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Vegetation composition and structure in the Green Open Space (GOS) Area of Surakarta City, Central Java, Indonesia

Komposisi vegetasi dan struktur pada Ruang Terbuka Hijau (RTH) di Surakarta, Jawa Tengah, Indonesia

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Abstrak. *Hanum Z, Armadhan WS, Kusuma D, Perwitasari IG, Almadani AR, Safira RN, Setyawan AD. 2024. Vegetation composition and structure in the Green Open Space (GOS) Area of Surakarta City, Central Java, Indonesia. Pros Sem Nas Masy Biodiv Indon 10: 72-88.* Green Open Space (GOS) is an area with unrestricted use and is a place to live for various plant species that grow naturally or are carried by humans. Surakarta city, Central Java, Indonesia, has many GOSs of various types, including city parks, urban forests, fields, river bank riparian, roadside green lines, etc. Vegetation is an important element in GOS because it is the source of the availability of ecosystem services in GOS. This study aims to analyze the vegetation's composition and structure to determine the type and structure of the vegetation in the GOS of Surakarta City. Data were collected in five GOS areas spread across five sub-districts in Surakarta, including the Bengawan Solo Urban Forest Park, Vastenburg Fort Park, Sriwedari Stadium Park, Manahan Stadium City Forest, and Pringgolayan Field. The research method used was a transect plots method to determine the composition and structure of vegetation in the GOS of Surakarta City. Based on the results of observations found 6,095 individual plants consisting of 181 species belonging to 55 families. The Bengawan Solo Urban Forest has the highest Shannon-Wiener Diversity Index (H'= 3.30) for the Evenness species index (E= 0.78) values of the five GOSs studied. While the highest Margalef species richness index (Dmg= 11.91)) value is at Sriwedari Stadium Park. That shows Sriwedari Stadium Park has the largest number of plant individuals compared to other research locations, and Bengawan Urban Forest has the highest number of species and a few dominant species.

Keywords: Important value index, green open space, vegetation structure

Abstrak. *Hanum Z, Armadhan WS, Kusuma D, Perwitasari IG, Almadani AR, Safira RN, Setyawan AD. 2024. Komposisi vegetasi dan struktur pada Ruang Terbuka Hijau (RTH) di Surakarta, Jawa Tengah, Indonesia. Pros Sem Nas Masy Biodiv Indon 10: 72-88.* Ruang Terbuka Hijau (RTH) merupakan suatu kawasan yang pemanfaatannya tidak terbatas dan merupakan tempat hidup berbagai jenis tumbuhan yang tumbuh secara alami maupun dibawa oleh manusia. Kota Surakarta, Jawa Tengah, Indonesia, mempunyai berbagai jenis RTH, antara lain taman kota, hutan kota, lapangan, kawasan riparian sungai, serta jalur hijau tepi jalan. Vegetasi merupakan elemen penting untuk RTH karena merupakan penyusun utama dalam jasa lingkungan dari RTH. Penelitian ini bertujuan untuk menganalisis komposisi jenis dan struktur vegetasi serta di RTH Kota Surakarta. Pengambilan data dilakukan di lima kawasan RTH yang tersebar di lima kecamatan di Surakarta, antara lain Urban Forest Bengawan Solo, Taman Benteng Vastenburg, Taman Stadion Sriwedari, Hutan Kota Stadion Manahan, dan Lapangan Pringgolayan. Metode penelitian yang digunakan adalah metode plot transek untuk mengetahui komposisi dan struktur vegetasi di RTH Kota Surakarta. Berdasarkan hasil pengamatan ditemukan 6.095 individu tumbuhan yang terdiri dari 181 spesies yang termasuk dalam 55 famili. Urban Forest Bengawan Solo memiliki Indeks Keanekaragaman Shannon-Wiener (H'= 3.30) tertinggi untuk nilai indeks Kemerataan spesies (E= 0.78) dari kelima RTH yang diteliti. Sedangkan nilai indeks kekayaan jenis Margalef (Dmg= 11,91)) tertinggi terdapat pada Taman Stadion Sriwedari. Hal ini menunjukkan Taman Stadion Sriwedari memiliki jumlah individu tumbuhan terbanyak dibandingkan lokasi penelitian lainnya, dan Hutan Kota Bengawan memiliki jumlah jenis terbanyak dan sedikit jenis dominan.

Kata kunci: Indeks nilai penting, ruang terbuka hijau, struktur vegetasi

INTRODUCTION

Green Open Space (GOS) is where various plants grow with open uses, generally planted with various species of plants that can play a role in providing environmental services such as regulation, support, provision, and socio-cultural services in urban areas. In urban landscapes, vegetation cover, structure, and composition determine habitat quality and become a provider of urban biodiversity. Biodiversity is not only in organisms above the ground but also diversity in organisms underground because the diversity of underground life is an important factor in ecosystems and the sustainability of above-ground life, as well as in maintaining landscape sustainability (Bach et al. 2020).

Surakarta City, Indonesia, has five districts: Jebres, Banjarsari, Pasar Kliwon, Serengan, and Laweyan. The GOS is spread across five districts in Surakarta, and it is estimated that the total area of GOS in Surakarta City is 3,729,714 m^2 (Kusumastuti et al. 2020). In Indonesia, the provision of GOS is regulated in UU No. 26 of 2007 about Spatial Planning. This law states that every city is required to provide a GOS of 30% of the city area. However, the city of Surakarta has not been able to provide 30% of GOS where it is known that the area of public GOS in Surakarta is only around 8.47%, while the area of other open green spaces is around 21% (Ramadhanty 2021). The Surakarta City Government (2022) states that GOS Surakarta has several functions: ecological, economic, educational, and recreational. GOS consists of several types of land, such as city parks, urban forests, open fields, stadiums, etc.

Green Open Space (GOS) in an urban area is important because Green Open Space has many ecosystem services that benefit the surrounding environment. These ecosystem services include regulatory, provider, supporting, and cultural services (Desman and Edial 2022). The existence of ecosystem services in the green open space area is related to the condition of the vegetation. Therefore, the structure and composition of vegetation affect the number of ecosystem services provided by green open space for the surrounding environment (Widanirmala et al. 2021).

Vegetation structure can be defined as the spatial organization of the individuals that make up a stand, vegetation type, or plant association. The main elements of the structure are stratification and closure growth forms (Agil 2021). Vegetation structure is a component of the vegetation itself as well as with other organisms, so it is a system that lives and grows and is dynamic (Selfiany et al. 2018). The structure of a vegetation stand consists of two directions, namely the horizontal and the vertical. The horizontal stand structure describes the distribution or distribution of individuals within the habitat species. The horizontal stand structure can also affect light absorption (Forrester et al. 2018). While the vertical stand structure is expressed as the distribution of the number of trees in different crown layers, the vertical structure is stratification into several different layers. The vertical structure is a functional relationship between height class and individual density (Rotinsulu et al. 2021). The density of these trees decreases as the tree height class increases if the density is accompanied by an increase in the growth rate, which indicates that certain individuals do not all grow to the next growth level (Istomo and Hartarto 2019). In a broader sense, the structure of vegetation also includes distribution patterns, types, and the number of species (Destaranti et al. 2017).

Research related to vegetation in Surakarta City shows that the land cover composition is dominated by low density (Sari et al. 2019), while Rini et al. (2018) shows that land use is as GOS is only 6.6% and it dominated by the trade sector. However, data collection regarding the species that compose GOS vegetation composition and structure analysis has never been carried out. Therefore, this study aimed to determine vegetation's structure and composition and indicators of plant species diversity. Those indicators include the Shannon-Wiener species diversity index (H'), Evenness species index (E), and Margalef species richness index (Dmg) in Green Open Spaces in Surakarta, Central Java, Indonesia.

MATERIAL AND METHODS

Study area

This research was conducted in several parks representing each district in Surakarta City, Central Java, Indonesia, on 12-13 December 2022. The geographical location of Surakarta City is at coordinates 110 45` 15” - 110 45` 35” E and 70` 36” - 70` 56” S, bordering Karanganyar District and Boyolali District to the north, Karanganyar District and Sukoharjo District to the east and west, and Sukoharjo District in the south (Figure 1). In addition, there are five research locations dividing into five line transect (Figure 2), including the (i) Bengawan Solo Urban Forest Park, which is located on the banks of the Bengawan Solo river, Jebres, Surakarta; (ii) Vastenburg Fort, which is located in Kedung Lumbu Village, Pasar Kliwon Sub-district, Surakarta City; (iii) Sriwedari Stadium Park which is located on Jalan Brigjen Slamet Riyadi No. 275, Laweyan Sub-district, Surakarta City; (iv) Manahan Stadium City Forest which is located in Banjarsari Sub-district, Surakarta City, and finally; (v) Pringgolayan Field which is located in Tipes, Serengan Sub-district, Surakarta City (Table 1).

Procedures

Tools and materials

The tools and materials used in this study included tally sheets, stationery, clip boards, roll meters, tape meters, raffia rope with variations in the size of 2, 5, 10, and 20 m, and tools (GPS) for determining coordinate locations.

Table 1. Name of observation location and coordinate point

Location	Coordinate Point
Sriwedari Stadium Park	7°34’3.925”S -110°48’46.629” E
Bengawan Urban Forest	7°34’18.65”S-110°50’50.76”E
Manahan Stadium Urban Forest	7°33’19.280” S - 110°48’23.520” E
Benteng Vastenburg Park	7°34’18.258” S - 110°49’50.693” E
Pringgolayan Field	7°34’55.750” S - 110°48’37.047” E

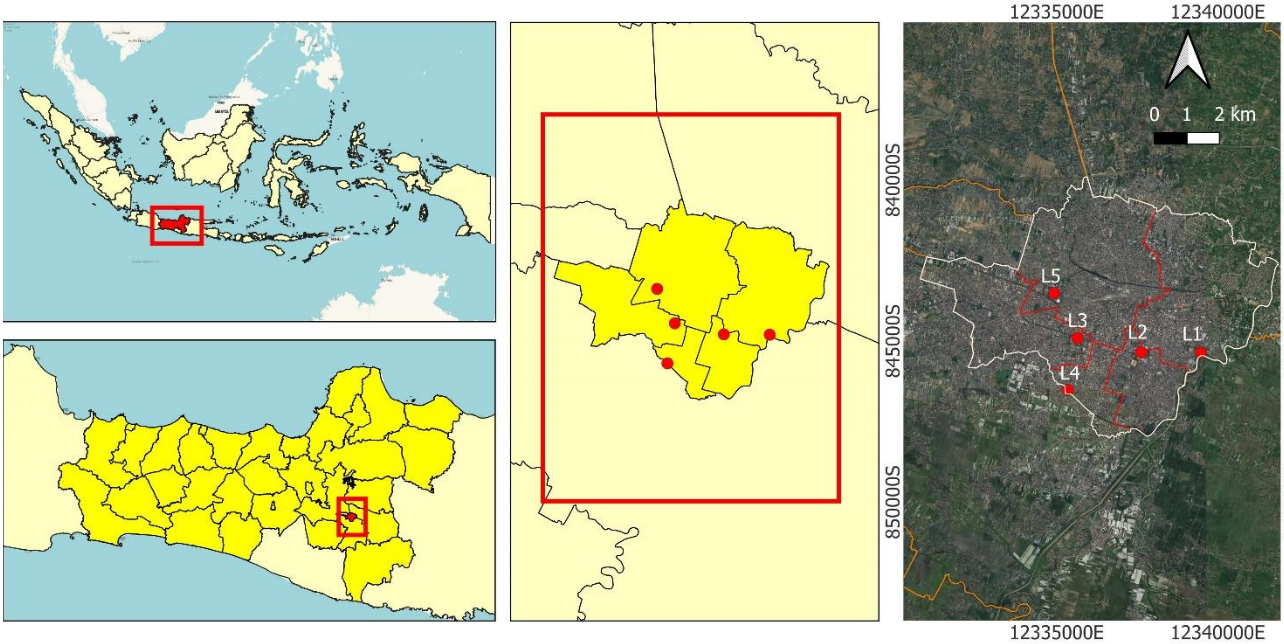

Figure 1. Map of the City Park Study area in Surakarta, Central Java, Indonesia. L1=Bengawan Urban Forest; L2=Benteng Vastenburg Park; L3=Sriwedari Stadium Park; L4=Pringgolayan Field; L5=Manahan Urban Forest

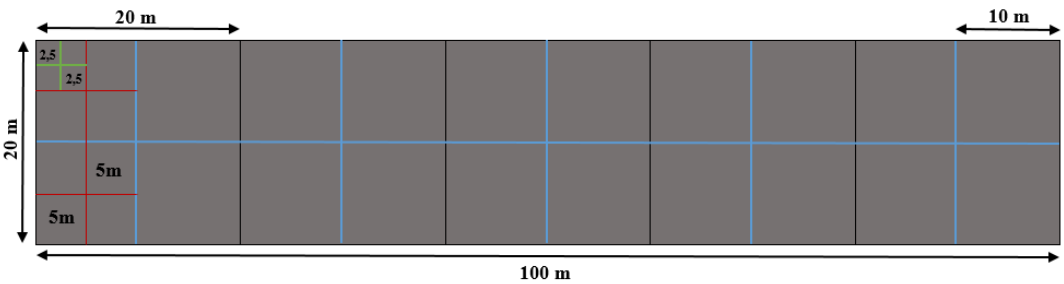

Figure 2. Transect design image

Sampling method

The data used are primary data through data collection by observing species in the field. In addition, observations were made to watch the original conditions of the research location directly to support data acquisition. The data collection method used was the transect plot method. Quadrant plots and transects were made at each location of 5 pieces 100 m long. The number and size of plots are determined based on physical conditions, including ecosystem type and the number of species or diversity of plants found at the study site. The quadrants plot consists of several sizes depending on the type and stage of the vegetation being measured (Nasrudin 2020).

Transect design

The transect design in the form of a quadratic plot was made at the data location, where each transect has five 100m long plots divided into 20×20 m plots (Figure 2). The number and size of the plots themselves are based on physical conditions, including the type of ecosystem and the number of increments of plant species or diversity found at the study site. Quadratic plots consist of various plot sizes with adjustments to the conditions of the measured vegetation stage. Plots for trees used size 20×20 m, poles 10×20 m, saplings 5×5 m, and shrubs 2×2 m (Gunawan et al. 2011). The habitus classification is based on its growth class or habitus: seedling (sprouts, 1.5 m high; sapling 1.5 m high and less than 10 cm in diameter); pole (sapling 10-20 cm in diameter; and tree more than 20 cm in diameter) (Doudi et al. 2020). Following, make five plots for the tree category measuring 20×20 m for each station. Plots for poles (10×10 m), saplings (5×5 m), and herbs (2×2 m) were made in plots measuring 20×20 m by placing the plots by purposive sampling (Sari et al. 2020) so that the total consists of 187 plots belong to 25 tree plots, 40 pole plots, 51 sapling plots and 71 shrub plots with a total plot area of 15,559 m².

Data collections

Data collection was carried out after observations in the field, including species name, number of species, height, and diameter. After observations, several obtained species were observed and recorded on the available tally sheets. In addition, it provided coordinates and documentation of research locations. The data collection was carried out based on habitus classification. Habitus type determination is done by measuring the diameter of breast height (dbh) and measuring the diameter of plants (trees/poles) at breast height (Latupapua et al. 2022). The classification of herbs and saplings is determined based on the plant's height, where the saplings are >1.5 m high. In addition to measuring the diameter, height measurements were also carried out for the collection of vegetation structure data according to the specified category, namely plant height referred to Fachrul (2007), where <1 m (A); 1-2 m (W); 2-5 m (C); 5-10 m (D); >10 m (E).

Identification

Taxonomic identification was carried out directly and indirectly (Yulia et al. 2023). First, direct identification was carried out on-site at the research location after observing the parts of the plant, assisted by open-access webs such as gbif.org, powo.science.kew.org, and Guan (2019). Meanwhile, indirect identification is carried out if there are difficulties in determining the type of plant on-site based on some parts of the plant itself. In addition, indirect identification is carried out by taking photos of several parts of the plant, which will then be discussed and the species determined later.

Data analysis

Important value index

Calculations are made using the Important Value Index (IVI) obtained from the data by performing calculations based on the formula: INP =KR+DR+FR, where KR is Relative Density, DR is Relative Dominance, and FR is Relative Frequency, which is calculated using the formula below:

a. Density (K) : $\frac{Total\ Individual}{Plot\ area}$

b. Relative Density (KR): $\frac{Density\ of\ a\ species}{Density\ of\ all\ species} \times 100$

c. Frequency (F) : $\frac{Total\ of\ plot\ for\ a\ species}{Total\ plot}$

d. Relative Frequency (FR): $\frac{Frequency\ of\ a\ species}{Frequency\ of\ all\ species} \times 100\%$

e. Domination (D) : $\frac{The\ basic\ area\ of\ a\ type}{Plot\ area}$

f. Relative Domination (DR): $\frac{Dominance\ of\ a\ species}{Dominate\ the\ whole\ plot} \times 100\%$

g. Important Value Index (IVI) : KR+FR+DR

Shannon-Wiener diversity index (Shannon and Wiener 1963)

H' =*Pi* In *Pi*

Where :
H'=Shannon-Wiener diversity index
ni = number of individuals of the i-th species
n = Total number of individuals of all species
pi = ni/n

Shannon-Wiener Diversity Index was defined as follows :
H'<1 = Low diversity
1<H'<3 = Moderate diversity
H'>3 = High diversity

Evenness index (Ludwig and Reynolds 1988)

$$E=\frac{H'}{Ln\ S}$$

Where :
E = evenness Index
H' = Shannon Wiener Diversity Index
S = Simpson's Diversity Index

Evenness Index was defined as follows :
E<0,31 : Low evenness level
0,31>E>1 : Medium evenness level
E>1 : High evenness level

Margalef species richness index (Magurran 1988)

$$D\ mg = \frac{(S-1)}{In\ N}$$

Where :
D = Margalef Species Richness Index
S = number of species in the habitat
N = Total number of individuals of all species in the habitat

The criteria for the Margalef Species Wealth Index value are as follows:
D<2.5 = Low level of species richness
2.5>D>4 = Moderate species richness level
D>4 = High level of species richness

RESULTS AND DISCUSSION

Location description

The selection of research sites was carried out in several parks representing each region of Surakarta. The geographical location of Surakarta City is at 110 45` 15" - 110 45` 35" East Longitude and 70` 36" - 70` 56" South Latitude, north of Karanganyar District and Boyolali District, East and west of Sukoharjo District, and Sukoharjo District in the south. Surakarta is located in the lowlands at an altitude of 105 m above sea level and 95 m above sea level in the city center. It has a tropical climate with average temperatures ranging from 24.8 to 28.1°C and average air humidity of 66-84% (Yuliani et al. 2021). There are five sampling locations, including the Urban Forest Bengawan on the banks of the Bengawan Solo River, Jebres in Surakarta. This park has various variants of trees and also herbaceous plants, which are grouped in one place on the banks of the Bengawan Solo River. Fort Vastenburg in Kedung Lumbu Village, Pasar Kliwon Sub-district, Surakarta City, to be precise, is the back garden of the Fort, which has a large area of land with trees and shrubs. Then, Sriwedari Stadium Park on Jalan Brigjen Slamet Riyadi No. 275, Laweyan, Surakarta City, in front of the Sriwedari Stadium Park, there are several trees and herbaceous plants planted along the edge of the sidewalk. Then, there is the Manahan Stadium City Forest in Banjarsari Sub-district, Surakarta City, and the Pringgolayan Field in Tipes, Serengan Sub-district, Surakarta City (Figure 3).

Horizontal vegetation structure

Horizontal vegetation is a type of component that describes the location of an individual to another individual. Vegetation analysis is a method for studying plant composition or composition concerning flora and plant community structure. The elements of vegetation structure are crown growth, stratification, and closure. For vegetation analysis, data on type, diameter, and height are needed to determine the Index of values that make up the forest biome (Yuningsih et al. 2018). Vegetation structure is limited by three components: the vertical arrangement of plant species or vegetation stratification, the horizontal arrangement of plant species or the distribution of individual vegetation, and the abundance of each existing plant species. Vegetation structure consists of individuals that form and stands in space. Vegetation structure is based on vegetation parameters such as Dominance, density, Frequency, important value index, and species diversity (Handayani and Ahmed 2022).

The horizontal vegetation structure found in five GOSs in five Sub-districts in Surakarta City was observed in this study. Based on the observations, 6,095 individual plants comprised 181 species belonging to 55 families. Of the five locations used as research sites, the Pringgolayan Field was the GOS with the highest number of individual plants, namely 1,617 individuals. This area is dominated by herbaceous plants that grow around the field, such as *Oplismenus hirtellus*, *Eleusine indica* and *Tridax procumbens*. Then, for the GOS area with the least number of individuals, there is Manahan Stadium Urban Forest with 464 individuals. This GOS also has the lowest number of species and families compared to other research locations. It is known (Table 2) that the number of species and families in the Manahan Stadium City Forest are 45 species and 24 families, respectively. Meanwhile, most plant species were found in Sriwedari Park, with 86 species and 39 families. That can be a marker of the high level of plant diversity here.

Table 2. Total Individuals, Species, and Families in each GOS

Location	Individu	Species	Family
L1	1516	69	32
L2	1237	64	30
L3	1261	86	39
L4	1617	65	35
L5	464	45	24

Note:
L1 : Urban Forest Bengawan (Sub-district Jebres)
L2 : Benteng Vastenburg Park (Sub-district Pasar Kliwon)
L3 : Sriwedari Stadium Park ((Sub-district Laweyan)
L4 : Pringgolayan Field (Sub-district Serengan)
L5 : Manahan Urban Forest (Sub-district Banjarsari)

Figure 3. Panoramic view of each research station: A. Bengawan Urban Forest (L1); B. Benteng Vastenburg Park (L2); C. Sriwedari Stadium Park (L3); D. Pringgolayan Field (L4); E. Manahan Urban Forest (L5)

Based on the observations and data analysis results, there were 86 species in 39 families in Sriwedari Park. Sriwedari Park is a historical public space that developed from the concept of an old city park. Since it was built, Sriwedari Park has made great strides in utilizing space, including constructing the Grand Mosque as part of the government's revitalization efforts. Various activities at Sriwedari Park have developed into entertainment sites that promote surrounding functionality. Sriwedari Park is a cultural heritage area because it has several buildings with cultural heritage status. Therefore, Sriwedari Park is a public and green space for community relaxation (Swastika et al. 2022).

Based on the observations and data analysis results, there were 69 species in 32 families at Bengawan Urban Forest. Plant site on Bengawan Urban Forest are the right solution for flood control frequently occurring in these locations. In addition, the planting tree on location that exists in the Green Open Space (GOS) especially Bengawan Urban Forest that has different vegetation type than other research stations. Bengawan Urban Forest is the only riparian zone of all research stations that is a terestrial zone. The riparian zone is located between terrestrial and aquatic ecosystems (Prasetyo and Hayati 2020). Bengawan Urban Forest is a riparian area surounding the Bengawan River, Surakarta. The ecological functions of riparian vegetation include maintaining river water quality, habitat for wildlife, maintaining water temperature, controlling the growth of aquatic photosynthetic organisms, and stabilizing river banks (Siahaan 2004). The existence of vegetation in riparian areas is one of the way for protecting the environment, especially in urban areas which are prone to land conversion into settlements, which has the potential to eliminate the loss of ecological functions and services from riparian areas.

This vegetation type is considered suitable as a flood barrier because the roots are strong and have large stems. Some tree species, such as *Mangifera indica*, can be bioindicators of air pollution caused by motorized vehicles. Trees have a significant role in the green belt because they reduce air pollution and maintain global climate balance. The existence of trees functions as providing the main habitat function for growing space. Natural vegetation or plant communities are the right choices to deal with air pollution and avoid high levels of air pollution. These green plants can do that, so they must be replanted or reduce pollutants by converting CO_2 gas into O_2 through photosynthesis (Ainy et al. 2018). Therefore, the banks of the Bengawan Solo River in Surakarta City, which consists of the Pucang Sawit Village, are one of the potential areas that can be used as a conservation area. However, that area may only be used as a green open space or as the heart of the city by relocating residents who live in illegal settlements on government land along the Bengawan Solo River. In support of the vision of developing a green and sustainable Surakarta City, considering the potential on the banks of the Bengawan Solo River and the development of this potential, the construction of Green Open Spaces (GOS) is important and to encourage people to care about the environment (Widiati et al. 2020).

Based on observations and data analysis, there were 64 species in 30 families in Vastenburg. The Surakarta Fortress Area Plan in Vastenburg as a Green Open Space (GOS), namely the Surakarta Fortress Area plan in Vastenburg as a Green Open Space (GOS), has a total area of 39,257 m^2 and several physical components: playground area, skate park, outdoor fitness arena, nature reserves, fountains, administrative buildings, and public toilets. Banteng (Fort) Vastenburg has a quite strategic location in the central city of Surakarta and is in the vicinity of office and trade areas, so a green park is needed to function as the city's lungs. In addition, Vastenburg Fort also has high cultural value related to the history of cultural development in Surakarta, so this green open space will not only function as the city's lungs but also as a place that can facilitate cultural activities (Herlambang et al. 2019). Vastenburg Cultural Park is a cultural park with a recreation area that can accommodate all cultural activities in Surakarta so that its activities can support and develop these activities.

In this study, the vegetation structure was observed in five districts in Surakarta. Based on observations at Manahan Stadium Park, there are 45 species and 24 families each. Manahan Stadium Park has a small number of species because there are similar species and families. However, Manahan Stadium Park is full of plants that automatically add oxygen to breathe every day, so green open spaces and parks are very important for the people. Manahan Stadium stands firmly among the surrounding buildings filled with houses, schools, places of worship, and green fields

Therefore, the Manahan Stadium Park is used by the community for sports and other purposes (Rahayu et al. 2020). Sriwedari Park is a historical public space developed from ancient gardens, so Sriwedari Park has the highest species and many families that are widely used as green spaces and cultural heritage areas. Thus, Sriwedari Park is Surakarta's tourist and recreational destination (Aulia et al. 2020).

For the rest of the three other station, Bengawan Forest City Park has 69 species and 32 families, Banteng Vastenberg has 64 species and 30 families, and Pringolayan Field has 65 species and 35 families. Each of the three station has a different number of species and families. However, three station are used as green spaces. One of them is Pringolayan Field, which is a soccer field for local residents. The community Bengawan City Forest used to find fish and planted trees as a water reservoir during floods to create a community shelter around the river. While in the Vastenburg Fortress, the conversion of land into a city has resulted in a lush open space, besides a cultural heritage site and a tourist attraction, including culinary tourism.

Important Value Index (IVI)

The Important Value Index is a value that indicates the degree of Dominance of a species in a community. This value is obtained from the summation of relative Frequency, relative density, and relative Dominance for tree-level vegetation. So that the Frequency, density, and dominance value will influence the index value; the species with the highest important index value will have the highest number of individuals, and the density and Frequency are also high (Indriyani et al. 2017).

Based on the research results, at each sampling location, four species were obtained with the highest IVI values at the tree, sapling, pole, and herb levels. Four species of trees with the highest IVI (Table 3) values were obtained in each location for the tree level, namely *Samanea saman*. These species have the highest IVI value in the two sites, with 93% L1 and 39% for L2. They are followed by *Ficus benjamina* 33%, *Hibiscus tiliaceus* 57%, and *Pterocarpus indicus* 84%. These four species have an important role in ecology, especially in carbon sequestration. Such as *Samanea saman* plays a role in carbon sequestration, so they are often used as species for reforestation (Hapsari and Safaruddin 2022). This species also has the potential to revegetate former mining sites (Subli et al. 2019). Apart from acting as a carbon sink, *Ficus benjamina* leaves also capture dust pollutants (Reyes et al. 2012). Those processed by secreting latex and leaf morphological characteristics that can bind dust and metal particles on or in leaf tissue and have been widely planted along highways (Shah et al. 2017). *Pterocarpus indicus* Willd is a species quite tolerant to dry conditions and could act as a shade and absorb Pb in the atmosphere (Syahbudin et al. 2018). The high IVI value at the tree level is due to several reasons such as the number of individuals, diameter breast height (DBH), and their distribution in each plot. For example, the banyan tree (*F. benjamina*) found at L3 has an average diameter of >1.5 m. As for its distribution in each plot, it is Glodokan tiang (*P. indicus)* which is commonly found on the sides of roads and is planted intentionally because instead of playing a role as a pollutant absorber this species also has an aesthetic function.

Table 3. Important Value Index of tree

Family	**Species name**	**Local name**	**IVI (%)**				
			L1	**L2**	**L3**	**L4**	**L5**
Anacardiaceae	*Mangiferia indica* L.	*Mangga*	59%	8%	14%	19%	
Annonaceae	*Polyalthia longifolia* (Sonn.) Thwaites	*Glodogan tiang*	23%		16%		
	Annona muricata L.	*Sirsak*				15%	
Apocynaceae	*Alstonia scholaris* (L.) R.Br.	*Pulai*		7%	9%		13%
Arecaceae	*Elaeis guinensis* Jacq	*Kelapa sawit*		15%			
Araceae	*Wodyetia bifurcata* A.K.Irvine	*Palem ekor tupai*		8%	24%		
Bignoniaceae	*Spathodea campanulata* Beauverd	*Kencrutan*		33%	10%		
	Handroanthus chrysotrichus (Mart. ex DC.) Mattos	*Tabebuya*		24%	14%		
	Kigelia africana (Lam.) Benth.	*Pohon sosis*		14%			
Calophyllaceae	*Calophyllum inophyllum* L	*Nyamplung*					10%
Casuarinaceae	*Casuarina equisetifolia* L.	*Cemara*				20%	13%
Combretaceae	*Terminalia catappa* L.	*Ketapang*		7%	8%	16%	
Fabaceae	*Samanea saman* (Jacq.) Merr.	*Trembesi*	93%	39%	15%		25%
	Leucaena leucocephala (Lam.) de Wit	*Kemlandingan*	81%	8%			15%
	Tamarindus indica L.	*Asam jawa*		22%	23%		15%
	Pterocarpus indicus Willd.	*Angsana*		19%	29%	52%	87%
	Delonix regia (Bojer ex Hook.) Raf.	*Flamboyan*		11%			14%
	Senna siamea (Lam.) H.S.Irwin and Barneby	*Johar*		8%			
	Acacia auriculiformis A.Cunn. ex Benth.	*Akasia*			12%		
	Bauhinia purpurea L.	*Daun kupu kupu*					13%
	Pongamia pinnata (L.) Pierre	*Malapari*		10%			
Lamiaceae	*Tectona grandis* L.f	*Jati*					20%
Malvaceae	*Hisbiscus tiliaceus* L.	*Waru*		10%		57%	14%
	Durio zibethinus Murray	*Durian*					14%
Meliaceae	*Azadirachta indica* A.Juss.	*Mimba*			16%		
	Swietenia mahagoni (L.) Jacq.	*Mahoni daun kecil*			27%	20%	18%
Moraceae	*Ficus racemosa* L.	*Loa*		18%			
	Ficus benjamina L.	*Beringin*		22%	33%	29%	
Muntigiaceae	*Muntingia calabura* L.	*Kersen*					14%
Sapindaceae	*Filicium decipiens* (Wight and Arn.) Thwaites	*Kerai payung*			23%	23%	
Sapotaceae	*Manilkara zapota* (L.) P.Royen	*Sawo*			11%		

As for the pole level (Table 4), the species with the highest IVI values at each location were *Mangifera Indica* has the highest IVI value in L1 and L4 with a value of 56%. *Hibiscus tiliaceus* 48%, *Cyrtostachys lakka* 61%, and *Polyalthia longifolia* 46%. *Mangifera indica* is also a pole-level species with high dominance in several locations. Based on the IVI at the pole level, four of the five sampling locations are dominated by woody plants, which potentially grow large and play a role in carbon sequestration, shading, or microclimate regulation. *Cyrtostachys renda* is the only species with an aesthetic function as an ornamental plant, commonly used as borders for roads, groves, or planted in pots (Loganathan et al. 2021). Nonetheless, *Cyrtostachys renda* also plays a role in carbon sequestration. Furthermore, it is one of the customary plants of the Dayak tribe, which is suitable for GOS because of its carbon absorption ability (Ludang 2015). The high IVI value in *M. indica* is a common condition. The reason is that this species has a large number of individuals so that many are found in each research station plot, besides that *M. indica* has many benefits in urban areas, namely as a road shade because it has a wide enough canopy, besides that this type also produces fruit that is commonly consumed by the community and has an easy management level.

Table 4. Important Value Index of pole

Family	Species name	Local name	IVI (%)				
			L1	L2	L3	L4	L5
Anacardiaceae	*Mangiferia indica* L.	*Mangga*	56%	29%	13%	56%	55%
Annonacae	*Annona squamosa* L.	*Srikaya*			25%		
	Polyalthia longifolia (Sonn.) Thwaites	*Glodokan tiang*	15%		24%		11%
Apocynaceae	*Plumeria* sp.	*Kamboja*	21%		23%		
	Cerbera odollam Gaertn	*Bintaro*			16%		
Arecaceae	*Cyrtostachys* sp.	*Palem*		61%			
Asteraceae	*Gymnanthemum amygdalinum* (Delile) Sch.Bip. ex Walp.	*Daun Afrika*	16%				
Bignoniaceae	*Handroanthus chrysotrichus* (Mart. ex DC.) Mattos	*Tabebuia kuning*		31%	17%		
	Spathodea campanulata Beauverd	*Kencrutan*			15%		
Calophyllaceae	*Calophyllum inophyllum* L.	*Nyamplung*					25%
Caricaceae	*Carica papaya* L.	*Pepaya*		16%			
Combretaceae	*Terminalia catappa* L.	*Ketapang*		24%			
Cycadaceae	*Cycas rumphii* Miq	*Pakis haji*			15%		
Ebenaceae	*Diospyros discolor* Willd.	*Bisbul*	12%				
Fabaceae	*Sesbania grandiflora* (L.) Poir	*Turi*	14%				
	Samanea saman (Jacq.) Merr.	*Trembesi*	14%				
	Gliricidia sepium (Jacq.) Kunth	*Gamal*		18%			
	Senna siamea (Lam.) H.S.Irwin and Barneby)	*Johar*		16%			
	Tamarindus indica L.	*Asam jawa*			13%		26%
	Bauhinia purpurea L.	*Daunkupu-kupu*			34%		
	Leucaena leucocephala (Lam.) de Wit	*Kemlandingan*			29%		
Gnetaceae	*Gnetum gnemon* L.	*Melinjo*	14%				
Malvacacea	*Hibicus tiliaceus* L.	*Waru*		48%			
Malvaceae	*Theobroma cacao* L.	*Cokelat*					29%
Meliaceae	*Swietenia mahagoni* (L.) Jacq	*Mahoni daun kecil*	25%		14%		42%
	Swietenia macrophylla G.King	*Mahoni daun besar*	18%				
Moraceae	*Ficus benjamina* L.	*Beringin*	13%	29%	22%	49%	
	Artocarpus heterophyllus Lam	*Nangka*			26%		
Moringaceae	*Moringa oleifera* Lam	*Kelor*	14%				
Muntingniaceae	*Muntingia calabura* L.	*Kersen*	13%				
Myrtaceae	*Melaleuca leucadendra* (L.) L.	*Kayu putih*	13%				
	Syzygium myrtifolium Walp	*Pucuk merah*		37%			28%
	Psidium guajava L.	*Jambu biji*			25%		
Oxalidaceae	*Averrhoa carambola* L.	*Belimbing*			34%		
Phyllanthaceae	*Antidesma bunius* (L.) Spreng	*Buni*	17%				
Rubiaceae	*Mussaenda pubescens* Dryand	*Pisang hias*		32%			
Rutaceae	*Citrus* sp.	*Jeruk*			13%		
Sapotaceae	*Mimusops elengi* L.	*Tanjung*	12%				
	Manilkara zapota L.	*Sawo*			17%	23%	36%
	Chrysophyllum sp.	*Sawo duren*					31%
Verbenaceae	*Duranta erecta* L.	*Sinyo nakal*			14%		
Zingiberaceae	*Kaempferia galanga* L.	*Kencur*		22%			

Table 5. Important Value Index of sapling

Family	Species name	Local name	IVI (%)				
			L1	**L2**	**L3**	**L4**	**L5**
Anacardiaceae	*Mangiferia indica* L.	*Mangga*	29%		12%		
Annonaceae	*Polyalthia longifolia* (Sonn.) Thwaites	*Glodogan tiang*	19%				
	Annona squamosa L.	*Srikaya*		17%			
	Cananga odorata (Lam.) Hook.f. and Thomson	*Kenanga*			9%	30%	
	Annona muricata L.	*Sirsak*				17%	
	Polyalthia longifolia (Sonn.) Thwaites	*Glodogan tiang*					29%
Apocynaceae	*Calotropis gigantea* (L.) W.T.Aiton	*Biduri*	14%				
	Cordyline fruticosa (L.) A.Chev.	*Hanjuang*		34%			
	Plumeria rubra L.	*Kamboja*		87%	14%		55%
Areaceae	*Licuala grandis* (T.Moore) H.Wendl.	*Palem Kipas Kol*			13%		
Arecaceae	*Cyrtostachys renda* Blume	*Palem Merah*	24%		13%	31%	
	Salacca zalacca (Gaertn.) Voss	*Salak*		30%			18%
Asparagaceae	*Dracaena fragrans* (L.) Ker Gawl.	*Sri Gading*				23%	
Asteraceae	*Cascabela thevetia* (L.) Lippold	*Oleander kuning*					28%
Bignoniaceae	*Handroanthus chrysotrichus* (Mart. ex DC.) Mattos	*Tabebuia kuning*		15%	13%	24%	
	Kigelia africana (Lam.) Benth.	*Pohon sosis*		14%			
Calophyllaceae	*Calophyllum inophyllum* L.	*Nyamplung*				33%	
Caricaeae	*Carica papaya* L.	*Pepaya*	17%	12%			
Casuarinaceae	*Casuarina junghuhniana* Miq	*Cemara Gunung*			14%	20%	
Combretaceae	*Terminalia catappa* L.	*Ketapang*					
Cycadaceae	*Cycas rumphii* Miq.	*Pakis haji*			14%		
Fabaceae	*Sesbania grandiflora* (L.) Poir.	*Turi*	20%				
	Millettia pinnata (L.) Panigrahi	*Malapari*		15%			
	Samanea saman (Jacq.) Merr.	*Trembesi*		18%			
	Leucaena leucocephala (Lam.) de Wit	*Kemlandingan*				16%	
	Tamarindus indica L.	*Asam jawa*					36%
Malvaceae	*Theobroma cacao* L.	*Cokelat*					26%
	Talipariti tiliaceum (L.) Fryxell	*Waru*				32%	
Meliaceae	*Swietenia mahagoni* (L.) Jacq.	*Mahoni daun kecil*	19%		19%		42%
	Swietenia macrophylla G.King	*Mahoni daun besar*	20%				
Moraceae	*Ficus benjamina* L.	*Beringin*	18%		46%		
Moringaceae	*Moringa oleifera* Lam.	*Kelor*				22%	
Muntingiaceae	*Muntingia calabura* L.	*Kersen*	18%				
Myrtaceae	*Syzygium myrtifolium* Walp.	*Pucuk merah*	22%	18%	63%		28%
	Melaleuca leucadendra (L.) L.	*Kayu putih*		20%			
Oleaceae	*Jasminum polyanthum* Franch.	*Melati*			7%		
Poaceae	*Saccharum officinarum* L.	*Tebu*	62%				
Rubiaceae	*Mussaenda pubescens* Dryand.	*Nusa Indah*		87%			
Sapindaceae	*Pometia pinnata* J.R.Forst. and G.Forst.	*Matoa*				34%	
Sapotaceae	*Manilkara kauki* (L.) Dubard	*Sawo Kecik*					25%
	Manilkara zapota (L.) P.Royen	*Sawo Manila*					31%

At the sapling level (Table 5), the species with the highest IVI value from each sample location were *Saccharum officinarum* 62%, *Mussaenda pubescens* 87%, *Syzygium myrtifolium* 63%, *Anona muricata* 34%, and *Mangiferia indica* 55%. *M. pubescens* and *Syzygium myrtifolium* have a role as ornamental plants; generally, people plant these two species to beautify their yards. In addition, *S. officinarum, A. muricata,* and *M. indica* are commodity plants that have economic value in large quantities of cultivation (Neguse et al. 2018; Idowu et al. 2022).

For shrubs plants, the species with the highest IVI (Table 6) values from each location were *Eleusine indica* 24%, *Acalypha indica* 44%, *Oplismenus hirtellus* 29%, *O. hirtellus* 41% in L4, and *O. hirtellus* 74% in L5. Of the five locations, it was found that *O. hirtellus* had the highest number of individuals in the three study locations. *Acalypha indica* L is a plant with medicinal uses; in several countries, this species has been used as medicine for generations (Zahidin et al. 2017). *Eleusine indica* is a weed tolerant of soils with low oxygen levels. Therefore, it is often found in fields and soils that experience compaction due to pedestrian and vehicle traffic (Shekoofa and Brosnan 2020). The species is classified as an invasive weed because it can produce abundant seeds and rapid growth (Satriawan and Fuady 2019), so *E. indica* has the potential to dominate an area and increase the degree of IVI.

The high IVI values at the sapling and shrub levels are generally due to the large number of individuals and high dominance. At the sapling level, high IVI values were indicated by species that have a role as ornamental plants such as *M. pubescens* which were planted intentionally, but several species were also found to grow as weeds, namely *S. officinarum* which was found mostly in L1. While at the shrub level is found species of grass such as *Eleusine indica* and *O. hirtellus*. The existence of these species can be found on the soil surface, this is good for the GOS area because it will maintain soil health and become a water absorb area and it is safe for community activities around the GOS.

Table 6. Important Value Index of shrubs

Family	Species name	Local name	IVI (%)				
			L1	**L2**	**L3**	**L4**	**L5**
Acanthaceae	*Asystasia gangetica* (L.) T.Anderson	*Ara sungsang*	9%	4%	1%	8%	
	Graptophyllum pictum (L.) Griff	*Daun ungu*	5%				
	Ruellia simplex Wright	*Ruelia*	3%	2%	24%	2%	
	Ruellia tuberosa L.	*Kencana ungu*	11%				
	Andrographis paniculata (Burm.fil.) Nees	*Sambiloto*				4%	
	Ruellia tuberosa L.	*Plethekan*	1%				
Amaranthaceae	*Alternanthera* Forssk.	*Kremah*	1%				
	Amaranthus blitum L.	*Bayam kotok*				5%	
	Amaranthus spinosus L.	*Bayam duri*		9%			
	Cyathula prostrata (L.) Blume	*Bayam Pasir*	1%				
	Gomphrena celosioides C.Mart	*Bunga bersujud*	4%	2%	1%	5%	
	Aerva sanguinolenta (L.) Blume	*Erpa*			3%		
Amaryllidaceae	*Hymenocallis littoralis* (Jacq.) Salisb.	*Lili laba-laba pantai*		4%			
Apocynaceae	*Calotropis gigantea* (L.) W.T.Aiton	*Biduri*	3%				
Araceae	*Epipremnum aureum* (Linden and André) G.S.Bunting	*Sirih Gading*				4%	
	Caladium bicolor (Aiton) Vent.	*Keladi*					6%
	Dieffenbachia sp.	*Daun bahagia*		2%			
Araliaceae	*Hydrocotyle sibthorpioides* Lam.	*Semanggi gunung*	3%	3%	5%	4%	
Arecaceae	*Salaca zalaca* (Gaertn.) Voss	*Salak*		2%			
	Livistona saribus (Lour.) Merr. ex A.Chev.	*Palem kipas*					5%
Asparagaceae	*Dracaena marginata* Lem.	*Drakaena*			4%		
	Cordyline fruticosa (L.) A.Chev.	*Andong*	1%		11%		
Asteraceae	*Cyanthillium cinereum* (L.) H.Rob.	*Sawi langit*	6%	4%			
	Cosmos caudatus Kunth	*Kenikir*	1%		1%		
	Spilanthes paniculata Jacq	*Jotang*			6%		
	Synedrella nodiflora (L.) Gaertn	*Jotang Kuda*	2%	12%	4%	2%	6%
	Melampodium divaricatum L.	*Bunga Matahari Mini*	43%				
	Bidens pilosa L.	*Ketul*	2%	5%			
	Chromolaena odorata (L.) R.M.King & H.Rob.	*Kirinyuh*		2%			
	Melampodium divaricatum (Rich.) DC.	*Melampodium*	1%				
	Praxelis clematidea (Griseb.) R.King and H.Rob.	*Bandotan*	4%		5%		
	Terminalia catappa L.	*Ketapang*	4%		1%	4%	
	Canna indica L.	*Bunga tasbih*	1%		4%		
	Tridax procumbens L.	*Gletang*	12%	2%		22%	
	Zinnia elegans Jacq.	*Bunga kertas*	5%	2%			
Capparaceae	*Cleome rutidosperma* DC	*Maman lanang*	5%	10%		1%	
Caricaceae	*Carica papaya* L.	*Pepaya*		2%			
Combretaceae	*Zinnia elegans* Jacq.	*Bunga kertas*	5%	2%			
Commelinaceae	*Callisia fragrans* (Lindl.) Woodson	*Calisia*			2%		
	Tradescantia pallida (Rose) D.R.Hunt	*Daun adam hawa*			3%		
Convolvulacea	*Ipomoea aquatica* Forssk.	*Kangkung air*	2%			1%	
	Ipomoea batatas (L.) Lam.	*Ubi jalar*			2%		
	Ipomoea obscura (L.) Ker Gawl.	*Morning glory*	1%				
Cyperaceae	*Cyperus rotundus* L.	*Rumput teki*			5%		
Euphorbiaceae	*Acalypha indica* L.	*Anting-anting*	9%	44%	1%	7%	27%
	Acalypha siamensis Oliv. ex Gage	*Teh-tehan*			8%	4%	
	Euphorbia heterophylla L.	*Daun katemas*	4%			3%	
	Euphorbia hirta L.	*Petikan kebo*	4%				
	Jatropha curcas L.	*Jarak pagar*	4%		1%		

	Manihot carthagenensis subsp glaziovii (Mull.Arg.) Allem	*Singkong karet*				5%	
	Pedilanthus tithymaloides (L.) Poit.	*Pohon zig-zag*	9%		2%		
Fabaceae	*Crotalaria pallida* Aiton	*Orok-orok*	12%				
	Tamarindus indica L.	*Asam jawa*		2%			
	Abrus precatorius L.	*Saga rambat*				1%	
	Acacia decurrens (J.C. Wendl.) Willd.	*Akasia*	1%				
	Samanea saman (Jacq.) Merr.	*Trembesi*	2%				
	Arachis hypogaea L.	*Kacang tanah*		5%	3%		14%
	Centrosema pubescens Benth.	*Sentro*	3%		1%		
	Cynometra cauliflora L.	*Namnam*			2%		
	Leucaena leucocephala (Lam.) de Wit	*Kemlandingan*		2%			
	Mimosa pudica L.	*Putri malu*	4%			4%	
	Senna siamea (Lam.) H.S.Irwin and Barneby	*Johar*		4%			
Heliconiaceae	*Heliconia psittacorum* L.f.	*Pisang hias*			3%		
Hypoxidaceae	*Molineria latifolia* (Dryand. ex W.T.Aiton) Herb. ex Kurz	*Congkok*	1%				
Lamiaceae	*Salvia splendens* Selloe ex Nees				5%		
Malvaceae	*Waltheria indica* L.					1%	
	Sida rhombifolia L.	*Sidagori*				2%	
	Hibiscus rosa-sinensis L.	*Bunga sepatu*			1%		
Meliaceae	*Melia azedarach* L.	*Mimba*			3%		
Moraceae	*Ficus benjamina* L.	*Beringin*			1%		
Moringaceae	*Moringa oleifera* Lam.	*Kelor*				2%	
Muntingiaceae	*Muntingia calabura* L.	*Kersen*			1%		
Myrtaceae	*Syzygium myrtifolium* Walp	*Pucuk merah*			2%		
	Psidium guajava L.	*Jambu biji*			2%		
Nephrolepidaceae	*Nephrolepis brownii* (Desv.) Hovenkamp and Miyam	*Pakis pedang*		2%			
Nyctaginaceae	*Bougainvillea spectabilis* Willd.	*Bunga kertas*				1%	
Oleaceae	*Jasminum sambac* (L.) Aiton	*Melati*	1%		1%	2%	
Oxalidaceae	*Oxalis barrelieri* L.	*Calincing*	7%	2%			
	Oxalis corniculata L.				2%		
Passifloraceae	*Passiflora foetida* L.	*Rambusa*	2%	4%			
Phyllanthaceae	*Phylanthus urniaria* L.	*Meniran merah*	1%				
	Phyllanthus niruri L.	*Meniran hijau*			1%	1%	
	Sauropus androgynus (L.) Merr.	*Katuk*			1%		
Poaceae	*Axonopus sprucei* G.A. Black	*Rumput gajah mini*	12%	9%			
	Eleusine indica (L.) Gaertn	*Rumput belalang*	24%	16%	4%	33%	14%
	Fargesia murielae (Gamble) T.P.Yi	*Bambu*			1%		
	Imperata cylindrica (L.) Raeusch.	*Alang-alang*		24%			
	Oplismenus hirtellus (L.) P. Beauv.		8%		29%	41%	74%
Polypodiaceae	*Drynaria quercifolia* (L.) J.Sm.	*Paku sarang burung*			1%		
Portulacaceae	*Portulaca grandiflora* Hook.	*Krokot*		5%	6%	1%	
Pteridaceae	*Adiantum philippense* L.	*Suplir*		2%			6%
	Cheilanthes farinosa H.Ito	*Pakis*		2%	1%		
	Pteris biaurita L.	*Pakis*					6%
	Pteris ensiformis Burm	*Pakis*			1%		
	Pteris multifida Poir.	*Pakis*			2%		
	Pteris vittata L.	*Pakis*		2%	5%	1%	5%
Rubiaceae	*Oldenlandia corymbosa* L.	*Rumput mutiara*			1%		
	Ixora paludosa (Blume) Kurz	*Bunga asoka*			4%		
	Morinda citrifolia L.	*Mengkudu*				1%	
	Richardia brasiliensis Gomes				1%	2%	
Rutaceae	*Citrus aurantiifolia* (Christm.) Swingle	*Jeruk nipis*				1%	
Salicaceae	*Salix repens* L.	*Willow*			3%		24%
Solanaceae	*Solanum nigrum* L.	*Leunca*	2%		2%		
	Capsicum frutescens L.	*Cabai*		2%			
Tectariaceae	*Tectaria* sp.	*Paku-pakuan*					5%

The high IVI value can indicate that the species is the main constituent of the community at the research site and a parameter that shows the role of the vegetation species in a community (Yuliantoro and Frianto 2019). As in the *Samanea saman* species has the highest IVI value in both research locations, where this species plays a very important role in improving the ecosystem at the research site. The high and low IVI values are also influenced by the species' ability to adapt and tolerate the habitat's environmental conditions.

Vertical structure

The vertical structure is defined as the distribution of the number of trees in the various canopy layers. In addition, the vertical structure also contains tree species and size distribution, including tree heights in the canopy layer. A good concept of vertical structure composition can be used as a sustainable area management scheme. Distribution identification can be made using levels of stratification or strata by grouping the forest canopy categories (Hamraz et al. 2017). Stratification, or another name for strata, is the identification of plant groupings based on the height of the plants in a vertical space. Each species category has a different height, so the stratification is determined according to the size of each species (Aldea et al. 2021). There are five stratifications based on tree height, namely by category (A) <1 m; (B) 1-2 m; (C) 2-5 m; (d) 5-10 m; (E) >10 m. The most common stratum category found in all stations is category strata A (Figure 5), with the highest percentage of 95,60% at research station L4 (Table 7).

Canopy A as a whole of all stations totals 93,25% (5570 individuals) (Table 7). With this number, some of them are *Centrosema pubescens*, *Psidium guajava*, and *Jasminum sambac*, *Phyllanthus niruri*, *Imperata cylindrica*. Canopy category B as a whole from all stations totaled 111. With this amount, some of them are such *M. indica*, *Handroanthus chrysotrichus*, *Spathodea campanulata*, *Ficus benjamina*. Canopy category C from all stations totaled 344. With this number, some of them are *S. saman*, *F. benjamina*, *P. indicus*, *Wodyetia bifurcata* A.K.Irvine, and *Swietenia mahagoni*. Canopy category D as a whole from all stations totaled 99. With this amount, some of them are *Tamarindus indica*, *Terminalia catappa*, and *Polyalthia longifolia*, and *Cerbera odollam*. The overall canopy category E for all stations is 0.

The existence of several tree canopies at GOS could reduce the ambient air temperature because they absorb air-polluting gases that increase the air temperature. In addition, it can store carbon, eventually leading to global warming (Kong et al. 2022). Global warming will continue to be an environmental problem, so carbon absorption and storage capacity need to be increased by spreading vegetation in areas. A large number of tree species at each GOS point shows that trees, through their biomass, can better absorb and store the content of polluting gases in the air (Zhang et al. 2021). Some trees, such as *trembesi* (*S. saman*), can absorb more air-polluting gases compared to other trees and also has good water absorption that is useful for the environment. Characteristics of the *trembesi* tree, it is easy to recognize the characteristic leaves shaped like umbrellas and their dilated growths.

Furthermore, the acacia tree (*Acacia auriculiformis*) is used as an ornamental plant because it is characterized by many flower characteristics (Collf 2017). In addition, acacia trees can absorb high air temperatures, lowering the air temperatures. With this ability, this tree is also used in reforestation or rehabilitation. Next is the beringin tree (*F. benjamina*), with its characteristic of easy living spread through its hanging roots, which are also used for breathing. Banyan (*Beringin*) is a tree that is very famous for its taproot that spreads to the ground (Herlina et al. 2017). Banyan tree, with their roots and trees that usually rise, makes this tree often used as shade trees. Finally, the mahogany tree (*S. mahago*ni) is a tropical plant called a protective tree because of its shady tree and ability to absorb air pollution. With its wide leaf characteristics, it functions to absorb pollutants around it, and its strong roots will bind water when it rains so that it has sufficient water storage. So that mahogany trees can easily survive in the dry season (Mendez et al. 2017).

Urban areas are where most people are active in non-agricultural sectors such as industry. The high level of industrial activity in urban areas encourages the urgency of providing plants in large quantities to stabilize air conditions. The increasing population encourages increased activities, affecting the increasing emissions produced. Emissions from activities involving the use of fuels, such as industrial activities and motor vehicles, increase the potential for air pollution. Air pollution can have a bad impact, especially on human respiratory health. Global warming and climate change are the worst impacts of air pollution due to high carbon dioxide levels.

Table 7. Vegetation stratification

Vegetation Stratification	L1		L2		L3		L4		L5	
	%N	%S	%N	%S	%N	%S	%N	%S	%N	%S
A (<1 m)	93,25%	10,61%	88,49%	8,75%	91,31%	14,32%	95,60%	9,28%	72,96%	3,18%
B (1-2 m)	2,31%	5,31%	1,77%	3,45%	2,38%	9,28%	0,80%	3,18%	2,14%	1,86%
C (2-5 m)	3,84%	5,84%	9,34%	8,75%	5,70%	5,57%	3,30%	6,37%	9,45%	6,90%
D (5-10 m)	0,60%	1,33%	0,40%	1,06%	0,61%	3,45%	0,30%	1,59%	15,45%	2,92%
E (>10 m)	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%

Note: N is the Total Percentage of Individual Strata, and S is the Total Percentage of Species Strata. L1=Bengawan Urban Forest; L2=Benteng Vastenburg Park; L3=Sriwedari Stadium Park; L4=Pringgolayan Field; L5=Manahan Urban Forest

Green Open Spaces are areas grouped or elongated, open to use, and are places for plants to grow, both naturally growing and not (Hidayah et al. 2021). Providing green open space in an urban area has many benefits, such as balancing the urban environment, environmental health, comfort, and environmental sustainability. These benefits are inseparable from the role of vegetation in green open spaces. Vegetation in green open spaces plays an important role in absorbing carbon dioxide in the air, which is useful for stabilizing air pollution in urban areas. Vegetation absorbs carbon dioxide used as the basic material for photosynthesis. In addition, vegetation also acts as a counterweight to the hydrological cycle. Vegetation can accelerate the infiltration system, reducing surface inundation and increasing groundwater reserves. Tree vegetation types best carry out the infiltration system. That is due to the roots of tree vegetation which can create shafts in the soil, and tree vegetation's high permeability, which accelerates infiltration (Harimi 2018). Vegetation in green open spaces is also useful as a windbreak. The greater the number and density of tree vegetation in an environment, the greater the ability of the vegetation to withstand wind. According to Jemali et al. (2022), Trembesi and Mahogany trees can withstand the wind due to the shape of their large canopy. The existence of vegetation also acts as a shade for urban areas. The mango plant (*M. indica*) is a type of tree vegetation widely used as a shade because it can control air humidity (Azizah and Utami 2021). Mango plants have a shady crown that can block the sun's radiation to the ground. That causes the temperature in the area around the tree to decrease so that the air cools. The existence of vegetation strongly supports the availability of ecosystem services from green open spaces. Therefore, in providing green open space in an urban area, attention must be paid to the type and amount of vegetation to provide green open space. Diana and Andini (2020) stated that open canopies would affect the condition of the plants underground. Figure 4 shows that the strata are dominated by strata A; in an open canopy, sunlight can penetrate the strata below, affecting the attractions as evidenced by the high number of individuals and species.

Plant species Shannon-Wiener diversity index

The diversity index describes the level of diversity of species studied in a place (Yulia et al. 2021). This Index is a description of the composition of an individual in a species that is in a community. The results of this index calculation can be divided into three levels low-level, medium-level, and high-level. An area's diversity level is said to be low if it has an H'<1 value. This condition can occur if in a location only one species is found in a community. The low index value illustrates that the ecosystem in the location is unbalanced, and productivity is low. The high environmental pressure causes low productivity value at the location, which disrupts the process of spreading and growing plants (Sumarjan 2021). Suppose the diversity value shows 1<H'<3, and the diversity of the location is included in the moderate category; that indicates that productivity is quite good and ecological conditions in the region are quite balanced. The diversity category in a location is said to be high if it is H'>3. The value of high diversity is obtained if a community has more than one species and has high productivity and balanced ecosystem conditions. High diversity values also indicate a species's even and stable distribution pattern (Mildasari et al. 2021).

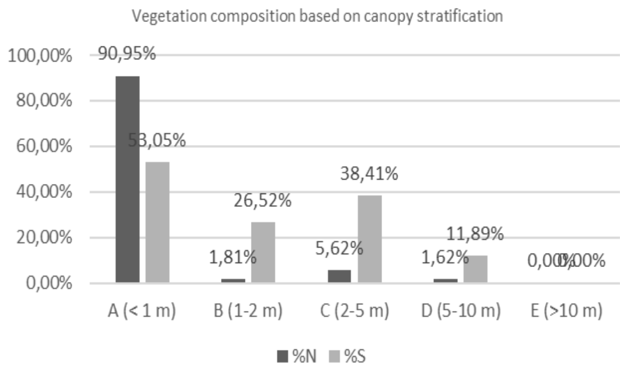

Figure 4. Percentage of N and S grades (N is the total percentage of individual strata, and S is the total percentage of species strata)

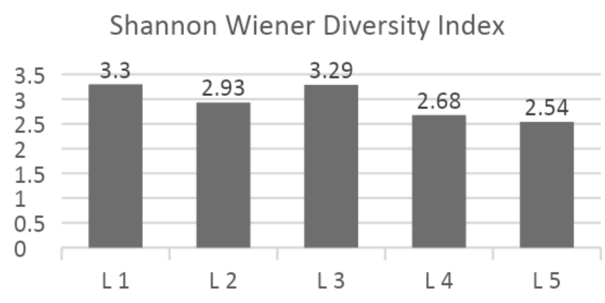

Figure 5. Shannon Wiener Species Uniformity Index on GOSs in Surakarta (L1 Urban Forest Bengawan, L2 BentengVastenburg City Park, L3 Sriwedari Stadium Complex, L4 Pringgolayan Field, L5 Manahan City Park)

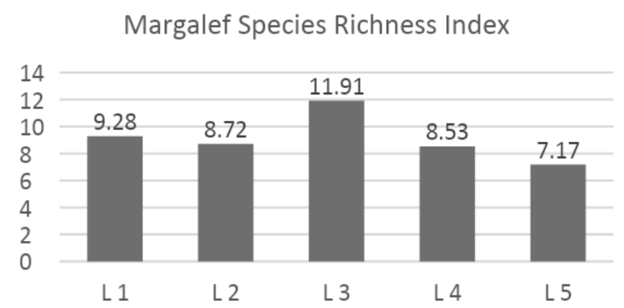

Figure 6. Margalef Species Richness Index in GOSs in Surakarta (L1 Bengawan Urban Forest, L2 BentengVastenburg City Park, L3 Sriwedari Stadium Complex, L4 Pringgolayan Field, L5 Manahan City Park)

In this study, the Diversity Index was calculated in five Surakarta City parks to determine the species diversity level in each park. It is known that the Diversity Index value of the park in Surakarta City is in the range of 2.54 - 3.30 (Figure 5). Of the five parks studied by the research site, Bengawan Solo Urban Forest Park has the highest Diversity Index value of 3.30. The value of such an index belongs to the high category. That is due to the large number of species found in this location. The high Diversity Index indicates that the Bengawan Solo Urban Forest Park ecosystem is in stable condition and has high productivity. In addition to the Bengawan Solo Urban Forest Park, other research locations have a Diversity Index value above 3 (high category), namely Sriwedari Park, with an index value of 3.29. It can be said that Sriwedari Park also has a stable ecosystem and good productivity. The lowest Diversity Index value was obtained at the Manahan Stadium City Forest research site, which was 2.54. However, at the lowest of the other four locations, the diversity index at the site is in the moderate category. The medium category indicates that the location has sufficient productivity and the condition of the ecosystem is quite stable. Other research locations in the medium category are Vastenburg Fort Park and Serengan Pringgolayan Field Park, with index values of 2.93 and 2.68, respectively. The moderate diversity index indicates that the species in that location are not too many. That causes productivity in the ecosystem not too good but not too bad. Low diversity can illustrate the stability of the ecosystem that has not been maximized. Khamalia et al. (2018) stated that the high number of species found is proportional to the high value of diversity. However, if the value of diversity is small, then the location is dominated by one or several species. The level of the species diversity index can be influenced by the species' ability to compete and survive in different growing conditions (Laely et al. 2020). L4 (Pringgolayan Field) and L5 (Manahan Stadium Urban Forest) are dominated by grass plants, especially *Oplismenus hirtellus*.

Margalef species richness index

The wealth index value is categorized into three categories, namely low (R<2.5), medium (2.5<R<4), and high (R>4) (Heriyanto and Gunawan 2020). The research shows that the plant species wealth index is in the range of 7.17-11.91 values, which shows that the value of plant species richness is high. The Margalef Diversity Index (Dmg) value or type of wealth indicates the richness of the type in each area or community, and this value is strongly influenced by the total number of individuals found (Santosa et al. 2008). Therefore, the higher the value of the type richness index indicates that the greater the number of types found, but inversely proportional to the increase in the number of individuals (Baderan et al. 2021). So generally, a community that has a high wealth value will have a small number of individuals in each species. That is because the Margalef index value is obtained from dividing the number of species by the natural logarithm function of the total individual.

According to the data Figure 6, it can be seen that of the five research locations, location 3 (Sriwedari Stadium Park) has the highest plant species-richness index value of 11.91, while the lowest value is obtained at location 5 or Manahan Stadium with a value of 7.17. That is because the number of species with the total number of individuals influences the species-richness index value difference. Furthermore, Figure 6 shows that the number of species and individuals in location 3 is higher than in location 5. That is because, in location 3, planting is carried out in addition to ecological functions, namely as a shade and carbon sink; it also has an aesthetic function. Moreover, in location 3, many ornamental plants grow in clusters with many individuals, thus increasing the number of species and individuals. While location 5 is more dominated by large-dimensional tree-level plants (diameter and height) and tends not to prioritize the number of species over individuals to provide optimal ecological functions to boost the quality of the urban environment. That is in line with Baderan et al. (2021), where communities or areas with high levels of richness are generally not followed by many individuals in each species.

The difference in species richness value depends on the number of species found in a sample plot. The more species identified, the wider the sample plot will show a greater species richness index value (Ismaini et al. 2015). Low species richness will impact the number of high individuals and vice versa. Species richness is closely related to species diversity, so the more species found will affect species diversity which can describe productivity, stability, and pressure in the ecosystem (Purnama et al. 2019). All research stations obtained species richness index values in the high category, which shows that the number of species found has a large number and correlates with the level of species diversity. The value of Shannon-Wiener diversity index proves it from L5, which has the lowest species diversity index and the lowest Dmg species index compared with other stations.

Evenness species index

The evenness index value indicates the degree of evenness of individual abundance between each species. The evenness index has a value range of 0-1, where if the index value obtained is close to 1, it indicates that the distribution is more even. If the value of evenness is 1, it indicates that each species has the same number of individuals and the community has a maximum evenness value. Based on the Figure 7 shows that the evenness index value of plant species is in the range of 0.64-0.78, which means that the evenness category of plants at the study sites is high or stable. That value indicates that the plant species at the study site have a relatively even number of species, and no certain species dominate. Stable community conditions are a sign that the community is not easily disturbed or has a high environmental resilience where the environment can restore its natural conditions after a disturbance (Baderan et al. 2021).

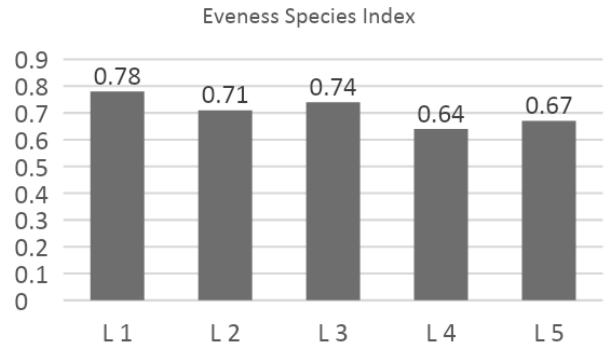

Figure 7. Species Evenness Index in GOSs in Surakarta (L1 Bengawan Urban Forest, L2 BentengVastenburg City Park, L3 Sriwedari Stadium Complex, L4 Pringgolayan Field, L5 Manahan City Park)

Figure 7 shows that L1 has the highest evenness value of 0.78, while L4 has the lowest evenness value of 0.64. Bengawan Solo Urban Forest Park is a green space established on the banks of the Bengawan Solo River. The utilization of riverbanks as GOS has begun to be encouraged by the government to fulfillment of regional green open areas as well as awareness of the important value of green spaces on riverbanks for the ecological function of rivers. GOS on riverbanks plays a very important role in improving the river ecosystem to maintain water and soil conservation along the riverbanks (Julianty 2019). Stable ecosystem conditions are the main focus in the development of green spaces, as well as in riverbank GOSs, as an effort to improve river ecosystems. These can be a factor in the high value of evenness in L1. However, the Figure 7 results show no significant difference in the evenness value in each location because all stations show an index value in a medium level of evenness. That means that the five sampling locations show that the condition of the artificial ecosystem built is stable. The medium value of evenness in all stations is related to the purpose of building GOS in providing a stable artificial ecosystem and improving the quality of the urban environment. Species evenness plays a role in providing more stable ecosystem conditions. This condition of evenness indicates that the distribution of plants is going well; it indicates the less dominant species. The existence of a dominant species can disrupt the balance of the ecosystem, especially species that are invasive-alien due to a high reproduction rate, so their presence can disrupt the existence of native species and suppress resources.

Based on the research results, it can be concluded that the vegetation structure in GOS of Surakarta City consists of 181 species, 55 families, and 6,095 individuals. The number of species of shrubs habitus is higher than other habitus. The highest IVI value is owned by the trembesi tree or *S. saman* with a tree habitus. The plant strata vertically are dominated by Strata A or less than 1 m in height. That happened in all locations regarding the number of individuals and species. While horizontally, L1 located in Bengawan Urban Forest, has the highest evenness value, and L4 located in Pringgolayan Field, has the lowest evenness value. Nevertheless, all five study sites showed high evenness values or were stable. Shrubs plants were the most dominant plant level at all sites. L3 is located in Sriwedari Stadium and has the highest species richness. Determination of plant species in each GOS of Surakarta City must pay attention to ecological functions, especially to improve the quality of the urban environment and services to the community.

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