Assessment and analysis of riparian zone downstream of Brantas River at three different points in Mojokerto region, East Java, Indonesia

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Abstract. This study aims to analyse the species richness downstream of the Brantas River riparian zone in the Mojokerto Region. The research was conducted in December 2023. The method used in this study was to analyse the vegetation ecology in which the quadrat technique was applied to a 5 x 5 m plot size to collect primary data on the riparian plants. The parameters of plant composition were analysed by measuring their relative abundance (RA), relative frequency (RF) and importance value index (IVI). This study discovers a total of 50 species (Herbs 42, tree 3, liana 3 and shrubs 2). The results showed that site 1 had 8659 individuals, with 20 species belonging to 13 families. In site 2, 2872 individuals were found with 22 species in 14 families and 2361 individuals with 33 species belonging to 22 families. The plant species with high IVI was *Lemna perpusilla* Torr, covering 61.49% in site 1, 43.40% in site 2 and 41.97% in site 3.

1 Introduction

Riparian vegetation, particularly trees, serves multiple ecological and environmental purposes. It plays a critical role in preventing soil erosion, acting as a natural barrier to sediment displacement, and protecting the surface environment. It helps regulate water temperatures, aids groundwater recharge, and provides habitats for plants and animals. Riparian vegetation also serves as an aesthetic boundary for human settlements and contributes to energy and nutrient balance. Additionally, valley vegetation helps shield rivers from pollution and regulates the microclimate, directly impacting the development and stability of river ecosystems [1]. Such biodiversity loss from forested areas causes negative feedback on ecosystem performance [2].

Riparian vegetation contributes significantly to essential cycles, including carbon, oxygen, nitrogen, and water. It also serves as an indicator of environmental quality and supports the structural integrity of riverbanks and cliffs [3]. In addition, riparian vegetation

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has a unique structure, physiological and biological characteristics, which program changes to water conditions and can even adapt to floods, settling, and abrasion [4]. It also acts as a filter for nutrients and waste, as well as a reservoir for biodiversity [5]. The deep root systems of riparian trees enhance soil stability, reduce surface runoff, and mitigate erosion [6]. Furthermore, aquatic vegetation plays a crucial role in determining water quality, particularly in spring-fed systems [7].

The riparian areas perform important functions and generate high profits [8]. However, they are increasingly at risk due to human activities. In Indonesia, population growth and urban development have led to significant land use changes [9]. These changes have reduced river corridor widths, decreased riparian vegetation coverage and affected the quality of both riparian flora and river water [10]. Methods such as the quadrat, line transect, and point frame are often used to analyse riparian vegetation and its ecological characteristics. Environmentalists have actively raised awareness about the importance of preserving these ecosystems [11-12].

As a tropical country, Indonesia faces various problems related to land use, especially deforestation and urbanisation, which are believed to cause increasing damage to watersheds. Agricultural practices in areas with steep slopes have been one of the main contributors to land degradation in Indonesia [13-14]. The Brantas River plays a very important role ecologically and economically, especially in East Java. As one of the main water sources, this river supports biodiversity and provides natural habitat for various species, making it a strategic location for studying the environment. In addition, economically, the Brantas River is the backbone of the agricultural and fisheries sectors, especially in the Mojokerto area, where its irrigation network greatly helps local productivity [15]. However, environmental challenges such as pollution, sedimentation, and domestic and industrial waste are increasingly becoming significant threats, especially in urban areas such as Mojokerto, which is known to have intensive urbanisation and industrialisation activities [16]. With this background, studies in this area are relevant to identify local impacts of environmental pressures while providing solutions that can be applied on a broader scale. This study aims to analyse the species richness downstream of the Brantas River riparian zone in Mojokerto Region.

2 Materials and methods

2.1 Type of Research

This research adopts a quantitative descriptive approach, as the analysis results are presented in numerical data form [17].

2.2 Research Location and Time

Mojokerto City, located in East Java Province, spans an area of 20,217 km² (20,217 hectares) and is bordered by the following regions: to the south, it borders Sooko District and Puri District, Mojokerto Regency; to the east, it borders Mojoanyar District and Puri District Mojokerto Regency; to the north, it borders the Brantas River; and to the west it borders Sooko District, Mojokerto Regency. Geographically, the city of Mojokerto is located between 7°27'0.16" to 7°29'37.11" South Latitude and 112°24'14.3" to 112°27'24" East Longitude [18].

The research was conducted in December 2023, downstream of Brantas River in Mojokerto, at coordinates of locations 7°27'33.7"S 112°23'13.8"E, 7°26'48.9"S 112°27'39.3"E and 7°32'59.7"S 112°41'01.7"E.

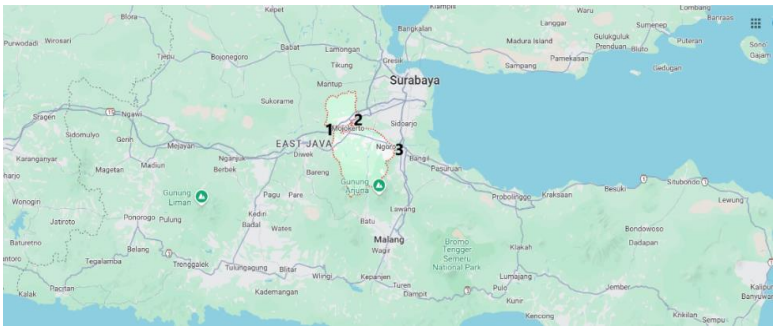

Fig. 1. Research Location of Brantas River at Mojokerto City

2.2.1 Plant sampling technique

Sampling points were determined using the purposive sampling method, and vegetation in three sampling areas was analysed using the quadrat method. At each station, research plans were made for ten plots on the left and right sides of the river. Tools and materials used are tools and materials Commonly used in the field and laboratory, such as GPS, digital camera, plant shears, tape measure, oven, alcohol and newsprint. The distance at each station is about 10 m, and the quadrat method is differentiated based on the plant habitus with a 5 x 5 m plot size for herbs and shrubs. A larger plot size was chosen to enhance data representation since herbs and shrubs/saplings are mixed in the field. The selection of research stations was based on variations in human activities around the area as well as differences in the physical morphology of river boundaries, which are expected to provide a more comprehensive picture of the condition of riparian vegetation in the area. Information about plants in the area and their scientific names was collected and classified. It also includes recording the latitude and longitude coordinates of the area. Schematic analysis of riparian vegetation [19-20] as shown in Figure 2 – 3.

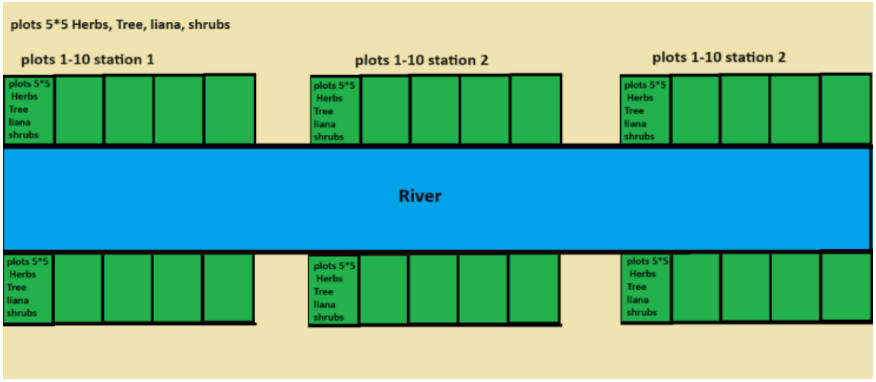

Fig. 2. Scheme analysis of riparian vegetation

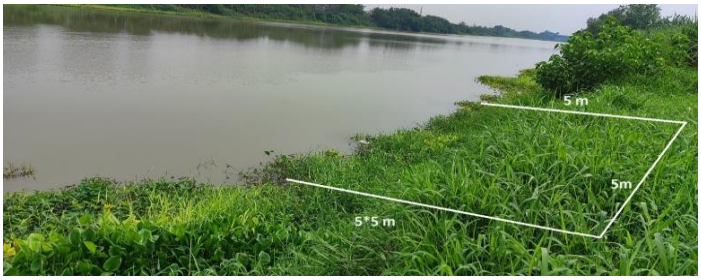

Fig. 3. Collect plant samples from sites

2.3 Data Analysis

Vegetation data was analysed in the form of relative abundance, relative frequency, and importance value index, which were obtained and tabulated using Microsoft Excel. Each species found was recorded for the Abundance and Frequency in one measurement plot. The species found are documented to make identification easier.

The variables observed include:
1. Abundance (A):

$$A = \text{Total number of individuals of a species in all quadrats or plots}$$

The total number of individuals of a species observed in a specific area or habitat.

2. Frequency (R):
The proportion of sampling points (plots or quadrats) where a species is present relative to the total number of sampling points.

$$R = \frac{\text{Number of plots containing the species}}{\text{Total number of plots}} \times 100 \quad (1)$$

3. Relative Abundance (RA):
The percentage of individuals of a particular species compared to the total number of individuals for all species in the area.

$$RA\ (\%) = \frac{\text{Abundance of a species}}{\text{Total abundance of all species}} \times 100 \quad (2)$$

4. Relative Frequency (RF):
The percentage frequency of a species compared to the total frequency of all species.

$$RF\ (\%) = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100 \quad (3)$$

5. Importance Value Index (IVI):
A measure of a species' ecological dominance, calculated by combining its Relative Abundance and Relative Frequency.

$$\text{Important Value Index (IVI)} = \text{Relative Abundance (RA)} + \text{Relative frequency (RF)} \quad (4)$$

3 Results and discussions

3.1 Riparian Vegetation Species on the Brantas River in Mojokerto

The presence of a particular plant species in a particular area shows that that area is able to adapt to the ecosystem and cope with various environmental challenges. Dominant species indicate the species' level of survival and control [21]. Data collection was conducted through riparian vegetation analysis to identify the species present in the riparian zone. Vegetation analysis carried out in three areas shows different levels of species (core plants/ herbs, trees, liana and shrubs). The research results showed that the total number of species found at all sampling points was 50 species. The results showed that 50 species were found across all sampling points, consisting of 42 herbs, two shrubs, three lianas, and three tree species. The study found that Site 1 had 20 species, Site 2 had 22 species, and Site 3 had 33 species, reflecting the differing levels of species across the three areas.

3.2 Analysis of Riparian Species

The riparian species found in each sampling area had varying levels of abundance for each species. The abundant species and dominant species found were analysed. Analysis of the potential of riparian species was carried out through literature studies.

3.2.1 Relative Frequency, Relative Abundance and Important Value Index (Ivi) riparian plants in the Site 1

3.2.1.1. Herb species

The riparian species found at the site were 20 species, with 8659 individuals from ten sampling points. Based on Table 1, the most abundant herb species was *Lemna perpusilla* Torr, which comprised 49.89% of the relative species' abundance. This was followed respectively by *Urochloa mutica* (Forssk.) T.Q. Nguyen 19.75%, *Pontederia crassipes* Mart 9.24%, *Pistia stratiotes* L 7.10%, *Ipomoea aquatica* Forssk 6.70%, *Alternanthera sessilis* (L.) DC 4.68%. Meanwhile, the other species have a relative abundance of less than 1%.

The quantitative analysis of relative frequencies indicated that the species with the highest values were *Ipomoea aquatica* Forssk, *Pontederia crassipes* Mart, and *Urochloa mutica* (Forssk.) T.Q. Nguyen, each with a relative frequency of 14.49%. These were followed by *Lemna perpusilla* Torr and *Alternanthera sessilis* (L.) DC, at 11.59% and *Pistia stratiotes* L, had a relative frequency of 10.14%.

The Importance Value Index (IVI) highlights the most dominant herbaceous species within a habitat. The IVI is calculated as the sum of relative abundance (RA) and relative frequency (RF). The results of the IVI calculation, as shown in Table 1, reveal that the species with the highest significance values were *Lemna perpusilla* Torr 61.49% and *Urochloa mutica* (Forssk.) T.Q. Nguyen 34.24%, *Pontederia crassipes* Mart 23.73%, *Ipomoea aquatica* Forssk 21.19%, *Pistia stratiotes* L 17.25%, *Alternanthera sessilis* (L.) DC 16.27%, *Commelina diffusa* Burm.f 6.25%. The most common herb species in this site is the *Lemna perpusilla* Torr, with the highest (IVI) being 61.49%. Meanwhile, the other species have a relative abundance between 1.4% and 2.9%.

Table 1. Relative frequency, relative abundance, and importance value index of riparian plant species in Site 1, before Mojokerto City, East Java Province, Indonesia

Species name	(A)	(F)	(RA)	(RF)	(IVI)
Alternanthera sessilis (L.) DC.	405	8	4.68	11.59	16.27
Bidens alba (L.) DC.	10	1	0.12	1.45	1.56
Ceratophyllum demersum L.	3	1	0.03	1.45	1.48
Colocasia esculenta (L.) Schott	5	1	0.06	1.45	1.51
Commelina diffusa Burm.f.	165	3	1.91	4.34	6.25
Cyperus brevifolius (Rottb.) Hassk.	10	1	0.12	1.45	1.56
Cyperus imbricatus Retz.	7	2	0.08	2.90	2.98
Eclipta prostrata (L.) L.	10	1	0.12	1.45	1.56
Ipomoea aquatica Forssk.	580	10	6.70	14.49	21.19
Ipomoea carnea Jacq.	1	1	0.01	1.45	1.46
Lemna perpusilla Torr.	4320	8	49.89	11.59	61.49
Manihot esculenta Crantz	1	1	0.01	1.45	1.46
Ottelia alismoides (L.) Pers.	1	1	0.01	1.45	1.46
Pistia stratiotes L.	615	7	7.10	10.14	17.25
Pontederia crassipes Mart.	800	10	9.24	14.49	23.73
Ruellia tuberosa L.	2	1	0.02	1.45	1.472
Saccharum officinarum L.	3	1	0.03	1.45	1.48
Sphaeranthus indicus L.	10	1	0.12	1.45	1.56
Urochloa mutica (Forssk.) T.Q.Nguyen	1710	10	19.75	14.49	34.24
Total	8658	69	100	100	200

3.2.1.2 Tree species

At Site 1, the only tree species observed in the riparian zone was *Hibiscus tiliaceus L.*, with a single individual recorded at one sampling point. This resulted in a relative abundance (RA) of 100%, relative frequency (RF) of 100%, and an Importance Value Index (IVI) of 200. The dominance of *Hibiscus tiliaceus* L. underscores the minimal tree diversity in the area, indicating that environmental or anthropogenic factors may be limiting the establishment of other tree species.

Table 2. Relative frequency, relative abundance, and Importance Value Index of tree species in riparian vegetation at Site 1, before Mojokerto City, East Java Province, Indonesia.

Species name	(A)	(F)	(RA)	(RF)	(IVI)
Hibiscus tiliaceus L.	1	1	100	100	200
Total	1	1	100	100	200

3.2.2 Relative frequency, relative abundance and Importance Value Index (IVI) of riparian vegetation in Site 2

3.2.2.1 Herbs species

The riparian species found at the site were 22 species with a total of 2872 individuals from ten sampling points. Based on Table 3, the herbaceous species with the highest relative abundance was Lemna *perpusilla* Torr, which comprised 33.11% of the total individuals. This was followed respectively by *Ipomoea aquatica* Forssk 19.96%, *Pontederia crassipes* Mart 11.00%, *Alternanthera sessilis* (L.) DC 8.22%, *Persicaria lapathifolia* (L.) Delarbre

8.05%, *Commelina diffusa* Burm.f 5.45 %, *Pistia stratiotes* L 5.27%, *Urochloa mutica* (Forssk.) T.Q. *Nguyen* 3.51%, *Alternanthera philoxeroides* (Mart.) Griseb 1.72%. Meanwhile, the other species have a relative abundance between 0.11% - 2.94%.

The relative frequency analysis highlights that the species with the highest values were *Ipomoea aquatica* Forssk, and *Pontederia crassipes* Mart, each with a relative frequency 14.71%, *Alternanthera sessilis* (L.) DC 13.24%, *Lemna perpusilla* Torr 10.30%, *Commelina diffusa* Burm.f, *Pistia stratiotes* L, each with a relative frequency of 8.82%, *Persicaria lapathifolia* (L.) Delarbre and *Urochloa mutica* (Forssk.) T.Q. Nguyen each with a relative frequency of 5.88%.

The Importance Value Index (IVI) is used to determine the most dominant herb species in a given habitat. The calculated IVI values are presented in Table 3. The species with the highest IVI values were as follows: *Lemna perpusilla Torr* 43.40%, *Ipomoea aquatica Forssk* 34.67%, *Pontederia crassipes* Mart 25.71%, *Alternanthera sessilis* (L.) DC 21.46%, *Commelina diffusa* Burm.f 14.27%, *Pistia stratiotes* L. 14.10%, *Persicaria lapathifolia* (L.) *Delarbre* 13.93%, *Urochloa mutica* (Forssk.) T.Q. Nguyen 9.40%, *Alternanthera philoxeroides* (Mart.) Griseb 4.66%. The most common herb species in this site is the *Lemna perpusilla* Torr, with the highest IVI at 43.40%. Meanwhile, the other species have a relative abundance between 1.58% and 3.40%.

Table 3. Relative Frequency, Relative Abundance, and Important Value Index of Riparian Plant Species in Site 2 after Mojokerto City, East Java Province, Indonesia

Species name	(A)	(F)	(RA)	(RF)	(IVI)
Alternanthera philoxeroides (Mart.) Griseb.	49	2	1.72	2.94	4.66
Alternanthera sessilis (L.) DC.	234	9	8.22	13.24	21.46
Bidens alba (L.) DC.	3	1	0.11	1.471	1.58
Colocasia esculenta (L.) Schott	5	2	0.18	2.94	3.12
Commelina diffusa Burm.f.	155	6	5.45	8.82	14.27
Cyperus imbricatus Retz.	8	1	0.28	1.47	1.75
Ipomoea aquatica Forssk.	568	10	19.96	14.71	34.67
Leersia virginica Willd.	35	1	1.23	1.47	2.70
Lemna perpusilla Torr.	942	7	33.11	10.30	43.40
Ludwigia adscendens (L.) H.Hara	13	2	0.457	2.94	3.40
Musa acuminata Colla	8	2	0.287	2.94	3.22
Paspalum conjugatum P.J.Bergius	33	1	1.16	1.47	2.63
Persicaria lapathifolia (L.) Delarbre	229	4	8.05	5.88	13.93
Pistia stratiotes L.	150	6	5.27	8.82	14.10
Pontederia crassipes Mart.	313	10	11.00	14.71	25.71
Urochloa mutica (Forssk.) T.Q.Nguyen	100	4	3.51	5.88	9.40
Total	2845	68	100	100	200

3.2.2.2 Liana's species

At Site 2, the liana vegetation consisted of three species, with a total of 14 individuals recorded across four sampling points. The liana species with the highest relative abundance was *Cayratia trifolia* (L.) Mabb. & J.Wen, 50%. This was followed respectively by *Cissus verticillata* (L.) Nicolson & C.E.Jarvis, 35.71% and *Camonea vitifolia* (Burm.f.) A.R.Simões & Staples, 14.30%. The relative frequency analysis highlights that the species with the highest values was *Cayratia trifolia* (L.) Mabb. & J.Wen, 50%, followed respectively by *Cissus verticillata* (L.) Nicolson & C.E.Jarvis and *Camonea vitifolia* (Burm.f.) A.R.Simões & Staples, each with a relative frequency of 25%.

Cayratia trifolia (L.) Mabb. & J. Wen emerged as the most dominant liana species at Site 2, with the highest IVI of 100, reflecting its significant ecological contribution to the riparian zone. It is followed by *Cissus verticillata* (L.) Nicolson & C.E. Jarvis (IVI = 60.72%) and *Camonea vitifolia* (Burm.f.) A.R.Simões & Staples (IVI = 39.29%). The dominance of *Cayratia trifolia* indicates its widespread presence and adaptability, while the diversity of other liana species adds to the overall structural and functional complexity of the riparian vegetation at Site 2.

Table 4. Relative frequency, relative abundance, and Important Value Index of liana species in riparian vegetation at Site 2 in Mojokerto City, East Java Province, Indonesia.

Species name	(A)	(F)	(RA)	(RF)	(IVI)
Camonea vitifolia (Burm.f.) A.R.Simões & Staples	2	1	14.30	25	39.29
Cayratia trifolia (L.) Mabb. & J.Wen	7	2	50	50	100
Cissus verticillata (L.) Nicolson & C.E. Jarvis	5	1	35.719	25	60.72
Total	14	4	100	100	200

3.2.2.3 Shrub species

At Site 2, the shrub vegetation consisted of two species, with a total of 11 individuals recorded across three sampling points. The shrub species with the highest relative abundance was *Ipomoea carnea* Jacq, 54.55%, followed by *Manihot esculenta* Crantz, 45.45%. The relative frequency analysis highlights that the species with the highest values was *Ipomoea carnea* Jacq, 66.67%, followed by *Manihot esculenta* Crantz, 33.33%. *Ipomoea carnea* Jacq. is the dominant shrub species at Site 2, with the highest IVI value of 121.21, reflecting its prevalence and ecological significance in this habitat, *Manihot esculenta* Crantz contributes moderately to the shrub layer, with an IVI of 78.70%. These indicate that the shrub community at Site 2 is relatively simple, dominated by Ipomoea carnea Jacq.

Table 5. Relative frequency, relative abundance, and Important Value Index of shrub species in riparian vegetation at Site 2 in Mojokerto City, East Java Province, Indonesia.

Species name	(A)	(F)	(RA)	(RF)	(IVI)
Ipomoea carnea Jacq.	6	2	54.55	66.67	121.21
Manihot esculenta Crantz	5	1	45.45	33.33	78.7
Total	11	3	100	100	200

3.2.2.4 Trees species

At Site 2, the tree vegetation consisted of a single species, *Muntingia calabura L*., represented by two individuals across two sampling points. The metrics for this species are as follows: relative abundance (RA): 100%, relative frequency (RF): 100% and Importance Value Index (IVI): 200%. *Muntingia calabura L*. is the sole tree species recorded at Site 2, making it the dominant and only representative in this category. Its presence highlights the limited diversity of the tree layer within the riparian ecosystem at this site, possibly influenced by specific environmental or anthropogenic factors.

Table 6. Relative frequency, relative abundance, and Important Value Index of trees species in riparian vegetation at Site 2 In Mojokerto City, East Java Province, Indonesia

Species name	(A)	(F)	(RA)	(RF)	(IVI)
Muntingia calabura L.	2	2	100	100	200
Total	2	2	100	100	200

3.2.3 Relative Frequency and Relative Abundance and Importance Value Index (IVI) riparian plants in the Site 3

3.2.3.1 Herb species

The riparian species found at the site were 33 species, with 2361 individuals from 10 sampling points. Based on Table 7, the most abundant herb species was *Lemna perpusilla* Torr, with a relative species abundance of 36.14%, followed respectively by *Ceratophylum demersum* L 15.30 %, *Urochloa mutica* (Forssk.) T.Q.Nguyen 14.75%, *Pontederia crassipes* Mart 5.97%, *Alternanthera sessilis* (L.) DC 5.38%, *Commelina diffusa* Burm.f 4.45 %, *Ipomoea aquatica* Forssk 2.71%, Meanwhile, the other species have a relative abundance of less than 1 %.

The results of the quantitative analysis of relative frequencies found that species had the highest values, respectively, namely, *Pontederia crassipes* Mart 9.71% and *Alternanthera sessilis* (L.) DC 8.74%, *Ceratophylum demersum* L 7.77%, *Urochloa mutica* (Forssk.) T.Q.Nguyen 6.80%, *Lemna perpusilla* Torr. 5.83%, *Cyperus alternifolius* L, *Cyperus imbricatus* Retz, *Ipomoea aquatica* Forssk, each with a relative frequency of 4.85%, *Ludwigia octovalvis* (Jacq.) P.H. Raven 4.81%, *Persicaria maculosa* Gray 3.85%, *Basilicum polystachyon* (L.) Moench 3.88%, *Cynodon dactylon* (L.) Pers, *Eclipta prostrata* (L) L, *Ludwigia adscendens* (L.) H. Hara, *Mikania micrantha* Kunth and *Typha latifolia* L., each with a relative frequency of 2.91% (Table 7).

The Importance Value Index (IVI) is used to identify the most dominant herb species in a habitat. The results of the IVI calculations are presented in Table 7. The species with the highest IVI values were *Lemna perpusilla* Torr 41.97%, *Ceratophylum demersum* L 23.10%, *Urochloa mutica* (Forssk.) T.Q.Nguyen 21.54 %, *Pontederia crassipes* Mart 15.68%, *Alternanthera sessilis* (L.) DC 14.12%, *Ipomoea aquatica* Forssk 7.57%, *Commelina diffusa* Burm.f 6.39%, *Cyperus alternifolius* L 6.42%, *Cyperus imbricatus* Retz 6.34%, *Ludwigia octovalvis* (Jacq.) P.H. Raven 5.96%, *Persicaria maculosa* Gray 5.32%, *Basilicum polystachyon* (L.)) Moench 4.73%, *Cynodon dactylon* (L.) Pers 4.44%.The most common herb species in this site is the *Lemna perpusilla* Torr, which has the highest IVI at 41.97%. Meanwhile, the other species have a relative abundance between 1.10% - 3.68 %.

Table 7. Relative Frequency, Relative Abundance and Important Value Index of species richness in site 3 in Porong, one of the cities in East Java Province, Indonesia

Species name	(A)	(F)	(RA)	(RF)	(IVI)
Alternanthera sessilis (L.) DC.	127	9	5.38	8.74	14.12
Basilicum polystachyon (L.) Moench	20	4	0.85	3.88	4.73
Bidens alba (L.) DC.	8	2	0.34	1.94	2.28
Ceratophylum demersum L.	361	8	15.30	7.77	23.1
Cleome rutidosperma DC.	4	1	0.17	0.97	1.14

Species name	(A)	(F)	(RA)	(RF)	(IVI)
Commelina diffusa Burm.f.	105	2	4.45	1.94	6.39
Cynodon dactylon (L.) Pers.	36	3	1.53	2.91	4.44
Cyperus alternifolius L.	37	5	1.57	4.85	6.42
Cyperus imbricatus Retz.	35	5	1.48	4.85	6.34
Digitaria sanguinalis (L.) Scop.	7	1	0.30	0.97	1.27
Diodia virginiana L.	3	1	0.13	0.97	1.10
Eclipta prostrata (L.) L.	16	3	0.68	2.91	3.59
Eleusine indica (L.) Gaertn.	21	1	0.89	0.97	1.86
Fimbristylis littoralis Gaudich.	1	1	0.68	0.97	1.65
Hyptis brevipes Poit.	16	1	0.17	0.97	1.14
Ipomoea aquatica Forssk.	4	1	2.71	4.85	7.57
Lemna perpusilla Torr.	64	5	36.14	5.83	41.97
Lindernia antipoda (L.) Alston	853	6	0.21	0.97	1.18
Ludwigia adscendens (L.) H. Hara	5	1	0.64	2.91	3.55
Ludwigia octovalvis (Jacq.) P.H. Raven	15	3	1.10	4.85	5.96
Mikania micrantha Kunth	26	5	0.64	2.91	3.55
Muntingia calabura L.	15	3	0.08	1.94	2.03
Ottelia alismoides (L.) Pers.	2	2	0.04	0.97	1.01
Persicaria maculosa Gray	1	1	1.44	3.88	5.32
Phyllanthus reticulatus Poir.	34	4	0.08	0.97	1.06
Pistia stratiotes L.	2	1	0.55	0.97	1.52
Pontederia crassipes Mart.	13	1	5.97	9.71	15.68
Puzolzia zeylanica (L.) Benn.	141	10	0.55	1.94	2.49
Scoparia dulcis L.	13	2	0.13	0.97	1.10
Typha latifolia L.	3	1	0.76	2.91	3.68
Urochloa mutica (Forssk.) T.Q.Nguyen	18	3	14.75	6.80	21.54
Vigna unguiculata (L.) Walp.	348	7	0.30	0.97	1.27
TOTAL	2360	103	100	100	200

3.2.3.2 Tree species

The updated observation at Site 3 revealed a single tree species, *Ficus racemosa L.*, which one individual represented across one sampling point. This species exhibited the following characteristics: relative abundance (RA) of 100%, relative frequency (RF) of 100% and Importance Value Index (IVI) of 200%. This indicates that *Ficus racemosa* L. is the sole dominant tree species at the site, contributing entirely to the tree vegetation structure in this riparian zone. The lack of diversity in the tree category reflects the specific environmental conditions or disturbances influencing the riparian ecosystem. However, it is important to note that tree vegetation at this site is minimal, as the riparian area is dominated by herbaceous.

Table 8. Relative frequency, relative abundance, and Important Value Index of trees species in riparian vegetation at Site 3 in Porong, one of the cities in East Java Province, Indonesia.

Species name	(A)	(F)	(RA)	(RF)	(IVI)
Ficus racemosa L.	1	1	100	100	200
Total	1	1	100	100	200

Lemna perpusilla Torr., a species of floating plant found dominantly in the research site, shows an important role in the riparian ecosystem downstream of Brantas River in Mojokerto. As an aquatic plant, *Lemna perpusilla Torr*. not only functions to improve water quality by filtering pollutants and reducing excess nutrients but also plays a role in stabilising the microclimate around the river. Based on the IVI, this species dominates the vegetation in the three research sites, covering 61.32% in Site 1, 41.89% in Site 2, and 41.90% in Site 3. The plant reproduces rapidly, floats on the water surface, and absorbs nutrients from the surrounding environment. *Lemna perpusilla* Torr. plays a role in reducing nutrient concentrations, especially phosphorus and nitrogen, which can cause water eutrophication. This makes it a very important indicator of water quality, where its presence is closely related to the health of riparian aquatic ecosystems [22]. The presence of invasive species, such as *Pontederia crassipes* Mart., raises significant concerns for ecosystem health, as these species can disrupt the balance of local ecosystems by outcompeting native plants and reducing biodiversity [23]. On the other hand, native species like *Ipomoea aquatica Forssk*. contribute positively by stabilising soil and promoting ecosystem resilience. These species play vital roles in nutrient cycling and providing habitat for aquatic fauna, enhancing biodiversity and supporting the ecosystem's stability [24].

The limited diversity of shrubs and trees across the study sites is noteworthy. For instance, the presence of only one tree species at each site (*Hibiscus tiliaceus* L., *Muntingia calabura* L., and *Ficus racemosa* L.) suggests that environmental or anthropogenic stressors, such as pollution, deforestation, or changes in hydrology, may be inhibiting the establishment of a more diverse woody vegetation layer. These factors are well-documented as limiting tree diversity and undermining riparian stability [25]. Trees in riparian zones are crucial for providing shade, stabilising soil, and supporting biodiversity, underscoring the need to address these pressures to ensure long-term ecological balance [26].

The dominance of herbaceous species, such as *Lemna perpusilla* Torr and *Urochloa mutica* (Forssk.) T.Q. Nguyen, indicates their potential for use in ecological restoration efforts. These species are valuable for stabilising sediments and reducing erosion, making them suitable for restoring degraded riparian habitats [27]. However, the management of invasive species like *Pontederia crassipes* requires careful consideration, as their spread could threaten the success of restoration projects by displacing beneficial native species [28].

4 Conclusion

The analysis of plant species richness across different growth levels in the riparian zone of the Brantas River revealed results aligned with the study's objectives. The plant species observed downstream the riverbank were identified and categorised as follows: The first site is inhabited by 20 species, with 8,659 individuals. The second site is inhabited by 22 species, with 2,892 individuals, while the third site contains 33 species, with 2,361 individuals. The most prevalent species observed at the three study sites was *Lemna perpusilla* Torr, followed by *Urochloa mutica* (Forssk.) T.Q. Nguyen, *Pistia stratiotes* L., *Pontederia crassipes* Mart, *Ipomoea aquatica* Forssk, *Alternanthera sessilis* (L.) DC, and *Commelina diffusa* Burm.f., The importance of these species in terms of their high Importance Value Index (IVI) across

all sites underscores their ecological role in water quality improvement and nutrient cycling within the riparian ecosystem. The study also highlights the low diversity in tree vegetation across all sites, with *Hibiscus tiliaceus* L. and *Muntingia calabura* L. being the sole representatives in Sites 1 and 2, respectively, and *Ficus racemosa* L. at Site 3.

The results indicate that the riparian vegetation in this area plays a significant role in stabilising the riverbanks, controlling erosion, and maintaining biodiversity. However, the low tree diversity suggests that further ecological factors, such as human disturbance and environmental conditions, may limit the establishment of tree species.

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