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The diversity of *Nepenthes* at the post-mining area in Sintang District, West Kalimantan, Indonesia

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[2]Department of Forestry, Faculty of Agriculture, Universitas Kapuas. Jl. Y.C. Oevang Oeray No. 92, Baning Kota, Sintang, 78612, West Kalimantan, Indonesia, Tel: +62-565-22256, Fax: +62-565-202-0034, ♥♥email: riarose.h@gmail.com

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Abstract. *Setiawan H, Wardhani HAK, Kamaludin, Hutagaol RR, Afriani R. 2018. The diversity of Nepenthes at the post-mining area in Sintang District, West Kalimantan, Indonesia. Biodiversitas 19: 1820-1827. Nepenthe is* a tropical pitcher plant found in Indonesian archipelago and lives in nutrient leak habitat. One of *Nepenthes* nutrient leak habitat commonly found in Kalimantan Island is the post-mining area. This research aimed to know the habitat condition, species composition, species richness and diversity index of *Nepenthes* in Post-mining area in Sintang District, West Kalimantan Province. Thirty plots, each measuring 5 x 5-meter square, were established to survey the *Nepenthes* diversity in five locations of the post-mining area in Sintang District. There were 910 individuals of *Nepenthes* found spreading in two sub-Districts and five areas. Habitat condition in the post-mining area tended to be high in light intensity and temperature but low in humidity. Five *Nepenthes* species were found, namely *N. ampullaria*, *N. bicalcarata*, *N. gracilis*, *N. mirabilis*, and *N. rafflesiana*. Four natural hybrids were also found including *N. xhookeriana*, *N. xkuchingensis*, *N. xneglecta*, and *N. xtrichocarpa*. The species richness in post-mining area were 1.25 in Danau BTN (Bank Tabungan Negara/State Savings Bank) 0.95 in Dusun Kerangas, 0.58 in Sungai Ana Village, 0.21 in Jerora 1 and 0.20 in Danau Baning. The diversity index in Danau BTN, Dusun Kerangas, Sungai Ana, Jerora 1 and Danau Banning area were of low levels, respectively, 1.66, 1.3, 1.0, 0.64, and 0.68. Cluster analysis of species richness, diversity index, and abiotic factors showed that Danau Baning-Sungai Ana-Jerora 1 was grouped in the same cluster while Danau BTN and Dusun Kerangas were in a separate cluster.

Keywords: Diversity, *Nepenthes*, post-mining, Sintang District

INTRODUCTION

Nepenthes (Family of Nepenthaceae) is the largest genus of pitcher plants (Moran and Clarke 2010). The genus contained 114 species over the world (IUCN) and distributed from Eastward of Madagascar to New Caledonia at Pacific Ocean (Jebb and Cheek 1997). Indonesian Archipelago is a central diversity of *Nepenthes* with 32 endemic species in Borneo Island, 24 endemic species in Sumatera Island and some species found in Java, Sulawesi, and Papua Islands (Jebb and Cheek 1997; Clarke 2001; Clarke 2006;).

Nepenthes are tropical carnivorous plants that evolved it leaf extensions into jug shaped structures which contain a pool of digestive enzymes to attract, trap and digest animals for its nutritional benefits (Clarke 2006). *Nepenthes* pitchers are passive, gravity-driven traps that show distinct functional zonation on their inner surfaces (Moran and Clarke 2010). Beside prey capturing, an extra nutrition also can be extracted from other scenario such as litterfall with “carpets” of pitchers at ground level and animal faces (*Kerivoula hardwickii*’s faces of *N. hemsleyana* and *Tupaia Montana*'s faces of *N. lowii*) (Clarke 2006; Moran and Clarke 2010; Gaume et al. 2016). This condition (nutrition sequestering by the pitcher) is vital because *Nepenthes* commonly found in lack nutrient habitat (Latiff et al. 2014).

The post-mining area is one of nutrient-deficient habitat where the *Nepenthes* is easily found. This area was formed by abandoned illegal gold mining or other mining activity in open space, usually in *kerangas* forest or watershed. This habitat is similar to *Kerangas* forest which generally has siliceous and acidic soil, higher temperature and lower humidity, all of which are preferred by *Nepenthes* (Latiff et al. 2014). In Sintang District, West Kalimantan Province, numbers of post-gold mining areas are increasing every year because of the local government policy to create a better ecosystem and fulfill the vision of "the Sustainable Sintang District." This research aimed to determine the species composition, species richness and diversity index of *Nepenthes* in Post-mining area in Sintang District.

MATERIALS AND METHODS

This research was conducted during February-July 2018 in five locations of post-mining areas in Sintang District, West Kalimantan Province. The post-mining areas are located in two sub-districts, i.e., Sintang Sub-district and Sepauk Sub-district. There were four post-mining areas in Sintang Sub-district namely post-mining Sungai Ana, post-mining Danau BTN (Bank Tabungan Negara/State Savings

Bank), post-mining Jerora 1, and post-mining Danau Baning. There were no longer mining activities in these four locations, and the areas are now being used for other activities such as tourism (swimming pool at the ex-mining hole), settlement area, and swallow-nest farm. Another location is in Sepauk Sub-district at Kerangas Village, where mining activity (gold and sand mining) is still ongoing but the sampling plots were placed on around the mining area. In each location, a plot of 5 m x 5 m size was set up to observe the *Nepenthes*. The location was determined by using a purposive sampling technique to ensure the presence of *Nepenthes* (Lestariningsih and Setyaningsih 2017). The research site was surveyed comprehensively in localities with *Nepenthes* presence, but the plots were set up randomly and discontinuously (Latiff et al. 2014; Lestariningsih and Setyaningsih 2017). Well-known *Nepenthes* were identified directly in the fields while unknown species were collected as herbarium specimen for further identification. Data collection in plots included several variables such as habitat description (another biodiversity in the location of *Nepenthes* presence) and microclimate (humidity, light intensity, and air temperature) which were later analyzed by PAST ver. 2.14's software (Hammer et al. 2001). Morphological data were analyzed descriptively, species richness was analyzed with Margalef's index (Aslam 2009; Endrawati et al. 2017), and diversity index was calculated using Shannon-Wiener's diversity index (Aslam 2009; Olopade and Rufai 2014; Komara et al. 2016).

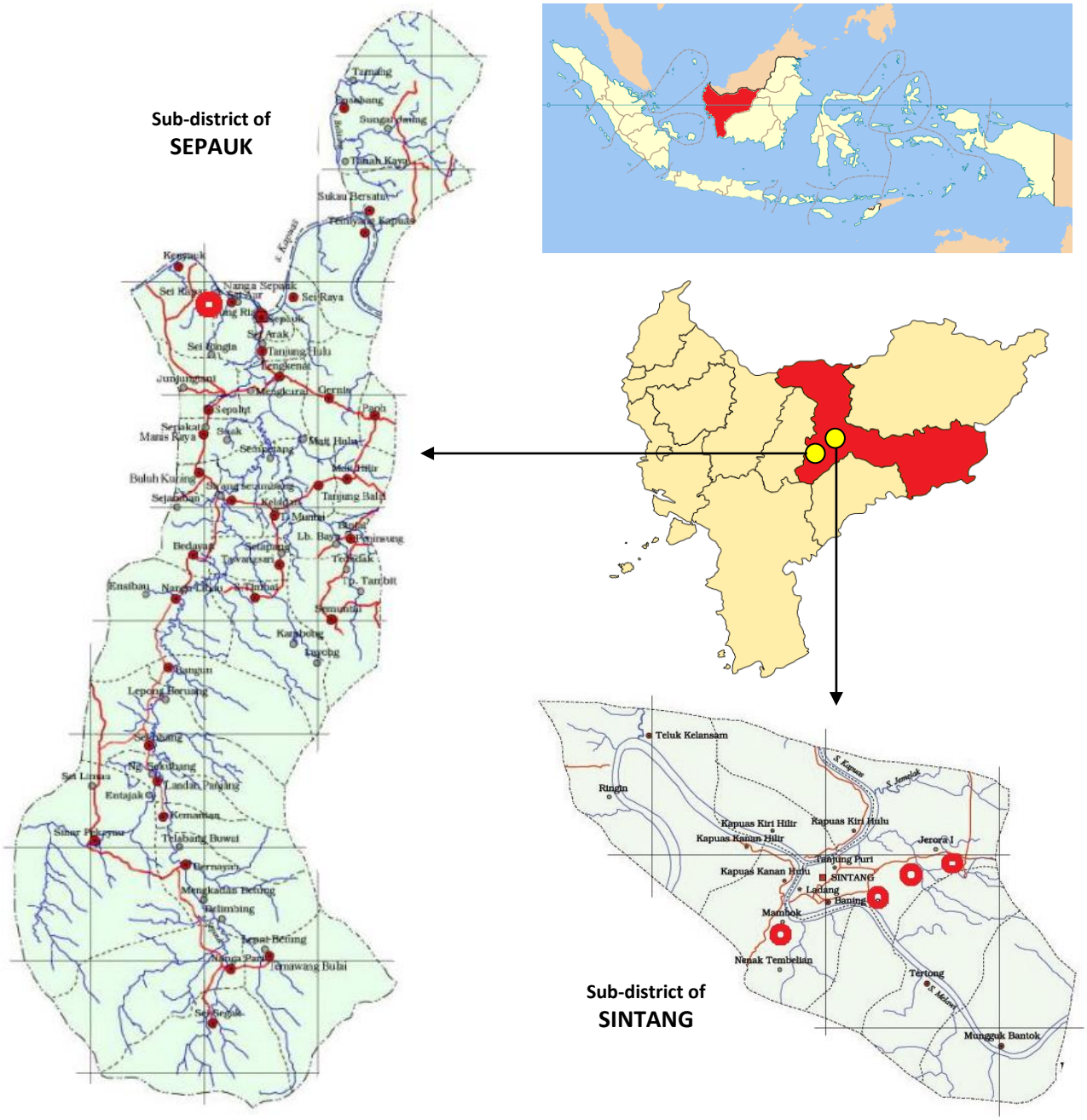

Figure 1. Study area in two sub-districts (Sintang and Sepauk Sub-district) of Sintang District, West Kalimantan Province, Indonesia. Red dots mean study sites

Margalef's index of species richness = (S-1)/ ln N

Where:
S : total species number
N : total of individual number in the sample
ln : natural logarithm

Shannon-Wiener's diversity index : H : - ∑ Pi ln Pi

Where:
Pi : S / N
S : total species number
N : total individual number in the sample
ln : natural logarithm

RESULTS AND DISCUSSION

Habitat conditions

All *Nepenthes* habitat referred to in this research is the post-mining areas in Sintang District. Some of this habitat was active illegal mining areas, and others were shifted to other activities like residential area and tourism. Before the illegal mining activity took place, all of this habitats were *Kerangas* forest. The soil in *Kerangas* forest was generally siliceous and acidic, the canopy was much lower then Dipterocarpaceae forest and tended to be more uniform (Clarke 2006).

In this research, habitat condition of the post-mining area was represented by air temperature, humidity, and light intensity (Table 1). All the variation of microclimate is dependent on the canopy and vegetation over the area. In an open area with less vegetation, air temperature and light intensity tended to be higher while the humidity was low (Table 1). This condition affected the presence of *Nepenthes*. In the area with high air temperature and light intensity like Sungai Ana, Danau Baning and Jerora 1, the number of species found tended to be less than that in closed canopy area with lower air temperature and light intensity like Danau BTN and Dusun Kerangas (Table 1). Clarke (2006) found that the climate of undisturbed *Kerangas* (the area before mining activity) is superficially similar to that in mixed Dipterocarpaceae forests. This type of climate supports the living of more *Nepenthes* as compared to the open canopy area.

N. gracilis and *N. mirabilis* were prone to be on the habitat with open canopy area while *N. ampullaria* and *N. bicalcarata* preferred the area with close canopy and high in humidity (Table 1). *N. rafflesiana* were found in both open and closed canopy areas. Most of *Nepenthes* hybrid was found in close canopy area while only one other species was found in open canopy area (*N. xneglecta*). *N. xneglecta* is a hybrid of *N. gracilis* and *N. mirabilis*. Although both *Nepenthes* commonly live in the same habitat, the hybrid was rarely found. The high abundance of the parents may likely be the reason for the existence of this hybrid (Clarke 2006).

Nepenthes compositions

There were five *Nepenthes* species and four natural hybrids that were found in five locations within 30 plots. *Nepenthes* found in the post-mining area included *N. ampullaria* Jack, *N. bicalcarata* Hook.f, *N. gracilis* Korth, *N. mirabilis* (Lour.) Druce, and *N. rafflesiana* Jack. var. typical. Moreover, four natural hybrids of *Nepenthes* were also found, i.e., *N. ampullaria* x *N. rafflesiana* (*N. xhookeriana*), *N. ampullaria* x *N. mirabilis* (*N. xkuchingensis*), *N. gracilis* x *N. mirabilis* (*N. xneglecta*), *N. ampullaria* x *N. gracilis* (*N. xtrichocarpa*). A total of 910 *Nepenthes* individuals were found in this research; the highest number was *N. gracilis* (401 ind) followed by *N. mirabilis* (245 ind) in the second place (Figure 2).

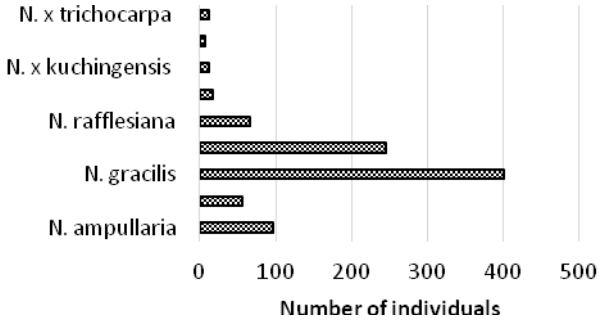

Figure 2. *Nepenthes* composition in the Post-mining area

Table 1. Humidity, air temperature, light intensity and number of individuals in each survey location

Location	Hm (%)	Temp (°C)	Lig (lux)	Number of individuals									Total of ind
				N.amp	N.bic	N.gra	N.mir	N.raf	N.xho	N.xkh	N.xne	N.xtr	
Sungai Ana (open canopy)	52.17	36.43	25970	0	0	58	68	43	0	0	6	0	175
Jerora 1 (open canopy)	52.33	34.07	43915	0	0	82	43	0	0	0	0	0	125
Danau Baning (open canopy)	53.00	33.83	31556	0	0	57	75	0	0	0	0	0	132
Danau BTN (closed canopy)	65.67	32.68	14823	34	49	126	13	20	17	9	0	12	280
Dsn Kerangas (closed canopy)	73.83	29.7	8241	62	6	78	46	3	0	3	0	0	198
Total				96	55	401	245	66	17	12	6	12	910

Note: Hm: humidity, Temp: air temperature, Lig: light intensity, N.amp: *N. ampullaria*, N.bic: *N. bicalcarata*, N.gra: *N. gracilis*, N.mir: *N. mirabilis*, N.raf: *N. rafflesiana*, N.xho: *N. xhookeriana*, N.xkh: *N. xkhucingensis*, N.xne: *N. xneglecta*, N.xtr: *N. xtrichocarpa*, Total of ind: total of individuals

Figure 3. Nepenthes species in the Post-mining area at Sintang District, West Kalimantan, Indonesia. A. *NEPENTHES ampullaria*, B. *N. bicalcarata*, C. *N. gracilis*, D. *N. xhookeriana*, E. *N. xkuchingensis*, F. *N. mirabilis*, G. *N. xneglecta*, H. *N. rafflesiana*, I. *N. Xtrichocarpa*. Bar = 2.5 cm

Description of *Nepenthes*

Each *Nepenthes* has a specific morphologic character that makes it distinct from one to another. This particular characteristic was used as a simple field identification of *Nepenthes*. The most variations appeared in the pitcher morphology and its colors (Clarke 2006). Some descriptions of *Nepenthes* found in post-mining habitat were different from those of *Nepenthes* in other habitats. The specific characters are presented below.

Nepenthes ampullaria

Nepenthes ampullaria has a unique lid of the pitchers which are cuneate and reflexed. These *Nepenthes* pitchers vary in colors such as light green, dark green, red, dark brown, bright green with red peristome, red with green peristome, green with red and brown blotches, red with brown blotches and some other combinations. In the post-mining area, *N. ampullaria* tended to be smaller than that in undisturbed habitat. The smaller size of *N. ampullaria* is an adaptative mechanism resulted from the lack of nutrient and to prevent the evaporation in an open area (Clarke 2006; Bauer et al. 2011).

Nepenthes bicalcarata

Nepenthes bicalcarata has a specific character that is distinct from other *Nepenthes* species, i.e., a pair of large thorns under the pitcher lid. This pair of large thorns is used to attract the nectar preys to enter the pitcher. The pitcher of *N. bicalcarata* is commonly found in two different forms; an upper pitcher and a lower pitcher in one individual to capture different types of preys. *N. bicalcarata* plants are the largest of genus *Nepenthes*, although the pitchers are not the largest one (Clarke 2006). *N. bicalcarata* has the largest stem and leaf in the *Nepenthes* genera. The stem of this plant can reach five m long in the post-mining area in Sintang District while other *Nepenthes* species can only achieve less than one meter in length.

Nepenthes gracilis

Nepenthes gracilis was commonly found in post-mining areas in Sintang District. Its pitcher is relatively smaller than that of other lowlands *Nepenthes* (less than 15 cm height). Its stem is triangular and climbs other vegetation to get better light. In the post-mining area, *N. gracilis* was found as a pioneer plant after the mining activity was closed. In this research, *N. gracilis* was always seen with *N. mirabilis* (Table 1) because both *Nepenthes* live in the same habitat (Clarke 2006; Setiawan et al. 2015).

Nepenthes mirabilis

Nepenthes mirabilis was the most adaptive *Nepenthes* in the post-mining area along with *N. gracilis*. It was found in different colors from light green to dark brown. Sometimes, it was found in full red from stem, leaves, and pitcher, especially in the profoundly disturbed habitat like post-mining area (Figure 3). This *Nepenthes* has most familiar flowers and fruits over seasons (Handayani 2017). In the post-mining area, the arthropods and wind factors facilitate the spread of the seed to entire habitat at the post-mining area.

Nepenthes rafflesiana

Nepenthes rafflesiana is lowland *Nepenthes* species in which lower and upper pitcher has many differences. The lower pitcher was more bulbous and had a pair of wing running from top to bottom. The upper pitcher looked more attractive with horn-shape and had a big lid to cover the peristome. Pitcher mouth of this *Nepenthes* was oblique and elongated into the neck at the back. Pitcher of *N. rafflesiana* was varying in colors from green to brown and blotches cover the pitcher's body (Listiawati and Siregar 2008). In the post-mining area, the color of *N. rafflesiana* pitcher was generally light green to dark green with red/brown blotches. This color variation is less than that in undisturbed habitat as an adaptation from habitat stress in the heavily disturbed post-mining area (Clarke 2006).

Nepenthes xhookeriana

Nepenthes xhookeriana is a natural hybrid from *N. ampullaria* and *N. rafflesiana*. The characteristic of *N. xhookeriana* is the combination of both of its parents. The pitcher was round and smaller than that of *N. rafflesiana*. The peristome of the pitcher was extended but less than that of *N. rafflesiana*. The lid of the pitcher was similar to that of *N. ampullaria* but broader and taller than one. The upper pitcher was ovoid and smaller than lower pitcher. The appearance of upper pitcher in *N. xhookeriana* was a contrast of *N. ampullaria* because *N. ampullaria* rarely produced it. The upper pitcher of *N. xhookeriana* was predicted from *N. rafflesiana* parentals (Clarke 2006).

Nepenthes xkuchingensis

Nepenthes xkuchingensis is a natural hybrid from *N. ampullaria* and *N. mirabilis*. According to Clarke (2006), this hybrid species was commonly found in Borneo but somehow appeared among both parental populations. In the post-mining area at Sintang District, it was only found in one location; in Danau BTN pal IV at Kapuas Kanan Hulu Village. The lower pitcher is more like that of *N. mirabilis* with well-developed wings and expanded peristome. The leaf size ranged between both parents and was smoother than that of *N. ampullaria*.

Nepenthes xneglecta

Nepenthes xneglecta is known as a natural hybrid from *N. gracilis* and *N. mirabilis*. According to Clarke (2006), even though both plants were commonly found in the same habitat but natural hybrids were rarely found. *N. xneglecta* is more like *N. gracilis* in shape, but in size, it is more like *N. mirabilis*. The leaf of its hybrid has the same characteristic as that of *N. mirabilis*. The stem of *N. xneglecta* is more cylindrical than *N. gracilis*.

Nepenthes xtrichocarpa

Nepenthes xtrichocarpa is a natural hybrid of *N. ampullaria* and *N. gracilis*. It was found in sandy-siliceous habitat in Danau BTN pal IV at Kapuas Kanan Hulu Village. The pitcher is relatively the same size as *N.*

gracilis but slightly wider in all aspects. The peristome is more like that of *N. ampullaria*. The lower pitcher is usually found in clumps cover the ground layer. The upper pitcher appears as a prove that *N. gracilis* parental is more dominant in this hybrid species. The upper pitcher is more like a "cup" with the lower part is smaller than the upper part.

Species richness

The post-mining area with the highest species richness (1.25) was Danau BTN in Kapuas Kanan Hulu Village followed by Dusun Kerangas and Sungai Ana Village with species richness of, respectively, 0.95 and 0.58. The lowest species richness was found in Jerora 1 (Jerora 1 Village) and Danau Baning (Banning Kota Village), respectively, 0.21 and 0.20 (Figure 4).

All of this *Nepenthes* species were found in post-mining areas affected by different community activities. Danau BTN is a post-mining area already covered by secondary vegetation like *Resam* fern (*Gleichenia* spp.), *Geronggang* (*Cratoxylum arborescens*), and *Jonger* (*Ploiarium alternifolium*). The dead root, stem and leaf of *Resam* fern are good growth media for lowland *Nepenthes*. Geronggang and *Jonger* are canopy trees in *Kerangas* habitat. The vegetation is an essential aspect of *Nepenthes* growth as it affects microclimate, soil organic matter, and biodiversity in that specific area/habitat (Clarke 2001; Clarke 2006).

The diversity index was used to determine the diversity of *Nepenthes* in each plot. The Shannon-Wiener Diversity Indices in five locations of the post-mining area showed some differences. The highest diversity index was found in Danau BTN (1.66) followed by Dusun Kerangas (1.30), Sungai Ana (1.00), Danau Baning (0.68), and Jerora 1 (0.64) (Figure 5). All of these diversity indices were categorized as less diverse (Gandhi and Sundarapandian, 2014). The diversity of *Nepenthes* in the post-mining area was impacted by habitat condition. In the location with high vegetation canopy cover like Danau BTN, the *Nepenthes* tended to be more diverse than that in open areas like Jerora 1 and Danau Baning since the soil nutrients in vegetated area (Danau BTN) was higher (than the disturbed area), which provided enough nutrient for plants growth (Singh et al. 2015).

Cluster analysis

Cluster analysis was used to identify the similarity between each location based on species richness, Shanon Wienner index, and abiotic factors. Cluster analysis divided the sites into three clusters, in which, Danau Baning, Sungai Ana and Jerora 1 were in one group, and Dusun Kerangas and Cluster Danau BTN were in a separate group (Figure 6).

Danau Baning, Sungai Ana and Jerora 1 are post-mining areas characterized by open canopy area, high temperature, and light intensity and low humidity. This cluster was also characterized with *N. mirabilis* as the dominant species. *N. mirabilis* was known as the most adaptive species in the genus and can live in a harsh habitat with high light intensity and temperature (Clarke 2006).

The cluster containing Danau BTN was characterized by the existence of *N. bicalcarata*, *N. xkuchingensis*, *N. xhookeriana*, *N. xtrichocarpa*. This area was a vegetated area with specific *Kerangas* secondary vegetation like *Gleichenia* spp and *Cratoxylum arborescens*. This vegetation makes a good condition (microclimate) for the growth of these *Nepenthes*.

Dusun Kerangas was a post-mining area, some of which were covered by secondary *Kerangas* vegetation. Different from Danau BTN, there were less *Gleichenia* spp. in Dusun Kerangas, but the area was covered by *Cratoxylum* spp. and other three species. The humidity was relatively higher, and the light intensity was the lower than other areas (Clarke 2006).

Based on biplot analysis, the group of Danau Baning-Sungai Ana-Jerora 1 was characterized by very dominant *N. mirabilis* in this area (Figure 7). Most of *N. mirabilis* was found in this group area. Dusun Kerangas was placed in a separate group characterized by high humidity and *N. ampullaria*. *N. ampullaria* was known as a species which tends to prefer a close canopy where it scrambles among low bushes (Clarke 2006). The group comprising Danau BTN was a group with many characters such as *N. bicalcarata*, *N. xhookeriana*, *N. xtrichocarpa*, and *N. kuchingensis*. Danau BTN was a vegetated habitat that supports the growth of *Nepenthes*. The existence of many *Nepenthes* in the same habitat provided [a] higher opportunity to find a hybrid species (Clarke 2006).

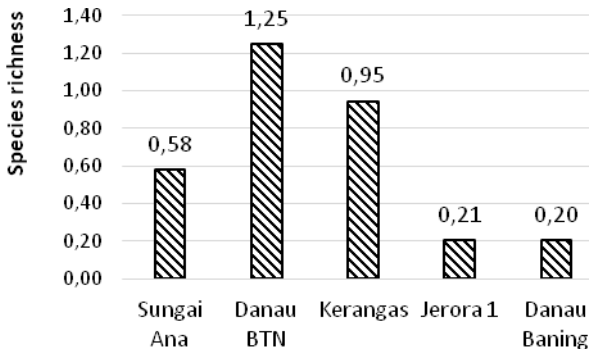

Figure 4. Species richness of *Nepenthes* in the post-mining area

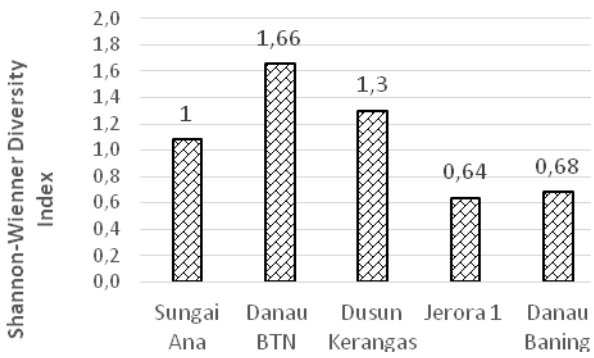

Figure 5. Shannon Wienner diversity index in the post-mining area

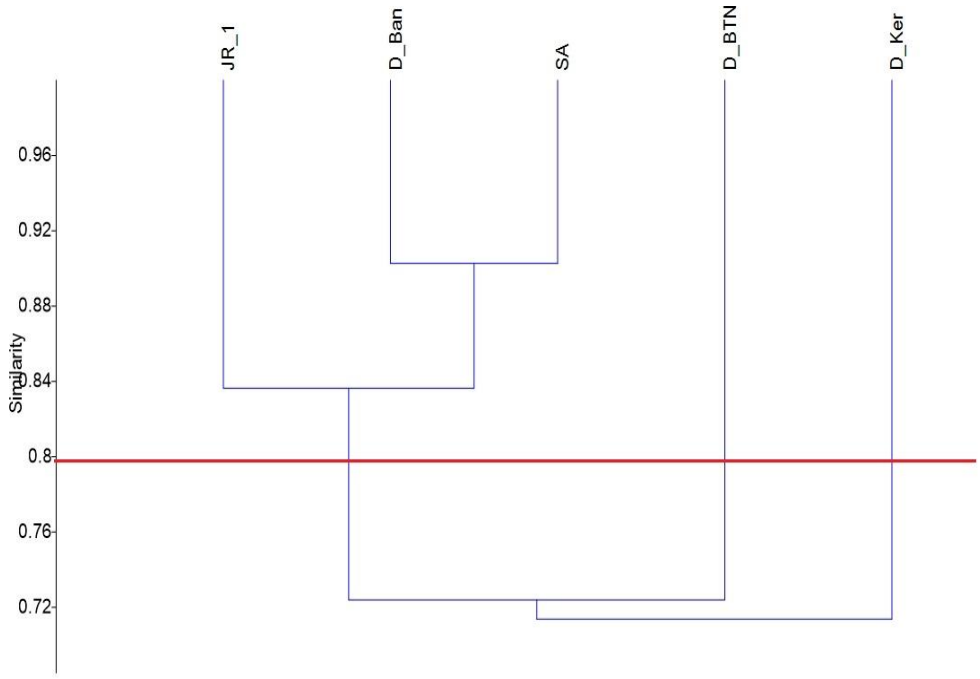

Figure 6. Cluster analysis of Species richness, diversity index, and abiotic factors. Note : JR_1= Jerora 1; D_Ban = Danau Baning; SA = Sungai Ana; D_BTN = Danau BTN; D_Ker = Dusun Kerangas

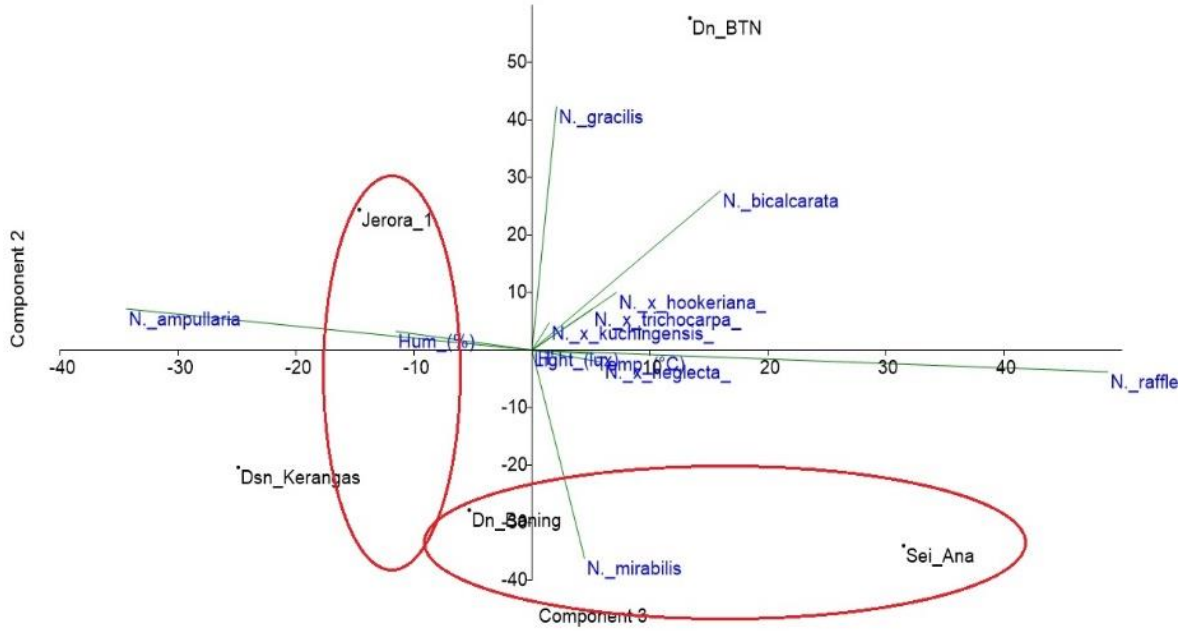

Figure 7. Biplot analysis of Species richness, diversity index, and abiotic factors

In conclusion, *Nepenthes* found in the post-mining area at Sintang Regency consisted of five *Nepenthes* species and four natural hybrids namely *N. ampullaria* Jack., *N. bicalcarata* hook.f., *N. gracilis* Korth., *N. mirabilis* Lour (Druce), *N. rafflesiana* Jack., *N. xhookeriana*, *N. xkuchingensis*, *N. xneglecta*, and *N. xtrichocarpa*. The condition of the post-mining area promoted the *Nepenthes* growth both in open canopy and closed canopy areas. There were 910 individuals of *Nepenthes* found with *N. gracilis* and *N. mirabilis* the top two in individual number (401 and 245 number of individuals, respectively). Species richness showed the number of species found in the

specific location. The highest species richness was found in Danau BTN (1.25), followed by that in Dusun Kerangas (0.95), Sungai Ana Village (0.58), Jerora 1 (0.21) and Danau BTN (0.20). The diversity index in Danau BTN, Dusun Kerangas, Sungai Ana, Jerora 1 and Danau Baning were on a low level, respectively, 1.66, 1.3, 1.0, 0.64, and 0.68. Based on cluster analysis of species richness, H' and abiotic factors, Danau Baning-Sungai Ana-Jerora 1 was grouped in the same cluster while Danau BTN and Dusun Kerangas were in a separate cluster. This means that Danau Baning-Sungai Ana-Jerora 1 had proximity habitat characterized by highly dominant *N. mirabilis* in this areas. Whereas, Danau BTN was characterized by dominant *Nepenthes* hybrid and Dusun Kerangas was characterized by existence of *N. ampullaria.*

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