Floristic and Forest Structural Study in Batangtoru Watershed, North Sumatra (Studi Floristik dan Struktur Hutan di Daerah Aliran Sungai Batangtoru, Sumatera Utara)

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ABSTRACT

A Forest ecology research has been done in Batangtoru watershed, North Sumatra to determine the species composition and vegetation structure. The study was conducted by using plots in four locations: Purnama, Gerhana, Kejora, and Teluk Nauli. A total of 387 species in 184 genera and 77 families were found. The species richness of trees (dbh >10 cm) was 192 species in 116 genera and 55 families, the richness of saplings (dbh 2 - 10 cm) was 211 species in 111 genera and 55 families, while the richness of seedlings (dbh <2 cm) was 153 species in 95 genera and 50 families. Tree density ranged from 850–1,700 individuals/ ha, while basal area was around 66.76 to 104.54 m^2/ha. The forest canopy at Purnama and Gerhana plots was relatively similar, forming three layers, while the Kejora and Teluk Nauli plots were simpler with only two canopy layers. Based on a principal components analysis of tree species, the forests in the research area tended to form three community types: 1) forest dominated by Pentaphylacaceae, 2) mixed dipterocarp forest, and 3) 'forest garden', or natural forest communities enriched with a variety of economically valuable forest tree species and therefore classified as an agroforestry system.

Keywords : Floristic, structure, forest community type, Batangtoru watershed, North Sumatra

ABSTRAK

Sebuah penelitian ekologi hutan telah dilakukan di Daerah Aliran Sungai Batang Toru DAS-Sumatera Utara untuk menentukan komposisi jenis dan struktur vegetasi. Penelitian dilakukan dengan menggunakan metoda petak di empat lokasi yaitu Purnama, Gerhana, Kejora dan Teluk Nauli. Total ditemukan 387 jenis, 184 marga dan 77 suku. Kekayaan jenis pohon (dbh $\geq$ 10 cm) 192 jenis, 116 marga dan 55 suku, tingkat belta (diameter batang 2 - $\leq$ 10 cm) 211 jenis, 111 marga dan 55 suku, sedangkan tingkat semai (tumbuhan bawah dan anakan pohon berdiameter < 2 cm) 153 jenis, 95 marga dan 50 suku. Kerapatan pohon berkisar antara 850 – 1700 individu/ha, sedangkan luas bidang dasarnya 66,76 – 104,54 m^2/ha. Lapisan kanopi di Petak Gerhana dan Purnama relatif sama yaitu cenderung membentuk 3 lapisan, sedangkan petak Kejora dan Teluk Nauli lebih sederhana yang hanya membentuk 2 lapis tajuk. Berdasarkan kehadiran jenis pohonnya yang dianalisis menggunakan PCA, hutan di lokasi penelitian cenderung membentuk tiga tipe komunitas, yaitu: a) Komunitas hutan yang didominasi oleh suku Pentaphylacaceae; b) Hutan Dipterokarpa campuran dan c) 'kebun hutan'. Komunitas 'kebun hutan' merupakan komunitas hutan alam yang diperkaya dengan berbagai jenis pohon hutan bernilai ekonomi yang dikategorikan sebagai sistem *agroforest*.

Kata Kunci : Floristik, struktur, tipe komunitas hutan, DAS Batangtoru, Sumatera Utara

INTRODUCTION

Since the issuance of commercial logging permits in the early 1970s, forest area in Indonesia has been decreasing dramatically. Data from the Ministry of Forestry (2012), based on interpretation of satellite images (Landsat 7 ETM + 2009/2010), show that primary forests in Indonesia now cover only 46.56 million hectares out of a total of 98.56 million hectares of forests in Indonesia. The rest is a mixture of formerly logged areas and timber concessions. Borneo and Sumatra have had the most widespread deforestation. From 2009-2013, Sumatra lost 1,530,156.03 ha or 12.12% of the area of natural forest cover in 2013, while Kalimantan lost 1,541,693.36 ha or 11.99% of forest cover nature in 2013 (Forest Watch Indonesia 2014). The forests of Sumatra and Kalimantan are included in the 11 regions in the world that will contribute more than 80% of global deforestation by 2030 (BBC Indonesia 2015).

One of the non-conservation forest areas that still has relatively intact forest canopy cover is in Batangtoru watershed area, situated between the three districts of South Tapanuli, Central Tapanuli, and North Tapanuli in North Sumatra. This region provides habitat for the Sumatran tiger and the Sumatran orangutan

(Holden & Priatna 2003; Wich & Geurts 2003). Most of the forest area is claimed by the local community as indigenous forest. The region also has gold deposits, resulting in mining activity. Given its important role in the preservation of the habitat of rare fauna and other ecological functions, there has been dialogue about making this forest a protected area. To assign more definitive status to the region, basic ecological data on the flora and fauna are urgently needed. Some researches has been done in this area on the existence and availability of food for tigers and orangutans (Holden & Priatna 2003; Wich & Geurts 2003). The study herein of the flora assesses the taxonomy and diversity of the flora (Takeuchi 2004; Rachman 2006). Information on the ecology of the forest in this region is still very limited. This study aimed to complement existing information on the condition of forests in the watershed of the Batangtoru River, especially regarding floristic and vegetation structure. The expected results of the study were to provide a more complete picture of the condition of forests in the watershed of the Batangtoru for the benefit of future land use planning.

MATERIALS AND METHODS

The study was conducted in the Batangtoru watershed forest area in South Tapanuli Regency and Central Tapanuli Regency, North Sumatra Province. Based on elevation, the forest in this region is a mixture of lowland forests and transitions between lowland forest and lower montane forest. The four locations in which our sampling occurred (Figure 1) were:

Purnama (01^0 30 '10.0 "N, 99^0 04' 33.4" E). Located at an altitude of 100-395 m above sea level, an old secondary lowland forest bordering orange orchards and rubber trees, run by Napa (Batak) villagers.

Gerhana (01^0 33 '04.6 "N, 99^0 04' 33.4" E). Located at an altitude of 520-580 m above sea level at Beringin village (Nias tribe). Forest conditions are relatively good and this is classified as primary forest.

Kejora (01^0 32 '15.4 "N, 99^0 04' 04.4" E). Located at an altitude of 800-805 m above sea level, a primary forest on a small hill between Purnama and Gerhana.

Teluk Nauli (01^0 41 '13.4" N, 99^0 02' 27.4" E). Located at an altitude of 800-805 m above sea level. Administratively, Teluk Nauli plot was in Anggoli Village, Subdistrict of Lumut, Central Tapanuli Regency. The forests could be classified as primary forest which has been logged. Administratively, Purnama, Gerhana, and Kejora plots were in Napa Village, Subdistrict of Batangtoru, South Tapanuli Regency.

Sampling was done using plots. Plot sizes at Purnama, Gerhana, Kejora, and Teluk Nauli were 2800 m^2, 1200 m^2, 400 m^2, and 400 m^2, respectively. Purnama and Gerhana were the main plots in the study. The Kejora and Teluk Nauli plots were intended to complement the other plots by providing information from the top of a small hill (Kejora) and in a former logging site (Teluk Nauli). Each plot was divided into sub-plots measuring 10 m x 10 m for the enumeration of trees that had trunk diameter at breast height (dbh) $\geq$ 10 cm. On each subplot 10 m x 10 m, we also established smaller plots measuring 5 m x 5 m to measure saplings, which had a trunk diameter of 2 - <10 cm. On each subplot 5 m x 5 m, we also made smaller plots measuring 1 m x 1 m to measure seedlings (undergrowth and small woody plants having trunk diameter <2 cm). Data collected included: species name, number of individuals,

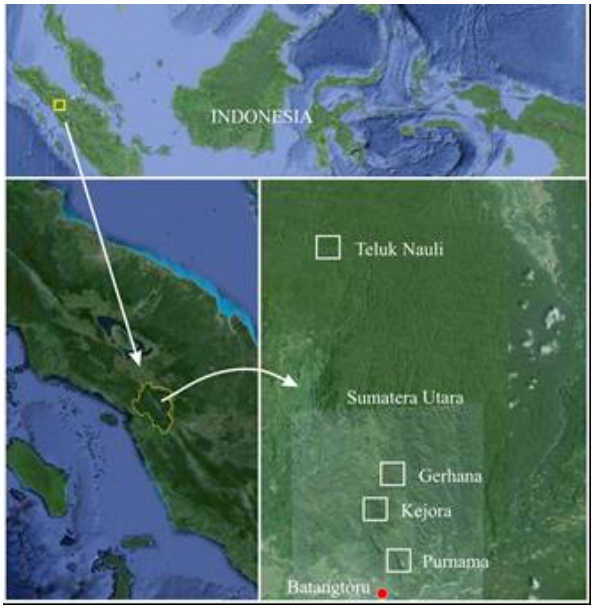

Figure 1. Map of Research Location in Batangtoru Watershed Area, North Sumatra.

canopy height, bole height, dbh of trees, and stem diameter at a height of 50 cm above the ground for saplings. Buttressed trunk diameter measurements were made at a height of 20 cm above buttresses. Data collected for the seedlings was limited to the name of the species and number of individuals. Voucher specimen was taken for identification purposes in Herbarium Bogoriense, Research Center for Biology LIPI in Cibinong. The data were analyzed to determine the frequency, density, dominance, and importance of each species and family (Greigh Smith 1964). At the community level, we performed a Principles Component Analysis (PCA) using the program PAST (paleontological Statistics) version 3:04 (Hammer 2014).

RESULTS

Floristic

The total of all plants (excluding epiphytes) that could be identified from our four study locations included 387 species belonging to 184 genera and 77 families. The species richness of trees was 192 species in 116 genera and 55 families. The richness of saplings was 211 species in 111 genera and 55 families, while the richness of seedlings was 153 species in 95 genera and 50 families. The data did not include unidentified species consisting of 81 and 90 voucher specimens of trees and saplings, respectively.

Purnama:

The number of tree species was 155 in 80 genera and 40 families. The density of trees was 1,082 individuals/ha, with a basal area of 66.76 m^2/ha (Table 1). Based on Family Importance Values (FIV), Malvaceae was the dominant family in this plot (FIV=24.22), containing four species with a density of 39 individuals/ha and basal area of 8.90 m^2/ha (Table 2). Malvaceae was mainly represented by *Durio oxleyanus* Griff which had a density of four individuals/ha and a basal area of 6.32 m^2/ha (Table 3). Other important families were Moraceae (FIV= 23.07) and Sapindaceae (FIV=19.55) (Table 2). Moraceae contained eight species with a density of 82 individuals/ha and a basal area of 4.05 m^2/ha. Moraceae was mainly represented by *Artocarpus elasticus* Reinw. ex Blume, which had a density of 29 individuals/ ha with a basal area of 1.96 m^2/ha (Table 3). Sapindaceae contained five species, with a density of 79 individuals/ha and a basal area of 3.73 m^2/ha (Table 2). Sapindaceae was mainly represented by *Nephelium lappaceum* L. which had a density of 43 individuals/ha with a basal area of 2.02 m^2/ha (Table 3). *D. oxleyanus, A. elasticus*, and *N. lappaceum* were also included as three of five main species based on Species Important Value (SIV) in Purnama

Table 1. Floristic data in each plots

	Purnama	Kejora	Gerhana	Teluk Nauli
Tree (dbh ≥ 10 cm)				
No. of species	155	41	65	42
No. of genus	80	19	43	22
No. of family	40	19	27	18
No. of individuals / ha	1082	1300	850	1700
Basal areas (m^2/ha)	66.76	72.48	104.54	90.94
Saplings (2cm ≤diameter<10cm)				
No. of species	204	23	68	53
No. of genus	93	13	44	28
No. of family	47	11	29	23
No. of individuals / ha	5386	3400	3200	8600
Basal areas (m^2/ha)	7.54	3.98	5.06	10.64
Seedlings (diameter <2cm)				
No. of species	90	20	58	24
No. of genus	60	19	44	20
No. of family	30	15	35	18
No. of individuals / 100 m^2	553	575	700	750

Table 2. Number of species, basal area, number of trees and Family Importance Value in each plots.

Family	Purnama				Kejora				Gerhana				Teluk Nauli			
	S	Ba	I	FIV	S	Ba	I	FIV	S	Ba	I	FIV	S	Ba	I	FIV
Anacardiaceae	4	2.1	25	9.97	2	5.23	100	31.32	4	12.25	58	26.74	1	2.86	25	10.54
Apocynaceae	1	0.06	4	1.34	-	-	-	-	1	1.65	17	5.58	-	-	-	-
Burseraceae	4	0.48	18	6.18	1	3.46	50	17.41	2	1.50	33	9.39	-	-	-	-
Calophyllaceae	1	0.1	4	1.41	-	-	-	-	1	0.39	17	4.34	-	-	-	-
Centroplacaceae	1	0.03	4	1.28	1	2.66	25	12.72	-	-	-	-	-	-	-	-
Chrysobalanaceae	-	-	-	-	1	0.24	25	7.70	2	1.03	25	7.84	-	-	-	-
Clusiaceae	6	1.59	43	12.61	2	4.16	75	26.06	1	5.61	8	8.36	-	-	-	-
Combretaceae	1	0.29	7	2.15	-	-	-	-	1	2.27	8	5.09	-	-	-	-
Dipterocarpaceae	7	3.64	46	17.67	2	12.1	125	48.70	4	18.49	92	37.20	-	-	-	-
Ebenaceae	2	0.26	11	3.32	1	0.25	25	7.72	1	0.11	8	2.98	-	-	-	-
Euphorbiaceae	3	1.36	18	6.98	1	0.67	25	8.59	2	1.08	42	10.06	-	-	-	-
Fagaceae	1	0.25	7	2.07	-	-	-	-	-	-	-	-	1	1.74	25	8.85
Ixonanthaceae	2	0.72	11	4.18	1	0.66	25	8.57	-	-	-	-	-	-	-	-
Lamiaceae	6	3.70	64	18.83	-	-	-	-	1	0.09	8	2.96	-	-	-	-
Lauraceae	-	-	-	-	-	-	-	-	1	0.09	8	2.96	2	7.13	100	27.30
Leguminosae	6	3.08	61	17.29	-	-	-	-	1	2.54	8	5.36	-	-	-	-
Malvaceae	4	8.90	39	24.22	-	-	-	-	2	1.81	17	7.52	-	-	-	-
Melastomataceae	1	0.27	18	3.25	1	4.27	50	19.10	1	1.46	8	4.30	1	1.19	75	12.09
Meliaceae	1	0.05	4	1.32	-	-	-	-	2	0.83	33	8.73	-	-	-	-
Moraceae	8	4.05	82	23.07	-	-	-	-	2	0.35	17	6.09	1	0.54	25	7.03
Myristicaceae	3	0.75	29	6.98	1	0.42	25	8.07	-	-	-	-	-	-	-	-
Myrtaceae	8	2.20	46	15.82	3	2.05	75	25.85	11	9.72	125	45.46	2	2.14	100	19.74
Ochnaceae	-	-	-	-	1	0.37	25	7.97	2	0.61	25	7.43	1	0.37	25	6.77
Oleaceae	-	-	-	-	1	0.81	25	8.88	1	17.89	50	25.82	-	-	-	-
Pentaphylacaceae	4	3.05	25	11.75	1	0.28	25	7.78	-	-	-	-	2	**20.5**	200	55.67
Phyllanthaceae	7	2.42	86	19.55	-	-	-	-	3	0.37	25	8.98	-	-	-	-
Polygalaceae	2	0.23	7	2.88	-	-	-	-	1	2.92	8	5.73	-	-	-	-
Rhizophoraceae	-	-	-	-	1	0.33	25	7.88	-	-	-	-	1	0.32	25	6.69
Rubiaceae	2	0.14	14	3.47	-	-	-	-	-	-	-	-	1	0.25	25	6.59
Rutaceae	3	0.77	14	5.50	-	-	-	-	2	1.57	17	7.28	-	-	-	-
Sapindaceae	5	3.73	79	19.55	-	-	-	-	1	1.72	8	4.56	-	-	-	-
Sapotaceae	6	2.86	29	13.47	1	1.07	25	9.42	4	6.52	75	23.31	3	11.00	175	43.46
Stemonuraceae	2	0.23	7	2.88	1	2.35	50	15.11	-	-	-	-	-	-	-	-

Notes: S=Number of species; Ba=Basal area m^2 per ha; I=Number of trees per ha; FIV=Family Importance Value. Only families which were found in at least two research sites (33 families). The other 22 families, found only one research site, were not listed.

plot, having SIVs of 10.21, 8.46, and 9.87, respectively. Two other main species were *Styrax benzoin* Dryand (SIV=12.23) and *Persea declinata* (Blume) Kosterm (SIV=9.65) (Table 3).

At the sapling level, we recorded 204 species in 93 genera and 47 families, with a density of 5,386 individuals/ha and a basal area of 7.54 m^2/ha (Table 1). Four of the main tree species, *D. oxleyanus, A. elasticus, N. lappaceum,* and *P. declinata,* could also be found as saplings, but were not included as the five main species based on species importance value (SIV). Five main sapling species based on SIV were *Baccaurea sumatrana* (Miq.) Müll.Arg., *Pternandra caerulescens* Jack, *Mallotus peltatus* (Geiseler) Müll.Arg., *Shorea ovata* Dyer ex Brandis, and *Microcos florida* Burret (Table 4). Saplings of *S. benzoin* were not found, but seedlings of the species were. Of the five major tree species, only *S. benzoin* and *P. declinata* had regenerated as seedlings, with a density of four individuals/100 m^2 each. The most abundant seedlings were *B. sumatrana, Nephelium rubescens* Hiern., and *Psychotria robusta* Blume, which had a density of 29 seedlings/100m^2 each (Table 5). The total number of species found as seedlings was 90, belonging to 60 genera and 30 families (Table 1).

Kejora:

The tree species richness in Kejora plot was 41, in 19 genera and 19 families. The density of trees was 1,300 individuals/ha, with a basal area of 72.48 m^2/ha (Table 1). Dipterocarpaceae was the main family in the Kejora plot (FIV= 48.70) with a density of 125 individuals/ha and a basal area of 12.14 m^2/ ha. Other families which were also important in this plot were Anacardiaceae (FIV=31.32) and Clusiaceae (FIV=26.06) (Table 2). Dipterocarpaceae was represented by two species, *Shorea* sp. and *Shorea ovata* Dyer ex Brandis, which

Table 3. Five top dominant species of trees (dbh ≥ 10 cm) based on species importance values (SIV) in each plots

No.	Species	Family	Basal Area (m^2/ha)	Density (ind/ha)	SIV
PURNAMA					
1	*Styrax benzoin* Dryand	Styracaceae	3.11	46	12.23
2	*Durio oxleyanus* Griff	Malvaceae	6.32	4	10.21
3	*Nephelium lappaceum* L.	Sapindaceae	2.02	43	9.87
4	*Persea declinata* (Blume) Kosterm.	Lamiaceae	1.82	39	9.65
5	*Artocarpus elasticus* Reinw. ex Blume	Moraceae	1.96	29	8.46
KEJORA					
1	*Shorea* sp.	Dipterocarpaceae	7.31	50	18.01
2	*Shorea ovata* Dyer ex Brandis	Dipterocarpaceae	4.83	75	16.51
3	*Swintonia schwenckii* Teijsm. & Binn. ex Hook.f.	Anacardiaceae	3.12	75	16.20
4	*Agathis borneensis* Warb.	Araucariaceae	6.73	25	13.24
5	*Calophyllum inophyllum* L.	Clusiaceae	3.68	50	13.01
GERHANA					
1	*Chionanthus montanus* Blume	Oleaceae	17.89	50	26.41
2	*Shorea falcifera* Dyer ex Brandis	Dipterocarpaceae	12.34	42	20.11
3	*Hydnocarpus polypetalus* (Slooten) Sleumer	Flacourtiaceae	9.17	17	13.00
4	*Gluta renghas* L.	Anacardiaceae	4.58	34	11.71
5	*Hopea mengarawan* Miq.	Dipterocarpaceae	3.55	25	9.75
TELUK NAULI					
1	*Adinandra dumosa* Jack	Pentaphylacaceae	11.92	175	29.07
2	*Schima wallichii* Choisy	Theaceae	9.78	175	26.71
3	*Palaquium* sp.	Sapotaceae	8.67	100	17.31
4	Sp6.	-	11.25	25	15.73
5	*Litsea* sp.	Lauraceae	6.83	75	15.69

Table 4. Five top dominant species of saplings (diameter 2 - < 10 cm) based on species importance values (SIV) in each plots

No.	Species	Family	Basal Area (m^2/ha)	Density (ind/ha)	SIV
PURNAMA					
1	*Baccaurea sumatrana* (Miq.) Müll.Arg.	Phyllanthaceae	0.31	200	11.05
2	*Pternandra caerulescens* Jack	Melastomataceae	0.24	157	8.57
3	*Mallotus peltatus* (Geiseler) Müll.Arg.	Euphorbiaceae	0.25	157	8.15
4	*Shorea ovata* Dyer ex Brandis	Dipterocarpaceae	0.27	114	6.93
5	*Microcos florida* Burret	Malvaceae	0.24	129	6.46
KEJORA					
1	*Palaquium hexandrum* (Griff.) Baill.	Sapotaceae	0.47	700	43.88
2	*Memecylon edule* Roxb.	Melastomataceae	0.76	100	25.99
3	Sp 5	-	0.58	100	21.25
4	*Santiria griffithii* Engl.	Burseraceae	0.16	300	20.42
5	*Nephelium rubescens* Hiern	Sapindaceae	0.20	300	17.69
GERHANA					
1	*Hancea penangensis* (Müll.Arg.) S.E.C.Sierra, Kulju & Welzen	Euphorbiaceae	0.50	267	24.02
2	*Hancea stipularis* (Airy Shaw) S.E.C.Sierra, Kulju & Welzen	Euphorbiaceae	0.50	234	22.83
3	*Pouteria oxyedra* (Miq.) Baehni	Sapotaceae	0.30	100	12.52
4	*Chionanthus nitens* Koord. & Valeton	Oleaceae	0.14	134	9.15
5	*Rinorea anguifera* Kuntze	Violaceae	0.28	67	8.70
TELUK NAULI					
1	*Memecylon edule* Roxb.	Melastomataceae	1.06	600	20.21
2	*Garcinia rostrata* (Hassk.) Miq.	Clusiaceae	0.50	500	13.75
3	*Meliosma nitida* Blume	Sabiaceae	0.75	200	10.98
4	*Palaquium ridleyi* King & Gamble	Sapotaceae	0.41	300	10.52
5	*Baccaurea pubera* (Miq.) Müll.Arg.	Phyllanthaceae	0.48	200	10.05

Table 5. Five top dominant species of seedlings (diameter < 2 cm) based on density in each plots.

No.	Species	Family	Density (ind/100m^2)
Purnama			
1	*Baccaurea sumatrana* (Miq.) Müll.Arg.	Phyllanthaceae	29
2	*Nephelium rubescens* Hiern	Sapindaceae	29
3	*Psychotria robusta* Blume	Rubiaceae	29
4	*Canarium littorale* Blume	Burseraceae	25
5	*Santiria apiculata* A.W.Benn.	Burseraceae	21
Kejora			
1	*Dryobalanops sumatrensis* (J.F.Gmel.) Kosterm	Dipterocarpaceae	50
2	*Syzygium* sp	Myrtaceae	50
3	*Nephelium rubescens* Hiern	Sapindaceae	50
4	*Saurauia* sp	Actinidiaceae	25
5	*Swintonia schwenckii* Teijsm. & Binn. ex Hook.f.	Anacardiaceae	25
Gerhana			
1	*Rinorea anguifera* Kuntze	Violaceae	50
2	*Nephelium mutabile* Blume	Sapindaceae	33
3	*Scaphium macropodum* (Miq.) Beumée ex K.Heyne	Malvaceae	33
4	*Santiria apiculata* A.W.Benn.	Burseraceae	25
5	*Shorea* sp.	Dipterocarpaceae	25
Teluk Nauli			
1	*Symplocos odoratissima* Choisy ex Zoll.	Symplocaceae	50
2	*Gymnostoma sumatranum* (Jungh. ex de Vriese) L.A.S.Johnson	Casuarinaceae	50
3	*Diospyros buxifolia* (Blume) Hiern	Ebenaceae	50
4	*Elaeocarpus petiolatus* (Jacq.) Wall.	Elaeocarpaceae	50
5	*Symplocos odoratissima* Choisy ex Zoll.	Symplocaceae	50

had the highest SIVs of 18.01 and 16.51, respectively, with a number of individuals of 50 and 75 trees/ha and basal area of 7.31 and 4.83 m^2/ha, respectively. Other species which were also important in the Kejora plot were *Swintonia schwenckii* Teijsm. & Binn. ex Hook.f., *Agathis borneensis* Warb., and *Calophyllum inophyllum* L. (Table 3).

At the sapling level, 41 species were found belonging to 19 genera and 19 families (Table 1). The main tree species were not found as saplings. Five main sapling species were *Palaquium hexandrum* (Griff.) Baill. (SIV=43.88), *Memecylon edule* Roxb (SIV=25.99), Unidentified - Sp.5 (SIV=21.25), *Santiria griffithii* Engl. (SIV=20.42), and *Nephelium rubescens* Hiern (SIV=17.69) (Table 4). The only important tree species found in the seedling stage were *Shorea* sp., *S. schwenckii*, and *A. borneensis*. The most abundant species of seedlings were *Dryobalanops sumatrensis* (J.F.Gmel.) Kosterm, *Syzygium* sp., and *Nephelium rubescens* Hiern (Table 5). The total species richness of seedlings in the Kejora plot was 20 in 19 genera and 15 families, with a density of 575 seedlings/100 m^2 (Table 1).

Gerhana:

Tree species richness in the Gerhana plot was 65 species in 44 genera and 28 families. Tree density was lower than in the other plots, at 850 individuals/ha, but the tree basal area was 104.5 m^2/ha which was more than in the other plots (Table 1). The main families by family importance value (FIV) in this plot were Myrtaceae, Dipterocarpaceae, and Anacardiaceae (Table 2). Myrtaceae had 11 species, where the most abundant species was *Syzygium suringarianum* (Koord. & Valeton) Amshoff (25 individuals/ ha). Dipterocarpaceae had four species, mainly represented by *Shorea falcifera* Dyer ex Brandis with a density of 42 individuals/ha and a basal area of 12.34 m^2/ ha and *Hopea mengarawan* Miq. with a density of 25 individuals/ha and a basal area of 3.55 m^2/ha. Anacardiaceae was also represented by four species and the most abundant was *Gluta renghas* L. with a density of 33 individuals/ha and a basal area of 4.58 m^2/ ha. *S. falcifera* (SIV=20.11), *H. mengarawan* (SIV=9.75), and *G. renghas* (SIV=11.71) were three of the five main species based on species

importance values in the Gerhana plot. Two other main species were *Chionanthus montanus* Blume (SIV=26.41) and *Hydnocarpus polypetalus* (Slooten) Sleumer (SIV=13.00) (Table 3).

Of the five major species at the tree level, only *C. montanus* and *H. mangarawan* were found as saplings. Five main sapling species, based on species importance values, were *Hancea penangensis* (Müll.Arg.) SEC Sierra, Kulju & Welzen (SIV=24.02), *Hancea stipularis* (Airy Shaw) SEC Sierra, Kulju & Welzen (SIV=22. 83), *Pouteria oxyedra* (Miq.) Baehni (SIV=12.52), *Chionanthus nitens* Koord. & Valeton (SIV=9.15), and *Rhinorrhea anguifera* Kuntze (SIV=8.70) (Table 4). The total number of sapling species recorded was 68 in 44 genera and 29 families (Table 1). Seedling species richness was 58 species in 44 genera and 35 families. Five main tree species were not found in the seedling stage. However, there were seedlings of *Chionanthus* sp. and *Shorea* sp. that could not be identified to species level. The most abundant seedling species were *Rhinorrhea anguifera* Kuntze (50 individuals / 100 m2) followed by *Nephelium mutabile* Blume and *Scaphium macropodum* (Miq.) Beumée ex K.Heyne, each of which had a density of 33 individuals / 100m^2 (Table 5).

Teluk Nauli:

Tree species richness in the Teluk Nauli plot was 42 species in 22 genera and 18 species. The tree density was 1,700 individuals/ha, higher than in the other plots, and basal area was 90.94 m^2/ha (Table 1). The main family based on its family important value (FIV) was Pentaphylacaceae (FIV=55.67), followed by Sapotaceae (FIV=43.46) and Theaceae (FIV=40.58) (Table 2). Pentaphylacaceae was mainly represented by *Adinandra dumosa* Jack and *Adinandra sarosanthera* Miq., which had densities of 175 and 25 individuals/ha, respectively, and basal areas of 11.92 m^2/ha and 8.54 m^2/ha, respectively.

The species of Sapotaceae that was most abundant was *Palaquium* sp., with a density of 100 individuals/ha and a basal area of 8.67 m^2/ ha. The most abundant species of Theaceae was *Schima wallichii* Choisy, with a density of 175 individuals/ha and a basal area of 9.78 m^2/ha. *A. dumosa* (SIV=29.07), *A. sarosanthera* (SIV=12.75), *Palaquium* sp. (SIV=17.31), and *S. wallichii* (SIV=26.71) were also listed as important in the Teluk Nauli plot. One more species of high SIV was *Litsea* sp., with an value of SIV=15.69 (Table 3). Unlike in the three other plots, Dipterocarpaceae was not found here.

Species richness at the sapling level was 53in 28 genera and 23 families (Table 1). Of the five major tree species, at the sapling level only *Palaquium* sp. and *Litsea* sp. were abundant, with densities of 100 and 200 individuals/ha, respectively. However, we note that these two species were the same as those found in the tree level. Five of the most important sapling species based on SIV were *Memecylon edule* Roxb. (SIV=20.21), *Garcinia rostrata* (Hassk.) Miq (SIV=13.75), *Meliosma nitida* Blume (SIV=10.98), *Palaquium ridleyi* King & Gamble (SIV=10.52), and *Baccaurea pubera* (Miq.) Müll.Arg. (SIV=10.05) (Table 4). Species richness at the seedling level was 24in 20 genera and 18 families (Table 1). Only *S. wallichii* of the dominant tree level was found in the seedling stage, at a density of 25 individuals / 100 m^2.

Forest Structure

Forest structure in all four study plots can be seen through the distribution chart of individual trees by diameter (dbh) class. Tree distribution by dbh class showed the same pattern in all four study plots, with an 'L' curve whereby the largest proportion of trees was in small dbh classes (Figure 2). In Purnama, Kejora, and Teluk Nauli there were 50% or more trees with dbh <20 cm. There was only one tree species with dbh> 50 cm in the Kejora plot, *Agathis borneensis* Warb., with a dbh of 58.6 cm. In Teluk Nauli, there were three species, *Adinandra sarosanthera* Miq. (dbh=66 cm), *Litsea* sp. (dbh=50.3 cm), and one species that could not be identified (Sp. 6) with a dbh of 75.7 cm. The Gerhana plot had a higher number of trees with dbh> 50 cm: 21 individuals in 16 species. The trees with the largest dbh were *Chionanthus montanus* Blume (dbh=118.0 cm) and *Hydnocarpus polypetalus* (Slooten) Sleumer (dbh=117.4 cm). Other species which also had large diameters in the Gerhana plot were *Mangifera laurina* Blume (dbh=95.5) and *Calophyllum venulosum* Zoll. (dbh=92.6 cm). The Purnama plot had 15 trees with dbh> 50

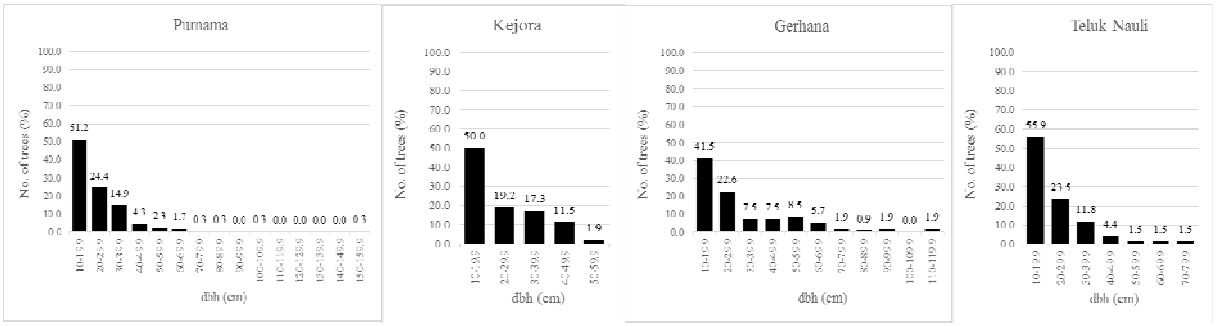

Figure 2. Graph of tree individual distribution based on diameter (dbh) class at each plots.

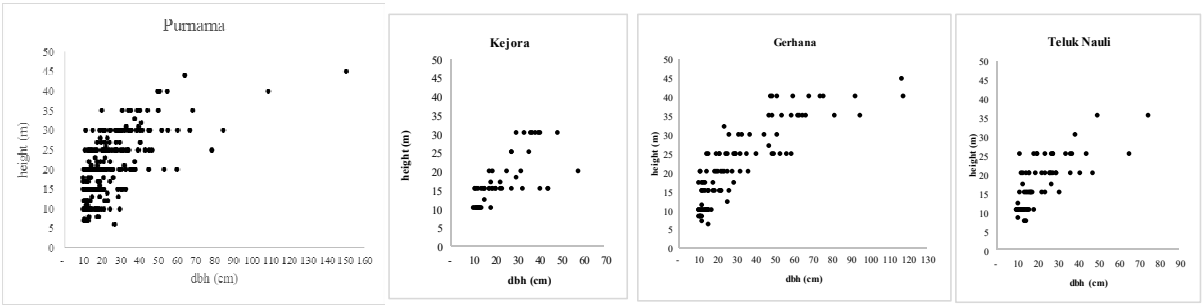

Figure 3. Correlation of Tree height and diameter (dbh) at each plots

cm, consisting of 14 species. In this plot *Durio oxleyanus* Griff had the highest dbh (150.2 cm). Other species that had large diameters were *Adinandra dumosa* Jack (dbh=84.8 cm) and one species that could not be identified (Sp. 1) with a dbh of 108.8 cm.

The vertical distribution of trees which was analyzed based on tree height tended to show a three-layer canopy. Canopy layer in the Gerhana and Purnama plots were relatively similar. The top layer ranged from 25-40 m, the middle layer was 15-25 m, and the bottom layer was 6-15 m. The prominent trees in the Gerhana plot were *Hydnocarpus polypetalus* (Slooten) Sleumer, *Alstonia angustiloba* Miq., and *Shorea falcifera* Dyer ex Brandis, while of the main trees at the Purnama plot were *Durio oxleyanus* Griff and *Shorea* sp. Kejora and Teluk Nauli had more simple forest structures with only two canopy layers. In the Kejora plot, the top canopy layer was at 15-30 m and the bottom layer at 7-15 m, while on the Teluk Nauli plot the top layer was at 15-25 m and the bottom layer at 7-15 m. But the Teluk Nauli plot also had emerging trees with heights higher than the average canopy layer, namely *Litsea* sp. (35 m) and *Adinandra dumosa* Jack (30 m). A description of the more obvious stature trees can be seen from the relationship between dbh and tree height in all four study plots (Figure 3).

DISCUSSION

Floristic

The tree species richness in our four study plots cannot be directly compared because the plot sizes differ. In tropical forests, known to vary widely from one place to another (Kartawinata *et al*. 2013), increasing the size of a plot will increase the number of species encountered. An important note in this study is that the species richness of trees (dbh> 10cm) in the Purnama plot (395 m asl.), which was only 0.28 ha in size, was 155 species. This is higher than other larger patches of forest in Sumatra, such as a 1 ha plot on the Alas River Bank, Ketambe, Gunung Leuser National Park (330 m asl.) that had 111 species of trees (Sambas & Siregar 2004) and Mount Muncung, Singkep, Riau Islands (400-450 m asl.) with 99 species (Sambas & Siregar 1999). It is even higher than a 1.6 ha plot in dipterocarp forest at Ketambe, Gunung Leuser national Park (450-670 m asl.) with 116 species (Abdulhadi *et al*. 1989).

The dominance of one species or family of trees in the forests is often used to name forest types, such as mixed Dipterocarpaceae forest (Simbolon 2008), Meliaceae forest (Abdulhadi 1991), and camphor forests (Kartawinata *et al*. 2013). On that base, the forest plots of Gerhana and Kejora, which were dominated by Dipterocarpaceae with its emerging trees, can be classified as mixed Dipterocarpaceae forest.

The Purnama plot was basically a lowland forest with commercial timber species of Dipterocarpaceae. Species richness of Dipterocarpaceae was higher in this plot (seven species) than on the Gerhana plot (four species), but with a smaller number of trees and lower basal area (Table 3). The abundance of tree species of economic value in the Purnama plot, such as *S.benzoin* and various species of local fruits especially *Durio* spp., *Nephelium* spp., *Artocarpus* spp., *Baccaurea* spp. and *Garcinia* spp., indicated the presence of human intervention in the form of cultivation. Forests in the Purnama plot appeared to be an agroforestry system (forest gardens) given its location adjacent to human settlement. In these plots, there were as many as 27 species (17.4%) of fruit trees that can be eaten as fresh fruit or processed into vegetable, with a density reaching 354 individuals/ha.

The Teluk Nauli plot showed a relatively different species composition. Dipterocarpaceae was not found in this plot. The most dominant families were Pentaphylacaceae, Theaceae and Sapotaceae. Besides having a location that was separate from the three other plots, the forest plot in the Teluk Nauli was relatively more disturbed.

The results of the PCA, using presence-absence data from each subplot analyzed based on the Bray-Curtis similarity index (Clarke 1993), showed that the forest in all four study plots tended to form three community types (Figure 4):

Forest community which was dominated by Pentaphylacaceae. This community was largely a representative of sub-plots in Teluk Nauli.

Forest community which was dominated by Dipterocarpaceae, otherwise known as mixed dipterocarp forest. This community was still divided into two groups, namely a community dominated by Dipterocarpaceae - Myrtaceae which was generally made up of Gerhana sub-plots; and Dipterocarpaceae – Anacardiaceae community that many was represented by sub-plots of Kejora.

'Forest garden' community which was dominated by *Styrax benzoin* and various species of commercially valuable trees from the Malvaceae, Moraceae, and Sapindaceae. This community consisted largely of subplots in Purnama.

Forest Structure

The forest structure we found, with distributions of trees in each diameter class forming an 'L' curve or upside down 'J' curve (Figure 2), is typical of tropical rain forests undergoing dynamic changes (Proctor *et al*. 1983; Hartshon 1980). The abundance of trees in smaller

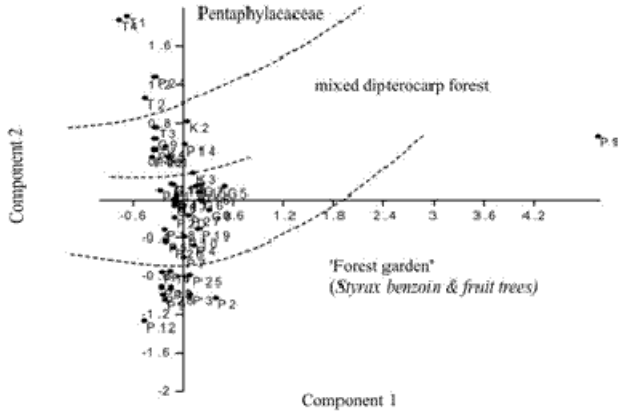

Figure 4. Clustering of Research Plots based on PCA analysis.

diameter classes shows the propensity of the forest tree community for regeneration (Simbolon 2008). However, the composition of tree species is also influential. Primary forests dominated by the families of Euphorbiaceae, Annonaceae, Myristicaceae, and Myrtaceae, which are often found in the tropical forest of western Malesia (Kartawinata *et al.* 2013), generally have a small diameter (Yusuf 2003) with steeper 'L' curve than do primary forests dominated by Dipterocarpaceae with emergent, large-diameter trees. For example in the Gerhana plot, although Myrtaceae had the highest number of species and individuals, the individuals only occupied the small diameter class and rarely appeared as an emerging species. Instead Dipterocarpaceae emerged as the dominant family with the highest basal area (18.5 m2/ha) and filled the top canopy layer. In these plots, large-diameter trees (dbh>50 cm) of Dipterocarpaceae were mainly represented by *Shorea falcifera* Dyer and *Hopea mengarawan* Brandis ex Miq.

Dipterocarpaceae was also dominant in the Kejora plot, but had an average dbh that was smaller (31.9 cm) than on the Gerhana plot (46.4 cm). The diameter difference may be due to elevation. Dipterocarpaceae generally dominates forests in the lowlands in Sumatra and Kalimantan (Ashton 1982; Simbolon 2008; Kartawinata *et al*. 2008). Altitudinal difference between the Gerhana plot (580 m asl.) and the Kejora plot (800 m.) were within 220 m, but the Kejora plot, a small hill in the watershed forest area of Batangtoru, was assumed to exhibit compression of vegetation zones known as massenerhebung effect (McKinnon 1996). Evidence of a massenerhebung effect was visible in the reduced stature of trees, with moss cover, at the tops of the mountains. It is also evident from the relationship of tree height and trunk diameter (Figure 3). This pattern is similar to on the vegetation zones on Mount Silam, Sabah, which has compression of vegetation zones so that the vegetation at an altitude of 610 m above sea level is contrasted to the vegetation above it at an altitude of 770 m above sea level. Even dipterocarp abundance at an altitude of 610 m above sea level was not found at an altitude of 770 m above sea level (Proctor *et al*. 1989).

CONCLUSION

The tree species richness in our four study plots could not be compared with each other due to differences in plot size. However, it can be concluded that forest plots in Gerhana had high richness compared to those in some other places with larger plots. Based on the family dominance and the results of PCA analysis, the Gerhana and Kejora plots can be categorized as mixed dipterocarp forest which is relatively different to forest plots in the Teluk Nauli, dominated by Pentaphylacaceae. Dominancy of Dipterocarpaceae was also found in the Purnama plot, but in the latter plot there had been human efforts to enrich forest diversity with species of economic value, forming an agroforestry system. The forest structure in the Teluk Nauli and Kejora plots was relatively simpler than in the Purnama and Gerhana plots that had emergent trees of dbh> 50 cm. Although the Kejora plot was dominated by Dipterocarpaceae and was relatively close to the Gerhana and Purnama plots, the stature of the trees was smaller and the canopy layer lower, presumably due to massenerhebung effects.

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