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RESEARCH ARTICLE

Bamboo Spreading Impacts as a Watershed Conservation Strategy in Upstream Area of Three Big Rivers of Sumatra

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Abstract: Water is the source of life. The uncontrolled use of natural resources is currently causing the massive pollution of rivers in Sumatra, so the availability of clean water for people's lives is started to decrease. One of the efforts to conserve watersheds is to preserve riparian vegetation. Where there is a source of water, there is bamboo. Bamboo that grows in riparian areas has a root system that can prevent erosion and filter water, increasing clean water availability. The purpose of this study was to conduct an inventory, study of ecology, and indicate environmental factors of bamboo species that can potentially maintain riparian environmental conditions, which can later be developed as soil and water conservation plants in the Sumatran watershed. This research was conducted in the riparian areas in upstream of three major Sumatran rivers: Kuantan, Kampar, and Rokan. We recorded 20 species of bamboo plants from 5 genera in three major rivers of Sumatra. The Rokan watershed has environmental conditions that are still maintained with low human activity so that the diversity of bamboo upstream of the Rokan river is high and is still well maintained. Meanwhile, the Kuantan and Kampar watersheds have a lot of human activities along the river, so the bamboo vegetation has been exploited in these two areas. *Based on* Canonical Correspondence Analysis, *Bambusa vulgaris* is found suitable for cultivation in Kuantan and Kampar watersheds, which is abundant in these watersheds as well as has high tolerance range for polluted watershed. We recommend that *B. vulgaris* be used as riparian vegetation for soil and water conservation in polluted watersheds.

Keywords: bamboo, conservation, diversity, ecology, watersheds

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Introduction

Rivers not only carry water, but they also carry life for human. Rivers help improve the quality of life and strengthen the local economy. The flow of river water can make every community survive because it is a source of livelihood, means of transportation, hydro-power, and a source of family water. The community has a great responsibility to care for and maintain the condition of the river because a damaged river will harm the environment.

Utilization of the potential of forest resources for various interests and human needs has led to massive forest degradation. Changes in the use of natural resources that are uncontrolled will affect the function and balance of the environment, such as aspects of the balance of water, nutrients, and biodiversity in the riparian area of the watershed. The land conversion that occurs en masse is also one of the main problems in the watershed, namely increasing pollution due to soil erosion causing the water entering the river to become dirty, so that the availability of clean water for people's lives begins to decrease.

Watershed conservation is an effort to control the reciprocal relationship between natural resources and the watershed environment with human activities to

preserve environmental functions and community welfare (Pambudi, 2019; Syafriet *et al*., 2020). One flora that plays an important role in watershed conservation is bamboo vegetation in riparian areas. It is worth to mention that riparian is a transitional ecosystem between aquatic and terrestrial ecosystems that functions to maintain river water quality (Chase *et al*., 2016; Swanson *et al*., 2017. Where there is bamboo, there is a river, so the presence of bamboo is a sign of the existence of a water source.

Bamboo is a group of plants from the Gramineae family, the children of the Bambusoideae tribe, that can grow and adapt to intolerant and extreme environments. Ecologically, bamboo has a hydrological function to maintain environmental balance because its root system can prevent erosion, regulate water management, or filter water while increasing groundwater discharge by 90% (Wong, 2004; Sukawi, 2010; Widnyana, 2012). These properties make bamboo suitable as a conservation plant for upstream areas and maintain the stability of habitats in watersheds. Sumatra has the highest bamboo diversity in Indonesia (80 out of 176 species) (Widjaja, 2019). Research conducted in Sumatra by Widjaja (1997) obtained six genera of bamboo consisting of 24 species. Then, Fitmawati (2020) research obtained five genera consisting of 17 species.

Sumatra has small rivers that form large rivers crossing the line and emptying into the open sea. Central Sumatra has three large rivers that impress the island of Sumatra, such as the Rokan River, Kampar River, and the Kuantan River. The most exciting area is the Bukit Barisan area as the upstream all of rivers in Sumatra with various species of habitats causing Sumatra to have a very high and diverse vegetation level (Middleton, 2019). The upstream area of the river is a recharge area that plays an important role in the process of air absorption, storage, and airflow gradually downstream of the river. Therefore, upstream rivers are generally located in hilly areas and are dominated by primary forest vegetation, which helps in the process of air absorption when there is an increase in rainfall. These ecosystems contain specific vegetation and soil characteristics that support replaceable values and various ecosystem functions and are highly responsive to changes in land management activities. This exploration was carried out in the upstream areas of three major Sumatran rivers by carrying out an inventory, ecological study, and indication of environmental factors for bamboo species that have the potential to maintain riparian environmental conditions which can later be developed as soil and water conservation plants in the Sumatran watershed.

From this research, potential bamboo species will be found to be cultivated by their ecological conditions. This study is important to overcome the threat of extinction if conservation measures are not taken immediately. Information on various conservation efforts to save the ecosystem and environment in the watershed is important to be studied and disseminated to the wider community. The results of this study are expected to be the basis for making policies in river management and input in developing riparian areas.

Materials and methods

Study location and Materials

The research was carried out in Riau Province, precisely in three districts by tracing the flow of a large river that has the potential to grow bamboo, including; (1) Rokan River (Rokan Hulu), (2) Kampar River (Kampar Regency), and (3) Kuantan River (Kuantan Singingi), (Figure 1).

The tools used in this research include stationery, bamboo identification book, camera, machete, GPS, herbarium kit (hanging etiquette, plant shears, roll meter, sasak, tie belt, oven), and newsprint. The materials used in this study were alcohol 70% and bamboo samples to make herbarium. Exploration was carried out along the watershed by relying on resource persons and information providers, either directly from key informants (Key Persons) or from data/libraries (Bompard & Kostermans, 1985).

Species Identification

The identification was carried out based on the morphological characters of collected specimens. Identification refers to kinds of literature, such as Widjaja, 1987, 1997, 2001a, 2001b, 2019 and Widjaja *et al*., 2005.We also use online identification by using the following website: www.gbif.org/species/search, citruspages.free.fr/limes.php;www.plantsoftheworld online.org.identify.plantnet.org/;www.worldfloraon line.org. The important characteristics observed for identifying bamboo species were the shape and color of bamboo shoots; the height, length, width, diameters,

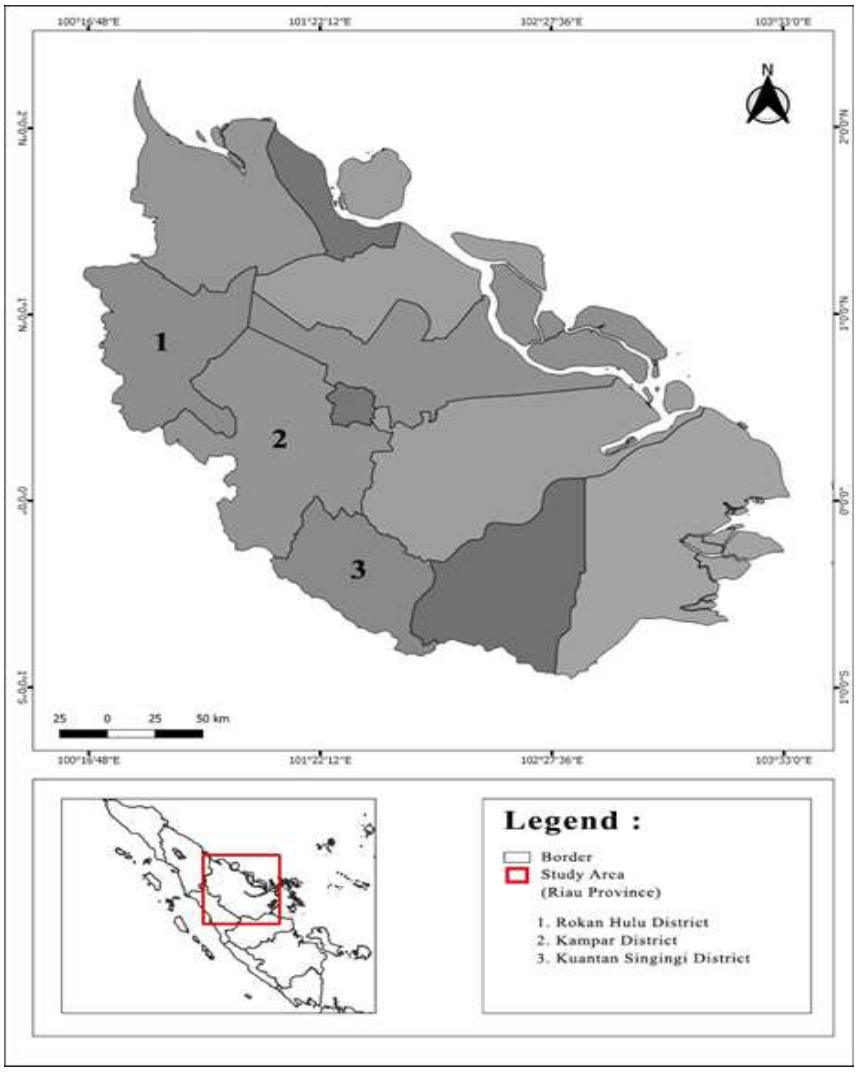

Fig 1. Study area map

color, branching system, culm leaves, and auricle of the culm leaves; the length, width, and color of the leaves.

Work Procedures

The abiotic data collected included observations of the microclimate included air temperature, soil temperature, soil pH, air humidity, wind speed, and light intensity. The abiotic data were measured using a 4 in 1 LM-8000 environmental measuring instrument, except for soil moisture and pH, which were measured using a soil tester. Data period was carried out three times, namely in the morning, afternoon and evening for 1 month in 2022. Topographic data retrieval in the form of coordinates, altitude, and distance from the nearest water source was measured using GPS (Global Positioning System). These data were used to map the distribution of the species.

Data analysis

Presentation and analysis of data in the following forms; The basic map of the distribution of the bamboo population was processed using ArcGIS software and analyzed descriptively. The correlation between the presence of Bamboo and the microclimate (soil moisture, soil pH, air temperature, humidity, wind speed, and light intensity) was analyzed by principal component analysis using the CANOCO 4.5 software type Canonical Correspondence Analysis (CCA) and presented in the form of tables, images, and histograms (Dolezal and Srutek, 2002; Pranata *et al*., 2019). CCA was used to summarize the data set and to evaluate the expected relationships (Bodaghabadi *et al*., 2011).

Canonical correspondence analysis (CCA) is a multi -variate method used to explain the relationship between the presence of species and their environment (Nezerkova *et al*., 2006) in three major river riparian areas of Sumatra, namely the Kampar River (Kampar Regency), Kuantan (Kuantan Singingi Regency) and Rokan (Rokan Hulu Regency). Every environmental factor affecting a species existence can be seen from the axis line in the diagram. The closer the axis, the greater the relationship (Bodaghabadi *et al*., 2011).

Results and Discussions

Diversity and Distribution of Bamboo

Rivers are complex ecosystems vulnerable to damage or even destroyed due to overexploitation and increased human population activities. The close relationship between rivers and human society, along with socio-economic developments, has caused considerable degradation and pollution of river ecosystems (Khorooshi *et al*., 2016). Protecting river ecosystems can be started by conserving riparian areas and using plants as ecological agents in carrying out their functions to improve water quality.

Currently, the forest has decreased with plant vegetation rich in root hairs to store water and has been replaced by monoculture forests that do not have root hairs so that rainwater that falls directly enters the river body. Water quality in rivers is detoratating due to no water filter flowing into the river. In the last ten years, many species of fish in the Kuantan River and several other rivers have been no longer found. Bamboo has a unique root morphology and fibrous roots that can withstand water, so it plays a significant role in the hydrological system. The existence of bamboo in river riparian is very important in the natural ecosystem.

Table 1. Distribution of Bamboo in the Upper Sungai Besar in Riau Province

No	Genus	Species	Availability (River)		
			1	2	3
1	*Bambusa*	*B. vulgaris* Schrad. ex J.C.Wendl (Cul : vulgaris striata wamini)	√	√	√
2		*B. multiplex* (Lour.) Raeusch. ex Schult.	√	√	√
3		*B. glaucophylla* Widjaja	√	√	√
4		*B. bluemeana* Schult.f.	√	√	-
5	*Gigantochloa*	*G. atter* (Hassk.) Kurz	√	√	-
6		*G. pruriens* Widjaja	√	√	√
7		*G. achmadii* Widjaja	√	-	-
8		*G. kuring* Widjaja	√	√	√
9		*G. hasskarliana* (Kurz) Backer	√	√	-
10		*G. scortechinii* Gamble	√	-	-
11		*G. nigrociliata* (Buse) Kurz	-	√	√
12		*Gigantochloa* sp.	√	√	-
13	*Schizostachyum*	*S. undulatum* S.Dransf.	√	-	-
14		*S. silicatum* Widjaja	√	√	√
15		*S. zollingeri* Steud.	√	√	√
16		*S. brachycladum* (Kurz ex Munro) Kurz	-	√	√
17		*S. mampouw* Widjaja	-	√	-
18	*Dendrocalamus*	*D. asper* (Schult.f.) Backer	√	√	√
19		*D. hirtellus* Ridl.	-	√	-
20	*Thyrsostachys*	*T. siamensis* Gamble	√	√	√

Bamboo is a plant species often found in springs or riparian areas and along rivers (Sofiah and Fiqa, 2011), have a high tolerance level in various habitats and can be found from the highlands to the lowlands (Wong, 2004). We recorded 20 species of bamboo plants from 5 genera in three major rivers of Sumatra, namely the Kuantan, Kampar, and Rokan rivers. The number of species we get the most is from the genus *Gigantochloa* (8 species), while the least is from the genus Thyrsostachys (one species) (Table. 1). The second genus is *Schizostachyum* consisting of five species. *Thyrsostachys* is a genus with minor species, namely *T. siamensis* Gamble .

The species diversity of each river varies due to different environmental conditions in the watershed of each district. Habitat quality is affected by the physical and chemical characteristics of the water (e.g., water temperature). Habitat conditions are indicators of watershed integration with other environmental factors, highly dependent on environmental and biological conditions. Twenty species of bamboo are found in three regencies. Rokan Hulu Regency has the highest diversity of bamboo species, with 17 species from five genera, Kuantan Singingi Regency with 16 species from five genera, and the lowest in Kampar Regency with 11 species from five genera.

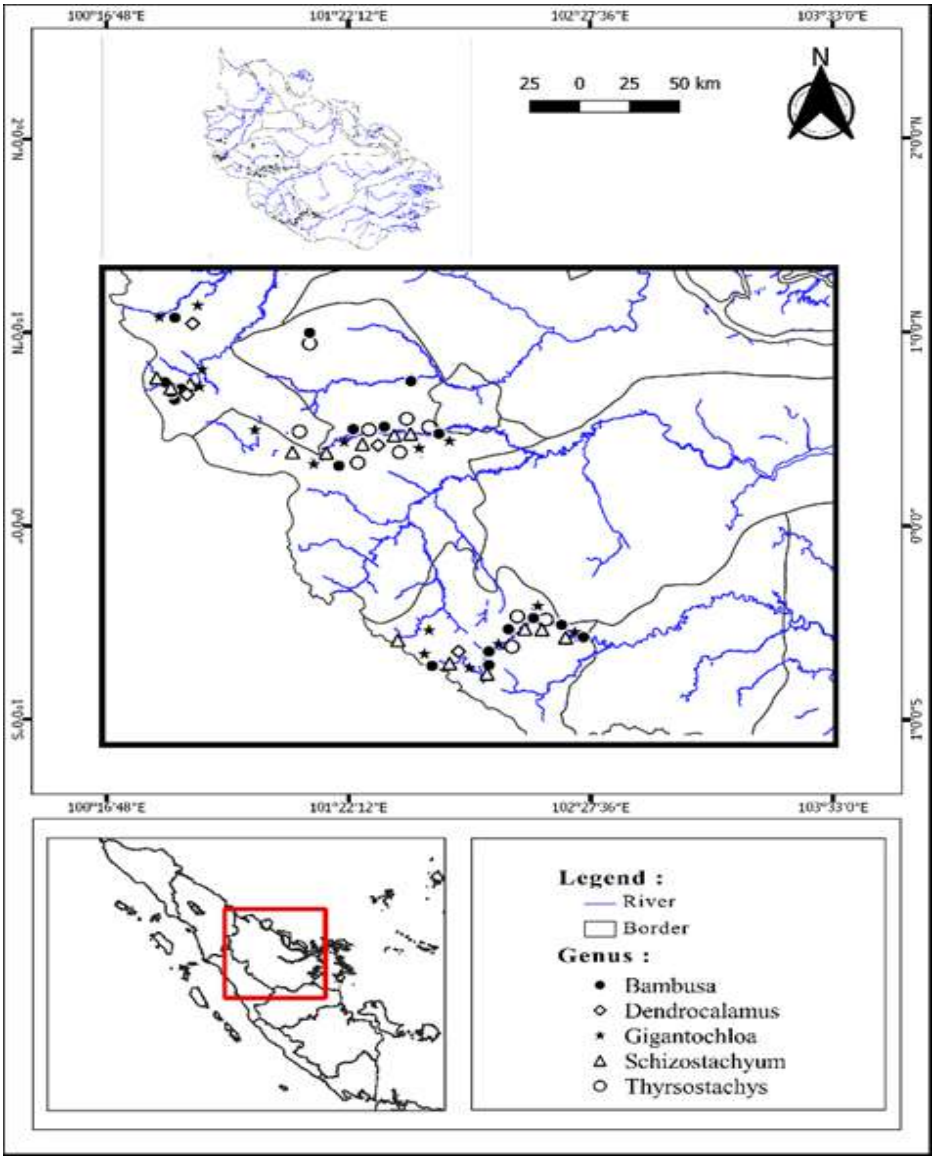

Fig 2. Map of distribution of the bamboo genera in three districts of Riau Province

The Rokan watershed has environmental conditions that are still maintained with low human activity so that the diversity of bamboo upstream of the Rokan river is high and is still well maintained. Along this river, bamboo forests are found with various species of wild bamboo clumps growing.

The existence of bamboo that grows along the three major rivers in Riau is scattered randomly. The distribution of some species of bamboo can vary. The distribution of bamboo was found in groups of five genera, namely in the upstream area of the Rokan River, Rokan Hulu Regency (Fig. 2) because bamboo that grows in clumps causes the distribution of bamboo to be clustered upstream of the river.

Meanwhile, the Kuantan and Kampar watersheds have had many human activities along the river, such as gold mining, especially the use of mercury which has accumulated and causes pollution of ecosystems and water quality. The construction of hydropower dams, sand mining, and palm oil monoculture farming belonging to the surrounding community also triggers the high exploitation of bamboo in these two areas. The species of bamboo that are tolerant of river water damage can survive in this river flow.

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Ecology of Bamboo

The distribution of bamboo in the three watersheds varies from12 to 385 m MSL. Based on observations in three districts, bamboo can be found at various heights from the lowlands to the highlands (Fig 3). The genera *Bambusa, Dendrocalamus, Gigantochloa,* and *Schizostachyum* can be found in various types of altitudes.

Rokan Hulu Regency is the only place where various species of bamboo are found in the highlands with an altitude of >350 meters above sea level. Meanwhile, the *Thyrsostachys* genus is often found in the lowlands with an altitude of 12 – 68 m MSL. The type of bamboo *G. nigrociliata* is a type of bamboo found at an altitude of 385 meters above sea level, making this type of bamboo grows on the highest plains in Riau Province. *D. asper* and *D. hirtellus* are species of bamboo that can be found in areas with an altitude of >100 meters above sea level, especially *D. hirtellus* species, which is only found in hilly areas with a wet climate with an altitude of 346 meters above sea level.

Another parameter observed from the distribution pattern of bamboo distribution is the distance from the river. Based on the results of observations in the three districts found with a distance of 0-500 m from a water source or river flow (Figure 4). The distance of bamboo found around the watersheds of the three regencies is about 0-50 m from springs and streams because many bamboos are found beside rivers, such as in the Kampar and Kuantan river basins planted for conservation purposes.

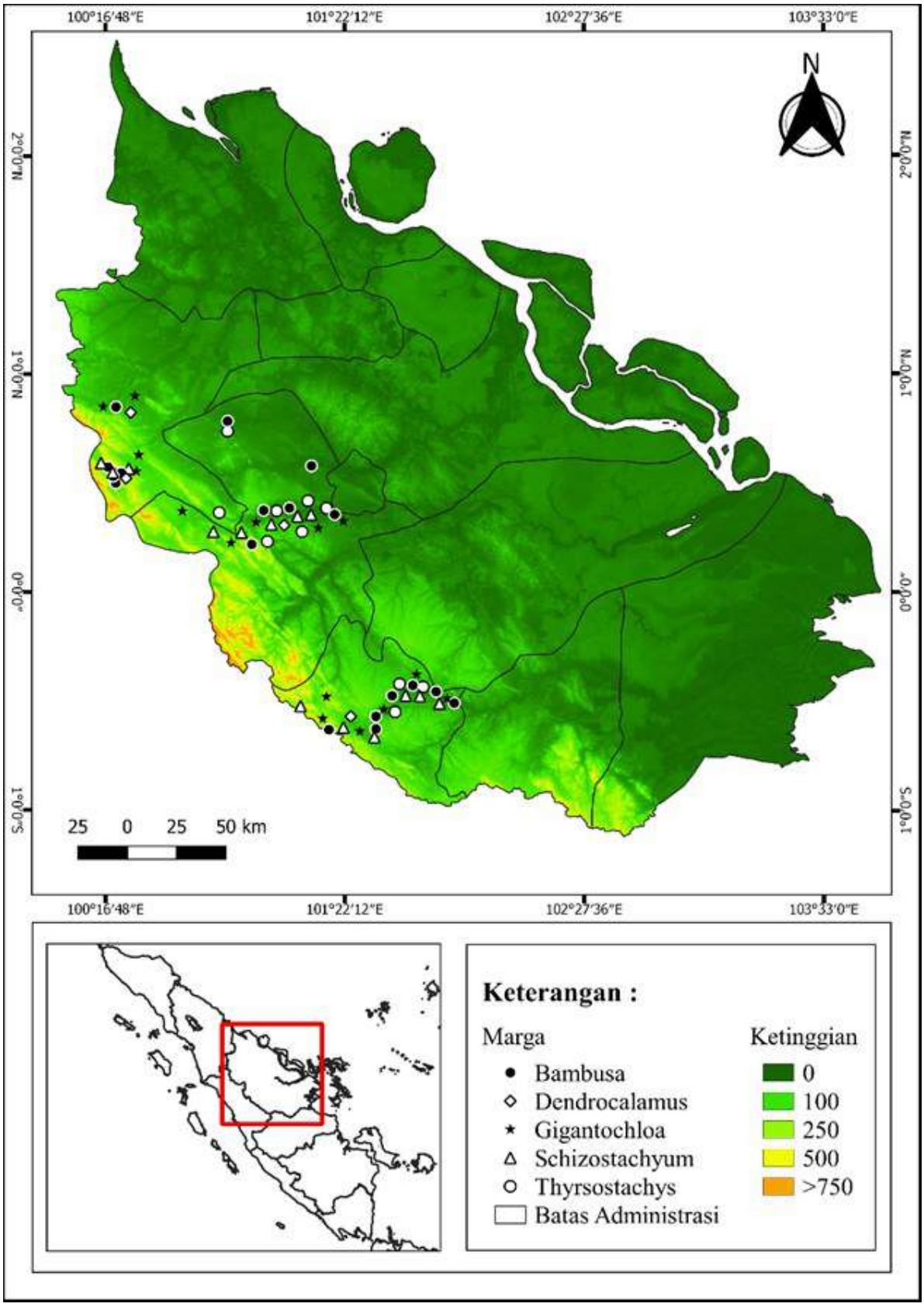

Fig 3. Map of distribution of bamboo genera based on altitude

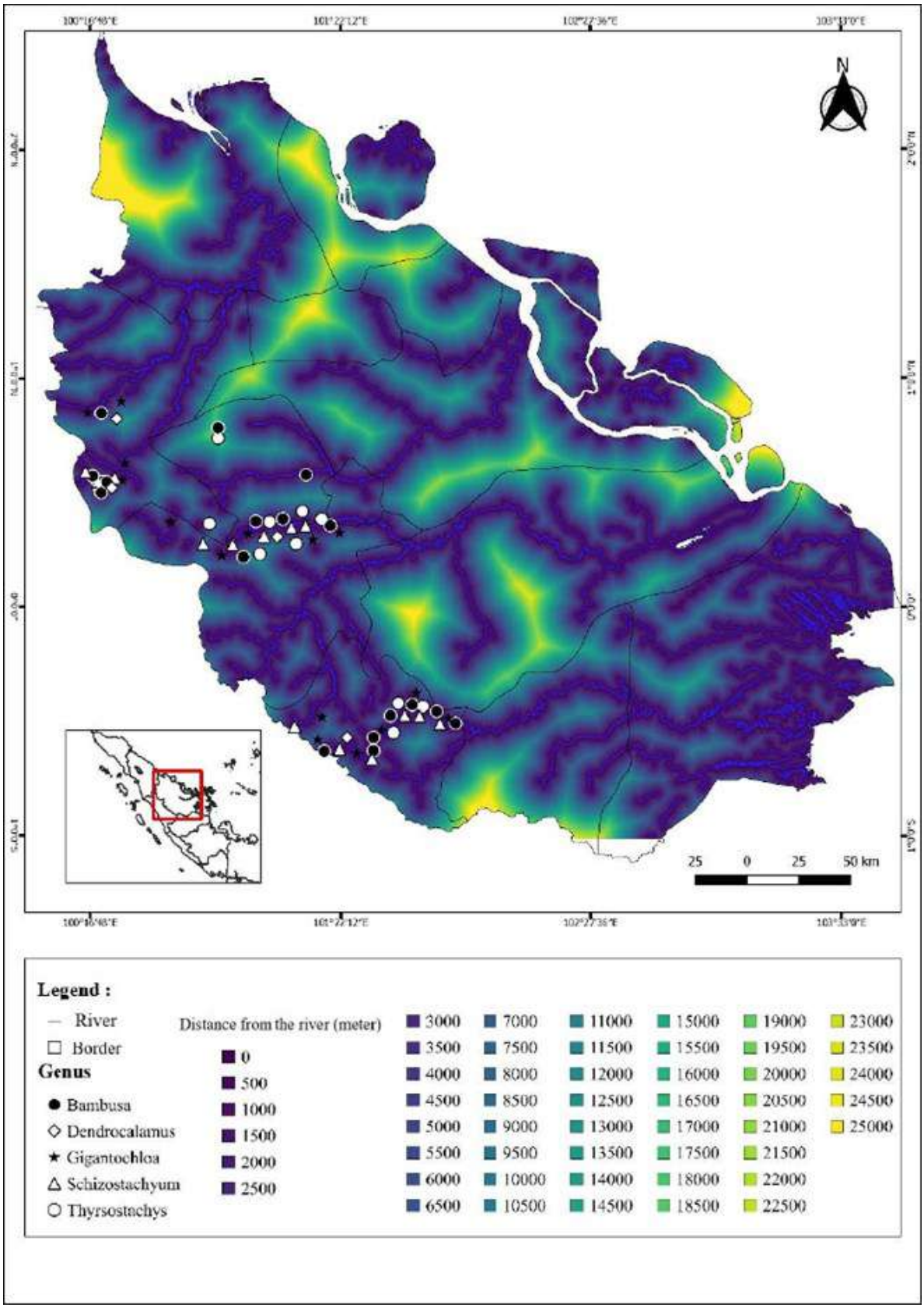

Fig 4. Map of the distribution of bamboo genera based on distance from the river (water source).

Environmental Factor Indication

The existence of different species of bamboo has a variety of environmental factors. Several environmental, and physical factors that indicate positive or influence the presence of bamboo in three major rivers are wind speed, light intensity, temperature, soil pH, and air humidity.

The first area with a relatively large river flow in Riau Province is Kuantan Singingi Regency. The upstream of this area is directly adjacent to the province of West Sumatra, precisely in the Sijunjung district. The total species of bamboo found in this area are 16 species. The existence of each individual of its kind has varying environmental conditions.

Based on the CCA analysis (Fig 5), it can be inferred that the presence of *Schizostachyum zollingeri, B. vulgaris var. striata, B. multiplex, and B. vulgaris var. Vulgaris* are strongly influenced by the environment. The genera *Bambusa*, *Dendrocalamus*, *Gigantochloa,* and *Schizostachyum can* be found in various types of altitudes. Rokan Hulu Regency is the only place where various species of bamboo are found in the highlands with an altitude of >350 meters above sea level.

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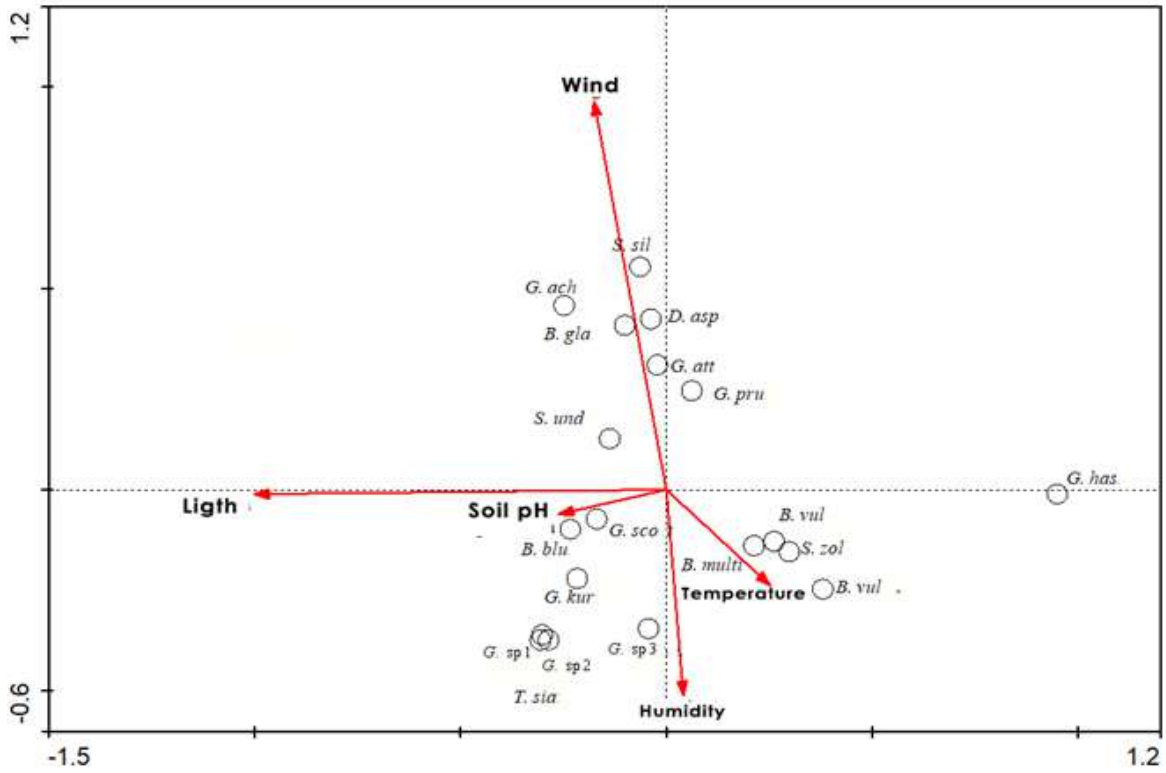

Fig 5. *Canonical Correspondence Analysis* (CCA) for bamboo species at Kuantan river

B. vul (*B. vulgaris*); *G. att (G. atter); G. pru (G. pruriens); B.vul (B. vulgaris* var. *striata); B. mul (B. multiplex); B. gla (B. glauchopylla); G. ach (G. achmadii); S. und(S. undulatum); S. sil (S. silicatum); G. sp1 (Gigantocloa* sp1.); G. kur (*G. kuring); T. sia (Thyrsostachys siamensis); G.sp2 (Gigantchloa* sp2.); *G. has* (*G. hasskarliana); B. blu (B. bluemeana); G. sco (G. scortechinii); G. sp3 (Gigantochlo a*sp3.); *D.* as (*Dendrocalamus asper); S. col (Schizostachyum zollingeri).*

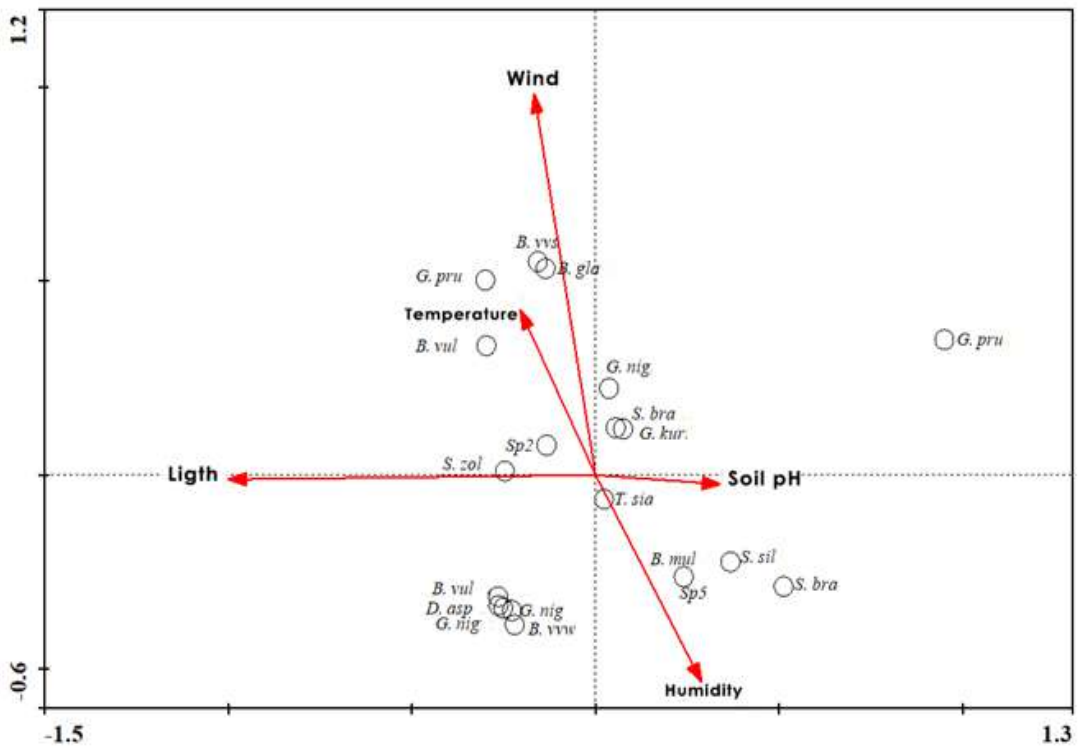

Fig 6. Canonical Correspondence Analysis (CCA) for bamboo species at Kampar River

G. kur (*G. kuring); S. zol (S. zollingeri); S. bra (S. brachycladum); B. vul (B. vulgaris* var. *striata); G. nig (G. nigrociliata), B. mul (B. multiplex); B.vul (B. vulgaris); G. pru (G. pruriens); T. Sia (T. Siamensis); S. sil (S. silicatum); G. nig (G. nigrociliata), B.vul (B. vulgaris var wamin); D. asr (D. asper); B. glau (B. glaucophylla),;* Sp2, and Sp5.

Kampar River is located in Kampar Regency, Riau is one of the largest rivers in Sumatra which originates in Bukit Barisan around West Sumatra. The Kampar Kanan river flows through the Lima Puluh Kota and Kampar Regencies and meets the Kampar Kiri River in the Langgam area, Pelalawan Regency, Riau.

The results of the analysis of the influence of environmental factors on the existence of bamboo species were found to be very varied. The total species of bamboo found in the Kampar River are 11 species. Based on the CCA analysis, it can be revealed that the presence of the species of *T. siamensis, B. multiplex,* and Sp5 strongly influenced by environmental factors of air humidity, *S. zollingeri* affected by light intensity, and *B. vulgaris* and *B. vulgaris* var. striata influenced by wind speed (Fig 6).

The Rokan River, Rokan Hulu Regency has the main river flow, namely the Rokan River with the upstream of the hills, the Bukit Barisan Mountains. The Rokan River has natural bamboo forest vegetation, so there are more bamboo species in this area than in the Kuantan and Kampar rivers. A total of 17 species of bamboo were found in this area. The CCA analysis indicated that the presence of *B. vulgaris* and *B. glaucophylla* is influenced by environmental factors wind speed, *G. nigrociliata, B. bluemeana*, and *S. zollingeri* affected by temperature, and *S. silicatum* affected by light (Fig 7).

Bambusa vulgaris is the most common species of bamboo found along watersheds because this species has a high tolerance level in wet climates, both in the highlands and lowlands. *B. vulgaris* has a high tolerance range to watershed damage (Sadiku *et al.* 2020). This species is abundant in the Kuantan and Kampar watersheds and also has a speedy growth time, so it can be recommended as riparian vegetation for managing polluted watersheds because bamboo has a rhizome root system that can filter water naturally. Hence, it has a close relationship with the hydrological function of the soil to ensure the availability of clean water in the watershed.

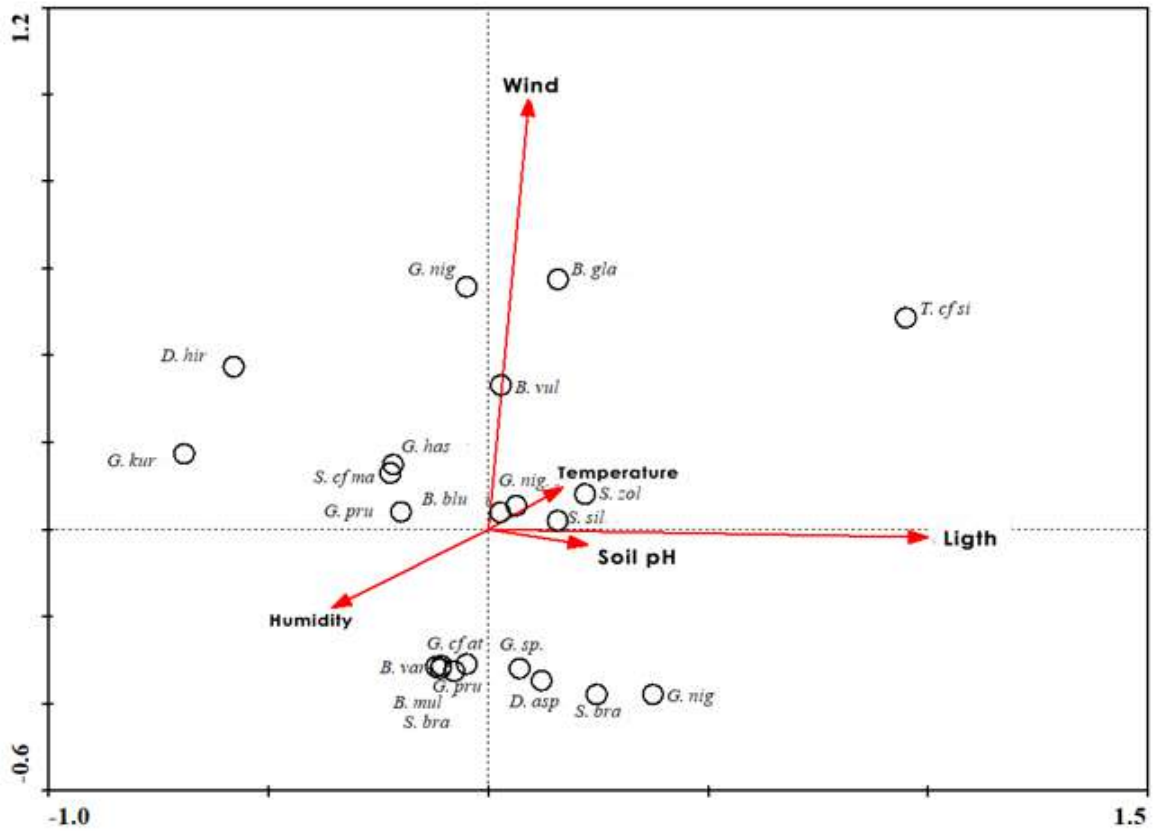

Fig 7. Canonical Correspondence Analysis (CCA) of Bamboo species in Rokan River

G. kur (*G. kuring); S. zol (S. zollingeri); S. bra (S. brachycladum); B. vul (B. vulgaris* var. *striata); G. nig (G. nigrociliata); B. mul (B. multiplex; B.vul (B. vulgaris); G. pru (G. pruriens); T. Sia (T. Siamensis); S. sil (S. silicatum); G. nig (G. nigrociliata); B.vul (B. vulgaris var wamin); D. asr (D. asper); B. glau (B. glaucophylla);* Sp2, and Sp5.

B. vulgaris has also been shown to adapt to a mud-substrate environment with high salinity so that it is considered a eurytopic species with a high productivity value (59.4%) and has the potential to be further developed in estuarine areas (Fitmawati *et al*., 2021). *B. vulgaris* can produce high biomass in sewage and mining polluted environments (Chen **et al.**, 2015; Nkeshita *et al*., 2020)) with the highest accumulation rate in root organs (Liu *et al.*, 2015), so this species is highly recommended. as a rehabilitation plant and conservation area.

In Indonesia, *B. vulgaris* is one of the prioritized species because its character is limited to a narrow or single locality which represented in large enough numbers, followed by *B. blumeana, B. polymorpha, B. tulda, Dendrocalamus asper, D. giganteus, D. vstrictus, Gigantochloa apus, Melocanna bacciera* and *Thysrostachys siamensis* (Selvan, 2015). Another species of *Bambusa*, the presence of B. rigida that grows along riparian zones in China, is an effort to conserve rivers from floods and water pollution (Auerswald *et al*., 2019; Chen *et al*., 2020). Flood disaster is a big problem caused by this rapid development (Saridewi *et al*., 2017). Bambusa can filter river water until it is clean so that sediment in the river can be reduced and this can prevent flooding.

The purpose of watershed management is to control the reciprocal relationship between natural resources and the watershed environment with human activities to preserve environmental functions and community welfare (Pambudi 2021). So it is necessary to integrate management from upstream to downstream by considering various interests and biophysical and socio-economic conditions in a watershed. One way is using a bamboo conservation strategy as riparian vegetation to maintain river water quality.

Of the total species of bamboo found, several species were domesticated by the community. Namely, *B. vulgaris, B. multiplex, B. vulgaris var vulgaris* and *striata.* The bamboo clan is a local plant often used by the community (urban) (Nirala & Kumari, 2016). Based on a map of the distribution of bamboo in the riparian areas of three major Sumatran rivers, the Bambusa clan is a cosmopolitan type of bamboo that grows at various types of altitudes (12-385 mdpl) and close to the banks of the river (0-100 m). Based on the analysis of indications of environmental factors, using CCA also proves that there are no specific environmental factors that determine the presence of Bambusa spp. Thus, it can be emphasized that this species can adapt well to various habitat conditions. Through this study, we recommend that species of the genus *Bambusa vulgaris* to be utilized for watershed conservation and rehabilitation.

Conclusions

Five bamboo genera, 20 species, and three bamboo cultivars were recorded in the riparian areas in upstream of three major Sumatran rivers, namely the Kuantan, Kampar, and Rokan rivers. The Canonical correspondence analysis results suggest that Bambusa vulgaris is suitable for cultivation in Kuantan and Kampar watersheds. In addition, B. vulgaris species is present in great quantity in these watersheds and high tolerance limit to the polluted watershed. B. vulgaris also has a speedy growth time, so it can be recommended as riparian vegetation for managing polluted watersheds because bamboo has a rhizome root system that can filter water naturally. Hence, it has a close relationship with the hydrological function of the soil to ensure the availability of clean water in the watershed.

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References

Arifin, H.S, Wulandari, C., Pramukanto, Q. and Kaswanto, R.L. 2009. Analisis Lanskap Agroforestry; Konsep, Metode dan Pengelolaan Agroforestry. Skala lanskap dengan studi kasus Indonesia, Filipina, Laos, Thailand dan Vietnam. IPB Press. Bogor.

Auerswald, K., Moyle, P., Seibert, S.P. and Geist, J. 2019. HESS opinions: socio-economic and ecological trade-offs of flood management - benefits of a transdisciplinary approach. Hydrol Earth Syst Sci 23:1035–1044. https://doi.org/10.5194/hess-23- 1035-2019

Ben-zhi, Z., Mao-yi, F., Jin-zhong, X., Xiao-sheng, Y. and Zheng-cai, L. 2005. Ecological functions of bamboo forest: research and application. *J Forest Res*. 16(2): 143-147.

Bodaghabadi, M.B., Salehi, M.H., Martínez-Casasnovas, J.A., Mohammadi, J., Toomanian, N. and Borujeni, I. 2011. Using Canonical Correspondence Analysis (CCA) to identify the most important DEM attributes for digital soil mapping applications. CATENA, 86 (1), 66–74. doi:10.1016/j.catena.2011.02.009

Bompard, J.M,, Kostermans, A.J.G.H. 1985. Wild mangifera species in Kalimantan, Indonesia. In Mehra, K.L. and S. Sastrapadja (Eds.). Proceedings of the Internasional Symposium on South East Asian Plant Genetic Resource. Lembaga Biologi Nasional. Bogor.p. 172-174.

Chase, J.W., Benoy, G.A., Hann, S.W.R. and Culp, J.M. 2016. Small differences in riparian vegetation significantly reduce land use impacts on stream flow and water quality in small agricultural watersheds. *J Soil Water Conserv*. 71(3): 194-205. DOI: 10.2489/jswc.71.3.194.

Chen, J., Shafi, M., Li, S., Wang, Y., Wu, J., Ye, Z., Peng, D., Yan, W. and Liu, D. 2015. Copper induced oxidative stresses, antioxidant responses and phytoremediation potential of Moso bamboo (*Phyllostachys pubescens*). *Sci Reps*. 4:135-54

Chen, G., Tang, X., Cai, C., Fan, S., Sun, L., Yang, F. and Liu, H. 2019. Air moisture and soil texture are crucial for the water dynamics of riparian bamboo in a subtropical region. *Plant Soil* https://doi.org/10.1007/ s11104-020-04696-w.

Dolezal, J. and Srutek, M. 2002. Altitudinal changes in composition and structure of mountain– temperate vegetation: A case study from Western Carpathians. *J Plant Ecol*. 158(16):201-221.

Fitmawati, Saputri, N.A., Hartanto, S., Resida, E., Kholifah, S.N., Kapli, H., Sofiyanti, N., Wahibah, N.N. and Khairijon. 2020. Diversity and utilization of bamboo (Bambusoideae) in five island around Riau Province, Indonesia. *SABRAO J Bred Genetics*. 52 (2) : 177-190.

Fitmawati, Ikhsan M, Kurniawan H, Yundika Z, Wahyuda B, Pranata S, Kholifah SN, Sofiyanti N,Wahibah NN, Khairijon and Adnan A. 2021. Species diversity and environmental effects on Bamboo (Bambusoideae) in estuaries along the east coast of Sumatra. *SABRAO J Bred Genetics* 53(3): 403-416.

Huzaemah., Mulyaningsih., T. and Aryanti, E. 2016. Identifikasi bambu pada daerah aliran sungai Tiupupus Kabupaten Lombok Utara. *J Biologi Tropis*. 16 (2) : 23-26.

Khorooshi, S., Mostafazadeh, R., Esmaliouri, A. and Raoof, M. 2016. River health, importance and applications. *Extens Develop Watershed Manage*. 14(3):30-40.

Liu, D., Li, S., Islam, E., Chen, J.R., Wu, J.S., Ye, Z.Q., Peng, D.L., Yan, W.B. and Lu KP. 2015. Lead accumulation and tolerance of bamboo seedlings: applications of phytoremediation. J Zhejiang Univ Sci 16:123-130

Middleton, D.J., Armstrong, K., Baba, Y., Balslev, H., Chayamarit, K., Chung, R.C.K., Conn, B.J, Fernando, E.S, Fujikawa, K., Kiew, R., Luu, H.T., Mu Aung, Newman, M.F, Tagane, S., Tanaka, N., Thomas, D.C., Tran, T.B, Utteridge, T.M.A., van Welzen, P.C., Widyatmoko, D., Yahara, T. and Wong, K.M. 2019. Progress on Southeast Asia's Flora Projects. Gard Bull Singapore. 71(2) : 267-319.

Nezerkova, PH. 2006. A canonical corresponence analysis (CCA) of the vegetation-environment relationships in Sundanese savannah, Senegal. *S Afr J Bot*. 71:256-262.

Nirala, P.D., Jain, S.C. and Kumari, P. 2016. Distribution of different bamboo species in different areas of North Chota Nagpur division of Jharkhand. *Biosci Discov*, *7*, 21-24.

Nkeshita, F.C., Adekunle, A.A., Onaneye, R.B. and Yusug, O. 2020. Removal of pollutants from abattoir wastewater using a pilot-scale bamboo constructed wetland system. Environ Eng. 7(2): 70-74.

Pambudi, A.S. 2019. Watershed management is Indonesia: A regulation, Institution, and policy review. *Indonesian J Develop plan*. 3(2): 185-202.

Pambudi, A. 2021. watershed approach of integrated water resources conservation in Indonesia. *Academia Letters*, Article 3225

Pranata, S., Sulistijorini, S. and Chikmawati T. 2019. Ecology of *Rafflesia arnoldii* (Rafflesiaceae) in Pandam Gadang West Sumatra. *J Trop Life Sci*. 9(3), 243-252.

Rugayah, Widjaja, E.A. and Praptiwi. 2004. *Pedoman Pengumpulan Data Keanekaragaman Flora* (I.). Bogor: Pusat Penelitian Biologi lembaga Ilmu Pengetahuan Indonesia.

Sadiku, N.A., Oluyege, A.O., Ajayi, B. and Bada, A.O. 2020. Basic working stress for naturally grown Bamboo (*Bambusa vulgaris*). J Bamboo Rattan. 19(4). 83-93.

Saridewi, T.R, Hadi, S., Fauzi, A. and Rusasatra, I.W. 2017. Paymanet for environmental services approach to reduce flood in Ciliwung watersheed. *Biotropia.* 24(2): 127-139.

Selvan, T. 2018. Bamboo Resources, Their Status, onservation and Strategies for Improvement: Section D Biodiversity Conservation and Tree Improvement. India. Tripura University

Sofiah, S., Setiadi, D. and Widyatmoko, D. 2013. Pola penyebaran, kelimpahan dan asosiasi bambu pada komunitas tumbuhan di Taman Wisata Alam Gunung Baung Jawa Timur. *Berita Biologi*, 12(2), 239-247.

Sofiah, S. and Fiqa, A.P. 2011. Karakterisasi (Tipe Kanopi dan Perakaran) Tumbuhan Lokal untuk Konservasi Tanah dan Air, Studi Kasus pada Kluwih (Artocarpus altilis Park. ex Zoll.) Forsberg) dan Bambu Hitam (*Gigantochloa atroviolaceae* Widjaja). *Jurnal Berkala Penelitian Hayati*. 5F : 29-32.

Sukawi. 2010. Bambu sebagai alternatif bahan bangunan dan konstruksi di daerah rawan gempa. Teras.X (1): 1-10.

Swanson, S., Kozlowski, D., Hall. R.K. and Linn J. 2017. Riparian proper function condition assessment to improve watershed manafement for water quality. *J Soil Water Conserv*. 72(2): 168-182. DOI: 10.2489/ jswc.72.2.168

Syafri, A., Surya, B., Ridwan., Bahri, S., Rasyidi, E.S. and Sudarman. 2020. Water quality pollution control and watershed management based on community participation in Maros City, South Sulawesi, Indonesia. *Sustainability*. 12(24): 1-39. DOI: https://doi.org/10.33 90 /su122410260.

Tamrin, Saam, Z. and Siregar, S.H. 2018. Analisis kegiatan penambangan pasir-batu terhadap erosi, kualitas air dan sosial ekonomi masyarakat di sekitar sungai Indragiri. *J Photon*. 8(2): 67-74.

Widjaja, E.A. 1987. A revision of Malesian *Gigantochloa* (Poaceae-Bambusoideae). *Reinwardtia.* 10(3): 291-380.

Widjaja, E.A. 1997. New taxa in Indonesian Bamboos. *Reinwardtia*. 11(2): 57-152

Widjaja, E.A. 2001a. Identifikasi Jenis-jenis Bambu di Kepulauan Sunda Kecil. Bogor (ID): Puslitbang Biologi-LIPI

Widjaja, E.A. 2001b. Identikit Jenis-jenis Bambu di Jawa. Bogor (ID): Puslitbang Biologi-LIPI.

Widjaja, E.A. and Karsono. 2005. Keanekaragaman bambu di Pulau Sumba. *Biodiversitas*. 6(2):95-99.

Widjaja, E.A. 2019. The spectacular Indonesian bamboos. Jakarta: Pola Aneka Sejahtera (Polagrade). ID

Widnyana K. 2012. Bambu dengan berbagai manfaatnya. Bumi Lestari**,** [S.l.], 8 (1),. ISSN 2527-6158.