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Full Length Research Paper

Vegetation composition and diversity of highland peats in Toba Plateau, North Sumatra, Indonesia

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The study was conducted at Humbang Hasundutan of Toba Plateau in North Sumatra, Indonesia to determine the vegetation composition and plant diversity of the highland peat. Four sampling plots of size 100 x 100 m were selected based on landscape usages in the study area and the plots were further divided into 400 subplots each measuring 10 x 10 m. On the basis of habitat characters and human activities, the total sampling area were categorized into five groups, namely flooded area, dried area, mining area, pine forest and agriculture area. All the vegetation under different areas was collected and identified. The vegetations were then grouped into different plant types, trees, shrubs and herbs. They were also classified as native or invasive species according to their severity and invasiveness. Diversity index and evenness of species were determined. The similarity between different sampling areas in respect of species composition was also measured. A total of 60 plant species from 40 families were identified. Dry area contained 55 species from 38 families; flooded area had 24 species from 19 families, while mining area had 10 species from 8 families. 18 species from 16 families were recorded from pine forest and 10 species from 9 families were found in agriculture area. The family Polypodiaceae had the highest number of species consisting of 6 species followed by Asteraceae and Ericaceae with 4 species each. The families Cyperaceae and Euphorbiaceae had 3 species each. The families Araliaceae, Lycopodiaceae, Moraceae, Myrtaceae and Theaceae consist of 2 species, and the other families recorded with only 1 species. 2 species of fern, *Dicranopteris pubigera* (Gleichiniaceae) and *Blechnum indicum* (Blechnaceae) were recorded from all the sampling areas. The highest diversity index was from dry area (2.268) and the lowest was from mining area (0.81). Among the species recorded, invasive weedy species were higher in number (68%) in comparison to native species (32%). Based on modified Morisita's similarity index, the vegetation at Toba highland peat can be divided into two main groups. The first group is composed of dry area and pine forest, which differed from other group (similarity index = 0.058) which includes mining area, agriculture area and flooded area. Within the second group, agriculture area and mining area was very similar with similarity index 0.895. Again these two areas were also closely similar to the flooded area (similarity index = 0.707).

Key words: Shanon-Winner index, Jackknife evenness index, highland peat, plants diversity, cluster analysis; plant composition.

INTRODUCTION

Peat is a type of organic soil which is at least 50 cm deep and contains more than 65% organic matter. It consists of dead and incompletely decomposed plant materials that had been accumulated over thousands of years in waterlogged environments and which lack in oxygen. Consequently, peat lands act as sinks and sources of huge amounts of carbon (Jaenicke et al., 2008). Tropical peat lands are important sources of atmospheric methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O). Recently, large areas of tropical peat land have been developed for agriculture plantations in Southeast Asia (Melling et al., 2005). Biodiversity is another value

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that gives special status to peat land (Page, 2004). In Southeast Asia, peat lands cover more than 26 million hectares (69% of all tropical peat lands), mostly near the coasts of East Sumatra, Kalimantan, West Papua, Papua New Guinea, Brunei, Peninsular Malaya, Sabah, Sarawak and Southeast Thailand (Wosten et al., 2008). Indonesia contains the largest area of tropical peat land in the world. Most of the peats in Indonesia are located in the sub-coastal lowlands of Sumatera (8.3 M ha), Kalimantan (6.8 M ha) and Irian Jaya (4.6 M ha). The highland peat in the Toba plateau of North Sumatera is estimated to cover an area of 2,400 ha (Nasution and Mashhor, 2004). These areas have been disturbed due to the heavy mining of peats for utilization of energy source and eventually these have partly destroyed the peat ecosystem. Conservation and protection of this unique highland peat is critical in order to maintain environmental quality and natural resources of this highland area.

The works on ecology and composition of vegetations in lowland peats are relatively well documented by several peat land ecologists including Rieley et al. (1996), Page (2004) and Mashhor et al. (2004). Due to the limited studies on highland peats, therefore this study was initiated to know the status of vegetation composition and species diversity of highland peat swamp forest at Toba Plateau.

MATERIALS AND METHODS

Study site

This study was conducted at Humbang Hasundutan in Toba Plateau (2° 14´ 05.27´´ N and 98° 53´ 01.40´´ E), North Sumatra, Indonesia during the period from May 2006 to November 2006. Four sampling, sites measuring 100 x 100 m (4 hectare) were selected in experimental site. Each plot was divided into smaller 10 x 10 m subplots on the basis of habitat characteristics and landscape usages. The total sampling areas were categorised into five groups namely: i) flooded area (FA), ii) dried area (DA), iii) mining area (MA), iv) pine forest (PF) and v) agriculture area (AA). All the plant species in the sub-plots were collected following list and quadrat method. The collected species were counted and identified based on Faridah-Hanum and Lepun (2004), Piggott (1988), Whitmore, (1973) and Ng (1989). The vegetation was then grouped into different plant types such as trees, shrubs and herbs. They were also classified as native and invasive species according to severity and invasiveness of the species. All vegetations were analyzed for species diversity and evenness.

Determination of diversity and evenness

The diversity was estimated by Shannon-Wiener formula as shown as follows (Maguran, 1988). Computer analysis was used for multivariate statistical package program (MVSP) in cluster analysis (Anon, 2002):

$$H' = -\sum_{i=1}^{s} \left(Pi \ln Pi \right)$$

Where:

H´ = Shanon' diversity index.
Pi = ni/N = relative abundance of each species.
ni = Number of individuals in a species.
N = Total number of individuals.
S = Total number of species in sample.

Then evenness component of $H´$ were computed as follows (Magurran, 1988):

$$E = \frac{H'}{H'\max} = \frac{H'}{\ln S}$$

$$\hat{S} = s + \left(\frac{n-1}{n} \right) k$$

Where:

$\hat{S}$ = Jackknife estimate of species richness
s = Observed total number of species present in n quadrats
n = Total number of quadrats sampled
k = Number of unique species

RESULTS

Vegetation composition

Sixty plant species belonging to 41 families were recorded within the five sampling areas (Table 1). Dried area had the highest number of species with 55 species from 38 families. Flooded area in the secondary forest had 24 species from 19 families whereas the mining area had 10 species from 8 families. 18 species from 16 families were recorded in the pine forest and 10 species from 9 families were recorded in the agriculture area. The family Polypodiaceae had the highest number of species consisting of 6 species following by Asteraceae and Ericaceae with 4 species each. The families Cyperaceae and Euphorbiaceae had 3 species each. The families Araliaceae, Lycopodiaceae, Moraceae, Myrtaceae and Theaceae consist of 2 species, and the other families recorded with only 1 species. In the flooded area, the families Cyperaceae and Ericaceae were dominant and each family had 3 species. 2 species from the family Araliaceae were recorded at the site. The other families had only 1 species. *Dicranopteris pubigera* was the dominant species at the mining area, and the area was almost covered with high populations of this species. The greater numbers of species found under this area were in families Asteraceae and Ericaceae with 2 species each. The other 5 families recorded with only 1 species.

In case of the pine forest, Asteraceae and Ericaceae were the families with higher number of species (2) and the other families were with 1 species, whereas the agriculture area was dominated by the species, *Blechnum indicum*. 2 species of family Ericaceae were recorded in

Table 1. Plants species recorded at highland peats in Toba Plataeu with their relative distribution in different sampling areas.

Family	Species	S F (Plot 1)	M A (Plot 2)	P F (Plot 3)		A A (Plot 4)	Native/invasive	Tree/shrub/herb
		F A	D A					
Acanthaceae	*Acanthus ilicifolius* (Linn.)	-	+	-	-	-	I	S
Alangiaceae	*Alangium javanicum* (Blume.) Wang	-	+	-	-	-	I	H
Andreaeaceae	*Andreaea* sp.	+	+	-	-	-	I	H
Aquifoliaceae	*Ilex* sp.	+	+	-	-	-	I	S
Aspleniaceae	*Asplenium* sp.	-	-	-	+	-	I	H
Araliaceae	*Arthrophyllum* sp.	+	+	+	+	+	I	S
	Scheflera sp.	+	+	-	-	-	I	S
Asteraceae	*Chromolaena inulifoium* (H.B.K.)	+	+	+	+	-	I	S
	Chromolaena odorata (Linn.) King	-	+	-	+	-	I	S
	Chromolaena paniculatum (Muell.)	-	+	-	-	-	I	S
	Gynura sp.	-	+	+	-	-	I	S
Blechnaceae	*Blechnum indicum* (Burm)f	++	+	-	-	+	I	H
Bromeliacae	*Ananas comosus* (Linn.) Merr.	-	+	-	-	-	N	H
Caprifoliaceae	*Viburnum lutescens* (Blume.).	-	+	-	-	-	N	S
Commelinaceae	*Commelina* sp.	-	+	-	-	-	I	H
Cyperaceae	*Lepironia mucronata* (L.C.) Rich	++	-	-	-	+	I	H
	Scleria novae-hollandiae (Boeck.)	++	-	-	-	-	I	H
	Scleria sumatrensis (Retz.)	+	+	-	-	-	I	H
Ericaceae	*Vaccinium korinchense* (Ridl.)	+	+	+	-	+	N	S
	Vaccinium littoreum (Miq.)	+	+	+	+	+	N	S
	Vaccinium bracteatum (Thunb.)	+	+	-	+	-	N	S
	Gaultheria sp.	-	+	-	-	-	N	S

Table 1. Contd

Euphorbiaceae	*Macaranga* sp.	-	+	-	-	-	I	S
	Mallotus sp.	-	+	-	-	-	I	S
Gleicheniaceae	*Dicranopteris pubigera* (Blume.). Nakai.	+	+	++	+	++	I	H
Hamamelidaceae	*Rhodoleia championii* (Hook.)F	-	+	-	+	-	N	T
Hypolepidaceae	*Pteridium aquilinum* (Linn.) Kuhn	-	+	-	-	-	I	H
Liliaceae	*Dianella ensifolia* (Red.)	+	-	-	-	-	I	H
Loganiaceae	*Fragraia* sp.	+	+	-	+	-	I	S
Lycopodiaceae	*Lycopodium cernum* (Linn.)	-	+	-	-	-	I	H
	Lycopodium phlegmaria (Linn.)	-	+	-	-	-	I	H
Melastomataceae	*Melastoma malabatrichum* (Linn.)	+	+	+	+	+	I	S
Moraceae	*Ficus deltoidea* (Jack)	+	+	-	-	-	N	S
	Ficus sp.	-	+	-	-	-	N	S
Myristicaceae	*Myristica* sp.	-	++	-	-	-	N	T
Myrsinaceae	*Ardisia lurida* (Blume.)	-	+	-	-	-	N	H
Myrtaceae	*Rhodomyrtus tomentosa* (Wight.) DC	+	+	+	+	+	I	S
	Syzygium sp.	-	+	-	-	-	I	S
Nepenthaceae	*Nepenthes gracilis* (Korth.)	+	+	-	-	-	I	H
Orchidaceae	*Eulophia* sp.	-	+	-	-	-	N	H
Passifloraceae	*Passiflora edulis* (Sims.)	-	+	-	+	-	N	S
Phyllanthaceae	*Glochidion* sp.	-	+	-	-	-	N	H
Pinaceae	*Pinus merkusii* (Junghuhn and de Vriese)	-	+	-	++	-	N	T

Table 1. Contd

Poaceae	*Isachne globosa* (Thumb)	+	+	-	-	-	I	H
Polygonaceae	*Polygonum runcinatum* (Holt.)	-	+	-	-	-	I	H
Polypodiaceae	*Polypodium* sp.	-	+	-	-	-	I	H
	Tectaria sp.	-	+	-	-	-	I	H
	Drynaria sparsisora (Desv.) Moore.	-	+	-	-	-	I	H
	Crypsinus stenophyllus (Blume.) Holtt.	-	+	-	-	-	I	H
	Phymatopteris triloba (Houtt) Pichi Serm.	-	+	-	-	-	I	H
	Phymatosorus longissimus (Blume) Pichi Serm.	-	+	-	-	-	I	H
Rubiaceae	*Coffea robusta* (Linn.)	-	+	-	-	-	N	S
Scrophulariaceae	*Scoparia dulcis* (Linn.)	+	+	-	-	-	I	H
Sphagnaceae	*Sphagnum* sp.	++	+	-	-	-	N	H
Theaceae	*Ploiarium alternifolium* (Vahl.)Melcior	-	+	-	-	-	I	S
	Schima walichii (Korth.) DC.	-	+	-	+	-	N	T
Tiliaceae	*Grewia* sp	-	+	-	+	-	I	S
Thelypteridaceae	*Colysis* sp.	-	+	-	-	-	N	H
Verbenaceae	*Lantana indica* (Linn.)	+	+	+	+	+	I	S
Xyridaceae	*Xyris indica* (Linn.)	+	-	+	+	+	I	H

(-): absence. (+): present. (++): dominant. SF = secondary forest, FA = flooded area, DA = dried area, MA = mining area, PF = pine forest and AA = agriculture area. N = native, I = invasive, T = tree, S = shrub and H = herb.

this area and the rest of the families were with 1 species only.

Species diversity and evenness

The highest diversity index was in the flooded area (2.17) followed by the dried area (2.16) and the lowest diversity index (0.81) was in the mining area. The highest evenness index was in pine forest (0.70) with 18 species followed by flooded area (0.68) with 24 species and the lowest evenness index was in mining area (0.35) with 10 species (Table 2). The agriculture area was characterized by medium value of diversity index (1.22) and evenness (0.53) with 10 species. Species richness that is the number of species in a community, of these sampling areas was high with the value of 85.6 and the standard deviation of species richness was 22.65. The number of unique species or the species found, only one from

Table 2. Diversity and evenness indices of plant species in the sampling area of highland peat in Toba plateau.

Sampling area	Index	Evenness	Number of species
Flooded area	2.17	0.68	24
Dried area	2.16	0.54	55
Mining area	0.81	0.35	10
Pine forest	2.03	0.70	18
Agriculture area	1.22	0.53	10

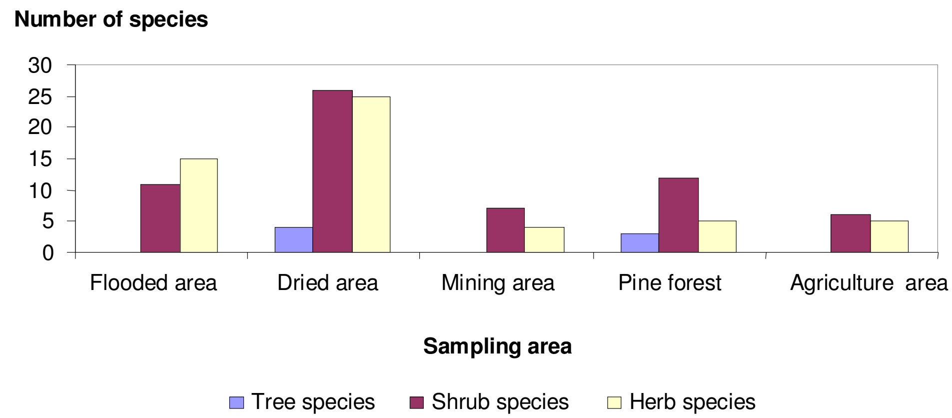

Figure 1. Distribution of vegetation types in different sampling areas of highland peat in Toba Plateau.

the sampling areas was 32.

Vegetation distribution

Vegetation at highland peat on Toba Plateau was dominated by shrubs in almost every sampling area, followed by herbs. Whereas tree species were only recorded at 2 sampling plots, dried and pine forest areas and were not recorded in other areas (Figure 1).

Species of commercial value

Five plants of commercial value namely: *Ananas comusus*, *Coffea robusta*, *Pinus merkusii, Ficus deltoidea* and *Vaccinium korinchense* were recorded in the study area. *F. deltoidea* and *V. korinchense* were found at four sampling plots of flooded area, dried area, pine forest and agriculture area. Endemic species *P. merkusii* populations were recorded at dried area in secondary forest and in pine forest. Whereas *A. comusus*, *C. robusta* and *P. merkusii* only were found at dried area. *A. commusus* and *C. robusta* are cultivated by local farmers. However, *P. merkusii*, *F. deltoidea* and *V. korinchense* grow naturally at the Toba plateau. The government of Humbang Hasundutan has encouraged the local community to cultivate the *P. merkusii* since resin in Indonesia is extracted from this plant.

Native and invasive/weed plant

Generally invasive species emerge after an area is cleared by local people. *D. pubigera* is an invasive species and was found at every sampling area. It was dominant in dried area. But in the mining and agriculture areas, the invasive species was higher in number, about four times than the native species (Table 3, Figure 2).

Cluster analysis

The results of cluster analysis of all the vegetations of sampling plots are shown in Figure 3. Two distinct groups were identified using the UPGMA (unweighted pair group method with arithmetic mean) dendogram based on modified Morisita's similarity index, as the secondary forest area (dried area and pine forest) and the disturbed area (flooded area, agriculture area and mining area). The results in Table 4 show that the dried area and pine forest are clustered together with similarity index of

Table 3. The number of native and invasive species found at highland peat in Toba Plateau.

Sampling plot	Native	Invasive
Flooded area	5	19
Dried area	18	37
Mining area	2	8
Pine forest	5	13
Agriculture area	2	8

Figure 2. The native and invasive species composition at highland peat in Toba Plateau.

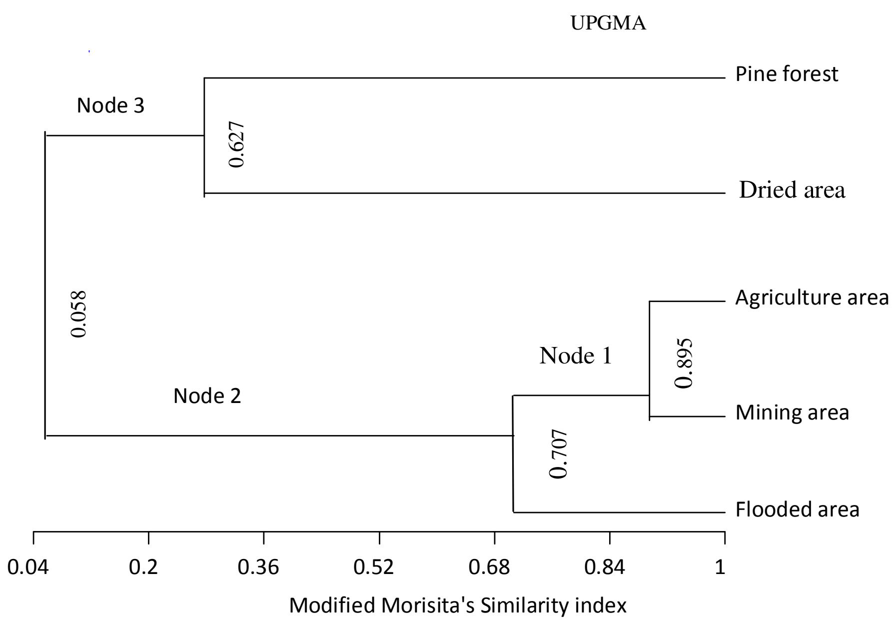

Figure 3. Cluster diagram of sampling areas of highland peat in Toba Plateau.

0.677, which was dominated by shrubs and trees, whereas the second groups consisting of agriculture area, mining area and flooded area was dominated by grasses and shrubs. The highest similarity index was noted between agriculture area and mining area (0.895). It means that both of these areas are almost similar in respect of their vegetation and these areas were dominated by weedy species. The flooded area was also

Table 4. Analysis of relationship between sampling plots in respect of vegetation composition based on modified Morisita's similarity index.

Node	Group 1	Group 2	Similarity	Object in group
1	Mining area	Agriculture area	0.895	2
2	Flooded area	Node 1	0.707	3
3	Dried area	Pine forest	0.677	2
4	Node 2	Node 3	0.058	5

almost similar to both of the areas (node 1) with similarity index of 0.707. However, the similarity index between nodes 2 and 3 is very low, 0.058; which indicates that the species of these groups are very different (Figure 3).

DISCUSSION

Species diversity is a result of many factors including ecological factors and human activities. In this study, effects of both factors are very distinct. The ecology of pine forest, dried area, flooded area, mining area and agriculture area are different from each other. The results indicate that the species within pine forest was evenly distributed compared to the other sites. On the other hand, the species were not evenly distributed in the mining area. It is to be noted that the species with more evenness are considered to have greater species diversity. Mining area and agriculture area are under human disturbances which caused more diverse species to grow. Gunawan et al. (2007) noted the diversity index in the peat swamp of Riau, Sumatra ranging from 2.2 to 2.9 and evenness from 0.53 to 0.64. However, this study showed different values. Asyraf and Mashhor (2002) stated that vegetation composition of disturbed peat swamps can be based on several criteria as human disturbances (for example, establishment of industries and housing areas extension), expansion of agriculture areas, plant succession and the development of secondary forest. On the basis of these criteria, the flooded area, mining area and agriculture area are regarded as disturbed peat swamps. The reason for dominance of shrubs in the secondary forest (flooded and dried area) might be due to high intensity of sunlight which influenced the shrub growth when the forest canopy was opened. Since the amount of space occupied by the trunks, branches, twigs and leaves of the trees at different levels determines the internal microclimates and the energy available for the other organisms (Richards, 1983), perhaps the whole system of food web on peat land ecosystem was destructed due to the landscape disturbances. Setiadi et al. (2007) observed main plant species as ramin (*Gonystylus* spp), jelutung (*Dyera costulata*), kempas (*Koompassia malaccensis*), ketiau (*Ganua motleyana*), and nyatoh (*Dishopsis elliptica*) in the lowland tropical peat forest in Central Kalimantan. These species are rare and protected plants.

In this study, the plants consisted primarily of small ericaceous shrubs (for example *Vaccinium libtoreum*), ferns (for example *Blechnum indicum*), and grasses (for example *Isachne globosa*), sedges (for example *Scleria sumatrensis*) and mosses (for example *Sphagnum* sp). Among the factors that affected the biodiversity, mining activities were the main factor which destroyed the peat land forest ecosystems at Toba Plateau and changed the vegetation diversities. The opening of peat swamp forest resulted in increasing of weedy species such as grasses and shrubs. These pioneer species are tolerant to the direct sunlight and the species grew very fast. The result from clustering analysis (Figure 3) based on modified Morisita's similarity index showed that the sampling areas can be divided into two groups. The first group was with dried areas and a pine forest and the second group was consisted of mining area, agriculture area and flooded area. In the first group, shrub and tree species were dominant vegetation, whereas the second group was disturbed areas, with herbs and shrubs as dominant vegetation. Therefore, the differences between these groups are more inclined toward human activities especially in land use utilization. When compared between plants of flooded areas and the dried areas, differences in availability of tree species were detected. It is because of the fact that each plant has a limited tolerant space to their habitat requirement.

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