IOP Conference Series: Earth and Environmental Science

The 6th International Conference on Agriculture and Bioindustry (ICAGRI)

To cite this article: 2025 *IOP Conf. Ser.: Earth Environ. Sci.* **1476** 011001

The 6th INTERNATIONAL CONFERENCE ON AGRICULTURE AND BIOINDUSTRY (ICAGRI)

"Promoting Agroecology and Climate-Smart Agriculture for Environmental Resilience, Biodiversity, and Sustainability"

Banda Aceh, 09 -10 October 2024

IOP Conf. Series: Earth and Environmental Science **1476** (2025) 011001 doi:10.1088/1755-1315/1476/1/011001

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Preface

The 6th International Conference on Agriculture (ICAGRI) 2024 marks another significant milestone in our ongoing commitment to advancing sustainable agriculture. Building upon the success of our previous conferences, this year's event continues to bring together a diverse array of academics, researchers, policy makers, and professionals from around the globe.

Our theme, " *Promoting Agroecology and Climate-Smart Agriculture for Environmental Resilience, Biodiversity, and Sustainability*", highlight the critical importance of sustainable agricultural practices. We recognize that sustainable agriculture must be ecologically sound, economically valuable, and socially just. It requires strategies that respect diversity, employ integrative approaches, maintain a long-term perspective, and ensure equality and sustainability.

This year, we are pleased to report that the conference received 131 submitted papers. After a rigorous review process, 105 papers were accepted for presentation directly in Hermes Palace Hotel, Banda Aceh. We extend our heartfelt gratitude to all those who have contributed to the success of this conference. Special thanks go to: The Rector of Universitas Syiah Kuala, The Dean and Vice Dean of the Agriculture Faculty (FP USK), The Head of Research and Community Service Institution (LPPM) *Universitas Syiah Kuala*, Our national and international partners, Our esteemed keynote and invited speakers and All committee members for their dedication and hard work.

We are confident that the 6th ICAGRI 2024 will serve as a platform for meaningful discussions and collaborations, contributing significantly to the future of sustainable development in agriculture. We look forward to the insights and innovations that will emerge from this gathering of minds. As we conclude, we invite you to engage fully in the conference proceedings and to carry the spirit of collaboration and innovation back to your respective fields. We hope to see you again at the 7th ICAGRI 2025 conference.

Cordially yours,

Prof. Dr. Eka Meutia Sari
Chairperson of the 6th ICAGRI 2024

IOP Conf. Series: Earth and Environmental Science **1476** (2025) 012030 doi:10.1088/1755-1315/1476/1/012030

Diversity of Riparian Plants Across Different Soil Characteristics in the Kampar Watershed for Ecosystem Conservation

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Abstract. Indonesia has committed to increasing ecosystem protection by targeting 32.5 million hectares of water conservation areas or 10% of Indonesia's water area by 2030, despite challenges from over-exploitation of resources. Protecting riparian vegetation is crucial for maintaining water quality and supporting aquatic and terrestrial ecosystems. This study aims to determine the diversity of riparian plant vegetation in the Kampar watershed according to two different soil types: peat soil and red-yellow podzolic. The methods used are plot installation, identification of riparian vegetation types, and analysis using the Shannon-Wiener index importance value index. The results show that the Kampar watershed riparian area has 129 plant species in 40 families with peat soil and an importance value index of 1.03-25.17 with the highest diversity index at 2.178 (Moraceae). The riparian area with podzolic soil has 140 species in 43 families, with an importance value index of 1.07-32.57 and the highest diversity index of 2.43 (Euphorbiaceae). The structure and composition of species found differ in each area, influenced by different soils and anthropogenic impacts experienced. The trees' height ranges from 35-50 m with an average of 37 m dominated by *Durio zibethinus* Merr., *Baccaurea macrocarpa* (Miq.) Müll.Arg. in red-yellow podzolic, *Vatica pauciflora Blume*, Koompassia excelsa (Becc.) Taub in peat soil.

1. Introduction

Indonesia has committed to enhancing ecosystem protection by targeting the designation of 32.5 million hectares of marine conservation areas (KKP), equivalent to 10% of Indonesia's marine territory, by 2030 [1]. However, due to excessive natural resource exploitation, the areas available for biodiversity protection are significantly limited [2–4]. Given their functions and contributions to both aquatic and terrestrial ecosystems, riparian zones are among the critical areas that require protection and wise management [5,6]. Riparian zones represent the transitional area between aquatic and terrestrial ecosystems, playing a crucial role in maintaining the stability of riverine and terrestrial ecosystems. Land-use changes in riparian areas impact their absorption capacity, particularly in river riparian zones, resulting in the reduction or even loss of vegetation [7–9].

The diversity of riparian vegetation surrounding water sources plays a crucial role in maintaining water quality [10,11]. This is because riparian vegetation is resilient to both wet and dry conditions, as well as to the dynamic flow of rivers [12]. Riparian tree vegetation also functions as a regulator of water management, but it is vulnerable to changes in vegetation patterns due to environmental influences and human disturbances [13].

Previous research has explored the relationship between riparian vegetation and soil and water conservation, particularly focusing on vegetation patterns. It has been found that vegetation with strip or band patterns and aggregated structures can significantly contribute to controlling soil erosion [14]. The study by Kemalasari and Choesin [15] indicated a correlation between riparian vegetation and the physicochemical conditions of water. Low vegetation cover was associated with high concentrations of chemical content in the river, increased light intensity, and soil compaction, which influence water runoff, particularly during the rainy season. Aparicio et al. [16] found that the severity of contamination can also impact the effectiveness of riparian vegetation in maintaining water quality. For instance, in areas of intensive agriculture, riparian vegetation plays a crucial role in filtering nitrate concentrations from agricultural runoff, preventing them from being directly carried into the river.

The less fragmented the vegetation, the more effective riparian vegetation becomes in trapping sediments and intercepting pollutants carried by runoff flowing into rivers [17]. However, riparian vegetation is highly influenced by environmental factors such as soil type, topography, natural disturbances like floods, and anthropogenic activities [18,19]. Soil is a primary contributor to the distribution and diversity of plants [20]. Several studies have found varying responses in plant composition related to soil type and water availability [20,21]. Prastiyo et al. [22] observed that the use of agroforestry land in the riparian areas of the Ciliwung watershed, under conditions of good plant diversity (moderate to high category), is beneficial for maintaining the quality and quantity of urban water management in Bogor City.

The Kampar River is one of the largest rivers in Riau Province. Its flow consists of two rivers: the Kampar Kanan River and the Kampar Kiri River (located in Kampar Regency), which converge in Pelalawan Regency. The Kampar watershed (DAS Kampar) exhibits varying soil characteristics, and a significant portion has been converted into residential areas, plantations, and industrial zones. According to Nurdin et al. [23], approximately 54.94% of the total land area in the Upper Kampar watershed has been utilized, including for agriculture and plantations. Titisari et al. [5] found that the water footprint performance scores for rice and maize crops in the Kampar watershed fall into the poor category. If this land use is not managed wisely, it could negatively impact river quality and reduce the water retention capacity of the riparian areas. This, in turn, will have varying effects on riparian vegetation in different regions. Therefore, it is crucial to understand the species diversity of riparian vegetation in the Kampar watershed based on different soil characteristics, including peat soils and red-yellow podzolic soils. This study can serve as a reference for better riparian land use planning, helping to preserve the biodiversity of riparian vegetation and maintain water quality in the Kampar watershed.

2. Materials and methods

2.1. Study site

This research was conducted from April to July 2024 in the Kampar River watershed, Indonesia, specifically in Kampar Regency, with the river flowing into Pelalawan Regency (Figure 1). The riparian area was defined with an optimal length of 20 meters from the riverbank.

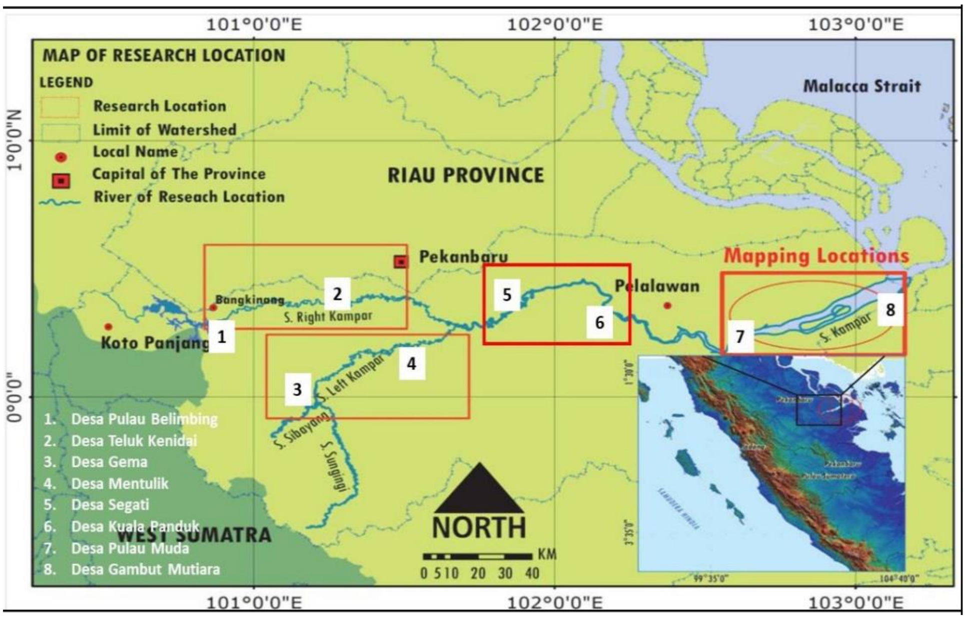

Figure 1. Study site

2.2. Data collection

The line transect method was used to assess riparian plant species recorded in the Kampar watershed. Transect lines were established along 1 km of the river, positioned 3 meters from the riverbank. The transect was divided into ten segments, each 100 meters apart, and plants within the transect area were recorded. Equipment such as raffia string, tape measure, stakes, and GPS was used to establish the transect lines. A camera was employed to document images of riparian plants found at the study site. Only specific plant species (not immediately identified) within each plot were collected for preservation as specimens to be processed at the Laboratory of Andalas University, West Sumatra.

2.3. Data analysis

The methods used included plot establishment, identification of riparian vegetation species, and analysis using the Importance Value Index and Shannon-Wiener Diversity Index with the following equations:

$$\text{INP} = \text{INP} = \text{Kr} + \text{Fr} + \text{Dr} \text{ (for tree and sapling vegetation)} \quad (1)$$

$$\text{INP} = \text{Kr} + \text{Fr} \text{ (for pole, seedling, and understory vegetation)} \quad (2)$$

$$H' = -\sum si = 1\ Pi\ In\ Pi \quad (3)$$

Where:
H = Shannon-Wiener Diversity Index
Pi = ni/N
ni = Number of individuals of a species
N = Total number of individuals of all species

3. Results and discussion

The research reveals differences in vegetation composition within the Kampar watershed. Such variations are commonly observed as each watershed has distinct characteristics. Vegetation composition is influenced by environmental factors, including soil type, which results in different plant species persisting in various areas. Additionally, pollution and contamination resulting from anthropogenic activities contribute to changes in the environment, affecting the reduction of vegetation composition. Figure 2 illustrates a comparison of riparian ecosystem profiles between mineral soils and peat soils in the Kampar River watershed.

Figure 2. Comparison of riparian ecosystem profiles in mineral soils (a) and peat soils (b) of the Kampar Watershed.

3.1. Riparian Diversity in Kampar watershed with peat soil characteristics in Pelalawan Regency

The riparian areas in Pelalawan Regency are dominated by peat soils. Peatlands in the Kampar watershed range from shallow to very deep. The lower Kampar watershed (Pelalawan Regency) has peat depths exceeding 3 meters, indicating that these peatland types fall within the protective function category where land clearing and drainage construction should be avoided to prevent impacts on river flow patterns. Based on vegetation analysis, a total of 129 plant species from 40 families were recorded in the riparian areas of the Kampar River with peat soil characteristics, exhibiting Importance Value Index values ranging from 1.03 to 25.17 (Table 1).

Table 1. Riparian plant diversity in the Kampar River Basin with peat soil.

Family	Species	Important Value Index	Diveristy Index (H')
Anacardiaceae	*Gluta renghas* L.	18,21	**1,693**
	Campnosperma coriaceum (Jack.) Hallier f.	11,84	
	Semecarpus heterophylla	8,02	
	Melanorrhoea wallichii Hook. f	6,87	
	Mangifera indica L.	1,55	
	Dracontomelon dao (Blanco) Merr. & Rolfe	1,33	
	Lannea coromandelica (Houtt.) Merr.	1,07	
Annonaceae	*Cananga odorata* (Lam.) Hook. f. & Thomson	3,15	**1,149**
	Polyalthia rumphii (Blume ex Hensch.) Merr.	2,16	
	Xylopia fusca Maingay exHook.F. & Thomson	2,14	
	Polyalthia littoralis (Blume) Boerl.	1,87	
Apocynaceae	*Dyera lowii* Hook. f.	9,15	**1.471**

	Alstonia angustifolia Miq.	9,13	
	Cerbera floribunda K. Schum.	3,12	
	Cerbera odollam Gaertn.	2,88	
	Tabernaemontana sphaerocarpa BL.	2,13	
	Voacanga grandifolia (Miq.) Rolfe	1,1	
Arecaceae	*Arenga pinnata* (Wurmb) Merr.	7,18	**0.406**
	Roystonea regia (Kunth) O.F. Cook	2,12	
Bombacaceae	*Durio zhibenthinus* Rumph. ex Murray	17,21	**0.653**
	Durio carinatus Mast.	15,12	
Burseraceae	*Dacryodes macrocarpa* H.J. Lam	8,77	**0.905**
	Santiria tomentosa Blume	4,18	
	Santiria laevigata Blume	3,97	
	Canarium vulgare Leenh.	3,77	
Crypteroniaceae	*Dactylocladus stenostachys* Oliv.	18,98	**0**
Datiscaceae	*Octomeles sumatrana* Miq.	3,61	0.622
Dilleniaceae	*Dillenia reticulata* King	8,12	**0.712**
	Dillenia indica L.	7,92	
Dipterocarpaceae	*Vatica rassak* (Korth.) Blume	18,12	**1.351**
	Shorea platycarpa F. Heim	12,92	
	Shorea bracteolata Dyer	12,56	
	Shorea ovalis Blume	11,17	
	Shorea parvifolia Dyer	11,09	
	Anisoptera marginata Korth.	7,13	
	Shorea uliginosa Foxw.	5,16	
Ebenaceae	*Diospyros cauliflora* De Wild.	7,11	**0.718**
	Diospyros macrophylla A. Chev.	6,77	
Elaeocarpaceae	*Elaeocarpus glaber* Blume	7,55	**0.430**
	Muntingia calabura L.	1,15	
Euphorbiaceae	*Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg.	19,22	**1.388**
	Macaranga triloba (BI.) Muell. Arg.	17,22	
	Macaranga gigantea (Reichb.f. & Zoll.) Müll. Arg.	12,77	
	Macaranga conifera (Zoll.) Müll.Arg.	8,11	
	Bacaurea recemosa M.A	7,65	
	Baccaurea motleyana (Müll. Arg.) Müll. Arg.	7,21	
	Macaranga javanica (Blume.)Mull. Arg.	7,2	
	Balakata baccata (Roxb.) Esser	7,12	
	Macaranga tanarius (L) Mull. Arg.	4,17	
	Dyrpetes brownii Vahl.	3,77	
	Bischofia javanica Blume	3,27	
	Aleurites moluccana (L.) Willd.	3,16	

	Mallotus paniculatus (L) Mull. Arg.	3,12	
	Sapium discolor (Champ. ex Benth.) Müll. Arg.	2,13	
Fabaceae	*Delonix regia* (Bojer ex Hook.) Raf.	7,34	**0.800**
	Calliandra houstoniana (Mill.) Standl.	3,12	
	Albizia procera (Roxb.) Benth.	1,83	
	Albizia lebbekoides (DC.) Benth.	1,77	
	Albizia chinensis (Osbeck) Merr.	1,61	
	Adenanthera pavonina L.	1,22	
	Albizia falcataria (L.) Fosberg	1,22	
	Gliricidia sepium Kunth ex Steud.	1,1	
	Pithecellobium jiringa Prain	1,08	
Guttiferae	*Calophyllum soulattri* Burm. f.	19,21	**0,961**
	Calophyllum pulcherrimum Wall. ex Choisy	17,22	
	Garcinia mangostana L.	1,92	
	Garcinia nigrolineata Planch. ex T. Anderson	1,13	
Hypericaceae	*Cratoxylum formosum (*Jack) Benth. & Hook.fil. ex Dyer	19,77	**0,693**
	Cratoxylum arborescens Blume	19,21	
Lauraceae	*Dehaasia caesia* Blume	17,21	**1,127**
	Litsea glutinosa (Lour.) C.B. Rob.	2,66	
	Litsea robusta Blume	2,34	
	Litsea odorifera Valeton	2,19	
	Litsea grandis (Nees) Hook. f.	1,99	
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.	8,17	**0**
Leguminosae	*Koompassia malaccensis* Maing.	15,21	
	Koompassia excelsa (Becc.) Taub.	14,44	
	Dialium platysepalum Baker	6,33	
	Dialium patens Baker	5,83	
Lytracheae	*Lagerstroemia thorelii* Gagnep.	1,11	**0**
Magnoliaceae	*Magnolia candolii* (Blume) H. Keng.	1,16	**0**
Malpighiaceae	*Hiptage benghalensis* (L.) Kurz	1,21	**0**
Malvaceae	*Heritiera javanica* (Blume) Kosterm	3,18	**1,099**
	Heritiera sumatrana (Miq.) Kosterm	3,17	
	Heritiera simplicifolia (Masters) Kosterm	3,11	
Meliaceae	*Swieteonia macrophylla* King	11,21	**0,584**
	Dysoxylum gaudichaudianum (A. Juss.) Miq.	4,17	
Moraceae	*Ficus benjamina* L.	8,19	**2,178**
	Ficus copiosa (Roxb.) Steud.	6,72	
	Ficus virens Aiton	6,12	
	Ficus racemosa L.	5,88	
	Ficus variegata Corner	5,14	

	Ficus septica Burm. f.	4,77	
	Arthocarpus altilis (Parkinson) Fosberg	4,12	
	Antiaris toxicaria Lesch.	3,11	
	Parartocarpus venenosus (Zoll. & Moritzi) Becc.	1,15	
	Parartocarpus triandis (Zoll. & Moritzi) Becc.	1,12	
Moringaceae	*Moringa oleifera* Lam.	1,05	**0**
Myristicaceae	*Myristica lowiana* King.	13,22	**0**
Myrtaceae	*Syzygium formosum* (Wall.) Masam.	13,21	**2,163**
	Syzygium densiflorum Wall. ex Wt. & Arn.	13,16	
	Syzygium kiahii (M.R.Hend.) I.M.Turner	11,17	
	Tristaniopsis obovata (Benn.) Paul G.Wilson & J.T.Waterh.	11,1	
	Syzygium littorale (Blume) Amshoff	9,21	
	Syzygium cumini L.	9,17	
	Eucalyptus populnea F. Muell.	9,12	
	Eucalyptus platyphylla F. Muell.	8,72	
	Syzygium polyanthum (Wight) Walp.	7,18	
	Syzygium pycnanthum Merr.& L.M.Perry	7,15	
	Syzygium polyanthum (Wight) Walp.	6,18	
	Psidium guajava L.	2,17	
	Rhodamnia cinerea Jack	1,16	
Olacacea	*Ochanostachys amentacea* Mast.	2,33	**0**
Rosaceae	*Parastemon urophyllus* (Wall. ex A. DC.) A. DC.	3,15	**0**
Rubiaceae	*Nauclea orientalis* (L.) L.	1,17	**0**
Sapindaceae	*Schleichera oleosa* (Lour.) Oken	3,16	**0,574**
	Nephelium ramboutan-ake (Labill.) Leenh	1,12	
Sapotaceae	*Palaquium leiocarpum* Boerl.	6,22	**1,092**
	Palaquium burckii H.J. Lam	5,18	
	Ganua motleyana (de Vriese) Pierre ex Dubard	4,77	
Sterculiaceae	*Pterospermum diversifolium* Blume	5,27	**1,266**
	Sterculia gliva Miq.	3,34	
	Sterculia foetida Linn	3,12	
	Kleinhovia hospita L.	1,03	
Tetrameristaceae	*Tetramerista glabra* T. glabra Miq.	17,16	**0**
Thymelaeaceae	*Gonystylus bancanus* (Miq.) Kurz	25,17	**0**
Urticaceae	*Dendrocnide stimulans* (L. f.) Chew	7,11	**0**
Verbenaceae	*Gmelina arborea* Roxb.	4,11	**0**
Vitaceae	*Ampelocissus thyrsiflora* (Blume) Planch.	4,51	**0**

Table 1 indicates that the highest Importance Value Index (IVI) is observed for *Gonystylus bancanus* (Miq.) Kurz, with an IVI of 25.17, signifying its dominant role in the ecosystem. *Gonystylus bancanus*

(Miq.) Kurz, a gaharu-producing tree, is categorized as Vulnerable on the IUCN Red List and is classified as a footprint-impacted species by the World Wide Fund for Nature. Gaharu does not require specific soil characteristics for growth and can typically thrive in a range of soil types, from peat to sandy soils [24,25]. This plant is commonly used by communities for medicinal purposes, incense, and fragrances [26,27], suggesting its potential for development as a source of income for local communities. Conversely, *Kleinhovia hospita* L. has the lowest IVI, at 1.03. This finding contrasts with the study by Mewengkang et al. [28], which reported *Kleinhovia hospita* as having the highest IVI (54) but only at an elevation of 0 meters above sea level. This discrepancy may be attributed to environmental factors, including elevation, which is a critical factor influencing the growth and development of young trees [29–31].

The Importance Value Index (IVI) of a species within a community serves as a parameter to determine its role and significance within that community [32,33]. The dominance of a species within a community reflects its adaptability to the habitat. A higher IVI indicates greater dominance within the community, and vice versa. Dominance in a habitat signifies that the species can exploit a substantial portion of the resources available in its environment [34]. The average IVI at the study site remains relatively high, dominated by *Vatica rassak* and *Koompassia excelsa*. This finding is consistent with Purwaningsih [35], who reported that riparian and peat forest vegetation exhibited a higher IVI of 57.92%, with dominant species including *Schima wallichii*, *Castanopsis javanica*, *Baccaurea minor*, and *Koompassia*. Ristawan et al. [36] also found that the environmental conditions and vegetation in the upper reaches of the Panjang River, Semarang, are still conducive to plant survival. In contrast, Lukas et al. [37] found that the riparian vegetation composition in the Sebangau River, Central Kalimantan, was dominated by herbaceous and grass species, with a lower presence of tree species.

3.2. Riparian Diversity in Kampar watershed with yellow red podzolic soil characteristics in Kampar Regency

Riparian vegetation with podzolic soil characteristics comprises 140 species from 43 families, with Importance Value Index (IVI) values ranging from 1.07 to 32.57 (Table 2). The most represented families include *Euphorbiaceae*, *Moraceae*, *Poaceae*, and *Fabaceae*. In contrast, Takarina et al. [38] reported that mining sites in the Cikadang River area featured 18 families and 42 plant species, with *Compositae* and *Poaceae* being predominant in Banten. Their study found a positive correlation between riparian diversity and distance from mining sites, with decreasing diversity trends observed closer to artisanal mining activities. The most prevalent species in their study were *Ageratum conyzoides*, followed by *Impatiens platypetala*, *Cibadium surinamense*, *Wollastonia biflora*, *Calliandra calothyrsus*, and *Pityrogramma calomelanos*. In contrast, Pertiwi et al. [39] found that the riparian tree vegetation in the littoral zone of the Lawo River consisted of 19 species distributed across eight distinct groups. The plant *Gmelina arborea*, from the *Verbenaceae* family, was the predominant species in the riparian tree vegetation of the Lawo River in South Sulawesi.

Table 2. The diversity of riparian plants in the Kampar Watershed with podzolic soil types.

Family	Species	Important Value Index	Diveristy Index (H')
Anacardiaceae	*Melanorrhoea wallichii* Hook. f	25,17	**1.782**
	Campnosperma coriaceum (Jack.) Hallier f.	21,52	
	Gluta renghas L.	19,28	
	Mangifera indica L.	17,15	
	Lannea coromandelica (Houtt.) Merr.	9,82	
	Dracontomelon dao (Blanco) Merr. & Rolfe	4,17	
	Semecarpus heterophylla Blume	3,88	
Annonaceae	*Polyalthia rumphii* (Blume ex Hensch.) Merr.	11,63	**1.52**

	Xylopia fusca Maingay exHook.F. & Thomson	23,17	
	Orophea enneandra Blume	11,95	
	Polyalthia littoralis (Blume) Boerl.	9,76	
	Cananga odorata (Lam.) Hook. f. & Thomson	2,9	
	Annona muricata L.	1,18	
Apocynaceae	*Dyera lowii* Hook. f.	27,66	**1.13**
	Wrightia tomentosa Roem. & Schult.	4,66	
	Alstonia angustifolia Miq.	2,17	
	Tabernaemontana sphaerocarpa BL.	2,14	
	Cerbera floribunda K. Schum.	1,41	
	Cerbera odollam Gaertn.	1,21	
Arecaceae	*Arenga pinnata* (Wurmb) Merr.	3,17	**0.69**
	Roystonea regia (Kunth) O.F. Cook	3,11	
Bombacaceae	*Durio zhibenthinus* Rumph. ex Murray	18,23	**1.097**
	Durio carinatus Mast.	17,88	
	Ceiba pentandra (L.) Gaertn.	16,22	
Burseraceae	*Protium javanicum* Burm. f.	7,61	**1.22**
	Dacryodes macrocarpa H.J. Lam	17,21	
	Santiria tomentosa Blume	11,92	
	Canarium vulgare Leenh.	2,67	
Capparaceae	*Capparis micrantha* A. Rich.	1,88	**0**
Caricaceae	*Carica papaya* L.	2,17	**0**
Crypteroniaceae	*Dactylocladus stenostachys* Oliv.	16,29	**0**
Datiscaceae	*Octomeles sumatrana* Miq.	29,17	**0**
Dilleniaceae	*Dillenia indica* L.	3,16	**0**
Dipterocarpaceae	*Shorea ovalis* Blume	23,18	**1.228**
	Shorea parvifolia Dyer	21,63	
	Vatica rassak (Korth.) Blume	17,23	
	Anisoptera marginata Korth.	3,52	
Ebenaceae	*Diospyros macrophylla* A. Chev.	2,11	**0**
Elaeocarpaceae	*Elaeocarpus glaber* Blume	8,11	**0,67**
	Muntingia calabura L.	6,34	
Euphorbiaceae	*Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg.	31,17	**2.43**
	Macaranga javanica (Blume.)Mull. Arg.	24,17	
	Macaranga gigantea (Reichb.f. & Zoll.) Müll. Arg.	22,56	
	Dyrpetes brownii Vahl.	21,55	
	Macaranga triloba (BI.) Muell. Arg.	19,22	
	Mallotus paniculatus (L) Mull. Arg.	11,74	
	Sapium discolor (Champ. ex Benth.) Müll. Arg.	10,34	
	Baccaurea motleyana (Müll. Arg.) Müll. Arg.	4,17	

	Phyllanthus reticulatus Poir.	4,17	
	Baccaurea recemosa M.A	3,98	
	Phyllanthus niruri L.	3,82	
	Bischofia javanica Blume	3,12	
	Balakata baccata (Roxb.) Esser	2,75	
	Aleurites moluccana (L.) Willd.	1,12	
Fabaceae	*Parkia speciosa* Hassk.	21,17	**1.973**
	Pithecellobium jiringa Prain	5,88	
	Parkia timoriana (DC.) Merr.	3,17	
	Senna spectabilis Blume	3,12	
	Gliricidia sepium Kunth ex Steud.	2,18	
	Albizia chinensis (Osbeck) Merr.	2,11	
	Calliandra houstoniana (Mill.) Standl.	1,88	
	Albizia lebbekoides (DC.) Benth.	1,31	
	Albizia falcataria (L.) Fosberg	1,19	
	Delonix regia (Bojer ex Hook.) Raf.	1,19	
	Albizia procera (Roxb.) Benth.	1,11	
	Adenanthera pavonina L.	1,07	
Guttiferae	*Garcinia mangostana* L.	18,19	**1.14**
	Garcinia nigrolineata Planch. ex T. Anderson	14,12	
	Calophyllum pulcherrimum Wall. ex Choisy	3,22	
	Calophyllum soulattri Burm. f.	3,17	
Hypericaceae	*Cratoxylum arborescens* Blume	11,18	**0**
Lauraceae	*Litsea glutinosa* (Lour.) C.B. Rob.	14,6	**1.73**
	Dehaasia caesia Blume	14,29	
	Litsea grandis (Nees) Hook. f.	11,84	
	Litsea robusta Blume	9,71	
	Litsea odorifera Valeton	9,64	
	Persea americana Mill.	2,91	
Leguminosae	*Dialium patens* Baker	6,24	**0.67**
	Dialium platysepalum Baker	4,17	
Lytracheae	*Lagerstroemia thorelii* Gagnep.	2,83	**0**
Magnoliaceae	*Magnolia candolii* (Blume) H. Keng.	4,18	**0**
Malpighiaceae	*Hiptage benghalensis* (L.) Kurz	7,14	**0**
Malvaceae	*Heritiera javanica* (Blume) Kosterm	16,84	**1.09**
	Heritiera simplicifolia (Masters) Kosterm	15,16	
	Heritiera sumatrana (Miq.) Kosterm	11,89	
Meliaceae	*Swieteonia macrophylla* King	29,17	**0.64**
	Dysoxylum gaudichaudianum (A. Juss.) Miq.	15,31	
Moraceae	*Ficus racemosa* L.	21,66	**2.33**

	Ficus virens Aiton	17,33	
	Ficus benjamina L.	17,29	
	Ficus variegata Corner	15,21	
	Ficus copiosa (Roxb.) Steud.	14,21	
	Ficus septica Burm. f.	12,95	
	Parartocarpus venenosus (Zoll. & Moritzi) Becc.	11,88	
	Parartocarpus triandis (Zoll. & Moritzi) Becc.	11,17	
	Arthocarpus altilis (Parkinson) Fosberg	2,86	
	Arthocarpus heterophyllus Lam.	2,74	
	Arthocarpus kemando Miq.	2,44	
	Arthocarpus elasticus Reinw. ex Blume	1,98	
	Arthocarpus sericicarpus F.M. Jarrett	1,98	
	Antiaris toxicaria Lesch.	1,51	
Moringaceae	*Moringa oleifera* Lam.	3,79	**0**
Myristicaceae	*Myristica lowiana* King.	16,22	**0**
Myrtaceae	*Syzygium formosum* (Wall.) Masam.	12,17	**1.88**
	Syzygium littorale (Blume) Amshoff	11,99	
	Eucalyptus populnea F. Muell.	9,17	
	Eucalyptus platyphylla F. Muell.	8,92	
	Tristaniopsis obovata (Benn.) Paul G.Wilson & J.T.Waterh.	5,12	
	Psidium guajava L.	4,88	
	Rhodamnia cinerea Jack	5,22	
Olacacea	*Ochanostachys amentacea* Mast.	8,15	**0**
Oxalidaceae	*Averrhoa bilimbi* L.	1,14	**0**
Piperaceae	*Piper ningrum* L.	2,11	**0.69**
	Piper cubeba (Raf.) Hook. f.	1,77	
Poaceae	*Gigantochloa hasskarliana* (Kurz) Backer	21,17	**2.36**
	Bambusa heterostachya (Munro) Holttum	12,17	
	Bambusa glaucophylla Widjaja	11,22	
	Schizostachyum brachycladum Kurz	9,71	
	Thyrsostachys siamensis Gamble	9,18	
	Dendrocalamus asper (Schult.) Backer ex. Heyne	9,17	
	Schizostachyum latifolium Gamble	9,12	
	Bambusa vulgaris Schard. ex Wendl.	7,14	
	Bambusa vulgaris Schard. ex Wendl.var. striata	6,22	
	Bambusa multiplex (Lour.) Raeusch. ex Schult	5,12	
Rosaceae	*Parastemon urophyllus* (Wall. ex A. DC.) A. DC.	16,77	**0**
Rubiaceae	*Nauclea orientalis* (L.) L.	3,11	**0**
Sapindaceae	*Schleichera oleosa* (Lour.) Oken	7,54	**0.70**
	Nephelium ramboutan-ake (Labill.) Leenh	7,14	

Sapotaceae	*Palaquium leiocarpum* Boerl.	32,57	**0.67**
	Ganua motleyana (de Vriese) Pierre ex Dubard	21,42	
Sterculiaceae	*Pterospermum diversifolium* Blume	12,74	**1.48**
	Kleinhovia hospita L.	6,81	
	Sterculia gliva Miq.	5,22	
	Sterculia foetida Linn	3,92	
	Theobroma cacao L.	3,17	
Tetrameristaceae	*Tetramerista glabra* T. glabra Miq.	4,77	**0**
Thymelaeaceae	*Gonystylus bancanus* (Miq.) Kurz	29,44	**0**
Urticaceae	*Dendrocnide stimulans* (L. f.) Chew	7,14	**0**
Verbenaceae	*Gmelina arborea* Roxb.	12,77	**0**
Vitaceae	*Ampelocissus thyrsiflora* (Blume) Planch.	2,21	**0**

Table 2 shows that *Palaquium leiocarpum* Boerl. has the highest importance value index (IVI), with an IVI of 32.57. This finding indicates that the species *Palaquium leiocarpum* Boerl., commonly known as Balam Suntai, plays a highly dominant role in the podzolic soil ecosystem. Balam Suntai typically thrives in peat swamp forests [40]. This species demonstrates its ability to adapt both physiologically and morphologically to cope with the nutrient-poor and highly acidic conditions of podzolic soil. Podzolic soil is characterized by low phosphorus availability due to high fixation and low phosphorus mobility. Phosphorus is an essential element for plant growth. *Palaquium leiocarpum* and other plants in the same environment have adapted to enhance phosphorus use efficiency (PUE) [41,42]. Balam Suntai wood is widely used for construction materials, bridge building, boat making, and railway sleepers (Partomihardjo et al., 2020). Additionally, Balam Suntai is known for producing high-quality latex [40]. Although this species is not protected, according to the IUCN Red List, Balam Suntai is classified as Near Threatened [43].

Adenanthera pavonina L. has the lowest importance value index (IVI) of 1.07 in the podzolic soil ecosystem. This value indicates that this species plays a minimal role and is less dominant compared to other species within this ecosystem. The findings suggest that *Adenanthera pavonina*, or Saga Tree, has limited ability to adapt or compete with other species in podzolic soil environments. This could be influenced by factors such as the low nutrient availability in podzolic soils, soil conditions, and interspecies interactions [44,45]. In contrast, the findings of Yuslinawari et al. [46], who studied the vegetation diversity of riparian ecosystems along the Pusur River, a sub-watershed of the Bengawan Solo River Basin, show that *Adenanthera pavonina* had an IVI of 4.47, which is considered high. Additionally, according to the research by Heriyanto et al., as cited in Rochmayanto et al. [47], *Adenanthera pavonine* exhibited a high IVI of 22.14 in the peatland area of PT. RHM. These differences in IVI values indicate that *Adenanthera pavonina* performs differently depending on environmental conditions, such as soil type and nutrient availability, which in turn influence its dominance and adaptability across various habitats.

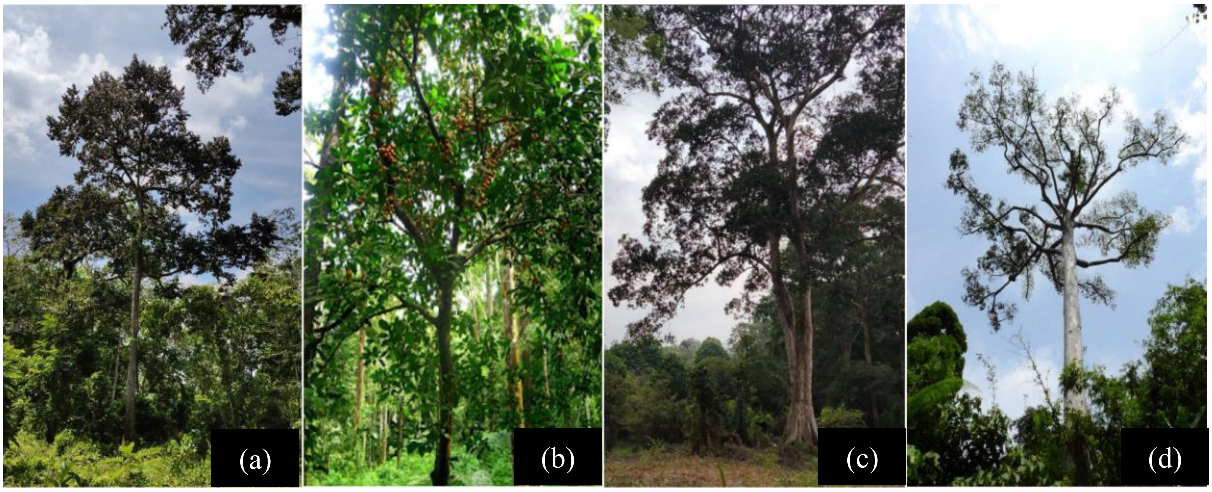

Figure 3. Dominant species (A and B in mineral soil, and C, D in peatland) found in ecoriparian Kampar watershed (a) *Durio zibethinus* Merr., (b) *Baccaurea macrocarpa* (Miq.) Müll.Arg., (c). *Vatica pauciflora* Blume, (d). *Koompassia excelsa* (Becc.) Taub.

3.3. Unique species diversity in Kampar watershed riparian ecosystems on peat and yellow red podzolic soil

The unique species diversity in the riparian ecosystems of the Kampar watershed varies significantly between peat soils and red-yellow podzolic soils. Table 3 and Table 4 illustrate the differences in unique species that thrive in distinct soil characteristics. The species composition varies significantly between peat soil and red-yellow podzolic soil, reflecting the specific adaptations and ecological requirements of the vegetation in each soil type.

Table 3. List of unique species to peat soils.

Species	Local Name	IUCN Red List Status
Barringtonia acutangula (L.) Gaertn.	Putat	Least Concern (LC)
Cratoxylum formosum (Jack) Benth. & Hook.fil. ex Dyer	Garageh	Least Concern (LC)
Dillenia reticulata King	Simpur	Least Concern (LC)
Diospyros cauliflora De Wild.	Eboni	Least Concern (LC)
Koompassia excelsa (Becc.) Taub.	Sialang	Conservation Dependent
Koompassia malaccensis Maing.	Kempas	Least Concern (LC)
Macaranga conifera (Zoll.) Müll.Arg.	Mahang	Least Concern (LC)
Macaranga tanarius (L) Mull. Arg.	Mara	Least Concern (LC)
Palaquium burckii H.J. Lam	Nyatoh	Critically Endangered (CE)
Santiria laevigata Blume	Kembajau burung	Least Concern (LC)
Shorea bracteolata Dyer	Meranti rawa	Endangered (EN)
Shorea uliginosa Foxw.	Meranti bako	Endangered (EN)
Shorea platycarpa F. Heim	Meranti paya	Critically Endangered (CE)
Syzygium cumini L.	Jamblang	Least Concern (LC)
Syzygium densiflorum Wall. ex Wt. & Arn.	Klampok	Vulnerable (VU)
Syzygium kiahii (M.R.Hend.) I.M.Turner	Jambu-jambuan	Least Concern (LC)

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Syzygium pycnanthum Merr. & L. M. Perry	Jambu klampok	Least Concern (LC)
Voacanga grandifolia (Miq.) Rolfe	Birit	Least Concern (LC)

In the analysis of species diversity in riparian ecosystems on peat soils, several unique species were identified, indicating specific adaptations to the peat environment (Table 3). For example, *Shorea bracteolata* (swamp meranti) and *Shorea uliginosa* (bako meranti) are listed as Endangered (EN), while *Shorea platycarpa* (marsh meranti) and *Palaquium burckii* (nyatoh) are listed as Critically Endangered (CE) on the IUCN Red List. Additionally, *Syzygium densiflorum* (klampok) is listed as Vulnerable (VU), demonstrating relatively better adaptability but still facing the risk of population decline. This indicates that peatlands serve as crucial habitats for species with threatened conservation statuses. Peat soils provide habitat for species that heavily rely on high moisture levels, low acidity (pH<4), and fibrous soil texture [48,49]. The importance of conservation efforts to protect peatland ecosystems from changes that could threaten biodiversity is emphasized [50].

Table 4. List of unique species to yellow red podzolic soils.

Species	Local Name	IUCN Red List Status
Annona muricata L.	Sirsak	Least Concern (LC)
Arthocarpus elasticus Reinw. ex Blume	Bendo	Not Evaluated (NE)
Arthocarpus heterophyllus Lam.	Nangka	Not Evaluated (NE)
Arthocarpus kemando Miq.	Pudau/sukun	Near Threatened (NT)
Arthocarpus sericicarpus F.M. Jarrett	Peluntan	Least Concern (LC)
Averrhoa bilimbi L.	Blimbing wuluh	Least Concern (LC)
Bambusa glaucophylla Widjaja	Bambu putih	Not Evaluated (NE)
Bambusa heterostachya (Munro) Holttum	Bambu payung	Least Concern (LC)
Bambusa multiplex (Lour.) Raeusch. ex Schult	Bambu cina	Not Evaluated (NE)
Bambusa vulgaris Schard. ex Wendl.	Bambu kuning	Not Evaluated (NE)
Capparis micrantha A. Rich.	Bintaro	Data Deficient (DD)
Carica papaya L.	Pepaya	Not Evaluated (NE) (Domesticated)
Ceiba pentandra (L.) Gaertn.	Kapuk randu	Least Concern (LC)
Dendrocalamus asper (Schult.) Backer ex. Heyne	Bambu betung	Not Evaluated (NE)
Gigantochloa hasskarliana (Kurz) Backer	Buluh busi	Not Evaluated (NE)
Orophea enneandra Blume	Nangka-nangka	Near Threatened (NT)
Parkia speciosa Hassk.	Petai	Least Concern (LC)
Parkia timoriana (DC.) Merr.	Kedaung	Least Concern (LC)
Persea americana Mill.	Alpukat	Least Concern (LC)
Phyllanthus niruri L.	Meniran	Not Evaluated (NE)
Phyllanthus reticulatus Poir.	Mangsian	Least Concern (LC)
Piper cubeba (Raf.) Hook. f.	Kemukus	Not Evaluated (NE)
Piper nigrum L.	Lada	Not Evaluated (NE) (Domesticated)
Protium javanicum Burm. f.	Trenggulun	Near Threatened (NT)
Schizostachyum brachycladum Kurz	Bambu talang	Not Evaluated (NE)
Schizostachyum latifolium Gamble	Bambu suling	Not Evaluated (NE)
Senna spectabilis Blume	Johar	Least Concern (LC)

Theobroma cacao L.	Kakao	Not Evaluated (NE) (Domesticated)
Thyrsostachys siamensis Gamble	Bambu tali	Not Evaluated (NE)
Wrightia tomentosa Roem. & Schult.	Mentaos	Not Evaluated (NE)

Podzolic soil ecosystems support a diversity of species capable of adapting to challenging environmental conditions, such as low soil acidity (pH<6) and poor essential macro-nutrient availability [51,52]. Many unique species found in podzolic soils (Table 4), such as *Annona muricata* (soursop) and *Artocarpus sericicarpus* (peluntan), are listed as Least Concern (LC), indicating that these species are relatively well-adapted to this environment. However, some species, like *Artocarpus kemando* (breadfruit) and *Oroxylum enneandra* (nangka-nangka), are listed as *Near Threatened* (NT), signifying potential threats from environmental changes or human activities. Additionally, many species, such as *Artocarpus heterophyllus* (jackfruit), *Bambusa glaucophylla* (white bamboo), and *Theobroma cacao* (cacao), have not yet been evaluated (Not Evaluated (NE)) by the IUCN, highlighting the need for further research to address knowledge gaps regarding their conservation status. *Capparis micrantha* (bintaro) is listed as Data Deficient (DD), indicating a need for more in-depth studies to understand the distribution and ecology of this species within podzolic ecosystems. Moreover, domesticated species such as *Carica papaya* (papaya), *Piper nigrum* (black pepper), and *Theobroma cacao* (cacao) play significant roles in local economies and cultures. Overall, podzolic soils are crucial habitats that support a variety of species with diverse conservation statuses, some of which require special attention for conservation efforts.

4. Conclusions

In the riparian vegetation of peat soils, 129 species from 40 families were identified, with an importance value index ranging from 1.03 to 25.17. In contrast, podzolic soils supported 140 species across 43 families, with an importance value index between 1.07 and 32.57. The structure and composition of species varied across different areas, influenced by differences in soil types and anthropogenic impacts. Riparian vegetation in the Kampar Watershed is predominantly represented by *Vatica rassak* (Korth.) Blume, *Swietenia macrophylla* King, *Gluta renghas* L., *Gonystylus bancanus* (Miq.) *Kurz, Durio zibethinus* Merr., *Baccaurea macrocarpa* (Miq.) Müll.Arg., and *Shorea ovalis* Blume.

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Banda Aceh, Indonesia on 09-10 October 2024

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