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Urban Vegetation Types are Not Perceived Equally in Providing Ecosystem Services and Disservices

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Abstract: Urban vegetation is important in providing ecosystem services to people. Different urban vegetation types provide contrasting suites of ecosystem services and disservices. Understanding public perceptions of the ecosystem services and disservices can therefore play an important role in shaping the planning and management of urban areas. We conducted an online survey (n = 1000) to understand how residents in the tropical city of Singapore perceived urban vegetation and the associated ecosystem services and disservices. The questionnaire was designed to explore whether different urban vegetation types (grass, shrubs, trees, trees over shrubs, and secondary forest) were perceived as equal in providing benefits. Respondents considered ecosystem services provided by urban vegetation to be more important than disservices. Among ecosystem services, regulating services were most highly rated, with more than 80% of the respondents appreciating urban vegetation for providing shade and improving air quality. Respondents recognized that different vegetation types provided different ecosystem services. For example, secondary forest was most commonly associated with education and wildlife, while trees were strongly associated with cooling and air quality. We conclude that in developing plans and designs for urban vegetation and ecosystem services, it is important to understand the perceptions, priorities, and concerns of residents.

Keywords: urban vegetation; ecosystem services; ecosystem disservices; public perception; tropical city; urban ecosystems; urban ecology; sustainable development

1. Introduction

Natural and managed vegetation delivers a multitude of benefits, or "ecosystem services", to urban residents [1,2]. These ecosystem services contribute to improving urban quality of life [3–6]. In rapidly developing tropical cities, urban sprawl often removes green cover, thus impacting valuable ecosystem services [7]. Urban ecosystem services can be broadly classified into regulating, cultural, and provisioning services [8]. Examples of regulating services include ecological processes that improve air quality, attenuate noise, or reduce flood risk by regulating stormwater flows [1,9]. Cultural services include spiritual enrichment, recreation, and aesthetic experiences [10]. Provisioning services include all products and materials obtained directly from ecosystems [2,6]. While most effects of urban vegetation are generally positive, some may be less desirable [11–13]. Examples of such "ecosystem disservices" include vegetation being a source of pests and disease vectors, or the roots of street trees damaging property [11–13].

Different types of urban vegetation provide contrasting suites of ecosystem services [14] and disservices [13]. For example, urban woodlands can reduce air temperatures by up to 3.9 °C more than turf [15], and vegetation types with a higher understory volume have higher soil decomposition rates [16]. The balance of services and disservices provided by urban vegetation has a strong influence on how urban greenery is experienced, used, and valued by people [17]. It is important for urban planners to understand how city residents perceive ecosystem services to assess which services are most valued. Furthermore, understanding these perceptions will allow planners to gauge public willingness to accept vegetation types that are less popular but provide valuable benefits.

A complex mix of factors shape people's perception of ecosystem services and disservices. These include environmental pressures such as heat stress [18], the proximity and accessibility of green spaces [19–22], and individual interests, beliefs, and professional background [23–25]. Also important are education, access to relevant information, and local traditions and values [19,26–32]. Green spaces in cities are often relatively small and used by diverse stakeholders, which complicate the planning and design of urban landscapes. Several studies have shown that urban greening policies are more likely to be accepted if they take into account of public perceptions [33–35], including which types of ecosystems are wanted and where [36,37]. Public consultations also provide planners with valuable information about how preferences vary with time and location [13], which can help in designing solutions that are effective over an extended period and in the face of environmental changes [21].

There is growing awareness about the benefits of urban ecosystems, though information on how urban residents perceive and value these benefits is mostly not available to decision makers [38]. Furthermore, much of the existing knowledge is from temperate regions of Europe and North America [10,39], which have different types of vegetation and different suites of ecosystem services and disservices from those of tropical cities [40]. The aim of this study was to quantify how urban vegetation services and disservices are perceived by residents of the tropical city of Singapore. For this purpose, we designed an online questionnaire in which we asked participants questions about how they perceived and valued the main types of urban vegetation in Singapore. Specifically, the objectives of the study were to (1) examine the perceived importance of urban vegetation in providing ecosystem services and disservices, (2) identify the specific types of urban vegetation that were perceived to be mostly associated with providing ecosystem services and disservices, and (3) quantify preferences for the vegetation types that participants would most like to see more of in their neighborhood.

2. Materials and Methods

2.1. Case Study Site Description

Singapore (1°09′ N, 103°38′ E) is a city-state with a tropical climate, characterized by relatively high humidity (monthly mean 81.9–86.5%), uniform temperature (monthly mean 26.4–28.3 °C), and abundant rainfall (monthly mean 112.8–318.6 mm) [41]. Despite a small land area of 714.3 km^2, Singapore is highly urbanized, with a population of 5.6 million [42]. With little natural vegetation remaining, forested areas are confined to 0.16% of primary lowland dipterocarp forests, 19.64% of young secondary forests, 1.37% of old secondary forest, 0.91% of mangrove forest, and 0.39% of freshwater swamp forests [43]. On the other hand, actively managed urban vegetation including turf grass and planted trees cover 27.45% of the total land area [43]. For the purposes of the survey, five vegetation types commonly seen in Singapore were classified based on their differing vertical structures: grass, trees, shrubs, trees over shrubs, and secondary forest. Photographs representative of each vegetation types were included in the survey (Figure 1).

2.2. Survey Design

The survey quantified the socio-demographic information of respondents, perceptions of urban vegetation with regard to specific ecosystem services and disservices, and rankings of the five vegetation types according to which vegetation type people would like to see more of in their neighborhood.

Figure 1. The five vegetation types (grass, shrub, tree, tree over shrub, and secondary forest) specified in the survey.

The first part of survey included the statement "Please select the options to show how strongly you agree or disagree with the following statements about vegetation in Singapore", followed by a list of 15 positive and 10 negative statements. Each of the statements described either a cultural or regulating ecosystem service or disservice (Table 1). Respondents were asked to indicate their level of agreement with each statement on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree".

Table 1. Statements associated with (**a**) ecosystem services and (**b**) disservices in survey about urban vegetation types, with links to the CICES ecosystem services framework [8].

(a) Statements Associated with Ecosystem Services:	Ecosystem Service Type	Label in Figure 3
It improves air quality	Regulating	Air quality
It provides me with shade	Regulating	Shade
It reduces surrounding noise levels	Regulating	Noise Attenuation
It stores carbon	Regulating	Carbon
It controls the effects of heavy rainfall and flooding	Regulating	Flood Regulation
It is pleasing for me to look at	Cultural	Aesthetic
It encourages me to spend time outdoors	Cultural	Outdoor Recreation
It provides opportunities for me to learn more about nature	Cultural	Education
It possesses spiritual or religious value	Cultural	Spiritual
It provides me with a good place for socializing	Cultural	Social Space
It provides me with inspiration for art, creativity, and photography	Cultural	Inspiration
It makes me feel better (e.g., improve my longevity, relieves my feelings of stress, allow me to relax, etc.)	Cultural	Well-being
It increases my interaction with wildlife	Cultural	Positive Wildlife Interactions
It supports wildlife that I enjoy	Cultural	Positive Wildlife
(b) Statements Associated with Ecosystem Disservices:		**Label in Figure 3**
It encourages the presence of general pests (e.g., mosquitoes, rats, etc.)	NA	Pests
It is strong-smelling	NA	Smell
It poses a risk of spreading mosquito-borne diseases (e.g., dengue)	NA	Disease
It is damaging to sidewalks	NA	Damage
It looks messy	NA	Messy
It is a safety hazard to people and personal property	NA	Unsafe
It poses a crime risk	NA	Crime
It makes me feel uneasy	NA	Uneasy
It increases my interaction with wildlife that I do not enjoy	NA	Negative Wildlife Interactions

The second part of the survey included a section in which respondents were asked to select the urban vegetation type they most associated with the same positive and negative statements (Table 1). The statement "Please select the vegetation type which you feel the following statements best apply to" preceded a list of 15 positive and 10 negative statements. A "not applicable" option was included in this section for respondents who did not associate any particular vegetation type with the positive or negative statement. The proportion of responses for the ecosystem service that each statement corresponded to was calculated, and "not applicable" responses were excluded from the analysis.

In the third part of the survey, vegetation types were ranked by respondents on a scale of 1 (least preferred) to 5 (most preferred) to select which vegetation type they would like to see planted more in their neighborhood.

2.3. Survey Implementation

The phrasing and clarity of the survey questions was pretested in mid-June 2018 with a group of urban researchers who were living in Singapore at the time (n = 100). The final survey was conducted online from 4 to 15 September 2018 through the engagement of a survey company (QuestionPro Inc., Austin, TX, USA). Respondents throughout Singapore were randomly selected to participate in the survey. To ensure a balanced representation of the population, we obtained an even sex ratio and as broad a spectrum of age groups as possible (Appendix A, Figure A1). The online survey respondents were restricted to Singapore citizens, Singapore permanent residents, and long-term work visa holders. The time required to complete the survey was approximately 20 min. A total of 1000 complete responses were collected. The survey methodology was reviewed and approved by the Ethics Committee of ETH Zürich (EK 2018-N-65), and all participants gave informed consent to participate in the study.

2.4. Statistical Analysis

The perceived importance of urban ecosystem services and disservices was quantified as the proportion of respondents who "agreed" or "strongly agreed" with the statements relating to each service or disservice. Uncertainty was visualized using binomial confidence intervals [44]. Differences in perceived importance between the services and disservices were modelled as a binomial generalized linear mixed model, with the different indicators classified into "services" and "disservices" according to their positive or negative impact on people, and into "regulating functions" or "social and cultural impacts" broadly following the Common International Classification of Ecosystem Services (CICES) framework [8].

Overall variation in the proportion of respondents preferring to have more of each vegetation type in their neighborhood was compared using a chi-squared test. To compare the significance of differences between each of the pairs of vegetation types, separate pairwise chi-squared tests were made, and the resulting significance values were adjusted using the Bonferroni method. Confidence intervals for compositional proportions were added for visualization. All analyses were performed in the R v3.6.1 statistical computing environment [45].

3. Results

3.1. Perceived Importance of Urban Vegetation in Providing Ecosystem Services and Disservices

Ecosystem services provided by urban vegetation were significantly more likely to be perceived as important by respondents than ecosystem disservices ($p < 0.001$; Figure 2; Table 2). Services and disservices that influenced environmental conditions (regulating) were significantly more likely to be perceived to be important than those with a cultural or social impact (cultural) ($p < 0.001$; Figure 2, Table 2). The regulating services most commonly considered important were those contributing to shade, air quality, and flood regulation. More than 80% of respondents associated urban vegetation with benefits of providing shade and improving air quality. Amongst cultural ecosystem services, aesthetic and well-being benefits and positive wildlife interaction exposure were often highly valued (Figure 2).

Spiritual ecosystem service benefits were the least commonly valued. Amongst the disservices, less than 40% of respondents associated urban vegetation with pest or disease problems, and less than 20% of the respondents associated urban vegetation with causing all other ecosystem disservices (Figure 2).

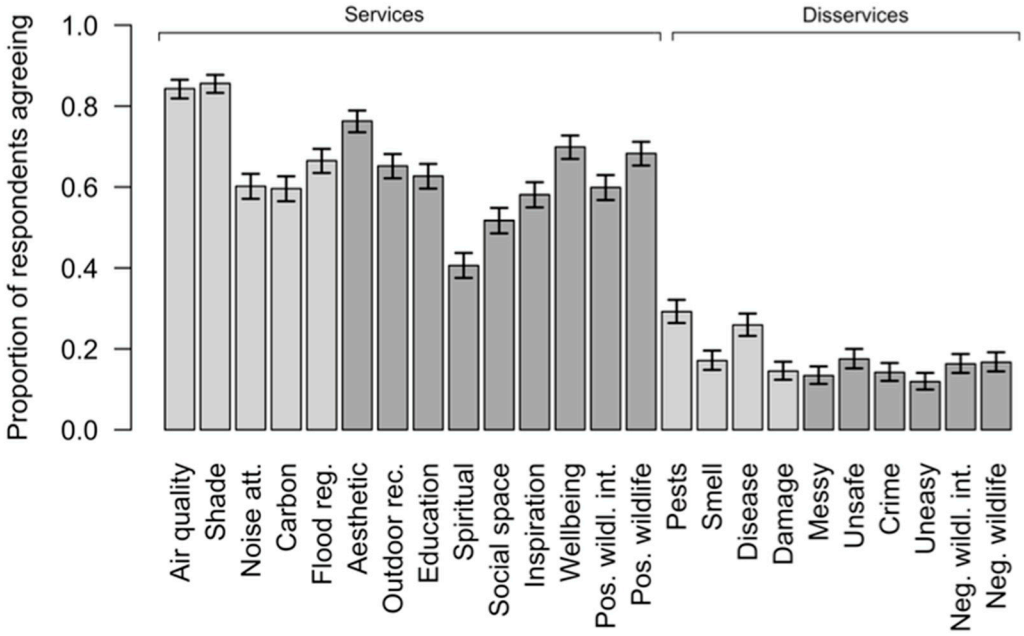

Figure 2. Perception of the importance of ecosystem services and disservices of vegetation in Singapore in general. Light grey bars indicate regulating services and disservices, and dark grey bars indicate cultural services and disservices. Error bars indicate 95% binomial confidence intervals (see Supplementary Materials).

Table 2. Binomial generalized linear model comparing the perception of importance of ecosystem services and disservices.

Variable	Coefficient	Standard Error	z	*p*
Intercept	−1.73	0.03	−50.0	<0.001
Services	2.20	0.04	52.2	<0.001
Regulating	0.45	0.05	8.5	<0.001
Interaction	−0.01	0.06	0.1	0.91

3.2. *Perceived Association of Vegetation Types with Ecosystem Services and Disservices*

Participants associated the various vegetation types with different ecosystem services (Figure 3). Secondary forest was most commonly associated with education and positive wildlife interactions and services with regulating functions, such as carbon storage and flood regulation (Figure 3, Appendix A, Table A1). Amongst disservices, the secondary forest was perceived as messy and associated with crime risk, disease, and pests. Tree canopy over a shrub layer was most commonly associated with aesthetic function, artistic inspiration, positive outdoor recreational space, well-being, and noise attenuation. Among disservices, this vegetation type was more strongly linked with property damage. Shrubs were mostly associated with aesthetic benefits and well-being; however, they were also associated with lack of safety, pests, and spread of disease. Trees were most commonly associated with cooling, air quality, noise attenuation, spiritual and well-being services, and infrastructure damage disservice (Figure 3). Grass was most commonly associated with providing space for social interactions, outdoor recreation, and well-being (Figure 3, Appendix A, Table A1). Grass was also associated with the disservices of pests and smell. Overall, grass was considered to provide fewer services than other vegetation types (Figure 3).

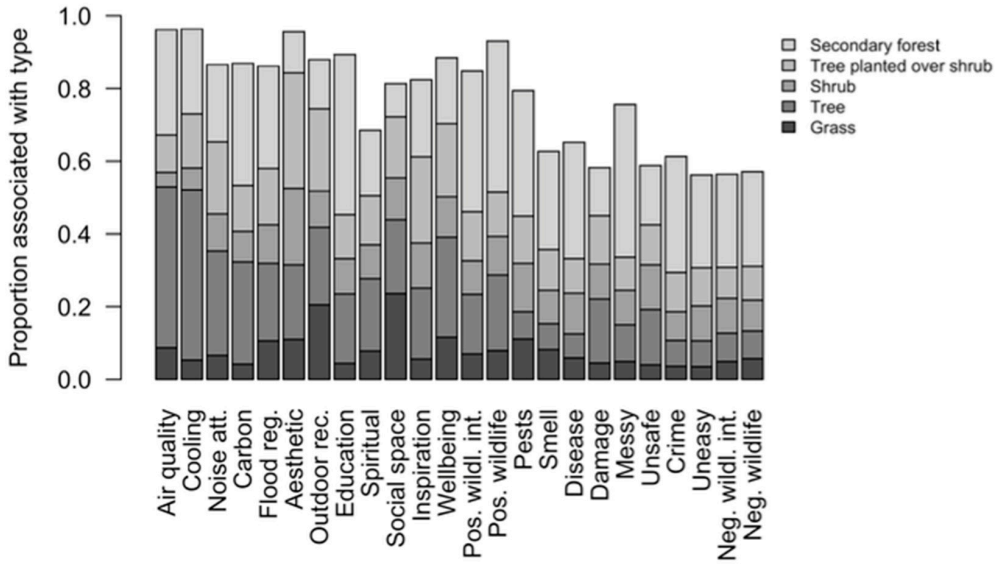

Figure 3. Perception of the relative importance of five broad vegetation types in providing ecosystem services and disservices. Proportion of 1000 respondents; non-responses are not shown (see Supplementary Materials).

3.3. Preference for Vegetation Types in Urban Landscapes

The proportions of respondents preferring different structural vegetation types varied significantly (ANOVA X^2 (4, 1000) = 125.6, $p < 0.001$; Figure 4). The most preferred vegetation types were trees, grass and trees over shrubs, with no significant differences among these types (Appendix A, Table A2). These were followed by secondary forest, and finally by shrub (Appendix A, Table A2).

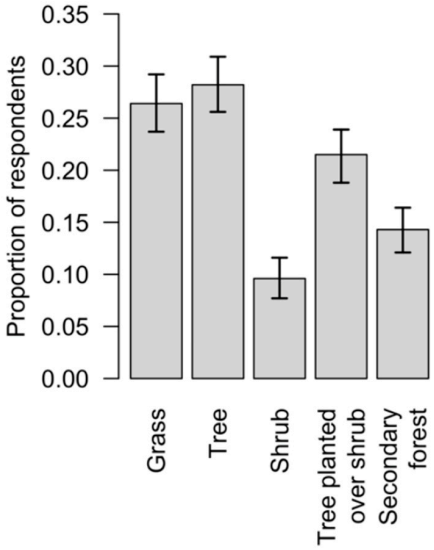

Figure 4. Preference for the vegetation type that respondents would most like to have more of in their neighborhood (n = 1000). Error bars indicate 95% compositional proportion confidence intervals (see Supplementary Materials).

4. Discussion

4.1. Perceived Importance of Urban Vegetation in Providing Ecosystem Services and Disservices

Respondents rated regulating services such as providing shade, improving air quality, and reducing floods more highly than other types of services. Perceptions about ecosystem services are shaped by

many factors [23], including local circumstances and media coverage [31]. The importance attached to regulating ecosystem services in our survey can be linked to the growing environmental pressures faced in Singapore. The period from 2008 to 2018 was the warmest decade on record [46], and extreme high temperatures also reached record levels during this time. High temperatures are widely recognized as a problem for Singapore because of potential negative effects upon outdoor thermal comfort [47,48], outdoor physical activity, and health [49]. Similarly, air pollution events caused by forest fires in neighboring Indonesia have periodically disrupted public life and the economy [50–52]. The pollutant standards index (PSI) reached a historical high of 401 in Singapore on 21 June 2013, with haze events of various intensity occurring in Singapore almost every year [50]. While severe flooding is rare in Singapore, flash floods have become more common in recent years [53]. The magnitude of these floods is small in comparison to those afflicting some other cities, but they receive significant coverage in the local media and have led to changes in water management [53,54].

Although less important than regulating services, many respondents valued the cultural services provided by urban ecosystems, including beneficial aesthetics, enhanced well-being, and positive interactions with wildlife. Through initiatives such as the "Garden City" and "City in a Garden" initiated since the 1960s, Singapore has long pursued the goal of being a green city. This narrative is reinforced in every park through information signs and branding [55]. The aesthetic value of vegetation is thus well-appreciated [56]. As wildlife interactions are frequent (also in very urbanized areas), Singapore residents are becoming more aware of the wildlife they share the city with [57]. Similarly, government campaigns to promote the well-being effects of greenery and outdoor recreation are likely to have been significant in increasing recognition of this. Through nationwide initiatives such as "Community in Bloom", the National Parks Board has encouraged outdoor activities such as gardening. Singapore now has over 1500 community gardens where residents' direct interaction with nature is being reinforced. More recently, so called "Therapeutic Gardens" have been designed for horticultural therapy, with a focus to support the well-being of the older generation [58].

Respondents rated ecosystem services more highly than disservices, though they had some concerns about the negative effects of urban vegetation. One of these was the role of vegetation in harboring pest and disease vectors, which is often mentioned in the media and in public debate [59]. Disease vectors, notably mosquitoes that carry dengue [60], are a significant concern in Singapore, while certain bird and invertebrate species have caused major disturbances, damage, and have been the focus of culling campaigns [61].

Overall, our survey suggests that Singaporean residents take a pragmatic and utilitarian approach towards managing their landscape, attaching more importance to the benefits related to health and comfort than to less tangible spiritual or cultural benefits. A similar attitude was also found among residents in Hong Kong, whose willingness to pay for urban green space was motivated more by the need to improve air quality than by spiritual considerations [62]. These results contrast with those obtained in some European cities, where less importance was attached to regulating ecosystem services [63]. In a study in Bilbao, Spain, for example, the most commonly perceived benefits of urban ecosystems were cultural services [36]. However, these European cities differed from both Singapore and Hong Kong in two important respects: first, they were much smaller cities, and, second, they were surrounded by extensive rural areas to which urban residents had easy access.

4.2. Different Vegetation Types are Perceived to be Associated with Different Ecosystem Services and Disservices

While many studies have been conducted to give a better understanding of the public perception of urban vegetation in general [64–66], few have compared differing perceptions across vegetation types. In this study, we found that among the five vegetation types analyzed, secondary forest was perceived to best provide cultural services such as education and positive wildlife interactions, and regulating services such as carbon storage and flood risk regulation. However, secondary forest was also most associated with disservices such as pest and disease risk, crime, and unattractive

aesthetics. These findings are consistent with other studies showing that people associate unkempt greenery with discomfort [67], risk of crime [68], and, more generally, with danger [17,69].

Trees planted over turf grass were most associated with regulating services such as improving air quality, cooling the environment, and sequestering carbon, but also with cultural services such as improving well-being. These findings corroborate previous work, in which shade and the cooling potential were ranked as the most important benefits by trees, followed by the ability of trees to make people feel calmer [70]. Fraser & Kenney (2000) [71] also found that the greatest willingness to pay was for planting shade trees. The ecosystem disservice associated with trees includes the risk of property or infrastructure damage. Damage to infrastructures, such as pavements due to tree root growth and risk of tree fall, have been found to be common concerns across studies in other countries such as in Poland, Mexico, the United States of America, and Sweden [25,65,70,72]. The overall positive perception of trees may be partially related to Singapore's vision to become a city in a garden, with education on the benefits of urban trees and annual tree planting days being a regular event since 1963 [73]. News and media may also influence people's perceptions, for instance with regard to the mitigating effect of trees on carbon emissions [74].

Trees planted over shrubs, and shrubs, were most associated with aesthetic benefits across the five vegetation types. Trees planted over shrubs were also highly associated with better well-being, probably due to the highest perceived aesthetic value of this vegetation type, where flowering shrubs are commonly planted along the roads in Singapore [75]. Studies have shown that flowering plants are favored by respondents [69], are considered to improve aesthetic quality [76], have a positive influence on psychological well-being, and provide a sense of safety or act as a positive emotion inducer [77].

Grass was most strongly associated with the provision of social space and outdoor recreation. Appreciation of lawns has been highlighted in previous work, showing that more people will tend to visit open spaces with accessible lawns [78], and that lawns were particularly valued as important places for different outdoor activities (playing, resting, picnicking, walking, socializing) [79].

4.3. Preference for Vegetation Types in Urban Landscapes

The most preferred vegetation type in Singapore neighborhoods was trees (Figure 4). This is unsurprising given that trees were perceived to be highly associated with regulating services such as air quality and cooling, while relatively less associated with disservices among the five vegetation types. Studies from United States of America have also found that the general public feels strongly positive about managed trees [70,80]. Shrubs were the least preferred vegetation type among the respondents, probably due to the relatively fewer benefits associated with this vegetation.

Respondents preferred managed landscapes (trees, grass, trees over shrubs) over more natural forest (secondary forest; Figure 4). This can be related to the perception that secondary forest is associated with most disservices, despite the perceived range of services that secondary forest can provide compared to other urban vegetation types. Similarly, a previous study in Singapore found that people in Singapore preferred low-diversity, manicured landscapes over high-diversity, naturalistic landscapes, even though they showed a general tendency towards nature conservation [81]. However, this study showed that people in Singapore do value the regulating services and socio-ecological significance of unmanaged greenery, notably for education opportunities and positive wildlife interactions [69]. There is evidence that peoples' familiarity with a location can moderate their preferences, with residents preferring to retain an area of unmanaged greenery to which they have become accustomed, rather than replacing it with managed vegetation [69]. It may, therefore, be important to raise awareness of the importance of ecosystem services through environmental education [63], as ecological knowledge can also influence a person's perception of nature [82]. Clear communication of the benefits provided by secondary forest, for example, may help in allaying concerns about disservices [64,83].

With a high preference for trees, there was also relatively high preference for trees planted over shrubs (Figure 4). Preference for denser and more complex urban vegetation has been noted previously in Australia [84]. In Singapore, complex vegetation planting that includes multiple overlapping

canopies, has been increasingly implemented since 2012, with currently 100 km of this vegetation type along the roads [85]. Acceptance or even preference for this more structurally complex vegetation type is important, as it is likely to better support biodiversity and some ecosystem services than tree or shrub vegetation alone. We recommend that this type of multi-tiered planting could be incorporated in highly urbanized residential areas, parks, gardens, and along roads in cities.

5. Conclusions

Our study compared public perceptions of the services and disservices of five different vegetation types in the tropical city of Singapore, demonstrating that urban vegetation types are not perceived equally in providing ecosystem services and disservices. To accommodate the wide range of conflicting demands on space and resources, and the preferences of various stakeholders, urban planners need to identify the trade-offs and synergies between the different types of ecosystem services and disservices provided by different vegetation types [14]. With a better understanding of people's preferences for different types of vegetation, planners and designers can make better informed decisions in the co-creation of multifunctional landscapes that optimize ecosystem service provision.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/12/5/2076/s1. Aggregated data used to generate Figures 2–4 are available on Figshare using the following permanent doi:10.6084/m9.figshare.11952567. Individual-level data are available on reasonable request, subject to personal data protection.

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Appendix A

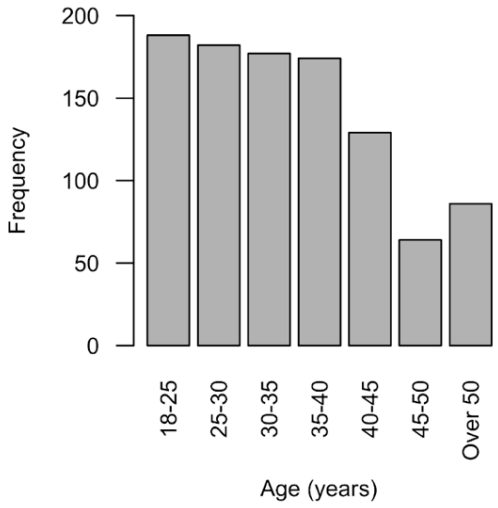

Figure A1. Age group distribution among 1000 respondents.

Table A1. Chi-squared tests of significance for variation in the number of respondents associating each structural vegetation type with different ecosystem services and disservices. Threshold for significance following Bonferroni correction = 0.002.

Ecosystem (Dis)Service	Number of Samples	Degrees of Freedom	χ^2	p	Most Associated Vegetation Type
Air quality	1000	4	593.3	<0.001	Tree
Cooling	1000	4	604.4	<0.001	Tree
Noise att.	1000	4	183.1	<0.001	Tree
Carbon	1000	4	377.0	<0.001	Secondary forest
Flood reg.	1000	4	132.1	<0.001	Secondary forest
Aesthetic	1000	4	153.4	<0.001	Tree over shrub
Outdoor rec.	1000	4	69.2	<0.001	Tree over shrub
Education	1000	4	540.7	<0.001	Secondary forest
Spiritual	1000	4	81.1	<0.001	Tree
Social space	1000	4	88.8	<0.001	Grass
Inspiration	1000	4	132.6	<0.001	Tree over shrub
Well-being	1000	4	103.4	<0.001	Tree
Pos. wildl. int.	1000	4	379.9	<0.001	Secondary forest
Pos. wildlife	1000	4	402.5	<0.001	Secondary forest
Pests	1000	4	286.4	<0.001	Secondary forest
Smell	1000	4	215.7	<0.001	Secondary forest
Disease	1000	4	358.8	<0.001	Secondary forest
Damage	1000	4	82.3	<0.001	Tree
Messy	1000	4	608.5	<0.001	Secondary forest
Unsafe	1000	4	79.5	<0.001	Secondary forest
Crime	1000	4	414.8	<0.001	Secondary forest
Uneasy	1000	4	252.3	<0.001	Secondary forest
Neg. wildl. int.	1000	4	238.0	<0.001	Secondary forest
Neg. wildlife	1000	4	239.0	<0.001	Secondary forest

Table A2. Chi-squared tests comparing preferences for vegetation types that respondents would most like to have more of in their neighborhood.

Comparison	Raw p	Adjusted p
Grass vs. Tree	0.645	0.645
Grass vs. Shrub	<0.001	<0.001
Grass vs. Tree over shrub	0.136	0.151
Grass vs. Forest	<0.001	<0.001
Tree vs. Shrub	<0.001	<0.001
Tree vs. Tree over shrub	0.051	0.063
Tree vs. Forest	<0.001	<0.001
Shrub vs. Tree over shrub	<0.001	<0.001
Shrub vs. Forest	0.018	0.025
Tree over shrub vs. Forest	0.006	0.009

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