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Analysis of riparian vegetation in the Siwaluh River, Karanganyar District, Central Java, Indonesia

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Abstract. *Pramadaningtyas PS, Chandrasari N, Izdihar RS, Iqbal WM, Cahyaningsih AP, Setyawan AD. 2023. Analysis of riparian vegetation in the Siwaluh River, Karanganyar District, Central Java, Indonesia. Intl J Bonorowo Wetlands 13: 45-56.* This research was conducted in the Siwaluh River Basin region, Karanganyar District, Central Java, Indonesia. Land conversion into residential areas has lowered infiltration capacity, particularly in the Siwaluh River riparian vegetation, in the form of reduced or even lost vegetation that should serve as a water catchment area and habitat for riparian plants. The research was done to analyze riparian vegetation in the Siwaluh River to collect data for the conservation of the riparian zone, which plays a vital role in ecology and the ecosystem. Calculating the maximum IVI value and the existence of plant species from the diversity of riparian vegetation could determine the dominant vegetation type in a given area. The quadratic plot method employed was used; square plots of 20mx20m for trees, 10mx10m for poles, 5mx5m for saplings, and 2mx2m for seedlings were established at each sampling location. After that, the vegetation investigation comprised density, dominance, frequency, Shannon-Wiener diversity index, and IVI. The survey identified 209 plant species; *Kigelia africana* dominated the highest IVI value in tree habitus. Practically, in each upstream, middle, and downstream location, *Bambusa* sp. dominated the highest IVI in the pole habitus, *Manihot esculenta* controlled the highest IVI in the sapling habitus, and *Ageratum conyzoides* dominated the seedling habitus. Variations in the diversity index (H') of tree, pole, sapling, and seedling habitus result from reduced or even disappearing vegetation due to land changes. Therefore, it changes the distribution pattern of riparian vegetation.

Keywords: Riparian, Siwaluh River, vegetation analysis

INTRODUCTION

A river naturally flows freshwater from a high place to the lower; it has an estuary in a bigger sea, lake, or river bordered on the right and left by boundaries (Pane and Suhelmi 2021). Upstream river currents are typically swifter than downstream. While the watershed is the flow of rainwater catchments limited by mountain ridges that will flow into the main river, these catchments are limited by mountain ridges. The watershed is vital for the river and its tributaries, according to Government Regulation No. 37 concerning Watershed Management. The watershed collects, stores, and channels rainwater to the oceans, lakes, and natural reservoirs. In addition, riparian is the transition zone between river habitats and terrestrial ecosystems. This riparian ecosystem is essential since it protects the river's surrounding living (Siahaan and Ai 2014). The riparian also comprises places inhabited by organisms that influence or are influenced by water bodies.

In the riparian zone, an assortment of plants grows. Moreover, riparian vegetation has unique morphological, physiological, and reproductive properties, making it easily adaptable to damp conditions and even capable of adjusting to flooding, settling, and abrasion (Naiman et al. 2005). Riparian vegetation ecosystems serve multiple purposes, including erosion control, as a sediment device to protect the surface of the environment, particularly to prevent rising water temperatures, aiding groundwater supplies, as a habitat for flora and fauna, as a development site, and as an aesthetic boundary for human settlements. Riparian vegetation has the function of regulating the flow of energy and nutrients. Riparian vegetation serves as a river defense against pollutants and a microclimate regulator. The existence of riparian vegetation influences the evolution of a river ecosystem (Ainy et al. 2018). Riparian vegetation also serves as a supporting ecosystem that plays a part in the carbon, oxygen, nitrogen, and water cycles. In addition, riparian vegetation can indicate environmental quality and contribute to preserving the cliffs' structural integrity (Mulyadi 2001).

Indonesia, after all, is experiencing a rise in population and development, leading to a heightened level of land use alteration (Handayani et al. 2020). As a result of this phenomenon, there is a decrease in the riparian zone's width, which subsequently reduces the riparian vegetation. Alterations in land use are anticipated to impact the caliber of riparian flora and water quality in rivers (Liu et al. 2019). The alteration in question has implications for riparian ecosystems, given their role in safeguarding and maintaining the riverine milieu (Kudubun et al. 2020).

Oktaviani and Yanuwiadi (2016) stated that riparian areas serve crucial functions and provide numerous benefits. However, these areas are increasingly vulnerable to threats from human activities that exploit them. Disposing of the household waste directly into aquatic systems can escalate the concentration of contaminants (Susanti 2015). The diminution of riparian vegetation is expected to affect ecological functions and riparian ecosystems' stability negatively (Singh et al. 2021). The reduction of riparian zones through the implementation of river streamlining, shortcuts, and embankment construction can lead to a decrease in riparian vegetation (Bando et al. 2016). Introducing invasive species poses several obstacles to eliminating or restricting riparian areas (Jones et al. 2022).

The Siwaluh River traverses Karanganyar District and is considered one of the lengthiest rivers in this area. The Siwaluh River exhibits a physical cross-sectional profile that deviates from its width and depth. The Siwaluh River, located in Karanganyar District, Indonesia, has been identified as a river that has been contaminated due to improper waste disposal practices. The river above spans roughly 37 kilometers, traversing six districts. Research on the riparian diversity of the Siwaluh River has not been previously conducted. Therefore, it is imperative to study the vegetation types to understand the formation of the vegetation community structure. The study aimed to examine the riparian vegetation in the Siwaluh River region, intending to gather data to support the conservation of the riparian zone in the Siwaluh River. This zone is known to have significant ecological and ecosystem. The study of vegetation was carried out by analyzing the growth rate of various trees, saplings, poles, and seedlings types. The parameters to be assessed are the Important Value Index (IVI) and the Species Diversity Index (H').

MATERIALS AND METHODS

Study area

The Siwaluh River, situated in the Karanganyar District of Central Java, Indonesia, is a hydrological unit that drains water and other resources from its surrounding areas. The river spans roughly 37 kilometers and traverses six sub-districts, specifically Karangpandan, Matesih, Karanganyar, Tasikmadu, Jaten, and Kebakkramat. The Siwaluh River's upstream region is in the Karangpandan Sub-district of the Karanganyar District, while its downstream region is in the Bengawan Solo River. The study was conducted at three locations within the Siwaluh River, specifically the upstream, middle, and downstream regions. The initial station, the upstream region, is in Gerdu Village (750 m asl) at geographical coordinates 07°38'24.4"S 111°05'59.8"E. Next, the second station, the central area, is situated in Bejen Village (185 m asl.) at geographical coordinates 7°35'39.9"S 110°57'10.2"E. Finally, the third station, the downstream area, is situated in Sroyo Village (80 m asl.) at geographical coordinates 7°31'16.2"S 110°52'57.0"E. The study was carried out in May 2022 (Figure 1).

Sampling technique

The study employed a purposive sampling technique, whereby participants were selected based on various factors to ensure they represented the entire population. Research data were collected at three stations, specifically the upstream, middle, and downstream areas. Subsequently, five observation plots were established at each station. Furthermore, abiotic variables were also measured, including altitude, light intensity, water pH, air humidity, air temperature, soil pH, and water temperature. Each plot consists of an area of 20 meters by 20 meters, divided into three sub-plots measuring 10 meters by 10 meters, 5 meters by 5 meters, and 2 meters by 2 meters, respectively. The study employs plots of varying sizes to collect vegetation samples. Specifically, tree vegetation samples are collected using plots measuring 20mx20m, and pole vegetation samples using 10mx10m plots. Then, sapling vegetation samples using 5mx5m plots and seedling vegetation samples using 2mx2m plots. The configuration of the applied vegetation analysis plot is depicted in Figure 2.

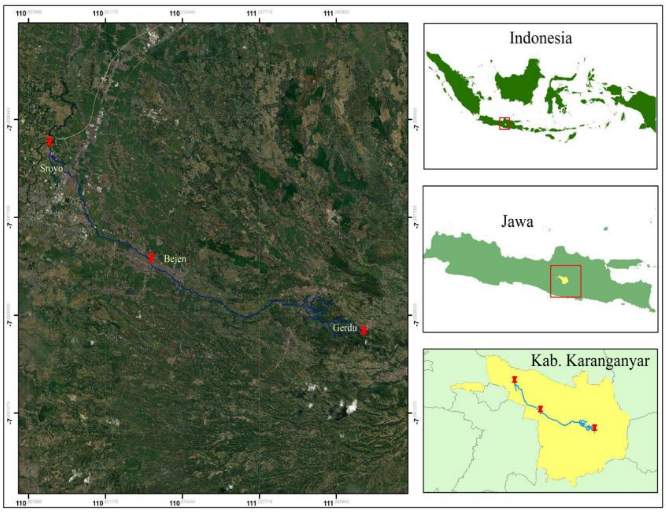

Figure 1. Map of the Siwaluh River research location, Karanganyar, Central Java, Indonesia

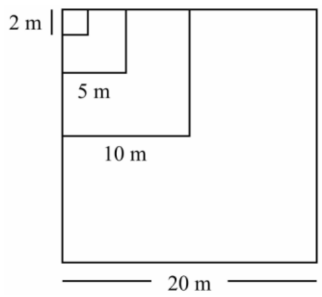

Figure 2. Vegetation analysis plot design

Data analysis

Identification data on tree species, poles, saplings, seedlings, and their number are recorded on a tally sheet. This study involved an analysis of the data about species density, frequency, dominance, Important Value Index (IVI), and Diversity Index (H'). Magurran (1988) stated that the Shannon-Wiener Index is suitable for measuring diversity due to its widespread usage and established conceptual framework. The level of species diversity in an ecosystem can be determined by the value of H', where a classification of low species diversity is assigned when H'<1, moderate species diversity is assigned when 1≤H'≤3, and high species diversity is assigned when H'>3.

$$H' = \sum_{i=1}^{s} (Pi)\ x\ (LnPi)$$

Where:
Pi : Σni/N
H': Shannon-Wiener Diversity Index
Pi : The number of individuals of a species / the total number of all species
Ni : The number of individuals of the i-th species
N : Total number of individuals

The formula developed by Soerianegara and Indrawan (1988) was utilized to calculate the species density, frequency, dominance, and Important Value Index (IVI). Fachrul (2007) has proposed a categorization scheme for IVI values, wherein values greater than 42.66 are classified as high, values ranging from 21.96 to 42.66 are classified as moderate, and values less than 21.96 are classified as low. The equations above encompass the following expressions:

(i) Density

$$Density\ (K) = \frac{\sum \text{Individual}}{\text{Sample plot area}}$$

$$Relative\ Type\ Density\ (KR) = \frac{\text{K of a type}}{\text{K of all type}} x100\%$$

(ii) Frequency

$$Frequency\ (F) = \frac{\sum \text{subplot where type found}}{\sum \text{subplot of all sample type}}$$

$$Relative\ Frequency\ (FR) = \frac{\text{F of a type}}{\text{F of all type}} x100\%$$

(iii) Dominance

$$Dominance\ (D) = \frac{\text{Base area of a type}}{\text{Sample plot area}}$$

$$Relative\ Dominance\ (RD) = \frac{\text{D of a type}}{\text{D of all type}} x100\%$$

(iv) Important Value Index
IVI of tree and pole: KR + FR + DR
IVI of sapling and seedling: KR + FR

RESULTS AND DISCUSSION

Species found

A total of 209 species of riparian vegetation were identified. The occurrence of a particular plant species within a given geographical region indicates its capacity to acclimate to the local ecosystem and withstand various ecological stress. A botanical survey in the Siwaluh River catchment area revealed various plant species exhibiting different growth forms, such as trees, poles, saplings, and seedlings. The study revealed that the number of species in the upstream area was 77, while the middle area exhibited a species composition of 86. A total of 99 species were identified in the downstream area based on the species composition analysis. The study revealed that the tree habitus comprised 15 species, while the pole habitus had 15. The sapling habitus exhibited a species composition of 25, while the seedling habitus displayed a species composition of 179.

Diversity index value (H')

The Importance Value Index (IVI) and the Diversity Index (H') characterize vegetation distribution across the upstream, middle, and downstream areas. The Shannon-Wiener diversity index, denoted as H', is a commonly employed metric for examining the level of diversity present within plant communities' local flora (Sun and Ren 2021). The present study reports on the diversity index of the Siwaluh river area, specifically for the upstream (3.78), middle (4.05), and downstream regions. (3.92). The findings for the middle region indicate a higher diversity index value of 4.05 (high category) compared to the upstream and downstream regions. The Siwaluh River Basin exhibits a notable diversity level owing to land use alterations within the middle region, situated in Bejen Village. The Siwaluh River Basin region is geographically significant due to its proximity to inhabited localities. The preservation of riverbanks by the local community is achieved through the avoidance of construction activities along the riverbanks and the implementation of vegetation planting measures in the surrounding areas. Cultivating Bamboo in the central region and adjacent riverbanks is a commendable measure in mitigating the potential flooding hazards. Bamboo trees can retain water during periods of high-intensity precipitation (Sholikhati et al. 2020).

Numerous species of *Ageratum conyzoides*, and *Synedrella nodiflora* are present in the upstream region. The local populace commonly considers them weeds due to their significant prevalence. In addition, the Siwaluh River's upstream region is in Gerdu Village, on Mount Lawu. The inherent beauty of the natural environment presents diverse tourist destinations capable of attracting visitors. Additionally, the pleasant climate contributes to the allure of these destinations, thereby generating specific desires and motivations, such as the desire to establish a permanent residence (settlement). Moreover, there is a growing demand for land to be utilized for agricultural purposes, as evidenced by the expanding rice fields and plantations located in the upstream region of the Siwaluh River Basin. The conversion of natural vegetation to agricultural land in the upstream region displaces the former by-crops such as rice, vegetables, and fruits. Sholikhati et al. (2020) suggest that the upstream area is a conservation zone. Therefore, it is recommended that individuals residing in this area prioritize planting trees with ecological benefits, such as bamboo trees, over other species. Revitalizing the upstream region is imperative, as any harm inflicted could adversely affect the downstream area. Noverma (2017) clarifies that bamboo is a plant that exhibits water conservation properties due to its capillary nature. Specifically, Bamboo stems can absorb water during flooding and retain water for extended periods during dry seasons.

The field inventory findings indicate that communities downstream prefer cultivation more than conservation plants to mitigate the likelihood of landslides and floods. The cultivated flora comprises *Carica papaya*, *Musa* sp., and *Leucaena leucocephala*, whereas the conservation vegetation in the lower region solely consists of *Bambusa* sp. and *Tectona grandis*. The prevalence of *palawija* crops (annual crops on dry land) and shrubbery characterizes in most terrain. Winandar (2015) stated that the Siwaluh River Basin is subject to water pollution from human land use activities. The current Water Pollution Control measures prioritize the industrial sector but fail to sufficiently identify pollution loads and analyze the capacity to manage such loads; as a result, the downstream portion of the Siwaluh River remains contaminated. As per Winandar's (2015) findings, the Maximum Daily Load (DTBP) value in the lower regions of the Siwaluh River surpasses the Pollution Load Carrying Capacity value for all parameters, with recorded values of 22.59 (TSS), 28.73 (BOD), and 68.16 (COD). The diversity of habitats in the upstream and downstream sectors is greater than in the middle. The downstream regions underwent significant land-use alterations, including manufacturing facilities and communal gardens. These changes led to a reduction or complete loss of vegetation, with only several species remaining, specifically *Colacasia* sp., *Manihot esculenta*, and *Albizia chinensis*, exhibiting the highest levels of presence. The river's lower region is a hydrological basin that receives water from the upper and middle reaches. As a result, the probability of landslides and floods is significantly elevated, particularly in periods of heavy precipitation (Say et al. 2021). The downstream region's riparian zones underwent notable land use alterations, surpassing those observed in the upstream and midstream regions. The Siwaluh River's downstream regions are utilized for several industrial products. For example, soap and ethyl alcohol factories and plantation land use; also serve as a final disposal site for the nearby community.

Table 1 shows the values of the H' examination for the three sites at high. In contrast, land utilization in the lower region is comparatively higher. As per the findings of Aswin et al. (2019), the uniformity of habitat conditions across the upstream, middle, and downstream station areas has resulted in the similarity of diversity index categories. The stable ecosystem of the Siwaluh River is indicated by the high diversity index observed in the three locations. This study was consistent with Ismaini et al.'s (2015) assertion a greater diversity index corresponds to increased ecosystem stability.

Important Value Index (IVI)

Tree-level Important Value Index (IVI)

The IVI metric demonstrates the significance of a given plant species and its contribution to the surrounding ecosystem. This IVI value is achieved by calculating the cumulative value of Relative Type Density (KR), Relative Frequency (RF), and Relative Dominance(RD) across the various stages of vegetation growth, including tree, pole, sapling, and seedling. The concept of relative density pertains to the quantification of the population of a plant community within a designated study area. On the other hand, relative frequency refers to the proportion of a particular species' absolute frequency to the overall frequency of all species present in the entirety of the study area. The frequency of occurrence of a particular species in its habitat can be inferred from its presence. According to the Important Value Index (IVI) analysis conducted in the Siwaluh River Basin area, it has been determined that *Kigelia africana* exhibits the highest IVI (135.63). The *K. africana* is an autochthonous plant species that thrive in the Siwaluh River region. The *K. africana* is known to thrive in habitats characterized by fertile soils that exhibit a high proportion of clay content. The *K. africana* exhibits remarkable resilience to arid conditions and can thrive across a range of elevations spanning from 50 meters above sea level to 800 meters above sea level. The diversity index of the upstream area is 1.010, indicating a moderate level of diversity. It is attributed to the prevalence of *K. africana* among the plant species in the area, as it is more frequently present than other tree species. The *K. africana* exhibits potential utilization value in the field of health medicine. As per the findings of Fauzan et al. (2020), the *K. africana* fruit comprises active constituents, including flavonoids, coumarins, naphthoquinones, and iridoids. Furthermore, the conservation value of riparian vegetation for the environment is noteworthy. Mukhlison (2015) reported that *Tectona grandis* exhibits an IVI value of 134.83 and possesses the capacity to sequester carbon dioxide (CO_2), while *Terminalia catappa* demonstrates a high IVI value of 74.83 and is capable of effectively absorbing lead (Pb). The plants can manage atmospheric contamination efficiently, particularly lead (Pb) and carbon dioxide (CO_2) particles that typically emanate from vehicular exhaust emissions. The *T. grandis* can thrive in regions characterized by a relatively brief dry spell and a considerable amount of solar radiation throughout the year. The litterfall process, wherein branches and broad leaves fall to the ground, gradually decomposes the soil, impeding other plant species' growth. The Important Value Index (IVI) calculation outcomes for tree species within the Siwaluh River Basin Area are sown in the following (Table 2).

Pole-level Important Value Index (IVI)

The pole vegetation in the River Basin is dominated by *Bambusa* sp., with an IVI of 173.72. Due to their roots, bamboo plants can maintain environmental balance from their ecological (Rathour et al. 2022). Bamboo's deep, wide, and robust roots help reinforce soil structure and prevent erosion (Huzaemah et al. 2016; Mentari et al. 2018). Riparian vegetation plays a crucial role in preserving the rivers' hydro morphology; however, it has been widely overlooked in most hydro morphological assessment methods (Tánago et al. 2021). Riparian ecosystems provide vital habitats for several species, but it is not easy to assess vegetation status over a vast region and extended period (Assal et al. 2021). The findings of calculating the Important Value Index (IVI) for the different types of poles in the Siwaluh River Basin are shown here (Table 3).

Table 1. Diversity index found in the Siwaluh River Basin Area, Karanganyar, Central Java, Indonesia

Station	H'	Category
Upstream	3.78	High
Middle	4.05	High
Downstream	3.92	High

Table 2. Important Value Index of tree species found in the Siwaluh River Basin area, Karanganyar, Central Java, Indonesia

Name	Family	Station	KR	FR	RD	IVI
Artocarpus heterophyllus	Moreceae	Upstream	25	25	30.15	80.15
Bourbon coffee	Rubiciae	Upstream	25	25	34.22	84.22
Kigelia africana	Bignoniaceae	Upstream	50	50	35.63	135.63
Artocarpus heterophyllus	Moreceae	Middle	7.69	7.69	11.86	27.25
Carica papaya	Caricaeae	Middle	7.69	7.69	7.68	23.07
Leucaena leucocephala	Fabaceae	Middle	7.69	7.69	8.00	23.38
Muntingia calabura	Muntingiaceae	Middle	15.38	15.38	10.74	41.51
Naphelium lappacum	Sapindaeae	Middle	7.69	7.69	11.67	27.05
Samanea saman	Fabaceae	Middle	7.69	7.69	7.53	22.91
Tectona grandis	Terminaliaceae	Middle	46.15	46.15	42.52	134.83
Catalpa bignonioides	Bignoniaceae	Downstream	22.22	22.22	18.98	63.42
Ceiba pentandra	Malvaceae	Downstream	11.11	11.11	6.17	28.39
Commiphora mukul	Burseraceae	Downstream	22.22	22.22	37.61	82.06
Otoba novogranatensis	Myristicaceae	Downstream	11.11	11.11	14.02	36.24
Tectona grandis	Terminaliaceae	Downstream	11.11	11.11	11.82	34.04
Terminalia catappa	Terminaliaceae	Downstream	22.22	22.22	30.38	74.83

Notes: KR: Relative Type Density, FR: Relative Frequency, RD: Relative Dominance, IVI: Important Value Index

Table 3. Important value index of the types of poles found in the Siwaluh River Basin area, Karanganyar, Central Java, Indonesia

Name	Family	Station	KR	FR	RD	IVI
Archidendron pauciflorum	Fabaceae	Upstream	7.14	7.14	6.97	21.25
Artocarpus heterophyllus	Moraceae	Upstream	14.29	14.29	19.60	48.17
Bambusa sp.	Poaceae	Upstream	17.86	17.86	11.05	46.76
Carica papaya	Caricaceae	Upstream	3.57	3.57	1.51	8.65
Cedrela montana	Meliceae	Upstream	7.14	7.14	19.69	55.40
Ficus sp.	Moraceae	Upstream	7.14	7.14	5.31	12.45
Kigelia africana	Bignoniaceae	Upstream	3.57	3.57	9.25	23.53
Leucaena leucocephala	Fabaceae	Upstream	7.14	7.14	6.24	20.53
Mangifera indica	Anacardiaceae	Upstream	3.57	3.57	5.48	12.63
Tectona grandis	Terminaliaceae	Upstream	14.29	14.29	13.31	41.88
Zanthoxylum ailanthoides	Poaceae	Upstream	3.57	3.57	1.60	8.75
Bambusa sp.	Poaceae	Middle	15.79	15.79	13.62	45.20
Carica papaya	Caricaceae	Middle	15.79	15.79	15.21	46.78
Leucaena leucocephala	Fabaceae	Middle	10.53	10.53	9.04	30.09
Samanea saman	Fabaceae	Middle	10.53	10.53	10.50	31.56
Tectona grandis	Terminaliaceae	Middle	47.37	47.37	51.63	146.37
Albizia chinensis	Fabaceae	Downstream	11.76	11.76	16.06	39.59
Bambusa sp.	Poaceae	Downstream	58.82	58.82	56.07	173.72
Leucaena leucocephala	Fabaceae	Downstream	23.53	23.53	20.55	67.60
Samanea saman	Fabaceae	Downstream	5.88	5.88	7.33	19.09

Notes: KR: Relative Type Density, FR: Relative Frequency, RD: Relative Dominance, IVI: Important Value Index

Sapling level Important Value Index (IVI)

The vegetation distribution at the sapling level in the upper, middle, and lower sections of the Siwaluh River, the proportion of KR (%) and FR (%), and the dominant sapling level vegetation were dominated by *Manihot esculenta*, *A. chinensis,* and *Colacasia* sp. These three species have relatively high-density ratings because they have the greatest number of individuals per unit area in a research location. Their presence at each research station is nearly identical, with the corresponding IVIs of the three species being 107.14, 70.97, and 68.97. The plant with the highest IVI is *M. esculenta* (107.14), which can be used as a vegetable ingredient with a high protein content or for others such as medicinal ingredients (Anwar et al. 2018); thus, many are planted purposely by locals and grow naturally near river flows and villages. The findings of calculating the Important Value Index (IVI) for saplings in the Siwaluh River Basin are displayed in (Table 4).

Seedling level Important Value Index (IVI).

The vegetation distribution at the seedling level in the upper, middle, and lower sections of the Siwaluh River river revealed that *A. conyzoides*, *S. halepense*, and cleavers had the largest percentages of KR, FR, and IVI, respectively. These three species have high IVI values because they have the greatest number of individuals per unit of research site area. The IVIs of the three species were, respectively, 21.48, 14.51, and 10.54. Changes in land use pose a grave threat to riparian vegetation, necessitating land use management to alter riparian vegetation for biodiversity conservation (Borisade et al. 2021). Increasing habitat heterogeneity through vegetation restoration can improve the diversity of riparian vegetation (Saulino et al. 2021). Riparian vegetation is influenced by river size, with variations depending on the flow system (Shahimi et al. 2019). The result of the Important Value Index (IVI) for seedling kinds in the Siwaluh River Basin is displayed in (Table 5)

Abiotic factor

Furthermore, the observations on abiotic measured the following environmental factors: altitude, light intensity, water pH, humidity, air temperature, soil pH, and water temperature. Table 6 displays the results of measuring environmental factors.

Table 4. Important value index of sapling species found in the Siwaluh River Area, Karanganyar, Central Java, Indonesia

Name	Family	Station	KR	FR	IVI
Calliandra sp.	Fabaceae	Upstream	1.72	1.72	3.45
Carica papaya	Caricaceae	Upstream	1.72	1.72	3.45
Colacasia sp.	Araceae	Upstream	34.48	34.48	68.97
Cordyline fruticosa	Asparagaceae	Upstream	1.72	1.72	3.45
Cupaniopsis anacarioides	Sapindaceae	Upstream	5.17	5.17	10.34
Dryopteris cristata	Dryiopteridaceae	Upstream	1.72	1.72	3.45
Garnicia mangostana	Clusiaceae	Upstream	1.72	1.72	3.45
Leucaena leucocephala	Fabaceae	Upstream	17.24	17.24	34.48
Mangifera indica	Anacardiaceae	Upstream	1.72	1.72	3.45
Garciniamangostana	Clusiaceae	Upstream	1.72	1.72	3.45
Morinda citrifolia	Rubiaceae	Upstream	1.72	1.72	3.45
Musa sp.	Musaceae	Upstream	17.24	17.24	34.48
Peperomia pellucida	Piperaceae	Upstream	6.90	6.90	13.79
Sterculia carviflora	Passifloraceae	Upstream	1.72	1.72	3.45
Tectona grandis	Terminaliaceae	Upstream	3.45	3.45	6.90
Amaranthus sp.	Amaranthaceae	Middle	2.38	2.38	4.76
Annona squamosa	Annonaceae	Middle	1.19	1.19	2.38
Carica papaya	Caricaceae	Middle	4.76	4.76	9.52
Leucaena leucocephala	Fabaceae	Middle	5.95	5.95	11.90
Manihot esculenta	Euphorbiaceae	Middle	53.57	53.57	107.14
Morinda citrifolia	Rubiaceae	Middle	7.14	7.14	14.29
Albizia chinensis	Fabaceae	Downstream	35.48	35.48	70.97
Citrus maxima	Rutaceae	Downstream	12.90	12.90	25.81
Leucaena leucocephala	Fabaceae	Downstream	9.68	9.68	19.35
Manihot esculenta	Euphorbiaceae	Downstream	9.68	9.68	19.35
Solanum carolines	Solanaceae	Downstream	16.13	16.13	32.26
Solanum melongena	Solanaceae	Downstream	16.13	16.13	32.26

Notes: KR: Relative Type Density, FR: Relative Frequency, RD: Relative Dominance, IVI: Important Value Index

Table 5. Important Value Index for the types of seedlings found in the Siwaluh River Area, Karanganyar, Central Java, Indonesia

Name	Family	Station	KR	FR	IVI
Ageratina riparia	Asteraceae	Upstream	1.45	1.45	2.90
Ageratum conyzoides	Asteraceae	Upstream	10.74	10.74	21.48
Ageratum houstonium	Asteraceae	Upstream	2.18	2.18	4.35
Antirrhinum sp.	Plantangiaceae	Upstream	4.35	4.35	8.71
Arenga undulatifolia	Arecaceae	Upstream	1.60	1.60	3.19
Artemisia dracunculus	Asteraceae	Upstream	1.31	1.31	2.61
Artemisia verlotiorum lamotte	Asteraceae	Upstream	2.18	2.18	4.35
Asarum caudatum	Moraceae	Upstream	0.44	0.44	0.87
Asperlum onopteris	Aspleniaceae	Upstream	0.44	0.44	0.87
Asystasia gangetica	Aspleniaceae	Upstream	0.44	0.44	0.87
Basella alba	Basellaceae	Upstream	3.92	3.92	7.84
Caladium sp.	Araceae	Upstream	1.74	1.74	3.48
Cantella asiatica	Araceae	Upstream	4.35	4.35	8.71
Celtis australis	Cannabaceae	Upstream	1.45	1.45	2.90
Ceropegia papillata	Asclepiadaceae	Upstream	2.18	2.18	4.35
Cherry manila	Rosaceae	Upstream	0.44	0.44	0.87
Circaea alpina	Onagraceae	Upstream	5.08	5.08	10.16
Clidemia hirta	Melastomataceae	Upstream	2.18	2.18	4.35
Coccinia grandis	Cucurbitaceae	Upstream	0.15	0.15	0.29
Cordyline fruticosa	Asparagaceae	Upstream	2.47	2.47	4.93
Curcuma petiolata	Zingiberaceae	Upstream	0.15	0.15	0.29
Cyperus rotundus	Cyperaceae	Upstream	2.18	2.18	4.35
Desmanthus sp.	Fabaceae	Upstream	0.58	0.58	1.16
Dichrocephala integrifolia	Asteraceae	Upstream	1.60	1.60	3.19
Dryopteris cristata	Dryopteridaceae	Upstream	0.44	0.44	0.87
Dsarum caudalum	Aristolochiaceae	Upstream	2.03	2.03	4.06
Duruta repens	Verbenaceae	Upstream	2.47	2.47	4.93
Elusine indica	Poaceae	Upstream	0.15	0.15	0.29
Euphorbia hirta	Euphorbiaceae	Upstream	0.58	0.58	1.16
Galeopsis sp.	Lamiaceae	Upstream	1.45	1.45	2.90
Galinsonga quadruradiata	Asteraceae	Upstream	0.29	0.29	0.58
Gymnocarpium dryteris	Cystopteridaceae	Upstream	1.45	1.45	2.90
Gynura crepidioides	Asteraceae	Upstream	1.45	1.45	2.90
Hyptis capitata	Lamiaceae	Upstream	2.18	2.18	4.35
Ipomea turbinata	Convolvulaceae	Upstream	0.87	0.87	1.74
Manihot esculenta	Euphorbiaceae	Upstream	0.15	0.15	0.29
Marsilea crenata	Marsileaceae	Upstream	2.61	2.61	5.22
Miconia crenata	Melastomataceae	Upstream	1.31	1.31	2.61
Mimosa pudica	Fabaceae	Upstream	4.93	4.93	9.87
Naphelium nappaceum	Sapindaceae	Upstream	2.18	2.18	4.35
Otoba sp.	Myristicaceae	Upstream	0.29	0.29	0.58
Oxalis barrelieri	Oxalidaceae	Upstream	0.15	0.15	0.29
Pennisetum purpureum	Poaceae	Upstream	0.58	0.58	1.16
Physalis angulata	Solanaceae	Upstream	0.87	0.87	1.74
Pilea microphylla	Urticaceae	Upstream	0,44	0,44	0,87
Polygala senega	Polygalaceae	Upstream	0.44	0.44	0.87
Sorghum halepense	Poaceae	Upstream	7.26	7.26	14.51
Sphagneticola trilobata	Asteraceae	Upstream	3.05	3.05	6.10
Synedrella nodiflora	Asteraceae	Upstream	5.66	5.66	11.32
Xanthosoma violaceum	Araceae	Upstream	0.29	0.29	0.58
Xantosoma panduriforme	Araceae	Upstream	2.90	2.90	5.81
Acalypha australis	Euphorbiaceae	Middle	1.22	1.22	2.45
Adenostema sp.	Asteraceae	Middle	1.53	1.53	3.06
Ageratum conyzoides	Asteraceae	Middle	1.84	1.84	3.67
Alternanthera sessils	Fabaceae	Middle	1.22	1.22	2.45
Amaranthus sp.	Amaranthaceae	Middle	0.80	0.80	1.59
Amarantus viridis	Amaranthaceae	Middle	0.61	0.61	1.22
Asystasia gangetica	Acanthaceae	Middle	3.67	3.67	7.34
Biophytum petersianum	Celastraceae	Middle	2.75	2.75	5.51
Brachiara mutica	Poaceae	Middle	2.14	2.14	4.28
Callisia fragrans	Commelinaceae	Middle	0.31	0.31	0.61
Calyptocarpus sp.	Asteraceae	Middle	1.22	1.22	2.45
Catharanthus roseus	Apocynaceae	Middle	0.12	0.12	0.24

Name	**Family**	**Station**	**KR**	**FR**	**IVI**
Christella normalis	Thelypteridaceae	Middle	0.61	0.61	1.22
Chromolaena odorata	Asteraceae	Middle	4.28	4.28	8.57
Cleome rutidosperma	Cleomaceae	Middle	0.61	0.61	1.22
Cleome viscosa	Cleomaceae	Middle	0.06	0.06	0.12
Clitoria ternatea	Fabaceae	Middle	0.31	0.31	0.61
Colocasia esculenta	Araceae	Middle	2.26	2.26	4.53
Cornus sessils	Cornaceae	Middle	1.22	1.22	2.45
Cynoglossum lanieolatum	Boraginaceae	Middle	0.92	0.92	1.84
Cyperus esculenthus	Cyperaceae	Middle	0.12	0.12	0.24
Cyperus kyllingia	Cyperaceae	Middle	1.53	1.53	3.06
Cyperus odoratus	Cyperaceae	Middle	0.06	0.06	0.12
Cyperus rotundus	Cyperaceae	Middle	1.53	1.53	3.06
Dacty liandra	Cucurbitaceae	Middle	0.61	0.61	1.22
Delphinium sp.	Ranunculaceae	Middle	2.14	2.14	4.28
Digitania sanguinalis	Poaceae	Middle	0.61	0.61	1.22
Digitari uliaris	Poaceae	Middle	0.31	0.31	0.61
Digitaria milaryiana	Poaceae	Middle	0.92	0.92	1.84
Dioscorea hispida	Dioscoreaceae	Middle	0.61	0.61	1.22
Distichlis sp.	Poaceae	Middle	1.22	1.22	2.45
Dryopteris cristata	Dryopteridaceae	Middle	1.22	1.22	2.45
Echinochloa sp.	Poaceae	Middle	1.84	1.84	3.67
Euphorbia celastroides	Euphorbiaceae	Middle	1.22	1.22	3.30
Euphorbia heterophylla	Euphorbiaceae	Middle	1.65	1.65	1.22
Galium aparine	Rubiaceae	Middle	6.12	6.12	12.24
Gomphrena globosa	Amaranthaceae	Middle	1.16	1.16	2.33
Graptophyllum pictum	Acanthaceae	Middle	2.45	2.45	4.90
Holosteum umbellatum	Caryophyllaceae	Middle	0.61	0.61	1.22
Homalomena	Araceae	Middle	0.37	0.37	0.73
Hyptis capitata	Lamiaceae	Middle	1.41	1.41	2.82
Isotoma longiflora	Campanulaceae	Middle	0.06	0.06	0.12
Koeleria macrantha	Poaceae	Middle	1.22	1.22	2.45
Leucaena leucocephala	Fabaceae	Middle	0.31	0.31	0.61
Lommelina diffusz	Commelinaceae	Middle	1.84	1.84	3.67
Lygodium japonicum	Lygodiaceae	Tengah	0,12	0,12	0,24
Macadamia	Proteaceae	Middle	0.06	0.06	0.12
Melothria	Cucurbitaceae	Middle	0.06	0.06	0.12
Mimosa pudica	Fabaceae	Middle	2.08	2.08	4.16
Morinda citrifolia	Rubiaceae	Middle	0.06	0.06	0.12
Muhlenbergia sp.	Poaceae	Middle	0.92	0.92	1.84
Neprolephis cordifolia	Lomariopsidaceae	Middle	3.06	3.06	6.12
Nesgetis sp.	Aspleniaceae	Middle	0.18	0.18	0.37
Oldenlandia corymbosa	Rubiaceae	Middle	4.90	4.90	9.79
Oxalis barrelieri	Oxalidaceae	Middle	2.20	2.20	4.41
Panicium repens	Poaceae	Middle	1.84	1.84	3.67
Passiflora foetida	Passifloraceae	Middle	0.61	0.61	1.22
Pavetta abyssinisa	Rubiaceae	Middle	0.61	0.61	1.22
Pechonochloa colona	Poaceae	Middle	1.22	1.22	2.45
Peperomia pellucida	Piperaceae	Middle	0.06	0.06	0.12
Perilla shiso	Lamiaceae	Middle	0.61	0.61	1.22
Phylanthus urinaria	Phyllanthaceae	Middle	3.73	3.73	7.47
Phyllantus reticulatus	Phyllanthaceae	Middle	1.84	1.84	3.67
Ruellia tuberosa	Acanthaceae	Middle	2.02	2.02	4.04
Salium parisiense	Rubiaceae	Middle	0.61	0.61	1.22
Scutellaria orata	Commelinaceae	Middle	0.61	0.61	1.22
Solenostemo monostachhyus	Lamiaceae	Middle	1.53	1.53	3.06
Spermacole sp.	Rubiaceae	Middle	1.22	1.22	2.45
Sphagnetocola trilobata	Asteraceae	Middle	1.04	1.04	2.08
Synedrella nodiflora	Asteraceae	Middle	5.08	5.08	10.16
Tectona grandis	Terminaliaceae	Middle	0.37	0.37	0.73
Tridax procumbens	Asteraceae	Middle	3.24	3.24	6.49
Yerba porosa	Asteraceae	Middle	1.22	1.22	2.45
Achyranthes aspera	Amaranthaceae	Downstream	3.77	3.77	7.53
Acmella oleracea	Asteraceae	Downstream	1.00	1.00	2.01
Ageratina riparia	Asteraceae	Downstream	0.40	0.40	0.80
Alternanthera sessilis	Amaranthaceae	Downstream	3.01	3.01	6.03

Name	**Family**	**Station**	**KR**	**FR**	**IVI**
Althenanthera reineckii	Amaranthaceae	Downstream	0.20	0.20	0.40
Amaranthus sp.	Amaranthaceae	Downstream	0.40	0.40	0.20
Amarantus palmeri	Amaranthaceae	Downstream	3.01	3.01	0.80
Ambrosia sp.	Asteraceae	Downstream	0,25	0,25	0,50
Ashwagandha withania	Solanaceae	Downstream	0.20	0.20	0.20
Asystasia gangetica	Acanthaceae	Downstream	0.10	0.10	8.24
Atenanthera neineckii	Amaranthaceae	Downstream	0.35	0.35	0.70
Barleria Prionitis	Acanthaceae	Downstream	0.50	0.50	1.00
Beckmania sizygachne	Poaceae	Downstream	1.00	1.00	2.01
Brichiaria mutica	Poaceae	Downstream	0.25	0.25	0.50
Chamaecostus cuspidatus	Costaceae	Downstream	0.90	0.90	1.81
Cleistanthus collinus	Phyllanthaceae	Downstream	1.86	1.86	3.72
Cleome rutidosperma	Cleomaceae	Downstream	1.91	1.91	3.82
Colocasia esculenta	Araceae	Downstream	1.00	1.00	2.01
Commelina communis	Commelinaceae	Downstream	2.16	2.16	4.32
Croton tirtus litter	Euphorbiaceae	Downstream	1.00	1.00	2.01
Curcuma sp.	Zingiberaceae	Downstream	0.50	0.50	1.00
Cynosunus echinatus	Poaceae	Downstream	1.00	1.00	2.01
Cyperus esculentus	Cyperaceae	Downstream	0.70	0.50	1.41
Cyperus rotundus	Cyperaceae	Downstream	15.07	15.07	30.14
Cyrtococum patens	Poaceae	Downstream	5.02	5.02	10.05
Cyrtococum patin	Poaceae	Downstream	0.75	0.75	1.51
Dichrocephala	Asteraceae	Downstream	0.05	0.05	0.10
Echinochloa crussgalli	Poaceae	Downstream	1.26	1.26	2.51
Eleusine indica	Poaceae	Downstream	0.50	0.50	1.00
Epidendrum stamfordianum alba	Orchidaceae	Downstream	0.60	0.60	1.21
Erhanta erecta	Poaceae	Downstream	0.75	0.75	1.51
Euphorbia heterophylla	Euphorbiaceae	Downstream	0.15	0.15	0.30
Flacourtia sp.	Rosaceae	Downstream	0,05	0,05	0,10
Hedyotis corymbosa lamk	Rubiaceae	Downstream	2.01	2.01	4.02
Hyptis capitata	Lamiaceae	Downstream	0.55	0.55	1.10
Impatiens irvingi	Balsaminaceae	Downstream	0.30	0.30	0.60
Ipomeae gangetica	Convolvulaceae	Downstream	1.66	1.66	3.31
Ipomoea aquatica	Convolvulaceae	Downstream	0.45	0.45	0.90
Ipomoea triloba	Convolvulaceae	Downstream	2.01	2.01	4.02
Isodon sp.	Lamiaceae	Downstream	0.50	0.50	1.00
Laportea aestuans	Urticaceae	Downstream	1.26	1.26	2.51
Laportea interrupta	Urticaceae	Downstream	1.51	1.51	3.01
Lepidium draba	Brassicaceae	Downstream	0.35	0.35	0.70
Leucaena leucocephala	Fabaceae	Downstream	0.20	0.20	0.40
Lolium multiflorum	Poaceae	Downstream	1.51	1.51	3.01
Ludwigra decurrens	Onagraceae	Downstream	1.00	1.00	2.01
Luygourd cucurbitaceae	Cucurbitaceae	Downstream	2.26	2.26	4.52
Malvaviscus arboboreus	Malvaceae	Downstream	0.90	0.90	1.81
Manihot esculenta	Euphorbiaceae	Downstream	1.31	1.31	2.61
Melastoma sp.	Melastomataceae	Downstream	0.35	0.35	0.70
Melothria pendula	Melastomataceae	Downstream	1.00	1.00	2.01
Mimosa pudica	Fabaceae	Downstream	3.42	3.42	6.83
Oplismenus hirtellus	Poaceae	Downstream	1.00	1.00	2.01
Orthosiphon aristatus	Lamiaceae	Downstream	0.35	0.35	0.70
Ottochola nodosa	Poaceae	Downstream	0.40	0.40	4.02
Oxalis barrelieri	Oxalidaceae	Downstream	0.40	0.40	0.80
Pandanus amaryllifolius	Pandanaceae	Downstream	0.40	0.40	0.80
Panicum dichotomiflorum	Poaceae	Downstream	2,51	2,51	5,02
Passiflora foetida	Passifloraceae	Downstream	0,75	0,75	1,51
Pennisetum purpureum	Poaceae	Downstream	0.50	0.50	1.00
Peperomia pellucida	Piperaceae	Downstream	0.15	0.15	0.30
Phylanthus urinaria	Phyllanthaceae	Downstream	1.51	1.51	3.01
Polypodium aquatie	Polypodiaceae	Downstream	0.25	0.25	0.50
Ptelea trifoliata	Rutaceae	Downstream	0.75	0.75	1.51
Rhinacanthus acanthaceae	Acanthaceae	Downstream	1.51	1.51	3.01
Richardia brasiliensis	Rubiaceae	Downstream	0.30	0.30	0.60
Richardia scabra	Rubiaceae	Downstream	0.40	0.40	0.80
Ricinus communis	Euphorbiaceae	Downstream	0.05	0.05	0.10
Robinia neomexicana	Fabaceae	Downstream	0.30	0.30	0.60

Name	Family	Station	KR	FR	IVI
Ruellia tuberosa	Acanthaceae	Downstream	0.20	0.20	0.40
Sconnelina communis	Commelinaceae	Downstream	0.35	0.35	0.70
Scutelaria ovata	Commelinaceae	Downstream	0.10	0.10	0.20
Senna obtusiflora	Fabaceae	Downstream	2.76	2.76	5.52
Sida rhombifolia	Malvaceae	Downstream	0.35	0.35	0.70
Solanum carolinense	Solanaceae	Downstream	0.85	0.85	1.71
Solanum diphyllum	Solanaceae	Downstream	0.50	0.50	1.00
Solanum torvum	Solanaceae	Downstream	0.25	0.25	0.50
Sphagneticola trilobata	Asteraceae	Downstream	0.75	0.75	1.51
Stachytapheta urtilofolia	Verbenaceae	Downstream	0.10	0.10	0.20
Synedrella nodiflora	Asteraceae	Downstream	4.02	4.02	8.04
Tragia durbanensis	Asteraceae	Downstream	0.10	0.10	0.20
Triumfetta rhombiodea	Malvaceae	Downstream	0.75	0.75	1.51
Urtica sp.	Urticaceae	Downstream	0.35	0.35	0.70
Zoysia matrella	Poaceae	Downstream	0.50	0.50	1.00

Notes: KR: Relative Type Density, FR: Relative Frequency, RD: Relative Dominance, IVI: Important Value Index

Table 6. Abiotic factors in the Siwaluh River Basin area, Karanganyar, Central Java, Indonesia

Parameter	Station 1 (Upstraem)	Station 2 (Midstream)	Station 3 (Downstream)
Altitude (m dpl)	740	154	103
Light intensity (lux)	10830	28200	54100
Humidity (%)	79	65	35
Air temperature (Fahrenhait)	85	97.5	120
Soil pH	7.1	7.1	7
Water pH	6.7	7.8	8
Water temperature (°Celcius)	22	25	28

Therefore, the observation station's altitude is a factor that can influence its riparian vegetation; various altitudes cause various ambient temperatures. It was also observed that the ambient temperature tended to increase with decreasing height (Hastiana 2014). Furthermore, air humidity is related to river water and plant evaporation and is regulated by air temperature factors. According to Haryono (2011), air humidity will decrease as the air temperature rises, and conversely, air humidity will increase while the air temperature falls. The presence of trees in a region will prevent direct sunlight from reaching the soil's surface, influencing the local temperature. According to Sanger et al. (2016), tall plants and ample space will mitigate the warming effect. It is because tree leaves may intercept, reflect, absorb, and transmit sunlight. The tree cover at the study site can influence the intensity of light. The greater the number of trees, the lower the intensity of incoming sunlight. According to Putri et al. (2018), the length of daylight in a region will impact the light intensity in that region. Tree canopy cover is an additional factor that impacts light intensity. The density of the tree canopy reduces the amount of light that reaches the ground. Due to the number of tree crowns and the humidity that causes fog to gather in the area, Station 1 has a lower light intensity.

Based on the measurements taken at the three observation stations, the soil pH ranged between 7 and 7.1, indicating that the soil at the observation site was neutral. Balanced soil pH is optimal for plant nutrient absorption. In addition, the pH value influences the nitrification process in aquatic habitats. The pH level has a solid relationship with the survival of plants and animals (Hastiana 2014). According to Suryatini (2018), the optimal pH for nutrient accessibility and plant growth is close to neutral (6.5-7.5). According to Rachmawati and Retnaningdyah (2014), a low pH indicates a large diversity of shrub and plant species. As a phytoremediation agent, riparian vegetation can reduce heavy metal pollution and lower pH. Due to heavy metals binding OH^-, which was then removed by phytoremediation agents, the pH level could fall. Strong correlations exist between the riparian diversity index and the water's three physical and chemical parameters: water brightness, COD, and DO levels. Meanwhile, ambient temperature, DO levels, and salinity substantially correlate with the pattern of distribution of riparian vegetation (Hastiana 2014). Moreover, DO can originate from aquatic plants' photosynthesis and oxygen diffusion from the air into the water (Nakova et al. 2009). Ecological and ecosystem functions in the riparian zone that are in good condition will be able to support the ecosystem's productivity (Brodie et al. 2018). Therefore, the riparian zone can benefit the surrounding environment due to riparian vegetation providing shade for wild animals and providing leaf litter inputs that support aquatic food webs and fish assemblages. That is true, particularly for wild animal habitats and water catchment areas (Caissie 2006; Santos et al. 2020).

In conclusion, this study discovered 209 distinct species in the upstream, middle, and downstream regions. The high species variety at these three locations results from several environmental, social, and land use factors. The middle region in the Siwaluh River has the highest diversity value of 4. The riparian zone in the central area is quite diversified and complex, with the diversity values in the upstream and downstream regions being 3.78 and 3.92, respectively. Nevertheless, these three regions are categorized as having high values for species richness. The Important Value Index of Trees in the Siwaluh River Basin indicates that *K. africana* has the highest IVI (135.63). Furthermore, the vegetation near the poles is dominated by *Bambusa* sp. (IVI=173.72). In addition, the plant with the greatest IVI in the sapling habit was *M. esculenta* (107.14). At the same time, the plants with the greatest IVI in the seedling habitus were *A. conyzoides* (21.48). *Bambusa* sp., *M. esculenta*, and *A. conyzoides* have high IVI values, based on their habitus, due to having the greatest number of individuals in a research site. Therefore, many efforts can be arranged with diverse plants to protect natural riparian habitats.

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