretations. Community engagement suggestions include low-barrier activities such as open days, public events at Gardens, and historical exhibitions. A list of place-based recommendations for Botanical gardens is observable in Fig. 8.

4. Discussion

The research opens new perspectives on monitoring and evaluating the social benefits of nature in urban areas by uncovering social values through participatory procedures and using ES benefits to facilitate and organize the evaluation. By providing local, in-depth information on social values, the benefits of nature, and its impact on society, co-evaluation helps planners and decision-makers through policy optimization and decision-aiding within a cooperative, cost-effective approach. This section discusses the novelty and limitations of co-evaluating the social values of urban biodiversity through an adaptable methodology that uses ES to construct an experiential narrative to uncover these values.

4.1. Co-evaluating social values of urban biodiversity

Biodiversity and nature in urban areas not only serve as ecological assets but also as a reservoir of social values. To address challenges around the diversity of values and perspectives, we propose a package of co-evaluation through direct engagement with actors.

The narratives render a clear yet multifaceted understanding of the Botanical Gardens. The narratives are constructed in collaboration with visitors and actors regarding the Botanical Gardens' status, showcasing the perceptions, definitions, benefits, improvements, and possible interventions. The use of qualitative data extracted from sessions, interviews, and direct engagements is often limited by the broad scope of information (Campbell et al., 2016) and challenges in practical interpretations for management and planning (Toomey et al., 2025). The experiential narratives offer planners and decision-makers a novel approach to elaborating on information by engaging actors in the process. Narratives showcase how definitions of urban nature and urban biodiversity can overlap for citizens. The presence of green spaces, per se, equals more biodiverse spaces for participants. Participants contribute to narrative-making (as part of the co-evaluation process) through their inputs in each section of the narrative (perceptions, definitions, benefits, and interventions), directly by answering associated questions, or indirectly through prioritizations (like ES benefits). The contributions are then categorized and organized by facilitators and planners into coherent narratives. Additionally, the disbenefits mentioned often relate to the second narrative of urban biodiversity as controlled wilderness. It is evident that the division of narratives closely follows the general ES divisions (provision, regulating, and cultural). This relation shows how, within defined boundaries of nature benefits, social values differ based on contextual attributes and public perceptions.

In this case study, most interviewees and participants in collaborative sessions were mainly highly educated individuals affiliated with academic institutions. While this issue, per se, does not obstruct the evaluation, it might affect the scope of responses by having a bias towards specific values. For future research, it is necessary to involve actors who are distant (less concerned) and marginalized actors regarding the case study to offer a more comprehensive evaluation. The same limitations might apply to the pre-intervention evaluation, which primarily requires increasing interest in participation among potential participants—defined here as individuals who may be less concerned, more distant, or less willing to engage in the evaluation. Future research in this field should engage more closely with citizens and explore ways to reach out to and include citizens from diverse interest groups through the active dissemination of collaborative events. This could involve reorganizing how these events and engagement approaches are structured to improve recognition and justice in the process. Additionally, the co-evaluation participation rate is another limiting factor that might demand additional collaborative activities to acquire additional data (values and narratives). To ensure adequate participation in the proposed co-evaluation approach, separate public engagement methods (interviews, collaborative sessions, observation, and gamified priority-making) could be offered to engage actors in co-evaluation in future research.

4.2. Adaptable methodology for co-evaluation

Our proposed methodology provides a participatory framework that bridges the gap between ecological metrics and local social values when evaluating the recognized and perceived social-ecological benefits of urban nature. The co-evaluation process consists of direct face-to-face discussions and interviews with the actors and stakeholders in the case study, as well as the gathering of perceptions and narratives through focus groups and gamified procedures. Implementing the ES card game facilitates the interpretation of narratives on the social benefits of urban biodiversity and connects them to future intervention priorities.

The co-evaluation and narrative-making processes in this research face limitations and challenges regarding participation rate and diversity of participants in terms of affiliations and age groups. Despite public announcements and communications, the total number of participants in interviews and collaborative sessions is still relatively low compared to the total number of visitors to the Botanical Gardens. In scenarios where participants and interviewees are not representative of the majority, the procedure requires a higher number of participants. Due to time-limited operating hours at the Botanical Gardens and climate conditions, the number of visitors during the survey period was lower than expected. While the information gathered reflects a significant portion of opinions and narratives, it may not comprehensively cover all perspectives. Additionally, all participants in collaborative sessions and the majority of interviewees are affiliated with at least one institution at the Utrecht Science Park. Being affiliated with institutions does not impose any general limitation on the research, given the Botanical Gardens' location near an academic institution. Moreover, the majority of participants aged 20–40 are affiliated with academic institutions and hold higher education qualifications. As a result, reflected opinions and elaborations are mainly affected and limited by the scope of specific visitor groups. In this context, since the co-evolution was carried out in English, future studies aiming for broader sampling should consider conducting the process in participants' native language.

Ultimately, the selected case study imposes certain limitations on the co-evaluation process and visitors' experience. The winter closure of the Botanical Gardens to the public (the site is open to academically

affiliated users) limits direct experience of existing ES under different conditions with seasonal change, and it omits distinctive winter-use profiles by omitting off-season use patterns. Comparing social perceptions of nature during peak seasons (such as spring) with those during winter provides a comparative element on the perception of greenery, which, in this case, was not achievable. Future research in this context must consider the effects of seasonal changes on greenery and how these changes may affect human perception. Furthermore, the existing entry fee might limit the public's accessibility to and attractiveness of the Botanical Gardens. These barriers may limit the participant pool and potentially underrepresent the perspectives of groups unwilling to pay the entry fee during the co-evaluation process. Although these limitations may not invalidate co-evaluation, implementing policies like occasional multi-seasonal open days or free days (as suggested by participants) could help address these conditions.

The proposed co-evaluation procedure can mediate communication between citizens and decision-makers by providing interpretations of social values of nature in narratives and by prioritizing nature's perceived social benefits through citizens' interaction with urban nature. Evaluating the priorities (as presented in the narratives) through a participatory gamified approach provides a rigorous interpretation from multiple data sources. The co-evaluation approach, therefore, has the potential to be used as a complementary yet essential part of decision-making at the local scale, alongside top-down evaluation approaches, to render a complete picture of human-nature dynamics in all spectrums of socio-cultural and socio-economic variables (Dumitru et al., 2020).

5. Conclusions

Co-evaluating the benefits of nature in local urban areas is an important step in discovering humans' social values, perceptions, and relations with nature. The knowledge and scientific methods for in-depth evaluation of the social benefits of nature and biodiversity in urban areas are still evolving, and research applications and experience are at an early stage. This research provides an adaptable, replicable methodology that co-evaluates the social benefits of urban biodiversity across ES categories. The methodology was applied in the pilot area of the Utrecht University Botanical Gardens. The methodology focuses on direct engagement with citizens and stakeholders through collaborative workshops, interviews, and gamified ES selection to inform, engage, and educate people about the values of biodiversity and, at the same time, to support planners and decision-makers in improving local policies and the design of urban green areas. The authors argue that the tested application is cost-effective, generating rich qualitative information and increasing awareness and participation among local stakeholders. The method is easy to replicate because it is based on ES categories. Future research on this topic requires consolidating a decision-making process that embeds stakeholder engagement in discovering values of biodiversity and co-evaluates the social values and co-benefits that people prioritize when it comes to establishing policies or promoting urban transformation of green spaces (van der Jagt et al., 2023).

CRediT authorship contribution statement

Asef Ayatollahi: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing - original draft, Writing - review & editing. **Niki Frantzeskaki:** Conceptualization, Formal analysis, Methodology, Writing - original draft, Writing - review & editing, Supervision. **Eugenio Morello:** Writing - review & editing, Methodology, Supervision, Formal analysis.

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Declaration of Competing Interest

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

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2025.129236.

Data availability

Data is provided within the manuscript or supplementary materials.

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