



# Ecosystem services provided by urban green spaces in Bangkok Metropolis: Public awareness and planning implications

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## Abstract

Urban green spaces (UGS) are a cost-effective solution to overcome various problems faced by cities worldwide, such as air pollution, urban microclimate change, and pressure in urban life by providing diverse ecosystem services (ESS). Green space planning is increasingly focused on increasing UGS in cities. However, these strategies may not receive widespread public support because managers' expected values and people's perceptions may not be the same. Therefore, this study aims to investigate public awareness of ESS provided by UGS, the relationships between UGS and ESS and ESS with each other, as well as the influences of sociodemographic characteristics on people's perceptions in Bangkok metropolis. The research findings revealed highly consistent perceptions of different UGS, especially for public parks and residential gardens, against rooftops and household gardens. These are also the UGS generating the most diverse ESS, especially regulating and cultural ESS. Air quality regulating services ( $\text{CO}_2$  absorption, air pollutant purification, and temperature reduction) and cultural services (spiritual values, aesthetics, and health improvement) are the most crucial ESS of UGS perceived by entire urban residents. This research also reveals that cognitive differences come from differences in demographic characteristics. People with lower awareness of UGS and ESS are often low-income and younger, who frequently live far from UGS leading to low accessibility to UGS. The research also draws critical implications regarding UGS categories, ecosystem services and disservices of interest, and the population groups that need to be encouraged during the greening campaigns. This will be important information for the city government to achieve successful implementation of the "Green Bangkok 2030" project, which aims to further improve UGS and quality of life.

**Keywords** Cultural services · DisServices · Ecosystem services · Public awareness · Regulating services · Urban green space

## Introduction

Urban green spaces (UGS), encompassing parks, community gardens, green belts, natural reserves, and other landscaped spaces within urban environments, intentionally enhance the quality of life for residents in densely populated areas by providing a variety of benefits from environmental regulation to social interaction, and mental health (MEA 2005; Lee and Maheswaran 2011; Hunter et al. 2019). More

specifically, UGS can reduce microclimate change of urban heat islands up to  $12^{\circ}\text{C}$ , reduce air pollution, and improve thermal comfort (Aram et al. 2019; Priya and Senthil 2021; Wu and Chen 2023). The presence of UGS availability and greening characteristics significantly improve general health and mental health with specific medical evidence, e.g., the respiratory and cardiovascular disease risks are significantly reduced with UGS availability of  $> 15\%$  (Richardson et al. 2013; South et al. 2018; Astell-Burt and Feng 2019; Shuvo et al. 2020). Moreover, UGS not only contributes to environmental well-being but also fosters opportunities for meaningful social cohesion through extracurricular and outdoor activities (Jennings and Bamkole 2019).

Ecosystem services (ESS) from UGS, if fully guaranteed, can alleviate the negative impacts on the urban environments and enhance urban sustainability. However, accelerating urbanization brings challenges that extend

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beyond the mere physical expansion of cities and it can be difficult to ensure ESS meet demands. More explicitly, the United Nations (UN) indicates that to date, about 56.2% of the planet's residents live in cities and towns, and this amount will reach over 60% by 2030 (UN-Habitat 2020). Cities are increasingly crowded and dynamic transition from rural to populous urban areas with widespread spatial occupation of urban infrastructures and urban amenities that induces land use, land cover changes, shrinking and degradation of urban green spaces (UGS) (Haaland and van den Bosch 2015; Nguyen et al. 2022a, b). Moreover, the "obsolete" urban planning prioritized land consumption for urban infrastructures and housing, whereas UGS was frequently neglected and overlooked due to a lack of cost-benefits-impacts knowledge (Colding et al. 2020; Van Oijstaeijen et al. 2020; Semeraro et al. 2021). As a consequence, many compact cities worldwide, especially the Global South and developing cities currently have low UGS because of encroachment upon UGS leading to diminishing their capacity to provide essential ESS (Bille et al. 2023). Population growth, increased land use for construction, lack of prioritization of UGS planning, and negative impacts on the urban environments from climate change and pollution have posed pressures for effective planning of UGS.

The effectiveness of the UGS plan hinges on the comprehensive consensus it achieves among the key stakeholders, here is the general public. However, there are potential mismatches between the expected values from policy-makers and the real inherited values at the community level from a certain ecosystem. Local perception henceforth acknowledges these possible mismatches and indigenous knowledge, which can add unique knowledge to the current literature pools to enhance understanding of an ecosystem. Understanding the extent of public awareness regarding ESS provided by UGS is crucial for fostering sustainable practices and garnering public support for conservation efforts because they can aim to actual needs and preferences from those who directly benefit from them (Riechers et al. 2018; Ugolini et al. 2022). The level of public awareness also influences the effectiveness of urban planning initiatives aimed at preserving and enhancing UGS.

Currently, research on ESS supplied by UGS is widely studied in Europe, China, and the USA (Pinto et al. 2022). Meanwhile, Southeast Asia is one of the populous region, encapsulates the complexities of urban development, unique geographic and climatic conditions that underscores the needs for a nuanced understanding of ESS from UGS (Nguyen et al. 2023). The challenges posed by rapid urban expansion, climate change, and degradation of UGS make Bangkok Metropolis an intriguing case study for investigating the interplay between UGS, ESS, and public awareness (Nguyen et al. 2022a, b, 2023; Thanvisithaporn et al. 2023).

In the context of Bangkok Metropolis, the dual challenge of low UGS and potential lack of public awareness raises critical questions about the sustainability of the urban environments. The primary objective of this research is to comprehensively assess the ESS provided by UGS in Bangkok Metropolis. More specifically, this research aims to answer the following questions (1) What is the current community awareness of UGS and ESS in the Bangkok Metropolis? (2) What are the interrelationships between ESS-ESS and UGS-ESS? (3) How do socio-demographic characteristics influence perceptions of ESS? By addressing these nexuses, this study figures out the categories of UGS and ESS received high popular attention that could be involved in UGS planning. The interaction between ESS and UGS-ESS can support the planning of multi-functional UGS. Meanwhile, differences in perceptions between social groups can play as a basis for encouraging broad consensus in future plans of UGS development towards sustainable urban development.

## Study area

This study was conducted in Bangkok capital, the economic and cultural nucleus of Thailand. It is located on the mainland of Southeast Asia region (SEA), where is influenced by the tropical savanna climate with fairly hot year-round. The summer average temperature is about 34°C, and the highest temperature can reach 39–40°C in April (Pakarnseree et al. 2018; Nguyen et al. 2021).

Being one of the most dynamic cities in SEA, Bangkok has experienced rapid urbanization over the past few decades along with degradation of UGS (Can et al. 2021; Nguyen et al. 2022a, b). The average green space per capita at the beginning of the 21st century was only about 1.8 m<sup>2</sup>, which is substantially lower than the World Health Organization (WHO) standard of 9 m<sup>2</sup> per capita (Thaiutsa et al. 2008). It was a severe deficit of UGS in response to the dwellers' needs to ensure well-being when the city has been facing extreme climate events from global to local levels due to climate change and urban heat islands (Nguyen et al. 2023, 2024). Although the city government has been planning many public green spaces projects, the average green space per capita is still low compared to current standards (see Fig. 1). For example, the current green space per capita is about 7.6 m<sup>2</sup> including all kind of urban vegetation and informal green spaces, however, it drops to about 3 m<sup>2</sup> with only contribution from public green spaces. In the near future, the local authority will continue to increase UGS under the strategy of the "Green Bangkok 2030" within the framework of C40 cities to meet the objectives of the Paris Agreement (Office of the Prime Minister 2017; Yarnvudhi et al. 2021). It encourages the collaboration between public, private, and civil sectors to add about 1,800 hectares of

green spaces by 11 pilot projects throughout the city and to increase the resilience of the city.

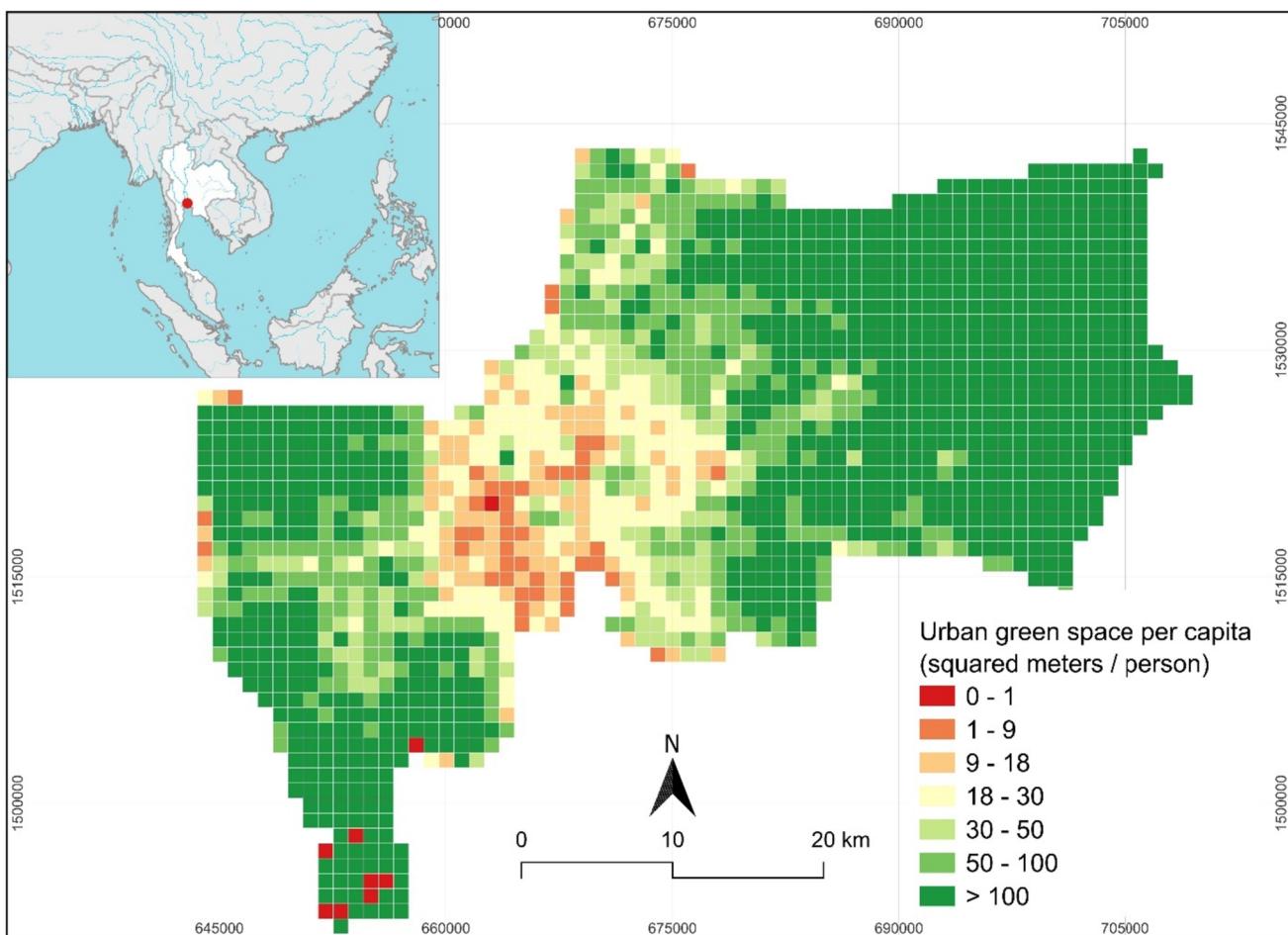
## Methodology

### Selected ecosystem services and green spaces

Initially, the state-of-the-art studies related to ESS provided by UGS were reviewed to identify potential ESS categories, ESS subclasses, and prominent ESS. Scrutiny of background information plays a critical role in adequately understanding an ecosystem since ESS can vary widely across ecosystems, functions, and even the geographic location of an ecosystem. For instance, rice-shrimp farming is a provisioning-oriented ecosystem in which farmers have direct incomes from goods forms; Other ESS categories still exist in this ecosystem. However, the vast benefits from supplied values inadvertently overshadow the perception of other ESS. The same

holds for UGS, a culturally inclined ecosystem, where urban residents often consume their time for outdoor and social activities rather than the provisioning values. Therefore, most studies assessing ESS of UGS considered their cultural ESS rather than other values (Maraja et al. 2016; Ko and Son 2018; Riechers et al. 2018, 2019). However, it should be noted that they also passively receive other benefits regarding local climate regulation and improvement of environmental quality.

Towards a more comprehensive assessment, this research included three additional ESS categories (i.e., provisioning services, supporting services, and regulating services) and disservices (DES) in addition to cultural services to explore and confirm cognitive bias among different ESS of UGS categories (du Toit et al. 2018). According to Breuste et al. (2013) and Rall et al. (2015), the definition of each ESS category is presented below. Cultural services (CES) are the most prominent ESS category of UGS, which are non-material and socio-ecological benefits that people obtain from contact to UGS. Provisioning services



**Fig. 1** Map of UGS per capita in Bangkok estimated from Sentinel-2 based green space extraction and population data from WorldPop, shows city center areas with low green space per capita compared to the World Health Organization standard (Source: Nguyen et al. 2022a)

(PES) are tangible benefits provided to humans by materials and energy outputs. Regulating services are benefits provided by acting as regulators through natural processes or functions of UGS. Supporting services (SES) enable other ESS to exist by providing living spaces. The SES is less visible, but it is essential for maintaining healthy urban ecosystems. Besides, disservices (DES) are negative impacts on human health and well-being that people encounter at UGS. After thoroughly considering local characteristics of ESS from UGS and pilot interviews, the identical and largely irrelevant ESS were in turn combined and eliminated from the final ESS sets. A list of selected ESS and DES for investigation are presented in Table 1, including three (3) provisioning ESS, eight (8) regulating ESS, two (2) supporting ESS, six (6) cultural ESS, and four (4) disservices.

Besides, we also attempted to investigate the relationships between UGS categories and their potential ESS. The classification of UGS is relatively diverse depending on classification criteria such as size, function, and management manner. This study included six major types of UGS including both formal and informal UGS (Nigel et al. 2002; Kim et al. 2018), i.e., public parks, transport corridors (street), residential parks, domestic gardens, rooftop gardens, recreational sites, agricultural fields, and wild-nature vegetation (wetland and over-growth plants).

### Questionnaire development and data collection

After thoroughly investigating the characteristics of the UGS and typical ESS categories, the initial questionnaire to collect residents' perceptions regarding UGS usage and ESS was

compiled. The questionnaire consists of three parts to collect corresponding information regarding demographic characteristics of respondents, their usage of UGS, and perception of ESS (Supplementary S1). In order to avoid respondents' boredom, the questionnaire adopted a strategy that eschewed initiating the interview with requests for personal information. Instead, it commenced by prompting respondents to assess and compare the importance of different UGS categories. It was then followed by questions related to UGS utilization, such as modes of transportation, visitation frequency, and activities engaged in during these visits. The second part mainly focuses on ESS and DES. The specialized terms were translated and described by understandable and plain language to ensure that respondents can answer the questionnaire with certainty without hesitation. For instance, the abstract notion of carbon sequestration would be clarified by describing it as the absorption of carbon dioxide. Finally, the questionnaire ends by collecting respondents' personal information.

The level of perception/importance was rated by a five-point Likert scale. The importance level gradually increases from 1 to 5 to limit respondents' scruples before answering with many choices (Cheng et al. 2021). It holds the same for rating perception of ESS/DES, however, it is understood as acceptance levels. Respondents were provided with statements about the benefits of UGS and asked to what extent they agree, with 5 being the highest. The relevance among adjacent information and the flow of the questionnaire also needed attention throughout the questionnaire design.

**Table 1** Description of selected ecosystem services provided by urban green spaces

ESS category	Service code	Description
Provisioning services (PES)	P1. Foods	Providing foods from UGS (e.g., fruits and vegetables)
	P2. Wood	Supply of timbers and firewood
	P3. Herbs	Ingredients for traditional medicines and folk remedies
Regulating services (RES)	R1. Temperature	Reduction of ambient temperature
	R2. Air pollution	Absorbing air pollutants and improving air quality
	R3. Noise	Noise reduction by softening urban environments
	R4. CO <sub>2</sub>	Carbon sequestration and storage
	R5. Flood	Flood moderation by increasing pervious surfaces
	R6. Groundwater	Enrich groundwater by increasing infiltration
	R7. Windstorm	Resistance to storms by reducing wind speed
	R8. Respiratory	Decreasing causative agents of respiratory diseases
Supporting services (SES)	S1. Habitats	Habitats for species
	S2. Biodiversity	Diversification of flora and fauna in urban environments
Cultural services (CES)	C1. Beauty	Beauty of nature and aesthetic values
	C2. Culture	Preserving cultural values and cultural diversity
	C3. Education	Opportunities for children to expose to nature
	C4. Exercises	Improvement of physical health by outdoor activities
	C5. Society	Increase social cohesion and interactions
	C6. Spirit	Provide open space to improve mental health
Dis-services (DES)	D1. Dirty	Littering, maintenance, and management concerns
	D2. Crowded	Concerns about public accessibility, noise, and crowds
	D3. Unsafe	Crime and safety concerns
	D4. Danger	Concerns about insect stings and wild animals or similar incidents

The initial questionnaire was checked by experts in ESS field to ensure the appropriateness of information before using it for trial interviews. The face-to-face rehearsal was deployed in July 2020 to verify the suitability of questionnaire length, information flow, and even interviewees' attitudes when responding to interviewers. Sample size was not considered during this step. Subsequently, the comments from both interviewers and respondents were synthesized and used to adjust the questionnaire as compact as possible by omitting questions with relatively similar meanings. The frequently rejected questions were scrutinized and decided to keep or remove from the final questionnaire. The flow and order of questions were also reconsidered to limit the confusion of respondents.

The final questionnaire was translated into Thai and compiled in Google Form for online data collection. During the lockdown period due to the Covid-19 outbreak, an online data collection campaign was carried out by sending questionnaire links to target groups of Bangkok residents through diverse information channels, such as students, Facebook groups, and social media. Although the selection and distribution of respondents can hardly be controlled through online interviews, it is based on voluntary so the information collected can be of better quality (Braun et al. 2021). At the same time, it is easy to collect sensitive personal information, such as income, that was often refused to be answered in our face-to-face mock interviews. Between March and July 2021, we obtained 146 effective respondents that could be used for analysis.

## Data analysis

The dataset of valid samples collected through the interview campaigns were initially tested for scale reliability using Cronbach's alpha coefficient (Hai 2022). Then, it was adopted to assess the internal consistency of the measuring scales for the importance of UGS, ESS, and DES. The tests verified that all measured scales worked well and achieved good internal consistency for further analyses ( $\alpha > 0.7$ ).

Firstly, descriptive statistics were conducted to explore respondent characteristics and general information of the datasets. Analysis of variance (ANOVA) was used to compare dissimilarities between ESS/DES. This research also applied normalized Shannon's diversity index ( $E_H$ ) to evaluate the diversity of ESS and DES.

$$E_H = \frac{H}{\log(k)} \quad (5.1)$$

$$H = - \sum_{i=1}^S p_i \ln(p_i) \quad (5.2)$$

where,  $H$  is the Shannon's index;  $p_i$  is proportion of the  $i^{th}$  individual ESS/DES;  $S$  is total number of ESS/DES;  $E_H$  is normalized Shannon's index;  $\log(k)$  is the maximum value of Shannon's index,  $\log(k) = \ln(S)$ .  $E_H$  is rearranged values from 0 to 1.

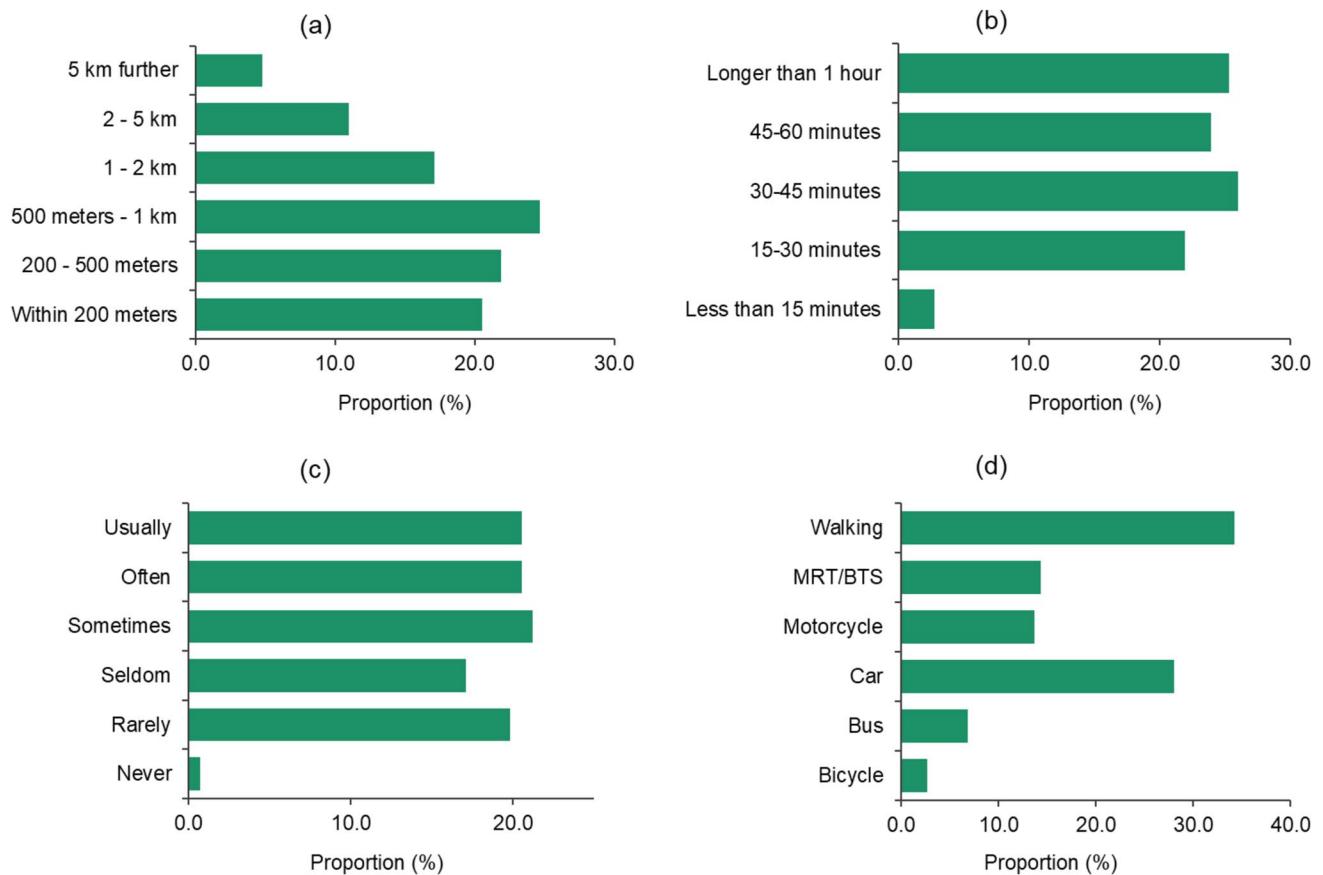
With respect to the potential interrelationships between ESS/DES and ESS/DES and UGS categories, this research applied Spearman's rank correlation coefficient ( $\rho$ ) to explore these relations among ranking ordinal variables. In addition to  $\rho$ , hierarchical cluster analysis (HCA) was applied to construct the ESS/DES bundles and tested whether the respondents perceived the services appropriately. The relevance of ESS/DES and UGS was revealed by correspondence analysis (CA) on the contingency table. Additionally, the demographic determinants of ESS/DES were analyzed using an integrated method of HCA on the output from principal component analysis (PCA), i.e., it retains only the first three dimensions.

## Results

### Demographic characteristics of respondents

The demographic characteristics of respondents in this survey revealed a diverse sample in terms of genders, age ranges, education, and occupations. Particularly, gender distribution among respondents was relatively even, with slightly more females (50.7%) than males (48.6%). They have spanned a wide range of age, however, there is a large portion falling in the 25–35 year-old range (49.3%). It is followed by middle age category (35–45), about 25.3%. The majority of respondents have high-education vocational certificates and higher education, who have stable incomes (81.5%) as they are office staff (68.5%). In contrast, about 18.5% is dependent population, filling into students and retirements.

Nearly two-thirds (67.1%) of respondents who engage in activities in UGS reported living within a one-kilometer radius of their favorite park, of which 42.4% are around 500 meters (Fig. 2). The distance from their houses to the park is a key element in deciding how they travel to the park. Specifically, about 34.2% of respondents walk to a nearby park, it is followed by private car (28.1%). Besides, public transportations such as BTS, MRT, and bus also account for a considerable proportion. About 62.3% of respondents revealed that they frequently visit a public park, with the remaining participating less frequently. The time consumption at public parks is relatively diverse, which evenly fills from 15 minutes to longer than an hour. However, they mostly spend around 30–60 minutes for each visitation (50%).



**Fig. 2** Respondents' characteristics related to UGS usage. **a** Distance of respondents to their favorite parks; **b** average time spent for each visitation at public parks; **c** frequency of visitation; and **d** major

modes of transportation used to access the parks. Note: MRT: Metropolitan Rapid Transit, BTS: Bangkok Mass Transit System

## Importance of urban green spaces

The role of eight UGS categories including formal and informal UGS was investigated through residents' perceptions. The diversity index of UGS perception is about  $E_H=0.991$ , implying an even assessment among UGS categories (Fig. 3). Particularly, parks received the highest and relatively consistent importance level ( $4.79 \pm 0.646$ ), with 86.9% of respondents asserting it as a very important UGS (5/5). It is followed by residential parks ( $4.71 \pm 0.612$ ), received by 78.1% of respondents at a very importance level. These two UGS are the most important green spaces, with high and uniform perception compared other categories (i.e., significant difference from others via ANOVA test,  $p < 0.05$ ).

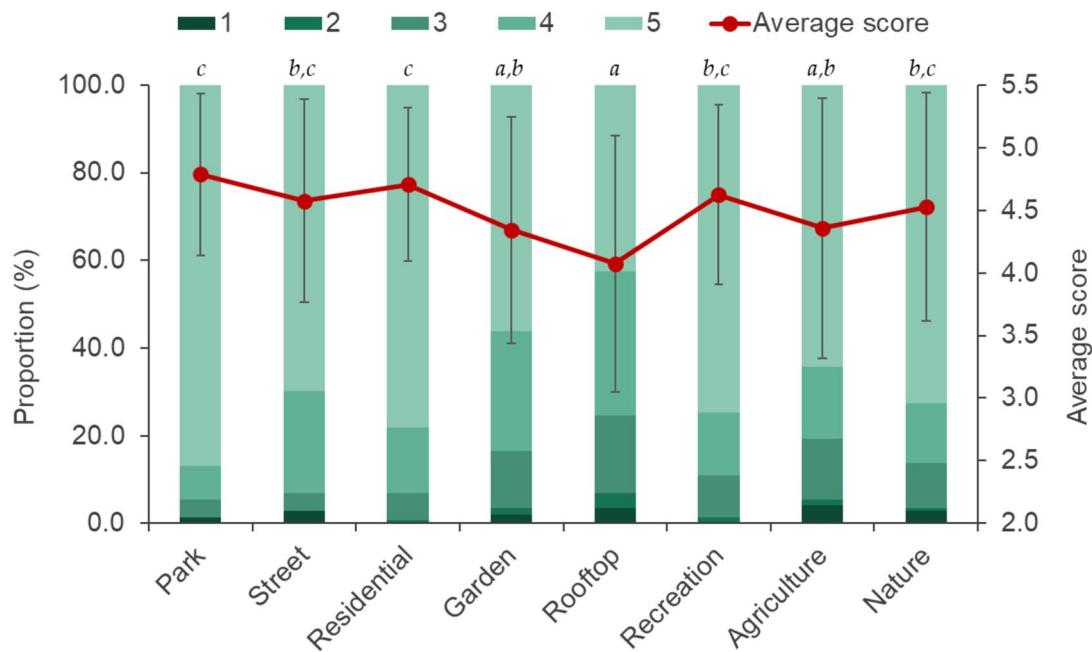
A group of UGS consisting of street trees, recreational sites, and natural vegetation is evenly rated as the next important UGS. The average score is approximately  $4.53 - 4.62$  and their importance has no significant difference between parks and the following group. Agricultural fields ( $4.36 \pm 1.042$ ) and household gardens ( $4.34 \pm 0.905$ ) were found to be less important for urban communities, as only more than half of them rated this as an important green space. Although rooftop

garden is expected to be an optimal solution to increase UGS in compact cities like Bangkok, they have not received much attention from the general public compared to other categories. For instance, about a quarter of respondents revealed that rooftop garden is not important for them.

## Ecosystems services and disservices from urban green spaces

### Qualitative richness of ESS/DES

Each individual service belonging to four ESS and DES categories was investigated for its value to urban dwellers via their perception of acceptance (Fig. 4). Generally, the UGS in Bangkok is supposed to provide a wide range of services ( $E_H=0.971$ ). The perception of ESS is relatively uniform among ESS groups and component services. Awareness regarding the regulation, cultural aspects, and support services exhibits some degree of partiality. The average Likert score of these ESS categories is significantly higher than that for provisioning and DES (ANOVA test,  $p < 0.05$ ). Specifically, culture is the most essential

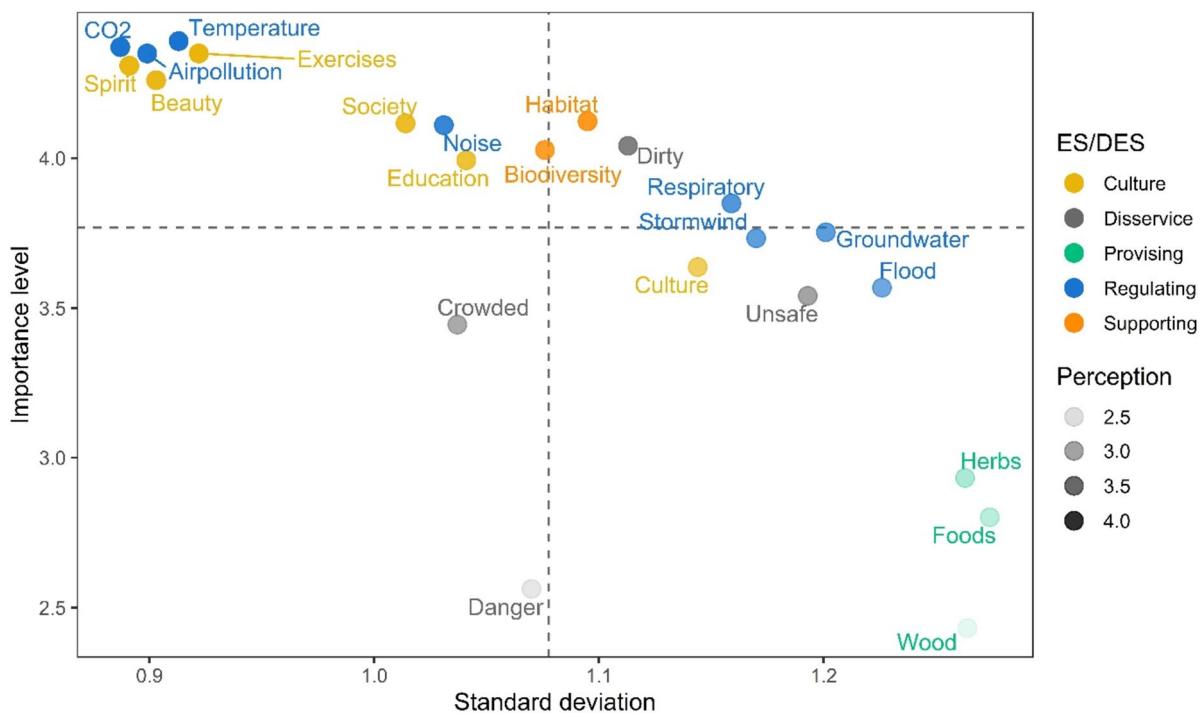


**Fig. 3** Proportion of importance levels for different UGS categories rated by respondents. The importance level gradually increases from 1 to 5 corresponding to absolutely not important to very important.

Solid red-line presents average importance score for each UGS type. Letters of a, b, and c represent significant differences among UGS categories via ANOVA test ( $p < 0.05$ )

ESS ( $4.11 \pm 0.844$ ), followed by supporting (4.08) and regulating (4.02). In contrast, the provisioning and DES were supposed to lowly contribute to residents' livelihood, which is at medium level of  $2.72 \pm 1.171$  and  $3.40 \pm 0.819$ , respectively.

Although the provisioning service is not highly appreciated, it is expected to provide ingredients for traditional treatments and folk remedies rather than foods and logging. Yet, the perception is less uniform among the general public.



**Fig. 4** Average importance level of ESS and DES. Horizontal and vertical axes present standard deviation and Likert importance levels, respectively. The lower the standard deviation, the more uniform the level of awareness of that service is among respondents

The most prominent ESS categories are regulating and cultural ESS in the top-left quadrant, with high importance level and low standard deviation values. These regulating services include temperature reduction (4.37), carbon sequestration (CO<sub>2</sub>: 4.39), air pollution reduction (4.35), and noise reduction (4.11), reflecting environmental and air quality improvement. The most prominent cultural services include aesthetical value (beauty: 4.26), spirit value (4.31), and health value (exercises: 4.35).

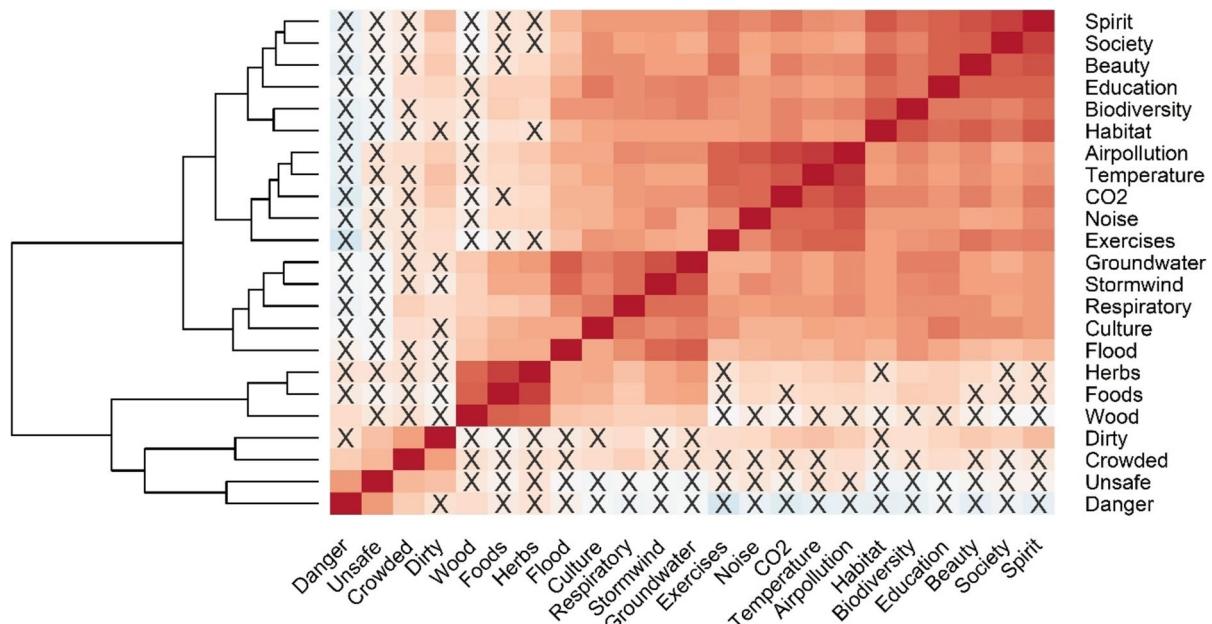
In addition to benefits, UGS also negatively affects human well-being through DES (Von Döhren and Haase 2015). A broad notion for DES to express every possible risk that UGS users may directly or indirectly encounter while visiting UGS was adopted. People are mainly concerned with management and comfort factors. They held the belief that UGS suffered from inadequate management and maintenance, resulting in unsanitary conditions, as indicated by an agreement level of 4.04 out of five (dirty). Overcrowding (crowded) was also mentioned consistently by the respondents as one of their concerns. Yet, such threats directly originated from UGS functions, such as wild animals and allergic agents from pollen, do not appear to be the primary concern influencing visitation decisions.

### Interrelationship among ESS and DES

Agreement level of ESS and DES were analyzed using an integrated approach of Spearman's rank correlation and cluster analysis (Fig. 5). It depicts interrelationship among

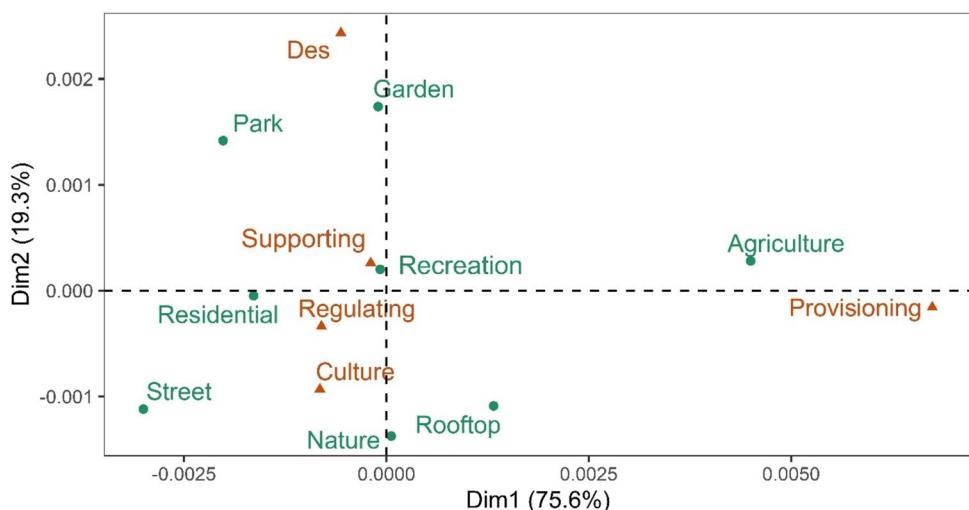
services within the same category and other ESS/DES categories. A service is adequately perceived for its importance, should have a highly positive relationship, and be in the same category as other component services. Overall, the bundling isolation convinces the distinction between different ESS and DES categories and the coherence of sub-services within the same category. The clustering analysis is relatively coherent and is capable of converging nominal sub-services within a specific ESS category. It reveals the homogeneous perception for ESS and DES in this city.

DES has the least significant correlation with other services. The most positive correlation at a moderate level is crowded–dirty ( $\rho=0.51$ ). It is followed by PES, which holds a few moderate relationships with flood and rainwater regulations, in which providing food–herb is the most substantial relation ( $\rho=0.85$ ). The following cluster is natural disaster regulating ESS that control possible damages caused by the storm, heavy rain, and floods. A bundle of RES of air quality improvement was equally valued, including carbon absorption, air, and noise pollution reduction, and temperature reduction, which is highly correlated with other services. Among the RES, the most significant correlations are temperature–air pollution ( $\rho=0.87$ ), CO<sub>2</sub>–air pollution ( $\rho=0.84$ ), and storm wind–groundwater ( $\rho=0.80$ ). The remaining services concentrate on a bundle of SES and CES (e.g., education, aesthetics, and social cohesion) that have broadly high relationships with remaining CES and RES. More explicitly, the correlation coefficients of spiritual values are high, such as spiritual value–society ( $\rho=0.84$ ) and spiritual value–beauty ( $\rho=0.80$ ).



**Fig. 5** Spearman correlation among ecosystem services and disservices and their clusters obtained from HCA. Cell shade is correlation coefficient, and cross mark presents insignificant relations at  $p \leq 0.001$

**Fig. 6** Correspondence analysis between UGS and ESS/DES categories. Green dots are UGS and orange points present ESS/DES



### Potential UGS sources providing ESS and DES

ESS, DES, and UGS categories were examined to explore potential sources for each ESS and DES through public perception. Generally, there are close associations between landscape types and expected benefits or barriers. The overall linkages between UGS types and ESS/DES categories are illustrated in Fig. 6 and Supplementary S2.

About 94.9% of extracted variances is explained by the first two dimensions. The UGS types of public parks, street trees, and residential trees that provide the most diverse ESS in different categories except for PES—strongly correlates with agricultural landscapes ( $\rho=0.325$ ) and rooftop gardens. More specifically, public park has high correlations with various ESS, but they are mostly at moderate level, including temperature reduction ( $\rho=0.319$ ), air pollution reduction ( $\rho=0.36$ ), noise reduction ( $\rho=0.342$ ), CO<sub>2</sub> absorption ( $\rho=0.34$ ), and cultural values of spiritual values ( $\rho=0.325$ ) and social values ( $\rho=0.357$ ). Street and residential UGS mainly contribute to reducing respiratory diseases ( $\rho=0.321$ ) and temperatures ( $\rho=0.30$ ), respectively. Meanwhile, natural UGS is a culturally inclined landscape. Regarding DES, public parks were found to interfere with users because of concerns related to cleanliness and safety on social issues. People were concerned about possible threats in home gardens from wild animals and unintentional accidents.

### Socio-demographic determinants of perceptions

The influences of sociodemographic attributes were analyzed by hierarchical cluster analysis (HCA) to explore the potential impacts of social features and respondents' habits on perceptions about ESS/DES. The perceptions about ESS/DES were divided into three clusters, which explained 68.1% of the extracted variance (Table 2, and Supplementary S3).

The first cluster (Cluster 1) represents low awareness of ESS/DES. The respondents in this cluster are often younger (18–35) who frequently engage in activities at UGS but spend a shorter time at UGS (15–45 minutes). The members of cluster 1 tend to reside at diverse distances to their favorite UGS, with the most contributors living around UGS, 0.5–1 km, and 2–5 km who often get there by walking and MRT/BTS. Cluster 1 is also the group with the most modest income compared to the other groups.

The second cluster (Cluster 2) has high awareness about cultural and supporting ESS. The interviewees of this cluster are often in the age group of 25–30 and are unskilled workers besides officers and students. They do not go to UGS as often as cluster 1 but tend to stay there longer (> 30 minutes). They also widely distribute from 200 meters to 2 km, and they often reach UGS by walking or private cars, depending on their distances. Cluster 2 is the group with the highest income, around 807 USD/month.

The third cluster (Cluster 3) has a high awareness of regulating, cultural, and supporting ESS. The perception of provionsing services is also at a relatively high level. It includes more mature people (35–60 years old) working as officers and private business owners. They often spend time at UGS (i.e., usually longer than 30 minutes); most stay there longer than one hour. Their locations are within 500 meters of their favorite UGS. This is the group mostly concerned with DES compared to other clusters.

## Discussions

### Implications for green space planning

Presently, the pivotal role of UGS in urban environments has been highly appreciated by urban residents with an average importance level above 4 "Importance of urban green

**Table 2** Mean importance level of ESS categories and DES for different clusters explored by HCA and clusters' characteristics

ESS/DES	Cluster 1	Cluster 2	Cluster 3
Provisioning service	2.43	1.84	3.81
Regulating service	2.76	3.94	4.71
Cultural service	2.72	4.23	4.66
Supporting service	2.7	4.11	4.71
Disservice	2.96	3.35	3.66
Gender	Male	Male	Female
Age	Young (18–25) Young adult (25–35)	Young adult (25–35)	Young Adult (25–35) Adult (35–45)
Education	Higher education Vocational certificate	Higher education	Higher education
Occupation	Officers Students	Officers Students General labors	Officers Students Private business owners
Time consumption	15–45 min	> 30 min	> 60 min
Distance	<200 meters 0.5–1 km 2–5 km	0.2–2 km	<500 meters
Visitation frequency	Usually Often	Sometimes Rarely	Usually Sometimes
Transportation	Walking MRT/BTS*	Walking Private car	Private car Walking
Average income (USD)	604	807	770

\* Metropolitan Rapid Transit (MRT)/ Bangkok Mass Transit System (BTS)

spaces" section. The UGS receives the most attention are public parks, residential trees, and street trees, which are broadly tied to the most numbers of potential benefits to urban dwellers "Potential UGS sources providing ESS and DES" section. It sets itself apart from other cities as Bangkok residents recognize the distinct significance of informal green spaces (IGS), including agricultural fields and natural vegetation (Rupprecht 2017; Kim et al. 2018). These areas have been clearly identified as playing a crucial role in the city's fabric. Therefore, it is possible to get people's consent for strategies to expand UGS using urban agriculture and other IGS solutions. However, it should be noted that the integrated green spaces such as household and rooftop gardens have low perception at recent. In the context of Bangkok, a dense and compact city with less available land budget for extensive public parks, integrated green space is an optimal intervention to mitigate microclimate change. Therefore, strategies to raise public awareness and pilot projects on the benefits of integrated UGS (e.g., rooftop gardens, green walls, and household gardens) are needed to achieve more consensus in the future.

Each UGS is closely related to one or several types of ESS "Potential UGS sources providing ESS and DES" section. At the same time, the component services of ESS are also interconnected "Interrelationship among ESS and DES" section. The research findings supported the previous studies about an internally positive relationships between services within each ESS category and with other ESS categories

(Plieninger et al. 2013; Christine and Rehdanz 2015; Rall et al. 2017; Ko and Son 2018). In other words, UGS can provide a wide range of ESS depending on UGS types and installed locations (Hoover and Hopton 2019). Favorable conditions can facilitate to creation of interference zones amid services with an abundance of benefits. The interference zone is also a criterion to evaluate a UGS site or type using the richness of benefits. Simultaneously, it stands for green planning orientation, aiming toward UGS to provide multiple ecosystem services for long-term benefits (Bezák et al. 2020).

### What can be gained from perceptions of ESS and DES?

Albeit UGS provides various ESS from all kinds of ESS categories, it is initially planned for regulating, cultural, and supporting services rather than provisioning services. It can be said that UGS is a cultural-inclined ecosystem. Therefore, a wide range of current literature has considered cultural aspects of UGS (Cheng et al. 2021).

It is encouraging that awareness of other ESS categories has consistently received high perception "Qualitative richness of ESS/DES" section. High perception not only indicates actual benefits but also reveals the desirable demand. Demands of ESS increase proportionally to the benefits they would like to receive (Casado-Arzuaga et al. 2013). More so, perceptions are more tied to demands than supply

values (Villa et al. 2014; Andersson et al. 2015). Also, public perceptions are driven by changes in ESS availability and its driving factors (Mugari et al. 2019). Therefore, high social perceptions can imply desirable benefits and demands – they would like to receive to address the current difficulties (Guanshi et al. 2021). In other words, the highest perception of RES, including temperature reduction, carbon sequestration, and air pollutant absorption "[Qualitative richness of ESS/DES](#)" section. It reveals that the city has been encountering intense urban temperature escalations (Hung et al. 2006; Giridharan and Emmanuel 2018), as well as severe air pollution acknowledged in many published works (e.g., Narita et al. 2019; Vu et al. 2020). Therefore, green plans to increase UGS and minimize the above negative impacts need to be urgently implemented to meet people's needs.

There are still low perceptions of hydrological regulating ESS (e.g., storm and flood prevention and groundwater enrichment), cultural heritage, and educational values. These findings align with previous research about commonly low awareness of cultural and educational values (Koh et al. 2022). The low awareness about these CES could impede the extension of future UGS due to a lack of public consensus. It raises the same challenges for RES of hydrological regulation while Bangkok has been encountering urban floods induced by the imperfection of the urban drainage systems and sea-level rise (Laeni et al. 2019; Quan et al. 2020). Hence, it is better to engage the importance of these ecosystem services in propaganda strategies to raise public awareness, which would encourage stakeholders' involvement in the cities' long-term strategies.

At the same time, a high perception regarding DES reflects the problematic management (Casado-Arzuaga et al. 2013). Residents in Bangkok extremely concerned cleanliness, which is closely associated with management and maintenance. These roadblocks must be addressed to boost the engagement of UGS users.

### Implications from sociodemographic perspective

The urbanization level and sociodemographic characteristics tightly control public perception of UGS (Riechers et al. 2018). The research findings extend those of Riechers et al. (2018, 2019) regarding the influences of social and behavioral factors on other ESS beside cultural services. The cluster analyses "[Socio-demographic determinants of perceptions](#)" section exposed the low aware groups who would be the main objects in the enriching awareness campaigns in Bangkok. They are mostly young people with low incomes who have limited time to engage in outdoor activities at UGS.

Interestingly, this research revealed negative relationships between visitation frequency-perception and distance-perception. Users who rarely get an opportunity to go to UGS are the ones who usually high appreciate ESS because they

have a higher demand. Lastly, it deserves to insightfully reconsider the optimal distance between the UGS to ensure equal distribution of ecosystem services to all dwellers since it cannot deliver ecosystem services beyond a certain distance of ~2 km. This is an important social revelation in addition to the quantitative evidence that supports sound green space planning in densely populated cities.

### Conclusion

This study presented a comprehensively social assessment of UGS and their benefits in Bangkok, one of the most populous cities in Southeast Asia, with a serious lack of UGS from the first of twenty-first century. Our findings revealed awareness and understanding of the benefits of UGS by social communities following the city's efforts to increase UGS. The key findings and implications are summarized as follow:

- The ecosystem services of UGS were highly aplicated at importance and very importance levels ( $\geq 4/5$ ), especially for regulating and cultural services and except for provisioning service. The services within a category are closely correlated with each other, and the positive relationships also extend to other categories implying interplays among ecosystem service categories. Therefore, it can potentially plan multiple functions of UGS towards long-term strategies rather than unsustainable short-term ones.
- Public parks, street trees, and residential green spaces are the most important UGS types, which are believed to supply diverse benefits to urban dwellers. However, there is still a lack of proper perspective and a lack of respect for integrated urban green spaces such as household and rooftop gardens, while they seems to be received many benefits from this kind of green spaces.
- By observing respondents' demographic features and perceptions, this research highlighted the groups of young and young adults with lower incomes and living far from the UGS who need to be attended to enrich awareness and get more community consensus on future greening strategies.

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**Data availability** All data generated and analyzed during this study are included in this article and its corresponding supplementary information.

## Declarations

**Author declaration** The authors of the manuscript certify that they have read and approved the final version of the submission. They warrant that the article is their original work, has not received prior publication and is not under consideration for publication elsewhere. They agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

**Ethical approval** The authors confirm that they have obtained study-specific approval by their university's ethics committee for their research involving human participants and informed consent from individual adult-only respondents of their questionnaire survey.

**Conflict of interest** The authors declare no competing interests.

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