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Impact of forest disturbance on the structure and composition of vegetation in tropical rainforest of Central Sulawesi, Indonesia

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ABSTRACT

Pitopang R. 2012. Impact of forest disturbance on the structure and composition of vegetation in tropical rainforest of Central Sulawesi, Indonesia. Biodiversitas 13: 178-189. We presented the structure and composition of vegetation in four (4) different land use types namely undisturbed primary forest, lightly disturbed primary forest, selectively logged forest, and cacao forest garden in tropical rainforest margin of the Lore Lindu National Park, Central Sulawesi Indonesia. Individually all big trees (dbh ≥ 10 cm) was numbered with tree tags and their position in the plot mapped, crown diameter and dbh measured, whereas trunk as well as total height measured by Vertex. Additionally, overstorey plants (dbh 2- 9.9 cm) were also surveyed in all land use types. Identification of vouchers and additional herbarium specimens was done in the field as well as at Herbarium Celebense (CEB), Tadulako University, and Nationaal Herbarium of Netherland (L) Leiden branch, the Netherland. The result showed that the structure and composition of vegetation in studied are was different. Tree species richness was decreased from primary undisturbed forest to cacao plantation, whereas tree diversity and its composition were significantly different among four (4) land use types. *Palaquium obovatum*, *Chionanthus laxiflorus, Castanopsis acuminatissima*, *Lithocarpus celebicus*, *Canarium hirsutum*, *Euonymus acuminifolius* and *Sarcosperma paniculatum* being predominant in land use type A, B and C and *Coffea robusta*, *Theobroma cacao*, *Erythrina subumbrans, Gliricidia sepium*, *Arenga pinnata*, and *Syzygium aromaticum* in the cacao plantation. At the family level, undisturbed natural forest was dominated by Fagaceae and Sapotaceae disturbed forest by Moraceae, Sapotaceae, Rubiaceae, and agroforestry systems by Sterculiaceae and Fabaceae.

Key words: tree diversity, land use types, tropical forest, Lore Lindu National Park, Sulawesi, Indonesia

INTRODUCTION

Sulawesi which was formerly known as Celebes, is one of the big island in Indonesia. The island is the important island in the *Wallacea subregion*, situated in the centre of the Indonesian archipelago, between Borneo (Kalimantan) and the Moluccan islands. Van Steenis (1979) revealed that phytogeography of Sulawesi is part of the Malesian floristic unit; its flora is reportedly related to the Philippines, New Guinea, and Borneo and belongs to the Eastern Malesian. The Scientific knowledge of Sulawesi's flora both taxonomically and ecologically is still limited due to lack botanical research and publication on this subject (Bass et al. 1990; Keßler 2002), for example the amount of botanical expedition in Sumatra 20 times than Sulawesi (Veldkamp and Rifai 1977) but Sulawesi has recently been identified as one of the world's biodiversity hotspots, especially rich in species found nowhere else in the world and under major threat from widespread deforestation (Pitopang and Gradstein 2003).

Total species richness and endemism of Sulawesi are comparable to those of Sumatra, Java, Borneo and New Guinea, in spite of the very different geological history of Sulawesi and the greater distance of the island to the mainland (Roos et al. 2004). Whereas the islands of Borneo, Sumatra and Java had terrestrial connections to mainland Asia in the past, Sulawesi was always isolated from these islands as well as from New Guinea by deep maritime straits as shown by Hall (1995) and Moss and Wilson (1998). Approximately 15% of the known flowering plant species of Sulawesi are endemic (Whitten et al. 1987). Van Balgooy et al. (1996) recognized 933 indigenous plant species on Sulawesi and of these 112 were endemic to the island. Endemism varies among groups, however, and is very high in orchids and palms which total 817 orchid species (128 genera) including 493 endemic ones (Thomas and Schuiteman 2002).

Tropical deforestation has become a major concern for the world community. Whole regions in South and Central America, Africa and Southeast Asia already completely lost their forest or are expected to become deforested in the near future (Jepson et al. 2001; Laurence et al. 2001). Based on recent mapping of the forest cover in Indonesia, Ministry of Forestry (MoF) has revealed that the rate of the deforestation in Indonesia approximately doubled between 1985 and 1997, from less than 1.0 million ha to at least 1.7 million ha each year; whereas Sulawesi lost 20% of its forest cover in this period (Holmes 2002).

Many studies document the loss of biodiversity caused by modification or clearing of tropical rain forest where Human activity is one of the most direct causes of wild biodiversity loss (WCMC 1992) and may also negatively affect biotic interactions and ecosystem stability (Steffan-Dewenter and Tscharntke 1999). Introduction of exotic species, overexploitation of biological resources, habitat reduction by land use change, pastoral overgrazing, expansion of cultivation, and other human activities are common factors and primary agents contributing to the vast endangerments and extinctions occurring in the past and in the foreseeable future (Kerr and Currie 1995; Pimm et al. 1995; Tilman 1999; Palomares 2001; Raffaello 2001).

Human exploitation also causes major changes in the biodiversity of these forests, even though research on this subject has been limited and results were often controversial (Whitmore and Sayer 1992; Turner 1996; Kessler 2005). Some studies reveal conspicuously reduced species richness in secondary or degraded rainforests (Parthasarathy 1999; Pitopang et al. 2002), even in over 100 years old regrown forest (Turner et al. 1997), local extinction of plants (Benitez-Melvido and Martinez-Ramos 2003) in other studies is increased (Kappelle 1995; Fujisaka et al. 1998). Area size is a crucial factor determining the changes in biodiversity due to human impact. Loss of diversity generally decreases when larger areas are considered; therefore the impact of human activities on plant diversity thus must be interpreted with caution (Mooney et al. 1995).

This research focused on the structure and composition of four land use types differing use intensity at the Lore Lindu National Park. The main objective was to determine the taxonomic composition and forest structure of four land use types.

MATERIALS AND METHODS

Study sites

The study area was located in the surroundings of Toro, a village at the western margin of Lore Lindu NP about 100 km south of Palu, the Capital of Central Sulawesi (Figure 1). The data of research was collected from August 2007-March 2009. Detailed information on the climate and soil conditions of this part of Central Sulawesi is not yet available (see Whitten et al. 1987). Gravenhorst et al. (2005) reported that mean annual rainfall in the study area is varied from 1,500 and 3,000 mm, mean relative humidity is 85.17%, monthly mean temperature is 23.40° C. Administratively, this village belong to Kulawi sub-district, Donggala District. This village is accessible by car, truck, motorbike and public car from Palu. As our study area, the margin of the National Park is characterized in many parts by a mosaic of primary forest, primary less disturbed forest, primary more disturbed forest, secondary forests, and several land-use systems with cacao, coffee, maize, and paddy (rice) as the dominating crops (Gerold et al. 2002). The elevation of the selected sites is between 800 m and 1100 m, therefore covering an altitudinal range that belongs to the submontane forest zone (Whitten et al. 1987).

Tree diversity was studied in four (4) different land use types with four replicates as follows: (i) Land use type A: undisturbed rain forest. (ii) Land use type B: lightly disturbed rain forest. Natural forest with rattan extraction, rattan palm removed. (iii) Land use type C moderately disturbed rain forest. Selectively logged forest, containing small to medium sized gaps, disturbed ground vegetation and increased abundance of lianas following the selective removal of canopy trees and rattan. (iv) Land use type D; Cacao forest garden, Cacao cultivated under natural shade trees (= remaining forest cover) in the forest margin (Table 1).

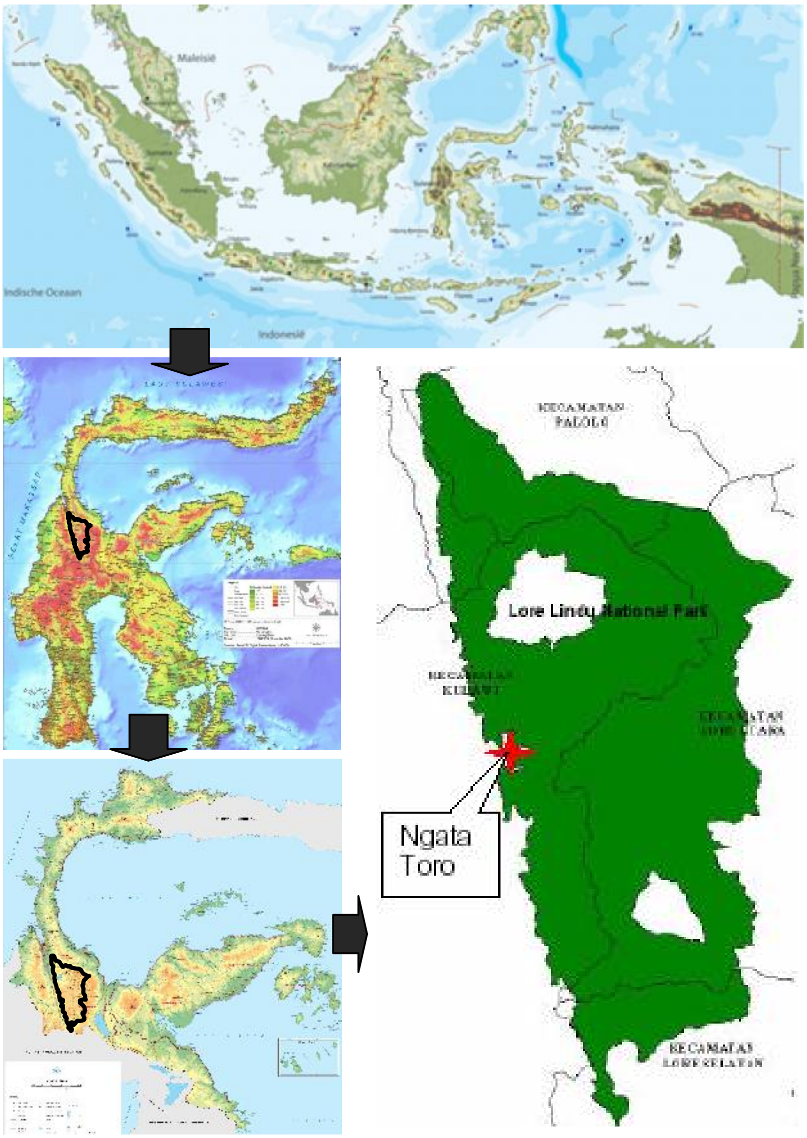

Figure 1. Map of study area, Ngata Toro at the western margin of the Lore Lindu National Park, Central Sulawesi, Indonesia

Table 1. Analyses of structural plant diversity; geographic position (measured by GPS Garmin 12), altitude and descriptions of each plot

Plot	Plot	Coordinates		Altitude	Exposi-tion	Incli-nation	Canopy cover		Description and remarks
Code	Locality	Longitute (S)	Latitude (E)	m	deg	deg	Upper%	Total %	
	Land use type A (undisturbed rain forest)								
A1	Bulu Kalabui	01^{0} 30’. 589	120^{0} 02'. 730	950	SE	30	80	80	Many large trees; on eastern slope of Bulu Kalabui but close to ridge; very sparse understorey and variable exposition
A2	Bulu Lonca	01^{0} 29’. 518	120^{0} 01'. 596	1080	ESE	25	75	75	Many large trees are reaching a height of approximately 35m, rattan dominating understory, bamboo on lower edge
A3	Buku Kalabui	01^{0} 30’. 714	120^{0} 02'. 750	950	W	20	80	80	Understory rattan dominated; fairly gentle slope; more slender and lower trees than other plots, even canopy structure; very close to ridge
A4	Kawumbu	01^{0} 29’. 486	120^{0} 03'. 054	1010	280	< 25	75	80	Single large trees are reaching a height of approximately 35m. Probably colluvium due to variable slope and micro relief. Large rocks on the soil surface. Spring inside plot, canopy very heterogeneous with some extremely large figs, understory relatively dense
	Land use type B (lightly disturbed rainforest)								
B1	Bulu Kuku	01^{0} 30’. 053	120^{0} 01'. 653	1050	90	30-40	60-70	85	One of the highest plots. Very dense understorey with much *Pandanus*; steep and large tree fall gap on lower edge; some smaller gaps already detectable
B2	Bulu Kalabui	01^{0} 30’. 558	120^{0} 02'. 967	840	ESE	25	80	60-70	Natural forest with very sparse understorey, close to open plantation for precipitation gauge
B3	Bulu Kuku North	01^{0} 29’. 400	120^{0} 01'. 607	1080	30	30	60-70	80	Highest and tallest B type. Variable understorey with obvious timber and rotan extraction
B4	Kolewuri	01^{0} 29’. 202	120^{0} 02'. 821	1000	270	35	80	80	Steep with light understorey. Fairly moist with tall and slender trees but only little rotan
	Land use type C (moderately disturbed rain forest)								
C1	Bulu Lonca	01^{0} 29’. 490	120^{0} 01'.738	1000	200	30	40	60	One large older treefall gap and smaller gaps from extracted timber. Variable relief and understorey
C2	Kolewuri	01^{0} 29’. 721	120^{0} 02'.802	990	30	20-40	30	60	There are some big tree such as *Anthocephalus* sp, *Pterospermum* sp, variable in relief, dense understory with also treefall gaps and moist soil
C3	Above Dusun Tujuh	01^{0} 30’. 441	120^{0} 01'.373	1000	SSW	30-40	50	60	Soil very rocky and dry. On upper slope below clear cut (precipitation gauge?); Understorey dense, extremely steep and far from Toro core area
C4	Bulu Kamonua	01^{0} 22’. 525	120^{0} 02'.170	1040	E	25	40	60	Evenly spaced gaps from timber extraction, understorey not too dense, little rattan
	Land use type D (Cacao forest garden)								
D1	Foot of Lonca	01^{0} 29’. 649	120^{0} 02'.134	840	NE	25-40	10	30	Owned by Pak Berwin; worst plot, large gap on lower side without cocoa; steep slope beneath plot towards creek with secondary vegetation. Sparsely spread cocoa, high degree of grass cover, few shade trees, very steep. Northern border transition into E-type plantation.
D2	Kaha	01^{0} 30’. 072	120^{0} 01'.761	920	E	0-20	15	50	Owned by Pak Abia; flattest type at highest elevation; one large gap of shade trees in center, trees very tall and at upper boundary; variable ground cover
D3	Kauboga	01^{0} 29’. 900	120^{0} 01'.821	840	10	30-35	35-40	65	Owned by Pak Penga; evenly spaced cocoa trees with few gaps and partly dense herbal undergrowth on even slope. Situated on lower edge of forest. Nearby opening as chance for precipitation gauge
D4	Foot of Bulu Kalabui	01^{0} 31. 047’	120^{0} 01'.986	815	200	30-40	50-60	75	Owned by Pak Ambi; steep with thick leaf litter layer and very little herbal undergrowth, highest shade tree cover with small gaps (some shade trees already ringed, some planted or secondary?) cocoa densely planted (< 80%) especially on lower slope

Sampling protocol

Plots size and sampling designed according to standardized protocols (Wright et al. 1997; Milliken 1998; Srinivas and Parthasarathy 2000; Kessler et al. 2005; Small et al. 2004). Plot size was determined by the minimum area curve (Suryanegara and Wirawan, 1986) and was 50 x 50 m with four (4) replicates. Each plot was subdivided into 25 subplots of 10 x 10 m² each and all trees dbh $\geq$ 10 cm were recorded. In these subplots (recording units), individually all big trees (dbh $\geq$ 10 cm) was numbered with aluminum tags and their position in the plot mapped, crown base crown diameter and dbh measured, and trunk as well as total height estimated. Furthermore, profile diagram of forest both vertical and horizontal was made by using "*Hand drawing methods*" (Laumonier 1997).

All recognizable morphospecies of trees were collected in sets of at least seven duplicates. Plant collecting was according to the "Schweinfurth method" (Bridson and Forman 1999). Additional voucher specimens of plant material with flowers or fruits were collected for identification purposes. Processing of the specimens was conducted at Herbarium Celebense (CEB), University of Tadulako, Palu. Identification was done in the field, in CEB, and the Herbarium Bogoriense (BO), Bogor. Vouchers were deposited in CEB, with duplicates in BO, GOET, L and BIOT.

Data analyses

Basal Area (BA), Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDo.), and importance value indices (IVI) were calculated and analyzed according to the formulae Dumbois-Muller and Ellenberg (Soerianegara and Indrawan 1988; Setiadi et al. 2001).

Basal area (m²) is the area occupied by a cross-section of stem at breast height (1.3 m) = [3.14 x (dbh/2)²]

Absolute values so obtained may be transcribed to relative values:

$$\text{Relative density (\%)} = \frac{\text{No. of individuals of a species}}{\text{Total no. of individuals in sample}} \times 100$$

$$\text{Relative dominance (\%)} = \frac{\text{Basal area of a species}}{\text{Total basal area in sample}} \times 100$$

$$\text{Relative frequency (\%)} = \frac{\text{Sampling units containing a species}}{\text{Sum of all frequencies}} \times 100$$

Importance Value Index (IVI) for a species is the sum of its relative density, relative dominance, and relative frequency (Soerianegara and Indrawan 1988; Setiadi et al. 2001).

RESULTS AND DISCUSSION

Species diversity

Statistically, the averages of number of species, genera, families, Shanon diversity index (H'), native species, timber tree, stem and basal area of tree did not differ among land use type A, B and C but was significantly different with D. The mean species number of tree was highest in land use type B (58.0±8), followed by land use type A (55.8±5.5) and type C (48.3±4.0). Cacao plantations, however, had significantly lower species numbers, with 20.8±7.8 tree species in cacao forest gardens.

Roughly one third of the tree species in the forest plots (15-20 spp.) were of economic importance as commercial timber trees; of these, 4-5 were major timber species and the rest minor ones. Timber diversity was little affected by moderate human use of the forest but was significantly reduced in cacao forest gardens and dropped to near zero in cacao plantations.

Taxonomic composition

Tree species at land use type A are mainly dominated by *Palaquium quercifolium* (Sapotaceae) and followed by *Castanopsis acuminatissima* and *Lithocarpus celebicus* (both Fagaceae), *Ficus trachypison*, *Chionanthus laxiflorus* (Oleaceae) and *Dysoxylum densiflorum* (Meliaceae), *Aglaia argentea* (Meliaceae), *Horsfieldia costulata* (Myristicaceae), *Meliosma sumatrana* (Sabiaceae), and *Dysoxylum alliaceum* (Meliaceae). Sapling species are presented by *Capparis pubiflora* (Capparidaceae), *Castanopsis accuminatisima, Horsfieldia costulata, Ardisia celebica* etc At the family level the forest was dominated by Fagaceae, Sapotaceae, Meliaceae and Lauraceae. At the land use type B tree species mostly dominated by *Neonauclea intercontinentalis, Palaquium quercifolium, P. obovatum, Pandanus sarasinorum, Meliosma sumatrana* etc. Whereas, sapling species is dominated by *Pandanus sarasinorum, Pinanga aurantiaca, Horsfieldia costulata, Areca vestiaria* etc. The predominant species in moderately disturbed forest (type C) were *Oreocnide rubescens* (Urticaceae), *Castanopsis accuminatisima, Lithocarpus celebicus, Pandanus sarasinorum, Neonuclea intercontinentalis* and *Canarium hirsutum* (Burseraceae). Sapling species are *Lithocarpus celebicus, Oreocnide rubescens, Castanopsis accuminatisima, Dysoxylum nutans, Dysoxylum alliaceum* etc.

Tree species in cacao forest garden (type D) mainly represented by *Theobroma cacao* (Sterculiaceae), *Coffea robusta* (Rubiaceae.), *Turpinia sphaerocarpa* (Staphyliaceae), *Horsfieldia costulata* (Myristicaceae), *Arenga pinnata* (Arecaceae), *Meliosma sumatrana*, *Melicope cf. confusa* (Rutaceae) and *Oreocnide rubescens*.

At the family level, the taxonomic composition of the habitat types showed major differences. Undisturbed natural forest (land use type A) was dominated by Sapotaceae, Fagaceae, Meliaceae, Lauraceae, Myrtaceae, Moraceae, Rubiaceae, Euphorbiaceae, Arecaceae and Oleaceae while Moraceae, Sapotaceae, Rubiaceae, Euphorbiaceae, Meliaceae, Lauraceae and Annonaceae were the most common tree families in disturbed forest (land use types B and C). In the cacao forest garden with moderate use intensity (D) was dominated by Sterculiaceae, Moraceae, Rubiaceae, Staphyleaceae, Euphorbiaceae, Cunoniaceae and Myristicaceae.

Forest structure and profile diagram

Forest structure and profile diagram of these studied land use types were provided in Figures 2, 3, 4, 5, 6 and 7 The analyses of forest structure revealed considerable differences in canopy height where tree species with height >30 m (emergent/top canopy species) was greater at the undisturbed rain forest (11.22%) and then followed by land use type B (8.7%) and C (3.9%). On the other side, only a few tree species > 30 m in height at the land use type D (0.9%), the middle canopy species (height 20.1-30 m) was higher at land use type B (16.35%) and C (13.8%) and followed by A (11.11%), D (7.4%). Contrary to the top canopy species, the undergrowth species (<10 m in height) was lower at the land use type A (undisturbed rain forest) and gradually increased from type B to D. The greater tree height in undisturbed rain forest (type A) and type B reflect that many originally top canopy trees persisted in these land use type.

At the land use type A (undisturbed natural rain forest), we recorded some top canopy tree species (with >30 m in height) such as *Palaquium quercifolium, Palaquium obovatum, Castanopsis accuminatisima, Lithocarpus celebicus, Bischofia javanica, Octomeles sumatrana, Cinnamomum parthenoxylon, Pangium edule, Pterospermum celebicum, Aglaia argentea, Dysoxylum sp, Chionanthus ramiflorus, Ficus* sp. and *Polyscias nodosa. Palaquium quercifolium* is one of tree species widely distributed at the land use type A, B and C which several individuals of this species can be reach up to 40 m in height.

At the land use type B (lightly disturbed forest) recorded the other top canopy species such as *Neonuclea intercontinentalis, Artocarpus elasticus, Elmerrillia ovalis, and Magnolia champaca*. Contrary to two forest types as mentioned before that there was no any emergent/ top canopy tree species founded at the land use type C (moderate use intensity), but only *Palaquium quercifolium, Castanopsis accuminatisima, Canarium hirsutum*, and a strangler *Ficus* sp with height not more than 30 m.

The middle canopy species (>20 dbh <30 m) which found at the forests (type A, B and C) are mostly presented by *Artocarpus vriesiana, Cryptocarya crassinerviopsis, Knema celebica, Goniothalamus brevicuspis, Aglaia argentea, Horsfieldia costulata, Chionanthus laxiflorus, Semecarpus forstenii, Sarcosperma paniculata, Litsea formanii, Castanopsis accuminatisima, Syzygium accuminatisima, Dysoxylum alliaceum, Pandanus polycephalus, Litsea densiflora, Trema orientalis, Broussonetia papyrifera* and *Mangifera foetida, Gironniera subaequalis, Astronia macrophylla, Ficus miquelii, Nauclea ventricosa, Acer laurinum, Santiria laevigata, Lithocarpus celebicus* and *Dracontomelon mangiferum.*

The lower canopy species were mainly composed by *Orophea celebica, Mitrephora celebica, Baccaurea tetrandra, Goniothalamus brevicuspis, Meliosma sumatrana, Gnetum gnemon, Siphonodon celastrineus, Antidesma celebica, Dracaena arborea, Dracaena angustifolia, Aglaia silvestris, Geunsia* sp., *Sterculia oblongata, Macadamia hildebrandii, Goniothalamus macrophyllus, Arenga pinnata, Picrasma javanica, Calophyllum soulatrii* and *Macaranga hispida.*

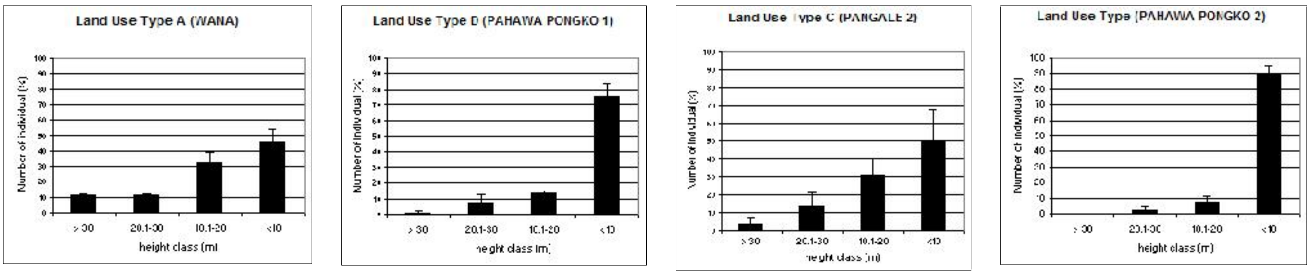

Figure 2. Relative distribution of height class among trees in the four studied Land use types. Error bars indicated + standard error. Notes: > 30 m = Top canopy species 20.1-30 m = meddle canopy species, 10.1- 20 m = lower canopy species, <10 m = undergrowth species.

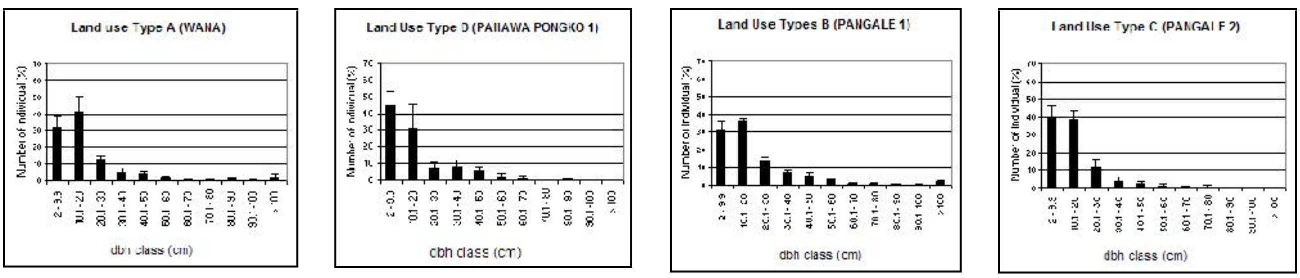

Figure 3. Relative distribution of diameter class among trees in the six studied land use types. Error bars indicated ± standard error.

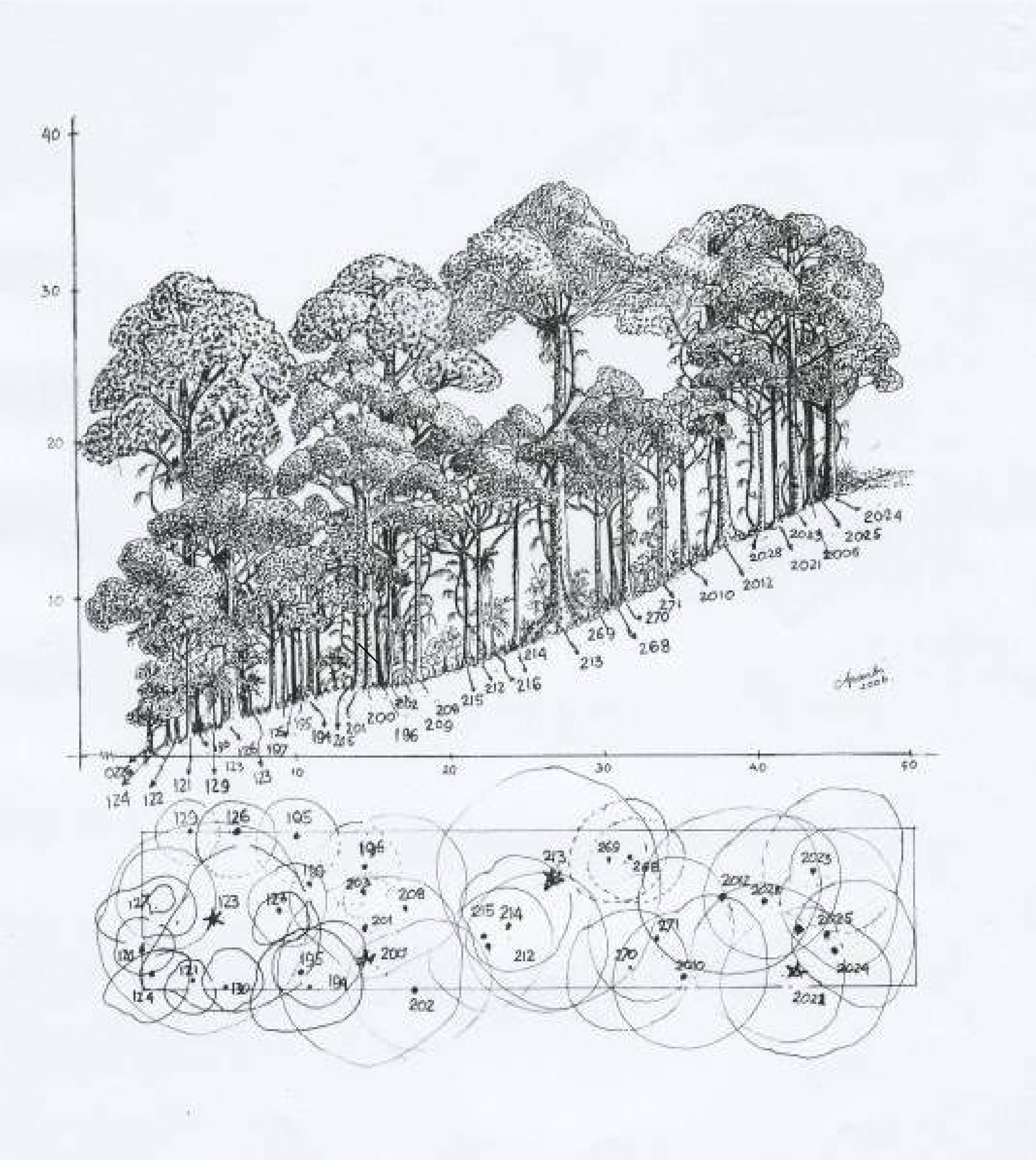

Figure 4. Profile diagram of land use type A (presented by column 5A to 5E of plot A2). *Goniothalamus brevicuspis* (122), *Palaquium quercifolium* (200, 201, 208), *Beilschmiedia gigantocarpa* (123), *Baccaurea tetrandra* (124), *Meliosma sumatrana* (125), *Antidesma celebicum* (126), *Semecarpus forstenii* (127, 194, 205, 2012, 2022), *Macadamia hildebrandii* (128), *Myristica kjellbergii* (129, 215, 217), *Pinanga aurantiaca* (130,132, 216), *Arytera littoralis* (131), *Castanopsis accuminatisima* (121, 213, 214, 2025, 2026), *Artocarpus vriesiana* (196), *Litsea* sp (197), *Pometia pinnata* (198), *Dysoxylum parasiticum* (199), *Chionanthus laxiflorus* (202), *Horsfieldia costulata* (203, 210, 268), *Ficus* sp (204, 270), *Ficus variegata* (207), *Pandanus lauterbachii* (209), *Litsea ferruginea* (211), *Sterculia longifolia* (212), *Ardisia celebica* (218), *Elaeocarpus* sp (269), *Calophyllum soulatrii* (271), *Litsea formanii* (2021), *Pisonia umbellifera* (2028), *Aglaia* sp (2024).

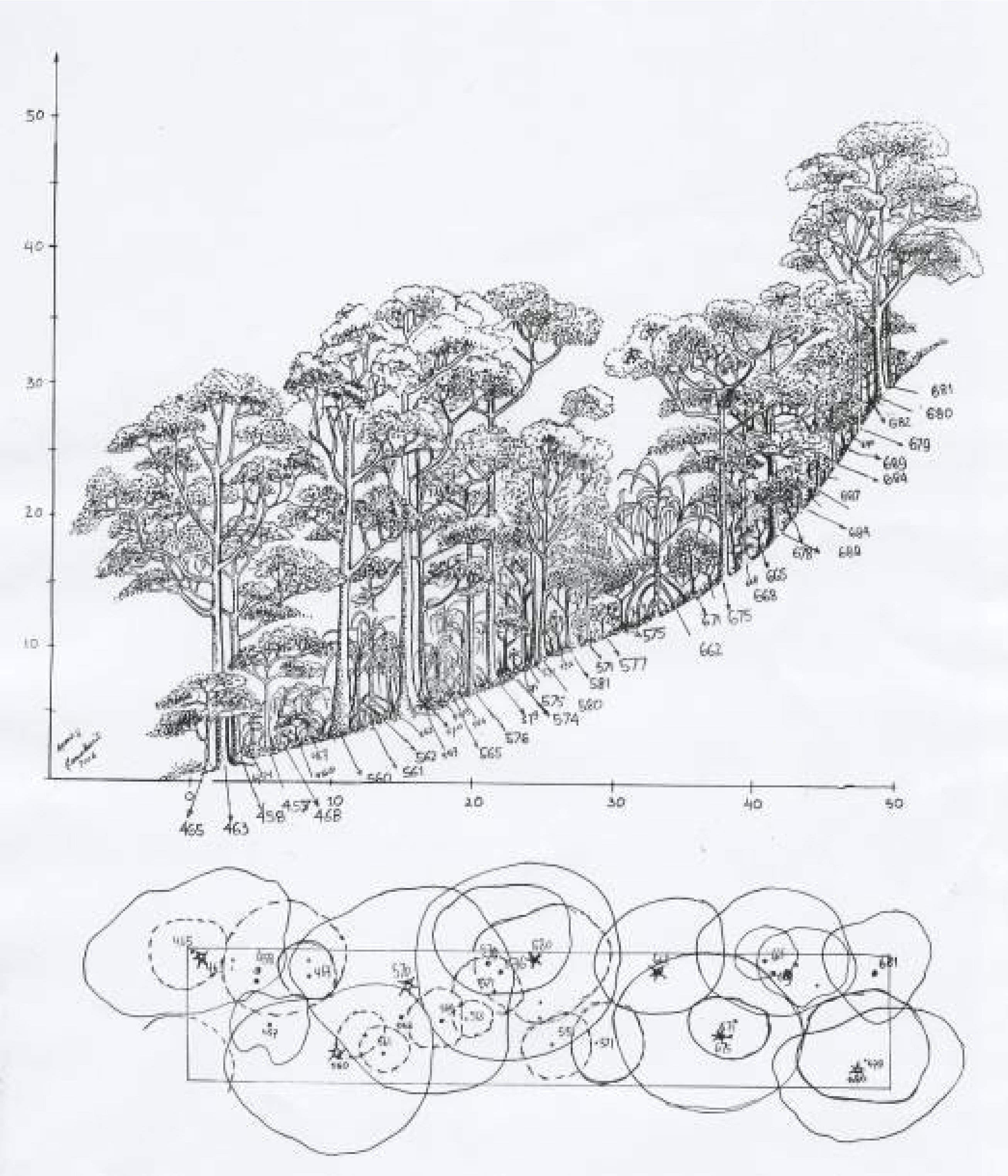

Figure 5. Profile diagram of land use type B (presented by column 5A to 5E of plot B1 at Bulu kuku). *Elaeocarpus angustifolius* (454, 577, 663, 670, 671, 674, 680, 685), *Garcinia dulcis* (455,575), *Antidesma stipulare* (457), *Chionanthus laxiflorus* (458), *Pterospermum celebicum* (459), *Macaranga tanarius* (460, 461, 462, 682, 683), *Sterculia oblongata* (464), *Horsfieldia costulata* (465, 466, 568, 687), *Pandanus sarasinorum* (467, 468, 469, 561, 562, 565, 566, 569, 662, 688), *Koordersiodendron pinnatum* (560), *Neonauclea lanceolata* (563), *Elmerrillia ovalis* (564), *Artocarpus vriesiana* (567), Ficus sp (570,676), *Meliosma sumatrana* (571, 574), *Dysoxylum alliaceum* (576, 580, 665, 669), *Goniothalamus brevicuspis* (578), *Aglaia silvestris* (579), *Dracaena angustifolia* (581), *Litsea formanii* (664, 668, 686), *Litsea oppositifolia* (666), *Gouia* sp. (673), *Neonauclea intercontinentalis* (677), *Picrasma javanica* (678), *Baccaurea tetrandra* (679), *Polyalthia glauca* (681), *Dehaasia celebica* (689) and *Litsea ferruginea* (668, 690).

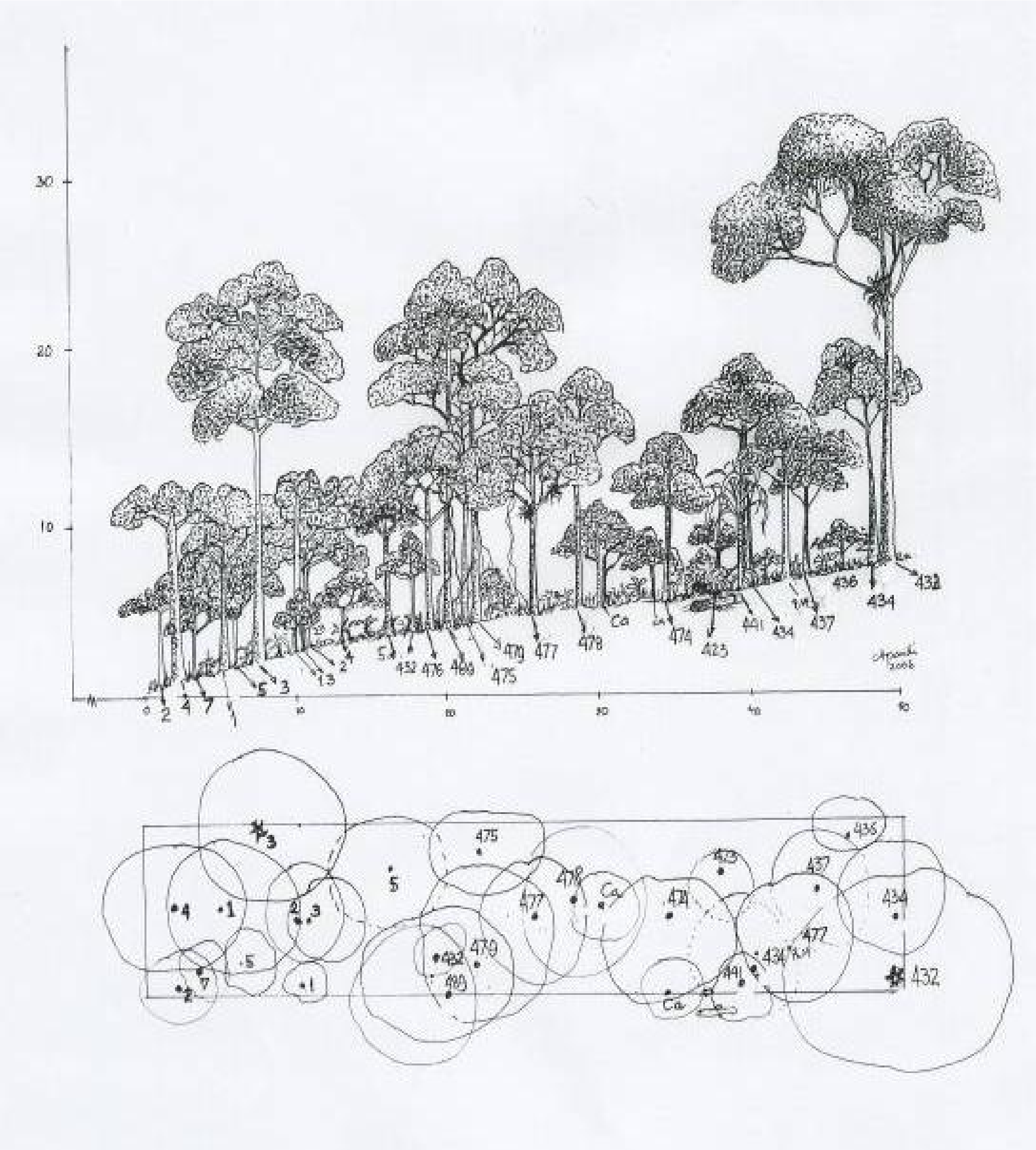

Figure 6. Profile diagram of land use type C (presented by column 2A to 2E of plot C4). *Macadamia hildebrandii* (2A-1), *Aglaia exelca* (2A-2), *Cryptocarya crassinerviopsis* (2A-3, 2B-2), *Mitrephora celebica* (2A-4, 478), *Aglaia silvestris* (2A-5), *Lithocarpus celebicus* (2A-6, 2A-9, 2A-12, 2A-13), 491, 492, 493), *Litsea albayana* (2B-1), *Dysoxylum alliaceum* (2B-4, 6, 7, 479), *Acer laurinum* (2B-5), *Castanopsis accuminatisima* (476, 477, 475, 494, 495, 496), *Elaeocarpus* sp (490), *Horsfieldia costulata* (474), *Pandanus sarasinorum* (441), *Sterculia oblongata* (432), *Pisonia umbellifera* (436), *Phaleria costata* (487), *Picrasma javanica* (438).

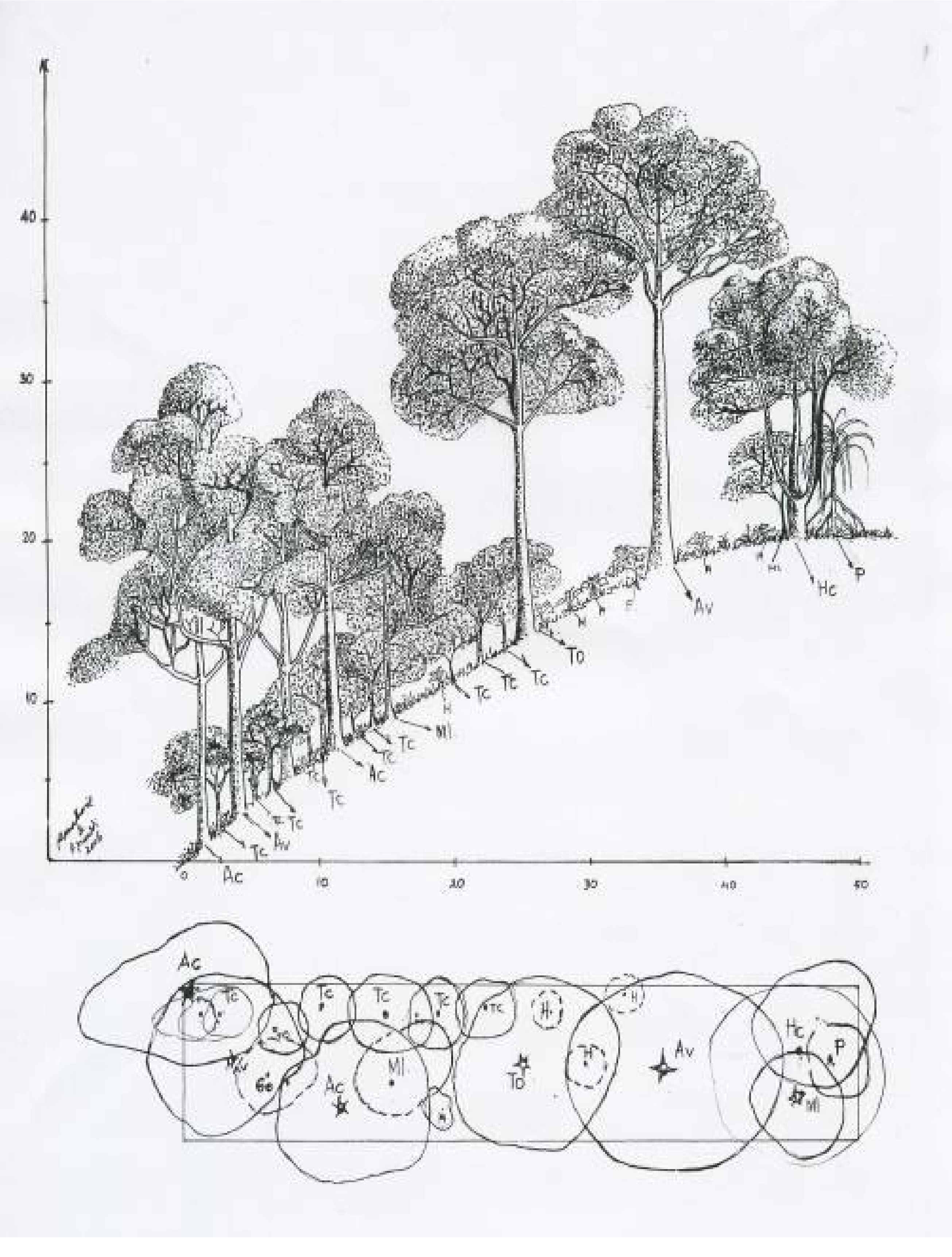

Figure 7. Profile diagram of land use type D which is presented by column 1A to 1E of plot D4. Ae = *Artocarpus elasticus,* Tc = *Theobroma cacao,* Av = *Artocarpus vriesiana,* Ge = *Geunsia* sp., Cr = *Coffea robusta,* Ml = *Melicope latifolia,* To = *Trema orientalis,* Ap = *Aphanamixis polystachya,* Da = *Dracaena arborea,* Hc = *Horsfieldia costulata.*

The small tree/ treelet or undergrowth species (<10 cm in height) are composed by *Timonius minahassae, Ardisia celebica, Dehaasia celebica, Pinanga caesea, Areca vestiaria, Pinanga aurantifolia, Caryota mytis, Oreocnide rubescens, Dendrocnide stimulant, Dysoxylum nutans, Antidesma stipulare, Lasianthus sp, Arenga undulatifolia, Eurya accuminata, Capparis pubiflora, Ficus gul, Garcinia parviflora, Fagraea racemosa, Tabernaemontana sphaerocarpa, Euonymus javanicus, Homalium javanicum* and one tree fern species is *Cyathea amboinensis.*

In contrast to the land use type A, We were not found any emergent/top canopy species at three cacao plantations. For example, at the land use type D (cacao cultivated under natural shade trees) there were only some big tree species such as *Turpinia sphaerocarpa, Trema orientalis, Artocarpus teysmanii, Artocarpus vriesiana, Bischofia javanica, Ficus variegata, Astronia macrophylla* and *Lithocarpus celebicus* but they can not reach more than 30 m in height.

Discussion

The analyses of forest structure revealed considerable differences in canopy height (Figure 2 and 3) where tree species with height >30 m (emergent/top canopy species) was greater at the undisturbed rain forest (11.22%) and then followed by land use type B (8.7%) and C (3.9%). Structure and composition of Sulawesi's forest is rather different to other islands (Keßler 2002). The investigated undisturbed rain forests around Toro, the emergent tree species were composed by *Palaquium quercifolium, Palaquium obovatum, Castanopsis accuminatisima, Lithocarpus celebicus, Bischofia javanica, Octomeles sumatrana, Pangium edule, Pterospermum celebicum, Aglaia argentea, Chionanthus ramiflorus,* and *Polyscias nodosa.* Laumonier (1997) reported the emergent tree species in the lowland forest of Jambi (Sumatra) mainly represented by fifteen *dipterocarp* species, three Anacardiaceae species and one species of *Apocynaceae.* Some of them are *Anisoptera costata, Anisoptera laevis, Anisoptera marginata, Dipterocarpus crinitus, Hopea dryobalanoides, Shorea acuminate, Shorea ovalis, Mangifera rigida, Mangifera torquenda, Pentaspadon velutinus* and *Dyera costulata.*

The timber volume was highest in land use type A (undisturbed rain forest) and gradually decreased with increased forest disturbance, and again towards forest gardens and was lowest in plantations. This result indicated that there were many large tree species in the land use type A than other land use type. Some of tree species in land use type A are mainly belong to mayor commercial timber such as *Palaquium quercifolium, Palaquium obovatum* (Sapotaceae) known as "nyatoh" or "nantu" ("trade name"), *Pterospermum celebicum* (Sterculiaceae) or "bayur", *Dysoxylum* spp. (Meliaceae) or "tahiti", *Madhuca* sp. *(Sapotaceae), Aglaia korthalsii, Alstonia scholaris* (Apocynaceae) or "pulai", *Calophyllum soulatrii* (Clusiaceae), beside that there were tree species as minor timber such as *Elmerrillia ovalis* (Magnoliaceae) or "cempaka", *Bischofia javanica (*Euphorbiaceae) "balintunga or pepolo", *Mussaendopsis celebica* (Rubiaceae), *Ailanthus* sp. (Rubiaceae), *Alseodaphne* sp. (Lauraceae), *Artocarpus teysmanii* or "tea uru", *Artocarpus elasticus* or "tea" (Moraceae), *Artocarpus integer*, (Moraceae), *Beilschmiedia gigantocarpa* (Lauraceae), *Canarium hirsutum* (Burseraceae), *Canarium balsamiferum* (Burseraceae*), Cinnamomum parthenoxylon* (Lauraceae), *Cryptocarya crassinerviopsis* (Lauraceae), *Lithocarpus grandifolius* (Fagaceae), *Dracontomelon dao* (Anacardiaceae), *Fragraea racemosa* (Loganiaceae), *Gymnacranthera* sp. (Myristicaceae), *Lithocarpus celebicus* (Fagaceae), *Litsea spp* (Lauraceae), *Myristica fatua (*Myristicaceae), *Octomeles sumatrana (*Datiscaceae*), Sterculia oblongata* (Sterculiaceae), *Santiria laevigata* (Burseraceae), etc. Generally, the timber tree species was found at the research site of Toro, LLNP mainly belong to the important non Dipterocarp trees (Soerianegara and Lemmens 1993; Lemmens et al. 1995; Sosef et al. 1998). Besides that, both *Neonauclea* spp and *Mussaendopsis celebica* (Rubiaceae) "pawa", were two economic tree species with heavy and good in quality which have been used locally for long time by the local people for construction, whereas Cacao, coffee and other fruit trees owned by many families at Toro as their cash income, besides collection of sap from the *Arenga pinnata* ("aren palm") is an important source of income for some families. The sap is collected in bamboo pole and a single tapped tree can produce up to 6 liters a day. The sap can be drunk directly but more often is boiled down to make palm sugar or fermented to produce palm wine (*saguer*).

Taxonomically, the investigated forests (types A-C) around Toro were mainly dominated by *Palaquium quercifolium, P. obovatum, Castanopsis acuminatissima, Lithocarpus celebicus,* and *Neonauclea intercontinentalis.* According to Keβler et al. (2002) and Keßler (2002) the genus *Palaquium* is represented by eight species in Sulawesi. *Palaquium obovatum* is common and widespread throughout Sulawesi but *P. quercifolium* is rare in Sulawesi and was previously only recorded from the southern province. Both *Palaquium* species appear to be common in Lore Lindu National Park where they form tall trees up to 40 m high. *Castanopsis acuminatissima* is common and widespread in Sulawesi and is one of two chestnut species known from the island, the other one being *Castanopsis buruana. Lithocarpus celebicus* is endemic to Sulawesi and widespread in the island, including Lore Lindu National Park. *Neonauclea intercontinentalis,* finally, seems to be common in Sulawesi (Keβler et al. 2002) and is one of about 20 timber species of the large family Rubiaceae (ca. 600 genera, 10.000 species) in Sulawesi. Other important timber species of Rubiaceae recorded in the forest near Toro include *Anthocephalus macrophyllus* and *Mussaendopsis celebica.* The latter two are endemic species of Sulawesi and are representatives of the eastern Malesian element in the island.

The number of endemic species is different among all land use types where endemic trees were best represented in the three forest types with 6-10 species per plot, and declined strongly in the three cacao agroforestry systems with 0-6 species per plot. This pattern was partly a result of the lower overall native tree diversity in the cacao agroforestry systems. When the percentage of endemic species was considered, then the cacao forest gardens did not differ significantly (0-20% endemic species) from the three forest types (10-20%), and only the two cacao systems with planted trees had significantly reduced percentages of endemic trees (0-13%). Endemic species are of considerable conservation concern and represent about 15% of the tree flora of Sulawesi (Keßler et al. 2002). This overall value is in good accordance with the percentages recorded by us at the plot level, with 10-20% of the native tree species recorded in the three forest types and the cacao forest gardens being endemic to the island. The representation of endemic species declined strongly to 0-13% in the two types of cacao plantations, however, showing that endemic species are more susceptible to severe habitat disturbances than widespread taxa. This is in accordance with general hypotheses on the vulnerability of endemic plants to habitat modifications (Kruckeberg and Rabinovitz 1985).

Secondary forests, regenerating after clear-felling, were not included in the present study but were treated by Pitopang et al. (2002). These forests stand out by their total lack of large trees and the abundance of thin-stemmed trees. The high richness of trees ≥5 cm in secondary forests showed that this forest type has the potential to recover a considerable richness, if allowed to mature. In terms of taxonomic composition, the abundance of Meliaceae, Lauraceae, and Moraceae appeared to be considerably reduced in secondary forests relative to primary forests, whereas in Euphorbiaceae, Urticaceae and Ulmaceae it was increased. The latter families are typical fast-growing pioneer taxa of early successional stages throughout the tropics (Turner 2001; Slik 1998) that are of little economic interest.

CONCLUSION

In conclusion, we found that moderate human use of the forest ecosystems by rattan and selected timber extraction did not result in significant decreases of tree biodiversity, but the forest structure and its composition were differ among land use type. Number of endemism of tree species was higher in primary forest and it was strongly reduced to cacao forest garden, although percentage endemism did not decline significantly in cacao forest gardens. Roughly one third of tree species in the forest plots were of economic importance as commercial timber trees; timber diversity was little affected by moderate human use of the forest but was significantly reduced in cacao forest gardens.

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