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Riparian plant diversity in relation to artisanal mining sites in Cikidang River, Banten, Indonesia

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Abstract. *Takarina ND, Sinaga IL, Kultsum TR. 2021. Riparian plant diversity in relation to artisanal mining sites in Cikidang River, Banten, Indonesia. Biodiversitas 22: 401-407.* Artisanal mining usually occurs in gold mining activities near the river banks and consequently, this will affect the downstream ecosystem include riparian habitat and its plant diversity. Here, this study aimed to assess the effects of artisanal mining sites on the riparian plant diversity in Cikidang River, Lebak District, Banten Province, Indonesia. The study was conducted by placing 10 sampling stations along 4 km of Cikidang River with width of 20 m. Riparian plant species were collected and identified from 10 m x 10 m sampling plots in each station**.** Plant diversity was assessed using Shannon-Wiener, Simpson, Margalef, and Pielou indices. There were in total 18 families and 42 plant species have been identified. Compositae and Poaceae were plant families that common here. *Ageratum conyzoides* was the most common species followed by *Impatiens platypetala*, *Cibadium surinamense*, *Wollastonia biflora*, *Calliandra calothyrsus*, and *Pityrogramma calomelanos*. Shannon-Wiener diversity index was in the range of 1.040-1.561. There was a positive correlation between riparian diversity with the distance to mining sites with decreasing diversity trends toward artisanal mining sites. Riparian habitats located far (> 1 km) from the mining sites have more species. While species observed in riparian habitats near (0.3-1 km) the mining sites were accounted only for 26.1% of total species found. To conclude, the presence of artisanal mining sites can affect the nearby riparian plant diversity.

Keywords: Artisanal, diversity, plant, mining, riparian

INTRODUCTION

Mining activities were known to have effects on ecosystem and biodiversity at multiple spatial scales included site, landscape, regional and global (Sonter et al. 2018). Those effects have resulted from direct activities like mineral extraction and indirect processes included industries supporting mining operations. Impacts on biodiversity have occurred across landscapes and regions. Mining activities in Madre de Dios in Peru have exported contaminated sediments to rivers in Brazil (Asner et al. 2013) and leave only tolerant species behind (Li et al. 2010). Iron mining has removed exceptionally diverse plant communities entirely as observed in Brazil (Jacobi et al. 2011). Mining impacts on biodiversity have emerged through indirect/ secondary and cumulative pathways at landscape and region-wide scales (Raiter et al. 2014). Indirect impacts happen when mining increases additional biodiversity loss through mining associated infrastructure development. This development can attract human populations causing new threats (Sonter et al. 2017) or even exacerbate existing threats including over-exploitation, hunting, fishing, invasive species presence and habitat loss for other anthropogenic-related land uses (Alamgir et al. 2017, Fatah 2008.).

Different mining methods pose different threats to biodiversity. One of mining methods is known as artisanal mining. Impacts of artisanal mining on ecosystem and biodiversity have been reported in many literature. In Ethiopia, artisanal mining has removed significant volumes of soil, destroyed massive tracts of vegetation, and have exposed dead trees and tree roots. Artisanal mining system has converted vegetated sites into dysfunctional landscape (Meaza et al. 2017) and degraded indigenous plant diversity (Girmay 2018). Artisanal mining activities were located near the river banks since the mines need water to process and discharge waste. This condition has caused environmental degradation on riparian habitat nearby with observed impacts included diversion and sedimentation of some rivers (Funoh 2014). In Pungwe river basin, the artisanal mining activities cause erosion and export large amount of sediment feeding the Pungwe river system make the water for domestic use and irrigation becomes unfit due to the suspended sediment (Pereira 2009). In Surow river, the main effects of the artisanal mining activities on river systems including changes in water conductivity, sediment loads and river morphology alterations (Macdonald et al. 2015). While in Cikotok mining, Banten, artisanal mining has released Pb and Zn to the environment (Latifundia 2015).

Riparian habitats were known for having plant diversity and this ecosystem was also affected by nearby artisanal mining activities. Despite there are numerous studies that reported effects of artisanal mining effects on riparian habitats, whereas the artisanal mining effects for particular riparian plant diversity have received little attention in the literature. One of the river systems that has experienced artisanal mining activities is Cikidang River in Banten Province. Kurniawan et al (2013) have recorded that mining in Lebak, Banten have occupied an area of 6445

Ha. For this reason, this study here aims to assess the plant diversity in Cikidang river, Banten influenced by nearby artisanal gold mining activities.

MATERIALS AND METHODS

Study area

The study was conducted in July 2020 in 10 stations located in Cikidang River, Lebak District, Banten Province, Indonesia (Figure 1). Each sampling station and mining site geocoordinate in decimal degrees were recorded using Global Positioning System (GPS) handheld Etrex Garmin. All sampling stations were situated at latitude of 6.791556 S-6.816861 S and longitude of 106.420389 E-106.438722 E. Total distance of all sampling stations was 4 km covering Cikidang river with width of 20 m.

Vegetation sampling

Vegetation sampling method was following Botha et al. (2015) and Van Rensburg et al. (2020). In each sampling station, a sampling plot sizing 10 m x 10 m was placed. Vegetation observed inside the plots were collected and stored in plastic bags for further identification. The vegetation samples were identified into family and species levels using Van Steenis (2006) plant identification book.

Data analysis

The vegetation data were assessed using Shannon-Wiener, Simpson, Margalef, and Pielou indices following Adesipo et al. (2020). Similarities among stations were analyzed using Bray-Curtis indices and interpreted as dendrogram. Those vegetation indices then were mapped and interpreted using thematic geographic information system (GIS) map. This map can provide the trends of plant diversity as function of sampling station distances to the mining sites. Equation to calculate Shannon-Wiener, Simpson, Margalef, and Pielou indices were following Premavani et al. (2017) described as follows.

Shannon-Wiener (H'): $-\Sigma\ (P_i)/\text{In}\ (P_i)$

Where, $P_i = n_i/N$, n_i = number of all individuals of one species, N = the total number of individuals of all species and In = Logarithm.

Simpson: $\Sigma_i n^2_i/N^2$

Where, n_i = number of all individuals of one species, N = the total number of individuals of all species.

Margalef (d): $S_1/\log N$

Where, S is the number of species and N is the number of individuals.

Pielou evenness (e): $H'/\log S$

Where, H' = Shannon index and S = number of species.

Obtained diversity indices then correlated with the distances to mining sites (m) using Pearson correlation.

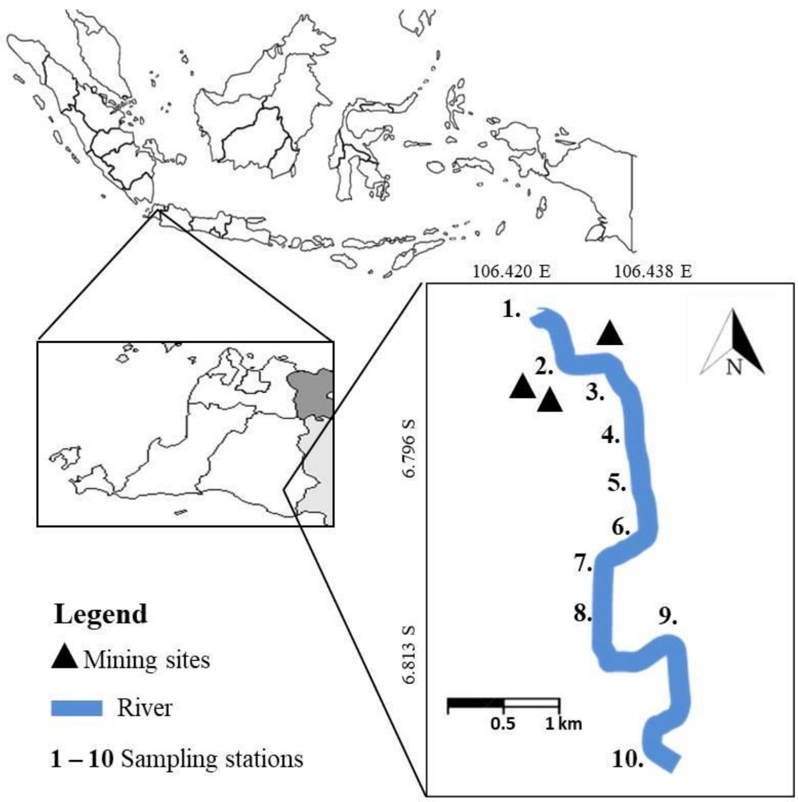


Figure 1. Map of Cikidang River, Banten Province, Indonesia with artisanal mining sites and 10 sampling stations (1-10)

RESULTS AND DISCUSSION

Plant diversity

The artisanal gold mining sites in Cikidang River were located in the north near the upstream areas. There were 1 site on the east bank and 2 sites on the west banks of Cikidang River. Sampling stations 1, 2, 3, and 4 were located close (0.3-1 km) to those sites. Whereas sampling stations 5, 6, 7, 8, 9, and 10 were located at a distance (1-4 km) from the mining sites.

This study has recorded families and species of plants in the riparian habitat of Cikidang as can be observed in Table 1. There were in total 18 family and 42 plant species have been identified. Compositae and Poaceae were plant families that common in riparian since these families have more species compared to other families. Station 3, 4, 5, 6, and 8 were having more plant families than other stations (Figure 2). Compositae and Poaceae were also recorded almost in every sampling station. Compositae was only absent in stations 2 and 5 while Poaceae absent in stations 2 and 7. *Ageratum conyzoides* was the common species from Compositae since it can be found in 3 stations. Other common species found in 2 stations were *Impatiens platypetala*, *Clibadium surinamense*, *Wollastonia biflora*, *Calliandra calothyrsus* and *Pityrogramma calomelanos.* While the rest of the species were distributed only in 1 station. Species that found near the mining sites were *Ageratina riparia*, *Ichnanthus pallens* and *Christella dentata* for station 1, *Diplazium* sp,, *Fimbristylis aestivalis* and *Hedyotis vestita* for station 2, and *Amaranthus tricolor*, *Ageratum conyzoides*, *Cibadium surinamense*, *Ficus* sp. and *Cynodon dactylon* for station 3.

Table 1. Plant diversity at family and species levels in Cikidang River riparian, Banten, Indonesia

Family	Species	Stations									
		1	2	3	4	5	6	7	8	9	10
Acanthaceae	*Thunbergia alata* Bojer ex Sims							+			
Amaranthaceae	*Alternanthera sessilis* (L.) R.Br. ex DC.				+						
	Amaranthus tricolor L.			+							
Araceae	*Colocasia esculenta* (L.) Schott						+				
Athyriaceae sp.	*Diplazium* sp. (f)		+								
Balsaminaceae	*Impatiens platypetala* Lindl.					+	+				
Commelinaceae	*Commelina diffusa* Burm F.							+			
	Murdannia nudiflora (L.) Brenan					+					
Compositae	*Ageratina riparia* (Regel) R.M.King	+									
	Ageratum conyzoides (L.) L			+			+	+			
	Bidens biternata L.									+	
	Bidens pilosa L.									+	
	Cibadium surinamense L.			+							+
	Crassocephalum crepidiodes (Benth) S. Moore						+				
	Eleutheranthera ruderalis (Sw.) Sch.Bip.				+						
	Sphagneticola trilobata (L.) Pruski										+
	Wedelia triloba (L.) Hitch								+		
	Wollastonia biflora (L.) DC.						+	+			
Cyperaceae	*Fimbristylis aestivalis* Vahl.		+								
Equisetaceae	*Equisetum ramossimum* Desf.					+					
	Hippochaete debilis (Roxb. ex Vaucher) Ching								+		
Lamiaceae	*Hyptis capitata* Jacq.								+		
Leguminosae	*Calliandra calothyrsus* Meisn.					+					+
	Zapoteca tetragona (Willd) H.M.Hern					+					
Moraceae	*Ficus* sp.			+							
Oxalidaceae	*Oxalis barrelieri* L.						+				
Poaceae	*Chionachne punctata* (R.Br.) Jannink					+					
	Cynodon dactylon (L.) Pers.			+							
	*Echinochloa colona (*L.) Link				+						
	Digitaria longiflora (Retz.) Pers.								+		
	Eragrotis anabilis (L.) Wight & Arn				+						
	Heteropogon sp.				+						
	Ichnanthus pallens (Sw.) Munro ex Benth	+									
	Leptochloa sp.						+				
	Panicum virgatum L.									+	
	*Paspalidium geminatum (*Forssk.)									+	
	Pogonatherum paniceum (Lam.) Hack.								+		
	Sacharum spontaneum L.										+
Pteridaceae	*Pityrogramma calomelanos* (L.) Link				+				+		
Rubiaceae	*Hedyotis vestita* R.Br. ex G.Don		+								
Thelypteridaceae	*Christela dentata* (Forssk) Browsey & Jermy	+									
Verbenaceae	*Stachytarpheta indica* (L.) Vahl.									+	

Note: **+:** present

Figure 3 presents the grouping of stations based on the plant vegetation assemblages. Based on the plant diversity characteristics there were 3 groups in Cikidang rivers. First group consists of stations 1, 2, 3 and 4 that similar to group of stations 7, 10. The last group is including stations 5, 6, 8 and 9. The plant diversity indices of the 10 stations are presented in Table 2. Those indices are showing positive correlation with the distance to mining sites. Margalef, Shannon-Wiener and Simpson indices were lower when riparian habitat was closed to the mining sites or the distance decreased. In contrast, the riparian plant diversity increased when the distance to mining sites increased as well (Figure 4). In contrast, Pielou indices increased when closed to the mining sites. Figure 5 confirms that the Shannon-Wiener was the fit model to describe the effects of artisanal mining on riparian plant diversity.

Shannon-Wiener indices increased from 1.04 to 1.561 when the mining sites were absent as can be seen in stations 4, 5 and 6 that have high indices. Similar trends were also observed for Margalef and Simpson indices. Plant species that contributes to the diversity in those locations were *Alternanthera sessilis*, *Eleutheranthera ruderalis*, *Echinochloa colona*, *Eragrostis anabilis*, *Heteropogon* sp., *Pityrogramma calomelanos* for station 4, *Impatiens platypetala*, *Murdannia nudiflora*, *Equisetum ramosissimum*, *Calliandra calothyrsus*, *Zapoteca tetragona*, *Chionachne punctate* for station 5, *Leptochloa* sp., *Oxalis barrelieri*, *Wollastonia biflora*, *Crassocephalum crepidiodes*, *Ageratum conyzoides*, *Impatiens platypetala*, *Colocasia esculenta* for station 6.

Table 2. Plant diversity indices and Pearson correlation with distances to mining sites in Cikidang River riparian, Banten, Indonesia

Diversity indices	Mean	95%(CI)	Pearson
Margalef	1.783	1.542-2.024	0.415
Pielou	0.957	0.933-0.980	0.207
Shannon-Wiener	1.297	1.140-1.455	0.119
Simpson	0.310	0.268-0.352	0.245

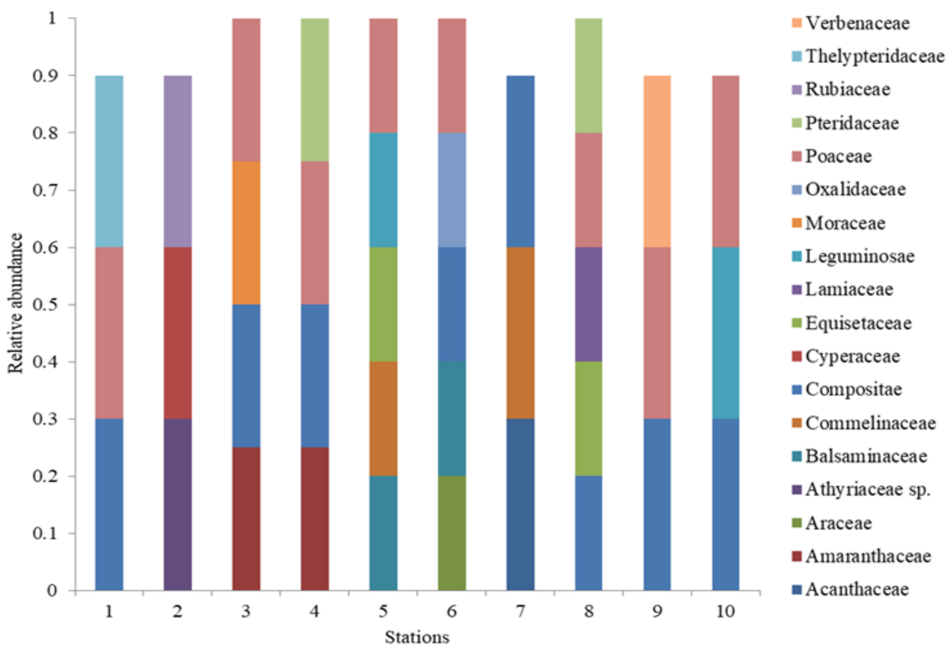


Figure 2. Plant family relative abundances in Cikidang river riparian, Banten, Indonesia

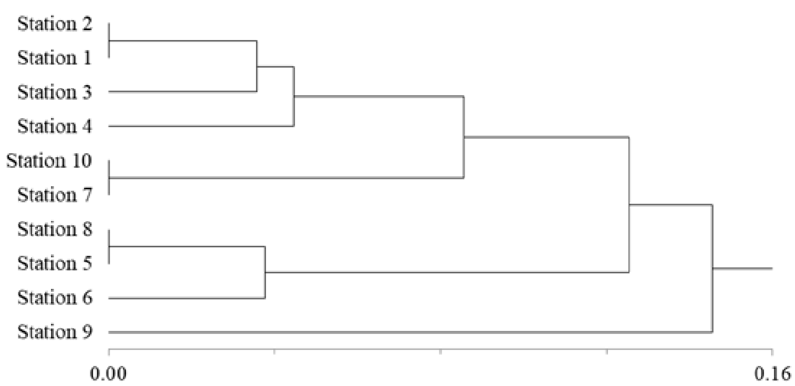
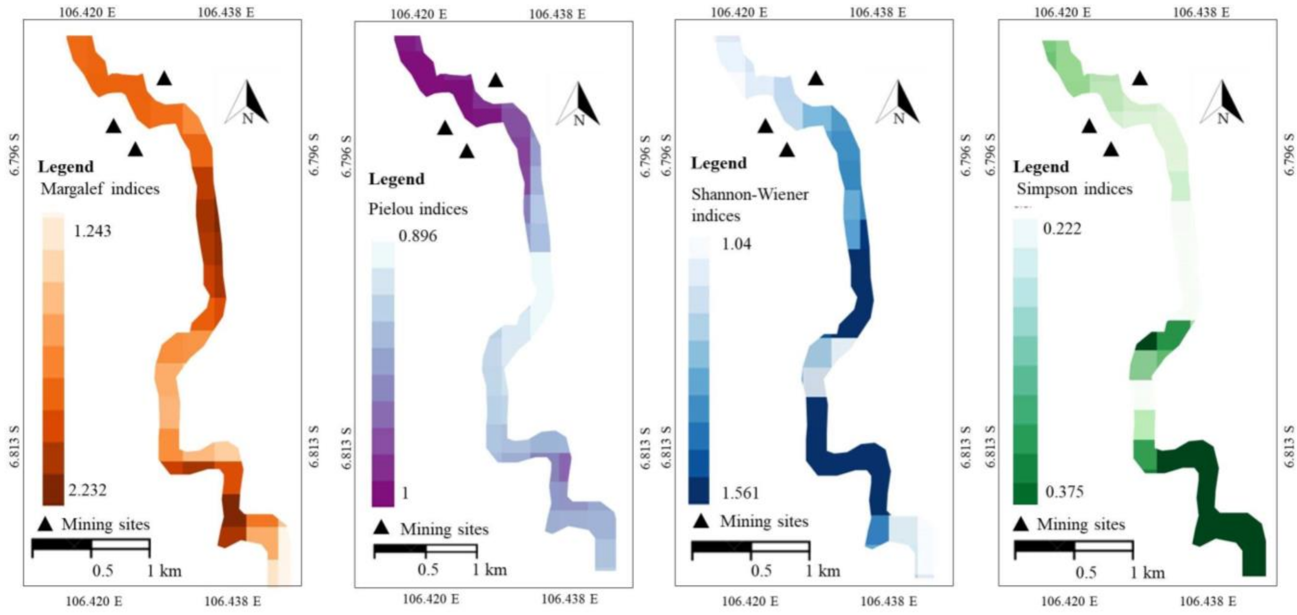
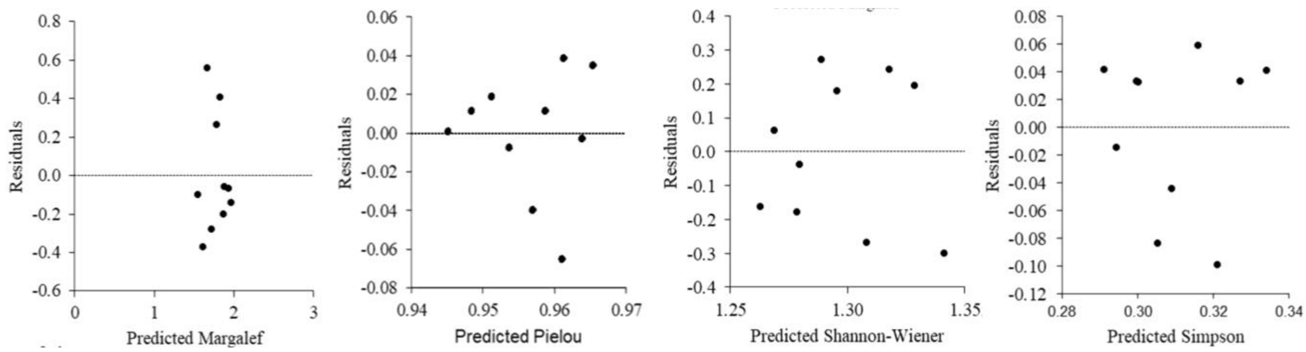


Figure 3. Bray-Curtis similarity dendrogram of the sampling stations in Cikidang river riparian, Banten, Indonesia



A B C D

Figure 4. Map of Margalef (A), Pielou (B), Shannon-Wiener (C) and Simpson (D) indices trends for vegetation in Cikidang river riparian, Banten, Indonesia



A B C D

Figure 5. Fitted model of Margalef (A), Pielou (B), Shannon-Wiener (C) and Simpson (D) indices

Discussion

Riparian plant diversity recorded in this study was in corroborations with other studies. In Cikidang riparian, Poaceae was one of family that more common and occurred in almost all stations. Bando et al. (2016) have reported that Poaceae was the biggest family of riparian plants recorded in Tewalen River, South Minahasa. Ainy et al. (2018) have also observed high abundance of Poaceae in Pesanggrahan River, South Jakarta. Poaceae has species that widely distributed and this supported by adaptation capacity that more advance compared to other families (Pandey 2003). Poaceae has preference on riparian habitat since this habitat was humid and provide more sunlight. Adaptation capacity of Poaceae explains the presence of one of these species in station 3 that close to the mining sites. *Cynodon dactylon* was the only species of Poaceae that presents in station 3. Hastiana (2014) reported the presence of *Cynodon dactylon* in Sematang Borang River, Palembang. High abundance of *C. dactylon* was observed in the Sematang Borang riparian that has been influenced by anthropogenic activities. Compositae was also riparian family that common in Cikidang. Badry et al. (2019) have reported that Poaceae along with Compositae were common and dominating the riparian habitats. One of Compositae species like *Ageratum conyzoides* was very common and widely distributed in 3 stations in Cikidang. In Ranoyapo River, Minahasa, *A. conyzoides* was a common Compositae species that inhabited riparian habitats (Siahaan and Ai 2014). Several riparian families with low abundance were *Moraceae* and *Oxalidaceae* (Girmay 2018). Those families were belonging to trees and have low abundance in comparison to herbs. Singkam et al. (2019) have reported presence of Oxalidaceae represented only in few individuals in riparian of Ketahun River, Lebong, North Bengkulu.

Riparian diversity pattern is influenced by the wide ranges of anthropogenic disturbances including grazing pressure, cultivation, exploitation, and erosion. As a result, riparian species and species numbers can be varied among stations. In Cikidang, several species were replaced by the presence of other species when the riparian habitats were closed to the mining sites. The removals of intact riparian species have been reported in Wami riparian, Tanzania (Mligo 2017). In here, the intact dominant plant species have been removed and allowed underrepresented species to perform in the area, resulting in the present plant diversity pattern. In this study, the apparent riparian diversity patterns were the diversity decline when the riparian was closed to the mining sites. This situation was supported by the spatial trends of diversity indices. The dendrogram based groupings were also confirming the separations of stations regarding the distance to mining sites. The cause of diversity decline was related to the removal of several plant species due to various mining-related activities. The diversity decline in this study can be observed from the reduction of H' from 1.561 in intact riparian to 1.04 in riparian near the mining sites. In Umzingwane River (Sibanda et al. 2014), the H' was also declining from 1.648 to 1.143 in disturbed sites. In Umzingwane River, several species were cleared and trees were logged to provide access and wood materials for the miners. The removal of high values plant species will leave less important species. This was evidenced by the presence of herb and grass species in stations 1, 2 and 3 near the mining sites.

Low diversity of riparian was also related to the nutrient inputs from the lands. Dybkjær et al. (2012) stated that high levels of eutrophication may explain environmental variability and riparian community richness. Erosion and nutrients leaching entering riparian areas promotes species that can grow faster and have strong competitive capabilities for nutrients and light. Artisanal mining can be the source of nutrients since it can export nutrient-enriched sediment to downstream (Affum et al. 2016, Stubblefield et al. 2005). The nutrient-enriched habitat coupled with the presence of fast-growing species can be observed in station 3 near mining sites. According to DPP Lebak (2019), soils in Lebak and nearby Cikidang riparians have contained alluvial, latosol, and podzolic soil layers that fertile considering their soil nutrient contents that can promote plant growth (Kosolapova et al. 2016). *Amaranthus tricolor* and *Cibadium surinamense* found in this station was known as fast-growing species (Otsamo 2002, Anhar et al. 2018).

Besides presence of mining sites, indirect causes resulted from mining activities can also influence the riparian habitat. Artisanal mining through its activities can impact riparian through deforestation, siltation, trench and pits formation, topsoil removal, water pollution, veldt fires, land degradation, and chemical releases. On of concerned impacts was deforestation since it can deliver instant impact on diversity reduction. Girmay (2018) reported that since artisanal miners are come from outside, it is common that they make a temporal residence around the mining areas. This imposes to devastate vegetation resources and ecosystem loss in the form of deforestation. Near the riparian where high mining was conducted, deforestation was higher in comparison to the far adjacent riparian. This situation explains the low abundance of tree species diversity that belongs to Moraceae family.

This study to conclude has formed part of few studies conducted in the tropical riparian to highlight the influence of riverine artisanal mining on riparian ecosystem. The results obtained in this study confirm that riverine artisanal mining can contribute to riparian plant diversity. The mining has altered the species composition and number of species as well with riparian plant diversity decreased when the artisanal mining sites were nearby. Riparian plant diversity near mining sites was characterized by the presence of *Ageratina riparia*, *Ichnanthus pallens, Christella dentata*, *Diplazium* sp,, *Fimbristylis aestivalis, Hedyotis vestita*, *Amaranthus tricolor*, *Ageratum conyzoides*, *Cibadium surinamense, Ficus* sp. and *Cynodon dactylon*.

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