The delivery of Cultural Ecosystem Services in urban forests of different landscape features and land use contexts

Wang, Yuan

2022-10

Wang , Y , Niemela , J & Kotze , J 2022 , ' The delivery of Cultural Ecosystem Services in urban forests of different landscape features and land use contexts ' , People and Nature , vol. 4 , no. 5 , pp. 1369-1386 . https://doi.org/10.1002/pan3.10394

http://hdl.handle.net/10138/349983
https://doi.org/10.1002/pan3.10394

Received: 29 November 2021 | Accepted: 11 July 2022

DOI: 10.1002/pan3.10394

PEOPLE AND NATURE
BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE

The delivery of Cultural Ecosystem Services in urban forests of different landscape features and land use contexts

Yuan Wang[1] | Jari Niemelä[2,†] | D. Johan Kotze[1]

[1]Faculty of Biological and Environmental Sciences, Ecosystems and Environment Research Programme, Niemenkatu 73, FI-15140, Lahti, University of Helsinki, Helsinki, Finland

[2]Faculty of Biological and Environmental Sciences, Ecosystems and Environment Research Programme, University of Helsinki, PO Box 3, FI-00014, Helsinki, Finland

Correspondence
Yuan Wang
Email: yuan.wang@helsinki.fi

Funding information
Chinese Scholarship Council; Helsinki Research Grants

Handling Editor: Davide Geneletti

Abstract

1. Urban greenspace provides citizens with important cultural ecosystem services (CES). Identifying landscape features and land use contexts that facilitate CES delivery is critical for guiding urban greenspace management. However, how landscape features and urban context interact with each other in influencing the CES of greenspaces remains unclear. Studies on the CES of patchy urban forests are needed as they are essential urban CES providers, but vulnerable under urban land use pressure.
2. To address these concerns, we compared the CES of 20 urban forest patches in Helsinki, Finland, with five different combinations of landscape features (i.e. size and connectivity) and land use contexts (i.e. surrounding construction density). CES were assessed through an on-site survey on visitors' use, perceptions of CES experience and overall satisfaction, to capture the possible disparities among CES measurements.
3. In larger (>20 ha) forests, visitors were highly satisfied with CES, particularly appreciating the experience of physical health improvement and inspiration through longer and more intense physical uses. Visitors of urban forests in a low construction density context appreciated experiences of cultural heritage, psychological restoration and physical health improvement.
4. Urban forests deliver unique CES characterised by physical use and the benefit of restoration, aesthetics and contact with nature. We suggest that maintaining large urban forests is more effective in promoting CES in high-density areas. In low-density areas, maintaining small forests with open greenspace in the surroundings can also promote CES experiences. We identify management gaps caused by a mismatch between use intensity and CES experiences of urban forests, while both are important in determining people's overall satisfaction.

KEYWORDS
Cultural Ecosystem Services, landscape, perceptions, urban forests

[†]Deceased

1 | INTRODUCTION

Nature has shaped human culture for thousands of years, yet we have only recently started to frame and quantify these non-material benefits people obtain from ecosystems as cultural ecosystem services (CES; Millennium Ecosystem Assessment, 2005). CES include cultural diversity, aesthetic values, spiritual and religious values, social relations, knowledge systems, sense of place, educational values, cultural heritage, inspiration, recreation and ecotourism. However, people are also losing experience with nature, attributed to biodiversity loss, technological changes and urbanisation (Soga & Gaston, 2016). The majority of people on earth experience nature primarily in the urban milieu. Recreational, aesthetic and social values are the most frequently reported urban CES, while almost the full set of CES have been mapped in urban areas (Rall et al., 2017). For example, people improve their physical health (Akpinar, 2016), restore their psychological status (Hauru et al., 2012) and meet their desire to connect with nature through walking, jogging and picking mushrooms etc., in urban greenspaces.

To promote CES for urban residents in their daily life, incorporating CES benefits in planning and the management of urban green infrastructure (UGI; defined as all types of natural and semi-natural greenspaces in the city) is an ongoing agenda (Davies & Lafortezza, 2017; Hansen & Pauleit, 2014). The CES of an UGI entity are affected by many factors, such as habitat type, location, management, biodiversity (Ridding et al., 2018), user characteristics (Hegetschweiler et al., 2017), as well as local people–nature interaction culture (Fischer et al., 2018). Urban planning and management strategies will have complex effects on CES through the spatial arrangement of UGI. For example, city managers may treasure large UGI in the city, for example, the central park in New York City, or the forests in peri-urban areas. Larger UGI is associated with increased park visitation rates (Zhang & Zhou, 2018), less stress (Akpinar, 2016) and more intense and diverse physical activities, along with greater and more diverse park benefits (Brown et al., 2018). Retaining large greenspaces in the city also enrich biodiversity, which may be associated with visitor's psychological wellbeing (Fuller et al., 2007). However, large UGI is not always available or easily accessible to all residents, leading to the preference and satisfaction of smaller but closer to home UGI (Mapita, 2014; Soga et al., 2015). Where greenspace area is limited, an increase in the connectivity among greenspaces is another UGI planning principle for either ecological or recreational targets (Davies & Lafortezza, 2017; Hansen & Pauleit, 2014). Greenspace connectivity achieved by green corridors or green networks has been found to facilitate species dispersal (Taylor et al., 1993), supports a biodiverse UGI and encourages people's movement around green networks, thus enhancing their physical and psychological health (Pietilä et al., 2015). However, few studies have tested the recreational effects of greenspace connectivity, except Brown et al. (2018) who reported intense physical activity and physical benefits associated with linear parks.

Variation in CES patterns depends not only on the landscape arrangement of UGI, but also on the surrounding urban context (Kraemer & Kabisch, 2021; Vierikko et al., 2020). Studies have shown that urban greenspaces in city centres surrounded by high construction and population density are rich in recreational and social-oriented CES (e.g. recreational, social, cultural heritage), while urban greenspaces in suburban areas with low construction density and greener surroundings are usually rich in nature-oriented CES (e.g. aesthetics, spiritual, inspirational, educational and nature experience; Palliwoda & Priess, 2021; Rall et al., 2017). People in neighbourhoods of higher tree cover tend to use UGI more frequently with longer duration, possibly because they have a closer connection with nature and thus tend to enjoy spending time in nature (Shanahan et al., 2017).

Although the above studies have explored the effects of landscape features (size and connectivity) or the surrounding urban context (land use and population) of UGI on the CES they deliver, which may support the initiatives of planning and management, the interaction of landscape features and urban context of UGI in their CES delivery are rarely studied. In addition, studies regarding the spatial variation of urban CES concentrate on recreational services due to the availability of visitation data (Cheng et al., 2019). However, different CES categories are not necessarily coupled (Hegetschweiler et al., 2017). Even the recreational services assessed by usage, preference or ratings can vary disparately among urban greenspaces (Gerstenberg et al., 2020; Kothencz et al., 2017). Knowledge on which CES are associated with which type of UGI in terms of landscape features and urban context (e.g. large vs. small, connected vs. isolated, high vs. low surrounding construction density) is missing. We intend to extend current knowledge by evaluating how urban remnant forests (the UGI studied here) of different size, connectivity and surrounding land use combinations differ in their CES delivery (in terms of use, perceptions of a full set of CES, and overall satisfaction).

As habitat type (parks vs. forests and wetlands) can have disparate impacts on CES delivery, focusing on one type of urban habitat facilitates our exploration of landscape and land use effects. We focus on urban remnant forests in this paper. Among all habitat types, forests are a main CES provider (Ridding et al., 2018), with spiritual and education being the signature CES of forest landscapes (Brancalion et al., 2014). Within urban areas, however, the study of CES provision by urban forests is rare, for example, compared to parks. Urban forests are defined here as continuous tree-covered patches, which can be remnants of native forests that are fragmented with urban expansion (Nielsen et al., 2017). As a core component in the development of urban green infrastructure, urban forests can be irreplaceable sources for CES delivery, for their layered vertical structure, unique biodiversity and the self-sustained natural dynamics they display. Baumeister et al. (2020) found that recreation and sense of place are the most important CES categories of peri-urban forests. Rall et al. (2017) found that across the city, forest land cover is associated with the activity of dog walking and experiencing the beauty of nature as well as the CES of nature experience and education, aesthetics and spirituality. However, the role of small urban forests (isolated or connected) versus large urban forests in delivering CES, in relation to the surrounding land use, has not been studied.

Yet it could be practical for the planning and management of urban forests to prioritise which greenspaces to preserve, given urban expansion or densification, since fragmented urban forests can be vulnerable under urban land use pressure (Nielsen et al., 2017).

In 2013, the city of Helsinki, Finland, conducted a public participatory survey on '*Mark the unique city nature on the city map*' in preparation of the launch of Helsinki's Master Plan 2050. Urban forests received far more citizen votes than any other type of urban nature. Furthermore, variation of perceived uniqueness of these forest patches across the city is large, and related to patch size, surrounding construction and population density (Wang et al., 2019). These findings provided a practical impetus for this study, where we conducted an on-site survey of people's direct use, experience and satisfaction of urban forests in Helsinki under different landscape features (size and connectivity) and land use contexts (surrounding construction density). Here we address the following questions: (1) What are the unique CES provided by urban forests? (2) How do landscape and land use context, individually and together, affect the CES of urban forests? We discuss the implications of our results for urban planning and the management of urban forests to promote CES.

2 | MATERIALS AND METHODS

2.1 | Study city and site selection

The municipality of Helsinki (60°N, 24°E) had 214 km^2 of land area (City of Helsinki, 2022) and 658,800 inhabitants at the end of 2021 (Statistics Finland, 2022). Helsinki is situated in southern Finland in the hemi-boreal forest zone, where Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and Birch (*Betula pendula*) are the most common tree species. Semi-natural habitats including forests and rocks make up 64% of the urban greenspace of Helsinki, with the remaining area consisting of anthropogenic (e.g. meadows, ruderal) and constructed habitat (e.g. parks, cemeteries; Vierikko et al., 2014). Urban forests are extensively managed for the purposes of biodiversity conservation and recreation, while stand structure corresponds to that of natural forests (Erävuori et al., 2020; Lehvävirta & Rita, 2002).

With the aim to compare CES among forest patches of different landscape and land use contexts, we designed the study by selecting forest patches of five landscape and land use types in Helsinki (see below). Then we surveyed forest users for individual CES in these sites. As a result, we explored two levels to evaluate differences between the five landscape and land use types, first at the individual respondent level, and then at the site level.

To characterise landscape and land use contexts in our study, we selected 20 forest patches representative of different size (large or small), connectivity (whether the patches are connected or isolated to the rest of the urban forests) and surrounding construction density (whether the forest patches are located in a high- or low-density urban context using percentage constructed land cover). According to the urban green infrastructure map of Helsinki (Vierikko et al., 2014), 865 urban forest patches are present in the city (no vehicular or water ways within these patches). Using information from the National Forestry Inventory and high resolution landcover maps from the municipality, we first characterised forest features with Geographic Information System (ESRI, 2011). We excluded patches on islands that can only be reached with boats, and patches dominated by open rocks and broadleaved trees (minor forest types in Helsinki), which resulted in 561 patches. We divided these patches into large or small using 20 ha as the criterion for size. This size criterion is based first on the area of Helsinki's popular recreational forests, and second on the threshold area for species richness of urban habitat patches, indicating the size of a patch below which species richness declines rapidly (Beninde et al., 2015). For connectivity, we use the median of functional connectivity of all patches to determine whether a small patch is connected or isolated in the forests network. Functional connectivity was calculated according to a modified incidence functional model (IFM; Moilanen & Nieminen, 2002) using an estimated dispersal distance of 100 m from an ecological perspective (Schleicher et al., 2011, see Supplementary Material, Appendix A). Using 300 m and even 500 m of dispersal distance from a recreational perspective (Soga & Gaston, 2016) did not alter our categorisation (except for one small fragment, which became connected at 500 m). We did not make a distinction in terms of connectivity for large forest patches, assuming they are used and perceived independently. For surrounding construction density, we calculated the percentage constructed land cover in a 500 m buffer and used the median (0.33) among all patches to determine whether a patch is located in a high- or low-density urban context. We use a 500 m buffer considering public urban greenspace is supposed to serve local visitors from 500 m distance (Shanahan et al., 2015). Constructed land cover here included buildings, roads and impervious surfaces derived from the land cover map of the Helsinki Region Environmental Services Authority (HSY).

Using this procedure, we identified five types of forest patches in Helsinki: (1) large forests with low construction density surroundings (Large.Low), (2) large forests with high construction density surroundings (Large.High), (3) small connected forests with low construction density surroundings (Small.Con.Low), (4) small isolated forests with low construction density surroundings (Small.Isol.Low) and (5) small isolated forests with high construction density surroundings (Small.Isol.High). The combination of small connected forest with high construction density surroundings was not achieved because almost all small connected patches are located in a low construction density urban context. Field visits followed to select study sites in each type. The aim of ground truthing was to minimise the potential impacts of factors other than landscape and land use context on CES of the urban forests studied. We first ensured that the selected forest patch was dominated by coniferous forest, and the ground layer consisted of typical forest herbs, that is, *Vaccinium myrtillus* or *Oxalis acetosella*. We also ensured that the selected forest patch had a clear trail entrance that is easy to find and reach from the surrounding urban matrix. Additionally, the patches selected had to have established trails, paved with fine gravel for recreational use. If a selected patch failed any of these criteria, a new candidate patch, through random selection, was chosen until four patches of each forest type were obtained. In total, 20 forest patches distributed across the city of Helsinki were chosen to represent the five landscape and land use context types of forests (Figure 1).

2.2 | Field survey

Based on the methodology proposed by Campbell et al. (2016) to measure park use and assess CES, we performed both visitor observations to collect data on use intensity and activity type per forest, and face-to-face questionnaires to collect individual use, experience and satisfaction data of forest visitors. Both methods were carried out during August–October 2016 in the 20 selected urban forest patches to capture urban forest visits during the high season in Nordic climates. The survey was conducted only on sunny or partly cloudy days. Observations were performed for at least 90 min during the busiest visiting time: on weekdays after working hours (16:00–18:00) and on weekends during the daytime, to achieve a more inclusive user group. We counted the forest visitors, including their gender, age class and activities. Age classes were estimated and classified into junior (under 18 years old), young adult (18–44), adult (45–64) and senior (over 65). Activities were categorised into cycling, walking, dog walking, Nordic walking (pole walking), playing with kids, picking berries or mushrooms, etc. We observed that visitors of the 20 selected urban forests had a similar age distribution as the population of Helsinki in 2016, with slightly more adults (45–64 years old), and fewer junior or senior visitors (City of Helsinki, 2016; Appendix B, Figure S1).

For the anonymous face-to-face questionnaires, we also visited each patch on both weekdays and weekends and attempted to reach every visitor we encountered until we completed 10 questionnaires per patch. For each respondent, we began the on-site questionnaire with an explanation of the survey aims and use of the information, then collected their verbal consent to participate in the study. We chose verbal consent because we conducted the questionnaire face-to-face. Our survey was performed in accordance with the declaration of Helsinki, and did not require an ethical review according to the Finnish ethical review system (TENK, 2019).

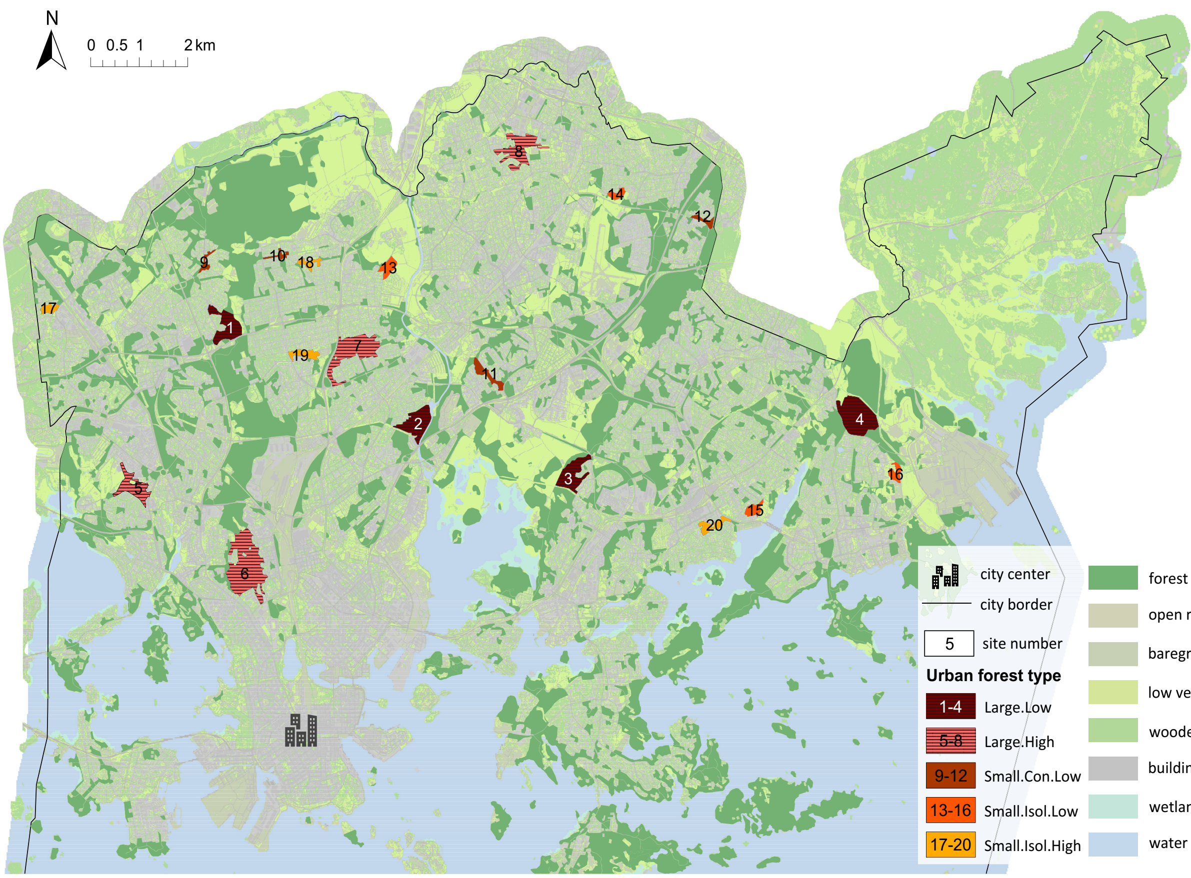

FIGURE 1 Distribution of urban forest patches surveyed in the city of Helsinki. The study sites are coloured according to their landscape and land use types and marked with site numbers. Large.Low: Large forests with low construction density in the surroundings. Large.High: Large forests with high construction density in the surroundings. Small.Con.Low: Small connected forests with low construction density in the surroundings. Small.Isol.Low: Small isolated forests with low construction density in the surroundings. Small.Isol.High: Small isolated forests with high construction density in the surroundings.

TABLE 1 Cultural Ecosystem Services (CES) categories examined and the description in the survey

Cultural Ecosystem Services		Description in the survey
Category (MEA)	Subcategory	
Recreation	Being connected with nature	I have contact with nature
	Physical change	I improve my physical health
	Psychological restoration	I feel restored from daily routines
	General relaxation	I enjoy leisure time
Sense of place		I feel a sense of place
Aesthetics		I experience beautiful scenery
Inspiration		I get inspired from nature
Education		I learn from nature
Spiritual		I have spiritual contact with nature
Cultural heritage		I appreciate the history of the landscape
Social relations		I enjoy meeting people

The questionnaire was divided into three parts (Appendix C). The first part asked about how visitors used this forest patch, for example, frequency and duration of visits, to indicate the visitor's pattern of use. The second part asked respondents about their experience in the forest, which consist of one open-ended question (to stimulate active thinking) and 5-scale ratings of 11 perceptions of CES experience (Table 1). We include all CES categories of the Millennium Ecosystem Assessment (2005) except knowledge system and cultural diversity because they are complex components that are suitably assessed at the community level rather than the individual level. We further include subcategories of recreational services: physical and psychological health improvement and experience of connected with nature, according to the discussion of the Common International Classification of Ecosystem Goods And Services (CICES) V4.3 (Haines-Young & Potschin, 2013); psychological restoration was chosen to represent the psychological benefit of visiting urban forests (Hauru et al., 2012).

We completed 241 on-site questionnaires, with an average response rate (the number of people who answered the questionnaire divided by the number of people we asked) of 70.7%. Just over 60% (60.6%) of the respondents were female. The youngest respondent was 16 years of age, the oldest 89. In general, our respondents represented more adults and less young adults, and practically no juniors compared to the city's population (Appendix B, Figure S1).

2.3 | Data analysis

Altogether, three use variables (visit frequency, duration of visit and travel time to the site), 11 variables on the perceptions of visit experience and one satisfaction rating variable from the questionnaire surveys were used to characterise CES at each site. In addition, visitation rates (number of visitors that passed the sampling spots per hour) from direct observations were used to further assess use intensity at each forest site.

We first tested the variation of use, experience and satisfaction among the five forests types. We acknowledge that we have a small sample size with limited statistical power at the forest site level ($n = 4$ per forest type), and may fail to identify an effect if it exists in the data (Makin & De Xivry, 2019). To support the reliability of our analysis, we performed variation tests at both the site and individual level (individual responses to questionnaires), which had considerable statistical power (see Appendix B, Table S1).

At the individual level (241 respondents in total), because most of the responses are ordinal, including Likert-type scaled variables, we used the non–parametric Kruskal–Wallis rank test, which examines whether samples (in our study, five forest types) had the same distribution (Corder & Foreman, 2011). The test was performed on all 15 individual response variables from the questionnaire (3 for use, 11 for experience and 1 for satisfaction). If a significant result was detected, Dunn's test (Dunn, 1964)—as a pair-wise post-hoc test—was employed to identify which pairs of forest types caused the difference.

At the site level (20 patches in total), we summarised individual responses to the questionnaire for each forest patch based on data type and distribution (Table 3). For example, for travel time, which is continuous, we used average travel time of the respondents at the site. While for visit frequency and visit duration, which are ordinal as framed by the questions, we calculated the proportion of respondents who use the forest more than once per week and who stayed in the forest more than 30 min. The experience and satisfaction variables are all Likert-type scaled data. Hence, we used the proportion of respondents who gave top ratings (5) to summarise experience and satisfaction at each urban forest site. Visitation rates per forest is also a site-level variable, and was thus also included in the analysis. For all 16 site-level variables, one-way analysis of variance (ANOVA) was used to test if differences are significant among the five types of forest, and Tukey's test was used to conduct post-hoc pair-wise comparisons to detect which pairs of forest types caused the difference. We used a significance level of 0.1 to denote significant difference

TABLE 2 Summary of the use, experience and satisfaction of urban forests of five landscape and land use context types

Forest types	Use pattern	Experience (perceived CES benefit)	Satisfaction
Large.Low	Longest travel time High visit rate Longest visit duration Rich in jogging and Nordic walking activities	Highest for all CES experiences Aesthetic as the most agreed CES Contact with nature among the top three agreed CES	High
Large.High	Short travel time High visit rate Long visit duration	High for inspiration Tied second highest with Small.Isol.Low for restoration, contact with nature and physical health Lowest for history	High
Small.Con.Low	Medium travel time Highest visit rate Shortest visit duration Rich in cycling	Lowest for contact with nature and inspiration Low for physical health	Low
Small.Isol.Low	Long travel time Low visit rate Medium visit duration Lack of cycling	High for appreciating landscape history Tied second highest with Large.High for restoration, contact with nature and physical health History among the top three agreed CES	Intermediate
Small.Isol.High	Shortest travel time Lowest visit rate Short visit duration Rich in dog walking Lack of jogging and Nordic walking activities and cycling	Lowest for physical health	Low

between different urban forest types because of the comparatively small sample sizes.

To better depict differences among urban forest types, we performed principal component analysis (PCA) with respect to the major dimensions of the inter-correlated CES measures (i.e. use, experience and satisfaction). The Kaiser criterion (i.e. eigenvalue >1; Kaiser, 1960) was used to select the principal components accounting for most of the variance of the CES measures. All statistical analyses were performed in R version 3.4.3 (R Core Team, 2017).

3 | RESULTS

To highlight the use, experience and satisfaction patterns across the five forest types, we summarise the main results in Table 2 and at the beginning of each subsection below, after which we present the results in more detail.

3.1 | Use of urban forests

Large forests with low construction density surroundings (Large.Low) had a high visit rate with rich jogging and Nordic walking activities, and the longest visit duration, although it takes people the longest time to reach them (Table 2). Comparatively, large forests with high construction density surroundings (Large. High) had much shorter travel times and slightly higher visit rates. Small and connected forests (Small.Con.Low) were the most intensively used forest type with the most cyclers, while the visit duration is shortest. Small and isolated forests with low-density surroundings (Small.Isol.Low) had lower use intensely, and long travel times. Small and isolated forests with high construction density surroundings had the lowest visit rates despite the shortest travel time. Activities in these forests were mostly walking dogs, while jogging and Nordic walking activities were the lowest.

Direct observations showed that visitation rates (visitor per hour) ranged from 4 to 37 (Figure 2). The Helsinki central forest (No. 6 in Figure 1) had a very high visitation rate of 206, and was treated as an outlier. Visitation rates between forests of different landscape and land use type showed significant differences (Table 3): rates were highest in small connected forests with low construction density surroundings (Small.Con.Low) with an average of about 26 visitors per hour. Also large forests had relatively high visitation rates (average between 15 and 20) compared to small and isolated forests (average of about 10 visitors per hour; Figure 2).

Among the observed visitors, most were walking (36%), walking dogs (24%) and cycling (20%; Figure 2). The share of activities also differed among different urban forest types. In particular, more physical activities related to fitness, like jogging and Nordic walking, were observed in large forests with a low surrounding construction density (Large.Low), compared small forest with a high surrounding construction density (Small.Isol.High; Figure 2, Appendix B, Table S2). More cyclists were observed in Small.Con.Low than in small and isolated forests (i.e. Small.Isol.Low, Small.Isol.High). The highest proportion of dog walking was observed in Small.Isol.High.

Summarised from the visitors' responses on forest use, 69% of the interviewees visited forests more than once a week. About half (49%) of the visitors stayed for longer than 30 min per visit. The

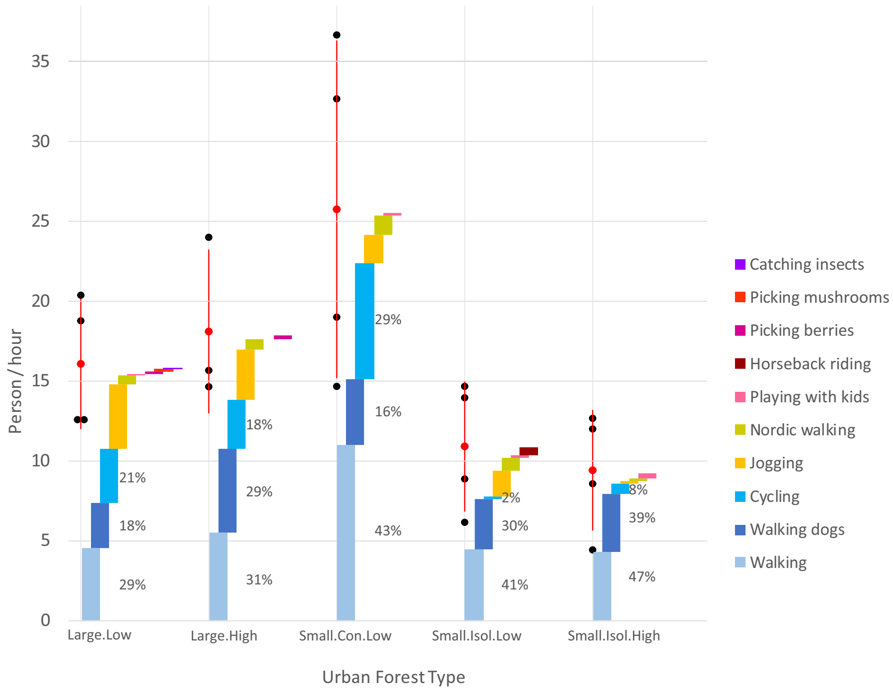

FIGURE 2 Summarised visitation rates and activity composition of surveyed urban forests with different landscape and land use contexts. Visitation rates of each forest are shown (black dot) together with the mean (red dot) and standard deviation (red bar) within each forest type. Activities are sorted from the most to the least abundant type, with percentages of the top three activity types labelled. Note that forest patch No. 6 (see Figure 1) is excluded because visitation rate of this patch is treated as the outlier, see Section 3.1 in the text

TABLE 3 Kruskal–Wallis rank test and ANOVA results among use, experience and satisfaction of five types of urban forests based on individual-level and forest site-level analyses

Analysis	Test at individual level (Kruskal–Wallis test)		Test at site level (ANOVA)	
Category	**Variable**	***p*-value**	**Variable**	***p*-value**
Use	Frequency	0.805	Proportion of visit frequency > 1/week	0.884
	Duration	<0.001	Proportion of visit duration > 30 min	0.002
	Travel time	0.032	Proportion of visit travel time > 10 min	0.034
Experience	Leisure	0.185	Proportion of leisure rating = 5	0.626
	Contact	0.015	Proportion of contact rating = 5	0.034
	Beautiful	0.080	Proportion of beautiful rating = 5	0.146
	Place	0.100	Proportion of place rating = 5	0.426
	People	0.108	Proportion of people rating = 5	0.771
	Learn	0.842	Proportion of learn rating = 5	0.367
	Spiritual	0.081	Proportion of spiritual rating = 5	0.305
	History	0.001	Proportion of history rating = 5	0.057
	Health	0.012	Proportion of health rating = 5	0.087
	Inspiration	0.049	Proportion of inspiration rating ≥ 3	0.007
	Restoration	0.043	Proportion of restoration rating = 5	0.048
Rating	Satisfaction	0.001	Satisfaction (rating = 5)	0.036
Visiting rates	—	—	Visiting rates (/hour)	0.016

median and mean travel time from home to the forests was 5 and 13 min respectively.

Responses to our questionnaire on forest use are illustrated in Figure 3, with responses at the individual level presented in the left panels, and responses at the site level in the right panels. The Kruskal–Wallis rank test based on individual respondents revealed significant differences between forests with different landscape and land use context in visit duration and travel time, but not in visit frequency (Table 3; Figure 3). The post-hoc tests further showed significant pair-wise differences (see paired symbols above the plots). More specifically, visitation duration of large forests (Large.Low, Large.High) was significantly longer than that of small forests (Small.Con.Low, Small.Isol.Low, Small.Isol.High; Figure 3c). Furthermore, among small forests the duration of a visit in Small.Isol.Low was significantly longer than in Small.Con.Low (Figure 3c). At the site level, ANOVA test revealed that the proportion of

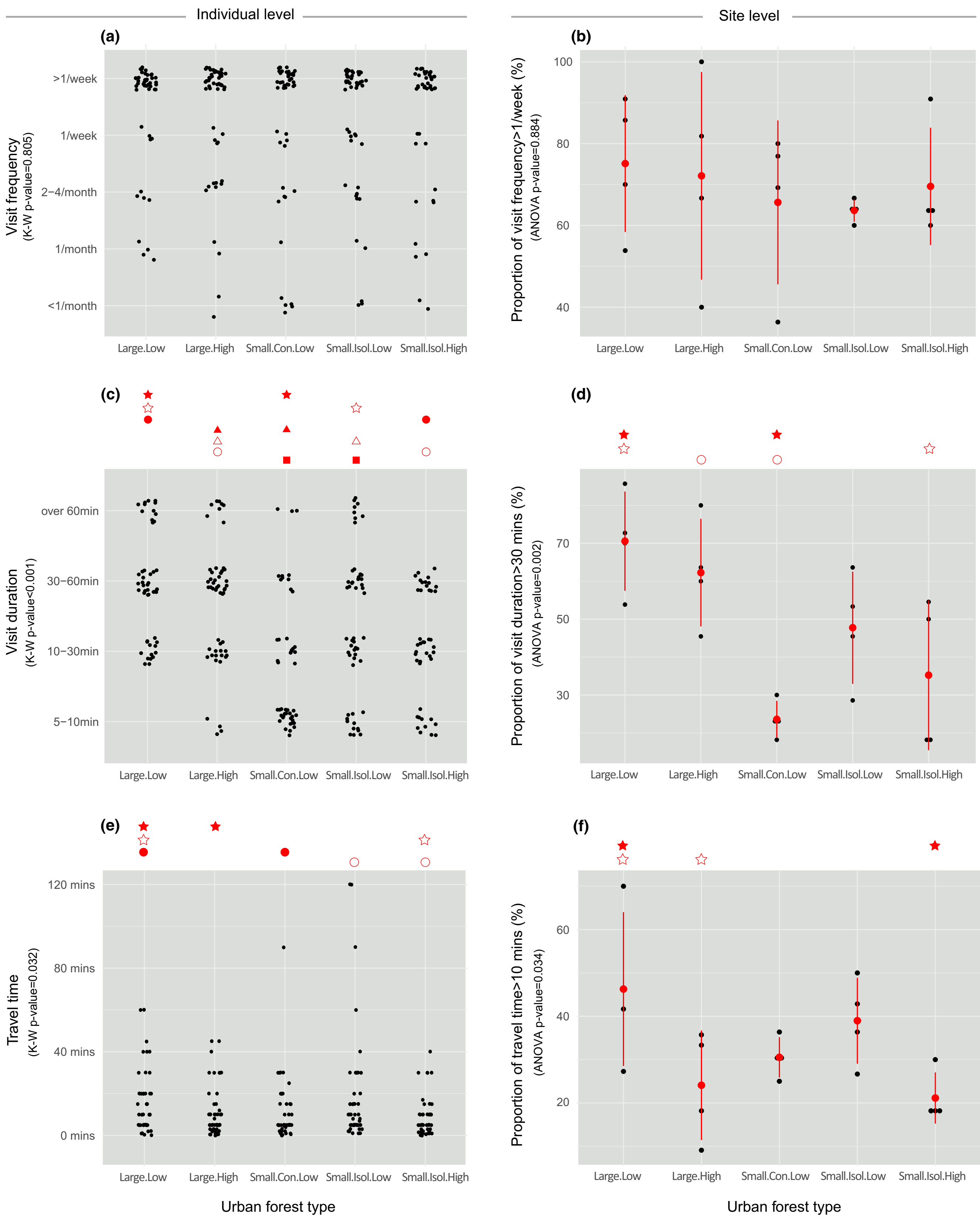

FIGURE 3 Differences in use (i.e. visit frequency, visit duration, travel time) between the five surveyed urban forest types of different landscape and land use contexts (Large.Low, Large.High, Small.Con.Low, Small.Isol.Low and Small.Isol.High). The left panels show the use by individual respondents. The right panels show the summarised use in each forest site, with the mean (red dot) and SD (red bar). Pairs of forest types with significant differences ($p < 0.05$ for the left panel, $p < 0.1$ for the right panel) from post-hoc tests are denoted with pairs of symbols on top of the plot (different symbols are used to distinguish pairs).

long-duration users (visit duration >30 min) in large forests (Large.Low, Large.High) is significantly higher (over 60%) than in Small.Con.Low (24%; Figure 3d). In addition, long-duration users of Large.Low (71%) are also significantly higher than that of Small.Isol.High (35%). These are consistent with our results based on individual respondents (cf. Figure 3c,d). In terms of travel time of individual respondents, the time travelled to Large.Low forests was significantly longer than that to Large.High, Small.Con.Low and Small.Isol.High. Furthermore, the time travelled to Small.Isol.Low was also longer than to Small.Isol.High forests (Figure 3e). This is most probably due to the fact that fewer people live in low construction density areas, and it would take them longer to reach the forest. Results at the site level further confirmed this pattern and revealed that the proportion of long-distance users (travel time > 10 min) was significantly higher in Large.Low (46%) than in Large.High (24%) and Small.Isol.High (21%; Figure 3f).

3.2 | Experience in urban forests

Large forests with low-density surroundings (Large.Low) performed the best in almost all CES experiences (Table 2). Large forests with high construction density surroundings (Large.High) perform well in providing experiences such as inspiration and contact with nature, but performed poorly in the experience of landscape history. Small and isolated forests with low-density surroundings (Small.Isol.Low) were much appreciated for the experience they provide, particularly for their landscape history and their benefits for restoration and physical health. The benefits of visiting small and isolated forests with high-density surroundings (Small.Isol.High) were hardly appreciated, particularly the experience in physical health. Small and connected forests with low-density surroundings (Small.Con.Low) received the lowest ratings in the experience of restoration, contact with nature and inspiration.

Responses to our questionnaire on forest experience showed large differences in various aspects of people's perceived experiences (i.e. CES benefits of urban forest; Figure 4). Nine of 11 experiences received a relatively high proportion (>50%) of high ratings (4 + 5), with the top three highly rated experiences being 'leisure', 'restoration' and 'beautiful'. Exceptions were 'enjoy meeting with people' and 'learn from nature', which were not well appreciated by most of the visitors. In particular, 'meeting people' received more than half (58%) of the low ratings (1 + 2), indicating that social experience is of minor importance when visiting forests in Helsinki. Note that the experiences of landscape history, spiritual and learning from nature received comparatively more 'do not know' answers,

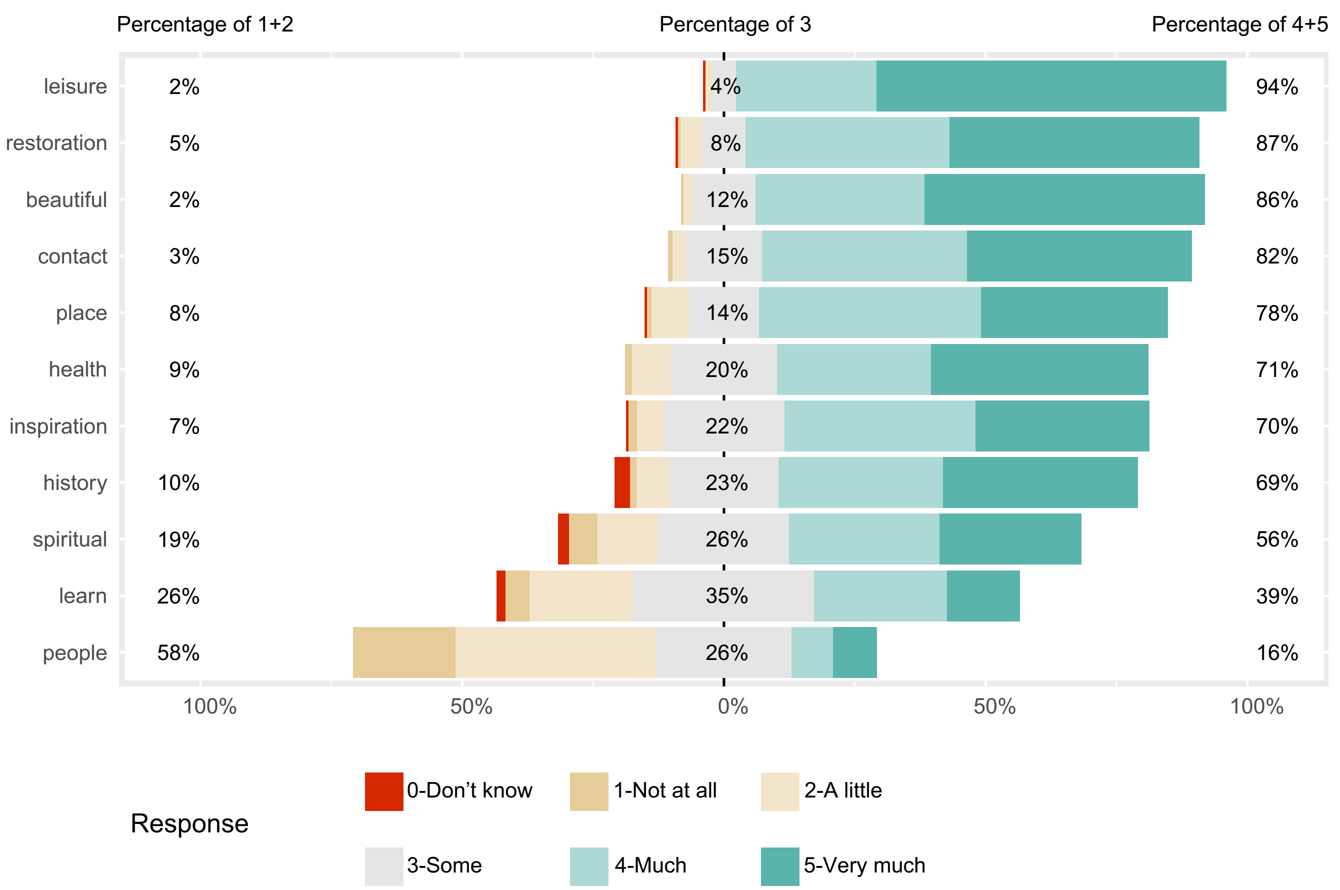

FIGURE 4 Summary of the experience ratings from all questionnaire respondents. All visitors are given this full list to rate for the site in which they are interviewed. Experiences are ranked by its ratings. The proportions of ratings of '1 + 2', '3 and '4 + 5' for each experience are given in percentages. The answer 'do not know' is shown in red.

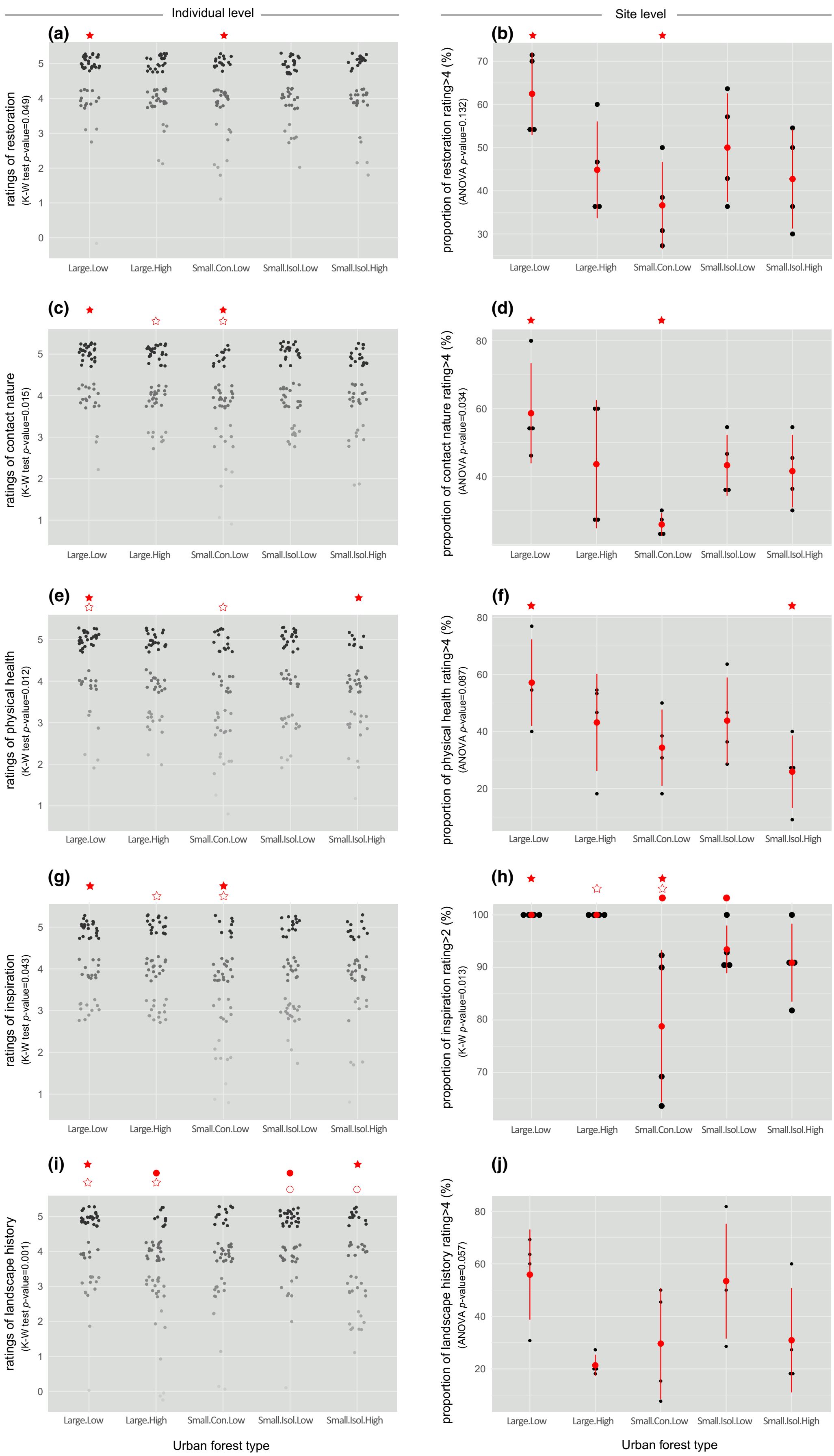
Individual level
Site level
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
ratings of restoration
(K-W test p-value=0.049)
proportion of restoration rating>4 (%)
(ANOVA p-value=0.132)
ratings of contact nature
(K-W test p-value=0.015)
proportion of contact nature rating>4 (%)
(ANOVA p-value=0.034)
ratings of physical health
(K-W test p-value=0.012)
proportion of physical health rating>4 (%)
(ANOVA p-value=0.087)
ratings of inspiration
(K-W test p-value=0.043)
proportion of inspiration rating>2 (%)
(K-W p-value=0.013)
ratings of landscape history
(K-W test p-value=0.001)
proportion of landscape history rating>4 (%)
(ANOVA p-value=0.057)
Large.Low
Large.High
Small.Con.Low
Small.Isol.Low
Small.Isol.High
Urban forest type

FIGURE 5 Differences in experience (i.e. restoration, contact with nature, physical health, inspiration and landscape history) between the five surveyed urban forest types of different landscape and land use contexts (Large.Low, Large.High, Small.Con.Low, Small.Isol.Low and Small.Isol.High). The left panels show the experience perception of individual respondents. The right panels show the summarised experiences in each forest site. Pairs of forest types with significant differences from post-hoc tests are denoted with pairs of symbols (see Figure 3).

indicating relatively large uncertainties in people when perceiving these experiences from their visit to an urban forest.

According to the Kruskal–Wallis rank test based on individual responses (Table 3), significant differences between forests of different landscape and land use contexts were detected in five of the 11 experiences surveyed (Figure 5). The five experiences are 'restoration', 'contact with nature', 'physical health', 'inspiration' and 'landscape history', most of which were ranked in the middle of the 11 experiences rated by respondents (Figure 4). With regard to 'restoration', Large.Low exhibited significantly higher values than Small.Con.Low based on both individual and site-level data (Figure 5a,b). With regard to 'contact with nature' and 'inspiration', large forests (Large.Low and Large.High) displayed a significantly higher rating than small connected forests (Small.Con.Low; Figure 5c,d,g,h). In particular, the low ratings for Large.Low were much less than that for Small.Con.Low (Figure 5d,h). For instance, all surveyed users of large forests rated the experience of inspiration higher than 3, significantly more than Small.Con.Low, where 21% of the surveyed users had a rating of 1 or 2 for inspiration (Figure 5h). With regard to 'physical health', Large.Low also received a higher rating than the other types of forest, significantly different from Small.Con.Low and Small.Isol.High (Figure 5e), especially in the proportion of high ratings (i.e. ratings = 5; Figure 5f). With regard to 'landscape history', forests in the urban context of low surrounding construction density (Large.Low and Small.Isol.Low) were more appreciated than those surrounded by a high construction density (Large. High and Small.Isol.High; Figure 5i,j), even though statistical differences were only found at the individual respondent level (Figure 5i) and not at the forest site level (Figure 5j).

3.3 | Satisfaction over urban forests

Large urban forests, regardless of their surrounding construction density (Large.High and Large.Low), had equally high average satisfaction rates (Table 2). Small isolated urban forests with low construction density surroundings (Small.Isol.Low) displayed the second highest average satisfaction rate following large forests and were the highest among small forest types. Small isolated urban forests with high-density construction surroundings (Small.Isol.High) had a relatively lower satisfaction rate. Small forests highly connected to the rest of the forest network (Small.Con.Low) had the lowest satisfaction rate.

The response to our questionnaire on satisfaction shows that in total, 58% respondents were highly satisfied (rating = 5) with the urban forests they were visiting, meaning that these forests meet most of their expectations during the visit. Less than 10% gave a satisfaction rating lower than 3, reflecting their neutral attitude or dissatisfaction with their visit. There were large differences in satisfaction among forests of different landscape and land use contexts (Figure 6). The average rate of satisfaction was generally higher in large (Large.Low and Large.High) than small forests (Small.Con.Low, Small.Isol.Low, Small.Isol.High) with Small.Con.Low receiving the lowest satisfaction (Figure 6b). Among small forest types, Small.Isol.Low showed the highest satisfaction rate. A significant difference was detected between Large.Low/Large.High and Small.Con.Low/Small.Isol.High, and between Small.Isol.Low and Small.Con.Low based on individual respondents (Figure 6a), while based on site-level satisfaction ratings, a significant difference is manifested between Large.Low/Large.High and Small.Con.Low in the percentage of highly satisfied respondents (rating = 5), with an average above 70% for Large.Low and Large.High but only 40% for Small.Con.Low (Figure 6b). A significant difference was also found in the proportion of satisfied respondents (rating ≥4) between Small.Isol.Low (94%) and Small.Con.Low (78%; results not shown).

3.4 | Relation between urban forests use, experience and satisfaction

A principal component analysis (PCA) reduced the 16 CES variables to five dimensions, which accounted for 79.8% of the total variance. The first two components of the PCA are illustrated in Figure 7. Information on the third, fourth and fifth dimensions can be found in the Supplementary material (Appendix B, Figure S2). The first component explains 38.4% of the total variance, and mainly represents variation of experiences except 'enjoy leisure time' and 'enjoy meeting people' (see also Appendix B, Figure S3a). This also indicates that most experience variables were highly positively correlated with each other. The second component explains 14.9% of the total variance, and mainly represents variation in use intensity. Both visit frequency and visit rate contributed to the positive loadings of this component, while travel time contributed negatively. Interestingly, people's overall satisfaction is equally explained by the first and second component (Figure 7 and Appendix B, Figure S3b), indicating that both people's experience and use intensity are important in determining their overall satisfaction with an urban forest.

The position of each forest patch in relation to the two major components is also depicted in Figure 7. It shows that Large.Low is well-separated from Small.Con.Low and Small.Isol.High along Dim 1, indicating overall higher experience values of Large.Low than that of Small.Con.Low and Small.Isol.High. On the other hand, Large.High is well-separated from Small.Isol.Low along the second component,

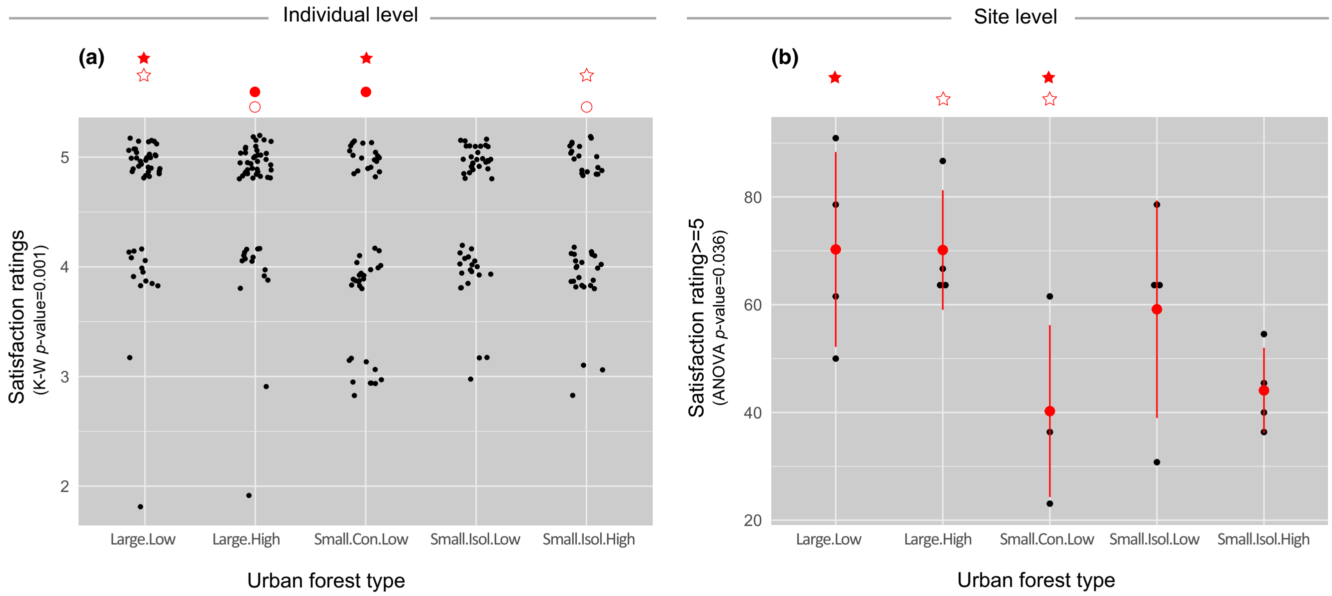

FIGURE 6 Differences in satisfaction ratings between the five surveyed urban forest types of different landscape and land use contexts (Large.Low, Large.High, Small.Con.Low, Small.Isol.Low and Small.Isol.High). The left panel shows the satisfaction rating of individual respondents. The right panel shows the summarised satisfaction rates in each forest site. Pairs of forest types with significant differences from post-hoc tests are denoted with pairs of symbols (see Figure 3).

indicating distinct usage patterns between these two types of urban forests. While the Large.High forests are associated with high use intensity (i.e. visit frequency and visit rate) and short travel time, Small.Isol.Low is associated with comparatively lower use intensity and longer travel times. Similar to results shown in Figure 6, the five types of forests are not clearly separated by their overall satisfaction. Even so, Large.High tends to have high satisfaction more consistently than other types of forests.

4 | DISCUSSION

4.1 | Unique Cultural Ecosystem Services provided by urban forests

We showed that 70% of urban forest users in Helsinki visit these forests more than once a week with an average travel time of 13 min, which agrees with previous studies that showed patchy forests in urban areas are used as close-to-home recreational areas in Helsinki (Neuvonen et al., 2007). With the close-to-home use pattern, over 80% of urban forest users agreed much or very much with the experience of 'contact with nature' during visits. Contrary to peri-urban forests or city trees, urban forest remnants provide a possibility to experience nature on a daily basis.

The top-rated CES categories of visiting urban forest remnants are recreational and aesthetic values, which agrees with CES in urban greenspaces, mostly parks (Rall et al., 2017). However, social benefits are rated as the least agreed CES in urban forests: less than half of the respondents enjoyed 'meeting with people', in contrast with a prominent benefit of social interaction in urban parks (Campbell et al., 2016; Zwierzchowska et al., 2018). Similarly, social activity, which is common in urban parks (e.g. resting, meeting friends and picnicking), is also lacking in urban forests with high tree cover (Palliwoda & Priess, 2021). On the other hand, physical activity, characterised by walking, walking dogs and cycling, followed by jogging and Nordic walking, is dominant (over 90%) in urban forests, which is in line with the use of urban forests in Germany (Gerstenberg et al., 2020). The type of use of urban forests seems to be intuitive given the enclosed forest environment, which attracts the enjoyment of privacy and promotes the perception of restoration, aesthetic and contact with nature.

4.2 | The effects of landscape features and land use context

As expected, we found that the size of an urban forest is a critical landscape feature in determining its CES. Larger forest, irrespective of land use context, has significantly more visitors, longer stays, is richer in jogging and Nordic walking activities, has higher reported benefits of physical health improvement and inspiration, and higher satisfaction rates. It has been demonstrated that larger greenspaces generally have more ecological features and recreational facilities (Zhang & Zhou, 2018), which provide the possibility for more diverse activities and associated benefits (Brown et al., 2018; Vierikko et al., 2020). As we did not find more diverse activities in larger parks, we agree with the study of Massoni et al. (2018) who suggested that higher structural diversity may not explain the greater CES of peri-urban forests. Instead, due to the promotion of physical activities for fitness and associated benefits we detected from large

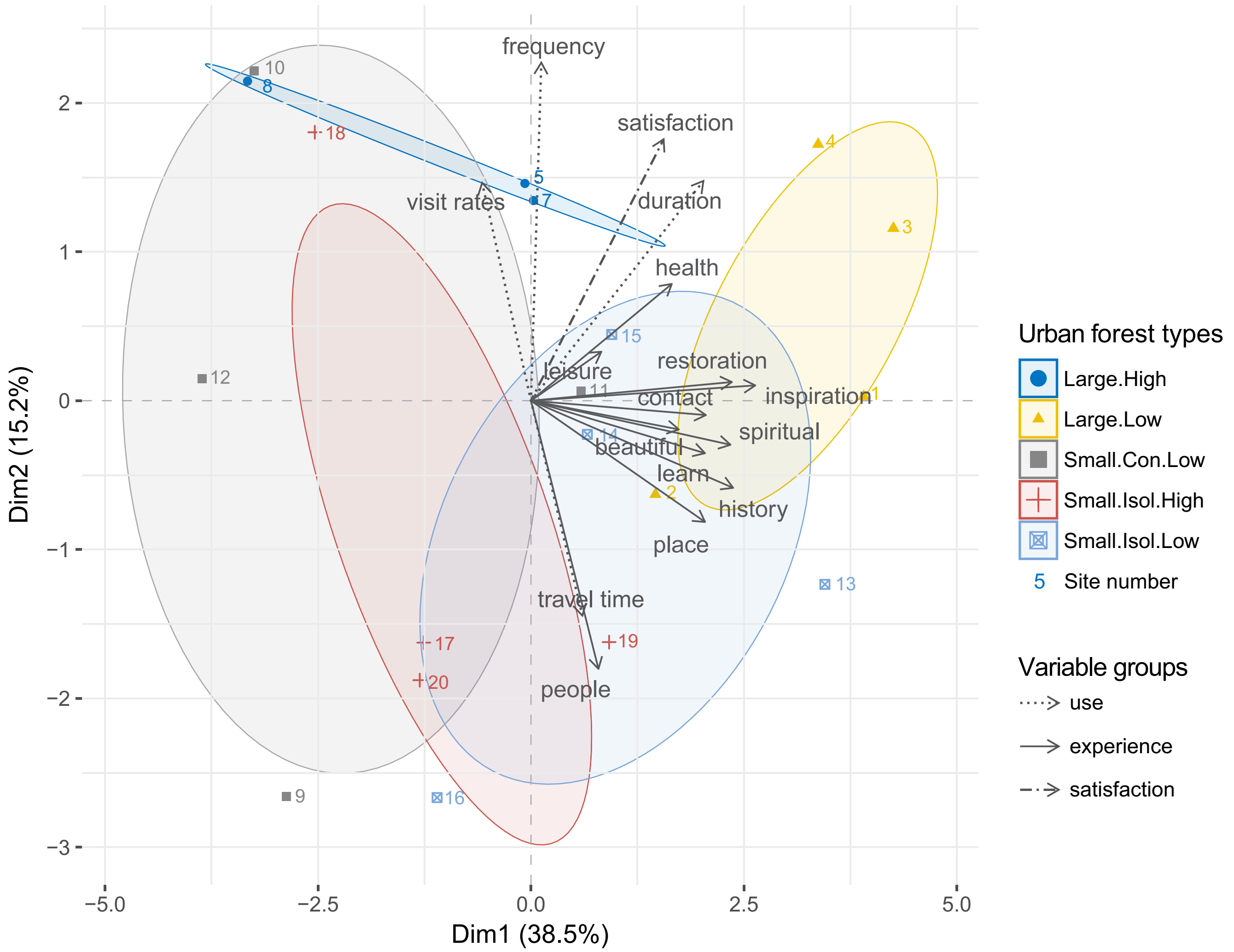

FIGURE 7 The first two principal components of the principal component analysis based on forest-level CES variables. The projection of CES variables (i.e. use, experience and satisfaction) and urban forest patch on the two principal components are denoted by arrows and dots. Forest patch number (see Figure 1) is shown next to the forest symbol. Note that forest patch No. 6 (Large.High) is excluded from the figure because of its high visitation rate, see Section 3.1. The ellipses represent 95% confidence regions of the five forest types (meaning that if the forest samples were repeated, 95% of the time the confidence region would include the 'true' values of this type).

forest, we suspect that the effects of forest size might come from immersive spaciousness and the associated perceived naturalness that people can enjoy through their physical activity along longer trails. Comparatively, small and isolated forests lack cycling activity, which might be due to cyclists preferring long straight routes (Gerstenberg et al., 2020) in urban forest, which could only be found in large forests or linear connected forests.

Connectivity within forest networks, which is achieved by linear forest strips and many small forest remnants (i.e. Small.Con.Low), encourages more people to use urban forests. This is partly in line with findings by Brown et al. (2018) who found that physical activities peak in linear parks, and validates the premise of maintaining green networks. However, our results show that linear or steppingstone forests fail to deliver well-appreciated CES, even physical benefits, compared to isolated small forests with similar low construction density surroundings. Our study suggests that their intensive use is most probably from everyday outings (walking and cycling) with the shortest visit duration among all forest types. Although commuting through urban forests can have physical and psychological benefits (Pietilä et al., 2015), our study suggests that the benefits of commuting through forests is less perceived than jogging, Nordic walking and other recreational activities there.

We found that urban forests in low construction density areas deliver better appreciated CES of psychological restoration, physical health improvement and cultural heritage, irrespective of their relatively long travel times. Previous studies have revealed that most CES perceptions are rated higher around the urban fringe than in urban centres, whereas use intensity concentrate in city centres (Rall et al., 2017; Riechers et al., 2019). The highly appreciated cultural heritage we found in the low construction density area is different to Rall et al. (2017), but in line with Riechers et al. (2019), probably due to that natural features are more important for the historical places in urban forests as shown by Baumeister et al. (2020). By using a detailed measurement of urbanisation (i.e. the surrounding construction density) rather than the urban centre–urban fringe gradient, we further revealed that at the urban fringe, forest with high-density surroundings can also be used intensely (e.g. our Large.High site 8 in Figure 1, Figure 7), but for a more relaxed feeling or recreational experience, people tend to choose forests with less constructed surroundings (Large.Low site 4). From another perspective, the appreciation of many forest CES in low-density areas might also result from its 'enjoyable' user group. Riechers et al. (2019) showed that in low construction density areas of a city, residents are often 'nature lovers', who have a high tendency to appreciate nature. We suggest that landscape and land use context may affect not only the supply of a CES, but also its demand, which deserves further study.

Remarkably, we note that the impact of landscape and land use contexts on CES values of an urban forest can interact with each other. For instance, some experiences of the small isolated forests with low construction density surroundings are similar to or even exceed the large forests with high construction density surroundings, suggesting that a low construction density urban context may compensate the shortcomings associated with small urban forests. Better physical benefits are not only met in forests that are large enough to move around in, but also in small forests that are surrounded by other greenspaces (e.g. parks, river sides, fields, etc.), where people have more potential to form their routes for walking or exercising in nature. This is in line with Liu et al. (2016), suggesting that a greenway should feature green surroundings composed of waterfronts, hillsides and large parks to encourage physical activity. On the other hand, although studies show that small but close-to-home greenspaces are preferred by citizens (Mapita, 2014) and pocket parks have a high perceived CES (Peschardt et al., 2016), we did not find this benefit for small forests scattered in high-density urban areas. A possible reason for this discrepancy is that people have different expectations for using urban forests compared to urban parks. As Palliwoda and Priess (2021) reported, parks in high-density residential area are expected to provide meeting places or places for everyday social life. However, there seems to be no such type of forest visit that can be easily fulfilled by small and isolated forests. It is therefore evident that the size benefit of urban forests is more effective in highly constructed urban areas, especially for use intensity and satisfaction rate.

Our results indicate that CES measured by use pattern, reported benefits, and overall satisfaction vary distinctly given the type of urban forest. For example, small and connected forests provide the most intense use, but unsatisfied CES experience. Therefore, assessing the CES of an urban forest could only be meaningful with regard to the specific CES category measured. Summarised from the various CES measures, we showed that CES benefit ratings of an urban forest are in a different dimension of the use pattern. The decoupling of people's experience and visitation rates has been shown by Shanahan et al. (2015) who revealed that visitation rates do not increase with the more natural experience of an urban park. From the two main principal components of PCA, our visitation rates displayed a negative association with social CES, that is, enjoy meeting people, and showed hints of a negative association with CES of cultural heritage, sense of place, educational and spiritual value, suggesting that high visitation rates may cause crowding, which deteriorate recreational quality as revealed by Arnberger (2012). The tolerance of visitor number could be even lower for active urban forest users who are seeking tranquillity and the feeling of being in a forest (Tyrväinen et al., 2007).

Interestingly, both use intensity and visitors' CES perception on site characterise the overall satisfaction towards an urban forest, which may reflect people's held values of CES. For example, people tend to have consistently high satisfaction rates in large forests with high construction density surroundings, even though popularity and visiting experience differed greatly in these forests. Alternatively, satisfaction is found to be better reflected by visit duration, which is understandable as highly rated forests are usually richer in recreational activities, either for physical fitness or natural experience, which require longer stays. Also, forests with higher recreational values, especially benefits of physical health, display higher satisfaction. Akpinar (2016) also revealed that longer duration of physical activities was associated with better physical health. We suspect that more utilised CES, like perceived health benefits are more likely to be incorporated into the value of nature that people hold.

4.3 | Implications for urban planning and the promotion of cultural ecosystem services

To eliminate the ecological impact of urban expansion, several cities have adopted planning policies dedicated to foster urban densification (Teller et al., 2021). However, urban densification can also profoundly impact cultural ecosystem services in the densified area (Andersson et al., 2020; Kyttä et al., 2013). In terms of urban forests, infill development may result in the shrinking of existing forests. Parts of large forests may be potentially taken as sites for infill projects, thus becoming smaller. The resulting smaller sized forests may have limited space for physical activities and tranquillity benefits, which are dominant CES provided by urban forest in our study. However, urban forest CES could also be achieved through the numerous smaller forest fragments, where construction can also take place. Which small forest to retain then? Our results suggest that managing small patchy forests near watersides, parks or fields can be spatially efficient to facilitate recreation. On the other hand, isolating a small forest fragment in-between densely built areas should be avoided, as forest use or experience can be hardly achieved in such scenarios.

Another possible impact of urban densification to forest CES is that the surroundings may be transformed from low to high construction density area. The increased surrounding construction density may result in more residents instantly able to reach urban forests. However, this increased use intensity and the perception of the surroundings may deteriorate the tranquillity and nature experience in the forest. On the other hand, many greenspaces in the neighbourhood could be potentially transferred to constructed areas. In other words, the urban context becomes less attractive. Forest visitors are then less attentive to move towards or between forests. Small patchy forests become further isolated thus are hard to be reached in either commuting or recreational route.

Under the challenge of further fragmentation and isolation of forest, it is more critical to form forests connections (Erävuori et al., 2020), mostly with linear forests or steppingstone forest (the highly connected patches in our study). Our findings show that high connectivity makes the linear forest more intensively used, as it could reach many other forests in short distance. However, the recreational experience of the linear forest could be largely questionable most probably due to the exposure to the surrounding urban matrix (Hauru et al., 2012). Urban planners also aim to ensure easy access to urban greenspaces. The logic is that accessibility will encourage use, which leads to health and other benefits (Pietilä et al., 2015). Our results show that the increased use of the highly accessible forests (e.g. Small.Isol.High, Large.High, Small.Con.Low) is mostly everyday outings, including walk, walking dogs and cycling, which can hardly provide appreciated restorative, natural or cultural experiences. We suggest that CES of urban forests are not necessarily achieved through ensuring accessibility and facilitating utilisation. Planning policies to promote physical activity might promote different aspect of CES, which requires further investigation.

Our findings of the mismatch between uses and experiences imply challenges for public participatory planning. Gaining support or acknowledgement from citizens may help identify planning priorities for an urban greenspace, and to carry out maintenance and construction. However, public opinion may be swayed towards popularity and overall satisfaction that is biased towards only some benefits. Comparing our results to the public participatory mapping results that will launch the Helsinki masterplan 2050 (2019), large forests have been marked by most people through participatory mapping as unique urban nature, although those in intensively built areas provide limited natural and psychological experience as revealed in our study. In contrast, in extensively built areas, small isolated forests (Small.Isol.Low) that provide good experiences have received less attention in participatory mapping because of their lower number of users. Moreover, little public support exists for small connected forests (Small.Con.Low), as their visiting outcomes are hardly perceived despite their heavy use by visitors. Since encouraging more people to use forests and promoting forest experience are both important for CES, we call for strategies to increase public awareness of the benefits of small forests and engage broader stakeholders to boost the discussion over the popularity and perceived benefits of urban forests in the planning process.

4.4 | Limitations and future studies

Compared to recent CES studies that employ postal or internet surveys (Rall et al., 2017; Shanahan et al., 2017) or big data from mobile phones and social media (Kothencz et al., 2017; Zhang & Zhou, 2018), our sample size was comparatively small, which is susceptible to reduced statistical power and an increase in sampling bias (Hill, 1998). However, our study is in line with other on-site questionnaires in terms of numbers of sites sampled (Akpinar, 2016; Zwierzchowska et al., 2018). Although we were able to reduce the statistical concerns and show that the age structure of our respondents was representative of that of the observed forest visitors, which was representative of the city population (see Appendix B, Figure S1), we acknowledge that our study is not a thorough assessment of urban forest CES. Yet, there is always a balance between survey coverage and site resolution with respondent credibility. Data sufficient studies also often suffer from sampling bias associated with low response rates or self-selecting users (Havinga et al., 2020). Our study design across landscape and land use features explicitly explored what happens within urban forests at the expense of sample size.

Future studies could survey for longer time periods and cover seasonal changes to improve our understanding of the dynamics of forest CES. We also suggest using a detailed categories for recreational services in urban CES evaluation, because the general recreational value (enjoy leisure time) is commonly agreed by urban forest visitors, while the benefit of psychological restoration, physical improvement and contact with nature are discretely rated.

5 | CONCLUSION

Through our on-site survey of the use, experience and satisfaction of urban forests of different landscape and land use contexts in Helsinki, we found that CES of urban forests are mainly manifested by its benefits for psychological restoration, aesthetics and sense of place through physical activities. Landscape and land use contexts are influential for urban forests to deliver CES, yet studying features separately, such as size, connectivity or construction density, are not sufficient to explain the CES provided. In general, larger forests deliver highly satisfied CES, particularly in terms of physical health, inspiration and restoration through long and intense use. Surrounded by low construction density areas also facilitate the CES of urban forests, especially the appreciation of its landscape history, the benefits for restoration and physical health. In contrast, highly connected forests do not perform well in perceived CES benefits, as reflected by low perceived experience and satisfaction rates, even though it encourages commuting in or through the forest. We suggest preserving large forest patches in low construction density urban areas for their high CES. In intensely built areas, large forests are vital to encourage use and improve satisfaction. Moreover, maintaining small forests in the vicinity of open green areas is an effective way to compensate limited forest areas in urban spaces and provide forest experiences. Our results indicate that both the use and perceptions of CES contribute to the overall satisfaction of an urban forest. Despite of that, a mismatch was detected between CES measures, suggesting that CES of an urban forest cannot simply be reflected by its use intensity or accessibility.

AUTHOR CONTRIBUTIONS

Yuan Wang, Jari Niemelä and D. Johan Kotze conceived the ideas and designed the study; Yuan Wang collected the data; Yuan Wang

and D. Johan Kotze analysed the data; Yuan Wang and D. Johan Kotze led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

ACKNOWLEDGEMENTS

We thank Annika Nuotiomaki and Sonja Still for the work they did in the field surveys. We appreciate Dr. Kati Vierikko's help in identifying urban forest sites. We also thank Helsinki Region Environmental Services Authority (HSY), the Finnish Forest Research Institute (Luke) and the Environmental Protection Department and Planning Department of Helsinki for providing information about municipality-level data and answering our questions about the data. The study was funded by Helsinki Research Grants and the Chinese Scholarship Council (CSC).

CONFLICT OF INTEREST

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

DATA AVAILABILITY STATEMENT

Data that support the findings of this study are archived in figshare: https://doi.org/10.6084/m9.figshare.20195039.

ORCID

Yuan Wang https://orcid.org/0000-0001-8770-2926

D. Johan Kotze https://orcid.org/0000-0003-4211-4420

REFERENCES

Akpinar, A. (2016). How is quality of urban green spaces associated with physical activity and health? *Urban Forestry & Urban Greening*, *16*, 76–83. https://doi.org/10.1016/J.UFUG.2016.01.011

Andersson, E., Haase, D., Scheuer, S., & Wellmann, T. (2020). Neighbourhood character affects the spatial extent and magnitude of the functional footprint of urban green infrastructure. *Landscape Ecology*, *35*(7), 1605–1618. https://doi.org/10.1007/S10980-020-01039-Z/FIGURES/4

Arnberger, A. (2012). Urban densification and recreational quality of public urban green spaces—A Viennese case study. *Sustainability*, *4*(4), 703–720. https://doi.org/10.3390/su4040703

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 and Urban Greening*, *48*, 126561. https://doi.org/10.1016/j.ufug.2019.126561

Beninde, J., Veith, M., & Hochkirch, A. (2015). Biodiversity in cities needs space: A meta-analysis of factors determining intra-urban biodiversity variation. *Ecology Letters*, *18*(6), 581–592. https://doi.org/10.1111/ele.12427

Brancalion, P. H. S., Cardozo, I. V., Camatta, A., Aronson, J., & Rodrigues, R. R. (2014). Cultural ecosystem services and popular perceptions of the benefits of an ecological restoration project in the Brazilian Atlantic Forest. *Restoration Ecology*, *22*(1), 65–71. https://doi.org/10.1111/rec.12025

Brown, G., Rhodes, J., & Dade, M. (2018). An evaluation of participatory mapping methods to assess urban park benefits. *Landscape and Urban Planning*, *152*, 18–31. https://doi.org/10.1016/j.landurbplan.2018.05.018

Campbell, L. K., Svendsen, E. S., Sonti, N. F., & Johnson, M. L. (2016). A social assessment of urban parkland: Analyzing park use and meaning to inform management and resilience planning. *Environmental Science & Policy*, *62*, 34–44. https://doi.org/10.1016/J.ENVSCI.2016.01.014

Cheng, X., van Damme, S., Li, L., & Uyttenhove, P. (2019). Evaluation of cultural ecosystem services: A review of methods. *Ecosystem Services*, *37*, 100925. https://doi.org/10.1016/j.ecoser.2019.100925

City of Helsinki. (2022). *Helsinki facts and figures 2022 [Booklet]*. City Executive Office, Urban Research and Statistics. https://www.hel.fi/hel2/tietokeskus/julkaisut/pdf/22_06_15_Helsinki_facts_and_figures_2022.pdf

City of Helsinki. (2016). *Statistical Yearbook of Helsinki*. Helsingin kaupunginkanslia/Kaupunkitieto. https://hri.fi/data/en_GB/dataset/helsingin-tilastollinen-vuosikirja

Corder, G. W., & Foreman, D. I. (2011). Comparing more than two unrelated samples: The Kruskal–Wallis H-Test. In *Nonparametric statistics for non-statisticians* (pp. 99–121). Wiley. https://doi.org/10.1002/9781118165881.ch6

Davies, C., & Lafortezza, R. (2017). Urban green infrastructure in Europe: Is greenspace planning and policy compliant? *Land Use Policy*, *69*, 93–101. https://doi.org/10.1016/j.landusepol.2017.08.018

Dunn, O. J. (1964). Multiple comparisons using rank sums. *Technometrics*, *6*(3), 241–252. https://doi.org/10.1080/00401706.1964.10490181

Erävuori, L., Hätälä, J., & Oksman, S. (2020). *Helsingin metsä ja puustoisen verkoston runko ja alueelliset yhteydet 2019 (Helsinki forest and wooded network frame and regional connections 2019)*. Helsingin kaupunki/Kaupunkiympäristön toimiala (in Finnish).

ESRI. (2011). *ArcGIS desktop: Release 10*. Environmental Systems Research Institute.

Fischer, L. K., Honold, J., Botzat, A., Brinkmeyer, D., Cvejić, R., Delshammar, T., Elands, B., Haase, D., Kabisch, N., Karle, S. J., Lafortezza, R., Nastran, M., Nielsen, A. B., van der Jagt, A. P., Vierikko, K., & Kowarik, I. (2018). Recreational ecosystem services in European cities: Sociocultural and geographical contexts matter for park use. *Ecosystem Services.*, *31*, 455–467. https://doi.org/10.1016/J.ECOSER.2018.01.015

Fuller, R. A., Irvine, K. N., Devine-Wright, P., Warren, P. H., & Gaston, K. J. (2007). Psychological benefits of greenspace increase with biodiversity. *Biology Letters*, *3*(4), 390–394. https://doi.org/10.1098/rsbl.2007.0149

Gerstenberg, T., Baumeister, C. F., Schraml, U., & Plieninger, T. (2020). Hot routes in urban forests: The impact of multiple landscape features on recreational use intensity. *Landscape and Urban Planning*, *203*, 103888. https://doi.org/10.1016/J.LANDURBPLAN.2020.103888

Haines-Young, R., & Potschin, M. (2013). *Common International Classification of Ecosystem Goods and Services (CICES)*. EEA Framework Contract No EEA/IEA/09/003. https://doi.org/10.1038/nature10650

Hansen, R., & Pauleit, S. (2014). From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. *Ambio*, *43*(4), 516–529. https://doi.org/10.1007/s13280-014-0510-2

Hauru, K., Lehvävirta, S., Korpela, K., & Kotze, D. J. (2012). Closure of view to the urban matrix has positive effects on perceived restorativeness in urban forests in Helsinki, Finland. *Landscape and Urban Planning*, *107*(4), 361–369. https://doi.org/10.1016/j.landurbplan.2012.07.002

Havinga, I., Bogaart, P. W., Hein, L., & Tuia, D. (2020). Defining and spatially modelling cultural ecosystem services using crowdsourced data. *Ecosystem Services*, *43*, 101091. https://doi.org/10.1016/j.ecoser.2020.101091

Hegetschweiler, K. T., de Vries, S., Arnberger, A., Bell, S., Brennan, M., Siter, N., Olafsson, A. S., Voigt, A., & 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. https://doi.org/10.1016/j.ufug.2016.11.002

Hill, R. (1998). What sample size is 'enough' in internet survey research. *Interpersonal Computing and Technology: An Electronic Journal for the 21st Century*, *6*(3–4), 1–12.

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement*, *20*(1), 141–151. https://doi.org/10.1177/001316446002000116

Kothencz, G., Kolcsár, R., Cabrera-Barona, P., & Szilassi, P. (2017). Urban green space perception and its contribution to well-being. *International Journal of Environmental Research and Public Health*, *14*(7), 766. https://doi.org/10.3390/ijerph14070766

Kraemer, R., & Kabisch, N. (2021). Parks in context: Advancing citywide spatial quality assessments of urban green spaces using fine-scaled indicators. *Ecology and Society*, *26*(2), 45. https://doi.org/10.5751/ES-12485-260245

Kyttä, M., Broberg, A., Tzoulas, T., & Snabb, K. (2013). Towards contextually sensitive urban densification: Location-based softGIS knowledge revealing perceived residential environmental quality. *Landscape and Urban Planning*, *113*, 30–46. https://doi.org/10.1016/j.landurbplan.2013.01.008

Lehvävirta, S., & Rita, H. (2002). Natural regeneration of trees in urban woodlands. *Journal of Vegetation Science*, *13*(1), 57–66.

Liu, K., Siu, K. W. M., Gong, X. Y., Gao, Y., & Lu, D. (2016). Where do networks really work? The effects of the Shenzhen greenway network on supporting physical activities. *Landscape and Urban Planning*, *152*, 49–58. https://doi.org/10.1016/j.landurbplan.2016.04.001

Makin, T. R., & De Xivry, J. J. O. (2019). Ten common statistical mistakes to watch out for when writing or reviewing a manuscript. *eLife*, *8*, e48175. https://doi.org/10.7554/eLife.48175

Mapita. (2014). *Helsinki 2050 survey final report*. Helsinki, Finland.

Massoni, E. S., Barton, D. N., Rusch, G. M., & Gundersen, V. (2018). Bigger, more diverse and better? Mapping structural diversity and its recreational value in urban green spaces. *Ecosystem Services*, *31*, 502–516. https://doi.org/10.1016/j.ecoser.2018.02.013

Millennium Ecosystem Assessment. (2005). Ecosystems and human well-being: Synthesis. *Ecosystems*, *1134*, 25–60. https://doi.org/10.1196/annals.1439.003

Moilanen, A., & Nieminen, M. (2002). Simple connectivity measures in spatial ecology. *Ecology*, *83*(4), 1131–1145. https://doi.org/10.1890/0012-9658(2002)083[1131:SCMISE]2.0.CO;2

Neuvonen, M., Sievänen, T., Tönnes, S., & Koskela, T. (2007). Access to green areas and the frequency of visits – A case study in Helsinki. *Urban Forestry and Urban Greening*, *6*, 235–247. https://doi.org/10.1016/j.ufug.2007.05.003

Nielsen, A. B., Hedblom, M., Olafsson, A. S., & Wiström, B. (2017). Spatial configurations of urban forest in different landscape and socio-political contexts: identifying patterns for green infrastructure planning. *Urban Ecosystem*, *20*(2), 379–392. https://doi.org/10.1007/s11252-016-0600-y

Palliwoda, J., & Priess, J. A. (2021). What do people value in urban green? Linking characteristics of urban green spaces to users' perceptions of nature benefits, disturbances, and disservices. *Ecology and Society*, *26*(1), 28. https://doi.org/10.5751/ES-12204-260128

Peschardt, K. K., Stigsdotter, U. K., & Schipperijn, J. (2016). Identifying features of pocket parks that may be related to health promoting use. *Landscape Research*, *41*(1), 79–94. https://doi.org/10.1080/01426397.2014.894006

Pietilä, M., Neuvonen, M., Borodulin, K., Korpela, K., Sievänen, T., & Tyrväinen, L. (2015). Relationships between exposure to urban green spaces, physical activity and self-rated health. *Journal of Outdoor Recreation and Tourism*, *10*, 44–54. https://doi.org/10.1016/j.jort.2015.06.006

R Core Team. (2017). *R: A language and environment for statistical computing*. R foundation for Statistical Computing. https://www.R-project.org/

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. https://doi.org/10.1016/j.ecolind.2017.02.001

Ridding, L. E., Redhead, J. W., Oliver, T. H., Schmucki, R., McGinlay, J., Graves, A. R., Morris, J., Bradbury, R. B., King, H., & Bullock, J. M. (2018). The importance of landscape characteristics for the delivery of cultural ecosystem services. *Journal of Environmental Management*, *206*, 1145–1154. https://doi.org/10.1016/j.jenvman.2017.11.066

Riechers, M., Strack, M., Barkmann, J., & Tscharntke, T. (2019). Cultural ecosystem services provided by urban green change along an urban-periurban gradient. *Sustainability*, *11*(3), 645. https://doi.org/10.3390/su11030645

Schleicher, A., Biedermann, R., & Kleyer, M. (2011). Dispersal traits determine plant response to habitat connectivity in an urban landscape. *Landscape Ecology*, *26*(4), 529–540. https://doi.org/10.1007/s10980-011-9579-1

Shanahan, D. F., Cox, D. T. C., Fuller, R. A., Hancock, S., Lin, B. B., Anderson, K., Bush, R., & Gaston, K. J. (2017). Variation in experiences of nature across gradients of tree cover in compact and sprawling cities. *Landscape and Urban Planning*, *157*, 231–238. https://doi.org/10.1016/j.landurbplan.2016.07.004

Shanahan, D. F., Lin, B. B., Gaston, K. J., Bush, R., & Fuller, R. A. (2015). What is the role of trees and remnant vegetation in attracting people to urban parks? *Landscape Ecology*, *30*(1), 153–165. https://doi.org/10.1007/s10980-014-0113-0

Soga, M., & Gaston, K. J. (2016). Extinction of experience: The loss of human–nature interactions. *Frontiers in Ecology and the Environment*, *14*(2), 94–101. https://doi.org/10.1002/fee.1225

Soga, M., Yamaura, Y., Aikoh, T., Shoji, Y., Kubo, T., & Gaston, K. J. (2015). Reducing the extinction of experience: Association between urban form and recreational use of public greenspace. *Landscape and Urban Planning*, *143*, 69–75. https://doi.org/10.1016/j.landurbplan.2015.06.003

Statistics Finland. (2022). *Key figures on population by region, 1990-2021 [web publication]*. Advisory Board of Official Statistics of Finland. https://statfin.stat.fi/PxWeb/pxweb/en/StatFin/StatFin__vaerak/statfin_vaerak_pxt_11ra.px/

Taylor, P. D., Fahrig, L., Henein, K., & Merriam, G. (1993). Connectivity is a vital element of landscape structure. *Oikos*, *68*(3), 571–573.

Teller, J. (2021). Regulating urban densification: What factors should be used? *Buildings and Cities*, *2*(1), 302–317. https://doi.org/10.5334/BC.123

TENK (Finnish National Board on Research Integrity). (2019). *The ethical principles of research with human participants and ethical review in the human sciences in Finland*. Helsinki. Finland.

Tyrväinen, L., Mäkinen, K., & Schipperijn, J. (2007). Tools for mapping social values of urban woodlands and other green areas. *Landscape and Urban Planning*, *79*, 5–19. https://doi.org/10.1016/j.landurbplan.2006.03.003

Vierikko, K., Gonçalves, P., Haase, D., Elands, B., Ioja, C., Jaatsi, M., Pieniniemi, M., Lindgren, J., Grilo, F., Santos-Reis, M., Niemelä, J., & Yli-Pelkonen, V. (2020). Biocultural diversity (BCD) in European cities – Interactions between motivations, experiences and environment in public parks. *Urban Forestry & Urban Greening*, *48*, 126501. https://doi.org/10.1016/j.ufug.2019.126501

Vierikko, K., Salminen, J., Niemelä, J., Jalkanen, J., & Tamminen, N. (2014). Sustainable green infrastructure of Helsinki – urban ecological research report and recommendations for the Helsinki master plan 2014 (in Finnish with English summary). *Reports of the general planning department*, *2014*, 27.

Wang, Y., Kotze, D. J., Vierikko, K., & Niemelä, J. (2019). What makes urban greenspace unique – Relationships between citizens' perceptions on unique urban nature, biodiversity and environmental factors. *Urban Forestry & Urban Greening*, *42*, 1–9. https://doi.org/10.1016/J.UFUG.2019.04.005

Zhang, S., & Zhou, W. (2018). Recreational visits to urban parks and factors affecting park visits: Evidence from geotagged social media data. *Landscape and Urban Planning*, *180*, 27–35. https://doi.org/10.1016/J.LANDURBPLAN.2018.08.004

Zwierzchowska, I., Hof, A., Iojă, I. C., Mueller, C., Poniży, L., Breuste, J., & Mizgajski, A. (2018). Multi-scale assessment of cultural ecosystem services of parks in Central European cities. *Urban Forestry & Urban Greening*, *30*, 84–97. https://doi.org/10.1016/J.UFUG.2017.12.017

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Wang, Y., Niemelä, J., & Kotze, D. J. (2022). The delivery of Cultural Ecosystem Services in urban forests of different landscape features and land use contexts. *People and Nature*, *4*, 1369–1386. https://doi.org/10.1002/pan3.10394