Jurnal Biologi Tropis

Original Research Paper

Riparian Vegetation and Invasive Species in the Boyong River, Yogyakarta

Eka Sulistiyowati*, **Dias Idha Pramesti, Abdul Rafi Hidyatulah, Asya Nur Hayati, Ilham Ikhlasul Amal**
Biology Study Program, Fakultas Sains dan Teknologi, UIN Sunan Kalijaga, Yogyakarta, Indonesia;

Article History
Received : June 07th, 2026
Revised : July 01th, 2026
Accepted : July 28th, 2026

*Corresponding Author: **Eka Sulistiyowati**, Biology Study Progam, Faculty of Science and Technology, UIN Sunan Kalijaga, Yogyakarta, Indonesia;
Email: eka.sulistiyowati@uin-suka.ac.id

Abstract: Riparian ecosystem in Boyong river represents an urban stream ecosystem exposed to multiple environmental pressures, including agricultural runoff, domestic wastewater discharge, and periodic post-eruptive material flows originating from Mount Merapi. The study was conducted through vegetation exploration and macrophyte species identification across several river segments (n sites= 3). The results revealed that the macrophyte community was predominantly composed of herbaceous and shrub species with high tolerance to environmental disturbances (the number of species =259). Native non-invasive plant species were relatively limited in number, whereas several introduced species exhibited high invasive potential within the riparian zone. These findings indicate the presence of ecological pressures that influence vegetation community structure and potentially contribute to the degradation of river ecosystem quality. This study provides preliminary ecological information on the condition of the Boyong River and highlights the importance of riparian vegetation management and invasive species control to maintain the ecological health of urban river ecosystems.

Keywords: Ecosystem riparian; Invasive; Risk of invasiveness; River ecosystem; Vegetation.

Introduction

Watersheds are landscape units that collect, store, and convey water from upstream to downstream areas through interconnected drainage networks, including streams and rivers (Asdak, 2023). As a major component of watershed systems, rivers play an important role in maintaining hydrological and ecological processes. Along river margins, distinctive ecological zones known as riparian ecosystems develop at the interface between terrestrial and aquatic environments (Naiman & Décamps, 1997).

Riparian ecosystems are transitional zones located between terrestrial and aquatic environments that play a crucial role in maintaining ecological stability and river health. These ecosystems function as natural buffers by filtering pollutants and excess nutrients, regulating material flow, and providing habitat and shelter for aquatic organisms (Pandey et al., 2022). Riparian areas, particularly those directly adjacent to water bodies, are commonly inhabited by diverse macrophyte communities. These vegetation assemblages contribute significantly to ecosystem functioning through their ability to stabilize riverbanks, control sediment deposition, and regulate nutrient accumulation within river systems (Yagci & Strom, 2022)

Despite their important ecological functions, in-stream macrophytes are often regarded as nuisance vegetation because their excessive growth can alter water flow dynamics and interfere with river channel function (Cotton et al., 2006). Proliferation of these macrophytes is frequently associated with nutrient enrichment, particularly elevated concentrations of nitrogen (N) and phosphorus (P), which commonly originate from agricultural runoff and other anthropogenic activities (Bucior et al., 2021).

This article is licensed under a Creative Commons Attribution 4.0 International License.

© 2026 The Author(s). This article is open access

Increased nitrogen availability in aquatic systems has been shown to correlate positively with rapid macrophyte growth and biomass accumulation, thereby contributing to the dominance of certain aquatic plant species under eutrophic conditions (Mebane et al., 2014).

In Indonesia, studies on freshwater macrophytes have been widely conducted in both riverine and lacustrine ecosystems. Previous research has explored various aspects of macrophyte ecology, including the identification of invasive and non-invasive species in river ecosystems (Pramono et al., 2024) and lakes (R. Kurniawan et al., 2023). n addition, several studies have highlighted the ecological role of macrophytes in supporting freshwater biodiversity, particularly their function in providing habitat and spawning grounds that facilitate the reproduction of freshwater fish species (Dharmono et al., 2022).

Previous studies have demonstrated that riparian vegetation plays a significant role in supporting the ecological integrity and sustainability of river ecosystems. Therefore, continued research on freshwater macrophytes is essential to improve the management and conservation of freshwater environments. In particular, greater attention should be directed toward macrophyte communities in small rivers and streams that are directly connected to agricultural landscapes and exposed to intensive anthropogenic activities.

Research on macrophytes in small streams is especially important because pollution occurring in these headwater systems can be transported downstream and subsequently affect larger rivers that support broader ecological functions and human populations. Nevertheless, water resource management efforts are often focused primarily on larger river systems, causing ecological processes in small streams to receive comparatively less attention. This oversight is critical because several studies have identified small streams as major contributors to the transport and dissemination of pollutants, including nitrous oxide (N_2O) emissions (Marzadri et al., 2021), and agricultural pesticides such as terbuthylazine, MCPA, boscalid, and tebuconazole (Halbach et al., 2021). Consequently, understanding the ecological dynamics of macrophytes in small-stream ecosystems is necessary to support more comprehensive and sustainable freshwater management strategies.

Furthermore, rapid urban expansion has intensified ecological pressures on river ecosystems in Indonesia. One of the major environmental concerns associated with this development is the increasing dominance of invasive riparian plant species, which can suppress native non-invasive vegetation and alter the structure and function of riparian habitats (Borden & Flory, 2021). The proliferation of invasive species may reduce biodiversity, disrupt ecological interactions, and decrease ecosystem resilience to environmental change. Therefore, the diversity of riparian plant species and the invasive risk associated with these species can serve as important indicators of river ecological health. Understanding these ecological conditions is essential for supporting sustainable river management, biodiversity conservation, and long-term ecosystem stability in urban and peri-urban landscapes.

Considering the important ecological role of macrophytes in small-stream ecosystems, this study aims to investigate the diversity of macrophyte vegetation in an urban river system. In addition, the study evaluates the invasive risk associated with riparian macrophyte communities. To address these objectives, field exploration was conducted in the Boyong River, Yogyakarta.

As a small stream, the Boyong River is exposed to multiple environmental pressures, including agricultural runoff and domestic wastewater pollution. Furthermore, the river is periodically affected by post eruptive material (lahar) flows originating from Mount Merapi, which may threaten the persistence and distribution of macrophyte communities (Kurniawan & Hadmoko, 2020). The continuous input of both natural and anthropogenic pollutants into the river system highlights the urgency of conducting macrophyte studies as an initial step toward understanding the ecological condition and overall health of the Boyong River ecosystem.

Materials and Methods

Locations of the Study

Sulistiyowati *et al.,* (2026). **Jurnal Biologi Tropis,** 26 (3): 866 – 877
DOI: http://doi.org/10.29303/jbt.v26i3.12181

The Boyong River is one of the river systems originating from the southern slopes of Mount Merapi and is located in Sleman Regency. The river extends for approximately 38 km and has been utilized as a source of sand and other construction materials (Class C mining materials) since the 1950s. Rivers originating from the southern flank of Mount Merapi, including the Boyong River, are highly vulnerable to periodic deposition of volcanic materials, such as sand and cold lava (lahar), transported by water flow and wind activity.

Continuous sedimentation processes in the Boyong River create extreme exposure to changes in soil composition. Deposition of volcanic ash containing pyroclastic materials, including sand, loam, and clay fractions, promotes continuous vegetation succession within the riparian ecosystem. In addition, recurring cold-lava disturbances constantly alter the morphology of the riverbanks, leading to changes in important abiotic factors such as river depth, substrate characteristics, and water current velocity. Due to its unique ecosystem, three locations are chosen based on riparian cover, bank stability, and human disturbance (Figure 1).

Considering the dynamic environmental conditions of the river, sampling locations were selected purposively by taking into account several hydrological and physical parameters, including water discharge, river depth, and current velocity. In this study, observations were conducted in river segments located within Candibinangun, Hargobinangun, and Sardonoharjo villages (Table 1).

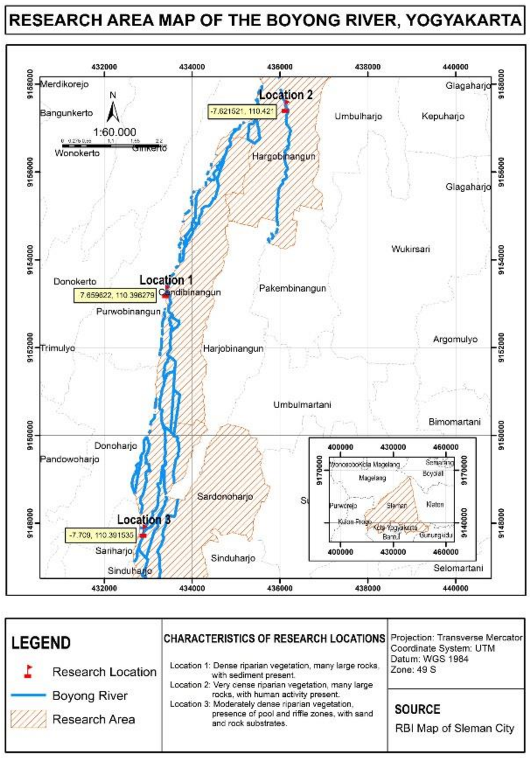

Figure 1. Map of Boyong River, showing three sampling locations

Table 1. Characteristics of the Boyong River riparian ecosystem study site

Site	Coordinates	Description	Environmental factors
Candibinangun (Site 1)	7°39'34.3"S 110°23'46.9"E	The riparian vegetation was relatively dense, with the river segment characterized by the presence of large boulders and sediment deposits.	This location is characterized by closed vegetation with a light intensity 242,156 lux, 36.1 °C air temperature, 45% soil moisture, and 6,4 soil pH. Observed anthropogenic activities include bridge construction, grazing, fishing, sand excavation, and waste disposal
Hargobinangun (Site 2)	7°37'17.5"S 110°25'15.2"E	The riparian vegetation was very dense, accompanied by numerous large rocks and noticeable human activities surrounding the river area.	This location is characterized by open vegetation with a 1,697 lux light intensity, 29,6 °C air temperature, 69% soul moisture, and 6,2 soil pH. Recorded anthropogenic activities include fishing and the disposal of organic waste.
Sardonoharjo (Site 3)	7°42'33.2"S 110°23'29.5"E	The riparian vegetation was moderately dense, and the river section exhibited distinct pool and riffle zones, with a riverbed substrate dominated by sand and stones.	This location is characterized by moderately dense vegetation with 10,429.9 lux light intensity, 32.4 °C air temperature, 59% soil moisture, and 6,5 soil pH. Observed anthropogenic activities include washing, waste disposal and fishing.

This research used the transect method with a combination of several research plots. The length and width of the transect line of 5 m x 5 m covers the right and left banks of the river. The next stage at each point of the study location, riparian vegetation was identified by recording important information such as species type, local name, number of species, location found, and type of riparian vegetation. Data on the amount of riparian vegetation at the research site were recorded on the worksheet. Riparian vegetation species were then grouped according to their family type.

The next process was the identification process. The identification process was carried out by taking photos of vegetation species, searching for local names and types of riparian vegetation species using the Picture This application. Once riparian vegetation data is collected, all data is entered into a spreadsheet for easy analysis. The data were then analysed based on the variables of density, dominance, and frequency.

Environmental data collection includes the measurement of several environmental variables, such as air temperature, light intensity, soil pH and soil moisture. The data obtained were then recorded on a worksheet, then entered into a spreadsheet to facilitate the processing of environmental parameter data. After all the environmental parameter data were collected, a descriptive analysis was carried out to identify patterns and trends.

Data Analysis

The structure and composition of riparian vegetation, as well as the environmental parameters of the Boyong River, were analyzed using the following calculations.

$$Density = \frac{Number\ of\ individuals\ of\ \ a\ species}{Number\ of\ plots} \qquad (1)$$

$$Relative\ Density = \frac{Species\ density}{Total\ density\ of\ all\ species} \qquad (2)$$

$$Frequency = \frac{Number\ of\ plots\ in\ which\ the\ \ species\ occurred}{Total\ number\ of\ plots} \qquad (3)$$

$$Relative\ frequency = \frac{Frequency}{Sum\ of\ frequency}\ X\ 100\% \qquad (4)$$

$$Dominance = \frac{Total\ basal\ area\ of\ a\ species}{Total\ plot\ area} \qquad (5)$$

$$Relative\ dominance = \frac{Species\ dominance}{Total\ dominance\ of\ \ all\ species}\ X\ 100\%$$

Importance Value Index (IVI)=

Relative density (%) + Relative frequency (%) + Relative dominance (%)

Shanon-Whinner Index (H')

$$H' = -\sum \quad Pi.\ln Pi$$

Evenness Index (E)
E= H'ln s
E = Evenness index
H' = Shannon-Winner index
ln = Natural logarithm
S = Number of species
0<E≤0,4 = Low evenness, stressed community
0,4<E≤0,6 = Moderate evenness, unstable community
0,6<E≤1,0 = High evenness, stable community

To analyse the risk level of macrophyte species, the assessment guidelines proposed by Tjitrosoedirjo et al (2016) were applied. Invasiveness was evaluated based on the rate of spread of invasive plant species, where species with rapid expansion rates were considered high priority. Impact refers to the economic, environmental, and social effects caused by invasive plants. Distribution potential indicates the total area in which invasive plant species are likely to establish and spread. The risk value was calculated using the following formula:

$$Risk = Invasiveness \times Impact \times Distribution\ Potential$$

The pre-border alien plant risk assessment methodology adapts the Indonesian Invasive Plant Risk Analysis System (Sistem Analisis Risiko Tumbuhan Invasif Indonesia / SAR TII) by Tjitrosoedirjo et al (2016). The data are sourced from the Global Invasive Species Database (GISD) and secondary literature.

Result and Discussion

Riparian Vegetation Composition

The study identified a total of 259 macrophyte species within the riparian ecosystem. Species diversity was evaluated across three study sites and categorized by ecological status (invasive vs. non-invasive). The distribution was as follows: Site 1 with 126 species, Site 2 with 133 and Site 3 with 87 (Table 2).

DOI: http://doi.org/10.29303/jbt.v26i3.12181

Table 2. Profile of macrophyte species composition in the Boyong River

Site	Number of Invasive Species	Non-Invasive Species	Total Number of Species	Percentage of Invasive Alien Species (%)
Site 1	28	98	126	22.22
Site 2	23	110	133	17.29
Site 3	12	75	87	13.79

Table 2 presents the list of species with an IVI > 3 across the study sites, comprising 8 species at Site 1, 16 species at Site 2, and 11 species at Site 3. This study restricts the visual presentation to species with an IVI > 3% as a threshold to distinguish between the main component species determining the community structure and the minor species whose ecological contributions to the stand could be neglected (Avolio et al., 2019).

Table 3. Species with an IVI > 3 in the Boyong River

Species	Family	IVI
Site 1		
Spathodea campanulata	Bignoniaceae	18.25
Xanthosoma sagittifolium	Araceae	13.07
Syzygium aqueum	Myrtaceae	11.05
Alternanthera lanceolata	Amaranthaceae	10.82
Mikania micrantha	Asteraceae	9.95
Mimosa diplotricha	Fabaceae	8.11
Syngonium auritum	Araceae	7.15
Alternanthera ficoidea	Amaranthaceae	3.19
Dendrocnide stimulans	Urticaceae	3.08
Site 2		
Microstegium vimineum	Poaceae	12.71
Mimosa pudica	Fabaceae	10.23
Wedelia trilobata	Asteraceae	7.01
Alternanthera lanceolata	Amaranthaceae	5.96
Typhonium blumei	Araceae	5.93
Cyperus alternifolius	Cyperaceae	5.51
Mikania micrantha	Asteraceae	5.16
Ludwigia adscendens	Onagraceae	4.25
Gigantochloa apus	Poaceae	4.14
Asystasia gangetica	Acanthaceae	4.11
Brachiaria mutica	Poaceae	4.05
Triumfetta rhomboidea	Malvaceae	4.03
Pouzolzia zeylanica	Urticaceae	3.73
Chromolaena odorata	Asteraceae	3.67
Drymaria cordata	Caryophyllaceae	3.46
Centrosema pubescens	Fabaceae	3.20
Site 3		
Thyponium blumei	Araceae	33.27
Leucaena leucocephala	Fabaceae	12.61
Gigantochloa apus	Poaceae	12.06
Syngonium podophyllum	Araceae	8.87
Microstegium vimineum	Poaceae	8.68
Dendrocalamus asper	Poaceae	6.89
Alternanthera lanceolata	Amaranthaceae	5.06
Dalbergia latifolia	Fabaceae	4.48
Centrosema pubescens	Fabaceae	3.23
Ficus aurata	Moraceae	3.19
Neonotonia wightii	Fabaceae	3.07

Calculations of the Importance Value Index (IVI) demonstrated that the highest IVI at each site belonged to *Spathodea campanulata* (IVI = 18.27 at Site 1), *Microstegium vimineum* (IVI = 12.71 at Site 2), and *Typhonium blumei* (IVI = 33.27 at Site 3). Notably, these species with the highest IVI values in the Boyong River are classified as invasive species.

Spathodea campanulata (Bingoniaceae) is an aggressive species distributed across tropical and subtropical regions, frequently dominating conservation areas (Shackleton et al., 2019). Despite possessing potentially beneficial bioactive compounds, its presence within the ecosystem warrants careful monitoring (Duryat et al., 2025).

Microstegium vimineum (Poaceace) is an invasive species native to Asia that has expanded its range into the Americas. Commonly known as Japanese stiltgrass, this species is highly resilient to eradication efforts due to its high invasion risk potential and broad adaptability within riverine corridors (Sullivan & DeBerry, 2026).

Typhonium blumei (Araceae), the dominant species at Site 3, also exhibits invasive potential. This species thrives in shaded areas with well-drained soils and can inhabit both intact forests and disturbed habitats, such as parks or roadsides (Brillo et al., 2025). The presence of invasive macrophytes within this riparian ecosystem indicates the progressive

DOI: http://doi.org/10.29303/jbt.v26i3.12181

displacement of natural habitats that support native, non-invasive species. In addition to invasive species, the riparian vegetation composition list with an IVI > 3 includes native species distributed across Indonesia (Table 4).

Table 4. Native species of riparian ecosystem in Boyong river with IVI>3

Species	Origin/Distribution	References
Syzygium aqueum	Native Indonesia/Malesia	(Lim, 2012)
Dendrocnide stimulans	Asia and South East Asia, including Indonesia	(Syafira et al., 2024)
Typhonium blumei	Australasia including Indonesia	(Hay, 1993)
Gigantochloa apus	Native Indonesia	(Syauqia et al., 2023)
Pouzolzia zeylanica	Native Tropical Asia	(Wilmot-Dear & Friis, 2004)
Dendrocalamus asper	Native South East Asia/Indonesia	(Suderman et al., 2026)

Among the native species found in the riparian ecosystem of the Boyong River, there are fruit-bearing trees (*Syzygium aqueum*), trees or small shrubs utilized as fodder (*Dendrocnide stimulans*), herbs (*Typhonium blumei*), and bamboo species that serve as building materials (*Gigantochloa apus* and *Dendrocalamus asper*). The diversity of lifeforms among these native plants demonstrates the complexity of the riparian ecosystem in supporting various ecological functions.

Risk of Invasiveness

The results of the invasive species risk assessment indicate that the majority of the surveyed invasive species fall into the "ignore" category (Table 5). Table 5 shows that the number of species with a negligible risk level exceeds those categorized under the low-to-medium risk tiers. Concurrently, no species were classified within the high or very high invasiveness risk categories. These figures indicate that although species with high invasive risks exist theoretically, the current conditions within the Boyong River ecosystem do not yet pose a threat. This risk level is heavily influenced by the degree of invasiveness, potential impact, and potential distribution (Tjitrosoedirjo et al., 2016). Furthermore, the majority of the riparian communities along the Boyong River exhibit moderate-to-high diversity characterized by stable ecological communities; similarly, the evenness index indicates a well-distributed and stable community structure.

Table 5. Number of species across invasiveness risk categories at each study site

Site	Risk Category (Number of Species)				
	Negligible (<13)	Low (13-38)	Medium (39-100)	High (101-192)	Very High>192)
Site 1	20	6	2	0	0
Site 2	21	1	1	0	0
Site 3	4	7	1	0	0

Table 6 indicates that the diversity index ranges from 2.73 to 3.21, falling within the stable community category. Meanwhile, the evenness index values range between 0.61 and 0.76, denoting high community evenness across the study sites. These mathematical indices indicate that the Boyong River ecosystem maintains a well-balanced distribution of individuals among species, preventing any single dominant taxon from completely suppressing the local flora. This stable ecological baseline suggests that the riparian zone still possesses a degree of ecological resilience against biological invasions.

Table 6. Diversity index (H') and Evenness index (E) of riparian vegetation in Boyong River

Site	H'	Category	E	Category
Site 1	3.21	high, stable community	0.66	High species evenness and a stable community
Site 2	3.69	high, stable community	0.76	High species evenness and a stable community
Site 3	2.73	moderate, stable community	0.61	High species evenness and a stable community

Although the study areas are situated within an urbanized river system, their geographic positioning in the upstream reaches accounts for the well-maintained species diversity and evenness observed. Upstream riparian corridors frequently retain a higher degree of environmental heterogeneity, lower anthropogenic disturbance, and more intact natural flow regimes than downriver urban zones, hence buffering the community structure against severe degradation. Nevertheless, the documented presence of low-to-medium risk invasive species warrants systematic monitoring, as these taxa can rapidly capitalize on localized disturbances if the ecosystem shifts toward an unstable state. Table 7 details the species categorized under low-to-medium invasiveness risks across the three surveyed sites. The inventory reveals that Site 1 harbors 8 species within this risk bracket. Conversely, Site 2 exhibits a lower vulnerability with only 2 species identified, whereas Site 3 presents an elevated susceptibility with 8 species classified in the low-to-medium risk tiers.

Table 7. Specific invasive species falling within the low-to-medium invasiveness risk categories

Spesies	Family	Invasiveness	Impact	Distribution	Risk	Category
Lokasi 1						
Ageratum conyzoides	Asteraceae	2	0,5	0,5	15,44	low
Clidemia hirta	Melastomataceae	3	0,5	0,5	27,37	low
Microstegium vimineum	Poaceae	3	1	1	54,74	medium
Mikania micrantha	Asteraceae	3	1	1	68,77	medium
Mimosa diplotricha	Fabaceae	2	0,5	0,5	29,47	low
Mimosa pudica	Fabaceae	2	0,5	0,5	15,44	low
Pennisetum purpureum	Poaceae	3	0,5	0,5	14,74	low
Sphagneticola trilobata	Asteraceae	2	0,5	0,5	15,44	low
Lokasi 2						
Mikania micrantha	Asteraceae	3	3,0	1,0	44,21	medium
Mimosa pigra	Fabaceae	3	3,0	0,5	22,11	low
Lokasi 3						low
Microstegium vimineum	Poaceae	2	2	0,5	21,05	low
Alternanthera brasiliana	Amaranthaceae	1	2	0,5	20,53	low
Asystasia gangetica	Acanthaceae	2	3	0,5	15,96	low
Cromolena odorata	Asteraceae	3	2	1	59,30	medium
Sida cordifolia	Malvaceae	1	2	0,5	14,21	low
Ageratum conyzoides	Asteraceae	2	1	0,5	15,44	low
Bidens pilosa	Asteraceae	1	2	0,5	14,21	low
Paederia foetida	Rubiaceae	2	2	0,5	17,37	low

Table 7 also describes the specific invasive species falling within the low-to-medium invasiveness risk categories across the studied riparian corridors. Although these taxa currently present a lower immediate risk compared to high-impact invaders, their presence shouldn't be overlooked. In invasion biology, low-to-medium risk plants frequently function as "sleeper species". These species exhibiting prolonged lag phases during which they remain naturalized but non-disruptive. However, sudden shifts in the riverine microclimate, increased nutrient runoff, or physical canopy gaps can trigger rapid population expansions. Consequently, these moderate-risk species serve as critical indicators of early-stage ecosystem vulnerability, necessitating proactive localized management to prevent future ecological displacement.

Ecologically, the riparian ecosystem dictates the specific plant assemblages capable of survival, establishing environmental filters that strongly align with the life-history traits of invasive herbs and shrubs. These adaptive characteristics include rapid growth rates, high dispersal capacities, pronounced disturbance tolerance, and high resource-use efficiency. Consequently, the herbaceous and shrubby lifeforms exhibit a marked dominance over tree lifeforms as invasive species within riparian zones.

Discussion

The riparian vegetation structure along the Boyong River is dominated by shrubs and herbs, indicating an open-canopy ecosystem shaped by continuous ecological pressures such as sediment deposition and Mount Merapi's volcanic activity. While the scarcity of trees reduces structural complexity and ecosystem maturity, this understory vegetation still provides crucial ecosystem services Lyons et al (2000). It effectively mitigates bank erosion, regulates nutrient dynamics, and exhibits rapid regeneration capacities that maintain habitat functionality immediately following severe disturbance events.

However, the long-term dominance of non-arboreal species presents ecological trade-offs, including increased solar exposure, water temperature fluctuations, and minimized carbon storage potential compared to forested zones. This transitional state risks ecological simplification and reduced biodiversity, making active intervention necessary.

Consequently, future riparian restoration strategies must focus on introducing native woody tree species to enhance structural heterogeneity while carefully preserving the functional roles of the existing, resilient shrub and herb communities.

The riparian ecosystem of the Boyong River generally experiences both natural and anthropogenic disturbances. Regarding natural factors, this river continuously receives volcanic material from the highly active Mount Merapi, rendering the succession process a natural phenomenon. Furthermore, due to the occurrence of cold lahars, open areas along the Boyong River are highly prevalent (Kurniawan and Hadmoko, 2020), with cold lahar floods constituting a common event (Wahyuni et al., 2023). In such an ecosystem, the presence of woody plants is not always persistent; thus, the ecological processes occurring within the riparian zone heavily rely on plant lifeforms such as trees and shrubs. The vegetation composition of shrub and herb lifeforms can significantly contribute to ecosystem stability in these open areas.

The study highlights that the diversity of non-invasive native plant species in the Boyong River is relatively low. The growing space within the Boyong River riparian ecosystem has likely been heavily occupied by invasive or introduced species, specifically cultivated agricultural species. This condition frequently occurs when invasive or cultivated species possess superior competitive traits, such as rapid growth rates, high seed production, broad environmental tolerances, and robust regenerative capacities.

Risk assessments regarding the invasiveness of riparian plants in Indonesia remain largely unexplored. Research has predominantly focused on invasive plants within terrestrial ecosystems, leaving aquatic and transitional ecosystems relatively understudied. In the context of riparian health evaluation, this limitation impedes the interpretation of ecosystem health conditions and the subsequent impacts of these species on hydrology, riverbank stabilization, carbon storage, and habitat provision.

To date, a comprehensive and standardized assessment framework that simultaneously evaluates both the positive and negative ecological impacts of invasive plants within riparian ecosystems does not exist in Indonesia. Even globally, riparian health assessment instruments have not been widely adopted and remain confined to research scales, as seen in Yuan et al. (2025) and Tela et al. (2025). Within the Indonesian context, existing instruments are generally restricted to experimental applications (Sulistiyowati et al., 2024). Consequently, the lack of standardized riparian ecosystem health assessments reduces the capacity to conduct fully objective evaluations of potential ecological dynamics, thereby limiting invasiveness risk assessments strictly to the distribution and direct impacts of the invasive riparian plants themselves.

The lack of standardized riparian ecosystem health assessments reduces the capacity to conduct fully objective evaluations of potential ecological dynamics. Consequently, invasiveness risk assessments remain restricted solely to evaluating the impacts and distribution of the invasive riparian plants themselves. To evaluate invasiveness risk, this study utilizes the framework developed by Tjitrosoedirjo et al (2016) , which is conventionally applied to terrestrial species. However, due to the absence of specific guidelines for evaluating invasiveness risk within riparian ecosystems, this terrestrial protocol was adapted and implemented within the context of the present study.

Several key findings can be confirmed from this study. First, the proportion of biodiversity richness classified as invasive species ranges from 13.29% to 22.22% of the total species recorded within the riparian zone of the Boyong River. Generally, a higher proportion of invasive species within an ecosystem is associated with a decline in river health. Invasive species diminish the capacity of ecosystems to provision environmental services, including primary production, nutrient and water cycling, decomposition, energy and water flow, and sedimentation (Lázaro-Lobo et al., 2023). Collectively, alterations to these diverse ecosystem services render the ecosystem potentially less resilient to disturbances and trigger ecological degradation, which serves as a primary indicator of declining ecosystem health.

Conclusion

The riparian macrophyte diversity within the Boyong River indicates that the ecosystem is potentially subject to ecological pressure driven by both anthropogenic activities and natural disturbances. The vegetation community is dominated by disturbance-tolerant herbs and shrubs, whereas the richness of non-invasive native plants is relatively low. Furthermore, several introduced species exhibit invasive potential that could compromise the structure and stability of the riparian ecosystem. Although the current Shannon-Wiener diversity index (H') and Pielou's evenness index (E) fall within a stable category, this apparent stability is sustained by a high diversity of invasive vegetation. Alarmingly, several invasive species have already escalated to a moderate-risk category, indicating an ongoing shift in vegetation composition that degrades the ecological quality of the river. Consequently, riparian vegetation management emphasized on the conservation of native plants and the control of invasive species is imperative to sustain the ecological functions of the Boyong River as an urban small-stream ecosystem.

Acknowledgment

The authors express their gratitude to the Integrated Laboratory of UIN Sunan Kalijaga for providing the equipment and facilities utilized in this study. We also extend our sincere appreciation to the Ecorivest Team for their invaluable assistance during field data collection, with special thanks to Dhiea Tsyuraya and Riski Ahmad Prayuda.

References

Asdak, C. (2023). *Hidrologi dan pengelolaan daerah aliran sungai*. UGM PRESS.

Borden, J. B., & Flory, S. L. (2021). Urban evolution of invasive species. *Frontiers in Ecology and the Environment*, *19*(3), 184–191. https://doi.org/10.1002/fee.2295

Brillo, S. C., Banogon, J. D. A., Aguila, N. A. A., & Mones, J. R. M. (2025). Species diversity of Araceae in Ninoy Aquino Parks and Wildlife Center and Arroceros Forest Park, Manila, Philippines. *Asian Journal of Forestry*, *9*(1). https://doi.org/10.13057/asianjfor/r090104

Bucior, A., Rippey, B., McElarney, Y., & Douglas, R. (2021). Evaluating macrophytes as indicators of anthropogenic pressures in rivers in Ireland. *Hydrobiologia*, *848*(5), 1087–1099. https://doi.org/10.1007/s10750-021-04516-x

Cotton, J. A., Wharton, G., Bass, J. A. B., Heppell, C. M., & Wotton, R. S. (2006).

The effects of seasonal changes to in-stream vegetation cover on patterns of flow and accumulation of sediment. *Geomorphology*, *77*(3–4), 320–334. https://doi.org/10.1016/j.geomorph.2006.01.010

Dharmono, D., Mahruddin, M., Irianti, R., & Fajeriadi, H. (2022). Aquatic plants as niche for lay eggs and raising juveniles by freshwater fish in three swamp habitats in South Kalimantan, Indonesia. *Biodiversitas Journal of Biological Diversity*, *23*(3). https://doi.org/10.13057/biodiv/d230341

Duryat, D., Ghozali, R. I., Saragih, Y. J., Rodiani, R., Maryono, T., Pardilawati, C. Y., & Ismanto, I. (2025). Exploration of bioactive compounds in invasive plant *Spathodea campanulata* flower originating from Bukit Barisan National Park, Lampung, Indonesia. *Biodiversitas Journal of Biological Diversity*, *26*(1). https://doi.org/10.13057/biodiv/d260136

Dybala, K. E., Steger, K., Walsh, R. G., Smart, D. R., Gardali, T., & Seavy, N. E. (2019). Optimizing carbon storage and biodiversity co-benefits in reforested riparian zones. *Journal of Applied Ecology*, *56*(2), 343–353. https://doi.org/10.1111/1365-2664.13272

Halbach, K., Möder, M., Schrader, S., Liebmann, L., Schäfer, R. B., Schneeweiss, A., Schreiner, V. C., Vormeier, P., Weisner, O., Liess, M., & Reemtsma, T. (2021). Small streams–large concentrations? Pesticide monitoring in small agricultural streams in Germany during dry weather and rainfall. *Water Research*, *203*, 117535. https://doi.org/10.1016/j.watres.2021.117535

Hay, A. (1993). The genus Typhonium (Araceae-Areae) in Australasia. *Blumea: Biodiversity, Evolution and Biogeography of Plants, 37*(2), 345-376.

Kurniawan, R., Ibrahim, A., Prihatinningtyas, E., Susanti, E., & Pratama, T. (2023). Introduce invasive alien macrophytes species in Indonesia national priority lakes (study case: Lake Rawa Pening, Sentarum, Tempe, Tondano, Sentani). *IOP Conference Series: Earth and Environmental Science*, *1260*(1), 012031. https://doi.org/10.1088/1755-1315/1260/1/012031

Kurniawan, V. O., & Hadmoko, D. S. (2020). Pemodelan aliran lahar Gunung Api Merapi untuk perhitungan risiko kerugian pada penggunaan lahan terdampak di bantaran Sungai Boyong, Pakem, Sleman, DI Yogyakarta. https://doi.org/10.7454/jglitrop.v3i2.64

Avolio, M. L., Forrestel, E. J., Chang, C. C., La Pierre, K. J., Burghardt, K. T., & Smith, M. D. (2019). Demystifying dominant species. *New Phytologist*, *223*(3), 1106–1126. https://doi.org/10.1111/nph.15789

Journal of Geography of Tropical Environments, *3*(2).

Lázaro-Lobo, A., Alonso, Á., Fernández, R. D., Granda, E., Romero-Blanco, A., Saldaña-López, A., & Castro-Díez, P. (2023). Impacts of plant invasions on ecosystem functionality: A perspective for ecosystem health and ecosystem services. In S. Tripathi, R. Bhadouria, P. Srivastava, R. Singh, & D. R. Batish (Eds.), *Plant Invasions and Global Climate Change* (pp. 31–56). Springer Nature Singapore. https://doi.org/10.1007/978-981-99-5910-5_2

Lim, T. K. (2012). Syzygium aqueum. In T. K. Lim, *Edible Medicinal And Non Medicinal Plants* (pp. 738–742). Springer Netherlands. https://doi.org/10.1007/978-94-007-2534-8_98

Lyons, J., Thimble, S. W., & Paine, L. K. (2000). Grass versus trees: Managing riparian areas to benefit streams of Central North America. *JAWRA Journal of the American Water Resources Association*, *36*(4), 919–930. https://doi.org/https://doi.org/10.1111/j.1752-1688.2000.tb04317.x

Maraseni, T. N., & Mitchell, C. (2016). An assessment of carbon sequestration potential of riparian zone of Condamine Catchment, Queensland, Australia. *Land Use Policy*, *54*, 139–146. https://doi.org/10.1016/j.landusepol.2016.02.013

Marzadri, A., Amatulli, G., Tonina, D., Bellin, A., Shen, L. Q., Allen, G. H., & Raymond, P. A. (2021). Global riverine nitrous oxide emissions: The role of small streams and large rivers. *Science of The Total Environment*, *776*, 145148. https://doi.org/10.1016/j.scitotenv.2021.145148

Mebane, C. A., Simon, N. S., & Maret, T. R. (2014). Linking nutrient enrichment and streamflow to macrophytes in agricultural streams. *Hydrobiologia*, *722*(1), 143–158. https://doi.org/10.1007/s10750-013-1693-4

Naiman, R. J., & Décamps, H. (1997). The Ecology of interfaces: Riparian zones. *Annual Review of Ecology and Systematics*, *28*(1), 621–658. https://doi.org/10.1146/annurev.ecolsys.28.1.621

Pandey, S., Kumari, T., Verma, P., Singh, R., & Raghubanshi, A. S. (2022). Impact of anthropogenic stresses on riparian ecosystem and their management perspectives. In *Ecological Significance of River Ecosystems* (pp. 299–324). Elsevier. https://doi.org/10.1016/B978-0-323-85045-2.00004-2

Pramono, C. L., Alyodya, D. A., Restuti, E. J., Meilani, F., Sholiqin, M., Dewangga, A., Yap, C. K., & Setyawan, A. D. (2024). Invasive and non-invasive macro aquatic plants in the Upper Bengawan Solo River, Indonesia. BONOR OW O W E TLA NDS.

Shackleton, R. T., Richardson, D. M., Shackleton, C. M., Bennett, B., Crowley, S. L., Dehnen-Schmutz, K., Estévez, R. A., Fischer, A., Kueffer, C., Kull, C. A., Marchante, E., Novoa, A., Potgieter, L. J., Vaas, J., Vaz, A. S., & Larson, B. M. H. (2019). Explaining people's perceptions of invasive alien species: A conceptual framework. *Journal of Environmental Management*, *229*, 10–26. https://doi.org/10.1016/j.jenvman.2018.04.045

Suderman, S. S., Mansor, H., Hamid, Y. S., Kamarudin, M. K., Ahmad, Z., & Anshari, B. (2026). Comparison of the embedment strength and mechanical characteristics of *Gigantochloa scortechinii* and *Dendrocalamus asper* in Malaysia and Indonesia. In Z. Li (Ed.), *Proceedings of the 10th International Conference on Civil Engineering and Materials Science* (Vol. 797, pp. 151–162). Springer Nature Singapore. https://doi.org/10.1007/978-981-95-5807-0_14

Sulistiyowati, E., Awaliyah, D. F., & Uyun, S. (2024). Penilaian kesehatan sungai menggunakan metode biotik dan fisik di Sungai Boyong, Sleman, Yogyakarta. *Jurnal Kesehatan Lingkungan Indonesia*, *23*(2), 162–169. https://doi.org/10.14710/jkli.23.2.162-169

Sullivan, R. A., & DeBerry, D. A. (2026). Cultural methods for the control of the invasive Japanese stiltgrass (*Microstegium vimineum*) in stream restoration. *Plants*, *15*(3), 477. https://doi.org/10.3390/plants15030477

Syafira, F., Nurainas, N., & Syamsuardi, S. (2024). New record and potential spatial distribution of *Curcuma sumatrana* (Zingiberaceae): An endemic wild turmeric in Sumatra, Indonesia. *Biodiversitas Journal of Biological Diversity*, *25*(11). https://doi.org/10.13057/biodiv/d251112

Syauqia, M. F., Chikmawati, T., & Ariyanti, N. S. (2023). Diversity, ecology and habitat suitability of Gigantochloa in Central Sumatra. *Agriculture and Natural Resources*, *57*(2). https://doi.org/10.34044/j.anres.2023.57.2.14

Tela, S. A., Masayi, N. N., & Tsingalia, M. (2025). Riparian vegetation as an ecological indicator of river health: A case study of Isiukhu River, Kenya. *Asian Journal of Environment & Ecology*, *24*(11), 39–55. https://doi.org/10.9734/ajee/2025/v24i11816

Tjitrosoedirjo, S., Setyawati, T., Sunardi, Subiakto, A., Irianto, R., & Garsetiasih, R. (2016). *Pedoman analisis risiko tumbungan asing invasif (pre border)*. FORIS Indonesia.

Wilmot-Dear, C. M., & Friis, I. (2004). The Old World species of Pouzolzia (Urticaceae, tribus Boehmerieae). A taxonomic revision. *Nordic Journal of Botany*, *24*(1), 5–111. https://doi.org/https://doi.org/10.1111/j.1756-1051.2004.tb00825.x

Yagci, O., & Strom, K. (2022). Reach-scale experiments on deposition process in vegetated channel: Suspended sediment capturing ability and backwater effect of instream plants. *Journal of Hydrology*, *608*, 127612. https://doi.org/10.1016/j.jhydrol.2022.127612

Yuan, Y., Li, H., Wang, H., Liu, T., Xue, Z., Song, J., & Xu, L. (2025). Riparian forest health assessment in the Valley Area of the Irtysh River Basin. *Forests*, *16*(2), 373. https://doi.org/10.3390/f16020373