Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(3): 3035 – 3059 (2025)
www.ejabf.journals.ekb.eg

Dynamics of Riparian Vegetation Structure in Logawa River: Ecological Impacts and Landscape Management

Nabela Fikriyya[1]*, Adinda Kurnia Putri[1], Mahardika Nur Permatasari[1], Yuriza Eshananda[2], Ishama Ibrahim[1], Aisyah Fajar Kartika[1], Retno Wulandari[1], Jefri Anjaini[3]

[1]Study Program Aquatic Resource Management, Faculty of Fisheries and Marine Science, Jenderal Soedirman University, 53122, Purwokerto, Indonesia
[2]Study Program Biology, Faculty of Biology, Jenderal Soedirman University, 53122, Purwokerto, Indonesia
[3]Study Program Aquaculture, Faculty of Fisheries and Marine Science, Jenderal Soedirman University, 53122, Purwokerto, Indonesia

[*]Corresponding Author: nabela.fikriyya@unsoed.ac.id

ARTICLE INFO
Article History:
Received: Feb. 4, 2025
Accepted: June 1, 2025
Online: June 22, 2025

Keywords:
CCA,
Logawa River,
Paraserianthes falcataria,
RDA,
Riparian vegetation

ABSTRACT

One of the riparian zone functions is to act as a buffer zone, playing crucial roles in economic and ecological aspects. The riparian area of the Logawa River is currently under anthropogenic pressure from sand mining activities, leading to habitat degradation. It is characterized by slopes >15% and high rainfall intensity and is prone to erosion. This research aimed to analyze the structure of riparian vegetation and its correlation with environmental parameters. Observations were conducted in July 2024 along the Logawa River, divided into the upstream, midstream, and downstream sections, with four stations in each section. Vegetation analysis was carried out using a purposive sampling method with plots measuring 20x20m (tree), 10x10 m (pole), and 1x1m (seedling), positioned parallel to the riverbank. Measured soil parameters included C-organic (%), N-total (%), P-total, and organic matter, while water parameters included pH, temperature, TDS, BOD, and COD. Riparian vegetation data were analyzed using alpha diversity indices, including the Shannon-Wiener index (H'), dominance index (D), and evenness index (e'). Further analysis was conducted using Redundancy Analysis (RDA) to explore the relationship between vegetation and habitat variation and Canonical Correspondence Analysis (CCA) to assess the correlation between vegetation presence and environmental parameters. The results showed that the H' ranged from 0.58 to 1.98, D ranged from 0.20 to 0.75, and e' from 0.30 to 1.00. RDA results indicate that Loc 5 in the midstream is closely associated with *Swietenia macrophylla* and *Cocos nucifera*. In contrast, Loc9 downstream is associated with *Artocarpus heterophyllus* and *Mangifera indica*, suggesting that these species are prevalent and commonly found in these areas. CCA results show that *Paraserianthes falcataria* is more strongly associated with higher levels of chemical oxygen demand and strongly correlates with the environmental gradient represented by N-total (%).

INTRODUCTION

The riparian zone of rivers refers to the land situated along the banks of rivers or bodies of water **(Clerici *et al.*, 2014; González *et al.*, 2017)**. Empirically, riparian zones are commonly found in regions with rivers and have historically been preferred areas for human settlement due to their easy access to freshwater resources and are believed to be among the earliest human habitation sites **(González *et al*., 2017; Singh *et al.* 2021)**. Economically, riparian areas are often used for recreation as well as food sources **(Rachmawati & Retnaningdyah, 2014; González *et al*., 2017; Singh *et al*., 2021)**. Ecologically, riparian zones help stabilize riverbanks, provide energy for food webs, serve as ecological corridors, and maintain biodiversity, especially in fragmented landscapes **(Clerici *et al.*, 2014; Singh *et al.*, 2021)**.

High anthropogenic activity and pressures in riparian zones are driven by their location at the core of human activities **(Capon, 2020)**. Riparian zones face significant threats from reclamation **(Clerici *et al.*, 2014)**, agricultural activities, urbanization, river flow alteration, overexploitation, climate change, and pollution **(Nóbrega *et al*., 2020; Singh *et al.*, 2021)**. Surface fluctuations due to riparian zone degradation can deteriorate river health **(Xu & Chang 2017; Lind *et al*., 2019; Zheng *et al*., 2023)** as well as causing global environmental changes. Similar threats have been observed in the Logawa River in Banyumas, where anthropogenic pressures include sand and stone mining, unsustainable fishing practices **(Susanto & Novitasari, 2017)**, and household waste pollution **(Puspitasari *et al*., 2023)**. The Logawa sub-watershed is dominated by hilly terrain with slopes exceeding 15% and receives high annual rainfall exceeding 3000mm **(Suwarno & Sutomo, 1999)**. Consequently, most of the Logawa River area is prone to erosion, with at least 50 landslide occurrences recorded in the Logawa sub-watershed **(Suwarno & Sutomo, 1999; Suwarno *et al*., 2017)**.

The degradation of riparian zones can lead to land degradation **(Capon, 2020)**, hydrological cycle changes, land cover alteration **(Merrit, 2022)**, and a decline in water quality **(Benavides *et al*., 2023)**. The Logawa River area faces land cover changes due to population growth, resulting in increased land conversion activities **(Sarjanti, 2023)**, leading to shifts in plant biodiversity **(Zheng *et al*., 2023)**. The Logawa River is also home to native fish species, such as *Brek* (*Puntius orphoides*), *Pelus* (*Psidonophis cancrivous*), and *Baceman* (*Mystus nemurus*), which require habitat protection **(Susanto & Novitasari, 2017)**. Therefore, it is essential to manage and restore riparian vegetation, particularly its structure and function **(Clerici *et al.*, 2014; Riis *et al*., 2014; Singh *et al*. 2021)**.

Protecting plant biodiversity in riparian zones can also support synergy between soil and plant communities, improve soil biogeochemical conditions, and increase soil porosity, enhancing river water quality, as one intriguing study related to riparian zones focuses on biodiversity and structural complexity **(Stella *et al*., 2013; Nóbrega *et al*., 2020)**. Research on riparian vegetation community structure, habitat suitability, and relationship with water and soil quality provides crucial information to investigate the status of the Logawa River's riparian zone. Therefore, this research could be the foundation for policy-making and river management. Furthermore, studying the plant community structure in river systems can provide insights into environmental characteristics and can hold potential for biomonitoring **(Alemu *et al*., 2017)**.

MATERIALS AND METHODS

Time and location

The research was conducted in July 2024 in the upstream, midstream, and downstream sections of the Logawa River, Banyumas Regency, Central Java (Fig. 1 & Table 1).

Materials

The tools used include 20x20, 10x10, and 1x1 plot sizes, DBH tape, Garmin GPS map, water quality checker, sample bottles, ziplock bags, shovel, and sieve.

Procedure

1. Sampling riparian vegetation

Vegetation sampling was conducted along the upstream, midstream, and downstream sections of the Logawa River, with four stations established in each section (12 stations in total). A purposive sampling approach was employed using the quadrat transect method. Each transect comprised three nested plots of different sizes: 20 × 20m for trees (diameter > 20cm), 10 × 10 m for poles (diameter 10–20cm), and 1 × 1m for seedlings (height < 150cm).

For each tree and pole, the species name, number of individuals, and diameter at breast height (DBH, measured at 1.3m) were recorded. Plant species were identified using the PlantNet application and further verified through the Plants of the World Online database. Each species was then classified as either native or introduced.

2. Soil sampling

Soil samples were collected from the 1 × 1 m plots, located perpendicular to the river channel. Samples were extracted from the top 0–20cm soil layer, following the method described by **Park and Kim (2020)**. The collected samples were analyzed for soil pH, total nitrogen (TN), total phosphorus (TP), available nitrogen (AN), and available phosphorus (AP).

3. Water quality measurement

Physical and chemical parameters of the river water were measured, including temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), biological oxygen demand (BOD), and chemical oxygen demand (COD).

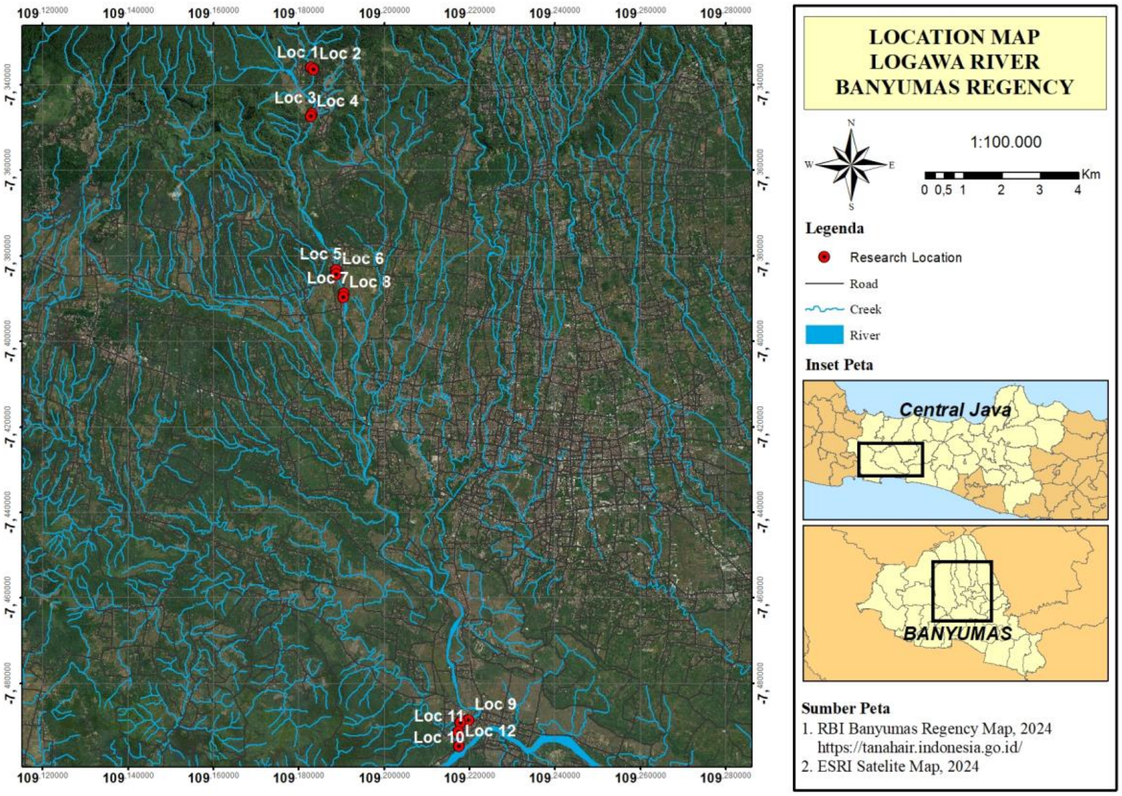


Fig. 1. Research site map

Table 1. Coordinate research site

Location			Coordinate	
Part of river	Station	Named	X	Y
Upstream	Station 1	Loc1	-7.33597	109.18293
	Station 2	Loc2	-7.33638	109.18346
	Station 3	Loc3	-7.34676	109.18319
	Station 4	Loc4	-7.34743	109.18288
Midstream	Station 5	Loc5	-7.38329	109.18888
	Station 6	Loc6	-7.38438	109.18886
	Station 7	Loc7	-7.38888	109.19064
	Station 8	Loc8	-7.38982	109.19055
Downstream	Station 9	Loc9	-7.48874	109.21992
	Station 10	Loc10	-7.48938	109.21797
	Station 11	Loc11	-7.49148	109.21753
	Station 12	Loc12	-7.49495	109.21760

Data analysis

1. Vegetation structure

The alpha diversity indices were used to analyze species diversity as follows:

Diversity Index (H') Shannon-Wiener **(Magurran, 2004)**:

$$H' = -\sum_{i=1}^{s} Pi \; In \; Pi$$

Dominance Index Simpson (D) **(Krebs, 1972)**:

$$D = \sum_{i=1}^{s} [P_i{}^2]$$

Evenness Index (e') Modified Hill's ratio **(Magurran, 2004)**:

$$e' = \left[\frac{H'}{ln\,(S)}\right]$$

Where:

H'= Diversity Index (H') Shannon-Wiener

Pi= $\frac{ni}{N}$

ni = The number of individuals of a species

N = Total number of individuals of all species

S = Number of spesies

Furthermore, the Importance Value Index (IVI) was calculated following the method of **Mueller-Dombois and Ellenberg (1974)**. For trees and poles, IVI was determined by summing relative density, relative frequency, and relative dominance. For seedlings, IVI was calculated using only relative density and relative frequency.

2. Soil analysis and water quality analysis

All soil and water samples were analyzed in the Laboratory of the Faculty of Fisheries and Marine Science, Universitas Jenderal Soedirman (UNSOED). Redundancy Analysis (RDA) was conducted to assess the relationship between vegetation structure and habitat variation, assuming linear species–environment responses **(Ramberg *et al*., 2020)**. In addition, Canonical Correspondence Analysis (CCA) was performed to evaluate the association between species presence and environmental parameters, using PAST (Paleontological Statistics) software, version 4.13.

RESULTS AND DISCUSSION

Riparian vegetation community structure

1. Importance value index (IVI)

Based on the research findings, 33 species were identified in the riparian zone of the Logawa River, with 17 species found in the upstream area and 14 species in the midstream and downstream areas, comprising 10 native species and 22 introduced species (Supplementary). Six species were identified in the upstream zone's tree layer, with *Paraserianthes falcataria* Nielsen. (122.08) having the highest Importance Value Index (IVI), followed by *Cocos nucifera* L. (65.77) (Fig. 2), while the other species had values below 50. *P. falcataria* is widely distributed in Southeast Asia, particularly in Indonesia, and is commonly found in lowland forests, along riverbanks, and in disturbed areas such as agricultural lands and plantations **(Krisnawati *et al*., 2019)**.

In the pole layer, four species were identified, with *Mangifera indica* L. (108.89) having the highest IVI, followed by *P. falcataria* (Fig. 2). Mango is well-adapted to a wide range of climates and soil types, though it is sensitive to low temperatures, high temperatures, and moisture conditions **(Navjot *et al*., 2012)**. 11 species were found in the seedling layer, with the highest IVI belonging to *Sphagneticola trilobata* (L.) Pruski (103.64), followed by *Elettaria cardamomum* (L.) Maton, with a significantly lower IVI of 15.41, while other species had values below 15 (Fig. 2). *S. trilobata* also had the highest IVI in the midstream section (116.19) and belongs to the Asteraceae family, an invasive species **(Zhang *et al*., 2022)**. This species is abundant not only in the Logawa River but also in the Banjaran River, as evidenced by its high IVI and presence at almost all stations **(Fikriyya *et al*., 2023)**.

In the midstream section of the Logawa River, 14 species were found, comprising four tree species, five pole species, and seven seedling species. *Cocos nucifera* L. had the highest IVI in the tree layer (142.38), followed by *Swietenia macrophylla* King. (75.98), while other species had IVIs below 50 (Fig. 2d). In the pole layer, *Leucaena leucocephala* (Lam.) de W. (102.13) had the highest IVI, followed by *P. falcataria* and *S. macrophylla*, with equal values of 58.35 (Fig. 2). *L. leucocephala* was only found in the midstream section of the river. In the seedling layer, seven species were identified, with *S. trilobata* having the highest IVI (116.19), followed by *Imperata cylindrica* (L.) Raeusch, while other species had IVI's below 20 (Fig. 2). *I. cylindrica*, commonly known as cogongrass, is a highly invasive grass species that poses significant threats to biodiversity and ecosystem productivity **(Holzmueller & Jose, 2012; Parker, 2022)**. Its ability to thrive in various environmental conditions, including nutrient-poor soils and disturbed areas, is attributed to its competitive nature, allelopathic effects, and extensive rhizome system **(Parker, 2022)**.

In the downstream section of the Logawa River, 14 species were identified, comprising three tree species, four pole species, and eight seedling species. The tree species with the highest IVI was *Tectona grandis* Linn. F. (199.79) (Fig. 2), only found in the downstream stations. For the pole layer, *P. falcataria* had the highest IVI (170.96) (Fig. 2). *T. grandis* (teak) is a valuable timber species that grows optimally in tropical regions with distinct wet and dry seasons **(Tanaka *et al*., 1998; Palanisamy *et al*., 2009)**. In the seedling layer, *Alternanthera paronychioides* A. St.-Hil had the highest IVI and was exclusively found in the downstream section of the Logawa River (Fig. 2). *Alternanthera* species exhibit varying degrees of tolerance to waterlogging and soil conditions. A. *philoxeroides*, an invasive wetland plant, demonstrates higher waterlogging tolerance and photosynthetic capacity **(Chen *et al*., 2013)**.

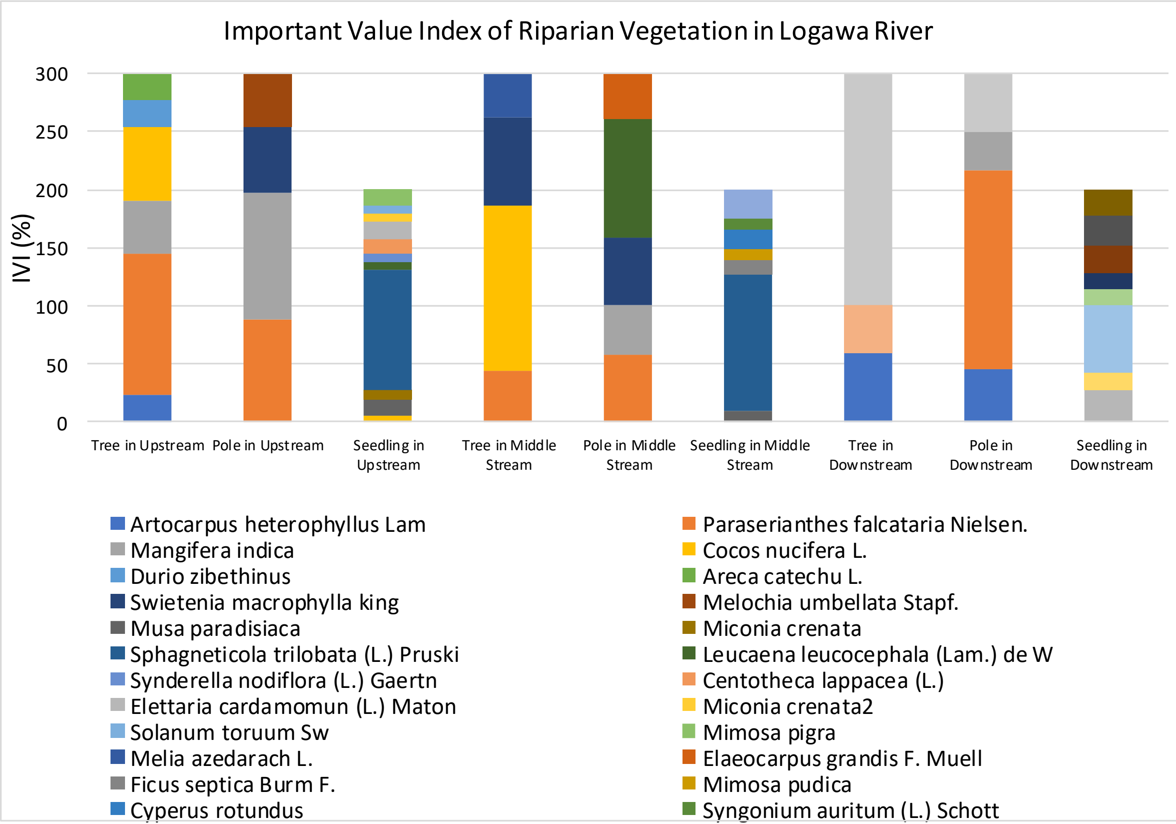


Fig. 2. IVI of vegetation riparian in Logawa River

2. Alpha diversity indices

The diversity index (H’) reflects the number of species and individuals per area that could persist in a region. The high H’ value indicates that the area is able to provide sufficient resources for each species, with no single species dominating, implying that the ecosystem is stable. Conversely, a low H’ value suggests that one species occupies the area disproportionately. The H’ in the riparian zone of the Logawa River ranges from 0.58 to 1.61, which falls within the low to moderate category (Table 2). The highest value, 1.61, is found at the pole growth stage in the midstream section, while the lowest value, 0.58, is found in the seedling stage downstream. Based on **Reed (1978)**, a high H’ value indicates more stable and varied environmental factors.

The H' value is inversely related to the dominance index (D); the lowest D value of 0.20 is found in the pole stage in the midstream area, which has the highest H' value (1.61) and vice versa (Table 2). High dominance in ecological communities suggests the prevalence of one or few species and can lead to reduced diversity **(Hillebrand *et al*., 2008; Braun, 2015)**. This dominance can result from unfavorable environmental conditions or anthropogenic disturbances **(Hillebrand *et al*., 2008)**. Although the number of species in the pole stage (6 species) is lower than in the tree stage (4 species), the number of individuals per species is more balanced, ranging from 1 to 3 individuals per species. Additionally, understanding dominance is crucial for assessing biodiversity impacts and complementing standard ecological analyses **(Hillebrand *et al*., 2008; Braun, 2015)**. Later, the H’ and D values correlate with the Evenness Index (e’), which ranges from 0 to 1. The closer the value is to 1, the more evenly distributed the species are, as shown by the highest e’ value in the midstream section (1) and the lowest e’ value of 0.30, which corresponds to the lowest dominance value (0.75) (Table 2).

Table 2. Alpha diversity indices

Indices	H'			D			e’		
Growth stage	Us	Ms	Ds	Us	Ms	Ds	Us	Ms	Ds
Tree	1.43	1.21	0.90	0.32	0.33	0.47	0.80	0.88	0.82
Pole	1.24	**1.61**	1.07	0.33	**0.20**	0.43	0.90	**1.00**	0.77
Seedling	0.90	**0.58**	1.59	0.65	**0.75**	0.27	0.38	**0.30**	0.76

Note: Us: Upstream, Ms: Midstream, Ds: Downstream

Environmental parameters

1. Soil parameters

Soil organic carbon (C-organic) represents the organic carbon content in the soil, and its values in the study area ranged between 0.66-1.73% (Table 3), with the highest value found at Loc2. Higher soil organic carbon (SOC) levels indicate more outstanding organic matter content, which can originate from plant residues or increased microbial activity. Organic agricultural systems have been shown to increase SOC and microbial activity compared to conventional systems **(Araújo *et al*., 2009)**. C-organic levels can also be influenced by organic inputs from anthropogenic activities **(Bhattacharya *et al*., 2016)**. The C-organic values in the downstream area (0.89-1.69%) are higher than in the midstream (0.92-1.47%), but the range is lower compared to the upstream section (0.66-1.73%). This could be due to lower agricultural activity in the downstream section compared to the upstream but with higher industrial activity compared to the midstream, leading to an accumulation of organic material and, consequently, higher values downstream. This aligns with **Jacobson *et al*. (2000)** findings that downstream areas of the Kuiseb River accumulate organic material transported from upstream due to hydrological decay. Organic matter content, representing the amount of organic material in the soil, ranged between 1.14-2.98 in the study area. Organic matter levels are directly proportional to C-organic, with the highest value observed at Loc2 (2.98) and the lowest at Loc1 (1.14).

The N-total value represents the nitrogen content in the soil, ranging from 0.02-0.22% in the study area (Table 3). The highest N-total content was found at Loc10. This higher nitrogen content in sediments can indicate more active organic matter decomposition at this station **(Berg & Matzner, 1997)**. Additionally, it suggests the presence of a significant nitrogen source, likely from runoff containing fertilizers or decomposed organic material **(Kaushal *et al*., 2011)** and possibly accumulation from upstream and midstream areas. Loc6 had the lowest N-total content at 0.02%. **Xu *et al*. (2014)** suggest low nitrogen values may indicate reduced microbial activity or limited nitrogen sources. Loc10, in the downstream section of the river, had the highest N-total content.

The *P*-total value represents the phosphorus content in the soil, expressed as P2O5%, with values ranging from 0.08-0.18% (Table 3). The upstream section showed relatively consistent P-total values, ranging from 0.11-0.13%. In the midstream section, values ranged from 0.11-0.18%, with the highest at Loc8. According to **Sharpley *et al*. (1999)** and **Carpenter (2005)**, high phosphorus (P) levels in an area can result from external inputs such as soil erosion and fertilizer use, leading to the eutrophication of aquatic ecosystems **(Sharpley *et al*., 1999; Carpenter, 2005)**. In the downstream section, *P*-total values were relatively low, ranging from 0.08-0.14%. Loc10 had the lowest phosphorus content at 0.08%, and low phosphorus levels can limit plant and microbial growth **(Lehtola *et al*., 2002)**.

The pH H_2O (1:2.5) represents the soil's acidity or alkalinity, measured in a 1:2.5 ratio, with values in the study area ranging from 5.58-6.57, indicating slightly acidic to neutral conditions (Table 3). The upstream section had pH values ranging from 5.75-6.36, showing slightly acidic soil conditions. The midstream section had a similar pH range of 5.70-6.33. The lowest and highest pH values were found in the downstream section, with 5.58 (lowest) and 6.57 (highest). Low soil pH can decrease the activity of soil microorganisms, P uptake and utilization, and elevated CO_2 decreases P uptake from soil by plants **(Maharajan *et al*., 2021)**. This is consistent with the findings in the study, where Loc10 had the lowest pH and *P*-total values.

Table 3. Soil parameters

Station	C-organic	Bahan Organic	N-total	*P*-total	pH H_2O (1,25)
Loc1	**0.66**	**1.14**	0.07	0.13	6.23
Loc2	1.73	2.98	0.12	0.11	5.93
Loc3	0.71	1.22	0.10	0.11	6.36
Loc4	1.46	2.52	0.08	0.13	5.75
Loc5	0.92	1.59	0.17	0.15	6.02
Loc6	0.94	1.61	**0.02**	0.16	6.33
Loc7	1.47	2.54	0.08	0.11	6.18
Loc8	0.91	1.57	0.04	**0.18**	6.54
Loc9	1.28	2.21	0.08	0.14	6.05
Loc10	**1.69**	**2.92**	**0.22**	**0.08**	**5.58**
Loc11	0.89	1.53	0.05	0.12	5.87
Loc12	1.09	1.89	0.05	0.14	**6.57**
Unit	%	-	%	P2O5%	-
Method	Spectrophotometry	Calculation	Kjeldahl	Spectrophotometry	Electrometry

2. Water parameters

The pH values of the water in the study area ranged from 7.24 to 8.95 (Table 4), which falls within the acceptable water quality standards of 6-9. The highest pH value was recorded in the midstream section at Loc7 (8.95), indicating a more alkaline environment. According to **Wang *et al*. (2020)**, alkaline conditions are often caused by mineralization or the presence of alkaline inputs from the soil or rocks. The lowest pH value was observed at Loc1, with a pH of 7.24. However, the highest water pH does not correspond with the highest soil pH found at Loc12. Additionally, the water temperature ranged between 22 and 28.1°C. The upstream section of the river exhibited lower temperatures compared to other sections of the river. The lower Temperatures in the upstream section may be due to geographical factors, such as more incredible vegetation cover, which aligns with the highest H' tree index compared to other areas (Table 2).

The dissolved oxygen (DO) values in the study area ranged from 6.82 to 11.74 mg/L, with the lowest value recorded in the downstream section at Loc9 (6.82 mg/L) (Table 4), indicating a high presence of organic matter that requires more oxygen for decomposition **(Liu *et al*., 2017)**. The low DO levels may be due to organic matter accumulation from upstream areas. This is consistent with the findings of **Lv *et al*. (2018)**, which state that high oxygen consumption is caused by the accumulation of organic matter and pollutants from upstream **(Lv *et al*., 2022)**. Meanwhile, total dissolved solids (TDS) measured the total amount of dissolved solids in water, ranging from 39-92mg/ L and the highest recorded at Loc12. High TDS values indicate the presence of dissolved solids, which may originate from natural sources such as soil and minerals or human activities **(Sun *et al*., 2020)**.

Biochemical oxygen demand (BOD) measures the oxygen microorganisms require to break down organic matter in water. Elevated BOD levels indicate significant organic pollution in freshwater **(Maddah, 2022)**. The lowest BOD value was found at Loc7, with a concentration of 1.4 mg/L. Hoyos *et al*. (2019) state that low BOD values suggest minimum organic matter requiring decomposition **(Hoyos, 2018)**. Chemical oxygen demand (COD) measures the amount of oxygen required to decompose organic and inorganic matter in water, ranging from 26.93 to 75.04mg/ L. The highest COD value was recorded at Station 1, while the lowest was found at Loc5 (Table 4).

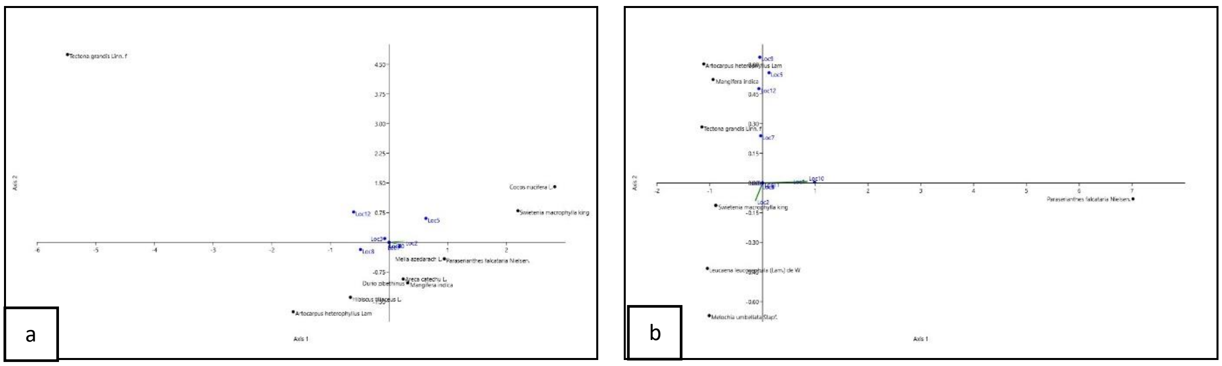
Table 4. Water quality parameters

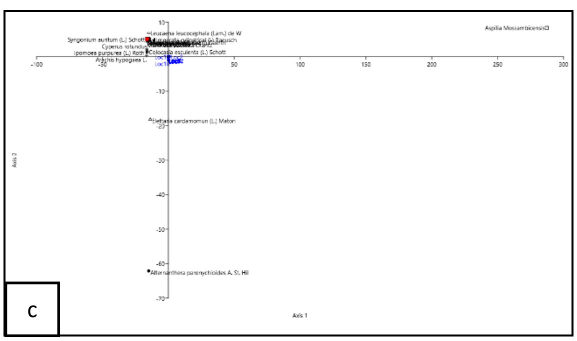
Station	pH	Temperature (°C)	DO (mg/L)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)
Loc1	7.24	22	10.73	42	3.7	75.04
Loc2	7.71	22.1	11.74	39	4.2	27.9
Loc3	8.02	23.3	10.74	36	2.3	39.44
Loc4	8.14	24.3	9.47	40	2.1	61.57
Loc5	7.38	25.6	7.38	61	2	26.93
Loc6	7.65	25.2	8.18	63	3.4	57.72
Loc7	8.95	26.5	8.09	55	1.4	32.71
Loc8	8.78	25	8.5	63	1.8	33.67
Loc9	7.58	26.3	6.82	70	3.5	42.33
Loc10	7.7	26.5	7.17	74	3.6	32.71
Loc11	7.73	26.6	7.64	65	1.7	45.21
Loc12	7.48	28.1	7.62	92	2.9	53.87

Relationship with environmental parameters

Redundancy analysis (RDA) explains the relationship between vegetation and habitat variation across 12 stations. Species that appear closer together on the plot share similar environmental preferences. Based on Fig. (3a), it is observed that Loc5 is closely associated with *Swietenia macrophylla* King and *Cocos nucifera* L., indicating their widespread distribution in this area. Both have the same habitat preference as the characteristics of Loc5, which is classified as midstream with relatively high rainfall. *Swietenia macrophylla* grows optimally in fertile alluvial soils, with good drainage and high rainfall. It tolerates light shade in early growth stages **(Krisnawati *et al*., 2011)**. Meanwhile, *C. nucifera* grows best in tropical, humid climates with annual rainfall over 1000mm and well-drained sandy to clay soils, especially near coastlines or along rivers **(Hartawan & Sarjono, 2016)**. Similarity, *Melia azedarach* L. and *Paraserianthes falcataria* Nielsen are close, suggesting they share similar environmental preferences. However, *C. nucifera* L. and *P. falcataria* are positioned on different axes, indicating that they prefer different conditions or habitats.

Fig. (3b) shows the RDA values at the pole, indicating that several species have different habitat preferences. Different plant species show preferences for specific microenvironments within riparian zones, leading to habitat segregation. Factors influencing plant distribution include flooding frequency, moisture tolerance, and light availability **(McCoy-Sulentic *et al*., 2017)**. For example, *Swietenia macrophylla* King. with Loc2, *Artocarpus heterophyllus* is associated with Loc5 and Loc9., *Tectona Grandis* Lonn. F with Loc7, and *Mangifera indica* with Loc12. *S. macrophylla* King is not only commonly found in upstream areas (Loc2 for poles) but also in midstream areas (Loc5 for trees). This indicates that it is a widely distributed species **(Wijayanto & Nurunnajah, 2012)**. However, *S. macrophylla* thrives in areas with better light access and stable soil conditions **(Pratiwi & Narendra, 2012)**, which align with midstream characteristics. Later, *A. heterophyllus* and *T. Grandis* Lonn are the exotic species with the former being also an invasive species **(Fabricante *et al*., 2013)**. Both species are found in various tropical regions. *Tectona grandis* is associated with midstream riparian zones because it prefers well-drained soils and moderately dry to moist conditions **(Rahmawaty *et al.*, 2016)**, which align with the environmental characteristics of the mid-riparian zone. At the seedling level (Fig. 3c), many species along the Logawa River riparian zone occupy similar ecological niches. However, a few species, such as *Aspilia mossambicensis* (*Sphagneticola trilobata* (L.) Pruski) and *Alternanthera paronychioides* A. St. Hil., exhibit different environmental preferences, indicating distinct habitat specializations. These results suggest moderate diversity and signs of early successional stages, typical of riparian zones affected by anthropogenic influences.





Part of river	Location Station	Named
Upstream	Station 1	Loc1
	Station 2	Loc2
	Station 3	Loc3
	Station 4	Loc4
Midstream	Station 5	Loc5
	Station 6	Loc6
	Station 7	Loc7
	Station 8	Loc8
Downstream	Station 9	Loc9
	Station 10	Loc10
	Station 11	Loc11
	Station 12	Loc12

Fig. 3. Redundancy a(RDA) correlation between vegetation and habitat variation (a) Tree (b) Pole (C) Seedling (d) Location codes (note: also for Fig. 4)

Fig. (4) presents the canonical correspondence analysis (CCA) to analyze the relationship between vegetation and environmental parameters. The proximity between a species and an environmental factor indicates a stronger association. The relationship between tree species and soil parameters (Fig. 4a) shows that *Cocos nucifera* L. is associated with Loc5 and N-total, while *Hibiscus tiliaceus* L. is linked to Loc2 and C-organic. This aligns with **Silverio-Gómez *et al.* (2022)** and **Kotecha and Ram (2022)**, who reported that *Cocos nucifera* L. thrives in nutrient-rich soils, particularly those with high nitrogen content. The availability of total nitrogen (N-total) at Loc5, the second highest among the sites (0.17; Table 3), makes this area favorable for the species. Conversely, *Hibiscus tiliaceus* L. shows a strong association with soil organic carbon. According to **Graham *et al.* (2017)**, *H. tiliaceus* influences organic carbon oxidation in sediments, and its ecological preference for soils high in organic matter is also supported by **Waldo (1975)**.

In contrast, *Areca catechu* L. does not exhibit a strong association with any specific parameter or station, suggesting its presence may be influenced by other environmental factors. However, the relationship with water parameters (Fig. 4b) reveals a more dispersed species distribution. The dissolved oxygen (DO) vector points toward the upper right quadrant, aligning with *A. catechu* and *Durio zibethinus*, suggesting a closer relationship with DO levels. This is consistent with ecological findings showing that both species favor well-drained soils, which are essential for optimal root development **(Staples & Bevacqua, 2006)**. Such soils typically offer improved aeration due to better structure, larger pore spaces, and enhanced hydraulic conductivity **(Leyton & Yadav, 1960)**, conditions that promote root respiration and elevate DO concentrations **(Prayitno, 2020)**.

Furthermore, *Mangifera indica* and *Paraserianthes falcataria* are located in the same quadrant as chemical oxygen demand (COD) in Fig. (4b), suggesting a possible influence. Plant litter from riparian zones contributes to COD, and species vary in their impact due to compositional differences **(Esslemont *et al.*, 2007)**. Leaves of *M. indica* are known to contain high levels of carbon and bioactive compounds, potentially affecting COD levels **(Ngoma *et al.*, 2015)**. *P. falcataria*, a fast-growing tree species, also contributes significantly to organic matter input in ecosystems **(Krisnawati *et al.*, 2011)**. In contrast, *Tectona grandis* Linn. f., *H. tiliaceus*, and *Artocarpus heterophyllus* Lam. show broader associations with water parameters such as pH, temperature, and total dissolved solids (TDS).

Fig. (4c) illustrates the relationship between pole vegetation and soil parameters. *P. falcataria* shows a strong correlation with N-total, indicated by its proximity to Loc10 on the plot, suggesting this species is widely distributed in that area. This may be attributed to nitrogen-fixing bacteria—primarily from the genera *Rhizobium* and *Bradyrhizobium*—present in the nodules of *P. falcataria*. Additionally, *C-organic* is closely associated with *Leucaena leucocephala* (Lam.), which contributes to soil organic carbon and total nitrogen accumulation **(Radrizzani *et al.*, 2011)**.

The relationship between vegetation and water quality (Fig. 4d) further indicates that *P. falcataria* and *M. indica* are closely associated with COD and biological oxygen demand (BOD), suggesting these species influence those parameters. Conversely, *L. leucocephala* is more closely related to TDS and temperature, implying that it may play a role in affecting those water quality variables.

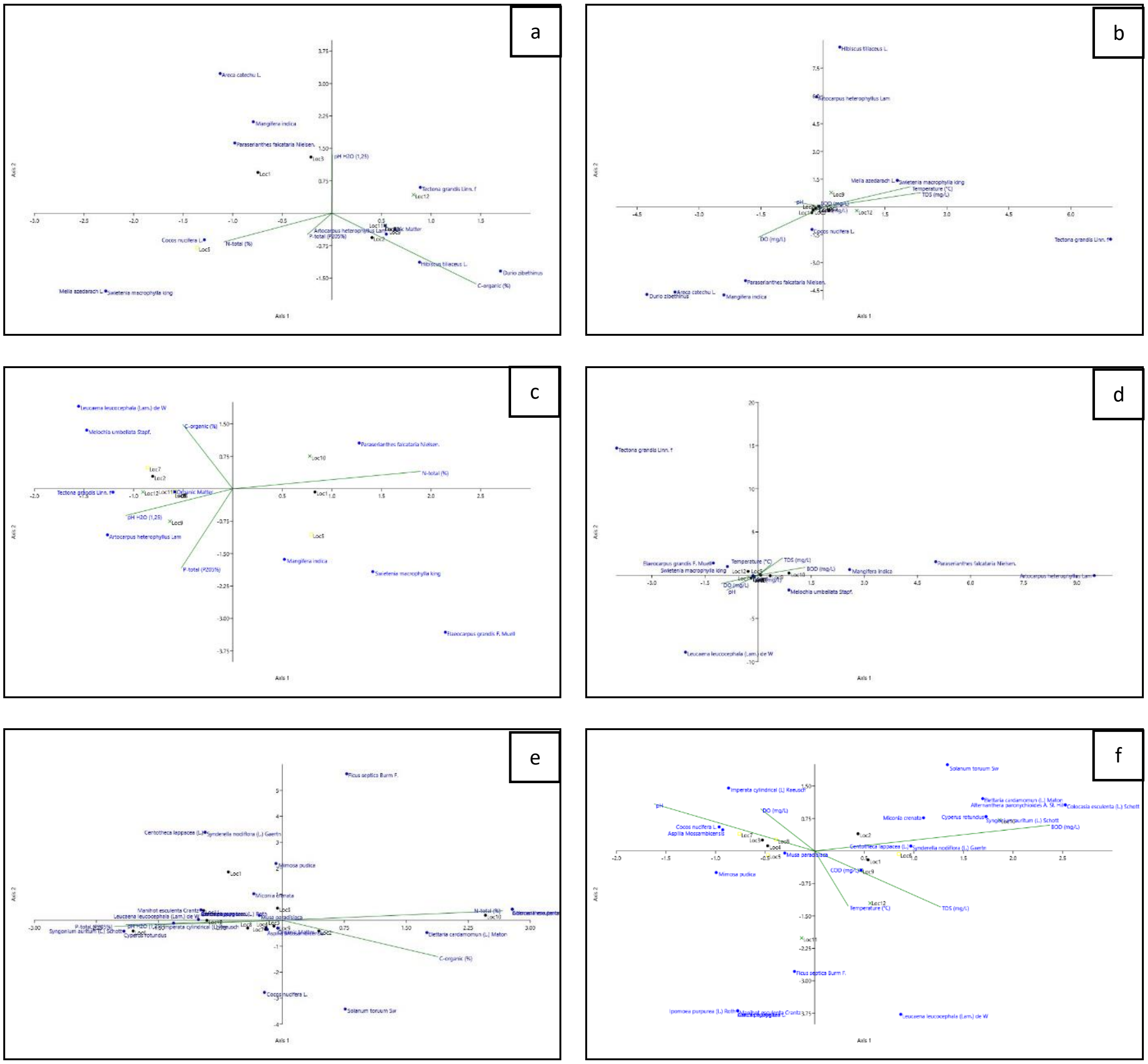


Fig. 4. Canonical correlation analysis (CCA) of the relationship between vegetation presence and environmental parameters: (a) Tree with soil parameters (b) Tree with water parameters (c) Pole with soil parameters (d) Pole with water parameters (e) Seedling with soil parameters (f) Seedling with water parameters. (note: using the same location codes with Fig. 3)

Fig. (4e, f) illustrates the relationship between environmental parameters and seedling vegetation. *Elettaria cardamomum* (L.) Maton is closely associated with Loc10 and N-Total, indicating that the high nitrogen levels in this location are suitable for the growth of this species, consistent with the N-Total values at Loc10 (Table 3). The relationship with water parameters is more apparent in Fig. (4f). For example, *Miconia crenata* is associated with COD and Loc1 with the highest value of COD. *M. crenata* is an invasive and contribute substantially to leaf litter in tropical streams **(Júnior *et al.*,**

2006) which can increase COD concentration **(Guo *et al*., 2017; Samudro *et al*., 2018)**. *Cyperus rotundus* and *Syngonium auritum* (L.) Schott is associated with BOD and Loc6, and *Cocos nucifera* L. is associated with DO.

Ecological impacts and landscape management

The findings of this study hold significant implications for local conservation policies and the management of the Logawa River ecosystem. The observed correlations between species presence and environmental parameters such as nitrogen content, DO, COD, and BOD provide a foundation for targeted conservation strategies aimed at protecting of native biodiversity while simultaneously controlling invasive species. For instance, the maintenance of *Paraserianthes falcataria*, a native known for its symbiotic relationship nitrogen-fixing bacteria, plays a crucial role in enhancing soil fertility, thereby supporting increased biodiversity through improved sufficient nutrients. Similarly, *Cocos nucifer*a, another native species with considerable economic importance, thrives under comparable environments, underscoring the necessity of habitat management that supports species with both ecological and socioeconomic value.

Furthermore, the presence of species that indirectly impact water quality such as *Areca catechu* and *Durio zibethinus*, which are strong positive correlations with elevated DO levels and serve as important bioindicators in conservation efforts. These species preferentially inhabit well-aerated soils that facilitate optimal root respirations and contribute to increased dissolved oxygen concentrations in adjacent aquatic systems. These insights endorse restoration interventions focused on promoting native species establishment, enhancing soil nutrient status and mitigating organic pollution sources.

However, the detection of 22 introduced species, notably the dominance *Artocarpus heterophyllus* Lam., present considerable challenges to the conservation of native habitats. Empirical studies from Brazil and Thailand have shown that *A. heterophyllus* significantly alters species richness, vegetation diversity, and soil composition in invaded areas **(Fabricante *et al*., 2012; Barbosa, 2016; Freitas *et al*., 2017)**. In riparian forests, *A. heterophyllus* can comprise over 35% of the vegetation structure, outcompeting native species **(Freitas *et al*., 2017)**. The species constant fruit production and genetic variability contribute to its invasive success **(Barbosa, 2016)**. Given its economic significance to local communities, public education is imperative to raise awareness regarding its environment impacts and the critical importance of conserving native diversity. Additionally, the implementation of an integrated management plan encompassing monitoring, control, and eradication of invasive species is vital to restore and sustain native species diversity and ecosystem services within the Logawa River Basin.

CONCLUSION

Overall, 33 species were identified in the riparian zone of the Logawa River, including *Paraserianthes falcataria* Nielsen. dominating the upstream section, *Cocos nucifera* L. in the midstream, and *Tectona grandis* Linn. F. in the downstream. The Shannon-Wiener Index (H') indicates low to moderate diversity, while the Evenness Index (e') ranges up to 1.00. The RDA results indicate that certain identified plant species are widespread and commonly found in specific areas. Also, several species, such as *P. falcataria*, *Hibiscus tiliaceus* L., and *Elettaria cardamomum* (L.) Maton were strongly correlated with N-Total.

ACKNOWLEDGMENTS

The author would like to thank Universitas Jenderal Soedirman and LPPM for funding this research through the Competency Development Research (RPK) scheme under contract number 26.667/UN23.35.5/PT.01/II/2024. The author also extends gratitude to Riskia Hardini, Abdillah Shohwatul Islam, and Akmal Triputra Wardhana for their assistance in data collection.

REFERENCES

Alemu, T.; Bahrndorff, S.; Hundera, K.; Alemayehu, E. and Ambelu, A. (2017). Effect of riparian land use on environmental conditions and riparian vegetation in the east African highland streams. *Limnologica*, *66*, 1–11. https://doi.org/10.1016/j.limno.2017.07.001

Araújo, A. S. F.; Leite, L. F. C.; Santos, V. B. and Carneiro, R. F. V. (2009). Soil microbial activity in conventional and organic agricultural systems. *Sustainability*, *1*(2), 268–276. https://doi.org/10.3390/su1020268

Barbosa, U. D. (2016). *Aspectos ecológicos e influência de Artocarpus heterophyllus Lam. na estrutura do componente arbóreo de fragmento florestal urbano, Recife - PE.*

Benavides, J.; Karages, J.; Mayes, K.; Rifai, H. and Castro, C. (2023). Gulf Coast Rivers of the Southwestern United States. In **D. Delong; T. Jardine; A. Benke and C. Cushing** (Eds.), *Rivers of North America* (Second Edition) (Second Edi). Academic Press.

Benjumea Hoyos, C. A. (2018). Determination of kinetics coefficients of organic matter degradation in Negro river (municipality of Rionegro, Colombia). *Bionatura*, *3*(1), 537–543. https://doi.org/10.21931/RB/2018.03.01.10

Berg, B. and Matzner, E. (1997). Effect of N deposition on decomposition of plant litter and soil organic matter in forest systems. *Environmental Reviews*, *5*(1), 1–25. https://doi.org/10.1139/a96-017

Bhattacharya, S. S.; Kim, K. H.; Das, S.; Uchimiya, M.; Jeon, B. H.; Kwon, E. and Szulejko, J. E. (2016). A review on the role of organic inputs in maintaining the soil carbon pool of the terrestrial ecosystem. *Journal of Environmental Management*, *167*, 214–227. https://doi.org/10.1016/j.jenvman.2015.09.042

Braun, A. C. (2015). Taxonomic Diversity and Taxonomic Dominance: The Example of Forest Plantations in South-Central Chile. *Open Journal of Ecology*, *05*(05), 199–212. https://doi.org/10.4236/oje.2015.55017

Capon, S. J. (2020). Riparian Ecosystems. In *Encyclopedia of the World's Biomes* (Vols. 1–5). Elsevier Inc. https://doi.org/10.1016/B978-0-12-409548-9.11884-6

Carpenter, S. R. (2005). Eutrophication of aquatic ecosystems: Bistability and soil phosphorus. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(29), 10002–10005. https://doi.org/10.1002/polb.1992.090301201

Chen, Y.; Zhou, Y.; Yin, T. F.; Liu, C. X. and Luo, F. L. (2013). The invasive wetland plant *Alternanthera philoxeroides* shows a higher tolerance to waterlogging than its native congener *Alternanthera sessilis*. *PLoS ONE*, *8*(11). https://doi.org/10.1371/journal.pone.0081456

Clerici, N.; Paracchini, M. L. and Maes, J. (2014). Land-cover change dynamics and insights into ecosystem services in European stream riparian zones. *Ecohydrology and Hydrobiology*, *14*(2), 107–120. https://doi.org/10.1016/j.ecohyd.2014.01.002

Esslemont, G.; Maher, W. A.; Ford, P. and Lawrence, I. (2007). Riparian plant material inputs to the Murray River, Australia: composition, reactivity, and role of nutrients. *Journal of Environmental Quality*, *36*(4), 963–74.

Fabricante, J. R.; Araújo, K. C.; Andrade, L. A. and Ferreira, J. V. (2012). Biological invasion of *Artocarpus heterophyllus* Lam. (Moraceae) in an Atlantic Forest fragment in Northeastern Brazil: impacts on phytodiversity and soils of invaded sites. *Acta Botanica Brasilica*, *26*, 399–407.

Fabricante, J. R. (2013). Sociabilidade de espécies da Mata Atlântica com a exótica invasora *Artocarpus heterophyllus* Lam. *Revista Brasileira de Biociências*, *10*(2). https://doi.org/10.5216/rbn.v10i2.26725

Fikriyya, N.; Kurnia Putri, A. and Silalahi, M. (2023). Keanekaragaman Vegetasi Riparian Sungai Banjaran di Kabupaten Banyumas, Jawa Tengah. *Buletin Kebun Raya*, *26*(3), 126–139. https://publikasikr.lipi.go.id/index.php/buletin

Freitas, W. K.; Magalhães, L. M.; Resende, A. S.; Brasil, F. D.; Vivès, L. D.; Pinheiro, M. A.; Filho, P. L. and Luz, R. V. (2017). Invasion Impact of *Artocarpus Heterophyllus* Lam. (Moraceae) at The Edge Of an Atlantic Forest Fragment in the Municipality of Rio De Janeiro.

González, E.; Felipe-Lucia, M. R.; Bourgeois, B.; Boz, B.; Nilsson, C.; Palmer, G. and Sher, A. A. (2017). Integrative conservation of riparian zones. *Biological Conservation*, *211*, 20–29. https://doi.org/10.1016/j.biocon.2016.10.035

Graham, E. B.; Tfaily, M. M.; Crump, A. R.; Goldman, A. E.; Bramer, L. M.; Arntzen, E. V.; Romero, E.; Resch, C. T.; Kennedy, D. W. and Stegen, J. C. (2017). Carbon inputs from riparian vegetation limit oxidation of physically-bound organic carbon via biochemical and thermodynamic processes. *bioRxiv*.

Guo, W.; Yang, F.; Li, Y. and Wang, S. (2017). New insights into the source of decadal increase in chemical oxygen demand associated with dissolved organic carbon in Dianchi Lake. *The Science of the Total Environment*, *603-604*, 699–708.

Hartawan, R. and Sarjono, A. (2016). Karakteristik fisik dan produksi kelapa dalam (*Cocos nucifera* L.) di berbagai ekologi lahan. *Media Pertanian: Media*

Komunikasi Hasil Penelitian dan Review Literatur Bidang Ilmu Agronomi, *1*(2), 45–54.

Hillebrand, H.; Bennett, D. M. and Cadotte, M. W. (2008). Concepts & Synthesis Emphasizing New Ideas To Stimulate Research in Ecology Consequences of Dominance: a Review of Evenness Effects on Local and Regional Ecosystem Processes. *Ecology*, *89*(6), 1510–1520.

Holzmueller, E. J. and Jose, S. (2012). Response of the invasive grass *Imperata cylindrica* to disturbance in the southeastern forests, USA. *Forests*, *3*(4), 853–863. https://doi.org/10.3390/f3040853

Jacobson, P. J.; Jacobson, K. M.; Angermeier, P. L. and Cherry, D. S. (2000). Variation in material transport and water chemistry along a large ephemeral river in the Namib Desert. *Freshwater Biology*, *44*(3), 481–491. https://doi.org/10.1046/j.1365-2427.2000.00604.x

Júnior, J. F.; França, J. S. and Callisto, M. (2006). Dynamics of allochthonous organic matter in a tropical Brazilian headstream. *Brazilian Archives of Biology and Technology*, *49*, 967–973.

Kaushal, S. S.; Groffman, P. M.; Band, L. E.; Elliott, E. M.; Shields, C. A. and Kendall, C. (2011). Tracking nonpoint source nitrogen pollution in human-impacted watersheds. *Environmental Science and Technology*, *45*(19), 8225–8232. https://doi.org/10.1021/es200779e

Krebs, C. J. (1972). *Ecology: The Experimental Analysis of Distribution and Abundance.* Harper & Row.

Krisnawati, H.; Kallio, M. and Kanninen, M. (2011). *Swietenia macrophylla* King: Ecology, silviculture and productivity. Center for International Forestry Research (CIFOR). https://www.cifor.org/publications/pdf_files/Books/BKrisnawati1101.pdf

Krisnawati, Y.; Febrianti, Y.; Pendidikan, J.; Alam, P.; Lubuklinggau, S.; Mayor, J.; Pingin, T.; Air, K.; Kec, K.; Timur, L. and Lubuklinggau, K. (2019). Identifikasi Tumbuhan Famili Solanaceae Yang Terdapat Di Kecamatan Tugumulyo. *4*(2).

Kotecha, J. L. and Ram, V. R. (2022). A review on plant nutrients correlation with fruit production of *Cocos nucifera* L. *Asian Pacific Journal of Health Sciences*, *9*(2), 240–242.

Lehtola, M. J. and Miettinen, Ilkka T Martikainen, P. J. (2002). Biofilm formation in drinking water affected by low concentrations of phosphorus. *Can J Microbiol*, *48*(6), 494–503.

Leyton, L. and Yadav, J. S. (1960). Effect of drainage on certain physical properties of a heavy clay soil [on forest research plot, Waterperry, Oxon]. *European Journal of Soil Science*, *11*.

Lind, L.; Hasselquist, E. M. and Laudon, H. (2019). Towards ecologically functional riparian zones: A meta-analysis to develop guidelines for protecting ecosystem functions and biodiversity in agricultural landscapes. *Journal of Environmental Management*, *249*(109391), 1–8. https://doi.org/10.1016/j.jenvman.2019.109391

Lv, S.; Li, X.; Wang, R.; Wang, Y.; Dong, Z.; Zhou, T.; Liu, Y.; Lin, K. and Liu, L. (2022). Autochthonous sources and drought conditions drive anomalous oxygen-consuming pollution increase in a sluice-controlled reservoir in eastern China. *Science of The Total Environment*, *841*, 156739. https://doi.org/10.1016/j.scitotenv.2022.156739

Maddah, H. A. (2022). Predicting Optimum Dilution Factors for BOD Sampling and Desired Dissolved Oxygen for Controlling Organic Contamination in Various Wastewaters. *International Journal of Chemical Engineering*, *2022*. https://doi.org/10.1155/2022/8637064

Magurran, A. E. (2004). *Measuring Biological Diversity*. Blackwell Publishing.

Maharajan, T.; D, C.; Krisha, T. and Ignacimuthu, S. (2021). Management of phosphorus nutrient amidst climate change for sustainable agriculture. *Journal of Environmental Quality*.

Mambanzulua Ngoma, P.; Hiligsmann, S.; Zola, E. S. and Culot, M. (2015). Comparative study of the methane production based on the chemical compositions of *Mangifera indica* and *Manihot* *utilissima* leaves. *SpringerPlus*, *4*, 75. https://doi.org/10.1186/s40064-015-0867-2

McCoy-Sulentic, M. E.; Kolb, T. E.; Merritt, D. M.; Palmquist, E.; Ralston, B. E.; Sarr, D. A. and Shafroth, P. B. (2017). Changes in community-level riparian plant traits over inundation gradients, Colorado River, Grand Canyon. *Wetlands*, *37*, 635–646. https://doi.org/10.1007/s13157-017-0899-4

Merrit, D. (2022). Riparian zones. *Encyclopedia of Inland Waters*, *22*, 276–289.

Muller-Dumbois, D. and Ellenbergh, H. (1974). *Aims and Methods of Vegetation Ecology*. Wiley & Sons Inc.

Navjot, N.; Gill, M. S. and Jawandha, S. K. (2012). Response of mango (*Mangifera indica* L.) to abiotic stresses: An overview. *Response of Mango (Mangifera Indica L.) to Abiotic Stresses: An Overview*, *5*(4), 459–462.

Nóbrega, R. L. B.; Ziembowicz, T.; Torres, G. N.; Guzha, A. C.; Amorim, R. S. S.; Cardoso, D.; Johnson, M. S.; Santos, T. G.; Couto, E. and Gerold, G. (2020). Ecosystem services of a functionally diverse riparian zone in the Amazon–Cerrado agricultural frontier. *Global Ecology and Conservation*, *21*, 1–15. https://doi.org/10.1016/j.gecco.2019.e00819

Palanisamy, K.; Hegde, M. and Yi, J.-S. (2009). Teak (*Tectona grandis* Linn. f.): A Renowned Commercial Timber Species. *Journal of Forest Science*, *25*(1), 1–24.

Park, H. and Kim, J. G. (2020). Temporal and spatial variations of vegetation in a riparian zone of South Korea. *Journal of Ecology and Environment*, *44*(1). https://doi.org/10.1186/s41610-020-00152-z

Parker, C. (2022). *Imperata cylindrica* (cogon grass). *CABI Compendium*. https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.28580

Pratiwi, P. and Narendra, B. H. (2012). Enhancing the productivity of degraded land through soil and water conservation technique in Carita Research Forest, West Java. *Indonesian Journal of Forestry Research*, *9*(2), 81–90. https://doi.org/10.20886/ijfr.2012.9.2.81-90

Prayitno, E. (2020). Analisis Kualitas Air Sumur Dangkal dengan Filtrasi Sederhana Berdasarkan Parameter DO dan DHL.

Puspitasari, H.; Fikriyya, N.; Fianjani, A. S.; Viana, R. O.; Transendenti, A. S.; Handayani, A. M. T. and Adharani, N. (2023). Keanekaragaman Makrozoobenthos di Sungai Logawa, Jawa Tengah. *Maiyah*, *2*(3), 257. https://doi.org/10.20884/1.maiyah.2023.2.3.9613

Rachmawati, E. T. and Retnaningdyah, C. (2014). Karakteristik Vegetasi Riparian dan Interaksinya dengan Kualitas Air Mata Air Sumber Awan Serta Salurannya di Kecamatan Singosari Malang. *Jurnal Biotropika*, *2*(3), 136–141.

Radrizzani, A.; Shelton, H. M.; Dalzell, S. A. and Kirchhof, G. (2011). Soil organic carbon and total nitrogen under *Leucaena leucocephala* pastures in Queensland. *Crop & Pasture Science*, *62*, 337–345.

Rahmawaty, R.; Siregar, N. C. and Rauf, A. (2016). Kesesuaian Lahan Tanaman Jati; "Studi Kasus di Arboretum Kwala Bekala, Universitas Sumatera Utara".

Ramberg, E.; Burdon, F. J.; Sargac, J.; Kupilas, B.; Rîsnoveanu, G.; Lau, D. C. P.; Johnson, R. K. and McKie, B. G. (2020). The Structure of Riparian Vegetation in Agricultural Aquatic-Terrestrial Linkages. *Water*, *12*(2855), 1–22.

Reed, C. (1978). Species Diversity in Aquatic Microecosystems. *Ecology*, *59*(3), 481–488. https://doi.org/10.2307/1936578

Riis, T.; Baattrup-Pedersen, A.; Poulsen, J. B. and Kronvang, B. (2014). Seed germination from deposited sediments during high winter flow in riparian areas. *Ecological Engineering*, *66*, 103–110. https://doi.org/10.1016/j.ecoleng.2013.05.006

Samudro, G.; Syafrudin; Nugraha, W. D.; Sutrisno, E.; Priyambada, I. B.; Muthi'ah, H.; Sinaga, G. N. and Hakiem, R. T. (2018). The Effect of COD Concentration Containing Leaves Litter, Canteen and Composite Waste to the Performance of Solid Phase Microbial Fuel Cell (SMFC).

Sarjanti, E. (2023). Analisis Daya Dukung Fungsi Lindung Untuk Kelesterian Lingkungan Di Subdas Logawa Kabupaten Banyumas. *Geomedia Majalah Ilmiah*

Dan Informasi Kegeografian, *21*(1), 43–48. https://doi.org/10.21831/gm.v21i1.43822

Sharpley, A. N.; Daniel, T.; Sims, T.; Lemunyon, R.; Stevens, R. and Parry, R. (1999). Agricultural Phosphorus and Eutrophication. In *Agricultural Research Service*. https://doi.org/10.1016/0003-9861(77)90421-0

Singh, R.; Tiwari, A. K. and Singh, G. S. (2021). Managing riparian zones for river health improvement: an integrated approach. *Landscape and Ecological Engineering*, *17*(2), 195–223. https://doi.org/10.1007/s11355-020-00436-5

Silverio-Gómez, M. D.; Ramírez-Silva, J. H.; Cortazar-Ríos, M.; Sosa-Rubio, E. E. and Herrera-Cool, G. J. (2022). Macronutrient Analysis of Soil and Leaf for Diagnosing the Nutritional Condition of Different Coconut (*Cocos nucifera* L.) Cultivars in Quintana Roo, Mexico. *OALib*.

Staples, G. W. and Bevacqua, R. F. (2006). *Areca catechu* (betel nut palm) (ver. 1.3). In **C.R. Elevitch** (Ed.), *Species profiles for Pacific Island agroforestry*. Permanent Agriculture Resources (PAR). http://www.traditionaltree.org

Stella, J. C.; Rodríguez-González, P. M.; Dufour, S. and Bendix, J. (2013). Riparian vegetation research in Mediterranean-climate regions: Common patterns, ecological processes, and considerations for management. *Hydrobiologia*, *719*(1), 291–315. https://doi.org/10.1007/s10750-012-1304-9

Susanto and Novitasari, D. I. (2017). Struktur Umur dan Faktor Kondisi Ikan di Sungai Logawa Wilayah Kabupaten Banyumas. *Jurnal Sainteks*, *14*(1), 1–10.

Suwarno, S. and Sutomo, S. (1999). Analisis kerawanan longsorlahan untuk penggunaan lahan berkelanjutan di sub das logawa kabupaten banyumas. *Pengembangan Sumber Daya Menuju Pembangunan Pertanian Bekelanjutan Dan Berwawasan Lingkungan*, 153–157.

Suwarno, S.; Sutomo, S. and Setiawan, E. (2017). Pemetaan Bahaya Erosi Di Sub-Daerah Aliran Sungai Logawa Kabupaten Banyumas Dengan Sistem Informasi Geografis. *Prosiding Seminar Nasional Penerapan Ilmu Pengetahuan Dan Teknologi*, 159–164.

Tanaka, N.; Hamazaki, T. and Vacharangkura, T. (1998). Distribution, growth and site requirements of teak. *Japan Agricultural Research Quarterly*, *32*(1), 65–77.

Waldo, R. (1975). *Hibiscus tiliaceus* L. *Environmental Science*, *Biology*.

Wijayanto, N. and Nurunnajah, N. (2012). Intensitas cahaya, suhu, kelembaban dan perakaran lateral mahoni (*Swietenia macrophylla* King.) di RPH Babakan Madang, BKPH Bogor, KPH Bogor. *Jurnal Silvikultur Tropika*, *3*(1). https://doi.org/10.29244/j-siltrop.3.1.%25p

Xu, X.; Schimel, J. P.; Thornton, P. E.; Song, X.; Yuan, F. and Goswami, S. (2014). Substrate and environmental controls on microbial assimilation of soil organic carbon: A framework for Earth system models. *Ecology Letters*, *17*(5), 547–555. https://doi.org/10.1111/ele.12254

Xu, Z. and Chang, L. (2017). *Identification and Control of Common Weeds: Volume 3*. *Identification and Control of Common Weeds: Volume 3*, *3*, 1–944. https://doi.org/10.1007/978-981-10-5403-7

Zhang, J.-J.; Cai, M.-L.; Chen, L.-H.; Lin, X.-H.; Peng, J.-D.; Huang, J.-D.; Shao, L. and Peng, C.-L. (2022). Photosynthetic physiological and ecological responses of the invasive *Sphagneticola trilobata* and the native *Sphagneticola calendulacea* to experimental shading. *Management of Biological Invasions*, *13*(2), 274–287. https://doi.org/10.3391/mbi.2022.13.2.02

Zheng, J.; Arif, M.; He, X.; Liu, X. and Li, C. (2023). Distinguishing the mechanisms driving multifaceted plant diversity in subtropical reservoir riparian zones. *Frontiers in Plant Science*, *14*(February), 1–14. https://doi.org/10.3389/fpls.2023.1138368

SUPPLEMENTARY

No	Species	Native	Introduced	No	Species	Native	Introduced
1	*Alternanthera paronychioides* A.St.-Hil		✓	17	*Ipomoea purpurea* (L.) Roth		✓
2	*Arachis hypogaea* L.		✓	18	*Leucaena leucocephala* (Lam.)deW		✓
3	*Areca catechu* L.		✓	19	*Mangifera indica* L.		✓
4	*Artocarpus heterophyllus* Lam		✓	20	*Manihot esculenta* Crantz		✓
5	*Asystasia gangetica* (L.)		✓	21	*Melia azedarach* L.	✓	
6	*Carica papaya* L.		✓	22	*Melochia umbellata* Stapf.	✓	
7	*Centotheca lappacea* (L.)	✓		23	*Miconia crenata* (Vahl) Michelang.		✓
8	*Cocos nucifera* L.	✓		24	*Mimosa pigra* L.		✓
9	*Colocasia esculenta* (L.) Schott		✓	25	*Musa x paradisiaca* L.		✓
10	*Cyperus rotundus* L.	✓		26	*Paraserianthes falcataria*	✓	
11	*Durio zibethinus* L.	✓		27	*Solanum torvum* Sw.		✓
12	*Elaeocarpus grandis* F. Muell		✓	28	*Sphagneticola trilobata* (L.)		✓
13	*Elettaria cardamomum* (L.)		✓	29	*Swietenia macrophylla* King.	✓	
14	*Ficus septica* Burm F.	✓		30	*Synderella nodiflora* (L.) Gaertn		✓
15	*Hibiscus tiliaceus* L.		✓	31	*Syngonium auritum* (L.) Schott		✓
16	*Imperata cylindrica* (L)	✓		32	*Tectona grandis* Linn. f		✓