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Perceived biodiversity of fruit species for urban greenery in Indonesia: Case studies in Bogor, Jakarta, and Yogyakarta

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Abstract. *Ruwaida IP, Santosa E, Susila AD, Widodo WD, Wachjar A, Nasrullah N. 2022. Perceived biodiversity of fruit species for urban greenery in Indonesia: Case studies in Bogor, Jakarta, and Yogyakarta. Biodiversitas 23: 3166-3177.* Urban greenery planning considering biodiversity scenarios is still rarely studied in Indonesia. This study aims to demonstrate edible fruit species (FS) as the scenario for urban greenery based on interviews with citizens in Indonesian cities. The study was carried out in the cities that have implemented smart city models i.e., Bogor, Jakarta, and Yogyakarta-Indonesia. Interviews were conducted in July-December 2019, involving 420 respondents. The results showed that 77.7% of all respondents agreed with the planting of FS as city greenery. In total for all cities, there were 79 species belonging to 32 families mentioned by the respondents consisting of 41 commercial and 38 underutilized FS. Each respondent was able to mention between 20.4 and 22.8 fruit species, irrespective of city. The ability to mention fruit species was affected by the respondent's background, especially exposure during childhood to FS, frequency as a domestic tourist, mobility mode, and frequency of visiting city parks. The rationale for selecting FS was the benefit of fruit as a food source, followed by the benefit of ecology, economy, aesthetics, and health. Based on the significant cultural index, mango ranked first as the most preferred commercial fruit species, followed by rambutan, rose apple, orange, papaya, starfruit, guava, avocado, sapodilla, and longan; and for underutilized FS were shoe-button, *pinang, nam nam,* mulberry, cactus, canistel, cherry, and pear. Value of species richness, Shannon-Wienner, and Simpson diversity indices of FS within a city ranged 0.97 to 1.06, 3.62 to 3.83, and 0.97, respectively. Biodiversity scenarios could be useful information in the greenery planning of smart cities to coop with evolving broader environmental services.

Keywords: Biodiversity, city greenery, edible fruit species, environment service, smart city

Abbreviations: MPTS: multipurpose fruit tree species, CSI: Cultural significant index.

INTRODUCTION

A city is a man-made ecosystem in which the situation changes over time depending on the citizen's preferences and local policy. Throughout the world, there is an emerging concept of a smart city by integrating data, infrastructure, and society in its development (Pagan 2018; Kirimtat et al. 2020). The smart city concept unifies various aspects of the economy, environment, governance, mobility, living, and the people living in it through the advanced uses of information and communication technologies (Cohen 2012).

One component of environmental aspects in the smart city concept is greenery vegetation (Fortes et al. 2021). In the urban environment, the vegetation functions to lower temperatures, improve health, create landscape beauty, sustain the ecology, increase social relations and even facilitate education to increase student success (Reid et al. 2017; Turner-Skoff and Cavender 2019). It also controls pollution (Nowak et al. 2014; 2018), promotes cities more humanely (Roman et al. 2021), support wildlife habitat such as birds (Prihandi and Nurvianto 2022), and maintains better hydrological conditions (Carlyle-Moses et al. 2020). According to Lüttge and Buckeridge (2020), the vegetation health profile becomes an urban health indicator as shown in dendrochronology and its biochemistry.

Smart city development has been initiated in Indonesia since 2009 (Atmawidjaja et al. 2015), and it has been continuing to evolve nowadays. In a most recent advance, the smart city development in Indonesia considers a forest city concept by planting multipurpose tree species (Mutaqin et al. 2021). There are already numerous studies that high tree diversity in a city could better in protecting the ecosystem and biodiversity, delivering environmental services, especially in terms of rainfall interception and carbon sequestration, improving societal health and wellbeing, supporting the development of a green economy, and sustaining the land, water and food (SEP 2012; Song et al. 2020; Santosa et al. 2021).

However, as compared to heat island scenarios, pollution mitigation, oxygen balance, windbreaker, and visual beauty (Hofierka et al. 2017; Wai et al. 2021), urban greenery planning using biodiversity scenarios is still rarely studied. Biodiversity refers to variability among living organisms, including within species, among species and its ecosystem (UN 1992), and mirrors the status of species richness in certain space and time (Gaines et al. 1999; Da Silva et al. 2006; Conde et al. 2017). Meinard et al (2019) propose 'biodiversity in practices' that include studies, actions, strategies based on aspiration, and long-term decision strategies and preferences. In the context of city planning, universalism by planting single or few vegetation species instead of a variety of plant species makes cities lose their identity (Simberloff 2013). It is also noted that single planting species might be vulnerable to disease and climate change (Petter et al. 2020).

Here, we propose an idea to use edible fruit species (FS) as multipurpose tree species for city greenery to fulfill a multi-facet of vegetation service in the smart city concept. Introducing FS to a city might strengthen food security and the conservation of genetic diversity of tree species (Santosa et al. 2020, 2021). The proposal is in line with Indonesia as mega biodiversity and strengthens the city's character. Thus, the study aims to demonstrate the idea of FS as the scenario for urban greenery based on interviews with citizens in three Indonesian cities, namely Bogor, Jakarta, and Yogyakarta. Factors related to background, preference, and perception of respondents, biodiversity, and their implication are discussed.

MATERIALS AND METHODS

Study area

The study was conducted from July to December 2019 in Bogor City (West Java Province), Yogyakarta City (DI Yogyakarta Province), and Jakarta City (DKI Jakarta Province) corresponding to small, big, and metropolitan cities on Java Island of Indonesia (Figure 1). City size in this study after Santosa et al. (2021).

Bogor and Yogyakarta Cities are well known as education cities, and Jakarta, as the capital city of Indonesia is known as a business city (Table 1). All cities are located at an altitude below 200 m above sea level. All sites involved in Smart City Project 2045 by the Indonesian Government (Atmawidjaja et al. 2015; Firmansyah 2019; Amijaya 2020).

Data collection

Data were collected through interviews using closed and open questionnaires. The interview was conducted on both weekdays and weekends. To ensure the respondents understood the questions, we conducted a pre-survey evaluation involving university students and senior high school students in Bogor City and Jakarta City. The final questionnaire was developed after the majority of interviewees could correctly understand the meanings of the question.

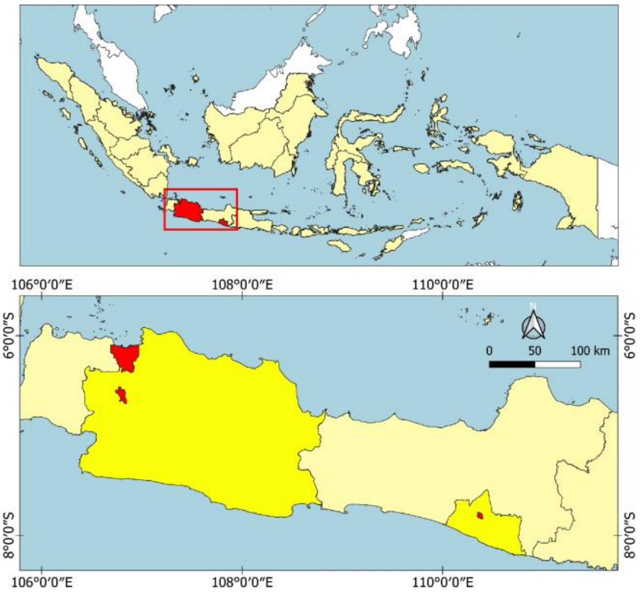

Figure 1. Study sites of Bogor, Jakarta, and Yogyakarta, Indonesia

Respondents who lived in Bogor, Jakarta, and Yogyakarta amounted to 150, 150, and 120 persons, respectively. The respondents were selected based on stratified random sampling from universities, companies, government officers, schools, and communities. Respondents in each stratum were selected randomly 24-30 persons. Before filling in the questionnaire, the scope of the questions and sign of consent were explained to ensure accurate answers. Some respondents filled the form in their houses and brought it back the following day.

The questionnaire contained three parts: (1) Basic information, including gender, age, and education level; (2) Experience to contact with greenery, including the presence of the big tree and fruit tree in his/her parent's house, frequency of abroad and domestic vacations, the frequency of park visits, and transportation mode of respondents; (3) Preference to FS including agree and disagree criteria to select species and species name.

For FS preference, the interviewees were asked to list up to 10 tree species for each public park (hospital, residential, religious facility, and city park). Thus, a respondent collected up to 40 tree species to complete the form. Furthermore, each respondent was also asked to list the 10 most preferred FS (five commercial [CF] and five underutilized species [UF]). CF was frequently traded or available on a regular basis according to its production season in the local market, while UF was sometimes available in the local market, but the limited amount, available by request, was exchanged among neighbors for free or consumed individually in a family. The clarification of the species name was made after finishing the interview to reduce the bias. In the clarification stage, tree images of stem, canopy, flower, fruit, and leaves were provided. In case the respondent was unable to define species into CF or UF, it was judged by the authors.

Table 1. Characteristics of the study area by 2018

Characteristics	Bogor City[z]	Jakarta City[y]	Yogyakarta City[x]
City identity			
Year founded	1448	1527	1756
City vision	Education	Business	Heroic/Education
Percentage of green space (%)	18.4	9.98	19.00
Geographic			
Area (km^2)	118.50	664.0	3,185.8
Monthly precipitation (mm)	345.0	219.1	166.2
Air relative humidity (%)	64-92 (Avg. 82)	70-94 (Avg. 81)	62-96 (Avg. 78)
Mid-day temperature (°C)	22.2-33.0 (Avg. 27.3)	23.7-33.7 (Avg. 27.9)	14.5-34.8 (Avg. 26.1)
Altitude (m above sea level)	190	26.2	75
Number of rivers	2	1	8
Demography			
Population (million)	1.08	10.56	3.80
Population density (per sq km)	9,122	72,627	1,193
Human Development Index	75.16	84.13	79.53
Food security index[w]	74.37	87.72	76.82
Economic level			
Economic growth last 5 years (%)	4.16-5.05	6.03-6.32	5.09-5.47
Annual number of tourist (million)	5.26	32.22*	26.51
Gross Domestic Product (trillion IDR)	38.51	539.99	31.31
Government Expenditure (trillion IDR)	2.26	78.67	5.30
Transportation facility			
Total road length (km)	757.4	2,437.78	4,366.42
Personal car (unit)	139,340	705,185	158,972
Motorbike (unit)	360,923	2,662,135	1,203,535

Note: [z]BPS Kota Bogor (2018); [y]BPS (2022a) DKI Jakarta; [x]BPS DI Yogyakarta (2019); [w]BKP (2018); *BPS (2022b); Avg-average

Data analysis

Biodiversity was evaluated using species richness (R), Shannon-Wiener's index (H'), and Simpson's index (D) (Gaines et al. 1999). The importance of tree species was evaluated using Cultural Significant Index (CSI) (Da Silva et al. 2006; Conde et al. 2017) with modification.

Species richness (R) is the number of species (Σn), where n=number of species.

Shannon index: $H' = -\Sigma\, p(i) \ln p(i)$, where p(i) = the proportion of individuals found in the i^{th} species, and ln p(i) = logarithm natural of p(i) that is estimated as n(i)/N. The value of H' usually falls between 1.5 and 3.5 and only rarely surpasses 4.5.

Simpson's index: $D = \Sigma\, [(n(i)(n(i)-1))/(N(N-1))]$, where n(i) = the number of individuals in the i^{th} species, and N = the total number of individuals. Simpson's index is expressed as 1-D.

Cultural significant index follow Conde et al. (2017): $CSI=\Sigma(i*e*c)$ *CF, where i: species management (1: underutilized, 2: commercial), e: preferential use (1: never use, 2: use as fruit), c: use frequency by community (1: up to 10%, 2: mentioned by >10% respondent), CF: correction factor (citations of species x/citations of the most cited species).

According to Gaines et al. (1999), biodiversity can be calculated from a sampling of a particular area based on the number of species and their frequency. Here, we modified the calculation by using retrieval species data from respondents. Four sets of a-10 species data were used as the replacement of the sampling area. Diversity among respondents was calculated based on a comparison among respondents, and diversity within a city was calculated based on the total number of respondents in a particular city.

Correlation analysis between the number of species and respondent characteristics was conducted using the Pearson correlation analysis in Minitab at a 95% level of confident. Respondent characteristics included sex, age, education level, employee type (government officer, private, no job), frequency of vacation (domestic and abroad), the way to commute, large tree in parent's house (including FS), native citizen or non-native, and frequency to visit city park.

RESULTS AND DISCUSSION

Respondent profile

Gender involved in the study was almost equal in Jakarta and Yogyakarta, while in Bogor, most respondents were women (Table 2). Most respondents were aged 19-23 years old, and the rest was 23-39 years old. The education level of 60.7-64.7% of respondents was senior high school, followed by undergraduate for Jakarta and Yogyakarta sites. In Bogor, 4.5% of respondents hold undergraduate and magister's certificates. It is important to note that although most respondents in Bogor were women, the gender composition was represented by age and education level. During the survey, many young men respondents in Bogor hesitated to participate, resulting in a larger number of women. However, we did not further evaluate the reason.

Table 2. Basic respondent information involved in the study

Basic information	Percentage of respondent		
	Bogor	Jakarta	Yogya-karta
Gender			
Men	27.3	46.0	50.9
Women	72.7	54.0	49.1
Age (year)			
19-23	50.1	56.7	40.9
24-28	18.7	16.7	20.9
29-33	10.0	13.3	11.8
>34	16.7	13.3	26.4
Education background			
Senior high school	60.7	64.7	60.9
Undergraduate degree	19.3	26.7	34.5
Master degree	20.0	8.6	4.5
Settle status			
Similar (native)	65.3	51.3	72.7
Different (non-native)	34.7	48.7	27.3
The parent's house had big trees			
Present	72.0	60.0	60.0
Absent	28.0	40.0	40.0
Parent's house had fruit trees			
Present	80.7	72.7	70.9
Absent	19.3	27.3	29.1
Abroad vacation (last 5 years)			
Never	84.7	80.0	80.9
At least once	15.3	20.0	19.1
Domestic vacation (last 5 years)			
Never	18.7	14.7	11.8
1-5 times	72.0	74.7	60.0
6-10 times	8.0	7.3	18.2
More than 10 times	1.3	3.3	10.0
Transportation mode			
On foot	30.0	11.3	3.6
Motorbike	52.7	68.0	84.6
Private car	5.3	9.4	6.4
Public transportation	12.0	11.3	5.4
Frequency to visit city park (per year)			
Never	19.3	15.3	19.1
1 to 2 times	67.3	68.7	66.4
3 to 4 times	3.3	8.7	5.5
5 to 6 times	4.0	5.3	1.8
7 to 8 times	6.0	1.3	1.3
> 8 times	-	0.7	-

The respondents were mostly native citizens of the city, while the rest were outsiders from other cities (Table 2). In Yogyakarta and Bogor, non-native citizens comprise 27.3% and 34.7% of the total respondents, respectively. Most of them initially moved to the recent city to pursue higher education; then they got a job and settled in the city. Non-native respondents in Jakarta were as high as 48.7%; the high number is probably due to Jakarta being a business city. We realized during the interview that some respondents commuted daily from surrounding towns to the study site, in this case, classified as non-native.

More than 60% of respondents encountered large trees in their parent's houses (Table 2). Among the large trees encountered, 70.9-80.7% of respondents stated these were FS. Many respondents went on vacation as domestic tourists with a frequency of almost once a year (Table 2), but 11.8-18.7% had never been a domestic tourist within the last five years. Up to 20% of the total respondent had been exposed to foreign countries as a tourist.

The motorbike was the most popular transportation mode (Table 2). But in Jakarta and Bogor cities, short distant mobility on foot was popular. The presence of safe walking paths likely became the main reason for people to walk 1-2 km in both cities. Some respondents used public transportation, especially *angkot* (a 12-passenger car) or train, that account for 12.0%, 11.3%, and 5.4% of respondents in Bogor, Jakarta, and Yogyakarta, respectively.

Most respondents visited city parks 1-2 times a year, while 19.3% in Bogor, 15.3% in Jakarta, and 19.1% in Yogyakarta had never visited the city park in the last 5 years (Table 2). About 8.6-16.0% of respondents visited city parks more than 3 times a year, especially at the weekend.

Preference for fruit species

On average, 77.7% of the respondents agreed to enrich the city using FS (Figure 2). In Jakarta, 82% of the respondents agreed to plant FS; the highest among the cities studied. Among them who agreed, 60-64% of respondents like seasonal species (Figure 2.B). The most popular seasonal fruits were durian, mango, and rambutan. Managing seasonal species is believed much easier than species with continuous fruiting and flushing like coconut, starfruit, guava, and rose apple.

Respondents who agreed to planting FS in the city, 73-78% were willing to pick fruits in the public park if the regulation allowed it, contrary to 22-27% of other respondents (Figure 2.C). On the other hand, respondents who refused to introduce FS almost all would not pick the fruit. They believed fruits were not safe due to being exposed to high city pollution. They were also aware that some fruit trees, like coconut, sometimes grew high, which might cause danger from fruit or frond falling to passersby. Indeed, some FS is suitable for intensive pruning, topping, and training to maintain height and safety such as durian, mango, rambutan, sapodilla, and jack fruit (Santosa et al. 2021), unlike coconut, areca nut, and dates trees (Arecaceae).

The respondents who were pro-FS introduction mainly considered it to produce fruit, stimulate healthy air, and beautify the city, while those contra-FS mainly due to afraid of fruits falling, dirty litter, stimulate children fighting for competing for fruit, and endanger walking people from fruit falling (Table 3). In Yogyakarta, 40.7% of respondents became contra-FS because unintentional fruit drops might cause slippery on pedestrian and road paths, like respondents in Bogor and Jakarta with 30.6% and 33.3%, respectively. Probably, a high number of respondents who mobile on foot and on motorbikes as shown in Table 2 were the groups who contra-FS introduction to their city (Figure 2.A).

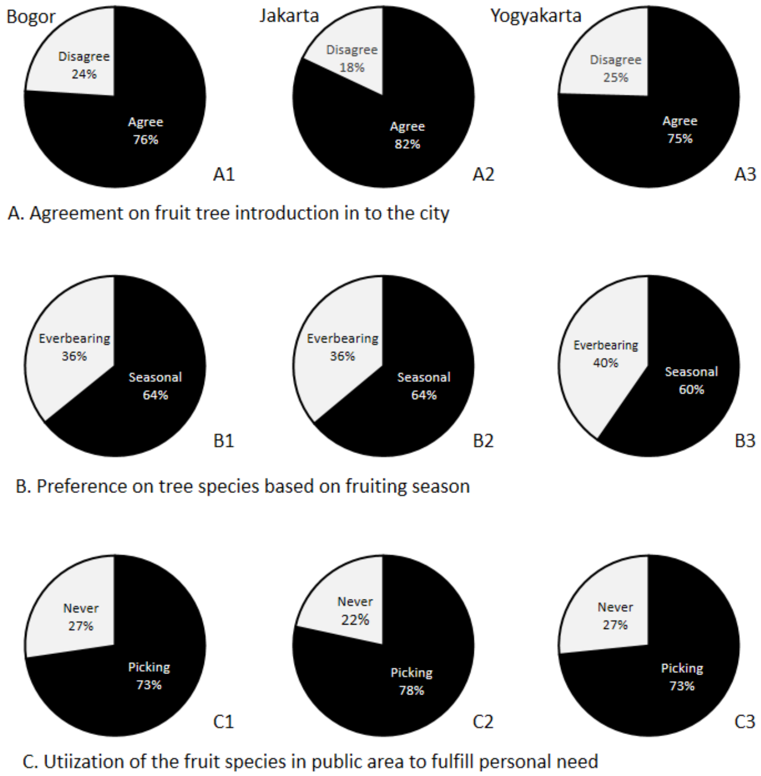

Figure 2. Preference on FS introduction (A), fruiting season (B), and fruit utilization (C) of respondents in Bogor (A1,B1,C1), Jakarta (A2,B2,C2) and Yogyakarta (A3,B3,C3)

Table 3. Respondents' reasons to agree or disagree with planting FS in Bogor, Jakarta, and Yogyakarta

Reasons to introduce species	Percentage of respondent[z]			
	Bogor	Jakarta	Yogya-karta	Aver-age
Agree/pro				
It produces edible fruit	75.4	63.3	77.1	71.9
It produces healthy air	70.2	60.0	75.9	68.7
It beautifies the city	57.0	40.7	75.9	57.9
It attracts birds and mammals	19.3	8.0	21.7	16.3
It reduces wind speed	22.8	12.7	38.6	24.7
Disagree/contra				
It causes dirty (fruit/litter)	61.1	66.7	70.7	66.2
It causes kids fighting for fruit	55.6	48.2	59.3	54.4
The fruit falling to people	47.2	44.4	40.5	44.0
It causes slippery path/road	30.6	33.3	40.7	34.9
The fruit unhealthy (polluted)	33.3	48.2	18.5	33.3
The fruit falling to vehicle	38.9	29.6	29.6	32.7

Note: [z]Maximum value of a reason is 100%

Biodiversity indicators and motive to choose fruit species

Each respondent was able to retrieve between 20.4 and 22.8 species of fruit species with an average of 22.0 species, irrespective of the cities (Table 4). Cumulatively, residents in Bogor and Jakarta wanted more diverse FS (75-76 species) than residents in Yogyakarta (68 species), leading to higher species richness among respondents in Bogor and Jakarta. However, species richness within the city was higher in Yogyakarta, indicating that evenness among respondents is higher than in the other cities.

Shannon index (H') of FS mentioned by the respondents was 2.92 on average (Table 4), indicating that the value ranged in medium diversity on a scale of 0 to 5. On the other hand, H' city ranged from 3.63-3.82, indicating the high diversity. Zulfikar et al. (2021) evaluated FS diversity at the level of village and subdistrict revealed an index H' of 0.80 to 1.40. In the forest, Awaii and Talla (2019) noted FS as a food source has H' 1.14 to 1.78. Simpson's index (D') city showed similar across cities, while D' respondents were lower in Yogyakarta (Table 4). The D' ranged from 0.96-0.97 expressing high diversity within the range 0 to 1.

All respondents resumed 12 criteria in choosing FS in which food security motive was the most dominant criterion (Table 5). The total score of the criterion reflects the importance in which the most popular criteria were the ability tree to produce tasty fruit, edible fresh fruits, and high production. It seems that the criterion for commercial fruit (CF) and underutilized fruit (UF) selection was almost equal for food security motives (average > 38.4%). For the aesthetic of the canopy, the respondent preferred UF to CF, but for other aesthetic criteria, they preferred CF. In Bogor FS with the ability to stimulate mental healing was noticeable by 8.0-14.0% of the respondents, irrespective of CF and UF. Table 5 concludes that food security was the most important motive, followed by ecology, economy, aesthetics, and health. The conclusion is close to farmers' motive in the tree selection for the agriculture field. In the Philippines, women farmers consider trees to provide high income, food for consumption, low capital requirement, high selling price, easy to market, high frequency of harvest, and a shorter growing period when selecting fruit species for their farm (Ureta et al. 2016). It is important to note that more than 50% of respondents in Bogor and Yogyakarta cities appreciated UF which produced tasty and ready-to-consume fruits.

Interestingly, unlike aesthetic motives that are easily clustered as shown in Table 5, ecological and economic motives are ranked in a different order. For example, ecological motives, i.e., ‘to stimulate healthy air’ and ‘to attract birds or mammals’ had a total score of 46.5 and 6.3, respectively. Similarly, ‘fruit has high price value’ ranked 42.5, which had a distant position to ‘producing timber for construction’ which ranked 3.7. It is probable that different city profiles as shown in Table 1, affect the respondents’ motives on ecological and economic aspects. It needs further study because respondents in Jakarta expected more birds and mammals in the city, unlike in two other cities. Respondents in Jakarta recommended mango, coconut, durian, rose apples, and guava trees because they attract birds, bats, squirrels, and common palm civets (*musang* in Indonesian) (*Paradoxurus hermaphroditus* Pallas 1777). In general, fruit utilization is allowable for the citizenry at a particular amount (Iqbal 2020), while timber harvesting in the city is prohibited by the law (Utami 2019). It is probable that clear regulation by the local government on timber utilization in the city leads to a lower consideration as an economic motive by the respondents.

Factor affecting respondent preference for fruit species

Male respondents in Bogor tended to name more species than female respondents, opposite them in Yogyakarta (Figure 3.A). In the case of Jakarta, gender had the same ability to name species. The younger age (19-28 years old) tended to name more FS than other age groups in Bogor and Jakarta (Figure 3.B), but unlikely for respondents in Yogyakarta. In all cities, respondents who graduated from university were able to name more FS than those from senior high school (Figure 3.C). Respondents who were non-native to Bogor were able to name more species (Figure 3.D), whilst native respondents to Jakarta and Yogyakarta named more species. It is probable that the gender bias of Bogor respondents as shown in Table 2, contributed to the result in the present study.

Table 4. Biodiversity indicators and Cultural Significant Index (CSI) of fruit species based on interviews in Bogor, Jakarta, and Yogyakarta

Biodiversity indicator	Value (mean±SE)			
	Bogor	Jakarta	Yogyakarta	All sites
Number of species				
Among respondents	22.8±0.5	22.7±0.5	20.4±0.5	22.0
Within city	75	76	68	79
Species richness				
Among respondents	3.61±0.08	3.47±0.08	3.22±0.07	3.43
Within city	0.97	1.00	1.06	1.01
Shannon index (H’)				
Among respondents	2.98±0.03	2.97±0.03	2.79±0.05	2.92
Within city	3.82	3.78	3.62	3.74
Simpson’s index (D’)				
Among respondents	0.97±0.00	0.97±0.00	0.96±0.00	0.97
Within city	0.97	0.97	0.97	0.97
CSI	2.18±0.26	2.30±0.29	2.22±0.29	1.99±0.25

Table 5. Motive and selection criteria of fruit species by respondents who agreed to plant fruit species in Bogor, Jakarta, and Yogyakarta

Motive	Selection criteria	Percentage of respondent^z								Score rank^y
		Bogor		Jakarta		Yogyakarta		Average		
		CF	UF	CF	UF	CF	UF	CF	UF	
Food security	The fruit taste	83.3	51.3	76.7	38.0	86.4	50.0	82.1	46.4	128.5
	Produce edible fresh fruit	63.3	50.7	46.7	40.0	79.1	60.9	63.0	50.5	113.5
	Produce a lot of fruit	52.0	32.7	47.3	30.7	51.8	51.8	50.4	38.4	88.8
Ecology	Stimulate healthy air	34.0	28.0	22.0	19.3	19.1	17.3	25.0	21.5	46.5
	Attract birds/mammals	1.3	0.7	10.0	3.3	1.8	1.8	4.4	1.9	6.3
Economy	Fruit has high price value	39.3	12.0	22.7	10.7	31.8	10.9	31.3	11.2	42.5
	Timber for construction	2.0	2.0	0.7	0	0.9	5.5	1.2	2.5	3.7
Aesthetic	Has beautiful canopy	10.7	14.7	4.0	9.3	13.6	16.4	9.4	13.5	22.9
	Tree sized medium	17.3	10.0	8.7	2.0	20.0	10.0	15.3	7.3	22.6
	Has beautiful flower	10.7	6.7	9.3	4.0	10.9	6.4	10.3	5.7	16.0
	Has beautiful leaves	8.0	15.3	6.0	5.3	10.0	8.2	8.0	9.6	17.6
Health/healing	Stimulate good feeling	14.0	8.0	2.7	2.7	3.6	0	6.8	3.6	10.4

Note: ^{z}Maximum value of criteria for CF or UF is 100%; CF: commercial fruit, UF: underutilized fruit; ^{y}Average CF+average UF

Parent's house with available large tree species had no clear effect on the respondent's ability to retrieve FS (Figure 3.E), while fruit species availability tended to increase the ability to retrieve FS in the case Jakarta and Yogyakarta (Figure 3.F). The relationship between childhood experience and current attitude toward trees has been widely studied (see Lohr 2004). Figure 3.G clearly shows respondents' ability to name species increased by increasing frequency as domestic tourists up to 10 times. Low FS number from respondents' frequency >10 times could be an outlier because the total respondents were 1.3%, 3.3%, and 10.0% of respondents in Bogor, Jakarta, and Yogyakarta, respectively (Table 2).

A similar trend was also shown in Bogor for abroad tourists, but not for respondents of Jakarta and Yogyakarta (Figure 3.H). Most respondents in Jakarta and Yogyakarta declared to go abroad to Saudi Arabia as haj. The arid situation of Saudi Arabia probably had less contribution to exposing diverse FS.

Frequent visiting city parks up to 3-4 times per year increased the number of species in all cities (Figure 3J). Finally, walking respondents named more species than those traveling used other modes in the case of Bogor and Jakarta (Figure 3I). Truong (2021) noted that interactions with biodiversity will increase awareness. It is probable that walking respondents interacted more with existing tree diversity in the city.

Cultural significant index (CSI) of fruit species among cities

The interviews resumed 79 species with 41 commercial fruit species (CF; 23 families) and 38 underutilized fruit species (UF; 20 families) (Tables 6 and 7).

Table 6. CSI of desired commercial fruit species (CF) according to respondents in Bogor, Jakarta, and Yogyakarta

Family	Species	Common name/ Indonesian	CSI			
			Bog	Jak	Yog	Total
Actinidiaceae	*Actinidia deliciosa* Liang & Ferguson	Kiwi fruit/kiwi	0.03	0.03	0^{z}	0.02
Anacardiaceae	*Mangifera indica* L.	Mango/mangga	8.00	8.00	8.00	8.00
	Spondias pinnata (L.f.) Kurz	Hog plum/kedondong	3.50	3.20	2.79	3.20
Annonaceae	*Annona muricata* L.	Soursop/sirsak	5.28	5.27	5.58	5.36
	Annona reticulata L.	Sweetsop/srikaya	4.33	4.03	4.23	4.20
Arecaceae	*Cocos nucifera* L.	Coconut/kelapa	3.89	4.50	3.55	4.18
	Phoenix dactylifera L.	Date palm/kurma	0.06	0.06	0	0.04
	Salacca zalacca (Gaertn.) Voss.	Snake fruit/salak	1.50	1.72	0.91	1.41
Bromeliaceae	*Ananas comosus* (L.) Merr.	Pineapple/nanas	2.06	2.01	2.19	2.08
Cactaceae	*Hylocereus undatus* (Haworth) Britton & Rose	Dragon fruit/buah naga	0.80	0	0	0.03
Caricaceae	*Carica papaya* L.	Papaya/pepaya	6.17	6.93	6.79	6.61
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum. & Nakai *	Watermelon/semangka	0.03	0.09	0	0.04
	Cucumis melo L.*	Melon/melon	0.03	0.15	0.04	0.07
Guttiferae	*Garcinia mangostana* L.	Mangosteen/manggis	5.44	6.04	4.83	5.49
Lauraceae	*Persea americana* Mill.	Avocado/alpokat	6.06	6.70	5.36	6.09
Malvaceae	*Durio zibethinus* L.	Durian/durian	2.94	2.90	2.49	2.81
Meliaceae	*Lansium domesticum* Corr.	Dokoo/duku	3.11	4.33	3.78	3.72
	Lansium parasiticum Osbeck) K.C. Sahni & Bennet	Longkong/langsat	2.39	1.36	1.36	1.75
Moraceae	*Artocarpus altilis* (Park.) Fosberg	Breadfruit/sukun	3.22	2.49	1.89	2.60
	Artocarpus heterophyllus Lam.	Jackfruit/nangka	4.72	4.62	2.94	4.20
	Artocarpus integer Spreng.	Cempeden/cempedak	1.89	2.31	1.13	1.83
Musaceae	*Musa paradisiaca* L.	Banana/pisang	5.06	6.16	5.36	5.52
Myrtaceae	*Psidium guajava* Linn.	Guava/jambu biji	6.00	6.87	6.79	6.52
	Syzygium mallaccense (L.) Merr. & Perry	Malay apple/jambu bol	4.44	4.15	3.55	4.09
	Syzygium aqueum Burm F	Rose apple/jambu air	6.72	7.47	6.49	6.92
Oxalidaceae	*Averrhoa bilimbi* L.	Bilimbi/belimbing wuluh	3.50	3.50	3.77	3.57
	Averrhoa carambola L.	Starfruit/belimbing	6.17	7.23	6.34	6.59
Passifloraceae	*Passiflora lingularis* L.*	Passion fruit/markisa	0.03	0	0	0.01
Lythraceae	*Punica granatum* L.	Pomegranate/delima	0	0	0.04	0.01
Rosaceae	*Fragaria × ananassa* (Weston) Duchesne ex Rozier	Strawberry/stroberi	0.03	0.09	0	0.04
	Malus domestica Borkh.	Apple/apel	4.72	5.81	3.85	4.86
Rutaceae	*Citrus × aurantiifolia* (Christm.) Swingle	Key lime/jeruk nipis, limo	2.44	3.67	1.59	2.64
	Citrus grandis Osbeck	Pamelo/jeruk bali	3.50	4.50	3.02	3.72
	Citrus limon (L.) Burm.f.	Lemon/jeruk lemon	4.11	3.97	3.62	3.93
	Citrus sinensis L. Osbeck	Sweet orange/jeruk siam	6.33	7.47	6.19	6.69
Sapindaceae	*Dimocarpus longan* (Lour.) Steud	Longan/lengkeng	5.61	5.87	6.64	5.98
	Litchi chinensis Sonn.	Lychee/leci	0.03	0	0	0.01
	Nephelium lappaceum L.	Rambutan/rambutan	6.78	7.59	7.47	7.25
	Pometia pinnata J. R & G. Forst	Matoa/matoa	3.50	3.62	4.38	3.78
Sapotaceae	*Manilkara zapota* L.	Zapota/sawo	6.28	5.98	5.66	6.00
Vitaceae	*Vitis vinifera* L.*	Grapes/anggur	0.14	0.38	0.26	0.26

Note: Bog: Bogor, Jak: Jakarta, Yog: Yogyakarta; ^{z} '0' means absent; * Climbing fruit species

Table 7. CSI of desired underutilized fruit species (UF) according to respondents in Bogor, Jakarta, and Yogyakarta

Family	Species	Common name/ Indonesian	CSI			
			Bog	**Jak**	**Yog**	**Total**
Anacardiaceae	*Bouea macrophylla* Griffith	Marian plum/gandaria, rasmania	1.56	1.57	0.49	1.27
	Mangifera caesia Jack ex Wall	Wani Bali, mangga Binjai	0.44	0.47	0.45	0.46
	Mangifera kamanga Blume	Kemang	0.72	0.42	0.11	0.45
Annonaceae	*Stelechocarpus burahol* (Blume) Hook F & Thomson	Kepel	0.69	0.68	1.25	0.84
Arecaceae	*Areca catechu* L.	Betel palm/pinang	0	0.03	0	0.01
Cactaceae	*Opuntea ficus-indica* (L.) Mill.	Prikly pear/kaktus	0	0.02	0	0.01
Ebenaceae	*Diosphyros kaki* L.f	Persimmon/kesemek	0.92	0.70	0.53	0.78
	Diospyros blancoi A.DC.	Velvet apple/bisbul	0.94	0.59	0.19	0.61
	Diospyros nigra (J.F.Gmel.) Perrier	Black sapote/sawo hitam	0.61	0.33	0.42	0.46
Muntingiaceae	*Muntingia calabura* L.	Calabur tree/kersen	1.06	0.70	1.13	0.95
Fabaceae	*Cynometra cauliflora* L.	Nam nam	0	0	0.04	0.01
Flacourtiaceae	*Flacourtia inermis* Roxb.	Batoko plum/lobi-lobi	0.69	0.56	0.23	0.52
	Flacourtia rukam Zoll. & Moritzi	Rukem	0.61	0.59	0.11	0.47
Clusiaceae	*Garcinia dulcis* (Roxb.) Kurz	Yellow mangosteen/mundu	0.44	0.65	0.57	0.55
	Garcinia forbesii King.	Mundar, manggis merah, kandis	0.18	0.12	0.09	0.14
	Garcinia sp.	White mangosteen/manggis putih	0.53	0.74	0.64	0.63
Meliaceae	*Sandoricum koetjape* (Burm.f.) Merr.	Santol/kecapi, sentul	1.00	1.69	0.53	1.11
Moraceae	*Artocarpus elasticus* Reinw. ex Blume	Benda, terap	0.10	0.15	0.08	0.11
	Morus alba L.	Mulberry/murbei	0	0.01	0	0.01
Myrtaceae	*Syzygium cumini* (L.) Skeels	Java plum/jamblang	0.94	1.10	0.38	0.84
	Syzygium polycephalum (Miq.) Merr. & Perry.	Gowok, kupa	0.61	0.80	0.34	0.60
Phyllanthaceae	*Antidesma bunius* L.) Spreng.	Bignay/buni	1.14	0.95	0.26	0.83
	Baccaurea motleyana Müll.Arg.	Rambai	0.19	0.18	0.17	0.18
	Baccaurea racemosa (Reinw.) Muell. Arg	Menteng, kepundung	0.94	1.27	0.38	0.90
	Phyllanthus acidus (L.) Skeells	Star berry/ceremai	1.50	1.51	1.40	1.48
Primulaceae	*Ardisia elliptica* Thunb.	Shoe-button/buni keraton, lampeni	0	0.01	0.02	0.60
Rhamnaceae	*Ziziphus jujuba* Mill.	Chinese dates/jujube	0.22	0.24	0.08	0.19
	Ziziphus mauritiana Lam.	Indian jujube/bidara	1.47	1.22	0.75	1.18
Rosaceae	*Prunus avium* L.	Sweet cherry/ceri burung	0.01	0.03	0	0.02
	Pyrus communis L.	Pear/pear	0.01	0.04	0	0.02
Rubiaceae	*Morinda citrifolia* L.	Moringa/mengkudu, pace	1.94	2.19	1.40	1.88
Rutaceae	*Aegle marmelos* (L.) Corr	Bael/maja legi	1.00	0.89	0.68	0.87
	Limonia acidissima L.	Wood apple/kawista	0.19	0.04	0.06	0.10
Sapindaceae	*Nepellium mutabile* Blume	Kapulasan	0.25	0.18	0.06	0.17
Sapotaceae	*Chrysophyllum cainito* L.	Star apple/kenitu, sawo manila	0.22	0.10	0.09	0.15
	Manilkara kauki (L.) Dubar	Sawo kecik	0.89	0.77	1.70	1.07
	Mimusops elengi Linn.	Spanish cerry/tanjung	0.72	0.59	0.45	0.60
	Pouteria campechiana Baehni	Canistel/alkesa, campolay	0.01	0	0	0.01

Note: Bog: Bogor, Jak: Jakarta, Yog: Yogyakarta

Eight CF were only desired by respondents in one or two cities (Table 6). The list of CF with the highest CSI value was mango (8.00), rambutan (7.25), rose apple (6.92), orange (6.69), papaya (6.61), starfruit (6.59), guava (6.52), avocado (6.09), sapodilla (6.00), and longan (5.98). Here, four climbing fruit species i.e., watermelon, melon, passion fruit, and grapes included in the important commercial species in Bogor, although CSI values were low (0.03 to 0.14).

From 38 UF, 8 species were exclusively desired by respondents in one or two cities, i.e., shoe-button, *pinang*, *nam nam*, mulberry, cactus, canistel, cherry, and pear (Table 7). CSI value of UF ranged from 0.01 to 1.88, indicating low importance from a cultural perspective in all study sites. List of UF with the highest CSI value were moringa (1.88), *ceremai* (1.48), mango plum (1.27), *bidara* (1.18), *kecapi* (1.11), *sawo kecik* (1.07), *calabur* (0.95), *menteng* (0.90), *maja* (0.87), java plum (0.84), and *kepel* (0.84).

Discussion

The present study showed that the knowledge of respondents to FS was affected by their profile especially previous and present exposure to FS (Figure 3E-3I). The role of respondent background on ornamental plant preference has been noted by Ruwaida et al. (2022).

Prior exposure to FS increased respondents' ability to name species, e.g., exposure during childhood in case Jakarta and Yogyakarta (Figure 3F), and frequency as a domestic tourist (Figure 3G). Recent exposure also determined the ability especially mobility mode (Figure 3I) and frequency of visiting city parks (Figure 3J).

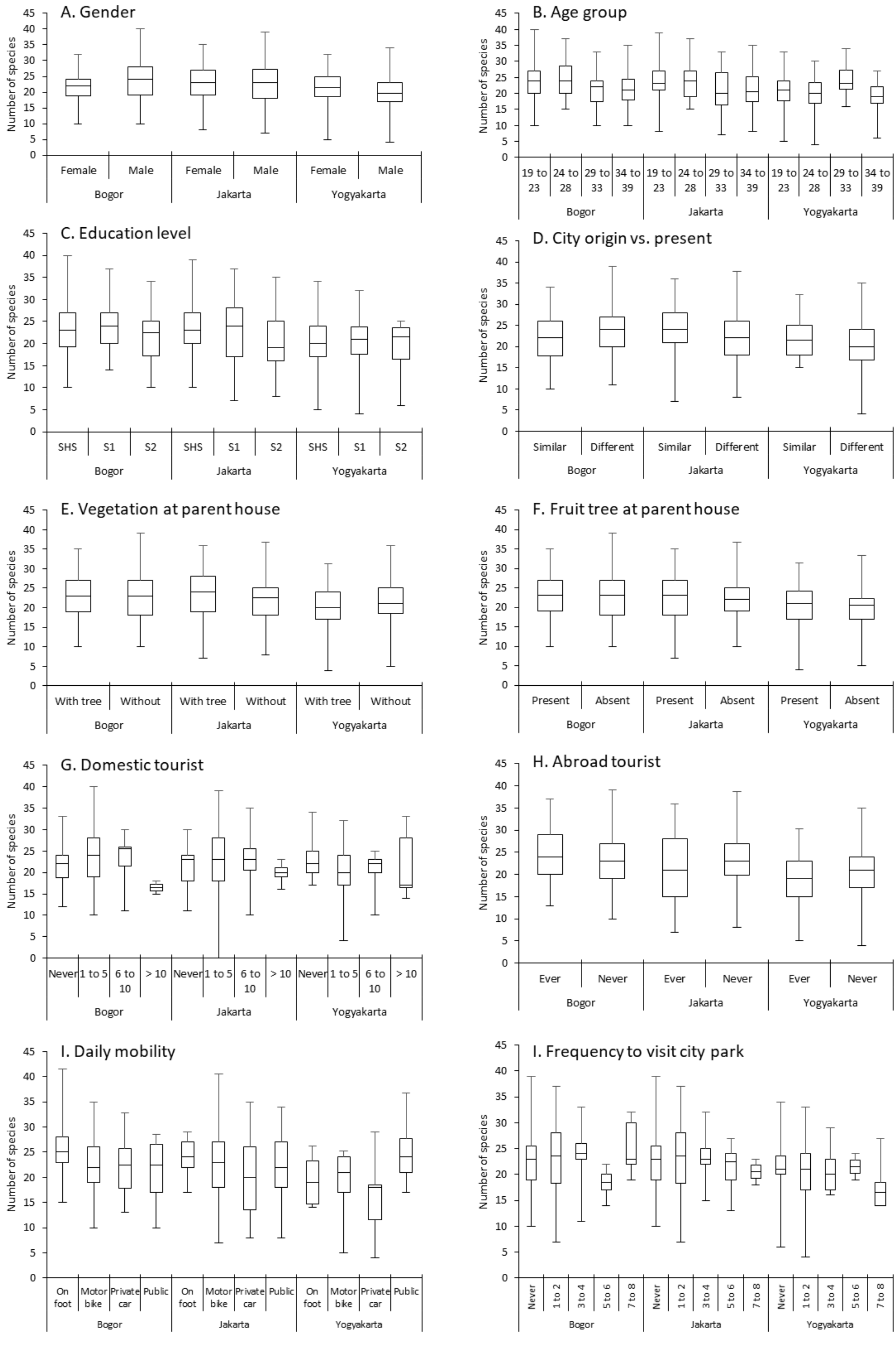

Figure 3. The number of retrieved fruit species based on respondent's profile. Bar ± SD

The higher number of FS desired by respondents in Bogor and Jakarta is presumably due to frequent exposure to nearby conservation sites such as the Bogor Botanical Gardens, Cibodas Botanical Gardens, Cilangkap collection orchard-Jakarta, Taman Mini, and Mekarsari Park. Biodiversity parks are tourist interests near Bogor and Jakarta (Hakim 2017; Rosiyanti and Susilowati 2017), while in Yogyakarta village scene is a popular interest (Marsono 2019). More than 81.3% of respondents frequently went as domestic tourists (Table 2).

The motive for selecting FS was food security, followed by ecology, economy, aesthetics, and health (Table 5). They argued that some residents faced insecure food due to limited income and land assets. However, Table 1 shows the food security index for all cities >74, indicating a secure level by BKP (2018). According to Irwan and Sarwadi (2015), most urban households maintain yards with an extent of less than 50 m^2. Respondents showed economic motive to FS as the source of income through selling fruits and cutting timber. The willingness to utilize city greenery as a timber source was noted by Hassan and Isaac (2018) in Lokoja-Nigeria. It means that respondents expected a multipurpose fruit tree species. Thus, urban planners and policymakers are challenged to optimize space and vegetation composition to support services (Song et al. 2020), comply with local limitations, biological complexity, social and economic aspects (Araújo et al. 2021; Judice et al. 2021), and also pressure from environmental stress and improper utilization by citizen (Lüttge and Buckeridge 2020).

In the context of the biodiversity scenario, analysis using species richness and Shannon-Wiener's index resolved better results than in the Simpson (Table 4). Moreover, CSI analysis could be used to select species for a particular city. CSI value across cities was 1.99±0.25, but CSI in Jakarta was higher than the other cities, i.e., 2.30. It is suggested to add more variables and to separate CSI analysis for CF and UF.

Selecting FS based on residents' motives and biodiversity scenarios from the perspective of the smart environment concept should be used with precaution. *First*, it is notable that respondents' ability to mitigate risk was diverse. According to Sæbø et al. (2003), urban trees must fulfill the following criteria: disease resistance, phenotypic plasticity, social factors, adaptive (to restrictive soil and space, pollution, strong wind, drought), and resistance limbs to breakage. On the other hand, respondents who focused on the direct risk of FS were notable (Table 3). Most respondents were concerned about FS planted along the roadside or road-median. Indeed, roadside and road-median in Indonesian cities are generally narrow. In Medan City, for example, Purwasih et al. (2013) measured the width of the green lane and the median road ranges from 1.0-4.5 m while the road width is 20-33 m. *Second*, combining diverse FS stimulates complicated management including maintenance costs and agronomic. In Europe, the establishment cost of trees in protected nature is €8-12 per ha (Morar and Peterlicean 2012) while a tree establishment in a city/street lane needs €200-1500 (Pauleit et al. 2002). The cost might increase in poor sites, frequent utility trenching, and vandalism. Vogt et al. (2015) identified cost components of a roadside tree: direct costs (provisioning, planting, pruning, watering, and maintaining), infrastructure interference, externality-related costs (allergies to pollen, leaf/debris cleanup), and opportunity costs (lost parking space, bike lanes).

People in Yogyakarta, Jakarta, and Bogor feel the need to green the city using diverse fruit species with various expectations. Although the evaluation of species biodiversity in the present study was carried out using a simple concept, the finding could be a model for urban greenery planning in Indonesian cities. It is recognized that each city has a unique feature. However, the case studies conducted in Bogor, Jakarta, and Yogyakarta, to some extent, elucidate the general trend of city communities in Indonesia. During the survey, most respondents expressed an understanding of the smart city concept. In the future, it is interesting to study the sustainability aspect of city-based fruit species conservation.

From the three cities, the study resumed 79 fruit species as desirable vegetations in the city. The adoption of these species will strengthen community benefit from city environmental services judging from the respondent's motive. It also incorporates cities as conservation sites because a city on average will maintain 34-40 commercial and 32-36 underutilized fruit species. In the future, it is important to incorporate citizen preferences on city greenery establishment for better impact on environmental service, especially food security and biodiversity.

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