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Undergrowth vegetation in the riparian zone of the Upper Bengawan Solo River, Central Java, Indonesia and its potential uses

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Abstract. *Saputra AF, Utomo AN, Pramesthi AZ, Madjid AA, Sulton MN, Dewangga A, Setyawan AD. 2024. Undergrowth vegetation in the riparian zone of the Upper Bengawan Solo River, Central Java, Indonesia and its potential uses. Asian J For 8: 194-206.* Riparian zone is the transitional zone between terrestrial water and land ecosystems, and an important part of river ecosystem. In riparian zone, the presence of vegetation, ranging from trees to undergrowth, is important to maintain ecosystem functions. Undergrowth vegetation in riparian zone is also widely utilized by local people for various purposes. This study aimed to determine the understory vegetation in riparian zone of the Upper Bengawan Solo River, Central Java, Indonesia and its potential use in the community. This research was conducted in three stations, i.e., Giriwono Village, Wonogiri District for the upstream, Sidowarno Village, Klaten District for the middle stream, and Gadingan Village, Sukoharjo District for the downstream. Data collection used transect method with size of 2×2 for seedlings and herbaceous plants and 5×5 plots for saplings and shrubs, each with five replications at each station. The study documented 78 species from 38 families of undergrowth vegetation across the three riparian locations. The vegetation diversity index (H') studied across the three stations is included in the medium category. The plant with the highest Index of Important Value (IVI) for seedlings and herbaceous plants was *Chromolaena odorata* with 15.56%, while that for saplings and shrubs was *Bambusa blumeana* with 47.74%. The higher elevation in the upstream (Wonogiri District) led to higher soil temperatures, while the midstream (Klaten District) had a more acidic soil pH and the highest air humidity. In the downstream (Sukoharjo District), high humidity due to proximity to the river, led to lower soil temperatures. Riparian vegetation along the Upper Bengawan Solo River also has diverse potentials with the dominance of medicinal uses, while other plants are used as animal feed, ornamental plants, food ingredients, and others.

Keywords: Potential use, riparian zone, undergrowth plant, vegetation

INTRODUCTION

Riparian zone is an ecotone in terrestrial realm in the form of transitional zone between land and river or stream. The riparian zone is one of the most important ecosystems on earth. As the boundary between terrestrial water bodies and land, it plays various ecosystem functions (Singh et al. 2021) and delivering numerous ecosystem services (Fu et al. 2016). Bank stabilization, buffering of pollutants and sediments, temperature regulation, provision of energy for riverine food webs and communities, groundwater recharge and provision of ecological corridors and habitat for wildlife, are some of the key ecosystem functions of the riparian zone that play a major role in river health (Singh et al. 2021). Riparian zone also functions as a place to reduce mercury heavy metal contamination that appears in subsurface streams with Hg-rich wet organic soils (Vidon et al. 2019). More recently, riparian zone also contribute to climate change mitigation as the vegetation can sequester and store carbon in great capacity (Paradika et al. 2021).

Riparian zone is covered with diverse vegetation ranging from shrubs to trees. According to Park and Kim (2020), elevation and distance from the water surface are the main factors that influence vegetation structure in riparian. Riparian vegetation is an important component of fluvial systems and has various socio-ecological functions (Dufour et al. 2019). More importantly, riparian vegetation helps to maintain water quality. According to Lyu et al. (2021), riparian vegetation determines soil's ability to absorb and maintain water quality in the watershed ecosystem.

Despite their importance, many riparian ecosystems are nowadays being threatened due to several pressures, such as urbanization, intensive agriculture, and river engineering works (Borisade et al. 2021; Urbanič et al. 2022). There is also accumulation of pollution which can reduce river water quality (Pangastuti et al. 2022). For example, riparian zones in Surabaya, Indonesia which were previously green open space, have been heavily degraded due to the high rate of population growth and development, turning the previously vegetated area into settlements and industrial areas, thereby reducing the carrying capacity of the environment, and reduce river water quality (Yudianingrum and Mangkoedihardjo 2016).

Bengawan Solo is recognized as one of most important river systems in Indonesia, encompassing two provinces in Java Island with the largest human population. There are several species of vegetation present in the riparian zone of the upper zone Bengawan Solo River with the prominence of understory vegetation. Understory plants are types of vegetation that live at the base of a tree community (Andriyani et al. 2023). Understory plants that make up an area have a certain distribution pattern and are usually found living near the parent plant (Iryadi and Wardhani 2023). Altitude has strong influence on the types of understory plants (Suprapta 2021) and this also applies to the riparian zone of the Bengawan Solo River. The existence of undergrowth that can grow easily in the riparian zone in Bengawan Solo provides benefits to local people, including from being used as medicine, animal feed, processed into food ingredients, etc. (Hanum et al. 2022). According to Liana et al. (2023), undergrowth is commonly utilized by local people as traditional medicines. However, if the river is polluted, it might impact on the condition of riparian zone, which is the habitat for understory plants. Therefore, this study was aimed to determine the understory vegetation in the Bengawan Solo River area and its potential uses by the community. We expected, the results of this study might be used as a reference for sustainable management and utilization of undergrowth by communities in the Upper Bengawan Solo River.

MATERIALS AND METHODS

Study area

The research was conducted in March 2024 and located in the Upper Bengawan Solo River, Central Java, Indonesia. Data collection was conducted at three stations, namely Giriwono Village, Wonogiri District for the upstream (7°47'45.10 "S and 110°56'12.70 "E), Sidowarno Village, Klaten District for the midstream (7°38'35.80 "S and 110°47'29.80 "E), and Gadingan Village, Sukoharjo District for the downstream (7°34'38.00 "S-110°50'45.10 "E) (Figure 1). In Giriwono Village, there is a special purpose forest area (KHDTK) called Alas Kethu where the KHDTK is located on the river bank or close to the river so there is a lot of undergrowth vegetation (Rindarto et al. 2021). Alas Kethu is a conservation forest dedicated for research and environmental education and conservation. Sidowarno Village was chosen because there is a bosket near the Bengawan Solo riverbank that makes it easier to find the undergrowth vegetation like bamboo and other plants. This village is located next to the river and has the characteristics of agroforestry land, where agriculture and forestry are integrated to maximize environmental and economic benefits. Gadingan Village was chosen because there was a lot of undergrowth vegetation on the riverbanks, beside that this zone is reachable to go inside the bosket. The Gadingan area is a forest area located in the riparian zone, which is known for its rich and diverse ecosystem because it is close to the river. The combination of these three locations provides a comprehensive picture of the variation in vegetation and environmental conditions along the river.

Data collection

Data collection used transect and purposive sampling methods. The transect method aims to understand the relationship between changes in vegetation and the environment, as well as to quickly determine the relationship between vegetation on a land (Sari et al. 2019). Meanwhile, purposive sampling is a sampling technique where researchers select samples based on certain assessments and criteria that are relevant to the research objectives (Etikan et al. 2016). The plots were determined by systematic sampling with initial randomization. First, a sampling point was determined randomly then a plot was made. Within the plot, the undergrowth vegetation in the form of herbaceous plants (seedlings) was counted in the 2×2 meter area and shrubs and small woody plants (poles) in the 5×5 meter area (Destaranti et al. 2017). Each station, there were five plots created with a distance of about 20 m, from upstream to downstream, totaling 15 plots in this study.

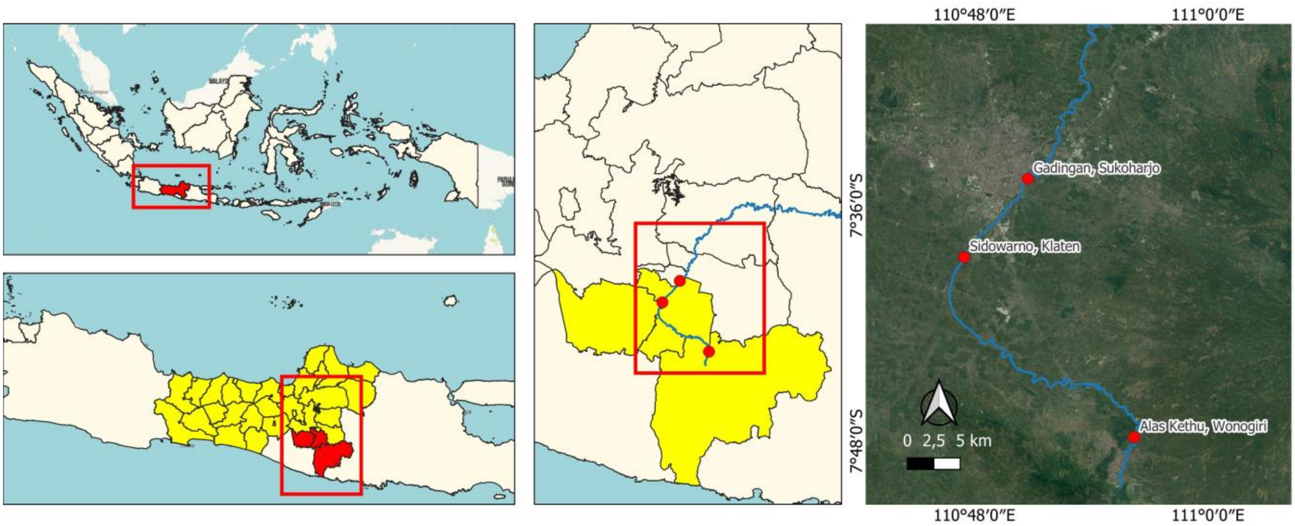

Figure 1. Map of research location at three stations along the Upper Bengawan Solo River in Central Java Province, Indonesia

The environmental variables measured include altitude above sea level, water pH, soil pH, air humidity, and air and soil temperature. Tools used for this measurement include an altimeter to measure altitude, a pH meter to measure the pH of water and soil, a hygrometer to measure air humidity, and a thermometer to measure air and soil temperature. The materials required include water and soil samples taken from the measurement location as well as buffer solution used to calibrate the pH meter before measurement.

Data analysis

The collected data was then analyzed descriptively and quantitatively. To analyze plant species, we first made direct observations at the research sites. These observations were recorded on a tally sheet. After that, we analyzed the data samples using the reference from Pertiwi et al. (2021) and the Global Biodiversity Information Facility (GBIF) website (www.gbif.org) for identification. Analysis was also carried out to understand the potential utilization of each plant from secondary data (journals, books, or articles). The data that has been identified is then analyzed to determine the dominant species in the three areas on the riparian of Bengawan Solo River, by calculating the Important value index and diversity index, which can be calculated by the following formula (Hutasuhut 2018).

Important value index (IVI)

IVI is a metric in ecology to evaluate the importance of a species in a plant community (Krebs 1989).

Density of a species

$$D = \frac{Number\ of\ Individuals\ of\ All\ Types}{\text{Area of All Sample Plots}}$$

Relative Density Species (RDi)

$$RDi = \frac{Density\ of\ a\ species}{Density\ of\ all\ species} x100\%$$

Frequency of a species

$$F = \frac{Number\ of\ sampled\ areas\ where\ species\ occurred}{number\ of\ total\ sampled\ areas}$$

Relative Frequency (RF)

$$RF = \frac{Frekuensi\ of\ a\ species}{Frekuensi\ of\ all\ species} x100\%$$

Important Value Index (IVI)

IVI = RDi+ RF

Shannon-Wiener Diversity Index (H')

Diversity Index is a metric indicating the level of species diversity in a community (Mokodompit et al. 2022)

$$H' = -\sum_{i=1}^{s} Pi(lnPi)$$

Where:

H': Species Diversity Index

pi: The ratio of the number of species I (ni) to the total number of individual species in the community (N)

In: Logarithms

S: Number of species that make up the community

From the magnitude of the diversity index value obtained, it can be categorized as follows:

A value of H'>3 indicates that the species diversity of a place is high. A value of 1≤H'≤3 indicates that the diversity of species in a place is moderate. A value of H'<1 indicates that the species diversity in a place is low

RESULTS AND DISCUSSION

Undergrowth species in the riparian zone of Bengawan Solo River

A total of 78 plant species from 38 families were recorded in the riparian zone of the study site (Table 1). Families with the largest number of species recorded were Poaceae and Fabaceae with nine species for each family. According to Usman et al. (2022), Fabaceae is the second most diverse family in the plant kingdom, and species from the family are widely distributed throughout the world. Families with the lowest number of species was Loganiaceae, Onagraceae, Vitaceae, Araliaceae, Anacardiaceae, Rhamnaceae, Apocynaceae, Rutaceae, Basellaceae, Sapindaceae, Pteridaceae, Lamiaceae, Amaranthaceae with only one species. The diversity of a vegetation community often cannot be estimated comprehensively using random sampling method (Roswell et al. 2021). In another study in Siwaluh River, there were 15 species at the stages of trees and poles, while for sapling there were 25 species and seedling were 179 species (Pramadaningtyas et al. 2023).

The most dominant species of seedling and herbaceous plants (i.e. in the 2×2 m plot) in the river upstream was *Microstegium vimineum* with 127 individuals, while the most dominant species of sapling and shrubs (i.e. in 5×5 m plot) was *Pleurolobus gangeticus* with 11 individuals (Table 1). Meanwhile, the most dominating species of seedling and herbaceous plants in the midstream was *Richardia scabra* with 137 individuals, and *Bambusa blumeana* dominated the shrubs and saplings with 79 individuals. The most dominant species of seedling and herbaceous plants in the downstream was *Mercurialis perennis* with 53 individuals, and the most dominant species shrubs and saplings was *B. blumeana* with 75 individuals. Bamboo is the plant most commonly found in this research, because the environmental conditions in the river are suitable for the bamboos to grow (Sutiyono et al. 2022).

Shannon-Wiener Diversity Index (H')

The Shannon-Wiener Diversity Index, denoted as H', is a commonly used metric to examine species diversity of plant community (Sun and Ren 2021). The H' at the three stations is included in the medium category where in the upstream the H' was 2.707, the midstream was 2.742, and the downstream was 2.488 (Table 2). Vegetation analysis is useful for assessing the current condition of the vegetation and monitoring future changes (Rambey et al. 2021). Other study in Siwaluh River, Indonesia showed a high diversity category (Pramadaningtyas et al. 2023).

Table 1. Undergrowth species found in the riparian zone of upper Bengawan Solo River, Central Java, Indonesia

Scientific name	Family	Local name	UP	MD	DN	Number of individuals
Seedling and herbaceous plants						
Alpinia galanga (L.) Willd.	Zingiberaceae	*Lengkuas*	3		3	6
Amaranthus spinosus L.	Amaranthaceae	*Bayam duri*		1		1
Amorphophallus oncophyllus Prain ex Hook.f.	Araceae	*Porang*	5			5
Anredera cordifolia (Ten.) Steenis	Basellaceae	*Binahong*	3			3
Bidens pilosa L.	Asteraceae	*Ketul*			17	17
Carica papaya L.	Caricaceae	*Pepaya*			1	1
Chromolaena odorata (L.) R.M.King & H.Rob.	Asteraceae	*Balakasida*	70	76		146
Colocasia esculenta (L.) Schott	Araceae	*Talas*			18	18
Curcuma longa L.	Zingiberaceae	*Kunyit*	9			9
Cyperus rotundus L.	Cyperaceae	*Rumput teki*	43	78		121
Dactyloctenium aegyptium (L.) *Willd*.	Poraceae	*Rumput mesir*		10		10
Dimocarpus longan Lour.	Sapindaceae	*Kelengkeng*			1	1
Dioscorea hispida Dennst.	Dioscoreaceae	*Gadung tikus*			8	8
Elephantopus scaber L.	Asteraceae	*Tapak liman*		21		21
Euphorbia heterophylla Desf.	Euphorbiaceae	*Patik emas*	6			6
Euphorbia hirta L.	Euphorbiaceae	*Patikan kebo*	11			11
Ficus septica Burm.fil.	Moraceae	*Awar-awar*			11	11
Hedera helix L.	Araliaceae	*Ivy*			6	6
Leea indica (Burm.fil.) *Merr*.	Vitaceae	*Girang merah*			3	3
Leucaena leucocephala (Lam.) *de Wit*	Fabaceae	*Lamtoro*		21		21
Ludwigia palustris (L.) Elliott	Onagraceae	*Buang-buang*		84		84
Macroptilium atropurpureum (DC.) Urb.	Fabaceae	*Siratro*	8			8
Manihot esculenta Crantz	Euphorbiaceae	*Singkong*		1	2	3
Manihot glaziovii Muell	Euphorbiaceae	*Singkong karet*		33		33
Microstegium vimineum (Trin.) A.Camus	Poaceae	*Rumput pengepakan*	127			127
Mikania micrantha Kunth	Asteraceae	*Sambung rambat*			56	56
Mimosa pudica L.	Fabaceae	*Putri malu*	52	38		90
Momordica charantia L.	Cucurbitaceae	*Pare*			15	15
Moringa oleifera Lam.	Moringaceae	*Kelor*	9			9
Musa paradisiaca L.	Musaceae	*Pisang*		7		7
Oplismenus hirtellus (L.) P.Beauv.	Poaceae	*Rumput keranjang*	53			53
Ottochloa nodosa (Kunth) Dandy	Poaceae	*Rumput sarang buaya*		81		81
Oxalis barrelieri L.	Oxalidaceae	*Belimbing tanah*	16	3		19
Pennisetum purpureum Schumach.	Poaceae	*Rumput gajah*		8	8	16
Peperomia pellucida (L.) *Kunth*	Piperaceae	*Daun suruhan*			2	2
Phyllanthus niruri L.	Phyllantaceae	*Meniran hijau*	61			61
Physalis angulata L.	Solanaceae	*Ciplukan*		2		2
Pilea pumila (L.) A.Gray	Urticaceae	*Clearweed*		21		21
Pteris vittata L.	Adiantaceae	*Pakis rem cina*	12			12
Richardia scabra L.	Rubiaceae	*Semanggi meksiko*		137		137
Rosa multiflora L.	Rosaceae	*Mawar rambler*		1		1
Ruellia angustifolia Sw.	Acanthaceae	*Kencana ungu*		7	8	15
Ruellia tuberosa L.	Acanthaceae	*Pletekan*		6		6
Sauropus androgynus (L.) Merr.	Phyllanthaceae	*Katuk*			4	4
Senna siamea (Lam.) H.S.Irwin & Barneby	Fabaceae	*Johar*		3		3
Spigelia anthelmia L.	Loganiaceae	*Kemangi cina*	13			13
Swietenia macrophylla G.King	Meliaceae	*Mahoni*			2	2
Synedrella nodiflora (L.) Gaertn.	Asteraceae	*Jotang kuda*		70	77	147
Syzygium polyanthum (Wight) Walp.	Myrthaceae	*Salam*			4	4
Tectona grandis L.f.	Lamiaceae	*Jati*	2			2
Tradescantia fluminensis Vell.	Commelinaceae	*Telinga kera*	10			10
Urena lobata L.	Malvaceae	*Pulutan*	11			11
Zea mays L.	Poaceae	*Jagung*		7		7
Zingiber zerumbet (L.) Roscoe ex Sm.	Zingiberaceae	*Lempuyang*	8			8
Total			**532**	**716**	**246**	**1494**
Sapling and small woody plants						
Bambusa blumeana Schult.f.	Poaceae	*Bambu duri*		79	75	154
Baptisia australis (L.) R.Br.	Fabaceae	*Nila biru*	10			10
Capsium frutescens L.	Solanaceae	*Cabai*		1		1
Citrus hystrix DC.	Rutaceae	*Jeruk purut*			1	1
Curcuma longa L	Zingiberaceae	*Kunyit*		14		14

Cyperus rotundus L.	Cyperaceae	*Rumput rotundus*		40		40
Dimocarpus longan Lour.	Sapindaceae	*Kelengkeng*			1	1
Ficus hispida L.fil.	Moraceae	*Luwingan*	1			1
Ficus septica Burm.fil.	Moraceae	*Awar-awar*	2			2
Gynura divaricata (L.) DC.	Asteraceae	*Daun dewa*	1			1
Hibiscus similis Bl.	Malvaceae	*Waru tisuk*		4		4
Laportea decumana (Roxb.) Wedd.	Urticaceae	*Pohon gatal*		6		6
Leucaena leucocephala (Lam.) de Wit	Fabaceae	*Petai cina*		36	4	40
Mangifera indica L.	Anacardiaceae	*Mangga*			3	3
Manihot glaziovii Muell	Euphorbiaceae	*Singkong karet*		3		3
Mitragyna speciosa Korth.	Rubiaceae	*Kratom*	2			2
Moringa oleifera Lam.	Moringaceae	*Kelor*	10		6	16
Muntingia calabura L.	Muntingiaceae	*Kersen*	1			1
Parkia speciosa Hassk.	Fabaceae	*Mlanding*			1	1
Pisum sativum L.	Fabaceae	*Kacang kapri*			2	2
Pleurolobus gangeticus (L.) J.St.-Hil. ex H.Ohashi & K.Ohashi	Fabaceae	*Daun bulu ayam*	11			11
Rosa multiflora L.	Rosaceae	*Mawar*			1	1
Saccharum spontaneum L.	Poaceae	*Rumput gelagah*		17		17
Sauropus androgynus (L.) Merr.	Phyllanthaceae	*Katuk*			4	4
Schizolobium parahyba (Vell.) S.F.Blake	Fabaceae	*Pakis brazil*		5		5
Sida rhombifolia L.	Malvaceae	*Seleguri*	2			2
Swietenia mahagoni (L.) Jacq.	Meliaceae	*Mahoni*		2		2
Syzygium polyanthum (Wight) Walp.	Myrtaceae	*Salam*			1	1
Tectona grandis L.f.	Lamiaceae	*Jati*		11	2	13
Vernonia amygdalina Delile	Asteraceae	*Daun afrika*	5			5
Wrightia pubescens R.Br.	Apocynaceae	*Bentawas*			1	1
Ziziphus mauritiana Lam.	Rhamnaceae	*Bidara*	5			5
Total			**50**	**218**	**102**	**370**

Note: UP: Upstream (Giriwono Village, Wonogiri District), MD: Middlestream (Sidowarno Village, Klaten District), DN: Downstream (Gadingan Village, Sukoharjo District)

Table 2. Shannon Wiener Diversity index of undergrowth in the riparian zone of Upper Bengawan Solo River, Central Java, Indonesia

Station	H'	Category
Upstream (Wonogiri)	2.707	Medium
Midstream (Klaten)	2.742	Medium
Downstream (Sukoharjo)	2.488	Medium

Important Value Index (IVI)

Seedlings and herbaceous plants

Plants exhibiting the highest IVI values at the seedling level play significant roles in the ecosystem dynamics. *Chromolaena odorata*, belonging to the Asteraceae family and locally known as *balakasida*, stands out with an IVI value of 15.56% (Table 3). This species demonstrates its ecological importance with a total of 146 individuals dispersed across five out of the fifteen existing plots. Following are *Synedrella nodiflora* and *Cyperus rotundus*, with IVI values of 13.74% and 13.70%, respectively. *S. nodiflora*, also a member of the Asteraceae family known as *jotang kuda* locally, and *C. rotundus*, part of the Cyperaceae family with the local name *rumput teki*, contribute significantly to the vegetation composition and structure. In another study in the Siwaluh River, species with the highest IVI was *Kerivoula africana* in which this species is known to thrive in habitats characterized by fertile soil with a high clay content. *K. africana* shows extraordinary resistance to dry conditions and can thrive in various heights ranging from 50 meters above sea level to 800 meters above sea level (Pramadaningtyas et al. 2023).

It's noteworthy that both the first and second highest IVI values originate from the Asteraceae family, renowned for its high diversity and extensive distribution within the Plant Kingdom. This underscores the ecological prominence of this family in shaping terrestrial ecosystems (Azzaroiha et al. 2022). Despite their significance, certain plant species exhibit notably smaller IVI values, indicating their limited presence and impact within the studied area. *Carica papaya* and *Amaranthus spinosus*, for instance, possess IVI values as low as 1.02% (Table 3). These plants are represented by only one individual each across the entire plot, reflecting their minimal contribution to the overall vegetation dynamics.

Saplings and shrubs

The highest IVI value recorded was *B. blumeana*, a member of the Poaceae family locally known as *pring ori*, reaching 47.74% (Table 4). *B. blumeana* can be used to eradicate certain species of pathogenic bacteria and fungi using minimum inhibitory concentrations via the agar well diffusion method (Saducos 2022). This species dominated the plots with 157 individuals spread across the three stations, indicating its considerable ecological importance.

Table 3. Frequency (F), Relative Frequency (RF), Density (D), Relative Density Species (RDi) and Important Value Index (IVI) of seedlings and herbaceous plants

Scientific name	Family	Local name	D	RDi (%)	F	RF (%)	IVI (%)
Alpinia galanga (L.) Willd.	Zingiberaceae	*Lengkuas*	0.100	0.45	0.133	1.89	2.33
Amaranthus spinosus L.	Amaranthaceae	*Bayam duri*	0.017	0.07	0.067	0.94	1.02
Amorphophallus oncophyllus Prain ex Hook.f.	Araceae	*Porang*	0.083	0.37	0.133	1.89	2.26
Anredera cordifolia (Ten.) Steenis	Basellaceae	*Binahong*	0.050	0.22	0.067	0.94	1.17
Bidens pilosa L.	Asteraceae	*Ketul*	0.283	1.26	0.067	0.94	2.21
Carica papaya L.	Caricaceae	*Pepaya*	0.017	0.07	0.067	0.94	1.02
Chromolaena odorata (L.) R.M.King & H.Rob.	Asteraceae	*Balakasida*	2.433	10.84	0.333	4.72	15.56
Colocasia esculenta (L.) Schott	Araceae	*Tales*	0.300	1.34	0.133	1.89	3.22
Curcuma longa L.	Zingiberaceae	*Kunyit*	0.150	0.67	0.200	2.83	3.50
Cyperus rotundus L.	Cyperaceae	*Rumput teki*	2.017	8.98	0.333	4.72	13.70
Dactyloctenium aegyptium (L.) Willd.	Poaceae	-	0.167	0.74	0.067	0.94	1.69
Dimocarpus longan Lour.	Sapindaceae	*Kelengkeng*	0.017	0.07	0.133	1.89	1.96
Dioscorea hispida Dennst.	Dioscoreaceae	*Gadung tikus*	0.133	0.59	0.133	1.89	2.48
Elephantopus scaber L.	Asteraceae	*Tapak liman*	0.350	1.56	0.067	0.94	2.50
Euphorbia heterophylla Desf.	Euphorbiaceae	*Patik emas*	0.100	0.45	0.067	0.94	1.39
Euphorbia hirta L.	Euphorbiaceae	*Patik emas*	0.183	0.82	0.067	0.94	1.76
*Ficus septica Burm.*fil.	Moraceae	*Awar-awar*	0.183	0.82	0.267	3.77	4.59
Hedera helix L.	Asteraceae	*Patik emas*	0.100	0.45	0.133	1.89	2.33
Leea indica (Burm.fil.) Merr.	Vitaceae	*Girang merah*	0.050	0.22	0.067	0.94	1.17
Leucaena leucocephala (Lam.) de Wit	Fabaceae	*Lamtoro*	0.350	1.56	0.333	4.72	6.28
Ludwigia palustris (L) Elliott	Onagraceae	*Krokot air*	1.400	6.24	0.133	1.89	8.12
Macroptilium atropurpureum (DC.) Urb.	Fabaceae	*Siratro*	0.133	0.59	0.067	0.94	1.54
Manihot esculenta Crantz	Euphorbiaceae	*Singkong*	0.050	0.22	0.133	1.89	2.11
Manihot glaziovii Muell	Euphorbiaceae	*Singkong karet*	0.550	2.45	0.267	3.77	6.22
Microstegium vimineum (Trin.) A.Camus	Poaceae	*Rumput pengepakan*	2.117	9.43	0.133	1.89	11.32
Mikania micrantha Kunth	Asteraceae	*Sambung rambat*	0.933	4.16	0.133	1.89	6.04
Mimosa pudica L.	Fabaceae	*Putri malu*	1.333	5.94	0.200	2.83	8.77
Momordica charantia L.	Cucurbitaceae	*Pare*	0.250	1.11	0.133	1.89	3.00
Moringa oleifera Lam.	Moringaceae	*Kelor*	0.150	0.67	0.200	2.83	3.50
Musa paradisiaca L.	Musaceae	*Pisang*	0.117	0.52	0.133	1.89	2.41
Oplismenus hirtellus (L.) P.Beauv.	Poaceae	*Rumput keranjang*	0.883	3.93	0.067	0.94	4.88
Ottochloa nodosa (Kunth) Dandy	Poaceae	*Rumput sarang buaya*	1.350	6.01	0.067	0.94	6.96
Oxalis barrelieri L.	Oxalidaceae	*Belimbing tanah*	0.317	1.41	0.200	2.83	4.24
Pennisetum purpureum Schumach.	Poaceae	*Rumput gajah*	0.267	1.19	0.067	0.94	2.13
Peperomia pellucida (L.) Kunth	Piperaceae	*Suruh*	0.033	0.15	0.067	0.94	1.09
Phyllanthus niruri L.	Phyllanthaceae	*Meniran hijau*	1.017	4.53	0.267	3.77	8.30
Physalis angulata L.	Solanaceae	*Ciplukan*	0.033	0.15	0.067	0.94	1.09
Pilea pumila (L.) A.Gray	Urticaceae	*Pilea pumila*	0.350	1.56	0.067	0.94	2.50
Pteris vittata L.	Pteridaceae	*Paku*	0.200	0.89	0.133	1.89	2.78
Rosa multiflora L.	Rosaceae	*Mawar*	0.017	0.07	0.133	1.89	1.96
Ruellia angustifolia Sw.	Acanthaceae	*Kencana ungu*	0.250	1.11	0.133	1.89	3.00
Ruellia tuberosa L.	Acanthaceae	*Pletekan*	0.100	0.45	0.067	0.94	1.39
Sauropus androgynus (L.) Merr.	Phyllanthaceae	*Katuk*	0.067	0.30	0.133	1.89	2.18
Senna siamea (Lam.) H.S.Irwin & Barneby	Fabaceae	*Johar*	0.050	0.22	0.067	0.94	1.17
Spigelia anthelmia L.	Loganiaceae	*Kemangi cina*	0.217	0.97	0.067	0.94	1.91
Swietenia macrophylla G.King	Meliaceae	*Mahoni*	0.033	0.15	0.067	0.94	1.09
Synedrella nodiflora (L.) Gaertn.	Asteraceae	*Jotang kuda*	2.450	10.91	0.200	2.83	13.74
Syzygium polyanthum (Wight) Walp.	Myrtaceae	*Salam*	0.067	0.30	0.133	1.89	2.18
Tectona grandis L.f.	Lamiaceae	*Jati*	0.033	0.15	0.333	4.72	4.87
Tradescantia fluminensis Vell.	Comellinaceae	*Telinga kera*	0.167	0.74	0.067	0.94	1.69
Urena lobata L.	Malvaceae	*Pulutan*	0.183	0.82	0.067	0.94	1.76
Zea mays L.	Poaceae	*Jagung*	0.117	0.52	0.067	0.94	1.46
Zingiber zerumbet (L.) Roscoe ex Sm.	Zingiberaceae	*Lempuyang*	0.133	0.59	0.133	1.89	2.48

Table 4. Frequency (F), Relative Frequency (RF), Density (D), Relative Density Species (RDi) and Important Value Index (IVI) of saplings and shrubs

Scientific name	Family	Local name	D	RDi (%)	F	RF (%)	IVI (%)
Bambusa blumeana Schult.f.	Poaceae	*Pring ori*	0.411	41.62	0.200	6.12	47.74
Baptisia australis (L.) R.Br.	Fabaceae	*Nila biru*	0.027	2.70	0.067	2.04	4.74
Capsium frutescens L.	Solanaceae	*Cabai*	0.003	0.27	0.067	2.04	2.31
Citrus hystrix DC.	Rutaceae	*Jeruk purut*	0.003	0.27	0.067	2.04	2.31
Curcuma longa L	Zingiberaceae	*Kunyit*	0.037	3.78	0.200	6.12	9.91
Cyperus rotundus L.	Cyperaceae	*Rumput teki*	0.107	10.81	0.067	2.04	12.85
Dimocarpus longan Lour.	Sapindaceae	*Kelengkeng*	0.003	0.27	0.067	2.04	2.31
Ficus hispida L.fil.	Moraceae	*Luwingan*	0.003	0.27	0.067	2.04	2.31
Ficus septica Burm.fil.	Moraceae	*Awar-awar*	0.005	0.54	0.067	2.04	2.58
Gynura divaricata (L.) DC.	Asteraceae	*Daun dewa*	0.003	0.27	0.067	2.04	2.31
Hibiscus similis Bl.	Malvaceae	*Waru tisuk*	0.011	1.08	0.067	2.04	3.12
Laportea decumana (Roxb.) Wedd.	Urticaceae	*Daun gatal*	0.016	1.62	0.067	2.04	3.66
Leucaena leucocephala (Lam.) de Wit	Fabaceae	*Mandingan*	0.107	10.81	0.267	8.16	18.97
Mangifera indica L.	Anacardiaceae	*Mangga*	0.008	0.81	0.200	6.12	6.93
Manihot glaziovii Muell	Euphorbiaceae	*Singkong karet*	0.008	0.81	0.133	4.08	4.89
Mitragyna speciosa Korth.	Rubiaceae	*Kratom*	0.005	0.54	0.067	2.04	2.58
Moringa oleifera Lam.	Moringaceae	*Kelor*	0.043	4.32	0.133	4.08	8.41
Muntingia calabura L.	Muntingiaceae	*Kersen*	0.003	0.27	0.067	2.04	2.31
Parkia speciosa Hassk.	Fabaceae	*Mlanding*	0.003	0.27	0.067	2.04	2.31
Pisum sativum L.	Fabaceae	*Kacang kapri*	0.005	0.54	0.067	2.04	2.58
Pleurolobus gangeticus (L.) J.St.-Hil. ex H.Ohashi & K.Ohashi	Fabaceae	*Daun picah*	0.029	2.97	0.200	6.12	9.10
Rosa multiflora L.	Rosaceae	*Mawar*	0.003	0.27	0.133	4.08	4.35
Saccharum spontaneum L.	Poaceae	*Rumput gelagah*	0.045	4.59	0.067	2.04	6.64
Sauropus androgynus (L.) Merr.	Phyllanthaceae	*Katuk*	0.011	1.08	0.067	2.04	3.12
Schizolobium parahyba (Vell.) S.F.Blake	Fabaceae	*Pakis brazil*	0.013	1.35	0.067	2.04	3.39
Sida rhombifolia L.	Malvaceae	*Seleguri*	0.005	0.54	0.067	2.04	2.58
Swietenia mahagoni (L.) Jacq.	Mileaceae	*Mahoni*	0.005	0.54	0.067	2.04	2.58
Syzygium polyanthum (Wight) Walp.	Myrtaceae	*Salam*	0.003	0.27	0.067	2.04	2.31
Tectona grandis L.f.	Lamiaceae	*Jati*	0.035	3.51	0.267	8.16	11.68
Vernonia amygdalina Delile	Asteraceae	*Daun afrika*	0.013	1.35	0.067	2.04	3.39
Wrightia pubescens R.Br.	Apocynaceae	*Bentawas*	0.003	0.27	0.067	2.04	2.31
Ziziphus mauritiana Lam.	Rhamnaceae	*Bidara*	0.013	1.35	0.067	2.04	3.39

Following was *Leucaena leucocephala*, a Fabaceae species known as *mandingan* locally, exhibited an IVI value of 18.97%, highlighting its role in the ecosystem. *L. leucocephala* has a common biological property that occurs when allelopathic plants produce allelochemicals that have a positive or negative impact on the growth, survival, development, and reproduction of other nearby plant species in the same ecosystem (Men 2021). Similarly, *C. rotundus*, belonging to the Cyperaceae family and commonly referred to as *rumput teki*, displayed an IVI value of 12.85%, signifying its contribution to the vegetation dynamics. *C. rotundus* is a species that is widely used in traditional medicine in various parts of the world, especially in Asian countries such as India and Pakistan. The anticancer potential of this species has been reported in the literature, suggesting that its chemical compounds may be effective against various types of tumor cells (Bezerra and Pinheiro 2022).

The IVI parameter serves as a crucial indicator of a species' ecological significance, with a threshold of IVI>15% suggesting a substantial role within the ecosystem (Irwansyah et al. 2019). However, some species showed notably lower IVI values, indicating their lesser influence on the surrounding vegetation. For instance, a collective IVI value of 2.31% was recorded for nine plant species, including *Capsicum frutescens*, *Citrus hystrix*, *Dimocarpus longan*, *Ficus hispida*, *Gynura divaricata*, *Muntingia calabura*, *Parkia speciosa*, *Syzygium polyanthum*, and *Wrightia pubescens*. Despite their presence, these species only accounted for one individual each across the entire plot, indicating their limited ecological impact within the studied area. *Capsicum* is a very important plant crop and is widely consumed throughout the world because it is an important source of several nutritional and dietary compounds including capsaicinoids, vitamins A and C, pigments, minerals and essential oils. Among the five *Capsicum* spp. cultivated, *C. annuum* has received maximum attention from researchers (Jaiswal et al. 2021). *C. hystrix* contains phytochemical compounds, including β-pinene, sabinene, citronellal, and citronellol; and the extract shows potential antidiabetic, antihyperlipidemic and anti-obesity activity, as well as preventing the development of hypertension (Siti et al. 2022).

Abiotic factors

Abiotic factors are non-biological components that make up an ecosystem and significantly affect the lives of organisms (Rahmawanto et al. 2015). Abiotic factor data from the three stations showed variations that can affect the distribution and adaptation of organisms in each location (Table 5). Such variations related to environmental and geographic factors such as altitude, soil type, land use and vegetation (Xie et al. 2019). The higher elevation in the upstream (Wonogiri District) caused higher ground temperatures, while soil pH in the midstream (Klaten District) was more acidic due to local factors. The highest air humidity was recorded in the midstream, possibly due to denser vegetation, while the downstream (Sukoharjo District) had high humidity due to its proximity to the river. Downstream soil temperature was lower due to higher soil moisture and thicker vegetation which provide shade. These factors collectively influence the physical and chemical conditions at each research station.

Abiotic factors also affect plants, i.e. light intensity affects photosynthesis in plants, pH determines the organisms that can live in the environment, air humidity affects water evaporation and transpiration in plants, temperature affects metabolism, reproduction, and distribution of organisms, and altitude or slope of the land affects temperature, air pressure, and oxygen availability. The differences in abiotic factors across the three stations create unique and diverse habitats, which in turn support different communities of organisms. Understanding the variation and influence of abiotic factors is essential for studying the ecology and distribution of organisms in different ecosystems.

Potential utilization of undergrowth plants

Lower plants show numerous potentials of utilization (Zaki et al. 2022) as shown in Table 6. It can be seen that the dominance of the potential utilization of lower plants in the research location is for medicinal purposes. For example, *Musa paradisiaca* has the potential to control blood pressure and improve digestion (Sirappa 2021) as well as *P. gangeticus* (Mohan et al. 2023). The utilization of lower plants as medicines has been carried out for generations (Rambey et al. 2024). There are also species that can be used as animal feed, including *Macroptilium atropurpureum* (Andini 2022) and *Pilea pumila* (Yang et al. 2021). Other potential uses are for ornamental plants, food ingredients, and others. This potential provides benefits to the community both from use value or economic value (Wahidah et al. 2022).

Table 5. Abiotic factors in three stations in the riparian zone of Upper Bengawan Solo River, Central Java, Indonesia

Station	Altitude (masl)	pH		Humidity (%)	Temperature (°C)	
		Water	Soil		Air	Soil
Upstream (Wonogiri)	122	7.2	7	60.6	30.6	32
Midstream (Klaten)	88	7.2	5.5	72.3	29.6	29
Downstream (Sukoharjo)	82	7.7	7	70	30.6	27.2

Table 6. Potential utilization of undergrowth plants in the riparian zone of Upper Bengawan Solo River, Central Java, Indonesia

Species	Local name	Utilization
Alpinia galanga (L.) Willd.	*Lengkuas*	As a natural fungicide (Cahyaningrum et al. 2023)
Amaranthus spinosus L.	*Bayam duri*	Wound healing in incision (Nasution 2018)
Amorphophallus oncophyllus Prain ex Hook.f.	*Porang*	Food, antioxidant and antibacterial (Utaminingsih and Muhtadi 2021)
Anredera cordifolia (Ten.) Steenis	*Binahong*	Growth inhibition of *E. coli* ATCC 35216 bacteria (Mamangkey et al. 2022)
Baptisia australis (L.) R.Br.	*Nila biru*	Effective for multiple shoot induction (Padmanabhan et al. 2017)
Bambusa blumeana Schult.f.	*Pring ori*	Making charcoal (Adawi et al. 2021)
Bidens pilosa L.	*Ketul*	Medication for malaria, diabetes mellitus, and inflammation (Silalahi et al. 2021)
Capsium frutescens L.	*Cabai*	Food, anti-inflammatory (Ismail et al. 2022)
Carica papaya L.	*Pepaya*	Food, increase milk production (Sebayang 2020)
Chromolaena odorata (L.) R.M.King & H.Rob.	*Balakasida*	Healing cut wounds (Zahira 2023)
Citrus hystrix DC.	*Jeruk purut*	Overcoming body fatigue and weakness after a serious illness (Karlina and Nasution 2022)
*Colocasia esculenta (*L.) Schott	*Tales*	Accelerates healing of contaminated wounds (Ristanti et al. 2021)
Curcuma longa L.	*Kunyit*	Antioxidants (Cahnia et al. 2022)
Cyperus rotundus L.	*Rumput teki*	Diarrhea, diabetes, pyrosis, inflammation, and malaria medication (Kamala et al. 2018)
Dactyloctenium aegyptium (L.) Willd.	*Tapak jalak*	Animal feed (Janbaz and Saqib 2015)
Dimocarpus longan Lour.	*Kelengkeng*	Food, lower uric acid levels (Asrimi 2023)
Dioscorea hispida Dennst.	*Gadung tikus*	Improves digestive tract health (Setiarto 2017)
Elephantopus scaber L.	*Tapak liman*	Antimicrobial (Nonci et al. 2014)
Euphorbia heterophylla Desf.	*Patik emas*	Laxatives (Somadayo 2015)
Euphorbia hirta L.	*Patik kebo*	Medicinal plants, anti-inflammatory (Komarudin et al. 2023)

Ficus hispida L.fil.	*Luwingan*	Medicinal plants (Fitria et al. 2021)
Ficus septica Burm.fil.	*Awar-awar*	Anti-inflammatory (Arief et al. 2018)
Gynura divaricata (L.) DC.	*Daun dewa*	Anti-inflammatory (Aprilliani et al. 2021)
Hedera helix L.	*Daun ivi*	Natural antioxidants (Candraningtyas et al. 2023)
Hibiscus similis Bl.	*Waru tisuk*	Antioxidants (Syahputra 2022)
Laportea decumana (Roxb.) Wedd.	*Pohon gatal*	Pain relief (Wailegi et al. 2024)
Leea indica (Burm.fil.) Merr.	*Girang merah*	Natural dyes (Astuti and Widihastuti 2022)
Leucaena leucocephala (Lam.) de Wit	*Lamtoro*	Medicinal plants, anti-inflammatory, antioxidant (Sudirman et al. 2023)
Ludwigia palustris (L.) Elliott	*Daun buang-buang*	Acne medication (Indayani 2023)
Macroptilium atropurpureum (DC.) Urb.	*Siratro*	Superior feed for livestock (Andini 2022)
Mangifera indica L.	*Mangga*	Food, anthelmintic (Afrian 2021)
Manihot esculenta Crantz	*Singkong*	Food, antioxidant, may increase appetite (Apriyani et al. 2022)
Manihot glaziovii Muell	*Singkong karet*	Raw materials for making ethanol (Aznury and Rezky 2020)
Microstegium vimineum (Trin.) A.Camus	*Rumput pengepakan*	As a weed (Logan 2021)
Mikania micrantha Kunth	*Sambung rambat*	Antitumor, cytotoxic, and analgesic (Amelia et al. 2020)
Mimosa pudica L.	*Putri malu*	Anti-inflammatory (Arfiandi et al. 2022)
Mitragyna speciosa Korth.	*Kratom*	Diarrhea, pain relief, cough, and hypertension medications (Raini 2017)
Momordica charantia L.	*Pare*	Acne medication and skin infection medication (Yusuf et al. 2022)
Moringa oleifera Lam.	*Kelor*	Hypoglycemic drugs, inflammation, bacterial/viral infections and cancer (Nurmalasari et al. 2021)
Muntingia calabura L.	*Kersen*	Boosts the immune system (Bamasri 2021)
Musa paradisiaca L.	*Pisang*	Food, controls blood pressure, improves digestion (Sirappa 2021)
Oplismenus hirtellus (L.) P.Beauv.	*Rumput keranjang*	Animal feed (Rachmalia et al. 2023)
Ottochloa nodosa (Kunth) Dandy	*Rumput sarang buaya*	Animal feed (Grinnell et al. 2022)
Oxalis barrelieri L.	*Belimbing tanah*	Antibacterial (Pazra et al. 2022)
Parkia speciosa Hassk.	*Mlandingan*	Medicine for liver disease, edema, and kidney inflammation (Verawaty and Novel 2018)
Pennisetum purpureum Schumach.	*Rumput gajah*	Animal feed (Sugandi et al. 2016)
Peperomia pellucida (L.) Kunth	*Daun suruhan*	Remedy for abscesses, boils, acne, and skin inflammation (Pratiwi et al. 2021)
Phyllanthus niruri L.	*Meniran hijau*	Traditional medicine (Ayuningsih 2021)
Physalis angulata L.	*Ciplukan*	Antifungal, diabetes, and influenza medication (Lau and Herman 2020)
Pilea pumila (L.) A.Gray	*Pilea*	Animal feed (Yang et al. 2021)
Pisum sativum L.	*Kacang kapri*	Food ingredients (Prasetyowati et al. 2023)
Pleurolobus gangeticus (L.) J.St.-Hil. ex H.Ohashi & K.Ohashi	*Daun picah*	Medicinal plants (Mohan et al. 2023)
Pteris vittata L.	*Pakis rem cina*	Houseplants (Efendi and Iswahyudi 2020)
Rosa multiflora L.	*Mawar*	Houseplants (Muzaki et al. 2021)
Ruellia angustifolia Sw.	*Kencana ungu*	Houseplants and antibacterial plants (Wati and Wakhidah 2023)
Ruellia tuberosa L.	*Pletekan*	Prevent diabetes, antioxidant (Pham et al. 2022)
Saccharum spontaneum L.	*Rumput gelagah*	Natural source of sugar (Zhang et al. 2022)
Sauropus androgynus (L.) Merr.	*Katuk*	Treat acid reflux (Zhang et al. 2020)
Schizolobium parahyba (Vell.) S.F.Blake	*Pakis brazil*	An effective adsorbent for treating drug containing wastewater (de O Salomón et al. 2022)
Senna siamea (Lam.) H.S.Irwin & Barneby	*Johar*	Antimicrobial (Kambale et al. 2020)
Sida rhombifolia L.	*Seleguri*	Natural antioxidants (Xu et al. 2022)
Spigelia anthelmia L.	*Kemangi cina*	Plenty of calcium to strengthen bones and teeth (Awotedu et al. 2020)
Swietenia macrophylla G.King	*Mahoni*	Midges (Telrandhe et al. 2022)
Swietenia mahagoni (L.) Jacq.	*Mahoni*	Antidiabetic (Sukardiman and Ervina 2020)
Synedrella nodiflora (L.) Gaertn.	*Jotang kuda*	Antimalarials (Chaniad et al. 2021)
Syzygium polyanthum (Wight) Walp.	*Daun salam*	Antibacterial (Nordin et al. 2019)
Tectona grandis L.f.	*Jati*	Building materials (Vyas et al. 2019)
Tradescantia fluminensis Vell.	*Telinga kera*	Phenol component (Míguez et al. 2022)
Urena lobata L.	*Pulutan*	Anti-inflammatory (Wahyuningsih et al. 2022)
Vernonia amygdalina Delile	*Daun afrika*	Antibacterial (Olusola-Makinde et al. 2021)
Wrightia pubescens R.Br.	*Bentawas*	Boosts metabolism (Karim et al. 2023)
Zea mays L.	*Jagung*	Food ingredients (Rizwan et al. 2019)
Zingiber zerumbet (L.) Roscoe ex Sm.	*Lempuyang*	Spices (Chavan and Dey 2023)
Ziziphus mauritiana Lam.	*Daun bidara*	Antibacterial (Jain et al. 2019)

In conclusion, the study documented 78 species from 38 family of undergrowth in the riparian zones of Upper Bengawan Solo River from three sites. The vegetation Diversity Index (H') is included in the medium category. Plant with the highest Index of Important Value (IVI) for seedlings and herbaceous plants was *C. odorata* with 15.56%, while that of saplings and shrubs was the *B. blumeana* with 47.74%. The higher elevation in the upstream (Wonogiri District) led to higher soil temperature, while the midstream (Klaten District) had a more acidic soil pH and the highest air humidity. In the downstream (Sukoharjo District), high humidity due to proximity to the river, led to lower soil temperatures. Undergrowth vegetation along the Bengawan Solo River also has diverse potential with the dominance of medicinal uses, and some plants are used as animal feed, ornamental plants, food ingredients, and others.

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