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Assessing the suitability of tree species for urban green space in a tropical university campus in Surakarta, Indonesia

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Abstract. *Yulia IT, Permatasari DP, Igustita, Berlin GE, Safira RN, Sugiyarto, Nazar IA, Himawan W, Sunarto, Pradhan P, Setyawan AD. 2023. Assessing the suitability of tree species for urban green space in a tropical university campus in Surakarta, Indonesia. Biodiversitas 24: 1713-1723.* The presence of tree vegetation plays an important role in urban ecosystem. It provides various ecological and sociocultural functions from comforting micro-climates to beautification of the landscape. The central campus of Universitas Sebelas Maret (UNS) in Kentingan, Surakarta City, Central Java, Indonesia, has various tree species that grow well and become a constituent part of the campus area. This central campus environment has been considered one of the urban forests for city of Surakarta. This study aimed to determine the tree diversity occurring in the campus area of Universitas Sebelas Maret and to assess the suitability of the tree species based on silviculture, management and aesthetic aspects. Data collection was conducted by field observations at four stations: east, west, north, and south. Across the stations, the name of the tree species with minimum diameter breast height of 10 cm, the size of the tree's circumference, the coordinates of the location of the tree, and tree's morphological characteristics were documented. Each tree was then assessed for suitability for urban green space by scoring based on several silviculture, management and aesthetic criteria indicators. The results found 106 tree species in the studied area. Among them, 69 species (65%) had high suitability level, while 34 other species (32%) and 3 species (3%) were in the medium and low category, respectively. Some species with the highest score of 45 were *kayu putih* (*Melaleuca leucadendra* (L.) L), *mimba (Azadirachta indica* A.Juss.) and *nyamplung* (*Calophyllum inophyllum* L.), while the lowest score of 28 was *kamboja (Plumeria acuminata* W.T.Aiton). Species with high score are therefore recommended to be used in urban green space in the university area, and vice versa. The findings of this study suggest that vegetation suitability planning can be carried out to ensure the sustainability and balance of ecological functions of urban green space.

Keywords: Suitability assessment, tree, Universitas Sebelas Maret, vegetation

INTRODUCTION

The urban ecosystem is an ecosystem in urban space in which biotic, abiotic, and sociocultural components interact and influence each other. It is characterized by a high degree of heterogeneity in the form and extent of space, culture and economic activity, and are, to some extent, connected to natural and semi-natural spaces such as forests, wetlands, parks and other green spaces within built environment (Tan et al. 2020). Green Open Spaces (GOS) in urban settings is important for the ecosystem to become safe, resilient and sustainable (Calderón-Argelich et al. 2021). In addition, urban ecosystems provide various environmental services which affect human well-being and health in cities (McPhearson et al. 2015). In particular, the green space's vegetation is beneficial to maintaining air quality (Barwise and Kumar 2020), providing cultural and recreational values, reducing noise and mitigating flood risk by regulating rainwater flow (Drillet et al. 2020). It is also crucial in providing a habitat for various organisms (Ortí et al. 2022).

An urban forest is a form of green space in urban settings dominated by tree vegetation. It serves as a shelter for lower canopy vegetation and fauna habitat and benefits humans by providing comfort and aesthetic values (Ulfa et al. 2022). Vegetation is one important component of an ecosystem that always experiences growth and development. Each vegetation type has certain characteristics which are affected by the biotic and abiotic factors of the ecosystem. Thus, each vegetation has specific suitability requirements for a particular ecosystem. When planning for planting vegetation as a green space in an urban area, it is important to consider the suitability of each vegetation type and plant species since incorrect application of vegetation can have impacts on space for human mobilities, inhibit the growth of the vegetation, reduce beauty, and even harm humans (Semeraro et al. 2021).

A study by Gülçin (2020) found that floristic species richness in urban forests affects the occurrence of urban birds and tree canopies of the vegetation have cooling effects on the microclimate conditions. Therefore, assessment and monitoring of vegetation, especially trees, are essential when implementing green space in urban areas (Lee et al. 2023). Some considerations when choosing vegetation type and plant species in urban forests include high tolerance to harsh environmental conditions in urban area, resistant to diseases, not infectious, and long-lived.

One example of urban forest can be found in the area of the Universitas Sebelas Maret (UNS), Surakarta, Central Java, Indonesia. The university's central campus, which is located in Kentingan, Surakarta, has a large area with various types of vegetation that grow well and become a constituent part of the campus area. This central campus environment has been considered one of the urban forests in Surakarta City (Triyadi 2015) and is much needed by the city (Sukarta et al. 2013). The vegetation consists of trees, herbs, shrubs, and grasses (Yalcinalp and Meral 2017), naturally or intentionally planted to grow in the campus environment.

Research by Ariyanto et al. (2016) found 61 tree species in the Universitas Sebelas Maret area. Nonetheless, the study did not explain whether such tree species are suitable according to universities' biotic, abiotic, and sociocultural aspects in urban areas. Therefore, this study aimed to determine the tree diversity in the Kentingan campus of Universitas Sebelas Maret, Surakarta and assess the tree species' suitability based on silviculture, management and aesthetic aspects. It is hoped that this research can guide the management and policy for selecting and maintaining vegetation at Universitas Sebelas Maret.

MATERIALS AND METHODS

Study period and area

This research was conducted on 7-10 December 2022 at Kentingan Campus, Universitas Sebelas Maret, Surakarta City, Central Java Province, Indonesia (Figure 1). Data collection was carried out from 8 am to 4 pm when the sun was still shining whereas it easier to identify plant species directly. Geographically, it is located at coordinates of 7°33′39″S 110°51′24″E. The study location has an altitude of 157 meters above sea level, with air temperatures ranging from 28.5-30ºC and humidity around 70-75% (Nisa 2018).

The studied area was divided into four stations in accordance with the cardinal directions to facilitate the data retrieval process. The North Station, with an area of 160,000 m² covered the areas of the Faculty of Teaching and Education (FKIP), sport center (GOR), and Javanology Center. The East Station, with an area 80,000 m², covered the areas of the Faculty of Mathematics and Natural Sciences, Faculty of Medicines and the library. The South Station, with an area 110,000 m², covered the areas of Faculty of Agriculture (FP), SPMB, PPLH, UNS Arboretum, and UNS Lake. The West Station, with an area 220,000 m², included Faculty of Engineering (FT), Faculty of Linguistic Sciences (FIB), Language Service Unit (UPT Bahasa), and Faculty of Art and Design (FSRD).

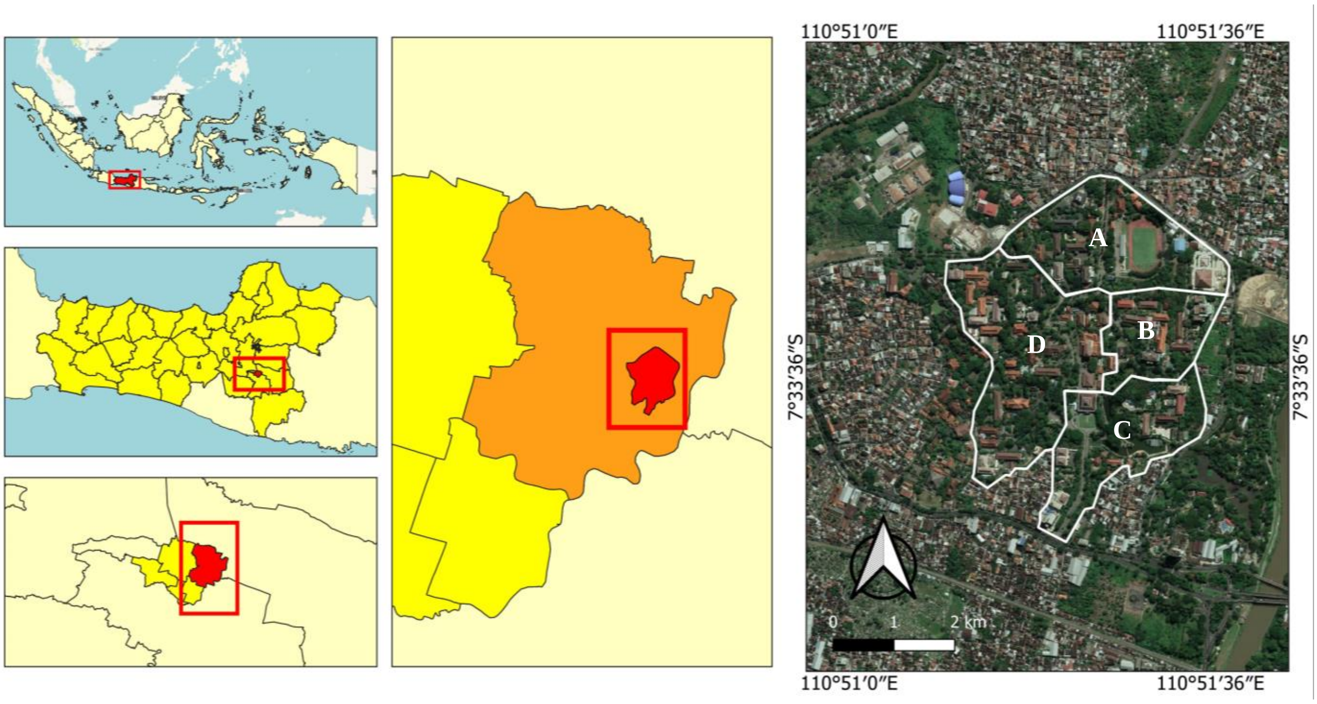

Figure 1. Map of the study area at Kentingan Campus, Universitas Sebelas Maret, Surakarta City, Central Java Province, Indonesia. A. North station, B. East station, C. South station, D. West station

Data collection

This research used survey method to identify the species of occurring in the studied location (Oktefebriyani 2021). The tools and materials used in the research were stationary and tally sheets to record data, cameras to carry out documentation, phi bands to determine growth stage categories and GPS to determine coordinate points

Primary data of the name of the tree species, the size of the tree's circumference, the coordinates of the location of the tree, and tree documentation were collected. The trees recorded in the study sites were those with a Diameter at Breast Height (DBH) of>10 cm and a height of>1.5 m (Afrianto et al. 2021). Data were collected at each station and measurement of tree trunk's diameter was conducted to determine that the individual belongs to the tree category. While the secondary data was collected through literature reviews from the CABI website and other scientific journals for scoring the suitability assessment based on silvicultural, management and aesthetic requirements (Afrianto et al. 2021)

Taxonomical identification was carried out directly and indirectly. For species unable to identify, their morphological characteristics were documented. Identification is carried out using the open-access web such as gbif.org, powo.science.kew.org, and Saw (2019).

Data analysis

The data obtained from the survey were analysed to assess the suitability of tree species for green open space based on silvicultural, management and aesthetic requirements according to Afrianto et al. (2021). The assessment components, criteria and scoring were detailed in Tables 1, 2 and 3. The suitability analysis of the constituent vegetation was carried out using tabulation, scoring, and a descriptive analysis approach (Syaifuddin et al. 2022). The suitability level is determined by calculating or scoring all vegetation found and is divided into three categories (Afrianto et al. 2021), namely (i) High (score 39-46); (ii) Medium (score 31-38); and (iii) Low (score 23-30).

Table 1. Silvicultural criteria of tree species in the urban forest according to Afrianto et al. (2021)

Component	Criteria	Score
Altitude	0-500 masl	2
	>500 masl	1
Rainfall	1200-2000 mm/year	2
	<1200 dan >2000 mm/year	1
Tolerant of nutrient-poor soils	Tolerant	2
	Intolerant	1
Ability to restore soil fertility	Able to fertilize the soil	2
	Not able to fertilize the soil	1
Resistant to pests and diseases	Resistant	2
	Not resistant	1
The nature of retaining leaves	Evergreen	2
	Deciduous	1
Resistance of main stems and branches to wind	Not easy to fall and break	2
	Easy to fall and break	1
The condition of the roots of the surrounding buildings	Tolerant	2
	Intolerant	1
Tolerance to sunlight	Tolerant	2
	Intolerant	1
Tolerance to high temperatures	Tolerant	2
	Intolerant	1
Tolerant of water shortage	Tolerant	2
	Intolerant	1

Table 2. Management criteria of tree species in the urban forest according to Afrianto et al. (2021)

Component	Criteria	Score
Easiness to plant	Easy	2
	Difficult	1
Easiness in maintenance	Easy and cheap	2
	Not easy and expensive	1
Easiness in protection	Easy	2
	Difficult	1
Canopy function as shade	Good as a shade (thick and dense canopy)	2
	Not good as a shade (thin and light canopy)	1
Canopy function as windshield	Good as windshield (strong and tight canopy)	2
	Not good as windshield (the canopy is not weak and light)	1
Utilization	Easy	2
	Not easy	1
Ability in pollution reduction	High	2
	Low	1

Table 3. Aesthetic criteria of tree species in the urban forest according to Afrianto et al. (2021)

Component	Criteria	Score
Habitus (canopy, branching, leaves, and/or flowers)	Yes	2
	No	1
Function as a means of education	Yes	2
	No	1
Fruit size	Small	2
	Large	1
Poisonous/dangerous sap	Not produce toxic/dangerous sap	2
	Produce toxic/dangerous sap	1
Potential allergy from pollen	No allergic potential	2
	Allergic potential	1

RESULTS AND DISCUSSION

Biotic and abiotic conditions at Kentingan Campus, Universitas Sebelas Maret

Universitas Sebelas Maret is an educational institution located in an urban area adjacent to the urban center, government center, and socio-economic activities. Even though it is located in an urban area, Universitas Sebelas Maret has a green open space area in the form of urban forest which is recognized as the lung of Surakarta City and is ranked 7th in UI Green Metric World University Ranking 2022 (UNS 2022), a ranking on green campus and environmental sustainability initiated by Universitas Indonesia in 2010 (UI 2023). The green open space at Kentingan Campus, Universitas Sebelas Maret supports a high level of biodiversity including various plant types, groups and species ranging from shrubs, ornamental plants, fruit plants, medicinal plants, and plants with high carbon stock. The high floristic diversity in the university is due to the favorable environmental conditions with relatively fertile soil, thus supporting the growth of existing vegetation. Other factors that support high biodiversity levels are physical and ecological conditions such as temperature, air humidity and altitude. The area of Universitas Sebelas Maret has altitude of 155-158 masl with air temperature ranging from 28-30°C and air humidity of 71%-75%, meaning that the climate is optimal for vegetation growth (Nisa 2018). From the observation, the dominant plant species at the North and East Station is the *glodokan tiang* (*Polyalthia longifolia*), while at the South and West Station are *angsana* (*Pterocarpus indicus*) and mahoni (*Swietenia macrophylla*), respectively (Figure 2).

Diversity of tree species at Kentingan Campus, Universitas Sebelas Maret

In this study, 106 plant species were found across the four observation stations belonging to 39 families (Figure 3). Fabaceae was the family with the largest number of species with 15 species, followed by Arecaceae and Moraceae families each with 8 species, Malvaceae with 7 species, Annonaceae, Myrtaceae, Meliaceae, and Sapindaceae each with 5 species, Apocynaceae with 4 species, Bignoniaceae and Araucariaceae with three species, and Anacardiaceae, Casuarinaceae, Combretaceae, Cupressaceae, Ebenaceae, Lamiaceae, Lecyrhidaceae, Lythraceae, Poaceae, and Sapotaceae each with two species. The other 18 families had only one species.

Fabaceae is the third largest family of higher plants with around 19.000 species which are widely distributed throughout the world in many ecological conditions from deserts of high latitudes to seasonally dry and wet tropical forests of equatorial regions (Shavanov 2021). Fabaceae members have a better ability to grow on disturbed soils that often present unfavorable conditions for plant growth. They are recognized as plant groups for phytoremediation (Davin et al. 2020). The existence of the Fabaceae family in Universitas Sebelas Maret can play an important role in increasing soil fertility. One of the most important features of in Fabaceae plant group (legumes) is the presence of root nodules in which the nodule bacteria are able to supply the plant with nitrogen fixed from the air (Belova and Protasova 2021).

The South Station consisted of the largest number of species with 60 species, followed by the North Station with 59 species, the West Station with 56 species and the East Station with 44 species (Figure 4). Various reasons can cause the differences in the number of species among stations. One of them is the total area of each station, area designation, soil contour, environmental conditions, etc. As an educational institution, Universitas Sebelas Maret does not have an obligation to provide urban forests so that the allocation of areas is prioritized for educational purposes and supporting education so that the diversity of existing vegetation cannot be as large as the area designated as green open space. These two reasons are the explanation of the highest number of species found in the South and North stations, which had the largest extent of area. The Arboretrum in Universitas Sebelas Maret is intended to accommodate vegetation collections. In addition to the size and designation of the site, environmental conditions such as temperature, light intensity, water availability, nutrient availability, and altitude can also affect biodiversity.

There were species that can be found at all stations including *Filicium decipiens* with the local name *kerai payung*, *P. indicus* with the local name *angsana*, *Acacia auriculiformis* with the local name *akasia*, *Delonix regia* with the local name *flamboyan*, *P. longifolia* with the local name *glodokan tiang*, *Pithecellobium dulce* with the local name *asam londo*, *Lagerstroemia speciosa* with the local name *bungur*, *Tectona grandis* with the local name *jati*, *S. macrophylla* with the local name *mahoni*, *Terminalia catappa* with the local name *ketapang*, *Plumeria acuminata* with the local name *kamboja*, and *Ficus benjamina*. with local name *beringin*. The occurrence of those tree species at the four stations is not because of the similarity of location conditions, good adaptability, or the availability of the required resources, but due to their use. Those species have use as shade plant or for aesthetic purposes. Plants such as *angsana* (*P. indicus*), *akasia* (*A. auriculiformis*), and *mahoni* (*S. mahagony*) have dense crowns and solid branches, making them very suitable as shade. Furthermore, among the shade plants, one plant does not function as a shade but for aesthetic purpose, namely *kamboja* (*P. acuminata*). Because of its function for aesthetic purposes, its existence is spread throughout all stations.

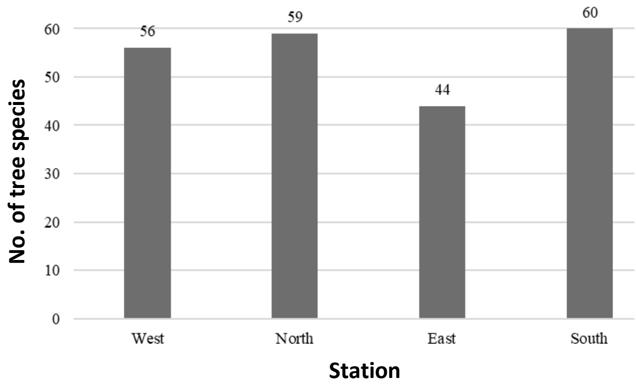

Figure 4. Number of species at each station in Kentingan Campus, Universitas Sebelas Maret, Surakarta, Indonesia

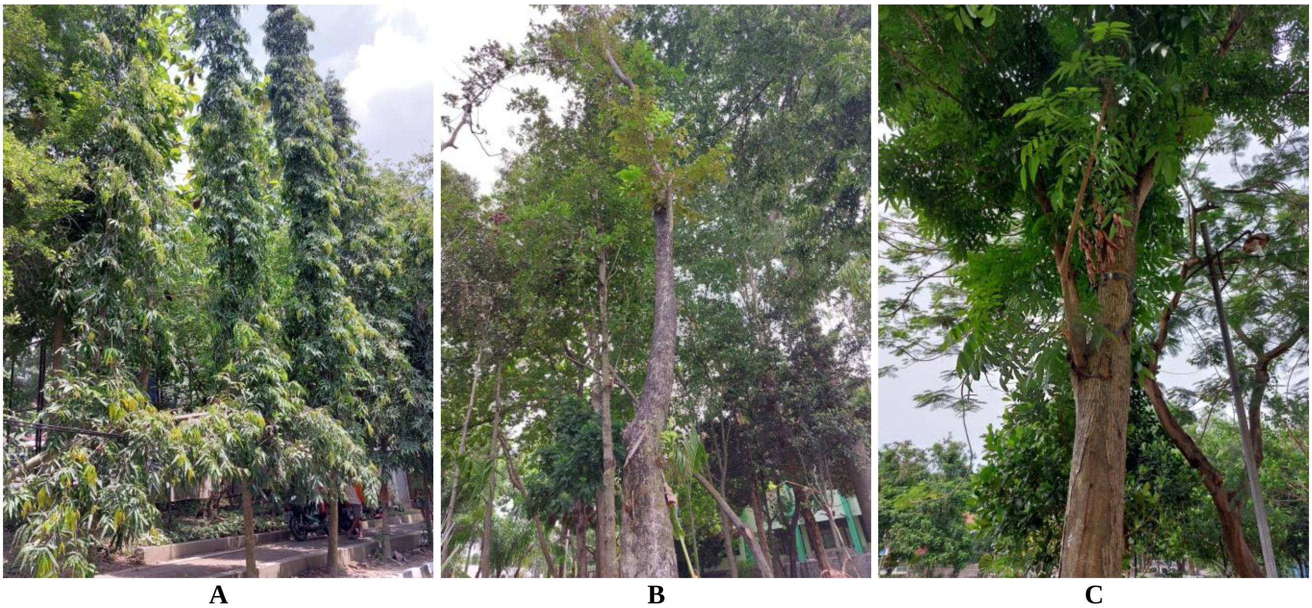

Figure 2. Dominant tree species: A. *Glodokan tiang* (*Polyalthia longifolia*), B. *Angsana* (*Pterocarpus indicus*), C. *Mahoni* (*Swietenia macrophylla*)

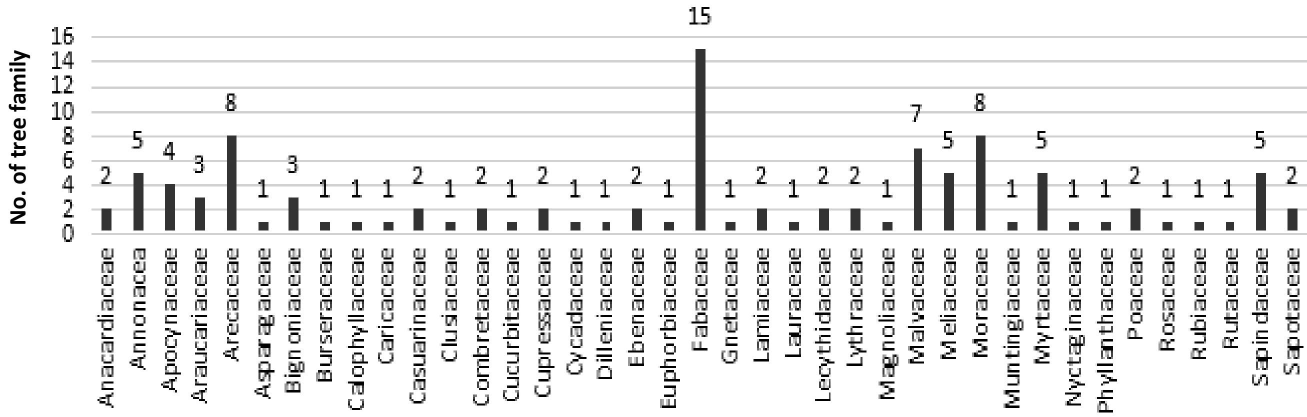

Figure 3. Number of species in each family in Universitas Sebelas Maret, Surakarta, Indonesia

Suitability assessment of tree species as the constituent of green open space

Trees have a significant role in all aspects, especially in ecological functions as a deterrent agent to environmental damage such as climate change. The existence and suitability of trees also have essential value in urban areas because they can function as part of urban ecosystems. The vegetation functions to lower temperatures, improve health, create landscape beauty, sustain the ecology, increase social relations and even facilitate learning process by student (Ruwaida et al. 2022). Land use suitability analysis is the process of determining the feasibility of a particular plot of land for certain uses according to certain requirements, preferences, or predictors of some activities (Huang et al. 2019). The suitability of tree planting in urban areas can make the site have the maximum function of trees according to its designation, for example, mitigating environmental problems in urban areas. Semeraro et al. (2021) states that vegetation can increase biodiversity in urban areas so the suitability of choosing tree vegetation in an urban forest can make trees have good growth so they can function optimally. The existence of trees and suitability value at environmental Universitas Sebelas Maret can be seen in Table 4.

Table 4. Suitability assessment of composing tree species in green open space in Universitas Sebelas Maret, Surakarta, Indonesia

Family	Species	Local name	Station				Score	Level
			North	East	South	West		
Anacardiaceae	*Mangifera indica* L.	*Mangga*	+	+	+	+	41	H
	Dracontomelon dao (Blanco) Merr. & Rolfe	*Sangkuang*	-	-	-	+	35	M
Annonaceae	*Annona squamosa* L.	*Srikaya*	-	-	-	+	33	M
	Polyalthia longifolia (Sonn.) Thwaites	*Glodokan tiang*	+	+	+	+	39	H
	Annona muricata L.	*Sirsak*	-	+	-	-	31	M
	Stelechocarpus burahol (Blume) Hook.f. & Thomson	*Kepel*	+	+	-	-	40	H
	Cananga odorata (Lam.) Hook.f. & Thomson	*Kenanga*	+	-	-	-	39	H
Apocynaceae	*Plumeria acuminata* W.T.Aiton	*Kamboja*	+	+	+	+	28	L
	Kopsia arborea Blume	*Kopsia*	+	-	-	-	35	M
	Alstonia scholaris (L.) R. Br	*Pulai*	+	-	-	+	39	M
	Cascabela thevetia (L.) Lippold	*Yellow oleander*	+	-	-	-	38	M
	Agathis kinabaluensis de Laub.	*Damar*	-	-	+	-	40	H
Araucariaceae	*Araucaria luxurians* (Brongn. & Gris) de Laub.	*Konifer*	-	-	+	-	36	M
	Araucaria heterophylla (Salisb.) Franco	*Cemara norfolk*	+	-	-	+	42	H
Arecaceae	*Wodyetia bifurcata* A.K.Irvine	*Palem ekor tupai*	+	+	-	+	34	M
	Cyrtostachys renda Blume	*Palem merah*	+	+	+	-	40	H
	Livistona saribus (Lour.) Merr. ex A. Chev	*Palem kipas*	-	+	-	-	42	H
	Caryota mitis Lour.	*Palem*	-	-	+	-	43	H
	Elaeis guineensis Jacq.	*Kelapa sawit*	-	-	+	+	34	M
	Cocos nucifera L.	*Kelapa*	-	-	+	-	36	M
	Adonidia merrillii (Becc.) Becc.	*Palem putri*	+	-	-	-	42	H
	Archontophoenix alexandrae (F.Muell.) H.Wendl. & Drude	*Alexandra palm*	-	-	-	+	38	M
Asparagaceae	*Cordyline fruticosa* (L.) A.Chev.	*Hanjuang*	+	-	-	+	35	M
Bignoniaceae	*Spathodea campanulata* Beauverd	*Kecrutan*	-	+	+	-	43	H
	Handroanthus chrysotrichus (Mart. ex DC.) Mattos	*Tabebuya*	+	-	+	+	42	H
	Kigelia africana (Lam.) Benth.	*Pohon sosis*	+	-	+	+	41	H
Burseraceae	*Canarium ovatum* Engl.	*Kenari*	+	-	-	+	43	H
Calophyllaceae	*Calophyllum inophyllum* L.	*Nyamplung*	+	+	-	-	45	H
Caricaceae	*Carica papaya* L.	*Papaya*	-	+	+	+	34	M
Casuarinaceae	*Casuarina equisetifolia* L.	*Cemara laut*	+	-	-	+	44	H
Clusiaceae	*Casuarina junghuhniana* Miq.	*Cemara gunung*	-	-	+	-	44	H
	Garcinia xanthochymus Hook.fil. ex J.Anderson	*Asam kandis*	+	-	-	-	40	H
Combretaceae	*Terminalia catappa* L.	*Ketapang*	+	+	+	+	39	H
	Terminalia mantaly Capuron	*Ketapang kencana*	-	+	-	-	37	M
Cucurbitaceae	*Cucurbita moschata* (Duchesne) Duchesne ex Poir.	*Labu*	+	-	-	-	33	M
Cupressaceae	*Platycladus orientalis* (L.) Franco	*Cemara kipas*	-	-	-	+	34	M
Cycadaceae	*Thuja orientalis* L.	*Bintami*	-	-	-	+	36	M
	Cycas rumphii Miq.	*Pakis haji*	+	+	-	-	37	M
Dilleniaceae	*Dillenia suffruticosa* (Griff.) Martelli	*Simpoh air*	+	-	-	-	37	M
Ebenaceae	*Diospyros blancoi* A.DC.	*Bisbul*	-	-	+	+	43	H
Euphorbiaceae	*Hura crepitans* L.	*Roda*	+	-	-	+	43	H
Fabaceae	*Leucaena leucocephala* (Lam.) de Wit	*Petai cina*	+	+	-	-	41	H
	Pterocarpus indicus Willd.	*Angsana*	+	+	+	+	42	H
	Acacia auriculiformis A. Cunn. ex Benth.	*Akasia*	+	+	+	+	40	H
	Delonix regia (Bojer ex Hook.) Raf.	*Flamboyan*	+	+	+	+	40	H
	Pithecellobium dulce (Roxb.) Benth.	*Asam londo*	+	+	+	+	41	H
	Adenanthera pavonina L.	*Saga*			+		40	H
	Bauhinia purpurea L.	*Pohon kupu-kupu*	-	+	+	+	36	M

	Samanea saman (Jacq.) Merr.	*Trembesi*	+	+	-	+	40	H
	Tamarindus indica L.	*Asam jawa*	-	+	-	-	44	H
	Sesbania grandiflora (L.) Poir.	*Bangturi*	-	-	+	-	35	M
	Senna siamea (Lam.) H.S.Irwin & Barneby	*Johar*	+	-	+	-	41	H
	Cynometra cauliflora L.	*Namnam*	+	-	+	-	41	H
	Inocarpus fagifer (Parkinson ex F.A.Zorn) Fosberg	*Gayam*	+	-	-	-	43	H
	Dalbergia latifolia Roxb.	*Sonokeling*	-	-	-	+	41	H
	Millettia pinnata (L.) Panigrahi	*Malapari*	+	-	+	+	43	H
Gnetaceae	*Gnetum gnemon* L.	*Melinjo*	-	-	-	+	41	H
Lamiaceae	*Tectona grandis* L.f.	*Jati*	+	+	+	+	41	H
Lauraceae	*Gmelina arborea* Roxb. ex Sm.	*Jati putih*	+	+	-	+	44	H
	Persea americana Mill.	*Alpukat*	+	-	-	-	37	M
Lecythidaceae	*Barringtonia asiatica* (L.) Kurz	*Keben*	-	+	+	+	39	H
Lythraaece	*Couroupita guianensis* Aubl.	*Sala*	-	-	+	-	39	H
	Lagerstroemia speciosa (L.) Pers	*Bungur*	+	+	+	+	38	M
	Lagerstroemia indica L.	*Bungur kecil*	-	-	-	+	34	M
Magnoliaceae	*Magnolia alba* (DC.) Figlar	*Kantil*	+	-	-	-	39	H
Malvaceae	*Sterculia foetida* L.	*Kepuh*	+	+	+	-	41	H
Meliaceae	*Theobroma cacao* L.	*Kakao*	-	+	-	-	36	M
	Ceiba pentandra (L). Gaertn.	*Kapuk randu*	-	+	-	-	40	H
	Durio zibethinus Murray	*Durian*	-	+	+	+	37	M
	Bombax ceiba L.	*Randu*	+	-	-	-	37	M
	Hibiscus rosa sinensis L.	*Bunga sepatu*	-	-	-	+	38	M
	Hibiscus tiliaceus L.	*Waru*	-	-	-	+	41	H
	Melia azedarach L.	*Mindi*	-	+	-	-	41	H
	Swietenia macrophylla G.King	*Mahoni*	+	+	+	+	43	H
	Azadirachta indica A.Juss.	*Mimba*	+	-	-	+	45	H
	Khaya anthotheca (Welw.) C.DC.	*Mahoni afrika*	-	-	+	-	40	H
	Toona sinensis (A.Juss.) M.Roem.	*Surian*	-	-	+	-	36	M
Moraceae	*Artocarpus heterophyllus* Lam.	*Nangka*	+	+	+	-	33	M
	Ficus benjamina L.	*Beringin*	+	+	+	+	40	H
	Artocarpus altilis (Parkinson) Fosberg	*Sukun*	+	+	+		38	M
	Ficus benjamina varigata L.	*Beringin daun putih*	-	+	-	-	41	H
	Ficus lyrata Warb.	*Ketapang biola*	-	+	-	-	41	H
	Ficus religiosa L.	*Bodhi*	-	-	+	+	40	H
	Ficus elastica Roxb.	*Karet kebo*	+	-	+	-	39	H
	Artocarpus integer (Thunb.) Merr.	*Cempedak*	-	-	+	-	33	M
Muntingiaceae	*Muntingia calabura* L.	*Talo/keresen*	+	-	+	-	44	H
Myrtaceae	*Rhodomyrtus tomentosa* (Aiton) Hassk.	*Kemunting*	-	-	+	-	38	M
	Psidium guajava L.	*Jambu biji*	-	-	+	-	39	H
	Syzygium aqueum (Burm.fil.) Alston	*Jambu air*	-	-	+	+	40	H
	Syzygium paniculatum Gertn.	*Pucuk merah*	+	-	-	+	38	M
	Melaleuca leucadendra (L.) L.	*Kayu putih*	+	-	-	-	45	H
Nyctaginaceae	*Bougainvillea glabra* Choisy	*Bougenville*	+	+	-	-	29	L
Phyllanthaceae	*Bridelia tomentosa* Blume	*Kenidai*	-	-	-	+	40	H
Poaceae	*Bambusa vulgaris* Schrad. ex J.C.Wendl.	*Bambu ampel*	+	-	-	+	42	H
Rosaceae	*Podocarpus neriifolius* D.Don	*Kiputri*	-	-	+	-	42	H
	Mussaenda philippica A.Rich.	*Nusa indah*	-	+	-	-	42	H
Rubiaceae	*Morinda citrifolia* L.	*Mengkudu*	-	-	+	+	36	M
Rutaceae	*Citrus maxima* (Burm.) Merr.	*Jeruk*	-	-	+	-	33	M
	Filicium decipiens (Wight & Arn.) Thwaites	*Kerai payung*	+	+	+	+	43	H
Sapindaceae	*Pometia pinnata* J.R.Forst. & G.Forst	*Matoa*	-	+	-	+	43	H
	Nephelium lappaceum L.	*Rambutan*	-	-	+	-	41	H
	Schleichera oleosa (Lour.) Oken	*Kesambi*	-	-	+	+	41	H
	Dimocarpus longan Lour.	*Kelengkeng*	-	-	+	+	39	H
Sapotaceae	*Manilkara kauki* (L.) Dubard	*Sawo kecik*	+	+	+	-	30	L
	Mimusops elengi L.	*Tanjung*	-	+	-	-	44	H
	Manilkara zapota (L.) P.Royen	*Sawo*	+	-	+	+	37	M

Note: Suitability level (i) High (H), (ii) Medium (M), dan (iii) Low (L); Presence (+) and absence (-). Reference sources: CABI Digital Library (2023), Arumugam et al. (2021), Assogba et al. (2019), Damaiyani et al. (2018), Dange et al. (2022), Ginting and Mirwandhono (2021), Husna et al. (2022), Karlinasari et al. (2021), Kumar et al. (2019), Larekeng et al. (2019), Megawati et al. (2020), Mohammedi et al. (2020), Mondal et al. (2021), Mong and Razili (2022), Nasution and Hadiati (2019), Neolaka et al. (2021), Okello et al. (2017), Oktefebriyani et al. (2019), Onoyima (2021), Quispetera et al. (2021), Pitri (2021), Rahardi et al. (2020), Raihandhany (2022), Rajendran et al. (2021), Rakhman et al. (2022), Saw (2019), Soemarwoto and Iskandar (2021), Subki et al. (2020), Susilowati et al. (2021), Wardatun et al. (2020), Wemheuer et al. (2020), Yulistyarini and Hadiah (2022), Zerkout et al. (2021)

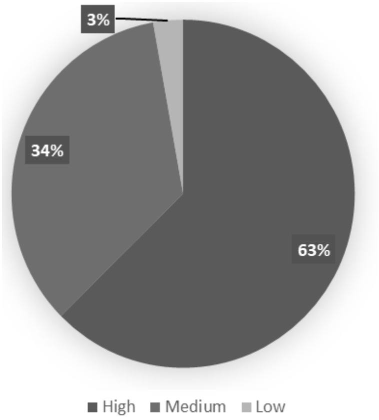

Figure 5. The composition of suitability level of tree species as the constituent of urban forest in Universitas Sebelas Maret, Surakarta, Indonesia

The results of the vegetation suitability assessment revealed that 63% (67 species) were in the high category, 34% (37 species) were in the medium category and 3% (3 species) were in the low category (Figure 5). From these results, we can see that the tree vegetation occurred in the Universitas Sebelas Maret area is dominantly suitable for green open space in the form of urban forest and urban park. In this case, the vegetation that had the highest rating with a score of 45 was *kayu putih* (*Melaleuca leucadendra*), *mimba* (*Azadirachta indica*), and *nyamplung* (*Calophyllum inophyllum*). In contrast, the vegetation with the lowest rating with a score of 28 was kamboja (*P. acuminata*).

In the vegetation suitability assessment, there are three aspects considered: silviculture, management, and aesthetics. In the silvicultural aspect, urban vegetation must tolerate high temperatures, water shortages, and intense sunlight. According to Afrianto et al. (2021), the existence of tree vegetation types in urban areas must meet silvicultural requirements such as being in a place suitable for growth, being able to grow in soils that have low nutrient content, being able to restore soil fertility, being tolerant to pests and diseases, having evergreen leaves, having solid stems and branches, so they don't fall and break easily, and having tree roots that do not damage roads or buildings around the tree's habitat.

Management activities in urban parks and green spaces can positively influence the vegetation composition and diversity, with associated benefits for wildlife and people. However, the presence of high plant biodiversity is sometimes negatively related to human preferences due to a desire for open space (Talal and Santelmann 2020). In addition, the selected vegetation must also have a thick, dense, and strong canopy to be used as shade and wind protection (Oktefebriyani et al. 2019). In this case, the selected vegetation must also be highly able to reduce environmental pollution to be used as greenery in urban areas. In the aesthetic aspect, there are five components assessed: habitus, function as a means of education, fruit size, toxic sap, and pollen allergy potential. To determine a plant's viability, it is important to consider the specific environment of each proposed planting site and the suitability of vegetation types in urban areas must have environmental conditions align with the objectives (Barwise and Kumar 2020).

Silvicultural criteria

Silviculture criteria represents the requirements of a tree species for specific habitat with biotic and abiotic elements that affect the tree. The silvicultural requirements would determine the optimal habitat conditions for the growth and development of trees. Assessment of these requirements is based on altitude, rainfall, resistance to pests and diseases, species that have evergreen leaves, trees with trunks and branches that are resistant to wind, rooting conditions that do not damage the surrounding buildings, and tolerance to high temperatures, intense solar radiation and limited water. According to the analysis results, the lowest score on silvicultural criteria was 12 and the highest was 22. Of the 106 trees identified, *kayu putih* (*M. leucadendra*) had the highest score in silvicultural criteria. This tree grows and develops quickly in various substrates and environments. This tree can also survive and adapt even though its habitat has poor drainage, poor soil with high salt content; therefore, this tree can also be referred to as a pioneer tree. Because of its ease of growth, this tree is needed in urban environments because it is adaptable to urban conditions. However, only a few individuals of this species occurred in the Universitas Sebelas Maret area, specifically in the North Station. It is necessary to carry out additional planting for this tree since its potential. Conversely, species with the lowest score in silvicultural aspect was *kamboja* tree (*P. acuminata*) and bougainvillea (*Bougainvillea glabra*). These two species have minimal tolerance for nutrient-poor soil, sunlight, high temperatures, and a lack of water, so its ability to grow in urban areas will be difficult.

Management criteria

The management criteria represent the ease of management and maintenance practices of trees for urban forest and green open space. According to Afrianto et al. (2021), tree species that are suitable to be developed in urban areas are those that are easy to plant, have easy and inexpensive maintenance, can be secured quickly, have a good crown function (thick and tight), have a function as wind protection (strong and steady), and can reduce pollution. Such considerations are important as urban areas are the predominant habitat for the majority of the world's population, thus urban ecosystem needs significant attention in the planning, design and management (Tan et al. 2020).

Based on the results of analysis, the largest and lowest score in term of management criteria were 14 and 8, respectively. Tree species that had the highest consisted of 22 trees, including the *kerai payung* (*F. decipiens*), *angsana* (*P. indicus*), *ketapang* (*T. catappa)*, *nyamplung* (*C. inophyllum*), *beringin* (*F. benjamina*), *matoa* (*Pometia pinnata*), *asam jawa* (*Tamarindus indica*), tanjung (*Mimusops elengi*), *trembesi* (*Samanea saman*), *beringin* *daun putih* (*F. benjamina* var. *varigata*), *jati putih* (*Gmelina arborea*), *kecrutan* (*Spathodea campanulata*), *talok* (*Muntingia calabura*), *tabebuia* (*Handroanthus chrysotrichus*), *pohon sosis* (*Kigelia africana*), *gayam* (*Inocarpus fagifer*), *kenari* (*Canarium ovatum*), *cemara norfolk* (*Araucaria heterophylla*), *mimba* (*A. indica*), *cemara laut* (*Casuarina equisetifolia*), *bisbul* (*Diospyros blancoi*) and *cemara gunung* (*Casuarina junghuhniana*). These trees have also been planted in many urban areas to reduce pollution and absorb carbon emissions (Momongan et al. 2017; Ragula and Chandra 2020). Conversely, there were two trees with a low score of management criteria, namely *sawo kecik* (*Manilkara kauki*) and *sirsak* (*Annona muricata*). Both trees are fruit trees with special planting and maintenance techniques so they can grow and produce fruit (e Silva et al. 2020; Santosa et al. 2021). Both trees also have a structure in the form of small trees which are not perfectly suitable for shade and wind protection.

In urban areas, vegetations do not only increase aesthetic value but also reduces the urban heat and creates comfort microclimate (Yang et al. 2019). The existence of plants that have the function of reducing environmental temperature is related their canopy structure which functions as shade. Trees which are good as shade will have thick and thight crown, and vice versa thin and light canopy will not optimal for shade. Tree species that have good canopy structure as shade were *kerai payung* (*F. decipiens*), *keben* (*Barringtonia asiatica*), and Ketapang (*T. catappa*). Meanwhile, tree species that were considered not good for shade were *palem putri* (*Adonidia merrillii*), *nam-nam* (*Cynometra cauliflora*) and *kamboja* (*P. acuminata*).

Aesthetic criteria

Aesthetic criteria represents suitability of tree species in green open space for the purposes of aesthetic suitability, education, comfort, and public health. Mu et al. (2022) stated that trees planted on open spaces such as roads and highways are essential for pedestrians as they provide a unique ecosystem service in the form as beautification. The indicators under the aesthetic criteria show the extrinsic or auxiliary function regarding the appropriateness of tree species in urban areas, including habitus or tree form (e.g. crown form, branching, leaves, or flowers) which act as aesthetic and beauty enhancers; the dimension and shape of the fruit which do not harm humans; not produce toxic sap and pollen that has the potential to be allergic or harmful to humans. The results of analysis showed 34 species had the for the highest score in term of aesthetic criteria with a total score of 10 and six species had the lowest score of 7. The trees with the highest score got a score of 2 in each indicator, suggesting that the presence of such trees in the city area is appropriate.

Some of the species with the highest score included *kupu-kupu* tree (*Bauhinia purpurea*), *asam jawa* (*T. indica*), and *cemara norfolk* (*A. heterophylla*). These species have pleasant crown form, branches, leaves, and beautiful flowers, making them have high aesthetic selling point. Furthermore, the small size of the fruit creates a distinct aesthetic impression and the absence of toxic sap as well as potential allergic pollen allergies are friendly to humans. Human allergic reactions can be caused by many environmental substances. Human allergic reactions to airborne pollen are 20% more likely in urban areas than in rural areas, due in part to species homogeneity and interactions between pollen dispersal and existing air pollutant (Barwise and Kumar 2020). One of the tree species that has the potential to cause pollen allergy is *kencrutan* (*S. campanulata*). Damaiyani et al. (2018) explain that the most relevant allergen molecules in *kencrutan* (*S. campanulata*) belong to polygalacturonase, pectaselyase, and beta-expansin. Several species, including *bungur* (*L. speciosa*), and *glodokan tiang* (*P. longifolia*) have a less appealing canopy shape, no educational function, and relatively large fruit size, which can harm humans if it falls.

The management of vegetation in green open space in urban area

The quality of urban areas is largely affected by the presence of vegetation. The abundance of vegetation indicates that a metropolitan area has implemented a good environmental management since there is a balance between the built components and biodiversity elements. However, in the early stages of urban area management, it is necessary to have a high level of biodiversity and to examine the function and designation of each type of vegetation in the urban area. The results of the scoring analysis using three criteria, namely silviculture, management, and aesthetics suggest that there are several tree species suitable for green open space in urban areas, i.e. those with a total score of 45, namely *mimba* (*A. indica*), *nyamplung* (*C. inophyllum*), and *kayu putih* (*M. leucadendra*) Such trees have a predominance of a value of 2 on each indicator across the criteria. Wherever possible, the selected species should have economic value or produces fruit that can be consumed directly; the canopy is quite shady and compact but not too dark; it is resistant to pests and diseases and it is long-lived.

There was a tree species not suitable for urban green space which is indicated by a low total score of 28, namely *P. acuminata*. Most of the indicators of this species got a score of 1 due to several unfavourable characteristics, such as not tolerant to nutrient-poor soils, pests and diseases, solar irradiation, high temperatures, limited water, and the vulnerability of stems to falling or breaking. In term of management criteria, only indicators of easy planting and utilization got the score of 2, while the other indicators got low score due to the shape of crown which do not serve as shade and wind protector, having low pollution reduction capabilities, and difficult to secure and maintain. In term of aesthetic criteria, *P. acuminata* qualified only on indicators of habitus and pollen that were not potentially allergenic. However, on the indicators of low educational function, the size of the fruit and the toxic sap is still classified as unsuitable for urban green space.

In conclusion, there were 106 species of tree found in the Universitas Sebelas Maret area. The majority of such species (69 species) are highly suitable for urban green space with total score of 39-46, while 34 species are in the medium category, and 3 species are in the low category.

The species under the low category is generally because they do not have a function as a shade as they do not have a strong and dense canopy, and they have minimal ability to absorb pollutants, have a toxic sap, and easily collapse or break. The results of this study can be used as a reference in selecting tree species to be planted in the campus area to suit conditions and functions. In addition, this suitability can make the vegetation function according to its designation and be more effective in overcoming environmental problems in the campus area.

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