REINWARDTIA

A JOURNAL ON TAXONOMIC BOTANY, PLANT SOCIOLOGY AND ECOLOGY

ISSN 0034 – 365 X | E-ISSN 2337 − 8824 | Accredited 10/E/KPT/2019

2019 18 (1)

REINWARDTIA

A JOURNAL ON TAXONOMIC BOTANY, PLANT SOCIOLOGY AND ECOLOGY

Vol. 18 (1): 1 – 50, June 28, 2019

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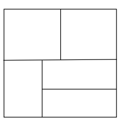

Cover images: *Begonia mattampensis* Ardi & D.C.Thomas *spec. nov*. (§ *Petermannia*). Top left: Habit. Top right: Stipules. Below left: Male inflorescence. Middle: Male flower & female flower. Below right: Fruit & ovary cross section (middle part). Photos: W.H. Ardi.

The Editors would like to thank all reviewers of volume 18(1):

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REINWARDTIA
Vol. 18. No. 1. pp: 1–18
DOI: 10.14203/reinwardtia.v18i1.3574

TREE SPECIES DIVERSITY, STRUCTURAL CHARACTERISTICS AND CARBON STOCK IN A ONE-HECTARE PLOT OF THE PROTECTION FOREST AREA IN WEST LAMPUNG REGENCY, INDONESIA

Received April 30, 2018; accepted March 18, 2019

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ABSTRACT
HERIYANTO, N. M., SAMSOEDIN, I. & KARTAWINATA, K. 2018. Tree species diversity, structural characteristics and carbon stock in a one-hectare plot of the protection forest area in West Lampung Regency, Indonesia. *Reinwardtia* 18(1): 1–18. — A study of species composition, structure and carbon stock in the lower montane forest in the Register 45B of the protection forest area in the Tri Budi Syukur District, Kebun Tebu Village, West Lampung Regency, Lampung Province was conducted in September 2016. The objective of the study was to undertake quantified measurements of floristic composition and structure of and carbon storage in the lower montane forest at 965 m asl in the protection forest area. A one hectare plot (100 m × 100 m) was established randomly. The plot was further divided into 25 subplots of 20 m × 20 m each to record trees. Quadrats of 5 m × 5 m for saplings and subquadrats of 2 m × 2 m for seedlings were nested in the tree subplots. We recorded 247 trees with diameter at breast height ≥ 10 cm representing 25 species and 19 families, with a total basal area of 59.14 m^2. Overall including seedlings and saplings we recorded 31 species. The species richness was very low due to disturbances, and was the lowest compared to that of other forests in Sumatra, Kalimantan and Java. The dominant species in terms of importance values (IV) were *Litsea* cf. *fulva* (IV=77.02), *Lithocarpus reinwardtii* (IV=45.21) and *Altingia excelsa* (IV=26.95). Dominant species in seedling and sapling stages were *Polyalthia lateriflora* (IV=27.54) and *Memecylon multiflorum* (IV=41.58). Biomass and carbon stock of trees with DBH ≥ 10 cm was 50.87 ton/ha and 25.43 ton C/ha, respectively. Regeneration was poor. Structurally and floristically the forest was a developing disturbed forest and the composition will remain unchanged in many years to come. The successions leading to terminal communities similar to the original conditions would be very slow and should be assisted and enhanced by applying ecological restoration through planting tree species native to the site.

Key words: Biomass, carbon storage, ecological restoration, West Lampung, montane forest, regeneration, structure, tree diversity.

ABSTRAK
HERIYANTO, N.M., SAMSOEDIN, I. & KARTAWINATA, K. 2018. Keanekaragaman jenis pohon, karakteristik struktur dan cadangan karbon dalam plot satu hektar di kawasan hutan lindung di Kabupaten Lampung Barat, Indonesia. *Reinwardtia* 18(1): 1–18. — Studi tentang komposisi jenis, struktur dan cadangan karbon di hutan pegunungan bawah di Register 45B kawasan hutan lindung di Desa Tri Budi Syukur, Kecamatan Kebun Tebu, Kabupaten Lampung Barat, Propinsi Lampung dilakukan pada bulan September 2016. Tujuan penelitian ini adalah untuk melakukan pengukuran kuantitatif komposisi floristik, struktur dan penyimpanan karbon di hutan pegunungan bawah pada ketinggian 965 m dpl di kawasan hutan lindung. Plot satu hektar (100 m × 100 m) dibuat secara acak, selanjutnya dibagi menjadi 25 subplot yang masing-masing berukuran 20 m×20 m untuk merekam pohon. Dalam setiap subplot dibuat kuadrat 5 m × 5 m untuk memcuplik belta/pancang dan subkuadrat 2 m × 2 m untuk merekam semai. Tercatat 247 pohon berdiameter setinggi dada ≥ 10 cm mewakili 25 jenis dan 19 suku, total luas dasar 59,14 m^2. Secara keseluruhan termasuk semai dan belta tercatat 31 jenis. Kekayaan jenis sangat rendah karena gangguan akibat aktivitas manusia, dan paling rendah dibandingkan dengan hutan lainnya di Sumatera, Kalimantan dan Jawa. Jenis dominan menurut Nilai Kepentingan (NK) adalah *Litsea* cf. *fulva* (NK=77,02), *Lithocarpus reinwardtii* (NK=45,21) dan *Altingia excelsa* (NK=26, 95). Jenis dominan pada semai dan belta adalah *Polyalthia lateriflora* (NK=27,54) dan *Memecylon multiflorum* (NK=41,58). Biomassa dan karbon dalam pohon dengan diameter setinggi dada ≥ 10 cm adalah 50,87 ton/ha dan 25,43 ton C/ha. Regenerasi hutan ini buruk. Secara struktural dan floristik hutan ini sedang mengalami gangguan. Komposisi hutan tersebut tidak akan berubah pada beberapa tahun mendatang. Suksesi yang mengarah ke komunitas terminal yang mirip dengan kondisi awal akan sangat lambat dan harus dibantu serta dipercepat dengan menerapkan restorasi ekologi melalui penanaman jenis pohon asli setempat.

Kata kunci: Biomassa, hutan pegunungan, keanekaragaman pohon, Lampung Barat, penyimpanan karbon, regenerasi, restorasi ekologi, struktur.

INTRODUCTION

West Lampung Regency of the Lampung Province is located at the south end of Sumatra, which was once entirely covered by tropical rainforests including the lowland dipterocarp forest (Whitten *et al*., 1984). It has a total area of 474, 989 ha, and comprised 77.76% forested areas and 22.24% non-forested lands assigned for agriculture and other uses (Pasya, 2011). In 1970 a total of 57% of the area was covered by primary forest, and declined to 13% in 1990, which was due to the establishment of plantations that had reached up to 60% (Syam *et al*., 1997). The three decades of deforestation in Southwestern Sumatra leading to plantation development has been reported by Gaveau *et al.* (2009). The establishment of plantations (mostly coffee plantation) was intense from 1984 to 1990, concomitant with the decrease of the extent of crop, vegetable and fruit tree gardens (Syam *et al*., 1997). The fast extent of mixed tree-coffee plantations, especially as a mean of conserving forests in combination with the uplifting people welfare, led to the profusion of research on coffee agroforestry (*eg.* Dietsch *et al.*, 2004; Hairiah *et al*., 2006; Philpott *et al*., 2008; Roshetko *et al.,* 1999; Suyanto & Otsuka 2001 & Suyanto *et al*., 2005).

This area and other section of the BBSNP (Bukit Barisan Selatan National Park) abound in wildlife researches, including Beukema *et al.* (2007); Elder (2013); Hasanah *et al.* (2006); Huang *et al.* (2014); Kinnaird & O'Brien (2005) and many others. Research on coffee agroforest in relation to carbon storage has been undertaken *e.g.* by Prasetyo *et al.* (2011) & Roshetko *et al.* (1999). Botanical exploration in BBSNP was conducted by Munawaroh & Latifah (2015) and orchid inventory by Munawaroh & Aprilianti (2011). Studies of plant communities in the BBSNP were, on the other hand, very meager. By far Solihah *et al.* (2014) studied montane forest at Mt. Sekincau at 1,100–1,719 m asl, with the multiple plot area of 2.5 ha, gave the number of species of 89 and density of 253 trees/ha. Arifiani & Mahyuni (2012) studied the young secondary forest with high density and low species richness (63) at Sukaraja Atas, and Wardani & Heriyanto (2015) in disturbed primary dipterocarp forest with low species richness (49) at Pemerihan. In the other province in Southern Sumatra, Ohsawa *et al.* (1985) studied the altitudinal zonation of forest vegetation at Mt. Kerinci and showed the decreasing species richness from 1,750 m to 3,100 m asl. Rahmah *et al*., (2016) studied the diversity of tree species in a lowland forest of Bukit Duabelas National Park, Jambi and recorded high species richness (113) in one hectare plot of regenerating disturbed lowland primary forest. Rosalina *et al*. (2014) conducted a study in one hectare plot of disturbed regenerating peat swamp forest with low species richness (73) in Selat Panjang, Riau.

The lowland forests in West Lampung have been disturbed by tree poaching and conversion into coffee plantation and other agroforests. Disturbed natural forests and secondary forests of different ages after heavy disturbances are present in the higher elevation of the lowland area. The disturbed forest in the Register 45B of the protection forest area has been selected as sites for the present study. It has high biodiversity value and the capability as an absorber (sink) of carbon dioxide (CO_2) from the atmosphere. Research on estimate of biomass and carbon stock in tropical forests is highly necessary because forests have great role in reducing CO_2 concentration, leading to the necessity of better forest conservation and management (Heriansyah *et al.,* 2007; Siregar, 2007; Siregar & Heriyanto, 2010; Subiandono *et al.*, 2013). Biomass data of an ecosystem is useful to evaluate the productivity patterns of various ecosystems (Nelson *et al.*, 1999). Thus the study in the Register 45B of the protection forest area is considered highly necessary and important.

The objective of the present study was to undertake quantified measurements of tree species composition, structural characteristics and estimation of the carbon storage in the lower montane forest in the Register 45B of the protection forest area. To date only few such initiatives have been undertaken. The scope of the paper is limited to the description of the forest in terms of the main structural parameters, species richness, pattern of relative abundance and family composition. The data and information secured may be useful for planning a park establishment and eventual park and protected forest management. Such data are also important for determination of species conservation status (IUCN 2001) measuring the suitability and the priority of conservation (Keel *et al.,* 1993), identification of vegetation types thus ecosystem types (Kartawinata, 2013), maintaining the carbon balance (Istomo *et al*., 2009) and for ecological restoration of disturbed forests. More studies on floristic composition and structure of various plant communities in both protected and non-protected areas are needed to test scientific theory explaining the cause of patterns of species richness but also for utilization, management and conservation of biodiversity (Whitmore, 1978).

MATERIALS AND METHODS

The study was conducted in September 2016 at the Register 45B of the protection forest in West Lampung Regency with the geographic coordinates of 5°01'43.63"S and 104°30'43.89"E (Fig. 1). Administratively, it is located at Tri Budi Syukur Village (*Desa Tri Budi Syukur*), Kebun

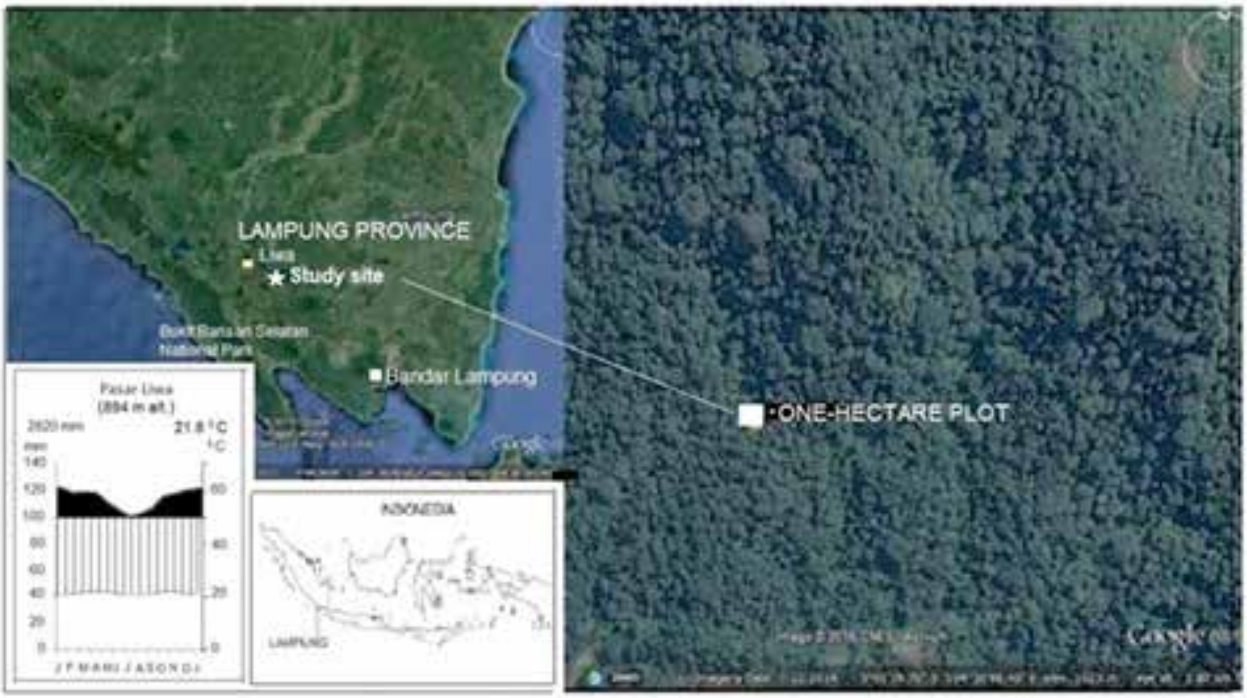

Fig. 1. The study site at the Register 45B of the protection forest in the Tri Budi Syukur Village, Kebun Tebu District, West Lampung Regency, complemented with the climate diagram at Pasar Liwa, Liwa, the capital city of the West Lampung Regency (Source: https://www.google.com/maps/@-5.02777,104.51702,8680m/data=!3m1!1e3, accessed 04 November 2016).

Tebu District (*Kecamatan Kebun Tebu*), West Lampung Regency (*Kabupaten Lampung Barat*), Lampung Province. It is located about 2 km south-east of Liwa, the capital city of West Lampung Regency and north east of the State Primary School 1 (*Sekolah Dasar Negeri* 1) Purajaya on the Tri Budi Syukur Highway.

The study area was located at an altitude of 965 m asl in a lower montane rainforest, bordering with community's agricultural areas, community forests and coffee agroforests. The topography and geomorphology of the Kebun Tebu District is hilly and mountainous with slopes of 8–35%. It constitutes a catchment area, where a big river Way Besay is flowing there. The soil at the study site belongs to the "tropudult" (USDA) type, which is known also as the Red-Yellow Podsolic soil (Pusat Penelitian Tanah dan Agroklimat**,** 1993; Soil Survey Staff, 2003). The soil parent material consists of acid tuff, sandstone and sand deposits. The soil solum was thick, with red to yellow, acids, and low nutrient. The texture was consistent with permeability ranging between low to medium and easily eroded.

The rainfall regime in the area was categorized as the rainfall type A of the Schmidt & Ferguson (1951) classification, with the mean annual precipitation of 3,300 mm, and the Q value (the ratio of dry months over wet months) of 2.40%, indicating a very wet climate. The mean air temperature range was 25°–28°C with the relative average humidity of 85% (BPS, 2016). Fig. 1 shows the climate diagram of Walter (1973) of the nearest rainfall station at Pasar Liwa (894 m asl), with the mean annual rainfall of 2,820 mm and the mean annual temperature of 21.8°C. The climate diagram indicated wet months throughout the year, where the mean monthly rainfall was greater than 100 mm, with the highest mean in January (701 mm) and the lowest in July (100.8 mm). The diagram was constructed on the basis of data available at Climate Data Org. (2017).

The quadrat method (Mueller-Dombois & Ellenberg, 1974) was used by establishing a one hectare plot (100 m × 100 m) randomly to represent the protection forest Register 45B, whose total area was ± 8,295 ha. The plot was further divided into 25 subplots of 20 m × 20 m each.

All trees with DBH (diameter at breast height at the height of 1.30 m) ≥ 10 cm were measured using phiband. Diameters of trees with buttresses were measured 20 cm above the buttresses. The tree height was measured with a Vertex II Haglof digital hypsometer. Saplings, defined as woody plants with DBH of 5–10 cm, were enumerated and their diameters were measured in the 5 m × 5 m quadrats. Seedlings, defined as woody plants with diameters < 5 cm, were counted and their diameters were measured in 2 m × 2 m subquadrats. Each species was identified and voucher specimen was collected for further identification carried out at the Botanical and Forest Ecology Laboratory, Forest

Research and Development Center, Bogor. A simulated forest profile diagram of the plot was constructed using the method of Kartawinata *et al*. (2004), by plotting in a linear row the tree height and sequential tree positions from tree no 1 in 1st subplot up to the last tree in 100th subplot, reflecting the sequence of field recording.

The standard method (Mueller-Dombois & Ellenberg, 1974; Cox, 1992; Purwaningsih *et al.* 2017) to define density, frequency and dominance was used. Density referred to the number of individuals per unit area. The number of individuals per species was calculated for the total area of the plot. The density in the plot is defined as the sum of the individuals of all species and is presented as the number of individuals per hectare. The Relative Density (RD) for each species was then computed as follows:

$$RD = \frac{number\ of\ individuals\ of\ a\ species}{total\ number\ of\ individuals}\ x100\ \%$$

Frequency was expressed as the number of occurrences of a species in subplots in the plot and was calculated as the percentage of the total number of subplots. Relative Frequency (RF) was obtained as follows:

$$RF = \frac{frequency\ of\ a\ species}{sum\ frequency\ of\ all\ species}\ x100\ \%$$

Usually the stem cover, which was expressed as basal area (BA), indicated dominance. BA was calculated with the formula:

$$BA = (½d)^2\pi$$

where *d* stands for diameter. Summing the BA values for all individuals in the species gave the dominance of a species. The Relative Dominance (RDo) was calculated as follows:

$$RDo = \frac{dominance\ of\ a\ species}{dominance\ of\ all\ species}\ x100\ \%$$

The sum of RD, RF and RDo indicated the importance of a species in the plot. The Importance Value (IV) is then calculated as follows:

$$IV = RD + RF + RDo$$

The Family Important Value (FIV) was computed by totaling the Importance Values of all species in a family (Kartawinata *et al.,* 2004).

Potential yield obtained from the stand volume and number of trees per hectare and was classified according to the following diameter classes: 10–19 cm, 20–29 cm, 30–39 cm, 40–49 cm, 50– 59 cm, 60–69 cm, 70–79 cm and ≥ 80 cm.

The stand biomass was measured by applying the formula of Chave *et al.* (2005) on the basis of volume and wood density, thus circumventing destructive sampling method, as follows:

$$Y = 0.0509 \times \rho \times DBH^2 \times T \quad \text{……….......(1)}$$

where Y = total biomass (kg), DBH = diameter at breast height, ρ = wood density (gr/cm^3) and T = bole height (m).

Carbon stock was measured by using the following formula (Brown, 1997; IPCC, 2006; Hairiah & Rahayu, 2007; Hairiah *et al*., 2011; and INCAS, 2015):

Carbon stock = plants dry weight × 50% ………………………………………..... (2)

Carbon sequestration was computed as follows:

Carbon (CO_2) sequestration = 3.67 × carbon stock ……………………………….…. (3)

The results were tabulated and analyzed using *Microsoft Office Excel Software* (2010).

RESULTS

The protected forest Register 45B is one of the natural resources that has an important role in the ecosystems in the region, including the Way Besay Watershed. This hilly area was formerly a primary forest which was the habitats of a variety of protected wild-life including the Sumatran tigers. At present the forest is rather heavily disturbed due to the influence of activities of local communities in the forests, directly adjacent to the protected forests. The communities developed coffee agroforests by planting coffee trees under the shade of the upper canopy of the protected forests (Fig. 2).

Table 1 shows the summary of the the vegetation characeristics of the one-hectare plot. It is clear that the forest has a low number of species totaling to only 25, low tree density of only 247 trees/ha and low basal area of only 59.14 m^2/ha. It should be noted also that the plot contains only two species of dipterocarp. All these features point to the fact that the forest is poorer compared to any undisturbed primary lower montane forest in Sumatra, Kalimantan and Java (Fig. 8) and reflect that it has suffered rather heavy disturbances in the past. Table 1 show also that the biomass, carbon and carbon dioxide are very low.

A. Species Composition

Overall we recorded in the one-hectare plot 247 trees of DBH ≥ 10 cm representing 25 species and

Table1. Summary of the vegetation characteristics of the study site.

Characteristic	Value
Site elevation (m asl)	965
Plot size (ha)	1.0
Number of tree species (DBH≥10cm)	25
Number of families	19
Number of Dipterocarp species	2
Density (trees/ha)	247
Basal area (m^2/ha)	59.47
Biomass (ton/ha)	50.87
Carbon (ton/ha)	25.43
CO_2 (ton/ha)	93.34

Table 2. Tree species with DBH ≥ 10 cm along with the values of absolute density (D), absolute basal area (BA), absolute frequency (F) and importance value (IV) in a one-hectare plot within the protection forest Register 45B in Tri Budi Syukur Village, Kebun Tebu District, West Lampung Regency. The species are arranged according to the descending order of IV.

No.	Species	D (Tree/ha)	BA (m^2/ha)	F (%)	IV
1	*Litsea* cf. *fulva* (Blume) Villar	87	14.72	92	77.02
2	*Lithocarpus reinwardtii* (Korth.) A. Camus	39	9.57	72	45.21
3	*Altingia excelsa* Noronha	18	7.28	40	26.95
4	*Dysoxylum* sp.	12	2.97	40	17.23
5	*Aporosa* sp.	11	3.3	36	16.65
6	*Memecylon multiflorum* Bakh.f.	11	3.44	36	16.89
7	*Artocarpus elasticus* Reinw. ex Blume	10	1.36	32	12.22
8	*Polyalthia lateriflora* (Blume) Kurz	9	2.88	28	13.65
9	*Macaranga tanarius* (L.) Műll-Arg.	8	2.08	28	11.9
10	*Phoebe cuneata* Blume	8	2.11	16	9.75
11	*Pimeleodendron* sp.	5	1.98	12	7.58
12	*Magnolia lanuginosa* (Wall.) Figlar & Noot.	4	1.77	16	7.55
13	*Endospermum quadriloculare* Pax. & K. Hoffm.	3	0.73	8	3.92
14	*Maesopsis eminii* Engl.	3	0.63	12	4.49
15	*Cryptocarya agathophylla* van der Werff	3	0.34	12	3.99
16	*Shorea platyclados* Slooten ex Endert	3	0.63	12	4.49
17	*Myristica* sp.	2	0.65	8	3.38
18	*Lithocarpus bennettii* (Miq.) Rehder	2	0.53	8	3.18
19	*Acer laurinum* Hassk.	2	0.45	8	3.04
20	*Garcinia celebica* L.	2	0.81	8	3.66
21	*Polyosma integrifolia* Blume	1	0.25	4	1.56
22	*Flacourtia inermis* Roxb.	1	0.02	4	1.17
23	*Symplocos fasciculata* Zoll.	1	0.31	4	1.67
24	*Bridelia glauca* Blume	1	0.15	4	1.39
25	*Drypetes* sp.	1	0.2	4	1.47
	Total	247	59.14	544	300

Fig. 2. A piece of lower montane forest that has been converted into a coffee agroforest in the vicinity of the study site, showing coffee trees planted under the shade of the tall original forest trees. Photo: N.M. Heriyanto.

19 families with a total basal area of 59.14 m^2 (Table 2). The families containing largest number of species were Lauraceae, Euphorbiaceae, and Moraceae.

Fig. 3 shows the species-area curve constructed on the basis of the cumulative data of the 25 subplots. It shows that the number of species tended to increase further as it reached a one-hectare area (25 plots).

Table 2 showed that of 25 tree species with DBH $\geq$ 10 cm, 10 species with IV > 10 were considered dominant. The most prominent species included *Litsea* cf. *fulva* (IV = 77.02), *Lithocarpus reinwardtii* (IV = 45.21) and *Altingia excelsa* (IV = 26.95). The density and basal area of the other dominant species are listed also in Table 2.

Although the plot was a disturbed forest among the 25 species recorded (Table 2) only nine species could be considered secondary forest species, which included primary forest species behaving like secondary forest species and invasive introduced species. They were *Bridelia glauca, Endospermum quardrilocurale, Garcinia celebica, Macaranga tanarius, Maesopsis eminii, Memecylon multiflorum, Phoebe cuneata, Shorea platiclados* and *Symplocos fasciculata*. Thus the 16 species in the seedling, sapling and tree stages were primary forest species.

B. Forest Stand Structure and Regeneration

Size and density as well as horizontal and vertical distribution of trees define forest structure (Kershaw, 1964; Mueller-Dombois & Ellenberg, 1974). It could be interpreted by the distribution of trees per unit area in various diameter classes (Bustomi *et al*., 2006). The structure of forests in the study site is depicted by a simulated profile diagram (Fig. 4) and the interior view on the ground (Fig. 6).

The species dominating the height in Stratum A (> 30m) were *Dysoxylum* sp. (43 m), *Altingia excelsa* (40.9 m) while in Stratum B (20–30 m) were *Lithocarpus reinwardtii* (35.5 m), *Altingia excelsa* (39.4 m) and *Shorea platyclados* (35 m); and in the Stratum C (10–20 m) were *Dysoxylum* sp. (29.9 m), *Phoebe cuneata* (29.5 m) and *Aporosa* sp. (29.4 m). The Stratum D was filled with saplings of trees composing the upper strata.

Fig. 5 shows the distribution of tree density of all species in the plot according to diameter classes. It is also evident from the interior view of the forest in the plot (Fig. 6) showing a sparse distribution of trees with DBH >30 cm and the absence of trees with DBH of 10–30 cm. It highlighted that the structure of forest stand at the

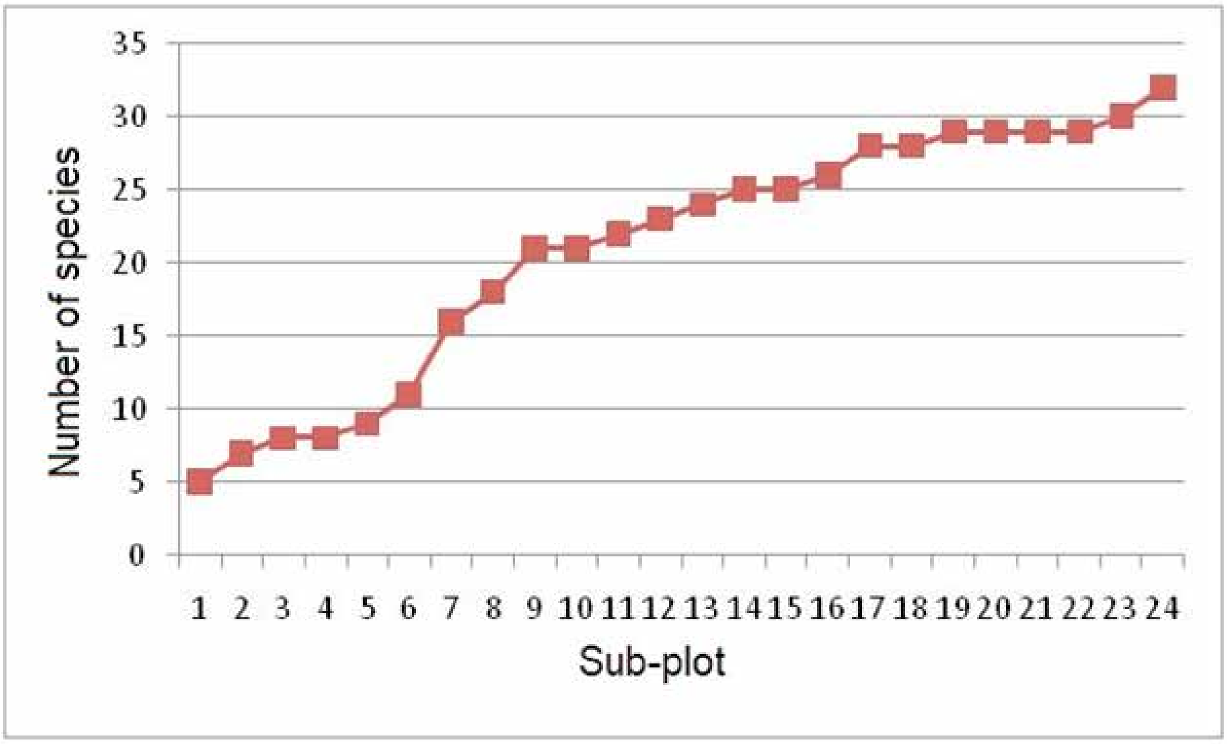

Fig. 3. Species-area curve constructed on the basis of tree species with DBH of ≥ 10 cm present in 25 subplots of (20 m × 20 m) in the one-hectare plot of the protection forest (Register 45B) at Tri Budi Syukur Village, West Lampung Regency.

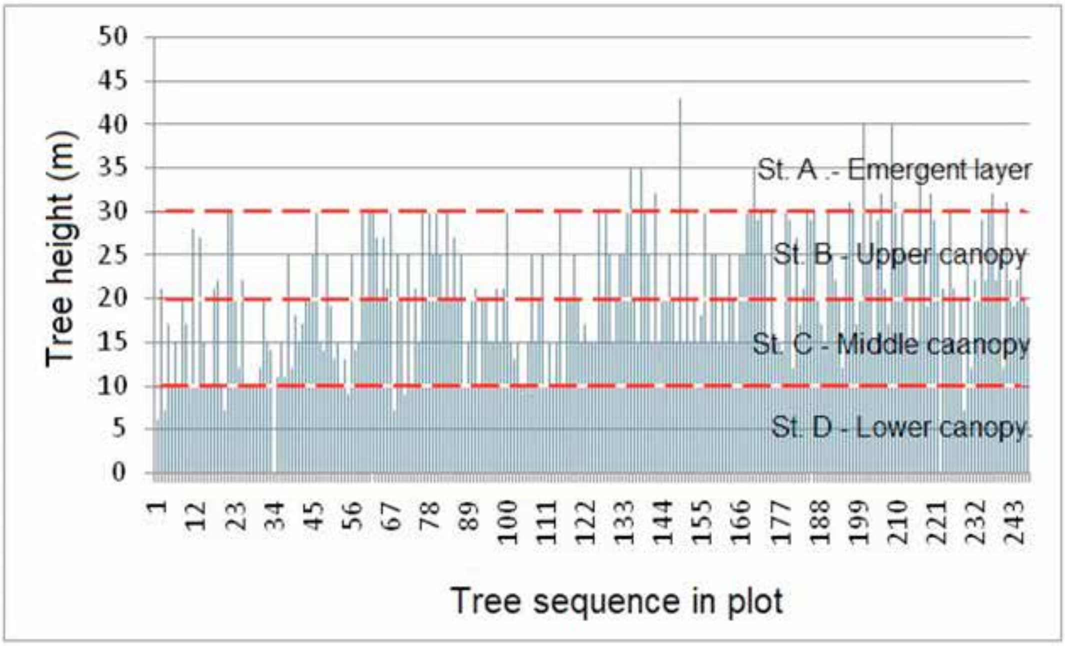

Fig. 4. The simulated forest profile diagram at the study plot, based on the tree height and sequential tree positions from tree no 1 in 1st subplot up to the tree no. 247 in 100th subplot in the one-hectare plot at lower montane forest in Register 45B of the protection forest in West Lampung Regency. It shows the height stratification: St. (Stratum) A = emergent layer (> 30 m); St. B = upper canopy (20–30 m); St. C = middle canopy (10–20 m); and St.D = lower canopy (< 10 m).

study site shows decreasing number of trees from the large diameter class to the small diameter class. The structure of the forest stand at the study site shows abnormal pattern; generally the number of trees with small diameters is much greater than trees with large diameters. In an undisturbed natural forest, stand structure may not be always similar, even in the same site, which could be caused by the differences in the ability of trees in using solar energy, nutrients/mineral and water, and competition. Therefore, trees in a forest stand will be distributed along diameter class gradient (Ewusie, 1980).

Table 3 shows the regeneration status of 31 species occurring in the study plot. It was very unusual that the trees in the diameter classes of (10–20) cm and (20–30) cm were absent leaving only three trees left (*Lithocarpus reinwardtii, Drypetes* sp. and *Endospermum quardriloculare*). Group 1 comprises species with representation in

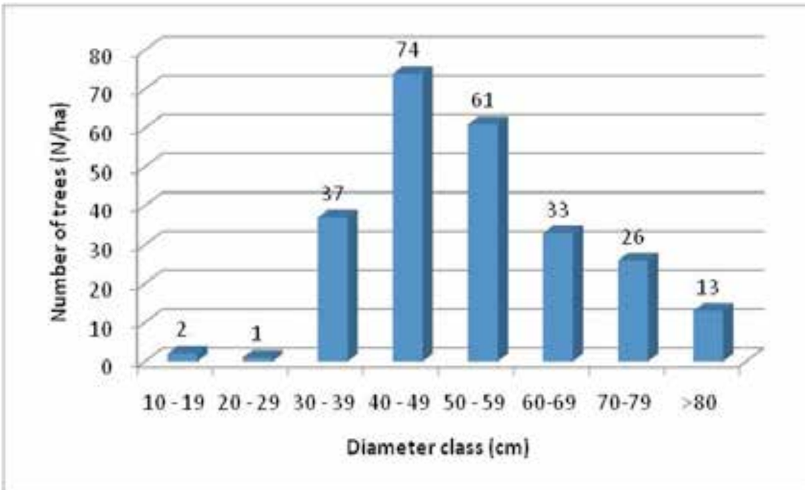

Fig. 5. Density of trees with DBH ≥ 10 cm according to the diameter class in the study site.

Fig. 6. The interior view of the forest in the plot showing a sparse distribution of trees with DBH > 30 cm and the absence of trees with DBH of 10–30 cm. Photo: N.M. Heriyanto.

Table 3. Regeneration as reflected by the diameter class distribution of all tree species in the study plot in the protection forest Register 45B in West Lampung Regency.

	Species	**Diameter class (cm)**									
		< 5	**5–10**	**10–20**	**20–30**	**30–40**	**40–50**	**50–60**	**60–70**	**70–80**	**>80**
No	GROUP 1										
1	*Litsea* cf. *fulva* (Blume) Villar	5	2	-	-	19	37	31	-	-	-
2	*Altingia excelsa* Noronha	4	7	-	-	1	1	2	3	8	3
3	*Lithocarpus reinwardtii* Korth.	1	-	-	1	4	12	6	9	5	1
4	*Macaranga tanarius* (L.) Műl-Arg.	11	3	-	-	4	6	-	-	-	-
5	*Memecylon multiflorum* Bakh.f.	31	9	-	-	1	3	4	1	3	-
6	*Polyalthia lateriflora* (Blume) Kurz	30	11	-	-	-	1	3	2	2	1
7	*Dysoxylum* sp.	8	4	-	-	1	1	3	4	1	1
8	*Acer laurinum* Hassk.	2	1	-	-	1	1	-	-	1	-
9	*Myristica* sp.	2	2	-	-	-	-	2	-	-	-
10	*Flacourtia inermis* Roxb,	2	1	-	-	-	-	-	1	-	-
11	*Phoebe cuneata* Blume	2	-	-	-	1	3	1	1	1	1
12	*Bridelia glauca* Blume	1	-	-	-	-	-	1	-	-	-
13	*Artocarpus elasticus* Reinw. ex Blume	-	2	-	-	1	-	2	3	1	-
	GROUP 2										
14	*Litsea* cf. *fulva* (Blume) Villar	1	1	-	-	-	-	-	-	-	-
15	*Schima wallichii* Choisy	6	1	-	-	-	-	-	-	-	-
16	*Litsea angulata* Blume	5	6	-	-	-	-	-	-	-	-
17	*Shorea* sp.	2	2	-	-	-	-	-	-	-	-
18	*Dehaasia incrassata* (Jack)Kosterm.	2	-	-	-	-	-	-	-	-	-
19	*Leea sambucina* Benth.	1	-	-	-	-	-	-	-	-	-
20	*Pinanga* sp.	-	1	-	-	-	-	-	-	-	-
21	*Streblus asper* Lour	-	2	-	-	-	-	-	-	-	-
	GROUP 3										
22	*Drypetes* sp.	-	-	1	-	-	-	-	-	-	-
23	*Endospermum quardriloculare* Pax & Hoffm.	-	-	1	-	-	-	-	1	1	2
24	*Cryptocarya agathophylla* van der Werff	-	-	-	-	1	1	-	1	-	1
25	*Lithocarpus bennettii* (Miq.) Rehder	-	-	-	-	-	-	1	1	-	-
26	*Maesopsis eminii* Engl.	-	-	-	-	2	1	-	-	-	-
27	*Magnolia lanuginosa* (Wall.) Figlar & Noot.	-	-	-	-	-	-	-	4	-	4
28	*Pimeleodendron* sp.	-	-	-	-	-	2	-	1	-	-
29	*Polyosma integrifolia* Blume	-	-	-	-	-	1	1	-	-	-
30	*Shorea platyclados* Slooten ex Endert	-	-	-	-	-	-	1	-	-	1
31	*Symplocos fasciculata* Zoll.	-	-	-	-	-	-	1	-	-	-

almost all diameter classes (except in diameter classes of 10–20 cm and 20–30 cm); with density in each diameter class varying from 1 to 58 trees. *Litsea* cf.. *fulva*, *Altingia excelsa* and *Lithocarpus reinwardtii* had a high number of large trees with diameters > 60 cm, but they had poor regeneration. *Litsea* cf. *fulva* and *Lithocarpus reinwardtii* were species that would perhaps survive and dominant in the forest in the future, although the new recruits were small in number. *Macaranga tanarius, Memecylon multiflorum* and *Polyalthia lateriflora* had a good representation in the seedling and sapling stages but poor in higher diameter classes. They tended to replace the old population with the young trees and new recruits. They are actually secondary forest species, where the new plants will fill every gap available in the forest. The rest of the species in Group 1 (*i.e. Acer laurinum, Artocarpus elasticus, Bridelia glauca, Dysoxylum* sp., *Flacourtia inermis* and *Myristica* sp.) would continue to exist with different sizes, but they were not aggressively regenerating themselves. Species in Group 2 were present only in seedling and sapling stages with small number of individuals. They could represent newly regenerating individuals or the remnants of the components of the original tree species in the forest. Species in Group 3 (except for *Leea sambucina*) were the remnant of the species in the original forest represented by a few big trees and scattered one individual of smaller trees. They would not be able to maintain themselves and are heading to extinction from the forests in the area.

Table 4. Species with complete regeneration in study site.

No.	Species	Importance Value		
		Seedling	Sapling	Tree
1	*Acer laurinum* Hassk.	5.41	4.22	3.92
2	*Altingia excelsa* Noronha.	20.27	15.49	26.94
3	*Artocarpus elasticus* Reinw. ex Blume		2.82	11.90
4	*Bridelia glauca* Blume		2.82	1.56
5	*Dysoxylum* sp.	6.29	14.40	16.89
6	*Flacourtia inermis* Roxb.		4.22	1.67
7	*Lithocarpus reinwardtii* Korth.	3.72	4.22	45.21
8	*Litsea* cf. *fulva* (Blume) Villar	6.99	7.04	77.02
9	*Macaranga tanarius* (L.) Műl-Arg.	13.28	15.80	12.22
10	*Memecylon multiflorum* Bakh.f.	24.97	41.58	17.23
11	*Phoebe cuneata* Blume	1.86	3.39	9.75
12	*Polyalthia lateriflora* (Blume) Kurz	27.54	37.73	13.65

Table 5. Estimate of biomass, carbon stock, and carbon sequestration in Register 45B of the protection forest in West Lampung Regency.

Diameter class (cm)	Measurement results using formula of Chave *et al*. (2005)		
	Biomass (ton/ha)	Carbon (ton C /ha)	Carbon dioxide (ton CO_2/ha)
10–19	0.02	0.01	0.04
20–29	0.02	0.01	0.04
30–39	2.64	1.32	4.85
40–49	9.20	4.60	16.87
50–59	11.13	5.57	20.43
60–69	8.82	4.41	16.19
70–79	10.72	5.36	19.66
>80	8.31	4.16	15.26
Total	50.86	25.44	93.34

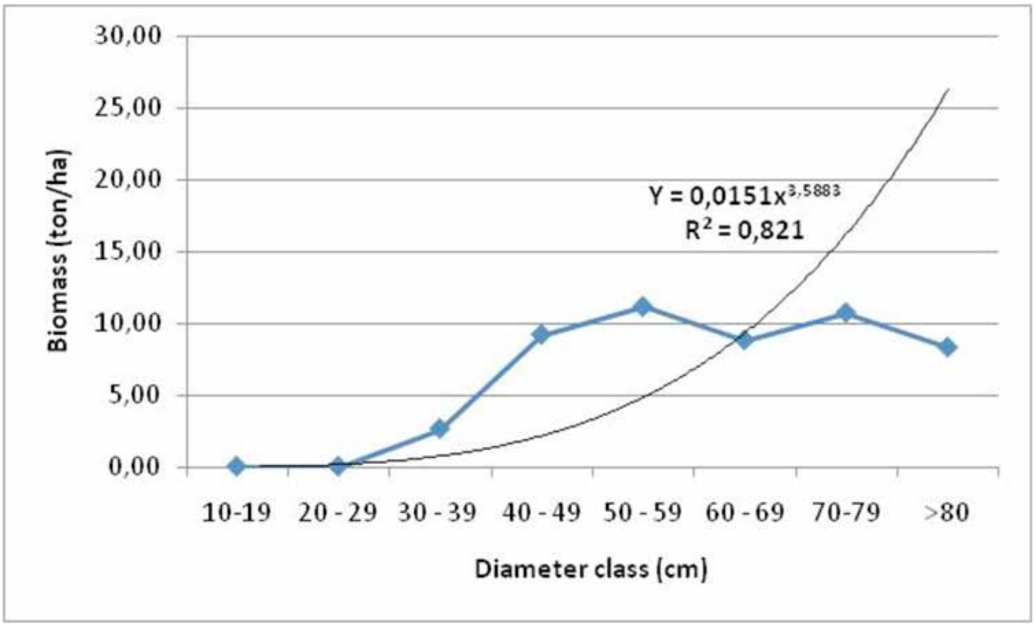

Fig. 7. Correlation between diameter and biomass at the study site.

Table 4 presented the Importance Values of 12 species having complete regeneration, as indicated by the presence of trees, saplings and seedlings. In terms of IV, *Altingia excelsa*, *Memecylon multiflorum* and *Polyalthia lateriflora* had good regeneration as indicated by the high values at the seedling and sapling stages.

C. Biomass and Carbon Stock

Using equation of Chave *et al*. (2005), the biomass and carbon stock of forest stand with DBH $\geq$ 10 cm in the study plot is presented in Table 5. The relationship between diameter and biomass in the study location is presented in Fig. 7. It should be noted that diameter is related relatively closely to the biomass, as indicated by the coefficient of the determination of above 80%.

DISCUSSION

The lowland forests in West Lampung have been much disturbed by tree poaching and conversion into coffee plantation and other agroforests. Relatively good tracks of least disturbed natural forests and those that have developed into secondary forests of different ages after heavy disturbances were observed at higher elevation of the lowland areas.

The Register 45B of the protection forest area is the headwaters of many rivers in Way Besay watershed, functioning as a regulator of water flow and control of erosion, floods and landslides. It also constitutes a life support system, which contains important genetic resources and wildlife habitats. The study site in the Register 45 of the protection forest area was bordering with villages of local communities, practicing coffee planting that threaten the primary forests. As indicated above this situation has led to profusion of research in agroforestry in an effort to design forest conservation while at the same time practicing coffee agriculture.

Overall we recorded in the one-hectare plot 247 trees representing 25 species and 19 families with a total basal area of 59.14 m^2 (Table 2). Fig. 3 shows that the species-area curve differed in pattern to those in the lower montane forest at the Batang Gadis National Park, North Sumatra (Kartawinata *et al*., 2004) and that in the lowland forests of East Kalimantan (Kartawinata, 2005), which show that after one hectare the numbers of species were still increasing. The curve in the present plot may flatten out if the area were expanded to more than one hectare, thus comparable to those in the lower montane forests at Mt. Gede-Pangrango and Mt. Halimun in Java.

Fig. 8 shows that the species richness [*i.e.* number of species in a sampling unit (McCune & Grace, 2002)] and tree density in the present plot along with that in Hutan Bukit Datu were the poorest compared to those in the lowland forests of Sumatra and Kalimantan and the montane forests of Java. It should be noted that they were all situated in the same wet rainfall type A regime of Schmidt & Ferguson (1951). Although they are located in almost the same altitudes within the lower montane forests, the number of species and density in the present study were lower than those in the montane forests at Mt. Gede-Pangrango National Park and the Mt. Halimun-Salak National Park in West Java. At the Bukit Sekincau in the Bukit Barisan lower montane forest area, Solihah *et al*. (2014) recorded 89 tree species and density of 253 trees/ha in the multiple plot with the total area of 2.5 hectare. The poor species richness could not be due to differences in climatic regime and altitudinal zone, but was likely related to the status of the forests, whether they were undisturbed or disturbed primary lowland and montane forests. The low density and total species in the present study showed that the forest had suffered heavy disturbances resulted from human activities. Such disturbances were indicated by the presence of eight tree stumps of *Altingia excelsa*, *Lithocarpus* spp. and *Shorea* sp., with diameter of up to 80 cm. It was possibly the result of tree poaching and early attempts of natural forest conversion to coffee agroforest and/ or coffee gardens. Furthermore the study plot was located near the community settlements and community coffee agroforests.

In the present study plot Dipterocarp species were represented only by *Shorea platyclados* and *Shorea* sp., many dipterocarp tree species are of high commercial values and might have been extracted from the site. Dipterocarps should have been very common in the forest at this altitude. It can be exemplified by the upper lowland forest at Batang Gadis, with altitude (660 m), slightly lower than the present study (965 m), where in one-hectare plot 16 species were recorded, including *Dipterocarpus palembanicus*, *Hopea beccariana*, *Shorea acuminata*, *S. exelliptica*, *S. gibbosa*, *S. parvifolia*, and *Vatica micranta*, of which *S. acuminata*, *S. gibbosa*, and *Hopea beccariana* with density of 20–24/ha (Kartawinata *et al*., 2004). Similarly, with species of Fagaceae, which are characteristic of montane forest, was only represented by two species. Common species to lower montane forest of Sumatra and Java, including *Castanopsis acuminatissima*, *C. argentea*, *C. javanica*, *Dacrycarpus imbricatus*, *Engelhardtia spicata, Lithocarpus pseudomoluccus, L. sundaicus, Myrsine hasseltii*, *Quercus lineata*, *Q. pyriformis*, *Turpinia sphaerocarpa* (Mansur *et al*., 2011; Simbolon & Mirmanto, 1997; Soepadmo, 1972; Steenis *et al.,* 1972; Whitmore & Tantra, 1986).

A species that had, on the average, one or fewer

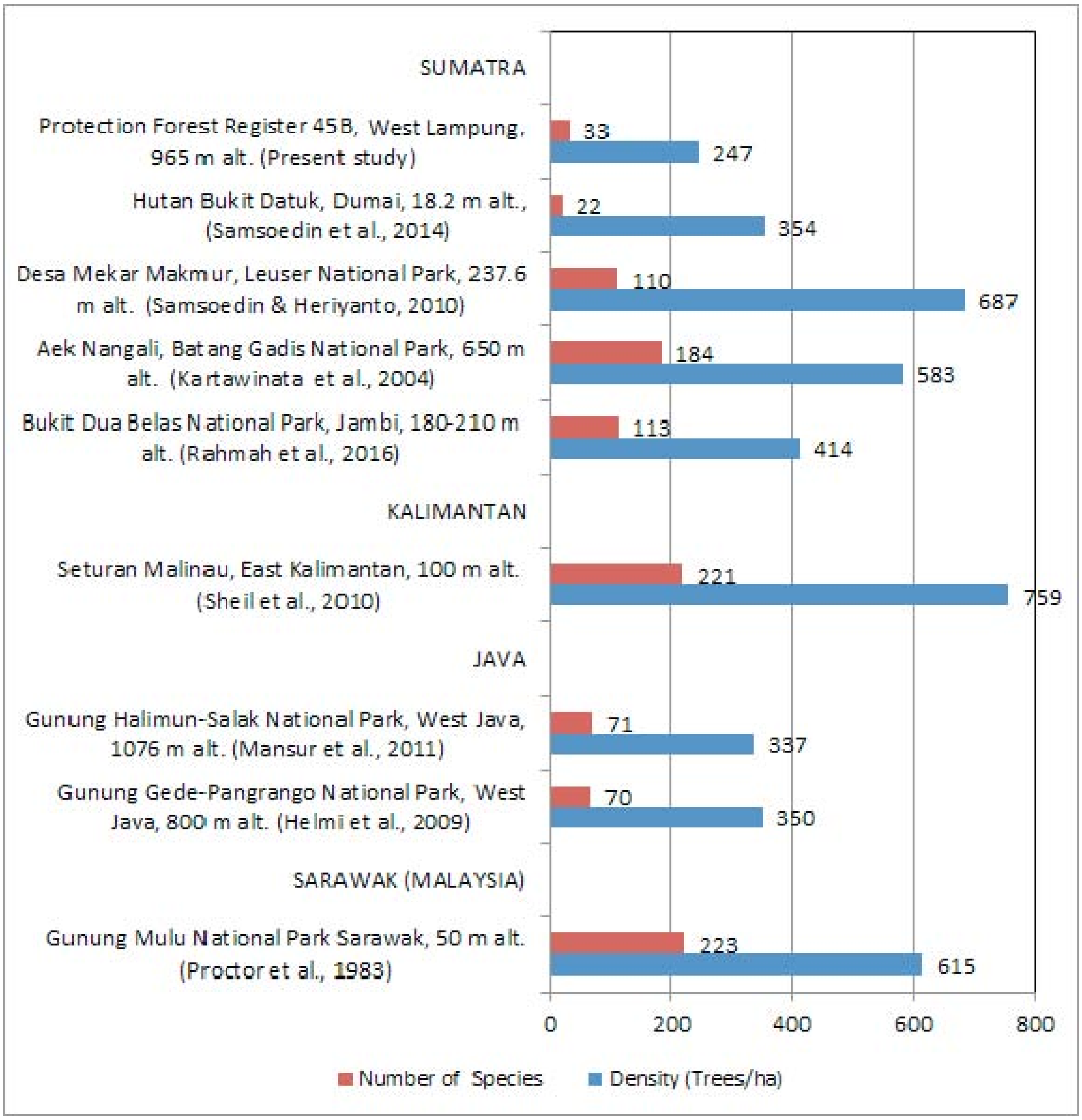

Fig. 8. Comparison of density and species richness of trees with DBH ≥ 10 cm in one-hectare plots in the present study site and in other sites elsewhere.

stems per hectare could be considered as a rare species (Hubbell & Foster, 1986) on the local scale and may not in any way be accepted on the global scale as defined by IUCN criteria of rareness. Applying this principle, the species that can be considered rare at least locally in the Register 45B of the protection forest (Table 2) included *Acer laurinum*, *Bridelia glauca*, *Drypetes* sp., *Flacourtia inermis*, *Garcinia celebica*, *Lithocarpus bennettii*, *Myristica* sp., *Polyosma integrifolia*, *Shorea platyclados* and *Symplocos fasciculata.*

It should be noted that most of the trees had diameters greater than 30 cm with the highest density was in the diameter class > 60 cm. It may be implied that such situation could be due to the cutting of trees with small diameters. It may be assumed to be the initial activities of local community to establish a coffee agroforest. They planted coffee in between and under the shade of the remaining standing large trees. Tree species that could have been extracted were those species that are characteristics of the lower montane forest as discussed above.

Regeneration in tropical forests is a complex process depending on so many factors including the incidental occurrences of natural gap formation (Richards, 1996; Whitmore, 1984). Complete profile of size class distribution from seedlings to the trees with largest diameters could be an indication of regeneration. Size-class distributions, however, depend on growth and mortality (Jones, 1950 cited by Richards, 1996) and may be related to site conditions as well as to the incidence of natural or artificial disturbances in the past (Richards, 1996). Regeneration is a natural phenomenon in which a young tree will replace a dead adult tree due to various causes, such as felling, burning, natural disaster or physiologically dead. The complete regeneration is indicated by good representation of population of individuals in tree, sapling, and seedling stages.

The protection forest in the Register 45B has been heavily disturbed by human activities, that have led to degradation of forests and lands. They are now recuperating and succession is slowly taking place heading to the forest similar to the original ones, dominated by typical lower montane forest species. Succession is a very slow process and yet it is a very important process in the forest. Such degraded forests and lands will have to be restored to similar original forest. The slow natural succession could be accelerated and assisted by applying ecological restoration method through planting primary forest species, rare species, endemic species, multipurpose species and species with high conservation value (Mansur & Kartawinata, 2017; Purwaningsih *et al.*, 2017; Rahmah *et al.*, 2016). It should be complemented with preventive actions to combat fire and tree poaching. For such purpose we could use important species in the Register 45B as listed in Table 2, as well as typical species in the lower montane forest including *Castanopsis acuminatissima*, *C. argentea*, *C. javanica*, *Dacrycarpus imbricatus*, *Engelhardtia spicata*, *Lithocarpus sundaicus*, *L. pseudomoluccus*, *Querqus lineata*, *Quercus pyriformis*, *Rapanea hasseltii* and *Turpinia sphaerocarpa.* Thus, in this regard we are practicing restoration to promote and amplify conservation. The ecological restoration would help a great deal in amplifying species diversity and improving forest hydrology and various ecosystem functions (Mansur & Kartawinata, 2017; Purwaningsih *et al.*, 2017; Rahmah *et al.*, 2016).

The biomass and carbon stock of the forest stand of trees with DBH $\geq$ 10 cm in Register 45B were relatively low (50.86 ton/ha and 25.44 ton C/ha), lower compared to the biomass and carbon stock in primary peat swamp forest of Central Kalimantan (Dharmawan, 2012), and in primary forest of the Siberut National Park (Bismark *et al*., 2008). In the primary forest of Batang Toru in North Sumatra, the carbon stock was 109.36 ton C/ha (Samsoedin *et al*., 2009); in Gede-Pangrango National Park was 275.56 ton C/ha (Siregar, 2007) and in Sarawak Malaysia it ranged between 165 to 202.5 ton C/ha (Brown, 1997). It is very much lower than that in the peat swamp forest at Tanjung Puting National Park, where the mean above ground carbon reached 200 ton C/ha (Murdiyarso *et al*., 2010). The correlation of diameter and biomass for the trees with DBH $\geq$ 10 cm at the study site is presented in Fig. 5. It showed that the diameter corresponded relatively closely to the biomass, as indicated by high coefficient of determination (>80%).

It is estimated that as much as 45–50 percent of forest biomass contained carbon (Brown, 1997). Forest stands, especially young trees (poles, saplings, and seedlings) have a great potential for absorbing and reducing atmospheric carbon dioxide as the result of the rapid growth process of young trees. Carbon sequestration is closely related to forest stand biomass, which is produced by biomass density and tree species (Heriyanto & Siregar, 2007; Onrizal *et al.,* 2008; Bismark *et al*., 2008; Dharmawan & Samsoedin, 2012).

The carbon emission in Indonesia is high. The carbon dioxide emissions from 2001–2006 reached 827,058 CO_2eq Gg/year derived from industrial processes (Purwanta, 2010). The highest CO_2 emissions amounting to 95 million tons of CO_2eq occurred in 2006 and the lowest was recorded in the amount of 74 million tons of CO_2eq in 2010 (INCAS, 2015) until the end of 1980, carbon emissions in the world reached 117 ± 35 G ton C (82–152 G ton C), due to the burning of fossil fuels and coal, as well as forest fire (IPCC, 2006). Forests as carbon sink should, therefore, be managed properly in order to be able to overcome such high amount of carbon dioxide in the atmosphere. Clean Development Mechanism requires developing tropical countries to be fully committed to reduce the rate of global warming by preventing forest degradation (Masripatin, 2007; Lucina *et al.,* 2011). Indonesia, the country having largest area of tropical rain forest in the world after Brazil and Zaire is required to establish baseline data of tropical rain forest capacity in absorbing carbon emission. The baseline data are critical to support the application of carbon trade regulation after successfully ratified (Siregar & Heriyanto, 2010).

CONCLUSION

Quantified measurements of species composition and structure of a lower montane forest of the Register 45B in West Lampung can be used as a basis for further field studies and assessments of other protection forests in the West Lampung Regency or even in the Lampung Province. The species richness in this forest was extremely poor due to heavy disturbances. We should emphasize that the one-hectare plot did not in any way constitute a representative of the surrounding montane forests of West Lampung. It did not denote a minimal area, but it provided a useful description of the forest locally. Structurally and floristically it was a developing and regenerating disturbed forest, with diverse species, consisting mainly of primary forest species. Species that were represented in almost all diameter classes, although with low density, will likely survive, develop and maintain them-selves in the forest in the future.

Because the regeneration was poor, we believe that the Register 45 B will remain unchanged in many years to come. Allowing it to return gradually through a natural succession to a forest similar to its original condition was one of many ways to manage and improve protection forests (Rahmah *et al.*, 2016). Since the succession was very slow, it could be assisted and enhanced by ecological restoration. It could be implemented by planting tree species native to the site, along with actions to prevent further disturbances, including fire and tree poaching. Restoration could also use species that were once assumed to be present in the forest, including, *Castanopsis acuminatissima*, *C. argentea*, *Dacrycarpus imbricatus*, *Engelhardtia spicata*, *Lithocarpus sundai-cus*, *Lithocarpus* sp., *Shorea platyclados*, *Shorea* spp., *Syzygium lineatum*, *Turpinia sphaerocarpa*. Other species that could be utilized in restoration included rare, endemic and species having multipurpose uses. Conservation and management of protection forest on scientific basis should be encouraged. Further study on structure and composition of forests over a wider area in Lampung is necessary to understand variation in composition related to habitat factors.

ACKNOWLEDGEMENTS

The authors would like to thank the Head of Forestry Service of Lampung Province, the people and village officers of Tri Budi Syukur who provided various assistance including helps during the field work.

REFERENCES

ARIFIANI, D. & MAHYUNI, R. 2012. Keanekaragaman flora di Taman Nasional Bukit Barisan Selatan, Provinsi Lampung. *Berita Biologi* 11 (2): 149–160.

BPS (BADAN PUSAT STATISTIK). 2016. *Lampung Barat Dalam Angka*. Badan Pusat Statistik Lampung Barat. Propinsi Lampung.

BEUKEMA, H., DANIELSEN, F., VINCENT, G., HARDIWINOTO, S. & VAN ANDEL, J. 2007. Plant and bird diversity in rubber agro-forests in the lowlands of Sumatra, Indonesia. *Agroforestry Systems* 70 (3): 217–242.

BISMARK, M., SUBIANDONO, E. & HERI-YANTO, N. M. 2008. Keragaman dan potensi jenis serta kandungan karbon hutan mangrove di Sungai Subelen Siberut. *Jurnal Penelitian Hutan dan Konservasi Alam* 5 (3): 297–306.

BROWN, S. 1997. *Estimating Biomass and Bio-mass Change of Tropical Forest: a Primer*. For the Food and Agriculture Organization of the United Nations. Rome. FAO Forestry paper No. 134.

BUSTOMI, S., WAHJONO, D. & HERIYANTO, N. M. 2006. Klasifikasi potensi tegakan hutan alam berdasarkan citra satelit di Kelompok Hutan Sungai Bomberai-Sungai Besiri di Kabupaten Fakfak, Papua. *Jurnal Penelitian Hutan dan Konservasi Alam* 3 (4): 437–458.

CHAVE, J., ANDALO, C., BROWN, S., CAIRNS, M. A., CHAMBERS, J. Q., EAMUS, D. FÖLSTER, H., FROMARD, F., HIGUCHI, N., KIRA, T., LESCURE, J. P., NELSON, B. W., OGAWA, H., PUIG, H., RIÉRA, B. & YAMAKURA, T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia* 145 (1): 87–89.

CLIMATE-DATA.ORG. 2017. https://en.climate-data.org/location/587431/ - Climate: Passer Liwa, 16 December 2017.

COX, G.W. 1992. *Laboratory Manual of General Ecology*. 2nd Ed. Wm. C. Brown Company Publisher, Dubuque, Iowa.

DHARMAWAN, I. W. S. & SAMSOEDIN, I. 2012. Dinamika potensi biomassa karbon pada landskap hutan bekas tebangan di Hutan Penelitian Malinau. *Jurnal Penelitian Sosial dan Ekonomi Kehutanan* 9 (1): 12–20.

DHARMAWAN, I. W. S. 2012. *Evaluasi Dinamika Cadangan Karbon Tetap pada Hu-tan Gambut Primer dan Bekas Terbakar di Hampangen dan Kalampangan, Kalimantan Tengah*. Institut Pertanian Bogor, Bogor. [PhD. Dissertation].

DIETSCH, T. V., PHILPOTT, S. M., RICE, R. A., GREENBERG, R. & BICHIER, P. 2004. Conservation policy in coffee landscapes. *Science* 303: 625–626.

ELDER, A. A. 2013. *Competition among three primate species at Way Canguk, Sumatra, Indonesia.* Stony Brook University, Stony Brook. [PhD. Dissertation].

EWUSIE, J. Y. 1980. *Pengantar Ekologi Tropika*. Terjemahan, ITB–Press. Bandung.

GAVEAU, D. L. A., LINKIE, M., SUYADI, LEVANG, P. & LEADER–WILLIAMS, N. 2009. Three decades of deforestation in southwest Sumatra: effects of coffee prices, law enforcement and rural poverty. *Biological Conservation* 142 (3): 597–605.

HAIRIAH, K., SULISTIYANI, M., SUPRAYOGO, H., WIDIANTO, D., PURNOMOSIDHI, P., WIDODO, R. H. & VAN NOORDWIJK, M. 2006. Litter layer residence time in forest and coffee agroforestry systems in Sumberjaya, West Lampung. *Forest Ecology and Management* 224: 45–57.

HAIRIAH, K., & RAHAYU, S. 2007. *Pengukuran Karbon Tersimpan di Berbagai Macam Penggunaan Lahan*. World Agroforestry Centre-ICRAF SEA Regional Office, Bogor & University of Brawidjaja, Malang.

HAIRIAH, K., EKADINATA, A., SARI, R. R. & RAHAYU, S. 2011. *Pengukuran Cadangan Karbon*: *dari Tingkat Lahan ke Bentang Lahan*. 2[ed]. World Agroforestry Centre-ICRAF SEA Regional Office, Bogor & University of Brawijaya, Malang.

HASANAH, N., TABADEPU, H., AHARI, B., BUCHORI, D. 2006. *Butterfly Community Structure in Bukit Barisan Selatan National Park, Sumatera*. *Wildlife Conservation Society.* Technical Report.

HELMI, N., KARTAWINATA, K. & SAMSOEDIN, I. 2009. An undescribed lowland natural forest at Bodogol, the Gunung Gede-Pangrango National Park, Cibodas Biosphere Reserve, West Java, Indonesia. *Reinwardtia* 13 (1): 33–44.

HERIANSYAH, I., MIYAKUNI, K., KATO, T., KIYONO, Y. & KANAZAWA, Y. 2007. Growth characteristics and biomass accumulations of *Acacia mangium* under different management practices in Indonesia. *Journal of Tropical Forest Science* 19 (4): 226 –235.

HERIYANTO, N. M. & SIREGAR, C. A. 2007. Biomasa dan kandungan karbon pada hutan tanaman tusam (*Pinus merkusii* Jungh et de Vriese) umur lima tahun di Cianten Bogor. *Jurnal Penelitian Hutan dan Konservasi Alam* 4 (1): 75–81.

HUANG, J. C-C., JAZDZYK, E. L., NUSALAWO, M., MARYANTO, I., UNKAMSI, M., WIANTORO, S. & KINGSTON, T. 2014. A recent bat survey reveals Bukit Barisan Selatan landscape as a Chir opteran diversity hotspot in Sumatra. *Acta Chiropterologica* 16 (2): 413–449.

HUBBELL, S. P. & FOSTER, R. B. 1986. Biology, chance and history and the structure of tropical rain forest tree communities. In: DIAMOND, J. M. & CASE, T. J. (Eds.). *Community Ecology*. Harper and Row, New York. Pp. 314–329.

INCAS (INDONESIA NATIONAL CARBON ACCOUNTING SYSTEM). 2015. Indonesia luncurkan alat baru hadapi perubahan iklim. Program REDD-I. Hutan dan Perubahan Iklim di Indonesia. Kementerian Lingkungan Hidup dan Kehutanan Indonesia.

IPCC (INTERNATIONAL PANEL ON CLIMATE CHANGE). 2006. *IPCC guidelines for nation greenhouse gas inventories*. IPCC National Greenhouse Gas Inventories Programme. IGES. Japan.

ISTOMO. 2002. *Kandungan Fosfor dan Kalsium serta Penyebarannya pada Tanah dan Tumbuhan Hutan Rawa Gambut. Studi Kasus di Wilayah Bagian Kesatuan Pemangku Hutan Bagan, Kabupaten Rokan Hilir, Riau.* Institut Pertanian Bogor, Bogor. [PhD. Dissertation].

IUCN, 2001. IUCN Red List and Criteria (version 3.1).

KARTAWINATA, K., SAMSOEDIN, I., HERIYANTO, N. M. & AFRIASTINI, J. J. 2004. A tree species inventory in a one-hectare a plot at the Batang Gadis National Park, North Sumatra, Indonesia. *Reinwardtia* 12 (2): 145–157.

KARTAWINATA, K. 2005. Six decades of natural vegetation studies in Indonesia. In: SOEMODIHARDJO, S. & SASTRAPRADJA, S. D. (Eds.). *Six Decades of Science and Scientists in Indonesia*. Naturindo, Bogor. Pp. 95–140.

KARTAWINATA, K. 2013. *Diversitas Ekosistem Alami Indonesia*. LIPI Press & Yayasan Pustaka Obor Indonesia, Jakarta.

KEEL, S., GENTRY, A. H. & SPINZI, L. 1993. Using vegetation analysis to facilitate the selection of conservation sites in Eastern Paraguay. *Conservation Biology* 7 (1): 66–75.

KERSHAW, K. A. 1964. *Quantitative and Dynamic Ecology*. Edward Arnold Publishing Co. Ltd. London.

KINNAIRD, M. F. & O'BRIEN, T. G. 2005. Fast foods of the forest: the influence of figs on primates and hornbills across Wallace's Line. In: DEW, J. L. & BOUBLI, J. P. (Eds.). *Tropical Fruits and Frugivores: In Search for Strong Interactors*. Kluwer Academic/ Plenum Publishers, the Netherlands. Pp. 155–184.

LUCINA, M., GINOGA, K. L., WIBOWO, A., BAINNAURA, A. & PARTIANI, T. 2011. *Prosedur Operasi Standar* (*SOP*) *untuk*

Pengukuran Stok Karbon di Kawasan Konservasi. Pusat Penelitian dan Pengembangan Perubahan Iklim dan Kebijakan. Badan Penelitian dan Pengembangan Kehutanan, Kementerian Kehutanan, Indonesia. Kerjasama dengan International Tropical Timber Organization (ITTO).

MANSUR, M., HIDAYATI, N. & JUHAETI, T. 2011. Struktur dan komposisi vegetasi pohon serta estimasi biomassa, kandungan karbon dan laju fotosintesis di Taman Nasional Gunung Halimun-Salak. *Jurnal Teknologi Lingkungan* 12 (2): 161–169.

MANSUR, M. & K. KARTAWINATA. 2017. Phytosociology of a lower montane forests on Mt. Batulanteh, Sumbawa, Indonesia. *Reinwardtia* 16 (2): 77–92.

MASRIPATIN, N. 2007. *Apa itu REDD*. Badan Penelitian dan Pengembangan Kehutanan. Departemen Kehutanan.

McCUNE, B. & GRACE, J. B. 2002. *Analysis of Ecological Communities*, MJM Software Design, Gleneden Beach, Oregon.

MICROSOFT OFFICE EXCEL. 2010. Microsoft Inc. United States of America.

MUELLER-DOMBOIS, D. & ELLENBERG, H. 1974. *Aims and Methods of Vegetation Ecology*. John Wiley & Sons. Inc. New York.

MUNAWAROH, E. & APRILIANTI, P. 2011. Eksplorasi keanekaragaman tumbuhan anggrek di Kawasan Taman Nasional Bukit Barisan Selatan, Kab. Lampung, Propinsi Lampung. In: WIDYATMOKO, D., PUSPANINGTYAS, D. M., HENDRIAN, R., IRAWATI, FIJRIDIANTO, I. A., WITONO, J. R., ROSNIATI, R., ARIATI, S. R., RAHAYU, S., PRAPTOSUWIRYO, T. N. (Eds.). *Prosiding seminar Nasional Konservasi Tumbuhan Tropika Kondisi Terkini dan Tantangan ke Depan*. Pp. 118–127.

MUNAWAROH, E. & LATIFAH, D. 2015. Eksplorasi dan inventarisasi Tumbuhan di Taman Nasional Bukit Barisan Selatan Resort Sukaraja, Lampung, Sumatera, dalam rangka konservasi keanekaragaman jenis Tumbuhan di Kebun Raya Liwa. In: YUZAMMI, HADIAH, J. T., ASIKIN, D., RISNA, R. A. (Eds.). *Prosiding Ekspose dan Seminar Pembangunan Kebun Raya Daerah*: *Membangun Kebun Raya untuk Penyelamatan Keaneka-ragaman Hayati dan Lingkungan Menuju Eko-nomi Hijau. Pusat Konservasi Tumbuhan Kebun Raya Bogor–LIPI*. Pp: 278–289.

MURDIYARSO, D., DONATO, D., KAUFFMAN, J. B., KURNIANTO, S., STIDHAM, M. & KANNINEN, M. 2010. Carbon Storage in Mangrove and Peatland Ecosystems: A Preliminary Account from Plots in Indonesia. *CIFOR Working Paper* 48: 1–35.

NELSON, B. W., MESQUITA, R., PERIERA, J. L. G., DE SOUZA, S. G. A., BATISTA, G. T. & COUTO, L. B. 1999. Allometric regressions for improved estimate of secondary forest biomass in the central Amazon. *Forest Ecology and Management* 117: 149–167.

OHSAWA, M., NAINGGOLAN, N., TANAKA, N. & ANWAR, C. 1985. Altitudinal zonation of forest vegetation on Mount Kerinci, Sumatra: with comparisons to the temperate region of East Asia. *Journal of Tropical Ecology* 1: 193–216.

ONRIZAL, ISMAIL, PERBATAKUSUMA, E. A., SUDJITO, H., SUPRIJATNA, J., & WIJAYANTO, I. H. 2008. Struktur vegetasi dan simpanan karbon hutan hujan primer di Batang Toru, Sumatera Utara. *Jurnal Biologi Indonesia* 5 (2): 187–199.

PASYA, G. 2011. *Model Penanganan Konflik Lingkungan Dalam Pengelolaan Kawasan Hutan Lindung. Studi Kasus Di Kawasan Hutan Lindung Register 45B Bukit Rigis Propinsi Lampung.* Institut Pertanian Bogor, Bogor. [PhD. Dissertation].

PHILPOTT, S. M., BICHIER, P., RICE, R. A. & GREENBERG, R. 2008. Biodiversity conservation, yield, and alternative products in coffee agroecosystems in Sumatra, Indonesia. Bio*diversity and Conservation* 17 (8):1805–1820.

PRASETYO, A., HIKMAT, A. & PRASETYO, L. B. 2011. Pendugaan perubahan cadangan karbon di Tambling Wildlife Nature Conservation Taman Nasional Bukit Barisan Selatan. *Media Konservasi* 16 (2): 87–91.

PROCTOR, J., ANDERSON, J. M., CHAI, P. & VALLACK, H. M. 1983. Ecological studies in four contrasting tropical lowland rain forests in Gunung Mulu National Park. I. Forest Environment, structure and floristics. *Journal of Ecology* 71: 237–260.

PURWANINGSIH, POLOSAKAN, R., YUSUF, R. & KARTAWINATA, K. 2017. Phytosociological study of the montane forest on the south slope of Mt. Wilis, East Java, Indonesia. *Reinwardtia* 16 (1): 31– 45.

PURWANTA, W. 2010. Penghitungan emisi karbon dari lima sektor pembangunan berdasar metode IPCC dengan verifikasi faktor emisi dan data aktivitas lokal. *Jurnal Teknologi*

Lingkungan 11 (1): 71–77.

PUSAT PENELITIAN TANAH DAN AGROKLIMAT. 1993. *Peta Tanah Pulau Sumatera.* Badan Penelitian dan Pengembangan Pertanian, Departemen Pertanian. Bogor.

RAHMAH, KARTAWINATA, K., NISYAWATI, WARDHANA, W. & NURDIN. 2016. Tree species diversity in the lowland forest of the core zone of the Bukit Dua Belas National Park, Jambi. *Reinwardtia* 15 (1): 11–26.

RICHARDS, P. W. 1996. *The Tropical Rain Forest: An Ecological Study*. 2nd Ed. Cambridge University Press. Cambridge.

ROSALINA, Y., KARTAWINATA, K., NISYAWATI, NURDIN, E & SUPRIATNA, J. 2014. Floristic composition and structure of a peat swamp forest in the conservation area of the PT. National Sago Prima, Selat Panjang, Riau, Indonesia. *Reinwardtia* 14 (1): 193–210.

ROSHETKO, J. M., DELANEY, M., HAIRIAH, K. & PURNOMOSIDHI, P. 1999. Carbon stock of home garden systems in Lampung, Indonesia. In: GINTING, C., GAFUR, A., SUSILO, F. X., SALAM, A. K., ERWANTO, KARYANTO, A., UTOMO, S. D., KAMAL, M., LUMBANRAJA, J. & ABIDIN, Z. (Eds.). Proceedings Seminar towards Sustainable Agriculture in Humid Tropics Facing 21st Century. Bandar Lampung, Indonesia Pp. 552–564.

SAMSOEDIN, I., HERIYANTO, N. M. & SIREGAR, C. A. 2009. Biomassa karbon pada Daerah Aliran Sungai (DAS) Batang Toru, Sumatera Utara. *Info Hutan* 6 (2): 111–124.

SAMSOEDIN, I. & HERIYANTO, N. M. 2010. Struktur dan komposisi hutan pamah bekas tebangan ilegal di kelompok hutan Sei Lepan, Sei Serdang, Taman Nasional Gunung Leuser, Sumatera Utara. *Jurnal Penelitian Hutan dan Konservasi Alam* 8 (3): 299–314.

SAMSOEDIN, I., HERIYANTO, N. M. & BISMARK, M. 2014. Keanekaragaman hayati flora dan fauna di kawasan hutan Pertamina Bukit Datuk Dumai, Provinsi Riau. *Jurnal Penelitian Hutan dan Konservasi Alam* 11 (1): 77–89.

SCHMIDT, F. H. & FERGUSON, J. H. 1951. *Rainfall Types Based on Wet and Dry Period Rations for Indonesia with Western New Guinea*. Verhandelingen Djawatan Meteorologi dan Geofisika, Djakarta.

SHEIL, D., KARTAWINATA, K., SAMSOEDIN, I., PRIYADI, H. & AFRIASTINI, J. J. 2010. The lowland forest tree community in Malinau, Kalimantan (Indonesian Borneo): results from a one-hectare plot. *Plant Ecology & Diversity* 3 (1): 59–66.

SIMBOLON, H. & MIRMANTO, E. 1997. Altitudinal zonation of the forest vegetation in Gunung Halimun National Park, West Java. In: YONEDA, M., SUGARJITO, J. & SIMBOLON, H. (Eds.). *Research and Conservation of Biodiversity in Indonesia. Volume II: The Inventory of Natural Resources in Gunung Halimun National Park, LIPI, JICA and PHPA*, Bogor. Pp. 14–35.

SIREGAR, C. A. 2007. Potensi serapan karbon di Taman Nasional Gede Pangrango, Cibodas, Jawa Barat. *Info Hutan* 4 (3): 233–244.

SIREGAR, C. A. & HERIYANTO, N. M. 2010. Akumulasi biomassa karbon pada skenario hutan sekunder di Maribaya, Bogor, Jawa Barat. *Jurnal Penelitian Hutan dan Konservasi Alam* 8 (3): 215–226.

SOEPADMO, E. 1972. Fagaceae. *Flora Malesiana* 7 (3): 265–403.

SOIL SURVEY STAFF. 2003. *Keys to Soil Taxonomy*, 9th Edition. USDA Natural Resources Conservation Service. Washington DC.

SOLIHAH, S. M., WARDANI, F. M. & RAHAYU, S. 2014. Variasi struktur dan komposisi pohon pada petak-petak cuplikan vegetasi di kawasan Gunung Sekincau Bukit Barisan Selatan, Lampung Barat. *Buletin Kebun Raya* 17 (2): 79–90.

STEENIS, C. G. G. J. VAN, HAMZAH, A. & TOHA, M. 1972. *The Mountain Flora of Java.* E. J. Brill, Leiden.

SUBIANDONO, E., BISMARK, M., & HERIYANTO, N. M. 2013. Kemampuan *Avicennia marina* (Forsk.) Vierh. dan *Rhizophora apiculata* Blume dalam penyerapan polutan logam berat. *Jurnal Penelitian Hutan dan Konservasi Alam* 9 (1): 23–32.

SUYANTO, S., PERMANA, R. P., KHUSUSIYAH, N. & JOSHI, L. 2005. Land tenure, agroforestry adoption, and reduction of fire hazard in a forest zone: A case study from Lampung, Sumatra, Indonesia. *Agroforestry System* 65: 1–11.

SUYANTO, S. & OTSUKA, K. 2001. From deforestation to development of agroforests in customary land tenure areas of Sumatra. *Asian Economic Journal* 15 (1): 1–17.

SYAM, T., NISHIDE, H., SALAM, A. K., UTOMO, M., MAHI, A. K., LUMBANRAJA, J., NUGROHO, S. G. & KIMURA, M. 1997. Land use and cover changes in a hilly area of South Sumatra, Indonesia (from 1970 to 1990).

Soil Science and Plant Nutrition 43 (3): 587–599.

WALTER, H. 1973. *Vegetation of the Earth* (English edition). The English Universities Press, London.

WARDANI, M. & HERIYANTO, N. M. 2015. Autekologi damar asam/*Shorea hopeifolia* (F. Heim.) Symington di Taman Nasional Bukit Barisan Selatan, Lampung. *Buletin Plasma Nutfah* 21 (2): 89–98.

WHITMORE, T. C. 1978. The forest ecosystem of Malaysia, Singapore and Brunei: description, functioning and research needs. *Tropical Forest Ecosystems*, *Natural Resource Research* XIV, UNESCO, Paris. Pp. 639–651.

WHITMORE, T. C. 1984. *Tropical Rain Forests of the Far East,* 2nd Ed., Oxford University Press, Oxford.

WHITMORE, T. C. & TANTRA, I. G. M. 1986. *Tree Flora of Indonesia. Check list for Sumatra*. Forest Research and Development Centre, Bogor.

WHITTEN, A. J., DAMANIK, S. J. & HISYAM, N. 1984. *The Ecology of Sumatra.* Gadjah Mada University Press, Yogyakarta.

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Published by Herbarium Bogoriense, Botany Division, Research Center for Biology, Indonesian Institute of Sciences
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REINWARDTIA
Vol. 18. No. 1. 2019
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