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Citizen science in Mapping and Monitoring the Benefits of Urban Forests as Nature-based Solutions

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Summary

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Approval

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EXECUTIVE SUMMARY

Citizens rank ecosystem services provided by urban forests overall as important, with cultural ecosystem services (CES) being considered more important than others, overall. As CES mainly provide intangible benefits, and as these benefits are personal, cultural-dependent and value-loaden, citizen science with a PPGIS tool can facilitate the mapping, monitoring and assessment of CES in urban forests. This report starts with a scoping review on CES in urban forests, and the potential role of citizen science (and more specifically PPPGIS) to gather localised perceptions on urban forests as nature-based solutions. A trait-based approach has been suggested, to link the ecosystem features and ecosystem qualities with intended and actual use and perceptions of stakeholders regarding the urban forest as a potential provider of nature-based solutions; The review also includes an overview of the potential and needs for a citizen science approach in the CLEARING HOUSE case study cities.

Based on the review, requirements for a localised and flexible PPGIS tool have been formulated. This has led to the selection and finetuning of My Dynamic Forest as the PPGIS tool for implementation in CLEARING HOUSE. The architecture behind My Dynamic Forest is explained, followed with an overview of how My Dynamic Forest was tested in five cities in Europe (Barcelona, Leipzig-Halle, Gelsenkirchen, Krakow, Zagreb). Based on the local co-design process and the explorative case study research, specific survey questions have been defined for every city. Citizens have been actively approached and have been nudged to fill out the PPGIS tool, using a localised version of the browser-based tool My Dynamic Forest. The report provides a summary of the results per case study. It ends with the description of the RECORDER app, developed for China and Hong Kong, developed in parallel with the work in Europe.

KEYWORDS

Citizen science; PPGIS; Conceptual framework; Urban forest as Nature-based Solution (UF-NBS); Trait perception; Tree health; Cultural ecosystem services (CES); Pollution; CLEARING HOUSE.

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1 Introduction

The CLEARING HOUSE project, with its keen focus on Urban Forests as Nature-Based Solutions (UF-NBS), delved into the multifaceted dimensions of urban forestry, encompassing technical, ecological, and socio-economic considerations. Urban forest solutions play a crucial role in achieving SDGs related to sustainable cities, climate action, and life on land by enhancing ecological conditions and providing continuous socio-ecological benefits (Ogden et al. 2019). Central to this endeavour is the recognition of urban trees and forests as pivotal in delivering Ecosystem Services (ES) and Cultural Ecosystem Services (CES), notably in recreation and health. This pivotal work forms the backbone of Task 3.3 in CLEARING HOUSE project, which is dedicated to the implementation of citizen science (CS) for the meticulous monitoring of UF-NBS. The insights gained from CLEARING HOUSE Task 2.1 (da Schio et al., 2021: CLEARING HOUSE report D2.1) and Task 3.1 (De Vreese et al., 2021: CLEARING HOUSE report D3.2) have been instrumental in identifying five pivotal themes: (1) the critical evaluation of perceived ecosystem and CES, juxtaposed with the disservices of UF-NBS, to address the gaps in supply and demand; (2) the exploration of the multi-functionality of UF-NBS and perceived CES to discern synergies and trade-offs; (3) the significant role of UF-NBS in adapting to climate change and mitigating its impact on health and well-being; (4) enhancing the ecological connectivity of UF-NBS and urban biodiversity; and (5) the imperative assessment of tree health conditions to devise more efficient, cost-effective strategies for UF-NBS management amidst increasing urban challenges, development pressures, resource constraints, and a prevalent lack of public understanding of UF-NBS.

Ecosystem services provided by UF-NBS, including intangible cultural ecosystem services, depend on the users perceptions and experiences. The collection of experiential and perceptual data from citizens is crucial in understanding the such services, such as affordances for activities and place appreciation, which may vary across genders, socio-economic groups, and age demographics. An essential aspect also involves addressing socio-environmental justice, particularly in terms of access to urban forests, barriers faced, and the benefits derived. In terms of conceptual connections, CS utilises participatory methods such as Public Participation Geographic Information Systems (PPGIS) and Volunteered Geographic Information (VGI) to gather rich data on tree condition, and diversity. These experiental data inform decision-making, assesses disparities in public funding and investments, identifies geographical areas or environmental and societal issues related to urban forests and trees, and identifies tree health problems and determines management needs. However, the selection of appropriate citizen science approaches and tools, particularly considering the cost of technology, data accuracy, formalisation of non-expert data, and jurisdictional challenges, remains a pertinent question. PPGIS- a participatory citizen science method, exemplified by platforms like https://maptionnaire.com/, have been employed to collect citizens' perceptions regarding the various services and disservices of urban forests, including aspects as recreational activities, location of the service or benefit, distance to the benfits available or obtained, and the quality of the ecosystem. Thi task ambitiously aimed to objectifying the benefits and values of (peri)urban forests, mapping them across socio-demographic/cultural and biophysical/ecological dimensions, and linking them to cultural services through pathways such as perceptions, experiences, and use.

The Task 3.3 has been central in the development of a bespoke, public participatory tool for UF-NBS data acquisition through innovative citizen science approaches, such as PPGIS and VGI. PPGIS broadens public participation by allowing non-experts to contribute spatial information, thereby empowering communities and promoting democratic decision-making processes (Brown, 2017) related to

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environmental planning and natural resources management (Sieber, 2006). On the other hand, VGI refers to the voluntary contribution of geographic data by individuals without formal training in geography (Sevinc et al., 2020). This data is collected, maintained, and shared by citizens through various platforms and digital tools (Thatcher, 2012). VGI plays a crucial role in producing geographical information and updating national geographic databases, emphasizing its impact on spatial data quality and information production (Haklay, 2012). Contributions to VGI can be explicit through focused mapping activities or implicit through data generation associated with geographic locations, such as geotagged photographs or microblogs (Haworth et al., 2018). A fundamental distinction between PPGIS and VGI is that PPGIS is primarily concerned with the process and outcomes, being goal-oriented and focusing on specific populations rather than the general public, in contrast, VGI is more expansive and centred on the application and information (Tulloch, 2008; Seiber, 2006).

This task we primarily focused on PPGIS and intended to capture both citizen perception and experiences of UF-NBS, UF-NBS quality and conditions, determining the requisite type of citizen data, whether cognitive or actual. Both the informations are crucial for UF-NBS management, decision-making, and knowledge co-production. A dual-pronged approach is common in contemporary research, which not only focuses on biodiversity to unravel socio-ecological connections but also evaluates CES to fortify the concept of UF-NBS as a form of social capital, poised to address both societal and environmental challenges.

The task was formulated with clear objectives, concepts, and methods to precisely assess the condition and quality of UF-NBS and to gauge citizens' perceptions of the CES benefits in European case-study cities. In this task, we demonstrated the development and application of a bespoke citizen science tool “My Dynamic Forest" (MDF), https://www.mydynamicforest.de/app, which was implemented at a number of UF-NBS case study citie i.e. Leipzig/ Halle, Germany; Drwinka River Park, Kraków, Poland; Gelsenkirchen, Germany; Barcelona, and Zagreb, Croatia.

2 Objectives

This task aimed to assess how societies view and demand UF-NBS services across different urban and peri-urban areas. The focus of this task ws hinged on the appreciation of cultural ecosystem services provided by urban UF-NBS - notably, the public's perception of health and recreational benefits derived from UF-NBS, as well as key elements like tree health (i.e. Leipzig), and the perceived impact and benefits of UF-NBS in the context of environmental pollution (i.e. air pollution e.g. Barcelona), positive and negative trait perceptions of UF-NBS connected to various cultural services (i.e. Kraków, and Gelsenkirchen). This approach was significantly strengthened by the adoption of a transdisciplinary and co-design methodology in the CLEARING HOUSE project (as per D3.2, CLEARING HOUSE report; De Vreese et al., 2021), which brought to the fore critical challenges and informational deficits pertaining to UF-NBS across the European CLEARING HOUSE case study cities.

The complexities and variabilities in UF-NBS settings, quality, tree health and condition, and demand for ecosystem services unearthed through these urban case studies (as dicussed in deatil in da Schio et al., 2021: CLEARING HOUSE report D2.1) have necessitated the conceptualisation and creation of a unique CS module within Task 3.3. In essence, the CLEARING HOUSE project CS module was developed as an adaptive, cost-effective and sustainable UF-NBS assessment and monitoring system for managing UF-NBS in urban landscapes that are experiencing a number of socio-ecological challenges (i.e. the

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case study cities as menationed earlier). Moreover, this strategy paved the way for the development of a web-based PPGIS aimed at gathering data on UF-NBS conditions, perceived ecosystem and cultural services, values, and impacts in the European cities mentioned above. This methodology was particularly adept at pinpointing city-specific issues related to UF-NBS conditions and quality, as well as gauging citizens' perceptions of the demand and supply of CES as focus, thereby enabling ongoing monitoring of UF-NBS conditions.

Owing to the collaborative learning approach in CLEARING HOUSE, to map UF-NBS condition across different case studies, and to capture the UF-NBS perceptual and experiential values - a systematic data collection and individual case-study analysis was proposed. Although comparing data across cities would provide a more nuanced approach, in this deliverable we reported the data to demonstrate the feasibility of the tool. The CLEARING HOUSE project case study cities (Brussels, Halle-Leipzig, Kraków, Gelsenkirchen, Barcelona, and Zagreb) represented a diverse spectrum of biogeographic, socio-economic, and demographic realities, all of which exert a profound influence on UF-NBS conditions and characteristics. While every question specific to these case studies bears significance, the CS tool "My Dynamic Forest" (MDF) was implemented, adapted and applied, particularly to advance the most salient themes and issues that emerged from the analysis of these cities and consultations with local partners. Some questions demand mapping of ecosystem services, benefits, and impact monitoring of UF-NBS (such as recreational demand, pressure on forest landscapes, tree health, climate change, human health, and well-being), whereas others call for both objective and subjective evaluation. Hence, the tool advanced an adaptive PPGIS model for citizen science in these European case study cities.

The impact of UF-NBS has been scrutinised through a three-stage data analysis process by undertaking a detailed assessment of spatially relevant, case-study specific issues and requirements. To advance Task 3.3, we delineated four primary objectives:

- to develop an effective citizen science tool (i.e., PPGIS or VGI) grounded in literature review, consultations with focus groups and city partners, and case-specific insights about UF-NBS (as documented in D2.1 and D3.2, CLEARING HOUSE reports).
- to assess public perceptions and preferences concerning the supply and demand of UF-NBS cultural ecosystem services and potential impacts of UF-NBS in European case-study cities.
- to monitor UF-NBS conditions (such as urban tree health) to implement a cost-effective, sustainable, and resilient tree and forest management strategy.

3 Background

While ecosystem services such as air quality improvement and biodiversity supports are essential functions of urban forests (Gao et al., 2020), the emphasis on cultural ecosystem services stems from their immediate and tangible benefits to urban populations. Recent studies have indicated that people living in urban areas highly value the cultural ecosystem services provided by urban green spaces (Ostoić et al., 2020). Cultural ecosystem services include recreational opportunities, aesthetic value, and spiritual experiences that contribute to the overall satisfaction and mental health of urban residents (Zhao et al., 2020), and are the most recognisable by lay people, compared to other ecosystem services (Tyrväinen et al. 2005, Lyytimäki, 2017; De Vreese et al. 2016a). Cultural services of natural environments are deeply interconnected with other ecosystem services (FAO, 2022) that support and help determine provisioning and regulatory services and their quality, specifically in case

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of urban areas as they are predominantly cultural landscapes. The preferences of urban dwellers for ecosystem services from urban forests highlight the significance of cultural aspects such as recreation, spiritual experiences, and noise reduction (Jo et al., 2020), warrant novel ways to assess, and to collect evidence and understand urban forests' traits impact on benefits. Using citizens to gather such information has become more frequent and popular among research projects (Cambria et al. 2021). Although ecosystems do not directly generate cultural services but deliver these value-based benefits and services through meaningful human-nature interactions, with these interactions being influenced by how humans perceive and value a specific ecosystem and its elements, and level of interactions (Hernández-Morcillo et al., 2013). This makes it important for citizens' involvement to provide a pluralistic meaning on those services, supporting improved decision-making (Cambria et al. 2021).

The essence of this scoping review was to support the development of a citizen science tool for evaluating benefits and disbenefits provided by UF-NBS, whereby the adaptability of the citizen science tool to capture NBS conditions and perceptual values in diverse settings is a novel approach.

3.1 Evidence on cultural ecosystem services of UF-NBS

3.1.1 Cultural ecosystem services and benefits of UF-NBS

Cultural ecosystem services are tangible and intangible, non-consumptive direct use values and preferences that people assign to certain non-material (monetary) benefits and services of ecosystems (e.g., park or a forest patch) (Kim and Son, 2021; Bullock et al. 2018; Dickinson and Hobbs, 2017; Hegetschweiler et al., 2017; Fish et al., 2016; Raymond et al., 2014; Milcu et al. 2013; Hernández-Morcillo et al. 2013; Assessment, 2005; O'Brien et al. 2017). With regards to ecosystem services of urban forest, provisioning services are relatively low in supply, rather shows a place-based supply and demand mismatch (Palacios-Agundez et al. 2015; Cheng et al. 2017) but high in public demand (De Vreese et al., 2016b) emphasising the role of urban forest in improving health and well-being and quality of life of urban residents (Wang et al. 2022). Despite such an importance of CES of urban forests, it less influences green space management, planning and political decision-making (La Rosa et al., 2016) related to UF-NBS.

According to Millennium Ecosystem Assessment (Assessment, 2005), urban green space benefits human health and well-being through certain cultural ecosystem services: 1) recreation and eco-tourism, 2) aesthetic experiences, 3) spiritual and religious services, 4) inspiration, 5) sense of place and identity, 6) cultural heritage values and cultural diversity, 7) educational opportunities, and knowledge system, and 8) social relations (Hernández-Morcillo et al. 2013), 9) intrinsic values (Milcu et al. 2013). Recently, studies have been enriching the existing classification of CES by adding themes, e.g. therapeutic and life-sustaining quality, sports services, etc. (Zhou et al., 2020). So far, the primary focus, of the classification, however, has been on the "supply" side of the ecosystem (Plieninger et al., 2013). "Recreation and eco-tourism" and "aesthetics" are the most frequently measured CES and most easily quantifiable CES (Hernández-Morcillo et al. 2013; Milcu et al. 2013), due to its tangible and observable nature, and especially for aesthetics, how the visual appeal and beauty of urban green spaces contribute to the well-being and quality of life of urban residents (Ostoić et al., 2020). This is followed by cultural heritage, sense of place and cultural heritage, educational, social relations, spiritual and religious, and inspirational values as the least investigated topic (Kim and Son, 2021; Hernández-Morcillo et al., 2013; Milcu et al., 2013).

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While considering CES assessment or developing context-specific CES indicators, positive or negative impacts of green space that represent the synergies or trade-offs between services are essential to consider in the calculation. Synergies and trade-offs ensure whether the green space's qualities, aspects, and attributes act as enablers of positive interactions with urban nature (Davies et al., 2017; Hoyle et al., 2017), constraints from habitat degradation, landscape fragmentation, or conflicting land use practices (Baumeister et al., 2021; Lyytimaki, 2017), or barriers including inadequate planning, lack of stakeholder engagement, or competing interests in land use (Wolff et al., 2022; Wang et al., 2015) in the context of a particular urban green space. The cascade model of Potschin-Young et al. (2018) or the synergy and trade-off matrix by Haase et al. (2012) elicit the necessity to identify the trade-offs between different ecosystem functions. For example, the provision of extensive recreation, restoration, health and well-being versus the protection of sensitive species, high naturalness, or a more diverse ecology (Hasse et al., 2014; Hoyle et al., 2017).

3.1.2 Health and well-being services and disservices of UF-NBS

The enabling qualities of urban green space promote human health and well-being through many positive services (i.e. recreation, restoration), constraining and detrimental factors are referred to as disservices (Baumeister et al., 2022; Lyytimäki, 2017), negatively impacting human health and well-being. These negative aspects are often referred to as physical or perceived qualities of nature, i.e. unpleasantness, fear, the threat of physical harm, direct or perceived health risks, aesthetic problems, and pollution and air quality (Roy et al., 2012, p. 353; Lyytimaki, 2017; La Rosa et al., 2016).

Urban trees and vegetation, part of UF-NBS, are being increasingly recognised as an essential component of an urban salutogenic environment, and visual and physical contact with trees is associated with multiple health benefits (Wolf et al., 2020; Davies et al., 2017; Nordh et al., 2009), and are primarily obtained locally through multisensory experiences (Dickinson and Hobbs, 2017). Natural environmnets impacts on human health through several supporting pathways , e.g. physical activities and mental health or psychological restoration and social cohesion (Frumkin et al., 2017; Ekkel and De Vries, 2017; Hartig et al., 2014).

Nature experiences show a positive influence on mood state and attention restoration (Tsunetsugu et al., 2013; Hartig et al., 2011) which increase with high species richness (Fisher et al., 2021) and the presence of natural auditive stimuli, i.e. bird, breeze, rustling leaves (Hedblom et al., 2017). Old and mature forests and old trees predict higher restorative potential (Kabisch et al., 2021; Simkin et al., 2020), whereas native tree species were found to enhance the visual appeal and increase perceived naturalness (Davies et al., 2017). Green space with high naturalness – based on high tree coverage, presence of more flora and fauna – provides a higher perceived nature experience (Kabisch et al., 2021), thereby providing higher perceived restorativeness (Fisher et al., 2021; Pasanen et al., 2018).

Physiological and psychological health benefits of viewing trees and green spaces have been well documented (Bakolis et al., 2018; Davies et al., 2017; Rall et al., 2017; Nordh et al., 2009). People interact with a green/blue space and perceive the quality and affordances by assessing the space's physical, social, aesthetic, and ecological domains and aspects (Knobel et al., 2019; Gidlow et al., 2018; 2012; Mishra et al., 2020). Moreover, visit frequency and recreation values are influenced by the place's welcoming-ness, design elements and quality, attractiveness and character of planting typology and features, tree composition and characteristics, the forest structure, and the amount and type of green space management practice (Hoyle et al., 2017; Davies et al., 2017). The sense of control over

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the environment, i.e. security and pleasure, is associated with green space design features, i.e. openness, vista, and the cleanliness of parks and park facilities (Davies et al., 2017; Kimic & Polko, 2022). In addition, both the synergies and trade-offs of benefits and services of urban nature can be observed between a place's serene and social quality, i.e. use intensity and perceived restoration (Peschardt & Stigsdotter, 2013; Yakinlar & Akpinar, 2022). In the end, accessibility to a green space (i.e. availability of accessible green space within a 300-meter radius) predicts restorativeness, especially the sense of being away (Hartig et al., 1997), which is further beneficial for outdoor learning opportunities and woodland-based recreational nature play opportunities (Davies et al., 2017).

Similar to health benefitting qualities of UF-NBS, there are constraining or detrimental factors of the green space, corresponding to ecosystem disservices, i.e. unpleasantness, ugly, unclean, less safe, perceived as dangerous, including conflicts between uses/activities, users, user groups; and negative impacts to health and well-being, e.g., allergenic potential, low air quality, noise (Scheuer et al., 2022). Although in a recent study in Southeast Europe, Ostoić et al. (2017) showed that citizens genuinely care for urban forests and green spaces in their cities but are not satisfied with their current state and expressed concerns about issues related to the misbehaviour, quality of facilities and management and maintenance. In addition, several barriers in regard to green spaces, including physical, institutional, or personal barriers, have been identified (Wolff et al., 2022). Green spaces are associated with physical barriers that reduce access to facilities and amenities that discourage users from using green spaces. These barriers may be perceived as, i.e. lack of seating spaces and access paths, places showing signs of dilapidation, lack of maintenance, trash, safety, and becoming a source of conflicts which generate disservices which are detrimental to human health and well-being. The disservices may arise due to detrimental factors that may amplify the issue due to the presence of barriers encountered at the personal level, i.e. lack of available leisure time, health issues, e.g., chronic conditions, asthma (Wang et al. 2015; Sefcik et al., 2019).

Regarding hitherto studies, the key UF-NBS qualities that are presented in Table 1 (Scheuer et al., 2022) primarily focus on health and well-being-related benefits such as recreation and restoration and stress reduction. In addition, detailed exemplary statements, and questions for the elicitation of citizen perception, and appreciation, with respect to selected enabling or constraining qualities have been reported in Table 2 (Scheuer et al., 2022).

Table 1: Selected UF-NBS qualities as possible health enablers (adopted from Scheuer et al., 2022)

UF-NBS Qualities	Health enablers
Naturalness, natural qualities, composition, structural complexity	• Naturalness, composition, planting arrangements, maturity of trees, structural complexity, natural qualities, and soundscape. • The dimension of UF-NBS is related to the experience of nature versus non-nature, a degree of wilderness, or a valuable nature site. For example, regarding the structural complexity of green spaces; • Planting typology to characterise similarity with natural to semi-natural vegetation;
Rich in nature, species, (perceived) biodiversity	• Richness in nature/species, (perceived) biodiversity

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Spatial qualities	• Related to the experience of an environment as being large enough, accommodating, of suitable extent, including spacious scope and connectedness
Prospect qualities	• The presence of open plains and vistas, allowing for visual control over the environment and being supportive of sports activities;
Social and cultural qualities	• Ornamental characteristics and amenity features that provide a sense of culture and place, e.g., fountains, ornamental plants, ponds, and other cultural elements and facilities, resulting in an environment supportive of social activities;
Serene qualities	• This may present a certain contrast to social-cultural qualities, as it refers to a calm, quiet and relatively undisturbed environment supportive of personal retreat;
Refuge qualities	• Being a safe environment, particularly including a child-friendly environment;
Accessibility	• Related to distance or proximity, walkability or access through other modes of transportation, but also the overall availability of green space;
Knowledge and information	• About nearby parks, opening times, and activities;

3.1.3 Health and well-being impacts of plant typology and vegetation structure

UF-NBS maybe seen as contributing to shape compatibility of green spaces, and thus, by extension, personal activities within these green spaces. I.e., compatibility may be understood that environmental qualities and constrains are locally supportive of personal intention, thus allowing for certain activities in a given environment (Hartig et al., 1997). Following Hartig et al. (1997), compatibility is one of several factors that govern environmental restorativeness in line with Attention Restoration Theory (ibid.). Other dimensions include extent, i.e., spatial qualities, as well as "being away" from everyday life's routines, and aspects of fascination (Hartig et al., 1997). Combinations of abovementioned qualities may thus also be seen to contribute to these dimensions of restorative quality.

However, similar to supporting or enabling qualities, constraining or detrimental factors may be identified, that either limit the positive impacts of UF-NBS, represent trade-offs, or correspond to ecosystem disservices, including:

- Local conditions that render UF-NBS/UGS as unpleasant, ugly, unclean, less safe, perceived as dangerous, including conflicts between uses/activities, users, user groups, etc.;
- Negative impacts to health and well-being, e.g., allergenic potential, low air quality, noise;
- Barriers to green spaces, including physical, institutional, or personal barriers (Wolff et al., 2022).

For example, Wang et al. (2015) notes lack of available leisure time, health issues, e.g., chronic conditions, asthma (Sefcik et al., 2019), or lack of financial affordability as a form of personal barriers. Other barriers, or detrimental factors for green space use, include safety concerns, e.g., fear of being robbed or illegal activities, but also personal dislikes related to nature experiences (bugs, pollution, wild animals, sunburn), or physical conditions of spaces, such as lack of seating, lack of maintenance, trash (Sefcik et al., 2019). Regarding the UGS-specific determination of these contributing or constraining qualities, the published literature provides a host of suggestions in the form of statements for the elicitation of perception, typically along a Likert-scale to express (dis-)agreement with the particular statements (cf. Table 2). Note that in addition, soundscape may be elicited, e.g., as being

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able to listen to/hearing birdsong, blue sounds, or describing local soundscapes as pleasant, chaotic, monotonous, calming, annoying etc. (cf. also Xiang et al., 2022).

Table 2. Exemplary statements and questions for the elicitation of citizen perception, appreciation, with respect to selected enabling or constraining qualities (following Grahn & Stigsdotter, 2010; Hartig et al., 1997; Holye et al., 2017; Kabisch et al., 2021a, 2021b; Peschardt & Stigsdotter, 2013; Püffel et al., 2018; Wang et al., 2015; Wendel et al., 2012)

UF-NBS quality	Exemplary statements
Naturalness, natural qualities, composition, structural complexity	• The urban park or urban open space has a nature quality. • The urban park or urban open space has a wild and untouched quality. • The urban park or urban open space has lots of trees. • The park or urban open space contains many bushes. • Are there benefits or problems with natural areas? • The planting along this walk is interesting (attractive, colourful). • The planting along this walk looks natural (cared for, designed, tidy, familiar to me). • How structurally complex would you describe this planting?
Accessibility, green space availability	• How would you rate your overall ease of access to this park? • How easy is it for you to physically get to this park? • There is a sufficient number of parks in my neighbourhood. • This park is close to where I live. • I can easily walk to this park. • How frequently do you visit this area? On the weekends? During the week? • Are there any other areas where you go to relax, visit with friends, or recreate? Can you describe the size of these areas? What do you use or do in these areas? • Do you think there are enough areas like this in your neighbourhood?
Knowledge and information	• I am aware of parks and park facilities in my neighbourhood. • I am aware of activities and programs held in the parks.
Rich in nature, species, (perceived) biodiversity	• One can detect several animals, like birds, insects, etc. • The urban park or urban open space consists of natural plant and animal populations. • There are many native plants to study. • How many different plant species do you think there are here? • How many native UK plant species do you think are in this planting? • The planting along this walk appears good for butterflies, bees, and other insects. • How many species of native UK insects (flies, butterflies, bees) do you think this planting will support?
Prospect qualities	• The urban park or urban open space contains plane and well-cut grass surfaces. • It is possible to have a prospect, vistas over the surroundings. • The lawns are cut. • The park or urban open space has soccer fields on grass (gravel). • There are showers and changing rooms available.

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	• I can do the things I like here. • I can easily navigate here. • I like this place.
Serene qualities	• One is able to spend time in the urban park or urban open space without coming into contact with too many people. • The urban park or urban open space is silent and calm. • There are no bikes in the urban park or urban open space. • There are plenty of people and movements in the urban park or urban open space. • The area is clean and well maintained. • There is too much going on. • Spending time here gives me a break from my everyday routine. • There is no traffic noise from the surroundings.
Spacious qualities	• The urban park or urban open space is experienced as spacious and free. • It is possible to find areas not crossed by roads and paths. • It is possible to find places where a company of several persons can gather. • There is much to explore and discover here. • I experience this place as very large.
Refuge, Child friendliness	• The park or urban open space keeps animals that children and adults may feed and pet. • There are sandpits. • There is play equipment, like swings, slides, etc. • It is possible to watch other people being active, playing, practicing sports, etc. • There are tables and benches. • There are benches with leans. • There are age-appropriate seating facilities/benches.
Safety, Unsafe conditions	• It feels safe spending time in the urban park or urban open space. • Are there any socio-personal issues (perceived safety) that make you avoid visiting this park? • I am concerned with my safety when I travel to this park. • There are people participating in illegal activities around this park. • This park is a place with high crime at night. • The urban park or urban open space has general good lighting. • I feel comfortable on this walk. • Safety concerns: Fear of being robbed, lack of police presence, prostitution, trash posing public health risks, presence of unrestrained dogs.
Social-cultural qualities	• This park is attractive to me because I can do my favourite activities here with other people of shared interest. • This park is attractive to me because there are people from my ethnic or cultural background. • The urban park or urban open space has the characteristic of a city park. • The urban park or urban open space is decorated with fountains. • The urban park or urban open space is decorated with statues. • The urban park or urban open space is ornamented with flowers.

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	• It is possible to watch entertainment, like a park concert. • There are plenty of people and movements in the urban park or urban open space. • The urban park or urban open space keeps special park animals, like swans, ducks and deer. • There are places in the urban park or urban open space sheltered from the wind. • There are tables and benches. • The urban park or urban open space contain roads and paths with hard surfaces, like asphalt, concrete bricks, etc. • There are sunny (shady) places. • The place was used as a space to hang out, explore or generate graffiti (BBQ, picnic, other use of nature).
Barriers	• Is there anything that limits how often you visit this area or other similar areas? • What do you like or dislike about this area? • I have a good work-life balance. I have enough leisure time to visit parks if I want. • How would you say your health in general? • Visiting and using public parks in my neighbourhood is an affordable activity.

In addition to perceptions, appreciations or preferences in regard to (multifunctional, cultural) benefits and aspects of green spaces, a key theme elaborated through the partner cities is tree health and tree-related impacts, benefits, or disservices. In this regard, particularly with respect to tree health, certain aspects may be observed, mapped and elaborated by citizens. These include, e.g., the appearance of trees, or the presence of specific traits and characteristics related crown/leaves or needles, branches, and stem, e.g., leaf scorch, premature discoloration etc., debarking, decaying, deformations, tumors, or fungi (Eichhorn et al., 2016). These traits may be mapped through citizens qualitatively, i.e., presence of absence, or quantitatively, i.e. in terms of ordinal scale assessment (indication of severity along a scale) or metric scale assessment (percentage affected).

Table 3. Observable trait expressions, i.e., tree characteristics, as indicators of tree health
(Eichhorn et al., 2016)

Part of tree	Examples of observable trait expressions
Overall	• Overall appearance of tree • Assessment of perceived planting space • Number of trees affected
Leaves, needles	• Leaves or needles devoured/missing • Fading or sparse canopy • Premature falling of leaves • Green to yellow discoloration • Red to brown discoloration • Visible flecking, spots • Leaf scorch

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	• Unusually small leaves • Visible deformations, e.g., curling, bending, rolling, twisting, folding, wilting • Visible signs of insects and tree pests, e.g., black coverages on leaves, nests, eggs, larvae etc. • Visible signs of fungi, e.g., fruiting bodies, black or white coverages on leaves, tree spot diseases
Branches, shoots	• Devoured or missing branches • Broken • Visible debarking • Cracks • Other wounds • Resin flow • Slime flux • Decaying or rotting • Visible deformations, e.g., wilting, bending, cankers, tumors • Signs of insects, e.g., nests, eggs, larvae, boring holes • Signs of fungi, e.g., fungal fruiting bodies
Stem	• Appears to be dying • Debarking • Cracks in the bark • Other wounds • Resin flow • Slime flux • Deformations, e.g., cankers, tumours • Tilted shape • Fallen • Necrosis • Insect activity, e.g., boring holes, nests, larvae, eggs • Boring dust/wood dust • Visible dust of wood, e.g., in bark crevices • Signs of fungi, for example, fungal fruiting bodies

3.2 Evidence on participatory methods and tools to elicit citizen perception

Citizen science approaches have been proved effective in urban forestry management (Foster et al., 2017). CS refers to the engagement of non-professional scientists, often members of the general public, in scientific research activities (Phillips et al., 2018; Aczel et al. 2022), which allows citizens without formal scientific training to collect data that contributes to scientific observations available to researchers and decision-makers (Bonney et al., 2009). Citizen science approaches to monitoring urban forests encompass a variety of objectives. These include conducting tree inventories and ecosystem service assessments (Callaghan et al. 2019; Rossi et al. 2022), tracking invasive species and forest pests (Hovis et al. 2020; Hulbert et al. 2023), assessing cultural services (Cambria et al. 2021), and mointoring tree health, tracking biodiversity, and assessing the impact of environmental factors on urban ecosystems (Zhang et al., 2020). Explorative research methods in CES studies use participatory methods, i.e., focus groups, surveys (questionnaires), interviews; non-monetary valuation using

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qualitative measures, constructed or Likert scales (De Vreese et al., 2016a); narrative methods (stakeholder values through stories); and spatial mapping (Haase et al., 2014; Wei et al., 2017).

The use of supply-based indicators (e.g. an abundance of habitat, recreational potential, landscape beauty, diversity of hiking paths), demand-based indicators (e.g. preferences for habitat, activities, landscape beauty, visitation rate, probability of using hiking paths), or both in CES studies are popular (Wei et al., 2017). Only a small number of studies have focused on spatial explicit mapping methods by overlaying biophysical variables on the stakeholder's perception of cultural services of the same landscape (Hernández-Morcillo et al., 2013; Cheng et al., 2019; 2021; De Vreese et al., 2016a), or to research the link between the ecosystem's social and ecological dynamics (Tyrväinen et al., 2007; Haase et al., 2014; Wei et al., 2017). Moreover, methods that have been articulating values through narrative expression (Kim and Son, 2021), capturing the relative importance of services (Baumeister et al., 2020), and mapping values spatially (Brown et al., 2018; De Vreese et al., 2016a; Korpilo et al., 2018a; García-Díez et al., 2020; Baumeister et al, 2020; Ives et al., 2017; Tyrväinen et al., 2007) have helped to measure CES with high subjective bias.

3.2.1 CES assessment protocols

The basic tenets of the CES assessment questionnaires and survey methods have been used to capture respondents' general attitude towards, and the opinion on (inter alia) the role of green space in their living environment; favourite green spaces for leisure time; specific information about the experience of positive and negative values of nature; identified services and disservices; benefits felt or obtained; respondents' familiarity, knowledge and interest for trees, forest, and green areas; preferred activity, visit frequency, perceived locations or paths for activities and recreation; perceived green space traits for health and welling (enablers or constraints); perception about the bio-physical variables; travel distance and time; level of satisfaction with the tree or forest management; respondents' relation and access to private gardens; the respondents' socio-demographic information; various conflicts and strategies related to conflict resolution; and the place value for health and well-being (Tyrväinen et al., 2007; Baumeister et al., 2022; 2020; Koh et al., 2022; Beckmann-Wubbelt et al., 2021; Gracia-Diez et al., 2020; Korpilo et al., 2018b). Few studies structured questionnaires around specific issues, e.g. impact assessment of recreational activities, off-trail behaviour in a forest setting, and perceived potential ecosystem services by park visitors under heat conditions (Korpilo et al., 2018a; Kabisch et al., 2021).

Studies with a focus on recreational services pursue the survey with questions related to the preference for the type of landscape for recreation, degree of naturalness, green space attributes that attract recreational visits, green space available for recreation, preferred activities in green space, perceived values impacting recreational visits (Nigussie et al., 2021). Moreover, some studies included scenario-based questions such as public perception about the reasons for current environmental changes, preferences for the future green and blue space types and characteristics, identification of future environmental problems, and the perceptions about the expected changes or solutions to ecological issues due to current or future greening efforts (Dou et al., 2017), for example.

3.2.2 Role of Public Participation GIS (PPGIS) in the assessment of UF-NBS trait perception and impacts

PPGIS is a participatory method combined with a GIS, in which participants provide geospatial information by identifying and marking locations on a map about the perceived nature values, services,

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conflicts, barriers, obtained benefits or disservices (Wolf et al., 2018). PPGIS as a participatory method use qualitative (Schoepfer and Rogers, 2014), and quantitative research techniques (Fagerholm et al. 2021b) to assess preferences (for example supply of intangible ES, De Vreese et al., 2016a) and/or to quantify the demand for the ecosystem services (Baumeister et al., 2022; Wei et al., 2017; Plieninger et al., 2013). The method directly engages stakeholders, green space users and citizens to explore nature values, perceptions and the distribution and heterogeneity of CES within a defined geographical extent and at different spatial scales (Wei et al., 2017; García-Díaz et al., 2020). Participatory methods combined with mapping of ecosystem service-production-and-consumption units can assess demands accurately if supplemented with GIS (Wei et al., 2017). For example, Baumeister et al., (2020) emphasised the need for a map-based approach to integrating CES into urban forest planning and management. Regarding urban forests, the power of visualisation using qualitative and quantitative information mapping can make the urban forest services and benefits more conspicuous to green space managers and decision-makers. The engagement and participative mapping platforms can maximise green benefits for all city dwellers through impacting on decision-making, planning, design and management (Baumeister et al., 2020).

PPGIS tools can significantly enhance the visibility of intangible ecosystem services and disservices. The PPGIS data may improve the understanding of spatial and temporal dynamics of ecosystems and help differentiate between the services and the benefits obtained. Moreover, the tools can be used to identify the socio-ecological hotspots, the spatial relevance of environmental impacts of green space, the significance of green spaces in public health, and explain the relative importance of CES obtained within a single spatial operational unit (De Vreese et al., 2016a; Baumeister et al., 2020; Wolf et al., 2018; Koh et al., 2022; Beckmann-Wübbelt et al., 2021; Fagerholm et al., 2021a; Korpilo et al., 2018 a,b). PPGIS tools are considered useful in identifying possible place-based or ecosystem-based synergies or trade-offs and analysing CES flow regimes along an urban gradient (Koh et al., 2022; Beckmann-Wübbelt et al., 2021; Baumeister et al., 2020). Moreover, PPGIS assures heterogeneity in spatial data and has shows correlations between demand hotspots and physical landscape features in specific studies (Baumeister et al., 2022). Furthermore, mapping exercises that combine PPGIS data with existing GIS-based land use and land cover data, bio-physical data, and demographic data are common (Baumeister et al., 2020; De Vreese et al., 2016a; Fagerholm et al., 2021a). Public participation has high conflict resolution capabilities (Raymond et al., 2009).

Table 4: Exemplary questions for the elicitation of citizen perception and appreciation, with respect to themes covered during different CES studies

Assessment CES themes	Questions used to explore CES aspects within that theme.
Urban Forest CES perception and experience	• What types of individual cultural services are reflected in the case of the study city by people's actual experiences? What are cultural ecosystem services relevant for urban forest visitors? Open question to capture the perceived place values, e.g. the meaning of place and place as experienced by people, which can be linked to CES categories. • How are different types of cultural services perceived by people distributed spatially?

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	• What are the public's cultural values of the urban forest? • What are the cultural ecosystem services (i.e., supply and demand) offered in the urban forest? • What are the cultural ecosystem benefits (CEB) enjoyed in the urban forest?
Urban forest disservices	• What are the individual constraint features of urban forests? • How important are disservices for urban forest visitors? Are mapped disservices spatially clustered? • Are there spatial bundles of both CES and disservices and the relevance of hot and coldspots with relevance to public interests within urban forests?
Activities, use, infrastructure	• What are the general forest and peri-urban forest-based activities like? And do they differ between urban and peri-urban locations in each urban functional area? • What is the level of satisfaction with urban and peri-urban forest infrastructure, green elements? • What are the contributions of urban forest features (human-made–and natural, i.e. land cover, forest characteristics like tree species, canopy cover density) to the supply of urban forests' CES? • What is the relative importance of urban forest features for the supply of each CES (e.g., recreation, cultural heritage, beauty)?
Relative importance, trade-off, and comparison between services production and consumption areas.	• What is the relationship between services and benefits in the urban forest? • How can CES services and benefits be uncoupled to improve understanding the multi-functionality of the urban and peri-urban forest? • Do the CES values vary between urban and peri-urban forests across urban and peri-urban populations?
Impact of socio-demographics on perceived CES	• Do socio-demographic characteristics of respondents influence perceived services and disservices?
Impact of pandemic, value and the role of UF-NBS in climate adaptation, UF-NBS management,	• How does the COVID-19 pandemic influence people's perceptions of ecosystem services of trees and forests? • What is the role of urban and peri-urban forest settings concerning human health (ailments or the impact of heat on mental health) under the condition of heat stress? • How do people perceive the role of urban and peri-urban forests in achieving climate change adaptation and mitigation?

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conflict resolution	• What do people perceive as the future benefits of greening efforts in the city? Public reflection of past, present and the future- the temporal scale? • What and how do people perceive the role of UF-NBS in improving environmental conditions (i.e., forms of pollution)?
impact of spatial scale on perceived CES	• Which regions of urban forests or cities with forests concentrate the largest number of attractions and constraints for CES supply and benefits? • How do residents of urban locations evaluate cultural ecosystem services of urban and peri-urban forests, and how do these perceptions differ between case study cities?
Inclusivity in participatory mapping	• What are the strategies to include wider social groups (i.e. older adults, children) in the public participatory GIS process? • How do urban and peri-urban forest CESs (perceptions, preferences, and activities) vary across different social groups? Effect of the demographic variable on the perceived and preferred CES.

3.2.3 PPGIS map-based data collection

The selection of a base map for a smooth and comfortable survey experience may follow certain criteria, i.e., user familiarity and availability of map, convivence to use, easy to read, navigate, zoom in (orientation for participants), easy to identify different locations with updated UF-NBS elements and features, trails, roads, and with adequate fine-grain information at the optimum zoom level. Open-source maps services such as orthophoto-maps (Microsoft® BingTM Maps, 2018) or a street map (OpenStreetMap contributors, 2018), and Google map services may be considered due to high use familiarity among citizens. The survey must accommodate flexibility for answering questions related to CES and using a marker to represent a CES on a map. The setting of map extent (size) in the survey may allow citizens to freely locate their perceived CES and benefits over a larger geographical area (e.g. the entire city region) and allow mapping of multiple perceived CES at multiple locations. With each marker(s) put on a map, the respondent may be able to choose between CES categories to answer and repeat using one marker at several locations representing one CES. Respondents may not be limited to using a few markers, discouraging citizens from reporting several perceived green space traits or demands for CES.

3.2.4 PPGIS sampling approach

Sampling design is one of the important issues to be considered when developing the methodology for the PPGIS application and the survey (Brown and Kyttä, 2014; Fagerholm et al., 2021b). Topics to be defined include:

1. making people aware of the PPGIS.
    a. facilitating and distributing the survey, e.g. flyers, advertisements, identification of locations to distribute information about the survey, selection of residential areas

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close to urban forests, city centre, areas facing multiple deprivations, and with high minority population density, city areas with high and low population density.
   b. contacting schools, colleges, universities, and local associations, communities, and youth centres;
   c. survey advertisement using radio, newspaper, local, new letters, blog posts, Youtube channel, local municipality website, local libraries.
2. selecting a random sample of city dwellers and keeping the gender ratio in balance,
3. developing a strategy to ensure a more inclusive survey ensuring through facilitation the participation of the most appropriate population segments; ensure the quantity of PPGIS data to show the power of inference and as a measure of data quality. dealing with data sufficiency problems, especially for a large study area: case study areas need to be identified, and study area boundaries need to be delineated to help respondents mark their responses accurately within the study area.

The distribution of the PPGIS tool should consider a broader demographic (i.e. older adults and children, people with differently abled, including visually impaired) and geographic representations. Wherever possible paper-based mapping on locations should be made available, for example, at local grocery stores, care homes, kindergartens, schools, churches, health cents, community clubs, and other local community organisations such as Men-Sheds to enhance participation.

3.2.5 Summary: requirements for a PPGIS for assessing CES demands in urban forests

Considering that hitherto studies have not drawn out their full potential, the proposed citizen science tool should consider certain challenges:

- Provide spatially explicit and site-specific socio-perceptual information from local to citywide scale as a contrast to existing ecological, infrastructural and statistical (geo-)data (Rall et al., 2018);
- Link subjective impressions of UF-NBS traits with objective, place-based attributes, e.g., activities or uses, in order to establish multifunctional perspectives on the compatibility of UF-NBS with respect to these objective attributes (Brown & Kyttä, 2014). This approach helps to uncover heterogeneities and support value transfer (Brown & Kyttä, 2014; Brown et al., 2020) by establishing (empirical) relationships between subjective perception, objective physical expression, and uses/behaviours as a function of trait-based affordances. For example, the size of an UF-NBS (trait) may be personally perceived as small (trait expression), speaking to a possibly limited spatial quality of the UF-NBS in question (quality). A subsequent evaluation of this trait perception may reveal a still-positive personal appraisal with respect to an intended use. I.e., the trait-based quality is, in such a case, not considered as constraining on a personal level. Other personal evaluations of said trait expression regarding size may however reveal negative appraisals with respect to intended uses. Therefore, specific traits, or trait expressions, respectively, may be assessed in the same way by different people, thus uncovering geographic discounting and heterogeneity in perceptions and place-based decision-making (Brown et al., 2020).
- Consider scope, complexity and potential impacts/applications of data for effectively supporting planning and decision-making (Brown & Fagerholm, 2015; Pietilä & Fagerholm, 2019).

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4 Mapping the demand for UF-NBS in a sample of European Cities

4.1 The study context

This task delved into the intricacies of UFNBS within a selection of European cities, drawing upon an "explorative case study analysis" (da Schio et al., 2021: CLEARING HOUSE report D2.1) and insights gleaned from "local stakeholder co-learning workshops" (De Vreese et al., 2021: CLEARING HOUSE report D3.2). These foundational studies not only illuminated the defining characteristics and challenges of UF-NBS (as detailed in D2.1) but have also set the stage for addressing city-specific UF-NBS issues in the current task. The case study cities exhibited a vast array of environmental and societal challenges, all of which critically influence the impact of UF-NBS on urban ecosystems and societies. These challenges ranged from assessing cost-effectiveness to evaluating the potential for replication in diverse urban settings. Furthermore, the preliminary tasks were to adress a multitude of barriers and knowledge gaps in the implementation and management of UF-NBS, as well as in augmenting societal awareness of their benefits.

Whilst each city involved in CLEARING HOUSE case studies presented distinct strategic aims, there was a strikingly evident pattern of common themes and challenges that permeates through them all. This notable overlap indicated a complex, shared foundation in addressing UF-NBS across diverse urban settings. Such a revelation accentuated the necessity for a method that is both nuanced and acutely aware of the specific contexts of each city. Hence, it was of paramount importance that our current endeavour not only focuses on pinpointing and comprehending these recurring themes but also on crafting tailor-made strategies that are finely tuned to the unique needs and circumstances of each individual city. This targeted and thoughtful approach was crucial to fully harnessing the potential of UF-NBS, thereby significantly enhancing urban ecosystems and elevating the quality of life within our cities. In the spectrum of themes and challenges identified, those that are common, notably significant, and peculiar to individual case cities were meticulously evaluated using an innovative, adaptive citizen science tool. The array of issues included were the impact of UF-NBS conditions, such as observable traits and tree characteristics that serve as indicators of tree health, as well as the role of UF-NBS in providing cultural ecosystem services like recreation and health benefits. Moreover, the research probed into the less favourable aspects of UF-NBS, including potential disservices like risks to tree health, concerns over tree damage and pests, noise pollution, and their role in climate change adaptation, particularly in terms of species selection and drought resilience. This comprehensive, multi-faceted analysis was pivotal in not only acknowledging but also effectively addressing the full spectrum of impacts associated with UF-NBS in our urban landscapes. In addition, this study assessed the degree of public awareness of the condition and benefits of urban trees, urban forest cost-effective and sustainable management practices, and bio-physical and spatial characteristics explaining the state of biodiversity and ecological connectivity, for example, the connectivity between urban and peri-urban forests, private gardens including the unobstructed movement of urban wildlife (see Appendix 1-3 and Figure 1).

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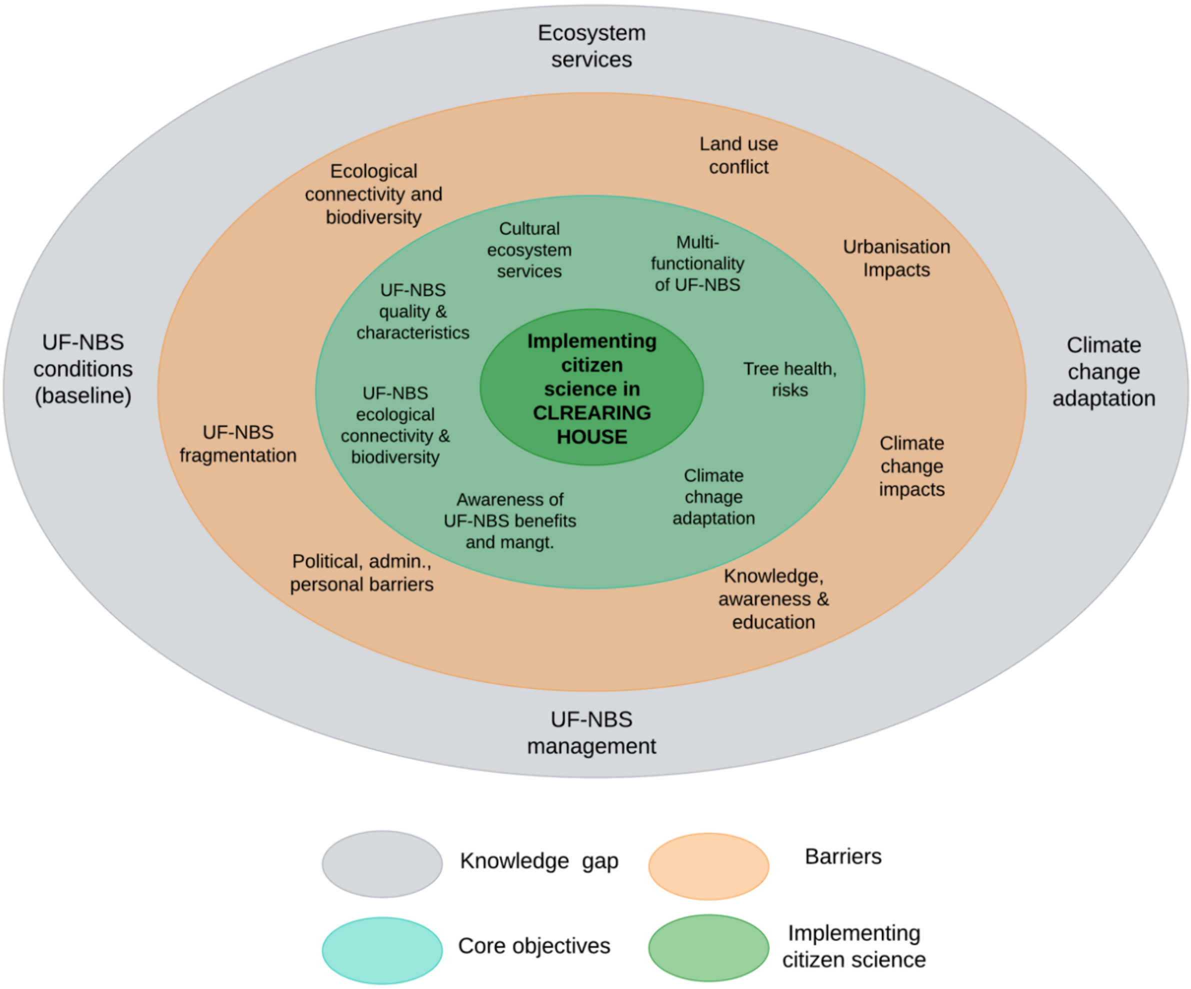

Figure 1: Overview of UF-NBS issues and themes for European Case Study Cities in CLEARING HOUSE. For detail, see Appendices 1- 3.

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4.2 Demand for citizen science information in case study cities

4.2.1 Sonian city, Belgium (Brussels metropolitan region and province of Vlaams-Brabant)

The study context

The UF-NBS in Sonian City consisted of the Sonian forest and the fragmented parts of the (peri-)urban forest and the urban core, including forest and parks, street trees, and the forest and trees on the private land.

Issues and challenges

The ecological structure of UF-NBS in and around the Sonian forest had been facing multiple issues, such as biodiversity fragmentation, environmental pressure from the existing street network and traffic (i.e., light and noise pollution, contaminating surface and groundwater quality), animal mortality, and diminishing landscape coherency. Moreover, severe forest fragmentation was observed in the urban core. Additionally, the road infrastructure in the forest impacted the quality of surface and groundwater. Furthermore, the (peri-) urban forest in the region (forest embedded into urban fabric) had been overly used for recreation activities. There had also been a constant challenge to supply sufficient accessible green space per inhabitant and improve the quality and distribution of green space. Poor conditions, scarcity of urban forest (trees), and lack of green connectivity were evident in the city center compared to regional territories. Although UF-NBS was found less fragmented in private areas, the urban forest lacked biodiversity connectivity caused by physical barriers such as roads and fences. Within the Sonian city region, UF-NBS-related improvement targets were identified, including forest expansion and species selection, reconnecting Sonian forest and its urban-rural territorial linkages, inner-city afforestation, improving mobility and performance of public spaces and streets, and enhancing awareness about CES and ES of private gardens. Fragmented Sonian forest patches in (peri-) urban locations (Brussels Metropolitan Region and the province of Vlaams-Brabant), in and around the settlements and school catchments, were the study focus areas.

It was important to determine the current perceived and actual UF-NBS potentials of the provisioning of ES, notably with existing fractured and sandwiched forest components. These forest structures were subject to multiple ecological challenges and the pressure of land use planning and land development processes underway within the regions. Similarly, a better understanding of the tree and forest ecosystem in private gardens, including the biodiversity flow regime and the connectivity, was expected to improve the ecological integration of Sonian forest and (peri-) urban forest patches. Brussels' urban heat island (UHI) effect was a growing public concern. The mapping of public appreciation and perception (place-specific studies) of UF-NBS in mitigating the UHI effects, and importantly, providing thermal comfort and improved urban forest resiliency, was identified as crucial to ensuring the success of UF-NBS in climate change mitigation and adaptation. There was a greater need to protect accessible forest patches within the urban area and create new ones to compensate for the loss of urban green space. Although Brussels is considered a green city, inequality in the distribution of UF-NBS was evident along its urban-rural gradient, suggesting that the green space per capita distribution was inadequate to ensure urban socio-environmental justice. Moreover, urban forest fragmentation was further decreasing the number of publicly accessible urban forests for recreation and relaxation.

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Although in Belgium, the involvement of citizens in policymaking was found to be in its infancy, in Brussels, public authorities and civil society, NGOs had been supporting citizen science projects, and many funded projects had been fostering citizen science approaches targeting a wide range of urban themes (e.g., air pollution, traffic safety).

Potential of the citizen science approach

In the context of the Sonian forest, it had been anticipated that a PPGIS mapping would uncover both the perceptual and actual recreational hot-spots, as well as factors affecting the frequency of visits and the popularity of UF-NBS. The research aimed to delineate place-specific recreational demands and pressures, along with health and well-being enablers and constraints, and to examine the place-keeping and management systems then in practice. One of the future actions that had been identified was to map the favorite Sonian forest destinations for recreation and forest CES and benefits. Certain characteristics of UF-NBS or observable traits had drawn particular interest, including aspects of UF-NBS sensitivity like naturalness, structural complexity, natural quality, biodiversity richness, spatial and serene qualities, socio-cultural qualities, and accessibility conditions related to walkability and proximity.

It had also been expected that CES mapping would reveal the observed, perceived, and preferred conditions and characteristics of private forests and gardens by landowners, such as tree inventory, conditions explaining tree health, garden richness, biodiversity, ecosystem benefits, and recreation potential. This knowledge was seen as a way to bridge the gap between the potential of ecosystem services and the condition and quality of private gardens in the Sonian City. Moreover, the citizen science approach was anticipated to encourage long-term tree monitoring systems to assess the health of urban trees, including those in private gardens. This information was intended to sensitise private landowners to adopt appropriate forest management techniques. Furthermore, using citizen science data to better understand the role of UF-NBS was expected to help mitigate urban heat island effects.

The citizen science module was intended to raise awareness among citizens about the environmental threats posed by various recreational behaviors and demands. Moreover, it was aimed to identify critical socio-ecological and physical barriers affecting the ecological continuity in Sonian City and biodiversity richness. Additionally, identifying and assessing key ES and CES services and benefits of private gardens was seen as offering valuable alternatives to public UF-NBS and to upscale private UF-NBS's contributions to the citywide ES and CES needs, such as health and recreational opportunities.

Future actions prioritised for citizen science were to

- improve the knowledge about the (peri-) urban Sonian forest recreation demand, pressure, and state of the provisioning of CES.
- improve the ecological and physical connectivity of UF-NBS and create meaningful public spaces.
- identify and assess essential ES and CES services and benefits of private gardens as an alternative to public UF-NBS.
- mobilise citizens to inform about the urban tree and forest-related issues and threats (i.e. crown damage, dryness, tree disease, use conflicts).
- adress the urban heat island issues through citizen science.
- monitor the health and condition of the tree in the public land using citizen science.

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4.2.2 Leipzig/ Halle, Germany

The study context

UF-NBS in Leipzig comprised commercial and industrial wasteland referred to as the fourth nature, naturalised fallow land, agricultural land, alluvial forest and floodplains, and other public green spaces. In addition, small neighbourhood green spaces were considered ecological steppingstones: nature conservation parks, allotment gardens, cemeteries, dry biotopes, and other green areas. The overall tree stock in Leipzig was found rather good, and the age of the trees were relatively balanced.

Issues and challenges

Urban in-fill developments and urban densification projects in Leipzig negatively impact the structure, quality and characteristics of UF-NBS. Moreover, uneven tree species distribution, soil compaction due to prior industrial use, and urban tree health further deteriorate UF-NBS structure, conditions and quality. Furthermore, the depleting groundwater and regular drought events slow urban tree growth and increase tree damage. Other notable environmental issues impacting the health of urban forests and trees were land sealing and soil compaction of river catchment areas, the alluvial forests, and the flood plains. Actions may be prioritised for their protection and conservation. Inner-city regions are facing a shortage of public green space due to the compact city building coupled with increased green space demand for recreation, further degrading green space quality and causing a green deficit. During the discussion, it was identified that these environmental concerns need an effective and citizen-led management strategy focusing on tree maintenance, including watering, protection of trees from damages caused by residents, and tree pruning and felling of dead trees.

Key identified challenges needed immediate attention i.e. boosting the UF-NBS benefits by allowing natural succession, increasing diversity, and supplementing with small-scale measures, for example, adding new species or intensive irrigation in dry periods. The information about the use of UF-NBS, public perception and appreciation with respect to enabling and constraining qualities of such environments might help determine the impacts of UF-NBS on health and recreation benefits. In this context, citywide actions such as identifying green corridors of unsealed land- in and around settlements and mapping their ecological and recreational potential, demands and pressure might help achieve synergy between different ecosystem services and benefits. Further, the data would inform effective place-based UF-NBS management strategy and biodiversity protection measures. It was recognised that, in Leipzig, participatory governance and citizen science focus on UF-NBS through extensive participation and coordination projects supported by volunteers, e.g. tree planting and management projects improving communication between citizens and city administration (da Schio et al., 2021: CLEARING HOUSE report D2.1).

Potential of the citizen science approach

It was anticipated that citizen science projects would continue to be successful in exploring topics related to the CES benefits associated with landscape features, how UF-NBS affordances could promote recreation and relaxation, and how citizens could support active tree maintenance and shape future tree and forest protection and management strategies. Public participatory methods were expected to use web-based tools or apps as a long-term urban tree monitoring system (i.e., i-tree) to gather data on public tree characteristics as indicators of tree health and ecosystem service. The data observed on tree traits were projected to inform the general tree conditions and the need for

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immediate or timely actions for green space management and maintenance. Citizen involvement in the tree data collection was likely to sensitize citizens towards various urban tree and forest management practices (i.e., tree watering, tree disc maintenance) and educate them to practice sustainable forest and tree management techniques (e.g., tree pruning and felling). Through this participatory process, it was hoped that informed citizens would raise societal awareness regarding selecting and planting climate adaptive tree species. Evidence-based participatory design of UF-NBS was expected to enhance forest resiliency and boost ES and benefits, for instance, through small-scale natural interventions such as intensification of tree irrigation and diversification of tree species. These efforts were seen as potential ways to fill existing knowledge gaps regarding the selection of future urban tree species by utilizing local knowledge on climate-adaptive reforestation, selection of urban tree species, and the design of UF-NBS to minimize the heat island effect in urban areas.

PPGIS was envisioned as a useful tool in mapping preferences and demands for recreational, social, and educational activities and pressure on the urban forest environments. The PPGIS data were expected to inform researchers about how people perceive land use conflicts and access as barriers to green space recreation. Furthermore, the tool was likely to help raise public awareness about the CES and other ES values of different UF-NBS, especially the value of old trees compared to the young tree population.

Future actions prioritised for citizen science were to

- improve knowledge about the multi-functionality (ES, biodiversity) of UF-NBS in and around settlement areas.
- establish a long-term urban tree health-monitoring system to tackle the impact of climate change in urban areas.
- promote and maintain blue-green infrastructure for climate change adaptation.
- determine how people perceive access as a barrier to using those spaces for green space recreation.

4.2.3 Kraków, Poland

The study context

The UF-NBS in focus in Kraków was a river parks (Drwinka River Park), including natural areas and parklands with forests. Green spaces in Krakow included public green spaces; contributing green space; organized green spaces; agricultural, post-industrial, natural and semi-natural landscapes; and forest areas (regular forest, forest parks). Other green space types included green space surrounding the old town, waterfront areas, a large meadow, various parks, church gardens, cemetery, allotment gardens, landscape park- urban, and Natura-2000 sites. In addition, it was found that there has been growing demand to create more urban forests, protected green areas, small parks, and protected regions that are unused but perceived as necessary to maintain a healthy local ecosystem.

Issues and challenges

Kraków citizens were concerned about the degradation of natural values and qualities of river parks due to rapid urban densification and development. The ecological dimension of the river parks was considered good, with rich flora and fauna diversity. However, citizens had perceived air pollution and

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stormwater flooding as environmental concerns. Moreover, during the recent pandemic (Covid-19), the people of Kraków had come to see river parks as indispensable social capital.

This task addressed the need to understand the role of river parks in the city's future development, enhancing the quality of living conditions, promoting the health and well-being of citizens, improving the quality of urban social life, and adapting the city's climate strategies. Furthermore, in political discourses, Kraków was recognized as needing quality green spaces and housing. Additionally, a balanced park-based recreation, restoration, and climate change adaptation strategy was seen as a way to enhance the socio-ecological quality of Kraków's river parks.

The city's objective was to develop a suitable business model for implementing UF-NBS for air quality improvement and prioritizing river parks' socio-ecological values (case study: Drwinka River Park, Kraków). Despite the poor participatory governance system in Kraków, the CLEARING HOUSE citizen science module had collaborated with active social networks in and around River park areas to mobilize public participation in the CES assessment of river parks. However, more collaborative efforts were acknowledged as necessary to reach out to the less-privileged population and children in the city.

The purpose of the PPGIS survey was to explore the social dynamics of river parks, such as public perception of park accessibility, opportunities for activities and recreation and tourism, nature interaction promoting health and well-being, essential cultural services and benefits, needs for management actions and protection measures, activity and land-use conflicts, and the provision of park facilities and amenities. Furthermore, adapting climate actions using NBS required understanding how citizens of Kraków perceived the health impact of climate and pollution (i.e., Urban Heat Island (UHI), heat waves, flooding, pollution, and air quality).

Potential of the citizen science approach

Durin the discussion, It was planned to map citizen perceptions of environmental quality, visit frequency, preferences for place-based recreation activities, facilities, amenities, and the perception of activity and land use conflict in Kraków river parks, which are favorite destinations for recreation and health. This places-based mapping of CES was seen as potentially influencing political mandates to promote river park area protection and quality enhancement efforts. For example, a PPGIS app was to map what and how people value different services in a river park during recent visits, including specific environmental features, opportunities for socializing, and favorite destinations for recreation and health. Additionally, the participatory mapping of citizen perception and appreciation was intended to extract the enabling and constraining qualities of Kraków river parks, such as accessibility, green space availability, natural attributes and biodiversity, prospect and serene qualities, spaciousness and child-friendliness, safety, and socio-cultural qualities.

The survey was to include questions investigating the significance of local knowledge about native and invasive plants in the river parks. Moreover, the perceived data on naturalness and biodiversity were expected to identify ecological hotspots. Similarly, the perception of physical barriers and land use conflicts was to determine the spatial relevance of the impact of urbanization and UF-NBS fragmentation of the river parks. Therefore, this citizen science approach in Kraków was envisioned as a political instrument to persuade the city administration to protect the borders and enhance the quality and characteristics of the river parks in Kraków.

Future actions prioritised for citizen science were to

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- capture perception and appreciation of cultural ecosystem services and values of the river parks in Kraków.
- assess the demand and supply of ecosystem services of Kraków river parks
- understand the public perception of the role of river parks in promoting health and well-being.
- identify how people perceive the role of different UF-NBS in mitigating environmental issues (i.e. air quality, UHI effects and location-specific stormwater and flooding issues) and health-related impairments (i.e. health issues due to extreme climate conditions, exhaustion, pandemic situations, concentration problems).

4.2.4 Gelsenkirchen, Germany

The study context

The study area- Gelsenkirchen comprised a large forest area within the city region. The bio-physical condition of UF-NBS in Gelsenkirchen was as large forest areas, predominantly the "fourth nature"- a post-industrial vegetation growth on abandoned land premises. These post-industrial forest settings (industrial wetlands) were perceived as waste sites, urban blight and anti-social environments and were subject to land contamination and many disservices (e.g., eutrophication, homogenisation of biodiversity, heavy pollution). In addition, there were a growing public concern about the type and quality of urban nature with regard to the access conditions, functions and use, quality of nature experience, the public attitude towards the forest and street trees, the public perception towards tree management and tree care, and perceived health and well-being potential (enablers and constraints).

Issues and challenges

The objective was to investigate the importance of different types of UF-NBS for CES benefits and the demand for creating UF-NBS types in the city. The study investigated key factors of UF-NBS supporting children's accessibility to nearby UF-NBS and the potential for nature play experiences for children, meeting the recreational demands of the citizens, and preference for different UF-NBS types. The priority had been to investigate school children's use and visit preferences and their appreciation for such an environment based on play affordances, accessibility, safety, and environmental quality.

In Gelsenkirchen, citizen science and participatory methods aspired to educate citizens about sustainable development, UF-NBS data acquisition, and increase citizen involvement in assessing the CES benefits. A continuous supply of information on urban tree conditions and the need for appropriate tree and green space management actions (e.g., felling, watering, tree crown management) was used to help adapt climate change strategies in the city. The participatory mechanism emphasized multiethnic integration, the integration of young people, and ways to enhance public engagement with each other and the administration. The participatory tool focused on multiethnic integration, the integration of young people, and ways to increase public engagement with each other and the administration.

Potential of the citizen science approach

Citizen participation in the assessment of CES of UF-NBS in Gelsenkirchen was seen as a potential way to raise awareness among urban citizens regarding the recreation and health potential of UF-NBS, as well as opportunities available for nature experience and education. The rich industrial wetlands were considered biodiversity hotspots and home to many endangered animal and plant species. It was

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believed that informed citizens could provide data that might help identify different pathways through which UF-NBS features provide ES (CES) or disservices and could improve our knowledge about the multi-functionality aspects of urban industrial nature. A PPGIS tool was expected to focus on a few key questions which might unfold the perceived UF-NBS factors influencing the popularity of UF-NBS as a visit and recreation destination for perceived and actual recreational affordances, place-specific management and maintenance requirements, conflicts, risks, and perceived disservices. Citizen data was anticipated to help evaluate the links between UF-NBS management practices and provision of CES and the public preferences for UF-NBS types depending on management regimes, aesthetic quality, and human-nature interaction.

Urban tree health and maintenance related to drought, disease, and crown damage had been a significant concern in Gelsenkirchen. Using an app, citizen scientists were expected to continuously supply information about tree conditions and the need for appropriate actions for tree management (e.g., felling, watering, tree crown management). Moreover, the conflict between the land use activities and the UF-NBS quality and benefits, community-based needs assessment for new forest planting, lack of consciousness toward UF-NBS approaches, cost optimization for the maintenance of UF-NBS for climate change adaptation, and biodiversity enhancement were identified as barriers that needed to be addressed through Citizen Science. In addition, by maximizing citizens' involvement in data collection, it was hoped that citizens could be sensitized towards the diverse ecosystem services and value of nature, be aware of sensitive handling and use of natural resources, and be able to bring the benefits of forest ecosystems more into the public interest.

Future actions prioritised for citizen science were to

- raise awareness among urban citizens about the recreational potential and nature experience opportunities and promote environmental education.
- improve knowledge about the multi-functionality of the urban industrial nature.
- evaluate the link between different UF-NBS management practices and provision of CES and the public preferences for different UF-NBS types.
- assess and monitor the urban tree health and maintenance related to drought, disease
- assess and monitor urban tree crown damages.

4.2.5 (Lower-)Llobregat Valley, Barcelona, Spain

The study context

The ecological setting of Llobregat valley consisted of a newly planted riparian forest lacking dominant plant community characteristics and forest structure. The landscape setting was rather artificial in character and comprises old agricultural-based channel systems. The study area holded a key role in the ecological and social connectivity in the Barcelona Metropolitan area, while the river landscape offers many recreational opportunities. However, the need to balance preserving ecological values and providing ecosystem services was recognised.

Issues and Challenges

The objectives of the Llobregat Lower Valley study area were to promote afforestation and UF-NBS to restore the lower Llobregat river catchment, reconnect the riparian ecosystem to surrounding green infrastructure (GI), and develop a sustainable GI strategy for the provisioning of ecosystem services.

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Pollution-induced health effects or illness and community environmental actions to tackle pollution were some of the issues that had raised concerns among citizens and research communities. A citizen science participatory approach had been used to relate various perceived pollution levels in the region with the different configurations of UF-NBS, structure, and characteristics of green areas (amount, connectivity, typology), perceived health benefits or disservices of UF-NBS, perceived barriers to access green space for recreation, and the effect of confounding variables, e.g., age and gender. Additionally, inquiries about the relationship between trees/urban forest and perceived air quality were crucial.

Other barriers that had inhibited the efficient functioning of the Llobregat lower river valley ecosystem included the lack of foreseeable river flood scenarios and the process of urbanization and transportation infrastructure that depleted the ecological functions and connectivity. Raising awareness and educating citizens about the ecosystem services, especially on topics related to the delivery of CES, had been a key priority in urban regeneration and the social and ecological integration projects of the Llobregat lower valley region. In Barcelona, public participation had been a popular planning activity for managing urban parks and gardens at the municipality level. In the region, many citizen science-based urban biodiversity projects and actions using GIS-enabled informative online tools, visualization tools, and citizen engagement activities had supported the planning of metropolitan parks. Additionally, the task's objective had been to assess the public awareness and acceptance of GI measures for pollution reduction to benefit the region, the city overall, and groups in society.

Potential of the citizen science approach

The areas in the Llobregat river lower valley region were recognised as socially and ecologically disconnected. It was proposed that a participatory mapping method could engage citizens in mapping the perception of the most and least favorite places for recreation, accessible and connected areas for recreation and social activities, and the assessment of the factors affecting such conditions not only in the Llobregat river lower valley but also in the entire Barcelona city region. Informed citizens were expected to express their appreciation for the types of ecological corridors (for humans and biodiversity). Using a PPGIS app, citizens could continuously monitor the impact of UF-NBS in the lower Llobregat valley. This task was anticipated to enhance the citizens' knowledge of the local biodiversity (species and condition) and place-specific requirements for ecological restoration in the Llobregat river lower valley region and the Barcelona metropolitan area, such as the identification and selection of Mediterranean species for cropland.

Additionally, participatory mapping tasks were envisioned to explore public preferences for different UF-NBS types and settings with varying regimes of management affecting or altering its attractiveness and naturalness, thereby influencing the CES outputs catering to a wide range of human-nature interactions. Local knowledge of the territorial and cultural memory explaining how they are connected to the existing landscape and how they can be restored was considered necessary for the protection of the socio-cultural and ecological values of the existing UF-NBS. Using citizen science to gather such information was seen as a way to reinforce local environmental restoration efforts, actions for climate change adaptation, and knowledge about preserving landscape values.

Future actions prioritised for citizen science were to

- identify areas in the Llobregat river (lower) valley region that are under threat and socially and ecologically disconnected.
- explore citizen appreciation for the types of ecological corridors (for humans and biodiversity).

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- relate areas with various perceived pollution levels with landscape configuration, structure/green areas (amount, connectivity, typology), and health, using age and gender as effect modifiers.
- investigate the relationship between trees/ urban forests and perceived air quality.

4.2.6 Summary the key interests of city partners

Partner LUKE conducted an analysis of key themes and corresponding actions and objectives for CS in the various European case studies involved in the CLEARING HOUSE project. In summary, these include:

a) Understanding baseline UF-NBS conditions in terms of citizen appreciation and perception, including accessibility to UF-NBS, dangers and threats/ecosystem disservices, for both public and private land. This is also including perceived barriers and conflicts, e.g., related to land-use, land ownership and ownership-related barriers and conflicts (fencing), or conflicts arising from (over-)use of UF-NBS, and may also involve conflicts arising from political-administrative boundaries, e.g., related to management;
b) Multifunctionality of UF-NBS, including the evaluation of UF-NBS for recreation, social balance, and green compensation, the accommodation of overlapping functions (e.g., citizen perception of conflicts between recreational access and nature conservation goals), and benefits, and negative impacts of uses, e.g., on conservation efforts;
c) The cultural ecosystem service values of different types of UF-NBS, including private gardens, public parks and places, forests, as well as remarkable trees;
d) Assessment of tree health;
e) Ecological connectivity, including the assessment of the efficiency of UF-NBS to maintain biodiversity and to assess the scope to increase connectivity, as well as the perception or appreciation of citizens regarding strategies to enhance ecological connectivity, e.g., to reduce or replace traffic infrastructure (wide streets, parking lots);
f) Climate change adaptation, including citizen evaluation of environmental issues (heat, drought, flooding), and the role of UF-NBS to maximize adaptation to climate extremes and climate change-related hazards and thus resilience through their benefits, e.g., heat island mitigation, flood protection; drought/water security and water system resilience;
g) Effects on health and well-being, e.g., including noise abatement;
h) Awareness of citizens regarding UF-NBS benefits/ecosystem services, for different types of public or private land.

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5 Framework for CLEARING HOUSE Citizen Science Approach

5.1 Conceptualizing the role of citizen science in UF-NBS research

The project aimed to establish connections between the available UF-NBS-related knowledge in different case study cities on the one hand, and perceptions, demands and needs formulated by citizens, stakeholders, and practitioners on the other hand. In CLEARING HOUSE, the transdisciplinary and co-design approach (De Vreese et al., 2021: CLEARING HOUSE report, D3.2) identified challenges and questions related to UF-NBS. Furthermore, a scoping of recent literature (Scheuer et al., 2022) revealed certain traits of urban nature, referred to as environmental enablers and constraints that promote or hinder health and wellbeing benefit delivery by urban forests. This scoping of the literature identified specific research gaps, which can be summarised below as (Scheuer et al., 2022):

a) Limited knowledge about the connection between subjective impressions of quality and characteristics and intended compatible use of UF-NBS;
b) Limited knowledge about the connection between UF-NBS traits and individual decision-making based on personal use intentions;
c) Limited differentiation between the perception of a trait (quality and characteristics of UF-NBS) and its evaluation in relation to the desired use as a function of trait-based affordances.

Regarding hitherto research gaps identified, this task aimed to facilitate a CS approach to engage urban societies (including less-privileged groups and children) to assess the conditions of UF-NBS and investigate the subjective impression of UF-NBS impacts on health and recreation. The CS module was developed with an aim to promote sustainable ways to manage and protect UF-NBS in case study cities and support climate adaptation in areas using UF-NBS. Further, this approach supported the development of a flexible and adaptive PPGIS app that can gather data around specific UF-NBS issues unique to each case-cities. It was inticipated that the PPGIS data might further allow for an intra-and-inter-city comparison to inform UF-NBS-related policies and strategies to create, protect, and popularise UF-NBS as a recreation destination, thereby enhancing the health-enabling qualities of UF-NBS and climate change adaptation.

5.2 Background

The development of the citizen science module was integral to the two research perspectives organized in CLEARING HOUSE, such as i) the process of "case study analysis and synthesis" of the findings and ii) the "exchange and dissemination of the knowledge.” A tool for citizen science was expected to systematically and continuously provide UF-NBS information and spatial relevance of citizen perception, appreciation, preferences for UF-NBS traits, and their potential for co-benefits. It was anticipated to augment knowledge about the current governance and management of UF-NBS and contribute to urban forest or tree-based urban regeneration and area revitalization. The evidence was expected to strengthen UF-NBS-related policy and planning incentives for investment in and implementation of UF-NBS projects. Mapping and monitoring UF-NBS impact was seen as supporting socio-economic analysis of UF-NBS, effective implementation of UF-NBS, and generating knowledge for evidence-based design, planning, and protection of UF-NBS in Europe. These scientific efforts were anticipated to significantly contribute to the restoration and enhancement of the capacity of urban ecosystems and the delivery of beneficial services and might reduce disservices. Furthermore, the citizen science approach was expected to help overcome specific barriers by enabling pro-UF-NBS

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attitudes, actions, policies, and political moods and advocating for short-term goals and policies benefiting UF-NBS. Balanced selection or participation of target groups was recognized as key to the success of any citizen science approach.

5.3 Development of a citizen science framework in CLEARING HOUSE

Public participation tools (for example, "My Dynamic City" or "Maptionnaire") has been developed to actively engage citizens using the PPGIS method to collect data on perception and appreciation of CES of green spaces and place-based activities. This method engages informed and conscious citizens in the data collection process, thereby capturing the cultural sensitivity of UF-NBS and its benefits and the gap between the demand and supply of CES of urban green spaces. Conceptually, this method is expected to consider the distinct socio-economic and environmental setting of UF-NBS, cultural interactions between people and biodiversity, the cultural relevance of green space use and behaviour, place affordances for activities and appreciation with an emphasis on gender, less-privileged group, socio-environmental justice.

In CLEARING HOUSE project, these issues were partly dealt with through the co-design process by addressing cultural specifics and questions, e.g. social interaction, and sense of place. Nonetheless, to mirror such distinct demands surfaced in the CLEARING HOUSE collaborative learning process, a web-based and PPGIS-enabled citizen science approach helps to bridge the knowledge gaps, identify barriers to UF-NBS services and benefits, and gather a rich dataset on UF-NBS impacts on societies and environments. In this context, CLEARING developed a citizen science methodological framework common to all case–cities with enough flexibility and adaptability to address issues relevant to each city separately (Scheuer et al., 2022).

To address the challenges as summarsied in 5.1, Interest of key partners as summarised in 4.2.6, and knowledge gaps related to enabling qualities, constraining or detrimental factors as summarised in 3.1.3 , conceptually, the proposed framework included: (i) an elicitation of trait perception, i.e., capturing perceived trait expressions; e.g., eliciting perceived "size" (trait) as "small" (trait expression); and (ii) an evaluation of trait perception with respect to the intended use ("too small for social gatherings"). In so doing, the framework aimed to establish linkages between personal trait perception, evaluation, UF-NBS qualities, and use outcomes, and thereby, to identify possible relationships between UF-NBS traits, and personal decision-making, e.g., by identifying UF-NBS traits governing (in-)compatibility—i.e., affordances or the lack thereof—of UF-NBS for certain uses. The framework consists of these building blocks (Figure 2):

1) A foreground architecture, i.e., an elicitation and pre-selection of UF-NBS/UGS traits distinguishing between non-disturbing (beneficial, enabling, supportive etc.) and disturbing (unpleasant, constraining, restricting, limiting etc.) qualities, drawn from literature;
2) A foreground loop, i.e., the assessment of personal perceptions and evaluations, including:
    a. an assessment of the personal perception of traits;
    b. an evaluation of perceived traits;
    c. an identification of enabling or constraining UF-NBS, as a function of trait, trait perception, and evaluation;
    d. an assessment of trait-based UF-NBS compatibility with respect to (specific) personal use intensions; an elicitation of additional information, guided by key themes and case study partner interests. Such information may be related to specific traits, and may include perceived alternatives to local conditions, thereby, indicating desirable

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changes (pathways), but may also include ancillary information, e.g., observed tree health.

3) A background loop, i.e., a context for exploring personal decision-making, e.g., how UF-NBS traits, trait perception, and evaluation shape affordances, i.e., compatibility of UF-NBS for certain uses, and conversely, how decision-making may shape certain traits.
4) An intervention context, i.e., a nexus for (external) pathways of design, interventions, development, or management, that may be informed, e.g., by perceived local alternatives (cf. point (e) of the foreground look), and that may either shape UF-NBS traits, and thus, UF-NBS qualities, thereby also impacting personal decision-making.

In addition to these building blocks, a background architecture technically implemented the citizen science framework, i.e., putting it into operation, e.g., in the form of an app or in a webbrowser. This operationalization was sensitive to (local) context. However, being in principle independent of the framework's conceptual parts, the background architecture was not described in this concept note in more detail.

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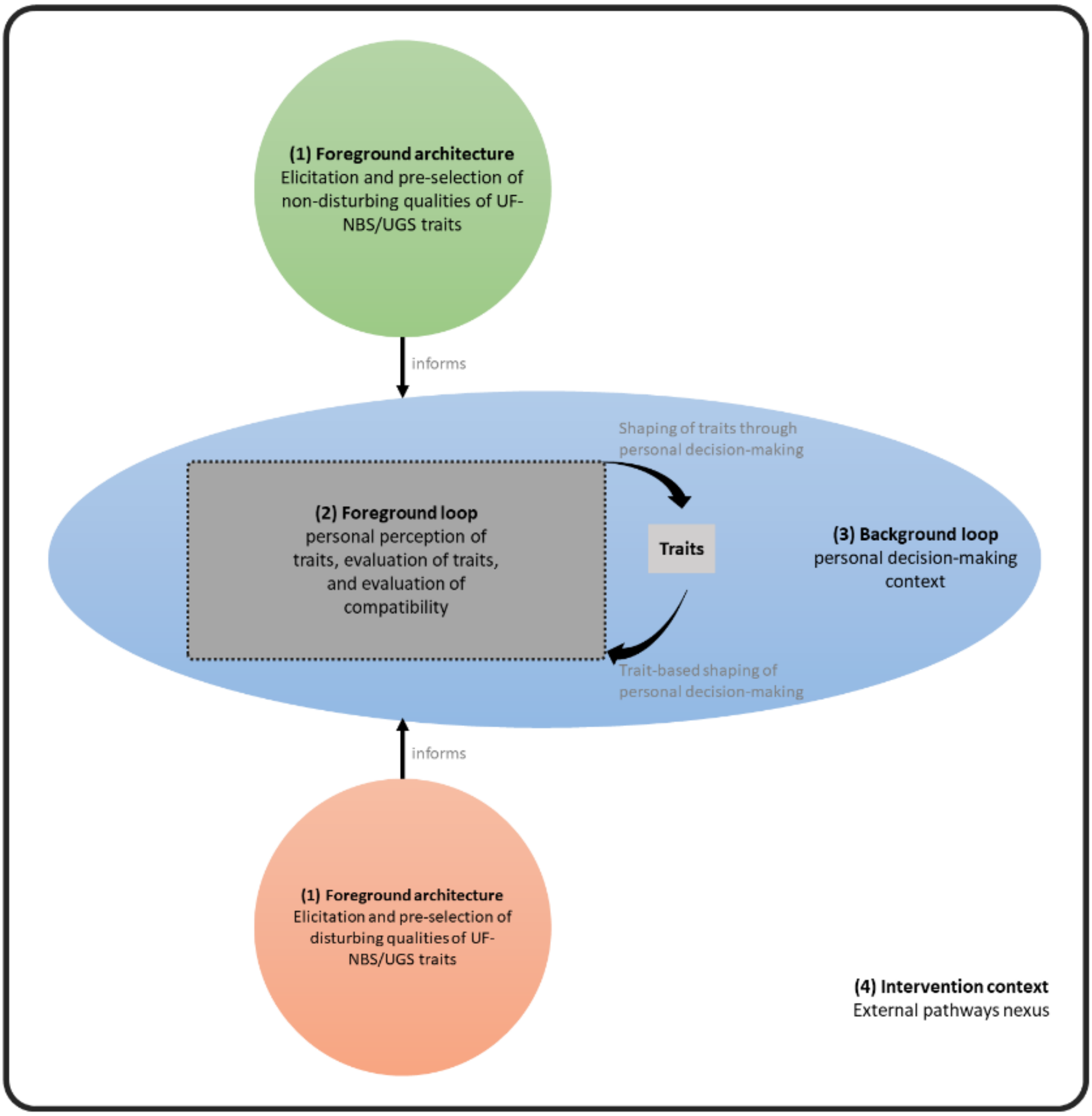

Figure 2: CLEARING HOUSE Citizen Science/PPGIS framework building blocks (Scheuer et al., 2022).

5.3.1 Foreground architecture

The foreground architecture was devised as an information component for guiding the more specific assessment through citizen science/PPGIS. Therefore, the foreground architecture guided the assessed traits, with respect to key themes and research objectives within the case study cities. The basic idea was that people perceive and evaluate a set of UF-NBS traits (i.e., provide a perception of trait expressions) related to selected UF-NBS qualities.

The character of these UF-NBS qualities maybe enabling, i.e., being founded on trait expressions evaluated as non-disturbing, in support of desired uses, or being beneficial in promoting human health and well-being, or constraining, i.e., being founded on trait expressions evaluated as disturbing, unpleasant, restricting, or limiting. The respective qualities are supported by published literature, as

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outlined above, and are founded, e.g., in Attention Restoration Theory or Perceived Restorativeness Scale (Hartig et al., 1997), Gestalt theory, or perceived multisensory dimensions (Grahn and Stigsdotter, 2010). They may furthermore be based on selectively constructed dimensions, e.g., related to accessibility or other UF-NBS characteristics (Wang et al., 2015). The foreground architecture was used in order to offer a set of traits which can be clustered/aligned to broadly used concepts such as accessibility, green qualities, attractiveness etc.

The qualities considered within the foreground architecture, has included various traits and criteria. These criteria were used for the differentiation of socio-economic-demographic groups, governed by the specific research interests in each case study city. This approach was considered sensitive to local context, and inclusive. It had alos been thought necessary to examine areas relevant to marginaliased groups, consider heterogeneity of people. Furthermore, it had explored factors governing outdoor recreation, as well as interactions with health and well-being of marginalised groups. This comprehensive and inclusive approach aimed to obtain more comprehensive and inclusive findings (Gentin, 2011, Roe, 2016). Moreover, differing perceptions, but also differing predispositions to recreational or restorative effects due to differences in personal (personality or other personal) characteristics had been considered. Interactions between such personal characteristics and UF-NBS traits and impacts had been evaluated (Feng et al., 2022; McEachan et al., 2018).

5.3.2 Foreground loop

As outlined above, the foreground loop, shown in the middle of Figure 2, consists of:

a) The elicitation of trait perception, i.e., how expressions of selected traits are received. For example, regarding a trait tree cover, this trait may be personally perceived as “scarce” (trait expression). The expression of traits may also be perceived as “present” or “absent”, e.g., regarding amenities/facilities.
b) A personal evaluation of these perceived trait expressions as “positive” or “negative” by the respondent/participant. Here, positive refers to enabling UF-NBS qualities, that render a space compatible with personal intentions, whereas negative refers to constraining qualities that may be perceived as incompatible with personal use intentions. The former qualities are depicted in Figure 2 in green, the latter in orange. The underlying assumption regarding this trait evaluation is that a given trait expression, e.g., “scarce tree cover” or “present trash bin” is not directly enabling or constraining an intended UF-NBS use (“seeking shadow”, “meeting friends”), but can be perceived differently at personal level (“too scarce”/“still enough”, “not enough trash bins”/”more than enough trash bins”).
c) The elicitation of the perceived UF-NBS compatibility, at a given location, for specific/intended uses, based on this personal evaluation (“I went home because I could not find a spot with enough shadow”). This is necessary in order to evaluate which trait expressions, or their perceptions therefore, affect the intended or realized UF-NBS use at personal level.
d) The elicitation of personally desired, locally-relevant alternative trait expressions. For example, this refers to preferred changes regarding specific traits (“prefer more tree cover”, “provide more means to dispose of trash”). Therefore, the framework does not only focus on an elicitation of perceptions with respect to the status-quo (current conditions), but seeks to elicit “alternatives”, i.e., possible changes in trait expressions, as a means to identify desirable future conditions, e.g., for a better support of intended uses.

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5.3.3 Background loop

The background loop is a decision-making cycle which consists of a behaviour intention, the perception and evaluation of trait expressions relevant for this intention, and the resulting use behaviour. The elicitation of perceptions of trait expressions and their personal evaluation is intended to reflect on a personal, trait-based decision-making process. The background loop sought to explore how personal decision-making is shaped by traits, and trait expressions, respectively, and conversely, how personal decision-making and resulting use behaviours may impact traits. The background loop had thus been thought to reflects on the impacts of traits on perceived use compatibility of UF-NBS.

5.3.4 Intervention context

The proposed intervention context conceptualised (external) pathways (yellow arrows in Figure 3). These pathways resembled different forms of actions, or interventions related to the management of UF-NBS. As a nexus, the intervention context linked such actions and interventions with UF-NBS traits, and was therefore conceptualised to describe the shaping of traits (or trait expressions, respectively) through actions/interventions, and thereby, possibly impacting decision-making at personal level.

Here, the pathways proposed were expected to be informed by findings from citizen science—here, e.g., elicited desired changes to trait expressions at personal level as part of the foreground loop—as well as stakeholders or other CLEARING HOUSE tasks, and would be aligned to local policy goals. Within the intervention context, conceptualised pathways were designed to link to various drivers, i.e., local challenges, local needs/demands, or planning, e.g., as elaborated by case study partners. In this context, demands were regarded as a broad umbrella term, denoting changes perceived as needed with respect to specific traits, e.g., targeting disturbing UF-NBS qualities such as the removal of barriers.

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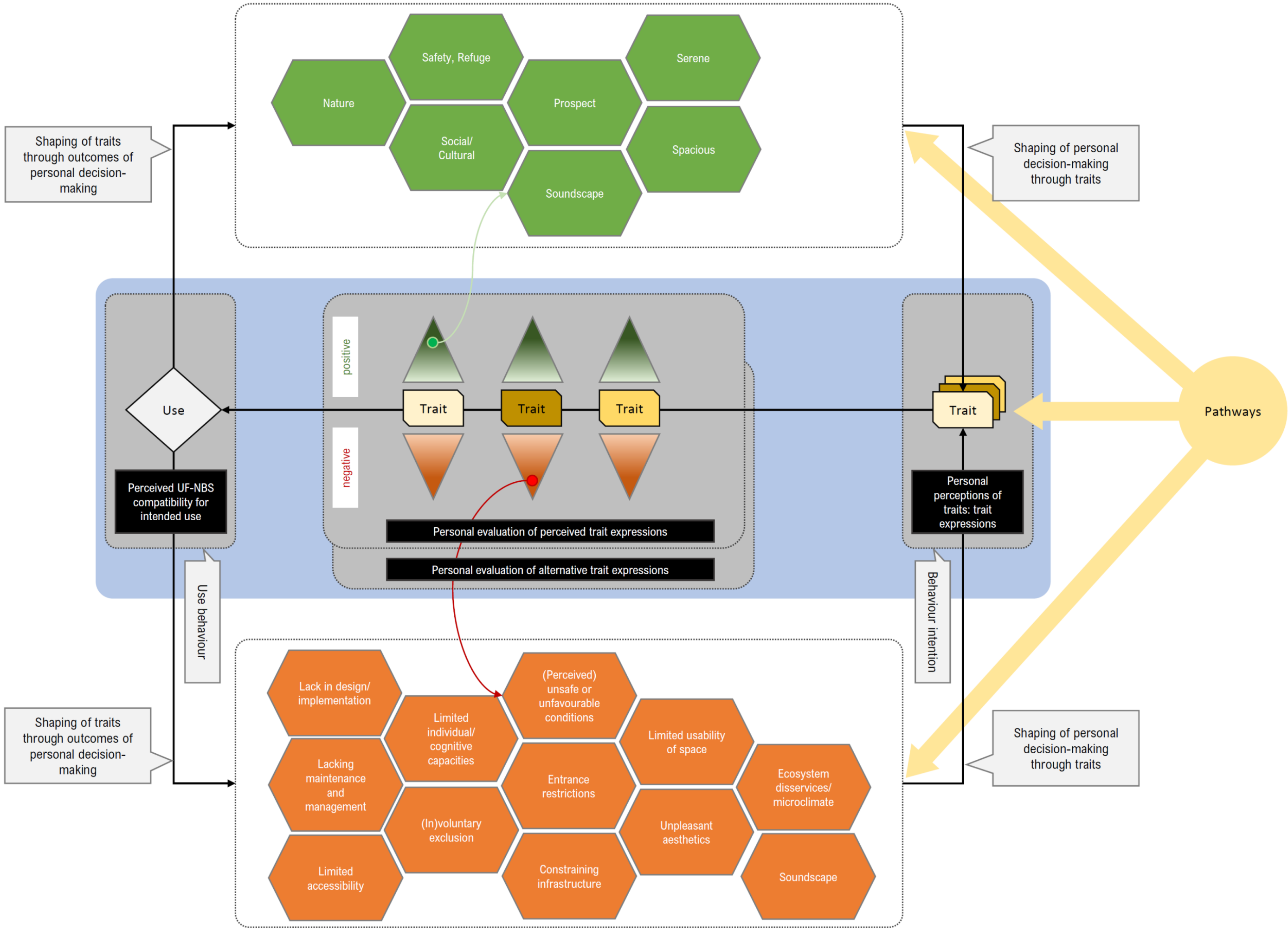

Figure 3: Detailing of the Citizen Science/PPGIS framework (Scheuer et al., 2022).

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However, the intervention context and corresponding pathways also aimed at the provisioning of additional, the improvement of existing, or the maintenance of current ecosystem service (benefits) delivery (cf. Scheuer et al., 2021), e.g., the assessment and subsequent improvement of tree health and thus tree-related ecosystem services/benefits. Therefore, the intervention context was expected to shape the proposed foreground architecture, and thereby, the foreground loop as citizen science in the narrower sense.

5.4 Piloting PPGIS for Citizen Science in CLEARING HOUSE

Piloting PPGIS as citizen science instrument in CLEARING HOUSE has been conducted in the city of Zagreb, Croatia. Here, piloting refers to testing methodological and technical PPGIS concepts, as well as feasibility of PPGIS use for the elicitation of (cultural) ecosystem (dis-)services, citizen perceptions, awareness, etc.

In the city of Zagreb, Croatia, the main aim for the implementation and use of PPGIS was to explore the perception and use of the city's tree-based urban green infrastructure as stated by citizens. Cultural ecosystem services and disservices were used as umbrella terms in the study. Knowing and understanding the dominant perception people hold towards certain UF-NBS types can enhance city-wide planning and managing of urban green infrastructure. PPGIS, with collecting spatial data of the stated perception adds a new, subjective, spatially explicit layer that can be used in decision-making.

For the purpose of this study, a web-based PPGIS tool called MyDynamicCity (MDC), initially developed by HUB prior start of the CLEARING HOUSE project, has been adapted. MDC Zagreb hosted a PPGIS questionnaire which collected spatial data on perception and use of Zagreb's urban green spaces. The questionnaire was designed to spatially explore the perception of several cultural ecosystem services' categories (Place Attachment, Recreation, Aesthetics, Education and Cultural Identity), ecosystem disservices, and additionally, specific attributes of perception and use (recreative activities, attributes of aesthetics and disservices). The focus of the study was only on urban green spaces in the city of Zagreb and the target group of respondents were citizens of Zagreb being 18 years old or older.

Data collection started in June 2021 and lasted until November 2021. During that time PPGIS questionnaire was distributed in different ways among citizens of Zagreb. In total, 384 citizens mapped 5,757 spatial points in the city of Zagreb in all explored categories of perception and use. Respondents mapped the most Place Attachment, Education and Cultural Identity followed by Walking (attribute of recreation) and attributes of aesthetics (Beautiful, Maintained, Natural and Restorative). Interestingly, the perception of disservices was not as expressed resulting in the lowest number of mapped spatial points for those attributes throughout the city of Zagreb.

Females dominated the collected sample of respondents, along with the respondents that are in the age category 31-45, those highly educated and employed. This sample deviates from the characteristics of the general population in the city of Zagreb. However, it is similar to samples in other PPGIS studies. In addition, respondents were frequent visitors to urban green spaces meaning they know and care for urban green spaces in Zagreb. Spatially, respondents to the PPGIS questionnaire were located in every city district in Zagreb, indicating city-wide coverage of collected data.

Since this was the first implementation of the PPGIS study in the city of Zagreb it can be concluded that it was successful since a significant amount of data was collected and locally important information

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was gathered that can be used in decision-making and long-term monitoring of UF-NBS in the city of Zagreb.

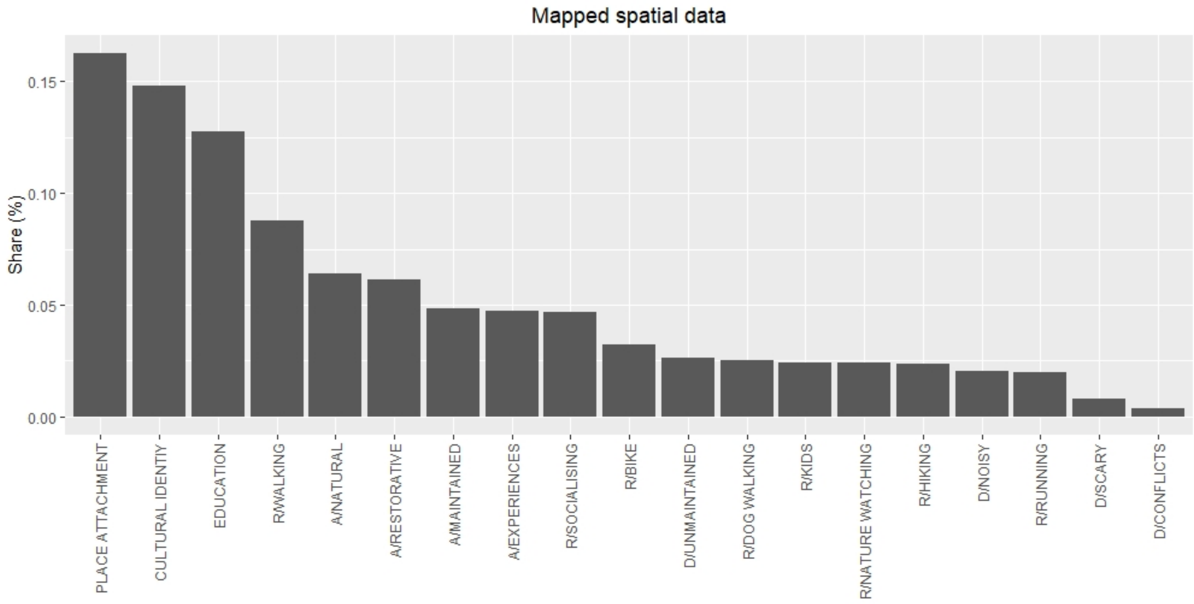

Figure 4. Percentage of observations and and different trait perceptions of UF-NBS.

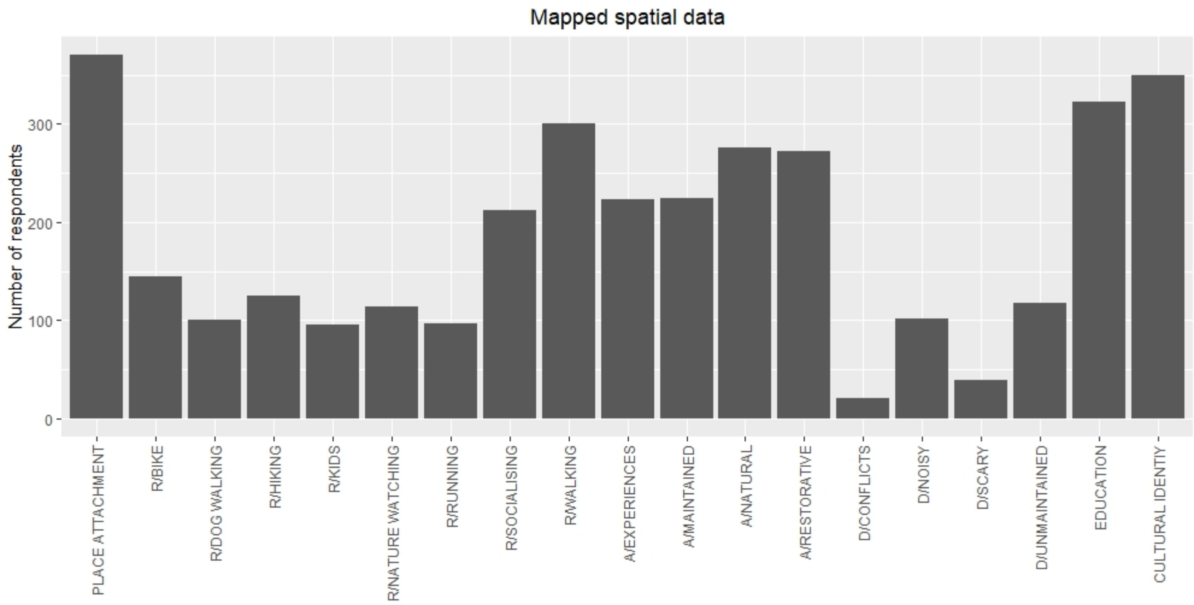

Figure 5. Number of observations and different trait perceptions of UF-NBS.

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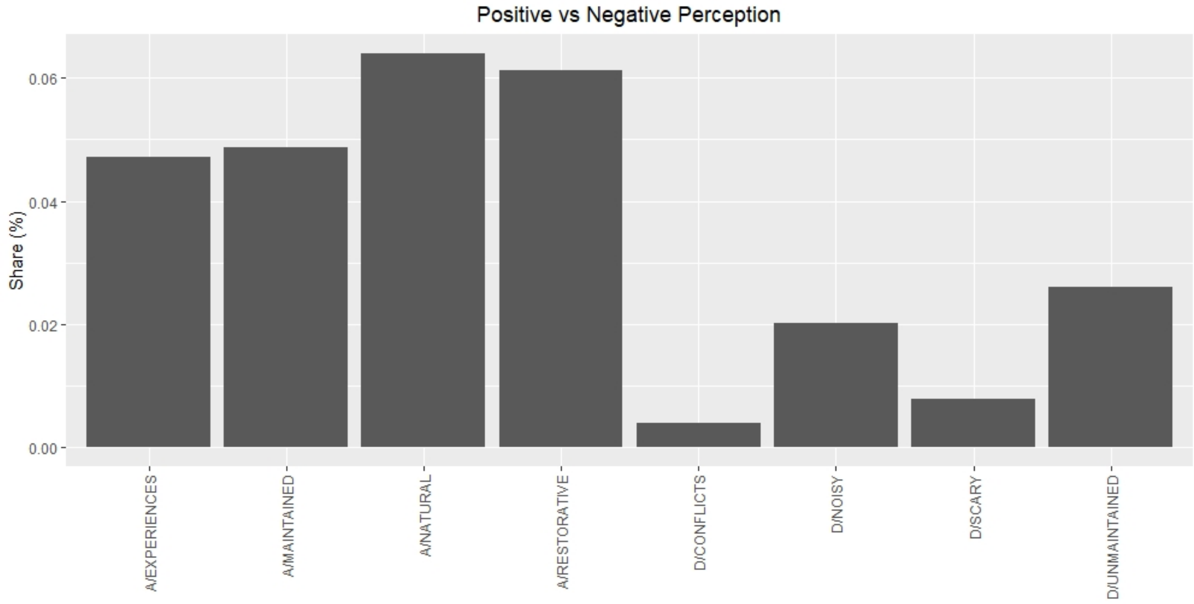

Figure 6. Percentage of observations and positive and negative perceptions of UF-NBS.

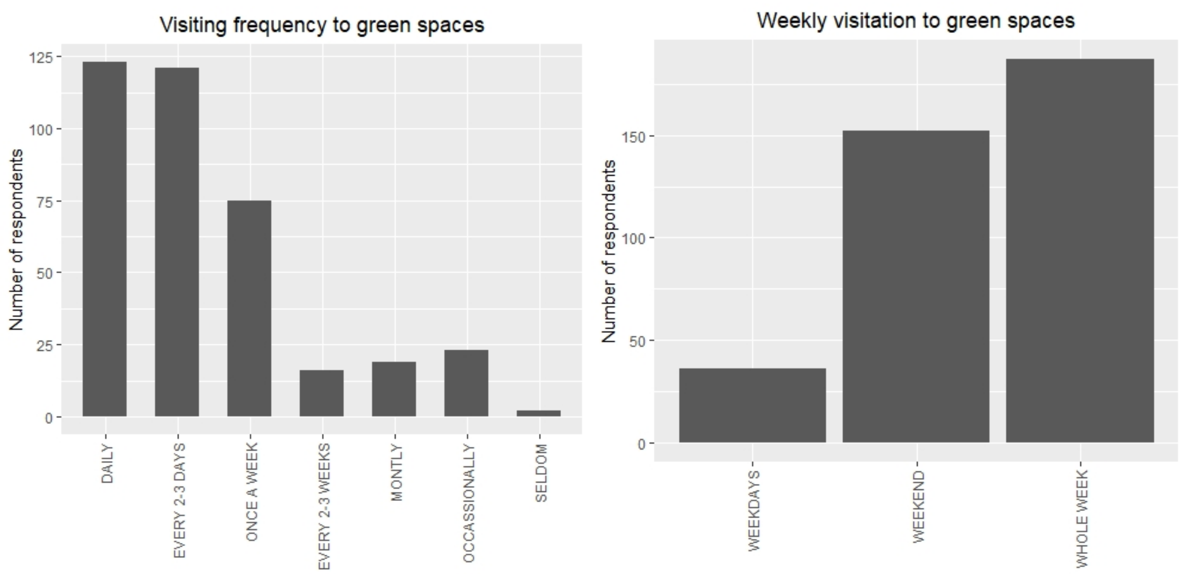

Figure 7. Number of respondents and visit frequency and weekly visitation to green sapces.

Spatial data regarding citizens' perception of cultural ecosystem services and disservices from tree-based urban green infrastructure in Zagreb is illustrated in Figure 8. The data reveals that citizens recognizsed both benefits and disservices across the city. Moreover, specific hotspots were identifiable, indicating areas where these benefits and disservices coincide. This data facilitated further spatial and statistical analyses, enabling a deeper understanding of the specific factors influencing the provision of benefits as well as disservices.

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Figure 8. Distribution of spatial data on the perception and use of tree-based urban green infrastructure in the city of Zagreb collected with MCD PPGIS questionnaire.

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5.5 Implementing PPGIS for Citizen Science in CLEARING HOUSE

Based on the piloting of PPGIS in Zagreb, Croatia, expériences gained from the application of MyDynamicCity (MDC) were evaluated in order to further implement PPGIS for the CLEARING HOUSE cases. Whilst it has been shown by the Zagreb pilot that PPGIS is a feasible tool for the scope and research interests in focus, several drawbacks were also identified. These mainly refer to technical aspects, particularly local tool deployment (hosting, web server admninistration etc.), that required critical involvement of local IT, and was deemed challenging to a certain extent. The involvement requiremend was considered a critical risk for deploying PPGIS in the cases, e.g., regarding personnel and IT resources. To mitigate these risks, therefore, it has been determined that a cross-case PPGIS deployment would be desireable, thus allowing a single PPGIS instance to be used simultaneously in different cases, thereby limiting technical expertise required in each case.

The PPGIS My Dynamic Forest (MDF), a further development of MDC realized outside the CLEARING HOUSE project but licensed for use within the project, has subsequently been chosen, adapted to project needs, and deployed for the implementation of CLEARING HOUSE citizen science (Scheuer et al., 2022). As such, it corresponded to the background architecture, i.e., the technical basis for conducting PPGIS surveys etc. The tool combines geofencing, an online questionnaire survey, and an online mapping interface, to collect aspatial and spatially explicit data. The CLEARING HOUSE PPGIS (i.e. MDF) was deployed and distributed through the case study cities and the CLEARING HOUSE project partners in 2023.

Methodologically, in line with the trait-based conceptual framework, MDF adopted the concept of social-ecological traits as research theme-related boundary objects for the conceptualisation and the design of PPGIS questionnaires/surveys. In this regard, depending on the research interest per case, questionnaires were tailored to the case's demands, and using (co-selected) sets of (most-important) traits, short and focused questionnaires were devised. So-doing was expected, (i), to facilitate eliciting most-relevant perceptions of spatial and aspatial UF-NBS (local, place-based) qualities, i.e., trait expressions ; and (ii), to foster multiple participation of respondents over space (i.e., at different locations) and time, thereby also allowing for the exploration of potentially small-scale variations in trait expressions and trait perceptions. Use of open-ended questions in addition to closed questions allowed for the elicitation of a broad range of subjective impressions and responses to a specific UF-NBS trait or issue, which were then categorised into a established framework of perceived UF-NBS traits as health enablers or constraints (see Table 1). Based on Baumeister et al. (2020; 2022), open questions were also used to capture additional values of UF-NBS, and to facilitate the identification of more intangible attributes such as inspiration, spirituality, or cultural significance of intended or desired use of UF-NBS, which are usually overlooked in favour of more commonly expressed benefits of the urban forest, e.g. recreation or aesthetics.

To delineate PPGIS areas of interest in accordance to a case's demands, i.e., areas within which specific surveys are used for the elicitaiton of citizen perceptions etc., MDF adopted geofencing, i.e., the availability of questionnaires to a respondent, based on user location.

Technically, MDF is a web application. MDF can host (store and provide to the user) a multitude of questionnaires, including questionnaires across cases, questionnaires across areas of interest for a given case, or multiple language versions of a given questionnaire. Geofences, that delineate areas of interests, are internally stored as geometry objects, and linked to applicable questionnaires. If a user

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opens the MDF application on a mobile device, provided uer permission and opt-in, the device's location is subsequently retrieved using the so-called geolocation API, and the user's location is used , on the one hand, to determine locally available questionnaires, and on the other hand, to implicitly georeference user responses. Mobile use of MDF is consequently the preferred mode of operation, however, as the application is responsive in design, it is alos designed to be used to conduct « classical » PPGIS surveys on desktop, e.g., based on disseminated codes/links.

Again also building on the expériences gained in the piloting of PPGIS in the form of MDC, MDF's methodological concept and the technical functionality were evaluated and tested as part of a seminar at HUB (Humboldt University, Berlin). In HUB, overall usability of the app was mostly positively evaluated by students, and the app was deemed functional. Results showed that spatialsation of responses using the geolocation API results in usable datasets, with margins of error, with few exceptions, typically within normal GPS accuracy. Hence, based on this intial testing, the overall PPGIS approach was considered feasible for application in CLEARING HOUSE case study cities. To support the use of MDF across cases, i.e., to enhance local acceptability, user convenience, and usability of the tool, the application's front-end (user interface) has been translated to German, English, Polish, and Catalan. Likewise, surveys were provided in the relevant locale, as well as in English.

Figure 9. The principle of My Dynamic Forest (MDF) tool. An MDF instance is able to host various questionnaires (left). Any given questionnaire is typically linked (geofenced) to an area of interest, as indicated by dotted lines. Notably, a given questionnaire may be linked to a single or to multiple areas of interest, and conversely, any given area of interest may be linked to one or more questionnaires. Subsequently, if a device is located within an area of interest, available questionnaires are determined, and responses spatialised.

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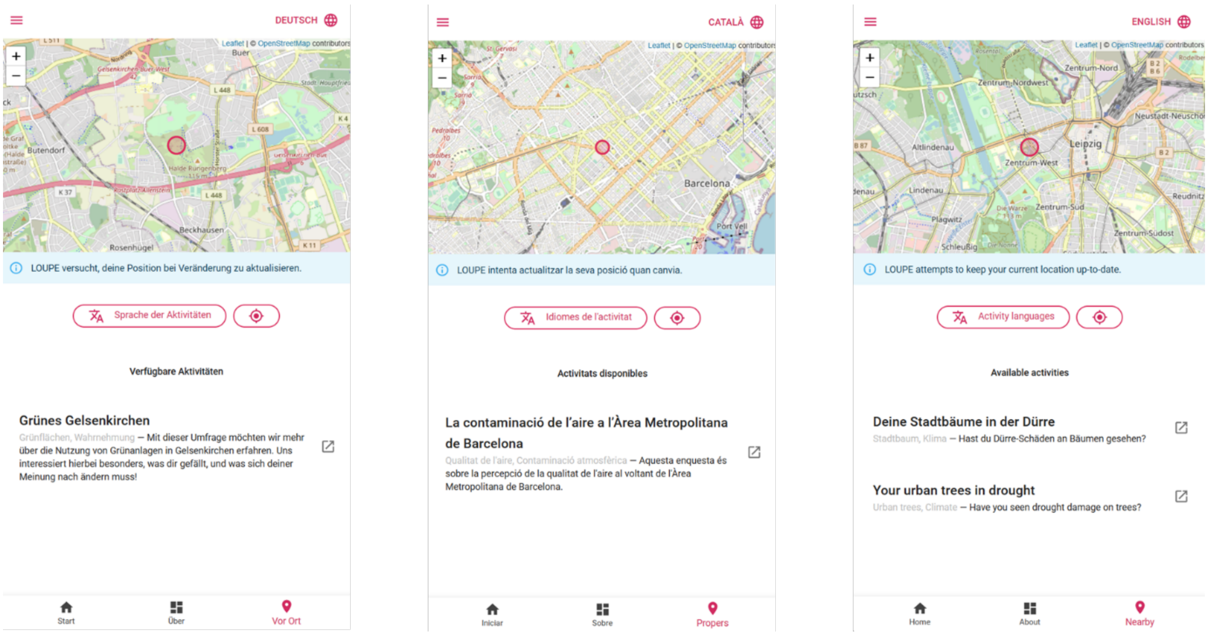

Figure 10. As MDF implements questionnaires across cases through geofencing, available questionsnaires are shown as a function of user location, exemplified for Gelsenkirchen (left), Barcelona (middle), Leipzig (right).

6 MDF Application and Results for CLEARING HOUSR European case studies

The purpose of this section is not to report the results or any comaparative analysis between cities, instead to demonstarte how the application of the MDF tool across various case study cities underscores its versatility in capturing and analysing UF-NBS)traits in relation to local issues. In Barcelona, Gelsenkirchen, and Kraków, MDF effectively gathered diverse data ranging from pollution traits and health impacts to public usage patterns and perceptions of urban greenery. This comprehensive gathering of spatial and demographic information, alongside perceptions of environmental quality and community needs, demonstrates MDF's capability to integrate local actions with broader environmental strategies. The success of MDF in these diverse settings highlights its efficacy in not only understanding but also enhancing the interaction between urban residents and their environment, proving it an invaluable tool in the management and improvement of urban UF-NBS.

My Dynamic Forest (MDF) was implemented between 2022- 2023, in various case study cities as part of the CLEARING HOUSE project to capture the unique UF-NBS issues inherent to each location. Despite identifying a broad spectrum of UF-NBS issues during the needs mapping phase, we strategically concentrated on the more urgent issues throughout the tool's piloting and testing stages (see also report D4.5). This selection process was detailed in Section 4.2, where specific issues were chosen based on their prioritisation. Furthermore, through MDF, we endeavoured to tackle the challenges highlighted in Section 5.1. The MDF framework we propose focuses on the elicitation of trait perception of UF-NBS, and evaluates these perceptions against the requirements of their intended use of place i.e. UF-NBS. This approach not only establishes connections between individual trait

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perceptions, evaluations, UF-NBS qualities, and outcomes but also aims to uncover potential correlations between UF-NBS traits, their qualities, while addressing the issues highlighted in the case study cities. Specifically, it seeks to determine how UF-NBS traits influence the compatibility – or lack thereof – of these solutions for specific uses. Here we present some of the results from applying the tool. This is to illustrate the tool's applicability in various geopolitical and environmental contexts and to demonstrate its ability to systematically elicit issue-based and context-specific trait perceptions of UF-NBS.

1. Leipzig/ Halle, Germany

This case focused on exploring the use of citizen perceptions of tree health, captured through the implemented PPGIS platform, as a means to support monitoring UF-NBS conditions and health. This was especially important for ensuring long-term delivery of tree-related benefits, however, with advancing climate change impacts, e.g., heat and drought, impacting tree health substantially. An effective management strategy driven by citizen involvement may support (long-term) maintenance of UF-NBS, e.g., focusing on tree care and the protection of green spaces, along with targeted actions such as planting new species and providing intensive care during dry spells. Therefore, in Leipzig, use of MDF for collecting tree health-relevant data was tested, mainly in two dedicated “field campaigns” in 09/2022 (with a sample size of 1032) and 09/2023 (with a sample size of 1683). In these campaigns, MDF was used for the systematic elicitation of perceived tree damage/stress traits, including, e.g., leaf scorch, leaf decolorations, leaf curling, tree crown de-densification/defoliation, bending of branches, branch fall, and dead shoots, etc. In addition, in 2023, affected tree genus has also been elicited, based on the most common tree species found in Leipzig.

Gathered data allowed to gain insights into commonly occurring tree damage/stress traits, based on public perception. Here, these include bending of branches, crown de-densification/defoliation, and to a lesser extent, bark cracking, leaf scorch, etc. In this regard, a single damage/stress trait is perceived most often, however, often, 2 and more damage/stress traits are also perceived simultaneously (Figure 8, 9). It may be hypothesised that such a simulatenous perception of multiple tree damage traits may indicate more severe impacts on tree health/UF-NBS conditions. Based on 2023 data, it appears that particularly Platanus and Populus trees, but also Tilia and Robinia are amongst the more-affected tree genera (Figure 9). Finally, in line with the overall MDF concept, submitted observations were georeferenced, i.e., bound to the user’s device location. This allowed mapping of perceived tree damage traits, thereby allowing a subsequent identification hotspots, as exemplified in Figure 10.

A long-term establishment of this PPGIS use case will subsequently support detection of trends, as exemplified by the 2022-2023 campaigns.

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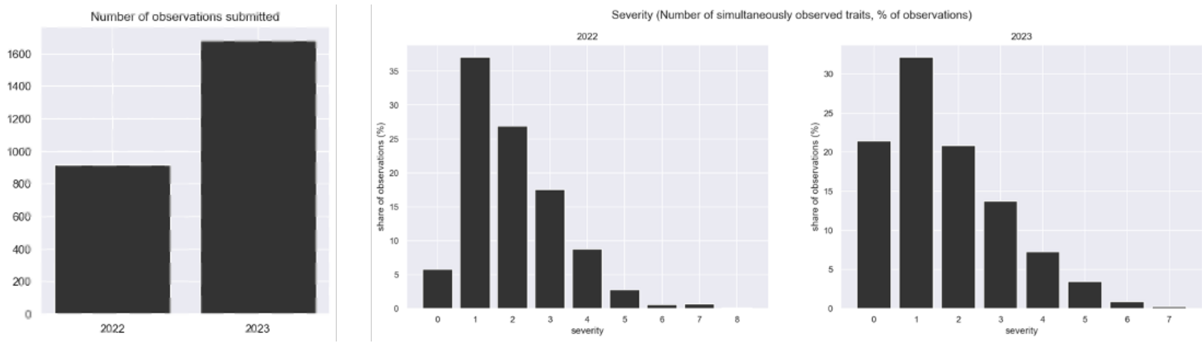

Figure 11. Number of observations and severity of tree conditions as shared observation (%).

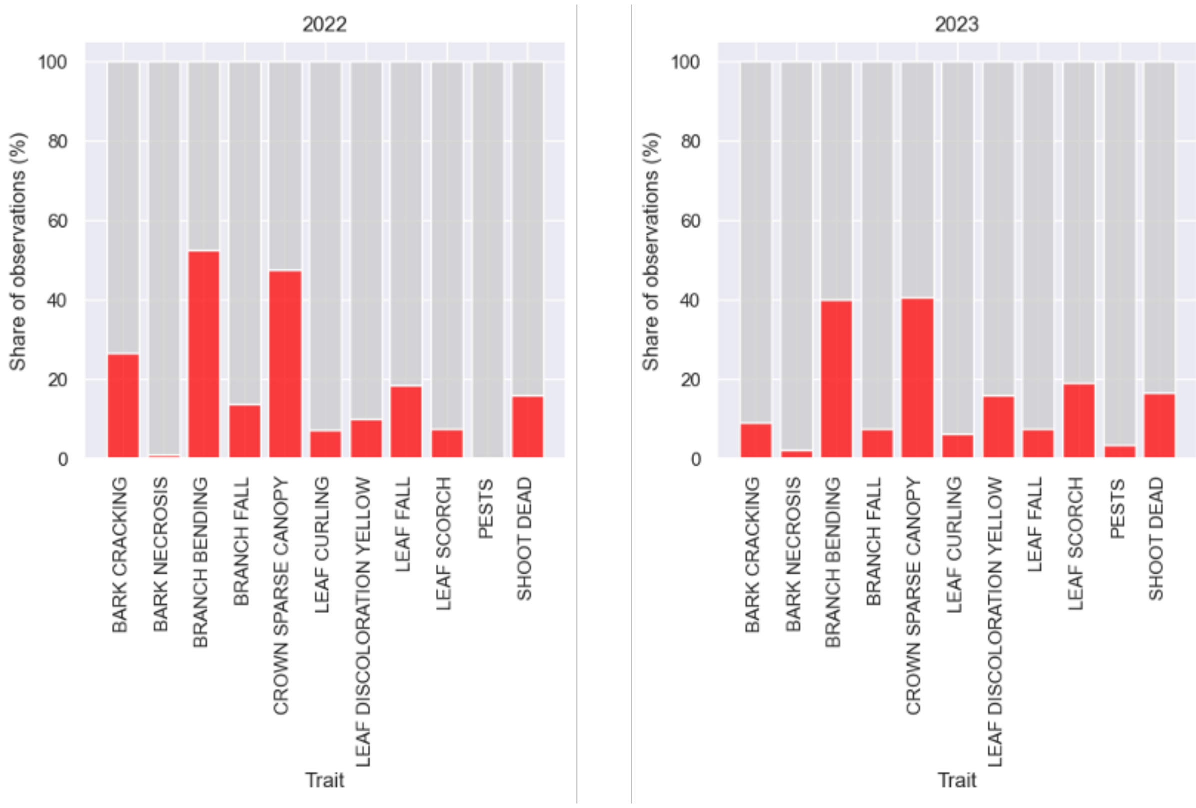

Figure 12. Share of observations with perceived tree damage/stree traits in 2022 (left) and 2023 (right). In both years, bending branches and crown de-densification/defoliation are the most commonly perceived tree damage/stress traits.

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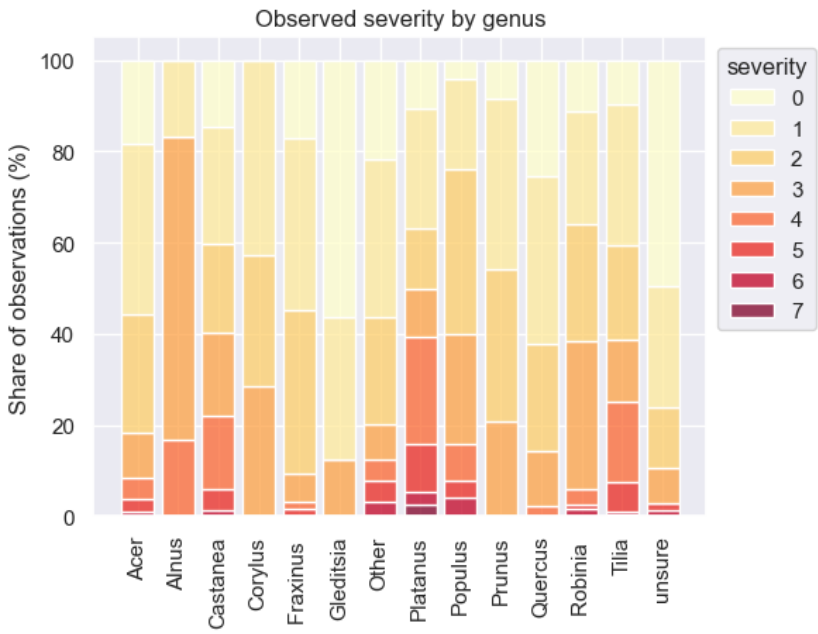

Figure 13. Number of simultaneously perceived tree damage/stress traits, per tree genus. Red colors indicate a higher number of simultaneously perceived traits, which may speak for higher affectedness of associated tree genera with impacts of heat/drought. Platanus, Populus, Robinia and Tilia are amongst the tree genera seemingly most impacted.

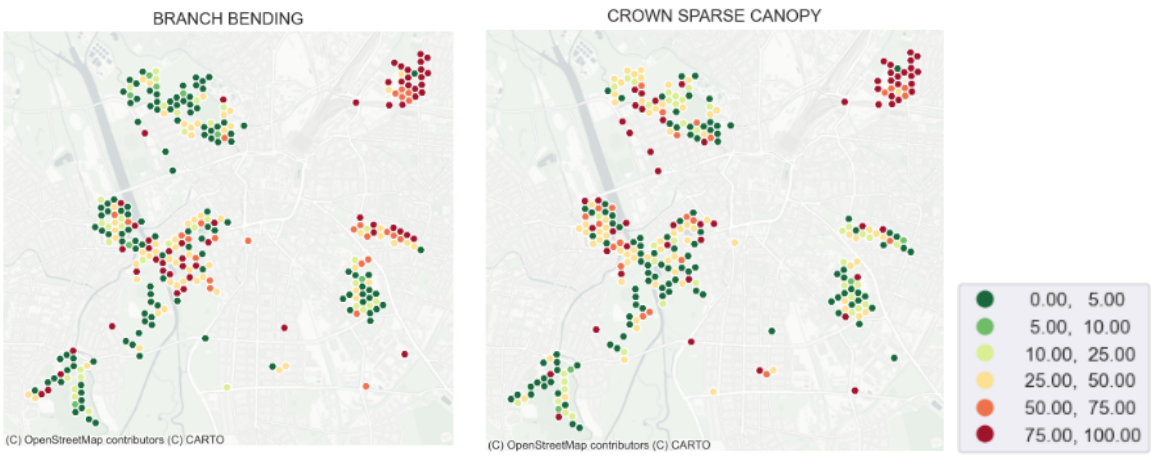

Figure 14. Share of trees with corresponding damage trait perceived in 2023, exemplified for branch bending trait (left) and crown de-densification/defoliation (right). It becomes clear perceived presence/absence of tree damage traits varies considerably between Leipzig's urban green spaces.

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2. Drwinka River Park, Kraków, Poland

In case of Kraków, the residents were increasingly worried about the impact of urban expansion on the natural virtues and qualities of their river parks, which remain ecologically vibrant with diverse flora and fauna. The study focused on the Drwinka River Park area, shows a pressing need to integrate river parks into the city's growth plans, focusing on enhancing living standards, health, and social life, while aligning with climate strategies. The aim of MDF application was to understand the public's interaction with river parks, covering accessibility, recreational activities, health benefits, and the necessity for management and protection, while also considering the residents' views on the climate and pollution-related health impacts, to inform climate-responsive actions. In Kraków, the MDF tool was implemented in 2023 to gather information on awareness and attitudes towards the Drwinka River, intended use and visitation frequencies, frequency of visits by purpose, spatial data on positively and negatively perceived UF-NBS traits, perceived issues and comments, perceived naturalness, agreement with preserving the current character, support for protection and restrictions, as well as demographic variables such as age, gender, education level, occupation, and place of residence. Additionally, there was a focus on discerning the community's perspective on the effectiveness of various UF-NBS in addressing environmental challenges, and eco-social compensation issues, comments and suggestions.

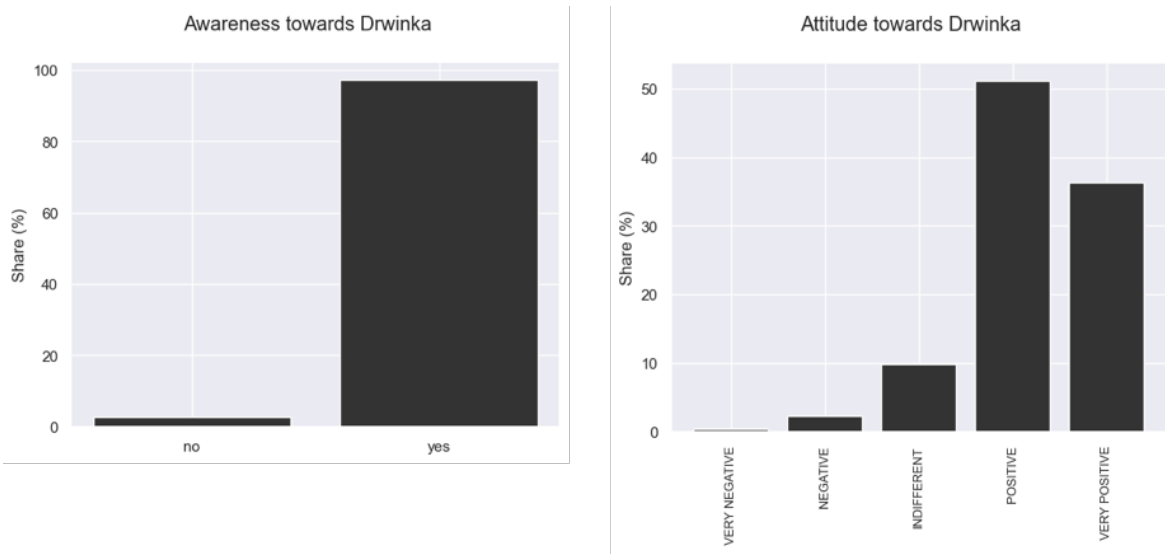

Figure 15. Respondents' awareness and attitudes towards Drwinka River Park.

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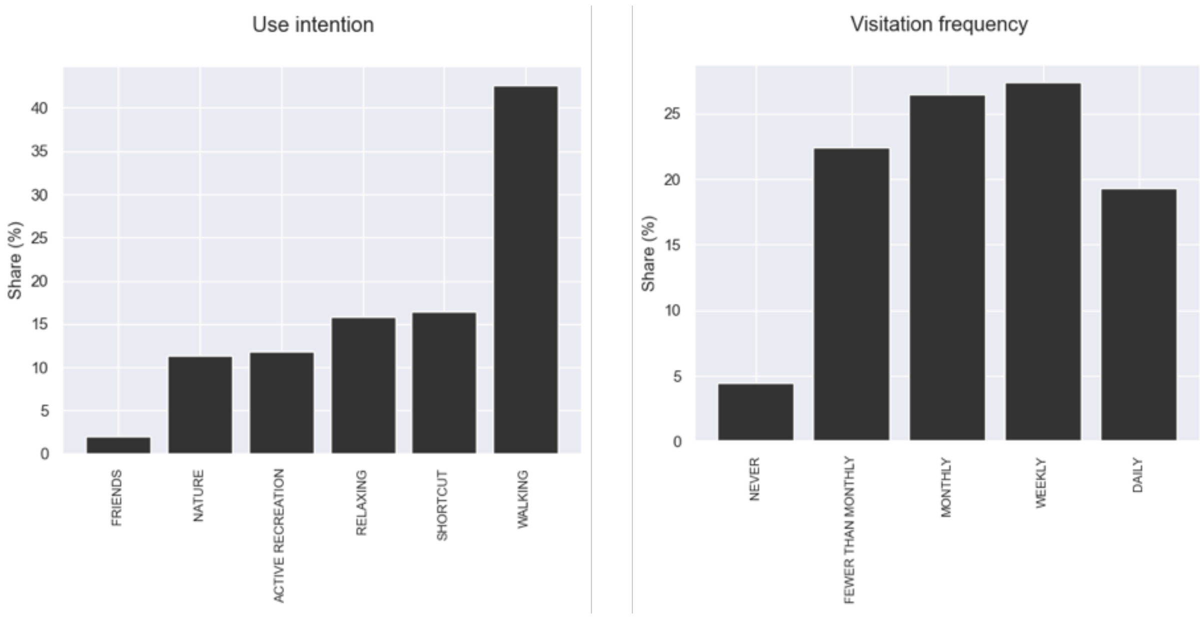

Figure 16. Respondents' use intention and visitation frequency.

Figure 17. Respondents' visitation frequency by purpose.

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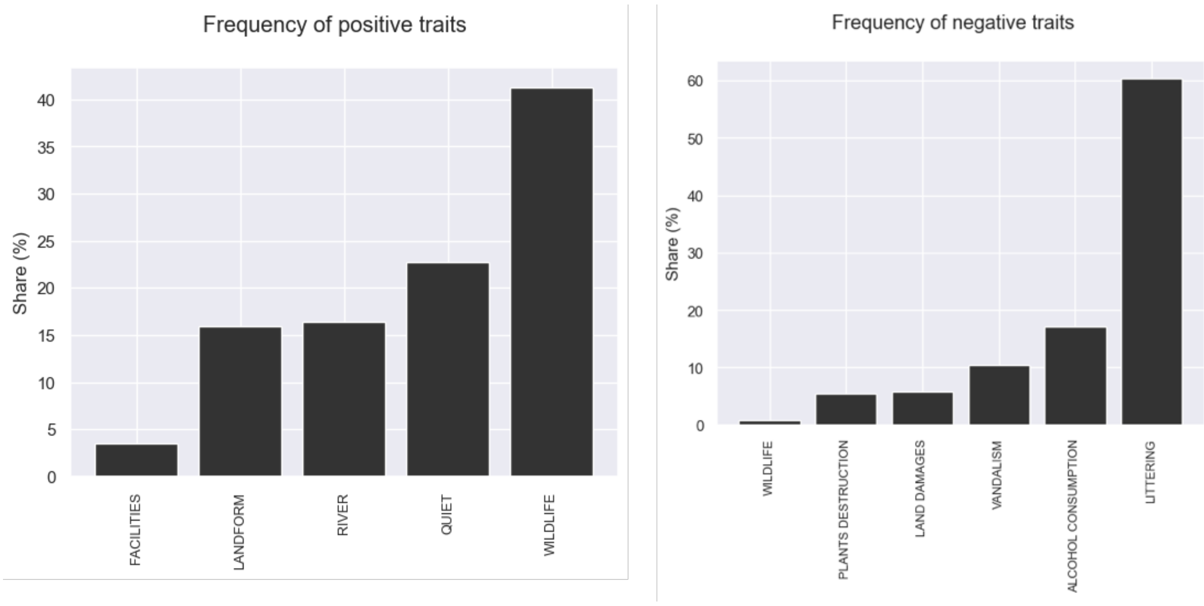

Figure 18. Respondents' perception on positive and negative trait of Drwinka River Park.

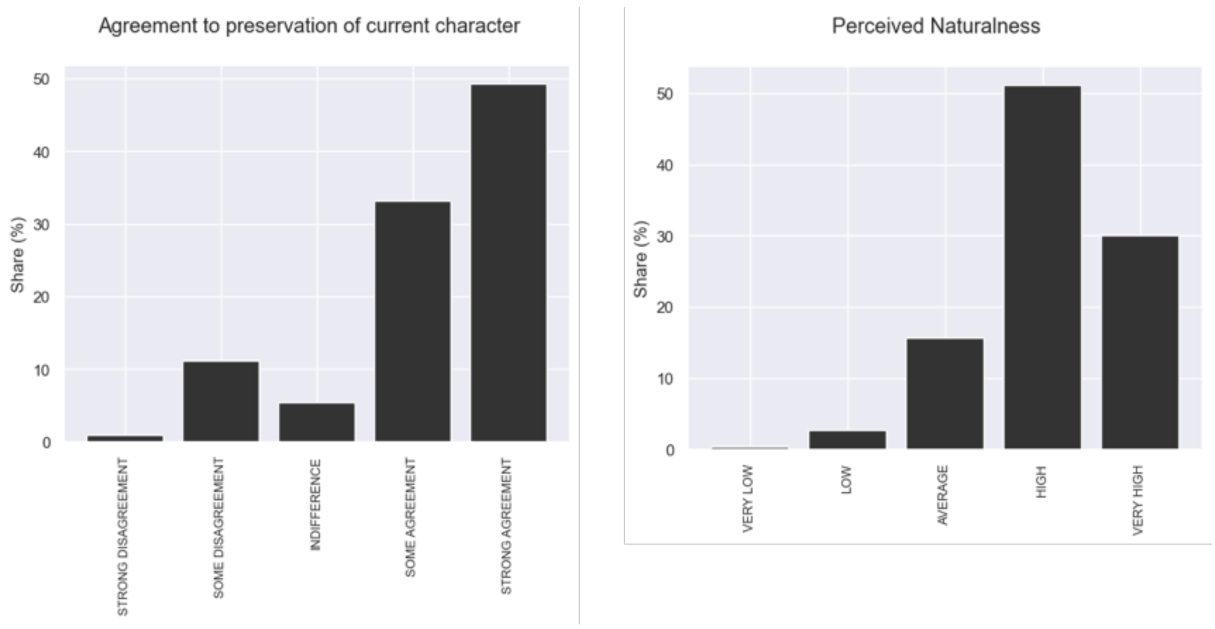

Figure 19. Respondents' opinions on perceived naturalness and the agreement to presenrve the current character of Drwinka River Park.

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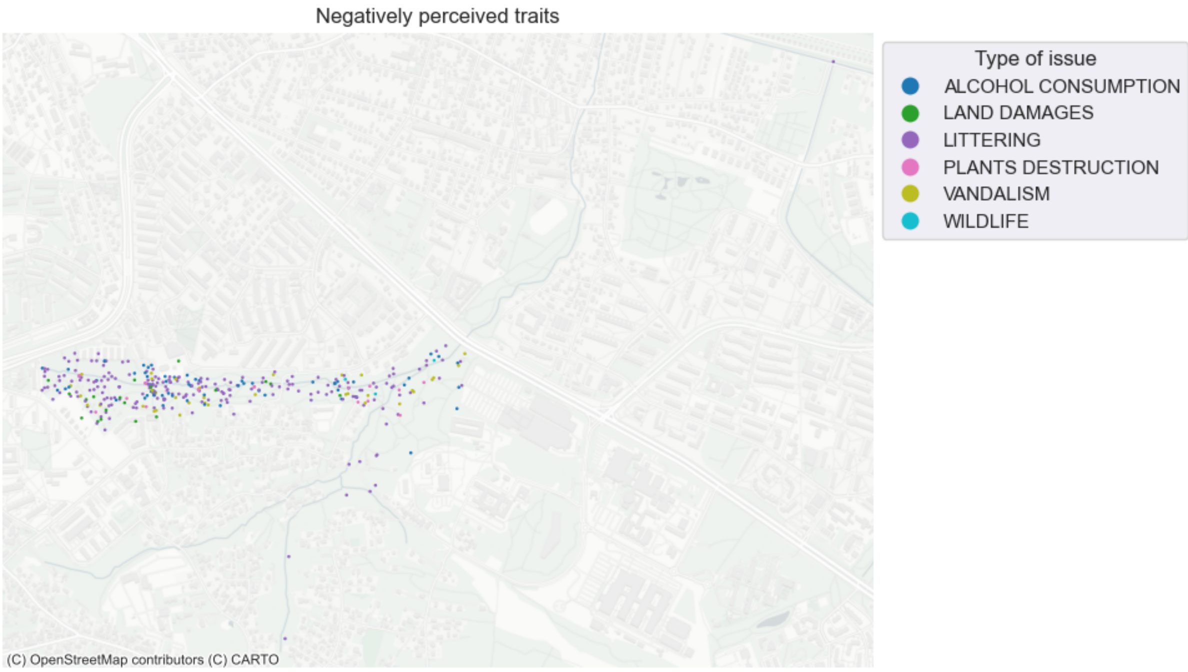

Figure 20. Location of respondents' perceived negative traits of Drwinka River Park.

3. Gelsenkirchen, Germany

During the mapping of demand for applying a citizen science tool in Gelsenkirchen, it became clear that using citizen science could enhance urban 'esidents' recognition of the recreational and health benefits these areas offer, along with opportunities for nature experiences and education. Therefore, in contrast to Leipzig, in Gelsenkirchen, MDF was used to gain insights into use intentions/use behaviour of citizens, and to elicit perceptions of citizens on the conditions and the state of selected urban green spaces, including the Grünlabor Hugo (primary location of data collection), Rheinelbe, Industriewald, and Hassel. Through contrasting of citizen expectations and their positive and negative perceptions, pathways for local management, i.e., a further improvement of green spaces should be identified. Moreover, this elicitation considered a potentially high place attachment of Gelsenkirchen residents, therefore seeking to elicit perceptions of local long-term changes, e.g., as a reality check for green space management. In Gelsenkirchen, MDF-based data collection has been kicked off 04/2023. Although initial promotion by local stakeholders and thus uptake was positive, in total, only 78 responses could be gathered thus far. However, data collection is still supported/ongoing.

Overall, despite the low total sample size, it was found that repondent's gender is comparatively balanced. Nature-seeking functions, e.g., experiencing nature, walking, and hiking are amongst the most commonly mentioned uses amongst the green spaces under investigation, followed by dogwalking. Active recreation (cycling, running, other sports) were mentioned less frequently. Visiting the green spaces under investigation for child play occurs infrequent (Figure 17). In most cases, green spaces were visited alone, followed by partners, friends, and family (Figure 18).

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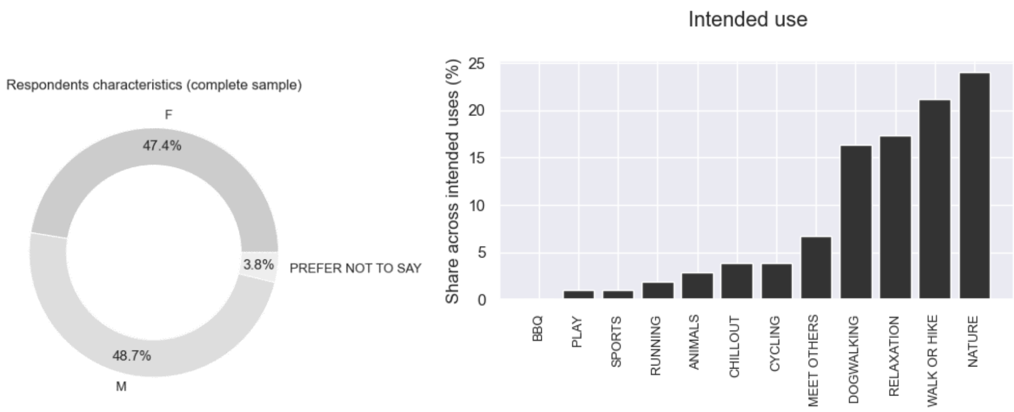

Figure 21. Respondents' gender distribution and stated use intention.

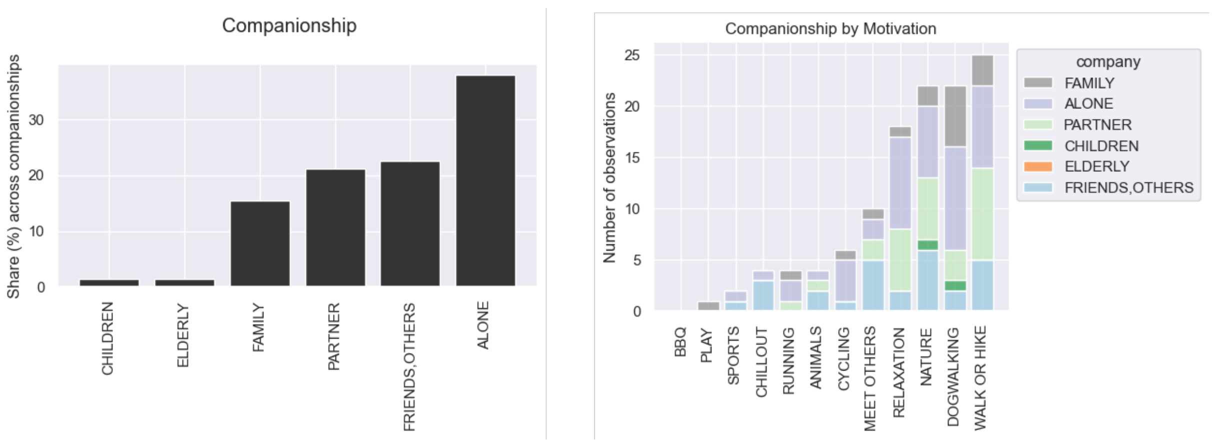

Figure 22. Respondents' answer towards companionship and companionship by motivation while using the place.

With traits referring to spatial and aspatial qualities of UF-NBS, a focus in Gelsenkirchen was on the elicitation of user expectations towards green spaces (Figure 19). It was found that ctizens particularly expect natural designs, lots of greenery, including trees, quit, and seating opportunities. When contrasting these expectations with positively perceived traits, it was found that citizens seemingly perceive green spaces as spacious green areas with varied designs. However, certain mismatches between perceptions and expectations may emerge from this comparison, i.e., particularly regarding the qualities quit, seating opportunities, and naturalness. These potential mismatches may inform local UF-NBS governance on potential improvements to UF-NBS. This also holds true for negatively perceived UF-NBS qualities. In this regard, vandalism, freeroaming dogs, and lack of certain facilities/amenities, particularly seating opportunities and trash bins, are most commonly reported. Moreover, about 10% of respondents noted that locally, green is perceived as being in a bad condition. On the one hand, this may indicate need for proper green space maintenance. On the other hand, similar to the Leipzig case, this may however also be related to impacts of heat and drought on the appearance/health and condition of trees, shrubs, and grasses.

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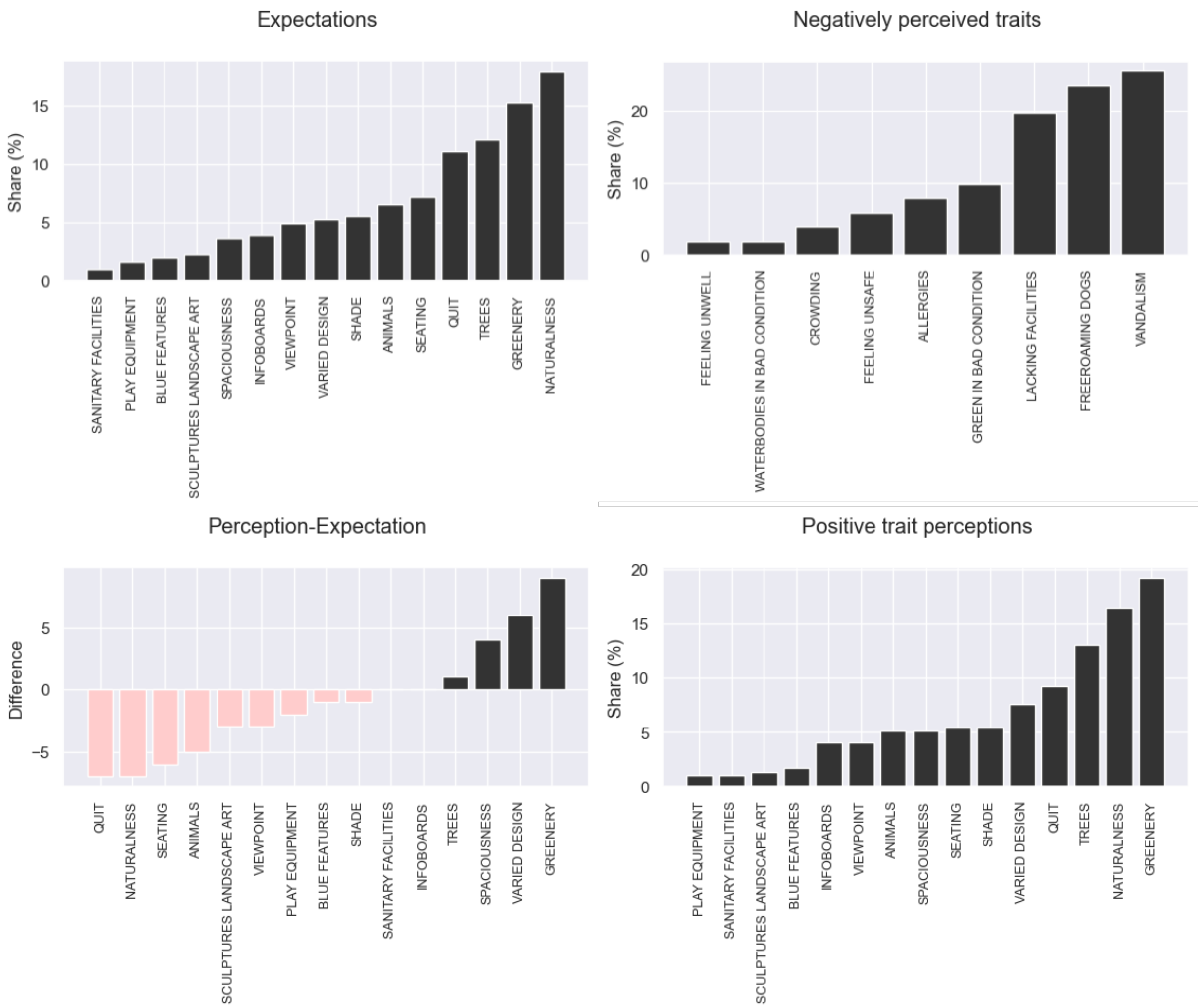

Figure 23. Shows the percentage of respondents' answer towards trait expectation, positive and negative trait perception and the difference between UF-NBS trait perception and expectation.

4. Barcelona (Llobregat Lower Valley)

As highlighted in the section 4.2.5, pollution and its health impacts, alongside community actions to address such issues, are key concerns among citizens and researchers. A citizen science participatory approach could link perceived pollution levels to UF-NBS configurations and the structure of green areas, exploring their health impacts, accessibility barriers for recreation, and influences of factors like age and gender. We, therefore, applied MDF to explore the spatially distributed perceived pollution level in conjunction with precieved traits of UF-NBS.

In Barcelona, MDF is in operation since 04/2023, focusing on locally perceived (air) pollution and other environmental burdens, subjectively perceived health impacts, perceived amount of green (UF-NBS) elements, personal avoidance strategies, and suggestions for local actions. 122 responses were collected thus far.

The most commonly perceived environmental burdens include noise, traffic, and smell, that were detected across wide parts of Barcelona's municipal area (Figure 20). Subjectively, citizens attribute these environmental burdens to a number of health impacts, including irritations of eye or nose,

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cough, breathing issues, headaches and tiredness. For example, eye and nose irritation and headaches were commonly reported as subjectively linked to perceived environmental burdens traffic, smoke, dust, smell; underlying correlations with noise may be due to co-perception of respective environmental issues. More generally, there appear to be considerable worries regarding health impacts due to pollution and other environmental burdens (Figure 21). To detect whether the (perceived) amount of local greenery might have been associated with perceptions of aforementioned issues, thus speaking towards potential UF-NBS benefits, local greenery-related traits were subsequently also elicited. In this regard, it may be the case that perceived burdens such as smoke and smell are spatially linked to perceptions of lack of greenery, i.e., no/few trees, as well as lack of available or distant urban green spaces (Figure 22). However, this requires a closer inspection, potentially awaiting a larger sample.

Nonetheless, citizen suggestions may already be used for informing policymakers and decision-makers. For example, a reduction of traffic as well as the creation of urban green spaces and the planting of trees are the most-often mentioned actions that citizens perceive as feasible action for the improvement of local conditions (Figure 27).

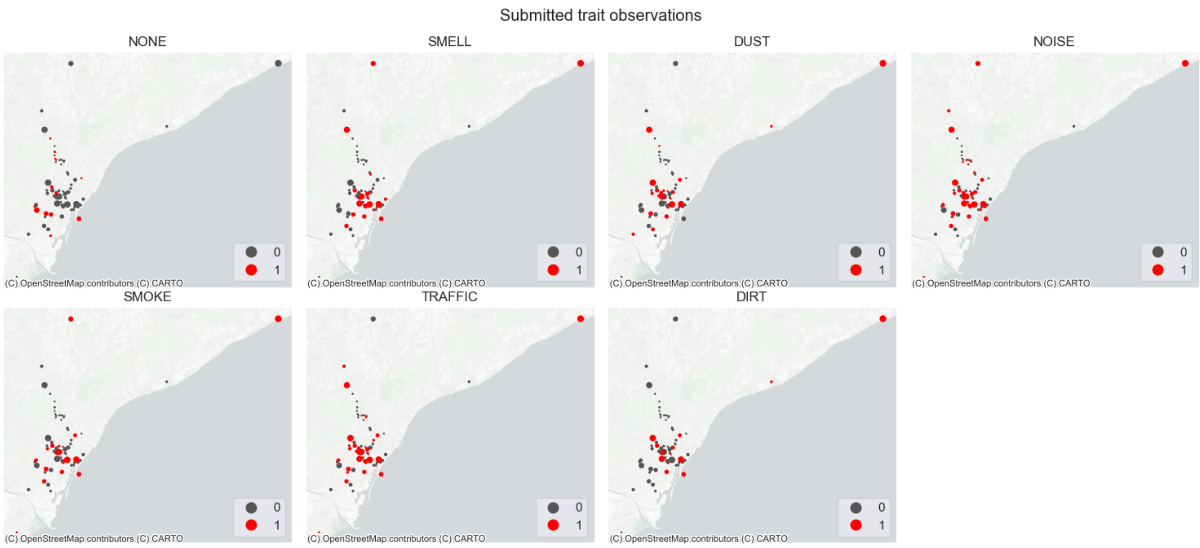

Figure 24. Number of observations on trait perception on pollution types and location of mapping trait perceptions.

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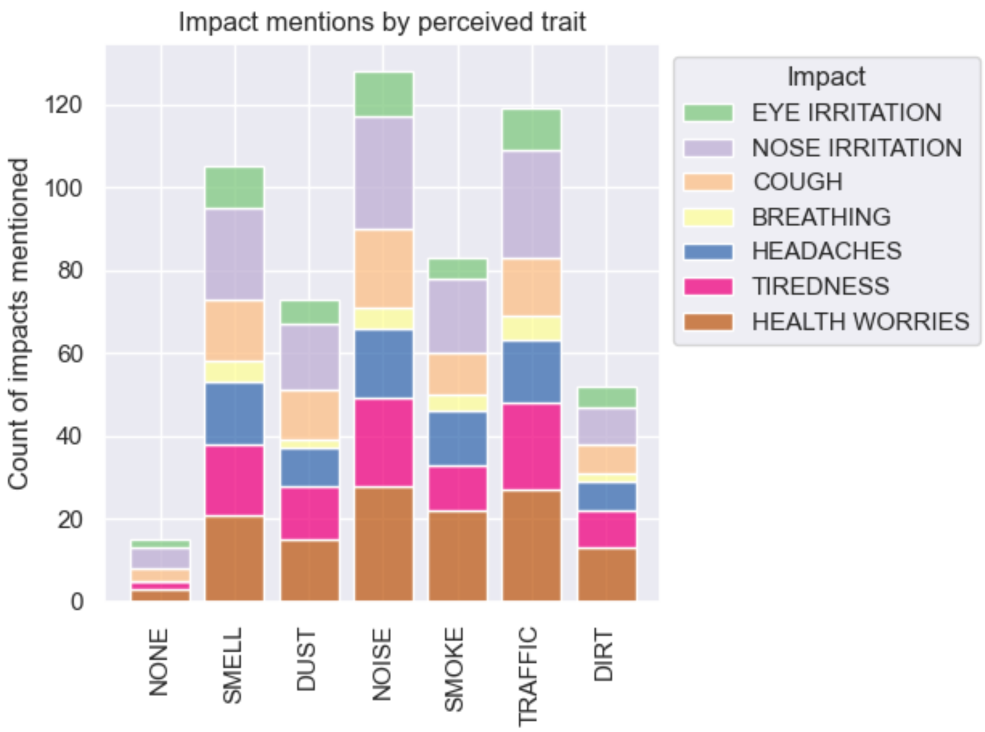

Figure 25. Perceived health impact mentioned by type of locally perceived (pollution) trait.

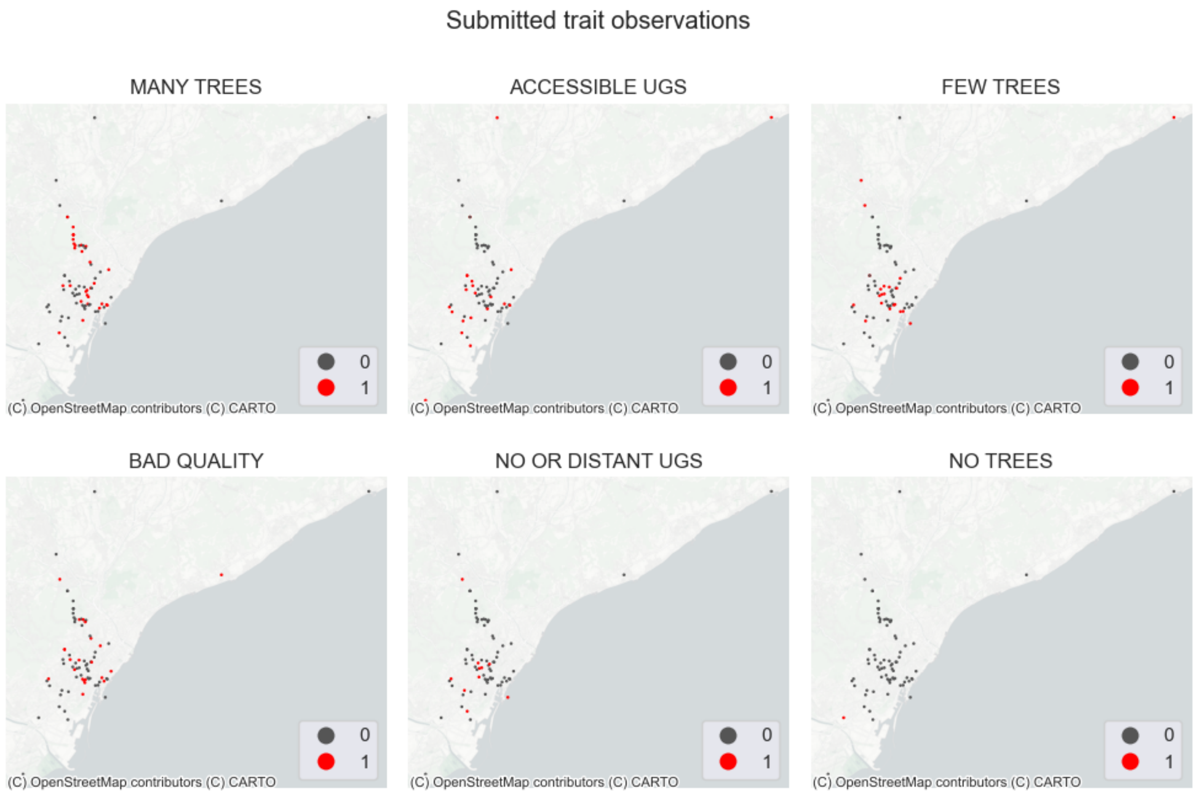

Figure 26. Perceived greenery-related traits and mapped perceived greenery-related traits.

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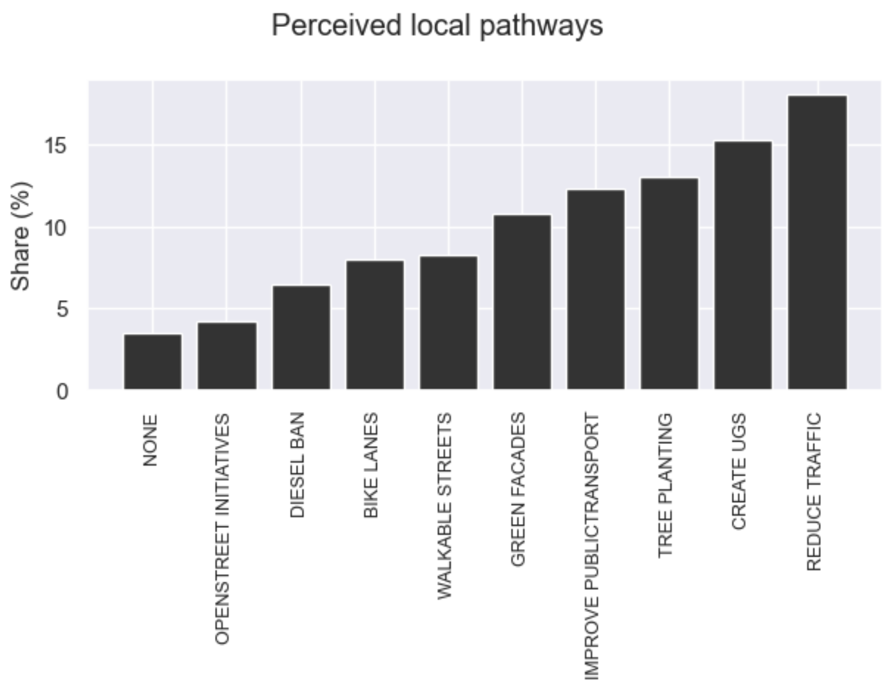

Figure 27. Suggestions by citizens for local action.

5. **Sonian city, Belgium**

The roll-out of the PPGIS tool in the Brussels case has been planned as part of the Strategic Horizon+ project in Vlaams-Brabant. The aim was to work with citizens to map trees on private and public land that have meaning to them, or to map places where additional trees would be welcomed by stakeholders. Unfortunately, due to staff changes, the project has been delayed, with the window of opportunity for implementing citizen science in Vlaams-Brabant moving beyond the timeframe of CLEARING HOUSE. A potential solution was found, to integrate the citizen science tool in the 30-30 campaign run by BOS+ in Flanders. This campaign aims to nudge people to spend 30 minutes in nature, for at least 30 consecutive days. Unfortunately, the funding for this campaign was only confirmed last minute, and an integration of My Dynamic Forest was not possible anymore in this backup-case. As a result, it was deemed impossible to roll-out the PPGIS tool in the Brussels case.

7 Recorder - a citizen science app for monitoring urban tree health for the Chinese case study cities

Hong Kong University has developed the Recorder app, a citizen science app for monitoring urban tree health, specifically for use in Hong Kong and Mainland China (available in Mandarin and English). The aims of the Recorder app is to increase public participation in collecting data on urban tree health, fill and bridge gaps in the official monitoring network, extending the type of data collected, and increasing social awareness on urban forests and urban trees.

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The principle and approach is very similar to the work done in Europe (implementing My Dynamic Forest), with a web-based front end (build in React Native) and the back-end running in AliCloud (as server and database to save the collected information on the trees, including location, species, and pictures). For navigation, users can select either Baidu Map (in Mainland China) or Google Maps (outside Mainland China). The flow is as follows

- Users move the map to select the location of the trees
- Data on tree and its health is inputted (in line with the concept note for citizen science as developed by CLEARING HOUSE, Scheuer et al. 2022)
- User can provide optional additional information (photos and tree species)
- User provides information on the habitat where the recorded tree is located
- User evaluates the habitat (evaluation criteria in line with the concept note (Scheuer et al., 2022)

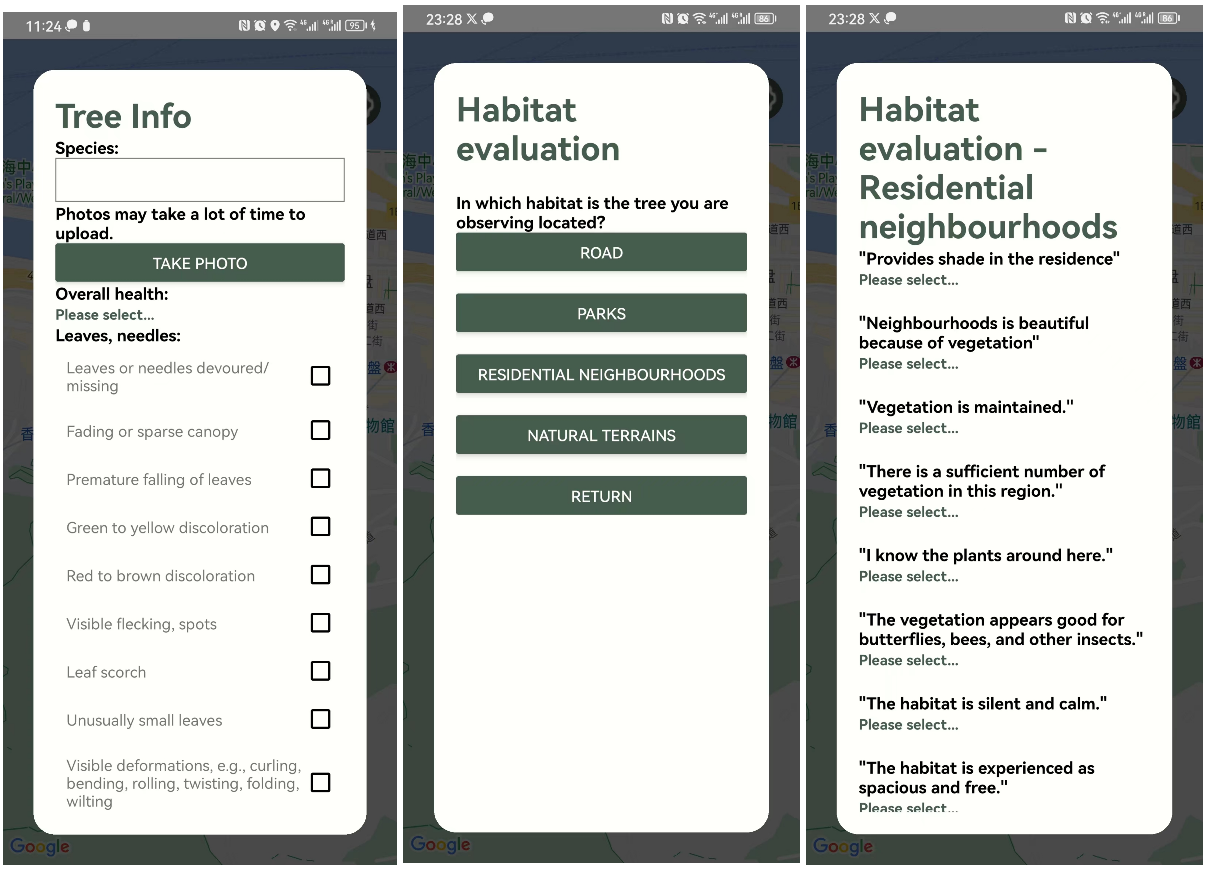

Figure 28. Frontend screens for inputting tree data (left), habitat data (middle) and the evaluation of the habitat (right).

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CONCLUSION

This report illustrates the importance of involving citizens in mapping and monitoring the benefits of Urban Forests as Nature-Based Solutions (UF-NBS) in a sample of five European cities. The report articulates a set of objectives, concepts and methods to assess and monitor the condition and quality of UF-NBS and evaluate citizens' perception of the cultural ecosystem service (CES) benefit in the case-study cities. The objectives of this study were articulated around a set of tasks, including developing a suitable citizen science tool based on scoping of literature and discussions with city partners and focus groups. The objective was also to map public perceptions and preferences and monitor conditions of UF-NBS. The mapping of the demand for UF-NBS in European case cities revealed a set of topics and issues which were organised into key themes, i.e. knowledge gaps, barriers, core objectives and implementing citizen science. The core issues that emerged during case study mapping were cultural ecosystem services, the multifunctionality of UF-NBS, tree health risks and concerns, climate change adaptation, awareness of UF-NBS benefits and management, ecological connectivity and biodiversity and UF-NBS characteristics.

The scoping of the literature gathered evidence on cultural ecosystem services and benefits of urban green space, the impact of UF-NBS characteristics/traits on benefits (ecosystem services) and trade-offs/ecosystem disservices, human health and well-being benefits concerning recreation and restoration potential of UF-NBS. Literature on citizen science best practices for evaluating CES, and in particular, evidence on participatory methods and tools to elicit citizen perception and appreciation of CES, were reviewed. The focus was particularly on the cultural ecosystem services and health and well-being benefits of exposure to and interaction with urban nature. The scoping selected some key UF-NBS qualities as possible health enablers, including naturalness and sereneness, natural qualities and characteristics, design and spatial qualities, perceived biodiversity richness, prospect qualities, social and cultural qualities, prospect and refuse qualities, accessibility, knowledge and information. The scoping of methods and approaches in CES evaluation revealed citizen science approaches, particularly participatory approaches regarding explorative research methods in CES studies. Finally, the review summarised themes for the PPGIS survey and relevant questions that are used to assess the impact of UF-NBS. Although all case-study-specific questions are considered essential, the PPGIS tool in CLEARING HOUSE assessed the most relevant and common themes and issues that emerged during scoping of literature, case study city analysis and consultation with the case city partners.

Due to the wide range of issues identified in all five case cities, Task 3.3 proposed an adaptive PPGIS model for citizen science (a web browers-based tool), which hase been implemented in the CLEARING HOUSE project, particularly in five European cities. Finally, the report elaborates a citizen science framework for the CLEARING HOUSE project. The tool has been developed using a versatile framework, allowing citizen science to be tailored to each case study city. This framework elaborates the development tool and various building blocks which have been conceptualized to implement the citizen science framework technically, i.e. putting it into operation.

The results, both statistical and visual, show that the MDF can effectively identify various UF-NBS related issues to aid in decision-making and planning. Additionally, the citizen science app developed alongside MDF by Hong Kong University will enhance public involvement in gathering data about urban tree health. This initiative will complement the official monitoring network by expanding the range of data collected and raising social awareness about urban forests and trees.

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BIBLIOGRAPHY

Aczel, M. R., Cao, D., & Makuch, K. (2022). Citizen Science for Conservation: Towards a Cleaner, Greener China. Electronic Green Journal, 1(46).

Assessment, M. E. (2005). Ecosystems and human well-being: wetlands and water. World Resources Institute.

Bakolis, I., Hammoud, R., Smythe, M., Gibbons, J., Davidson, N., Tognin, S., Mechelli, A., (2018). Urban mind: using smartphone technologies to investigate the impact of nature on mental well-being in real time. Bioscience, 10.1093/biosci/bix149.

Baumeister, C. F., Gerstenberg, T., Plieninger, T., & Schraml, U. (2020). Exploring cultural ecosystem service hotspots: Linking multiple urban forest features with public participation mapping data. Urban Forestry & Urban Greening, 48, 126561.

Baumeister, C. F., Gerstenberg, T., Plieninger, T., & Schraml, U. (2022). Geography of disservices in urban forests: public participation mapping for closing the loop. Ecosystems and People, 18(1), 44-63.

Beckmann-Wübbelt, A., Fricke, A., Sebesvari, Z., Yakouchenkova, I. A., Fröhlich, K., & Saha, S. (2021). High public appreciation for the cultural ecosystem services of urban and peri-urban forests during the COVID-19 pandemic. Sustainable Cities and Society, 74, 103240.

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen science: a developing tool for expanding science knowledge and scientific literacy. BioScience, 59(11), 977-984.

Brown, G. (2017). A review of sampling effects and response bias in internet participatory mapping (PPGIS/PGIS/VGI). Transactions in GIS, 21(1), 39-56.

Brown, G., & Fagerholm, N. (2015). Empirical PPGIS/PGIS mapping of ecosystem services: A review and evaluation. Ecosystem services, 13, 119-133.

Brown, G., & Kyttä, M. (2014). Key issues and research priorities for public participation GIS (PPGIS): A synthesis based on empirical research. Applied geography, 46, 122-136.

Brown, G., Reed, P., & Raymond, C. M. (2020). Mapping place values: 10 lessons from two decades of public participation GIS empirical research. Applied Geography, 116, 102156.

Brown, G., Rhodes, J., & Dade, M. (2018). An evaluation of participatory mapping methods to assess urban park benefits. Landscape and Urban Planning, 178, 18-31.

Bullock, C., Joyce, D., & Collier, M. (2018). An exploration of the relationships between cultural ecosystem services, socio-cultural values and well-being. Ecosystem services, 31, 142-152.

Callaghan, D. W., Khanal, P. N., & Straka, T. J. (2019). An analysis of costs and cost trends for southern forestry practices. Journal of Forestry, 117(1), 21-29.

Cambria, V. E., Campagnaro, T., Trentanovi, G., Testolin, R., Attorre, F., & Sitzia, T. (2021). Citizen science data to measure human use of green areas and forests in European cities. Forests, 12(6), 779.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821242. The content of this milestone document does not reflect the official opinion of the European Union. Responsibility for the information and views expressed lies entirely with the author(s).

Chen, X., Lupi, F., & Liu, J. (2017). Accounting for ecosystem services in compensating for the costs of effective conservation in protected areas. Biological conservation, 215, 233-240.

Cheng, X., Van Damme, S., Li, L., & Uyttenhove, P. (2019). Evaluation of cultural ecosystem services: A review of methods. Ecosystem services, 37, 100925.

da Schio N., Baró F., Basnou C., Bergier T., Cid E. L., Fransen K., Haase D., Mielczarek Ł., Nesselhauf G., Roitsch D., Rudgalwis N., Scheuer S., van Heur B., Vidal C. E., Wolff M., (2021) Report on the exploratory analysis of all the case studies (D2.1). H2020 project CLEARING HOUSE, agreement no. 821242.

Davies, H., Doick, K., Handley, P., O'Brien, L., & Wilson, J. (2017). Delivery of ecosystem services by urban forests. Research Report-Forestry Commission, UK, (026).

De Vreese, R., Leys, M., Dendoncker, N., Van Herzele, A., & Fontaine, C. M. (2016b). Images of nature as a boundary object in social and integrated ecosystem services assessments. Reflections from a Belgian case study. Ecosystem Services, 22, 269-279.

De Vreese, R., Leys, M., Fontaine, C. M., & Dendoncker, N. (2016a). Social mapping of perceived ecosystem services supply–The role of social landscape metrics and social hotspots for integrated ecosystem services assessment, landscape planning and management. Ecological indicators, 66, 517-533.

De Vreese, R., Malandrino C., Schante J., Fu W., Jin, J., Wang, C., (2021), Local co-design workshops synthesis report (D3.2).

Dickinson, D. C., & Hobbs, R. J. (2017). Cultural ecosystem services: Characteristics, challenges and lessons for urban green space research. Ecosystem services, 25, 179-194.

Dou, Y., Zhen, L., De Groot, R., Du, B., & Yu, X. (2017). Assessing the importance of cultural ecosystem services in urban areas of Beijing municipality. Ecosystem Services, 24, 79-90.

Eichhorn, J., Roskams, P., Potocic, N., Timmermann, V., Ferretti, M., Mues, V., ... & Wulff, S. (2016). Part IV Visual assessment of crown condition and damaging agents. Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests.

Ekkel, E. D., & de Vries, S. (2017). Nearby green space and human health: Evaluating accessibility metrics. Landscape and urban planning, 157, 214-220.

Fagerholm, N., Eilola, S., & Arki, V. (2021a). Outdoor recreation and nature's contribution to well-being in a pandemic situation-Case Turku, Finland. Urban Forestry & Urban Greening, 64, 127257.

Fagerholm, N., Raymond, C. M., Olafsson, A. S., Brown, G. G., Rinne, T., Hasanzadeh, K., … & Kyttä, M. (2021b). A methodological framework for analysis of participatory mapping data in research, planning, and management. International Journal of Geographical Information Science, 1-28. https://doi.org/10.1080/13658816.2020.1869747

FAO, (2022). Ecosystem Services & Biodiversity (ESB), Available at: https://www.fao.org/ecosystem-services-biodiversity/background/cultural-services/en/ , on 25.08.2022.

Feng, X., Astell-Burt, T., Standl, M., Flexeder, C., Heinrich, J., Markevych, I., 2022. Green space quality and adolescent mental health: do personality traits matter? Enrion. Res., 206, 112591.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821242. The content of this milestone document does not reflect the official opinion of the European Union. Responsibility for the information and views expressed lies entirely with the author(s).

Fish, R., Church, A., Willis, C., Winter, M., Tratalos, J. A., Haines-Young, R., & Potschin, M. (2016). Making space for cultural ecosystem services: Insights from a study of the UK nature improvement initiative. Ecosystem Services, 21, 329-343.

Foster, A., Dunham, I. M., & Kaylor, C. (2017). Citizen science for urban forest management? Predicting the data density and richness of urban forest volunteered geographic information. Urban Science, 1(3), 30.

Frumkin, H., Bratman, G. N., Breslow, S. J., Cochran, B., Kahn Jr, P. H., Lawler, J. J., ... & Wood, S. A. (2017). Nature contact and human health: A research agenda. Environmental health perspectives, 125(7), 075001.

Gao, T., Liu, F., Wang, Y., Mu, S., & Qiu, L. (2020). Reduction of atmospheric suspended particulate matter concentration and influencing factors of green space in urban forest park. Forests, 11(9), 950. https://doi.org/10.3390/f11090950

García-Díez, V., García-Llorente, M., & González, J. A. (2020). Participatory mapping of cultural ecosystem services in madrid: Insights for landscape planning. Land, 9(8), 244.

Gentin, S., 2011. Outdoor recreation and ethnicity in Europe—A review. Urban Forestry and Urban Greening, 10, 153–161.

Gidlow, C., van Kempen, E., Smith, G., Triguero-Mas, M., Kruize, H., Gražulevičienė, R., ... & Nieuwenhuijsen, M. J. (2018). Development of the natural environment scoring tool (NEST). Urban Forestry & Urban Greening, 29, 322-333.

Grahn, P., Stigsdotter, U., (2010). The relation between perceived sensory dimensions of urban green space and stress restoration. Landscape and Urban Planning, 94, 264-275.

Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., ... & Elmqvist, T. (2014). A quantitative review of urban ecosystem service assessments: concepts, models, and implementation. Ambio, 43(4), 413-433.

Haase, D., Schwarz, N., Strohbach, M., Kroll, F., & Seppelt, R. (2012). Synergies, trade-offs, and losses of ecosystem services in urban regions: an integrated multiscale framework applied to the Leipzig-Halle Region, Germany. Ecology and Society, 17(3).

Haklay, M. (2012). Citizen science and volunteered geographic information: overview and typology of participation., 105-122. https://doi.org/10.1007/978-94-007-4587-2_7

Hartig, T., Korpela, K., Evans, G., Gärling, T., (1997). A measure of restorative quality in environments. Scandinavian Housing and Planning Research, 14(4), 175-194.

Hartig, T., Mitchell, R., De Vries, S., & Frumkin, H. (2014). Nature and health. Annual review of public health, 35, 207-228.

Hartig, T., van den Berg, A.E., Hagerhall, C.M., Tomalak, M., Bauer, N., Hansmann, R., Ojala, A., Syngollitou, E., Carrus, G., van Herzele, A., Bell, S., Podesta, M.T.C., Waaseth, G., (2011). Health Benefits of Nature Experience: Psychological, Social and Cultural Processes, in: Forests, Trees and Human Health, Springer Netherlands, Dordrecht, pp. 127-168.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821242. The content of this milestone document does not reflect the official opinion of the European Union. Responsibility for the information and views expressed lies entirely with the author(s).

Haworth, B., Bruce, E., Whittaker, J., & Read, R. (2018). The good, the bad, and the uncertain: contributions of volunteered geographic information to community disaster resilience. Frontiers in Earth Science, 6. https://doi.org/10.3389/feart.2018.00183

Hegetschweiler, K. T., de Vries, S., Arnberger, A., Bell, S., Brennan, M., Siter, N., ... & Hunziker, M. (2017). Linking demand and supply factors in identifying cultural ecosystem services of urban green infrastructures: A review of European studies. Urban forestry & urban greening, 21, 48-59.

Hernández-Morcillo, M., Plieninger, T., & Bieling, C. (2013). An empirical review of cultural ecosystem service indicators. Ecological indicators, 29, 434-444.

Hoyle, H., Hitchmough, J., & Jorgensen, A. (2017). All about the 'wow factor'? The relationships between aesthetics, restorative effect and perceived biodiversity in designed urban planting. Landscape and urban planning, 164, 109-123.

Ives, C. D., Oke, C., Hehir, A., Gordon, A., Wang, Y., & Bekessy, S. A. (2017). Capturing residents' values for urban green space: Mapping, analysis and guidance for practice. Landscape and Urban Planning, 161, 32-43.

Jo, J., Park, S., JaChoon, K., Roh, T., Lim, E., & Yeo-Chang, Y. (2020). Preferences for ecosystem services provided by urban forests in south korea. Forest Science and Technology, 16(2), 86-103. https://doi.org/10.1080/21580103.2020.1762761

Kabisch, N., Kraemer, R., Masztalerz, O., Hemmerling, J., Püffel, C., & Haase, D. (2021). Impact of summer heat on urban park visitation, perceived health and ecosystem service appreciation. Urban Forestry & Urban Greening, 60, 127058.

Kim, J., & Son, Y. (2021). Assessing and mapping cultural ecosystem services of an urban forest based on narratives from blog posts. Ecological Indicators, 129, 107983.

Kimic, K., & Polko, P. (2022). The use of urban parks by older adults in the context of perceived security. International journal of environmental research and public health, 19(7), 4184.

Knobel, P., Dadvand, P., Alonso, L., Costa, L., Español, M., & Maneja, R. (2021). Development of the urban green space quality assessment tool (RECITAL). Urban forestry & urban greening, 57, 126895.

Koh, Y. F., Loc, H. H., & Park, E. (2022). Towards a "City in Nature": Evaluating the Cultural Ecosystem Services Approach Using Online Public Participation GIS to Support Urban Green Space Management. Sustainability, 14(3), 1499.

Korpilo, S., Jalkanen, J., Virtanen, T., & Lehvävirta, S. (2018). Where are the hotspots and coldspots of landscape values, visitor use and biodiversity in an urban forest?. PloS one, 13(9), e0203611.

Korpilo, S., Virtanen, T., Saukkonen, T., & Lehvävirta, S. (2018). More than A to B: Understanding and managing visitor spatial behaviour in urban forests using public participation GIS. Journal of environmental management, 207, 124-133.

La Rosa, D., Spyra, M., & Inostroza, L. (2016). Indicators of Cultural Ecosystem

Lyytimäki, J. (2017). Disservices of urban trees. In Routledge handbook of urban forestry (pp. 164-176). Routledge.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821242. The content of this milestone document does not reflect the official opinion of the European Union. Responsibility for the information and views expressed lies entirely with the author(s).

McEachan, R., Yang, T., Roberts, H., Pickett, K., Arseneau-Powell, D., Gidlow, C., Wright, J., Nieuwenhuijsen, M., 2018. Availability, use of, and satisfaction with green space, and children's mental wellbeing at age 4 years in a multicultural, deprived, urban area: results from the Born in Bradford cohort study. Lancet Planet Health, 2(6), e244-e254.

Milcu, A. I., Hanspach, J., Abson, D., & Fischer, J. (2013). Cultural ecosystem services: a literature review and prospects for future research. Ecology and society, 18(3).

Mishra, H. S., Bell, S., Vassiljev, P., Kuhlmann, F., Niin, G., & Grellier, J. (2020). The development of a tool for assessing the environmental qualities of urban blue spaces. Urban Forestry & Urban Greening, 49, 126575.

Nigussie, S., Liu, L., & Yeshitela, K. (2021). Indicator development for assessing recreational ecosystem service capacity of urban green spaces–A participatory approach. Ecological Indicators, 121, 107026.

Nordh, H., Hartig, T., Hagerhall, C. M., & Fry, G. (2009). Components of small urban parks that predict the possibility for restoration. Urban forestry & urban greening, 8(4), 225-235.or the European Union under conditions of land use change. Landscape Ecology, 32(3), 481-500.

O'Brien, L., De Vreese, R., Kern, M., Sievänen, T., Stojanova, B., & Atmiş, E. (2017). Cultural ecosystem benefits of urban and peri-urban green infrastructure across different European countries. Urban Forestry & Urban Greening, 24, 236-248.

Ogden, L. A., Aoki, C., Grove, J. M., Sonti, N. F., Hall, W., Locke, D., ... & Lagrosa, J. (2019). Forest ethnography: An approach to study the environmental history and political ecology of urban forests: Submission to "The Structure-Function Continuum: Understanding urban transformation through socio-ecological flows," a special issue of Urban Ecosystems. Urban ecosystems, 22, 49-63.

Ostoić, S. K., van den Bosch, C. C. K., Vuletić, D., Stevanov, M., Živojinović, I., Mutabdžija-Bećirović, S., ... & Malovrh, Š. P. (2017). Citizens' perception of and satisfaction with urban forests and green space: Results from selected Southeast European cities. Urban Forestry & Urban Greening, 23, 93-103.

Ostoić, S., Marin, A., Kičić, M., & Vuletić, D. (2020). Qualitative exploration of perception and use of cultural ecosystem services from tree-based urban green space in the city of zagreb (croatia). Forests, 11(8), 876. https://doi.org/10.3390/f11080876

Palacios-Agundez, I., Onaindia, M., Barraqueta, P., & Madariaga, I. (2015). Provisioning ecosystem services supply and demand: The role of landscape management to reinforce supply and promote synergies with other ecosystem services. Land Use Policy, 47, 145-155.

Pasanen, T.P., Ojala, A., Tyrväinen, L., Korpela, K.M., (2018). Restoration, well-being, and everyday physical activity in indoor, built outdoor and natural outdoor settings. Journal of Environmental Psychology, 59, 85-93, 10.1016/J.JENVP.2018.08.014.

Peschardt, K. K., & Stigsdotter, U. K. (2013). Associations between park characteristics and perceived restorativeness of small public urban green spaces. Landscape and urban planning, 112, 26-39.

Phillips, T., Porticella, N., Constas, M., & Bonney, R. (2018). A Framework for Articulating and Measuring Individual Learning Outcomes from Participation in Citizen Science. Citizen Science: Theory & Practice, 3(2).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821242. The content of this milestone document does not reflect the official opinion of the European Union. Responsibility for the information and views expressed lies entirely with the author(s).

Pietilä, M., & Fagerholm, N. (2019). A management perspective to using Public Participation GIS in planning for visitor use in national parks. Journal of Environmental Planning and Management, 62(7), 1133-1148.

Plieninger, T., Dijks, S., Oteros-Rozas, E., & Bieling, C. (2013). Assessing, mapping, and quantifying cultural ecosystem services at community level. Land use policy, 33, 118-129.

Potschin-Young, M., Haines-Young, R., Görg, C., Heink, U., Jax, K., & Schleyer, C. (2018). Understanding the role of conceptual frameworks: Reading the ecosystem service cascade. Ecosystem Services, 29, 428-440.

Pueffel, C., Haase, D., & Priess, J. A. (2018). Mapping ecosystem services on brownfields in Leipzig, Germany. Ecosystem Services, 30, 73-85.

Rall, E., Bieling, C., Zytynska, S., Haase, D., 2017. Exploring city-wide patterns of cultural ecosystem service perceptions and use. Ecological Indicators, 77, 80–95,

Raymond, C. M., Bryan, B. A., MacDonald, D. H., Cast, A., Strathearn, S., Grandgirard, A., & Kalivas, T. (2009). Mapping community values for natural capital and ecosystem services. Ecological economics, 68(5), 1301-1315.

Raymond, C. M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M. R., ... & Calfapietra, C. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environmental Science & Policy, 77, 15-24.

Raymond, C. M., Kenter, J. O., Plieninger, T., Turner, N. J., & Alexander, K. A. (2014). Comparing instrumental and deliberative paradigms underpinning the assessment of social values for cultural ecosystem services. Ecological Economics, 107, 145-156.

Roe, J., Aspinall, P. A., & Ward Thompson, C. (2016). Understanding relationships between health, ethnicity, place and the role of urban green space in deprived urban communities. International journal of environmental research and public health, 13(7), 681.

Rossi, L., Menconi, M. E., Grohmann, D., Brunori, A., & Nowak, D. J. (2022). Urban planning insights from tree inventories and their regulating ecosystem services assessment. Sustainability, 14(3), 1684.

Roy, S., Byrne, J., & Pickering, C. (2012). A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. Urban forestry & urban greening, 11(4), 351-363.'

Scheuer, S., Jache, J., Wellmann, T., Wolff, M., Haase, D., 2021. Report on a novel standardised Sino-European UFBS typology. Retrieved January 1st, 2022 from https://clearinghouseproject.eu/wp-content/uploads/2021/11/D1_1_Report_on_a_novel_standardised_Sino__European_UFBS_typology_V1.pdf.

Scheuer, S., Jache, J., Wellmann, T., Wolff, M., Haase, D., 2021. Report on a novel standardised Sino-European UF-NBS typology. Retrieved January 1st, 2022 from https://clearinghouseproject.eu/wp-content/uploads/2021/11/D1_1_Report_on_a_novel_standardised_Sino__European_UFBS_typology_V1.pdf.

Scheuer, S., Wolff, M., Haase, D., 2022. CLEARING HOUSE citizen science methodology (M3.9).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821242. The content of this milestone document does not reflect the official opinion of the European Union. Responsibility for the information and views expressed lies entirely with the author(s).

Schoepfer, I. and Rogers, S. (2014). A new qualitative gis method for investigating neighbourhood characteristics using a tablet. Cartographica: The International Journal for Geographic Information and Geovisualization, 49(2), 127-143. https://doi.org/10.3138/carto.49.2.1810

Sefcik J, Kondo M, Klusaritz H, Sarantschin E, Solomon S, Roepke A, South E, Jacoby S, (2019), Perceptions of Nature and Access to Green Space in Four Urban Neighborhoods, Int J. Environ. Res. Public Health, 16(13), 2313.

Sevinc, H., Karas, I., & Demiral, E. (2020). Mobile-web-base volunteered geographic information application and geometric accuracy analysis for traffic accidents. The International Archives of the Photogrammetry Remote Sensing and Spatial Information Sciences, XLIV-4/W3-2020, 375-378. https://doi.org/10.5194/isprs-archives-xliv-4-w3-2020-375-2020

Simkin, J., Ojala, A., & Tyrväinen, L. (2020). Restorative effects of mature and young commercial forests, pristine old-growth forest and urban recreation forest-A field experiment. Urban Forestry & Urban Greening, 48, 126567.

Thatcher, J. (2012). From volunteered geographic information to volunteered geographic services., 161-173. https://doi.org/10.1007/978-94-007-4587-2_10

Tsunetsugu, Y., Lee, J., Park, B.J., Tyrväinen, L., Kagawa, T., Miyazaki, Y., (2013). Physiological and psychological effects of viewing urban forest landscapes assessed by multiple measurements. Landscape and Urban Planning, 113, 90-93, 10.1016/j.landurbplan.2013.01.014.

Tulloch, D. L. (2008). Is VGI participation? From vernal pools to video games. GeoJournal, 72, 161-171.

Tyrväinen, L., Mäkinen, K., & Schipperijn, J. (2007). Tools for mapping social values of urban woodlands and other green areas. Landscape and urban planning, 79(1), 5-19.

Tyrväinen, L., Pauleit, S., Seeland, K., & De Vries, S. (2005). Benefits and uses of urban forests and trees. Urban forests and trees: A reference book, 81-114.

Wang, D., Brown, G., & Liu, Y. (2015). The physical and non-physical factors that influence perceived access to urban parks. Landscape and urban planning, 133, 53-66.

Wang, Y., Chang, Q., Fan, P., & Shi, X. (2022). From urban greenspace to health behaviors: An ecosystem services-mediated perspective. Environmental research, 213, 113664.

Wei, H., Fan, W., Wang, X., Lu, N., Dong, X., Zhao, Y., ... & Zhao, Y. (2017). Integrating supply and social demand in ecosystem services assessment: A review. Ecosystem Services, 25, 15-27.

Wendel, H. E. W., Zarger, R. K., & Mihelcic, J. R. (2012). Accessibility and usability: Green space preferences, perceptions, and barriers in a rapidly urbanizing city in Latin America. Landscape and urban planning, 107(3), 272-282.

Wolf, I. D., Brown, G., & Wohlfart, T. (2018). Applying public participation GIS (PPGIS) to inform and manage visitor conflict along multi-use trails. Journal of Sustainable Tourism, 26(3), 470-495.

Wolf, K. L., Lam, S. T., McKeen, J. K., Richardson, G. R., van den Bosch, M., & Bardekjian, A. C. (2020). Urban trees and human health: A scoping review. International journal of environmental research and public health, 17(12), 4371.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821242. The content of this milestone document does not reflect the official opinion of the European Union. Responsibility for the information and views expressed lies entirely with the author(s).

Wolff, M., Mascarenhas, A., Haase, A., Haase, D., Andersson, E., Borgström, S., ... & Biernacka, M. (2022). Conceptualizing multidimensional barriers: a framework for assessing constraints in realizing recreational benefits of urban green spaces. Ecology and Society, 27(2).

Xiang, Y., Hedblom, M., Wang, S., Qiu, L., & Gao, T. (2022). Indicator selection combining audio and visual perception of urban green spaces. Ecological Indicators, 137, 108772.

Yakınlar, N., Akpınar, A., (2022). How perceived sensory dimensions of urban green spaces are associated with adults' perceived restoration, stress, and mental health? Urban Forestry & Urban Greening, 72, 127572.

Zhang, H., Huang, R., Zhang, Y., & Buhalis, D. (2020). Cultural ecosystem services evaluation using geolocated social media data: a review. Tourism Geographies, 1-23.

Zhao, Q., Tang, H., Gao, C., & Wei, Y. (2020). Evaluation of urban forest landscape health: a case study of the nanguo peach garden, china. Iforest - Biogeosciences and Forestry, 13(1), 175-184. https://doi.org/10.3832/ifor3206-013

Zhou, L., Guan, D., Huang, X., Yuan, X., & Zhang, M. (2020). Evaluation of the cultural ecosystem services of wetland park. Ecological Indicators, 114, 106286.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821242. The content of this milestone document does not reflect the official opinion of the European Union. Responsibility for the information and views expressed lies entirely with the author(s).

Appendix 1: Identification of themes, objectives and actions related to UF-NBS to implement citizen science in EU case study cities.

Themes	Strategic objectives	Actions for Citizens Science based on strategic objectives	Case Study Cities
Baseline condition study of UF-NBS (private and public land)	To increase understanding of baseline condition of UF-NBS conditions and characteristics	Evaluate citizen appreciation for private UF-NBS based on their environmental characteristics and quality; Identification of possible dangers and threats.	Brussels
		Evaluate citizen appreciation for public UF-NBS in the locality and the city based on their environmental characteristics and quality; Identification of possible dangers and threats.	Leipzig, Gelsenkirchen, Kraków, Barcelona
Multifunctionality of UF-NBS	To increase multifunctionality of UF-NBS for co-benefits	Evaluate the multifunctionality of urban forests and parks for recreation and to promote social balance and green compensation.	Leipzig, Gelsenkirchen,
		Evaluate possibilities to accommodate overlapping functions	Leipzig, Gelsenkirchen
		Evaluate possible negative effects of multifunctional use of UF-NBS on nature conservation efforts.	Leipzig, Gelsenkirchen, Kraków
Ecosystem services	To increase cultural ecosystem services (CES) of UF-NBS and its contribution to public health and well-being promotion.	Evaluate CES of UF-NBS in private gardens.	Brussels

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		Evaluate CES of public parks and urban forest environments.	Gelsenkirchen, Leipzig, Kraków, Barcelona
		Evaluate CES of single trees (e.g. remarkable trees) on the public land.	Leipzig, Gelsenkirchen, Brussels, Kraków
Tree health risks and concerns	To tackle public health hazards and risk associated with UF-NBS	Assess public and private tree health (Lack of growth, damage to the crown, drought stress) concerning possible public health hazards, property damage, and permanent or temporary disruption to public life.	Gelsenkirchen, Leipzig, Brussels
Ecological connectivity and biodiversity	To reduce UF-NBS fragmentation to increase ecological connectivity and biodiversity	Evaluate the meaning and significance of structuring elements of green infrastructure (GI) for enhancing ecological connectivity,	Barcelona, Brussels
		Assess the efficiency of existing UF-NBS elements for maintaining biodiversity-rich urban forest environments	Brussels
		Assess the scope and possibilities to increase ecological connectivity between biodiversity patches or territories (i.e. private gardens and public urban forests)	Brussels, Barcelona
Climate change adaptation	To maximise the role of UF-NBS in climate change adaptation	Assess the efficiency of existing UF-NBS to mitigate various urban environmental issues, i.e. UHI, thermal discomfort, flooding, drought, air pollution, and noise.	Kraków, Leipzig,

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		Assess the scope of UF-NBS to increase water security and water system resilience	Kraków,
Awareness of UF-NBS ecosystem services and management practices	To educate, enhance and share knowledge and raise awareness about the ecosystem services (ES) and benefits of existing UF-NBS and lost elements of GI	UF-NBS component 1: Private trees, gardens, forests	Brussels
		UF-NBS component 2: Public trees, parks, gardens, and urban forests	Leipzig, Gelsenkirchen, Kraków, Brussels
		Water landscapes, i.e. river parks, riverine landscapes,	Kraków, Barcelona
		Cultural landscapes and memories	Barcelona,
		Agricultural landscapes contribute to landscape complexity, increase ecological connectivity and biodiversity, reduce flooding, fire, and order open spaces, i.e. agricultural fields, allotment gardens	Barcelona, Leipzig, Kraków,
		Ecological connectivity of urban GI,	Barcelona, Brussels
	To educate, enhance and share knowledge and raise awareness	Implementation of cost effective UF-NBS management and maintenance	Gelsenkirchen, Kraków,

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	regarding sustainable UF-NBS management practices.		
		Effective and sustainable tree and forest management techniques (use of pesticides, watering in dry periods)	Leipzig, Gelsenkirchen, Brussels
Note: Case study cities: 1- Gelsenkirchen, Germany; 2- Kraków, Poland; 3- Leipzig, Germany; 4- Llobregat Valley (Lower Llobregat Valley), 5- Spain; The Sonian City Belgium			

Appendix 2: Identification of themes and actions based on barriers related to UF-NBS services and benefits of implementing citizen science in EU case study cities.

Themes	Barriers	Actions for Citizens Science based on strategic objectives	Case Study City
Land use conflicts	UF-NBS quality and use (1) / active users of UF-NBS and commercial and real estate developers (2) / improvement of green areas and risk of degradation due to overuse (2).	Evaluate citizen perception about the land use conflicts with UF-NBS in the locality and in the city. / The impact of real estate and commercial development on UF-NBS in the locality and the city. / Evaluation of different UF-NBS environment types and the assessment of the risk of degradation.	Gelsenkirchen, Kraków
	Urban forest compensation against infill development.	Evaluate Citizens' appreciation of the green compensatory measures of infill developments in the locality and the city.	Gelsenkirchen,

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	Poor accessibility conditions to green space.	Evaluation of accessibility conditions of UF-NBS in the locality and the city (small-large green spaces).	Leipzig
	Existing vehicular roads pose challenges for ecological connectivity.	Evaluate citizens' appreciation of UF-NBS replacing car-intensive wider streets and parking spaces.	Brussels
Urbanisation impacts	The urbanisation of river landscapes in the locality and the city (2,4) / Intensive land development and reduction of green areas (5) / Parking reduce green space and ecological connectivity (5).	Evaluate citizens' perception on the impacts of urbanisation and intensive land development of urban river landscapes/ exiting green areas/ urban ecological connectivity.	Kraków, Barcelona, Brussels,
Landscape fragmentation	Fencing of private properties due to legal concerns and privacy reasons.	Evaluate citizens' perception of the current private garden fencing conditions.	Leipzig, Brussels
Ecological connectivity and biodiversity	Alteration of ecological process of existing green spaces (UF-NBS) (4)/ Fragmentation of urban ecological connectivity (4, 5)/ landscape fragmentation and agricultural intensification (4)/ Agricultural land as biodiversity desert (5).	Identifying urban features leads to ecological/ landscape fragmentation and evaluation of the impact on urban biodiversity (fauna diversity) using citizen science. Evaluate citizens' appreciation of physical or policy interventions to reduce ecological fragmentation.	Barcelona, Brussels,
Climate change adaptation	Degradation of urban environmental quality.	Citizens' understanding of the features leading to degradation of the quality UF-NBS in the locality and the city.	Kraków, Barcelona

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	The danger of river floods, climate change consequences, high and low regimes of water.	Citizens' evaluation of the urban environmental issues, i.e. flooding, heat, drought, and citizen appreciation of the role of UF-NBS in mitigating those effects in their locality and the city.	
	Watering vegetation during drought or dry summer periods.	Citizens' knowledge about UF-NBS or single tree conditions during dry summer and drought conditions in their locality and the city.	Gelsenkirchen, Leipzig, Barcelona
	Presence and abundance of exotic species (4) / Insufficient conservation efforts of protected species (4).	Identification of exotic species and appreciation of the need for conservation efforts for protected species.	Barcelona
Political and administrative barriers	Poor political and administrative consciousness about CES of UF-NBS.		Gelsenkirchen,
	Low involvement of business and private landowners for the protection of urban green areas.		Kraków
	Land ownership status and disputes lead to land abandonment and restricted public access.		Leipzig
	Nature conservation laws restrict access and use of protected areas.	Citizens' perceptions about nature conservation legislations and efforts restrict access and use of conservation areas.	Leipzig
	Poor equipment or design of public parks is regarded as an institutional barrier in planning and design.	Citizens' preferences for green space (UF-NBS) for their design and environmental quality, and services and amenities.	Leipzig

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Education and awareness of UF-NBS management	Despite best practices, citizens lack knowledge about UF-NBS services and benefits.	Evaluate citizen awareness about UF-NBS services and benefits.	Gelsenkirchen, Barcelona
	Poor management of private gardens and trees.	Citizen awareness about effective and sustainable tree and forest management techniques (use of pesticides, watering in dry periods)	Brussels
Note: Case study cities: 1- Gelsenkirchen, Germany; 2- Kraków, Poland; 3- Leipzig, Germany; 4- Llobregat Valley (Lower Llobregat Valley), 5- Spain; The Sonian City Belgium			

Appendix 3: Identification of themes and objectives based on knowledge gaps related UF-NBS in EU case study Cities.

Themes	Objectives	City
Baseline condition study of UF-NBS (private and public land)	Private garden tree and garden information (forest or single tree and permeability)	Brussels
	State of the soils in the city and contribution towards diversified plant development (private gardens)	Brussels
	Tree information (i.e. lack of growth, tree and crown damage, drought stress)	Leipzig
Ecosystem services	Citizens' understanding of the comprehensive and diverse ecosystem services and values of UF-NBS, the use and management of natural resources.	Gelsenkirchen, Leipzig, Kraków

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	Citizen needs and demands and the supply of green areas and cultural ecosystem services.	Gelsenkirchen, Leipzig, Kraków
	The link between the presence of the ecological network and the presence of certain species.	Brussels, Barcelona
UF-NBS management	Suitable and cost-effective methods for citizens to create, manage, and protect UF-NBS without losing biodiversity.	Kraków
	Insufficient data about Key CES of UF-NBS.	Barcelona
Climate change adaptation	Local knowledge about biodiversity, environmental, and bio-physical features of UF-NBS (Climate adaptive reforestation and species) is important for ecological continuity and minimise urban heat island effect.	Kraków, Leipzig, Barcelona
	Public knowledge about the impact of trees on urbanisation and urban pollution on tree ecosystems.	Brussels
Note: Case study cities: 1- Gelsenkirchen, Germany; 2- Kraków, Poland; 3- Leipzig, Germany; 4- Llobregat Valley (Lower Llobregat Valley), 5- Spain; The Sonian City Belgium		

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