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A phytosociological study of a lowland forest at the Tesso Nilo National Park, Riau

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ABSTRACT

A phytosociological study of a lowland forest was carried out at the Tesso Nilo National Park (TNNP), Riau. The objective of the study was to obtain quantitative data on the floristic composition and structure of the above-mentioned lowland forest. By establishing a plot of 1.0 ha, the quadrat method was used to collect the data. We recorded a total of 1,303 individuals of trees and saplings with diameters ≥ 2 cm, comprising 304 species, 153 genera, and 62 families. Using the dominance and density of two tree species, the forest community in the plot can be designated as ***Sloetia elongata-Pimelodendron griffithianum Association***. The species sharing the dominance were *Sloetia elongata* (Importance Value, IV = 14.43), *Pimelodendron griffithianum* (IV = 6.17), *Santiria laevigata* (IV = 5.45) and *Xylopia caudata* (IV = 5.17). Diameter records showed that 80% of trees in the plot were dominated by small individuals with diameters between 10-30 cm. Trees with diameters > 30 cm were *Dracaena* cf. *porteri* (diam. 75.6 cm), *Artocarpus elasticus* (63.3 cm), and *Ctenolophon parviflorus* (62.1 cm). Dipterocarp species was not important since they contributed only 4%, while non-dipterocarps shared 96% comprising 61 families. The highest basal area was shared by nine species, including one dipterocarp, *Shorea leprosula*. Several dipterocarp species occurring in TNNP have been listed in the IUCN Red List of Threatened Species, including *Anisoptera megistocarpa, Hopea ferruginea, Hopea pachycarpa, Shorea atrinervosa, Shorea faguetiana, Shorea lepidota* and *Vatica gamosepala*. The presence of a large number of small trees and a few large trees indicated that the forest in the plot was regenerating after heavy disturbances. Regenerating species were divided into five categories, in which 13 species were regenerating well with *Sloetia elongata* being the best regenerating species while dipterocarps were represented by *Shorea acuminata*. The occurrence of the majority of trees with a height of < 20 m further confirmed the dynamic status of the forest. The importance of primary and secondary forests in TNNP was discussed. Restoration to the original forest was recommended by planting primary forest species, including endemic, rare, and endangered tree species.

ABSTRAK

Penelitian fitososiologi di hutan pamah dilakukan di Taman Nasional Tesso Nilo (TNTN), Riau, dengan ujuan untuk memperoleh data kuantitatif tentang komposisi floristik dan struktur hutan pamah tersebut. Penelitian ini menggunakan metode kuadrat dengan membuat petak seluas 1.0 ha Studi ini mencatat 1.303 individu pohon dan anakan, yang terdiri atas 304 spesies 153 marga dan 62 suku. Dengan menggunakan kerapatan dan dominansi dua spesies, komunitas hutan dalam plot dapat dinamakan ***Asosiasi Sloetia elongata-Pimelodendron griffithianum***. Spesies yang berbagi dominansi adalah *Sloetia elongata* (NP/Nilai Penting = 14.43), *Pimelodendron griffithianum griffithianum* (NP = 6.17), *Santiria laevigata* (NP = 5.45) dan *Xylopia caudata* (5.17). Spesies *Dipterocarpaceae* tidak berperan penting karena hanya menyumbang 4% dan spesies nir-*Dipterocarpaceae* 96% ,yang mencakup 61 suku. Beberapa spesies *Dipterocarpaceae* yang terdapat di TNTN terdaftar dalam *IUCN Red List of Threatened Species*, termasuk *Anisoptera megistocarpa, Hopea ferrugineA, Hopea pachycarpa. Shorea atrinervosa, Shorea faguetiana, Shorea lepidota* dan *Vatica gamosepala*. Data diameter pohon menunjukkan bahwa 80% pohon didominasi oleh individu kecil dengan diameter 10-30 cm. Pohon dengan diameter besar >30 cm adalah *Dracaena* cf. *porteri* (diameter 75,6 cm), *Artocarpus elasticus* (63,3 cm) dan *Ctenolophon parviflorus* (62,1 cm). Kehadiran sejumlah besar pohon kecil dan beberapa pohon dengan diameter besar dalam plot menunjukkan bahwa hutan dalam plot tersebut beregenerasi setelah terjadi berbagai gangguan. Kehadiran mayoritas pohon dengan ketinggian <20 m menguatkan lebih lanjut status dinamka hutan. Hutan primer dan hutan sekunder di TNTN sebagai kawasan penting untuk konservasi dibahas. Restorasi ekologi untuk pemulihan kembali ke hutan yang mirip aslinya direkomendasikan melalui penanaman spesies hutan primer, termasuk spesies endemik, langka dan terancam punah.

Keywords: *conservation, lowland forest, national park, regeneration, restoration, species diversity, structure*

INTRODUCTION

Sumatra is one of the larger islands in Indonesia and its lowland tropical forest cover constitutes an important center for plant species and the distribution for many families and genera within the Malesian archipelago (Kartawinata, 2013; Whitmore, 1986). Yet, large areas of the forests have not been investigated. The forest in Sumatra is characterized by tall canopy trees dominated by dipterocarp species. Floristically, the forest of Sumatra remains relatively unknown (Laumonier, 1990). Scattered studies on vegetation, mainly forests, have been conducted in various parts of Sumatra, mainly in the

national parks and other protected areas. They have been reviewed by Anas et al (2019) and Rahmah et al (2016). The forests in Sumatra are the habitat of many species of flora, fauna, including several endangered species, such as tigers, elephants, rhinos, and orangutans.

During the last five decades the dipterocarp forests in Indonesia, including Sumatra, have experienced heavy disturbances, particularly extensive logging and conversion into oil palm plantations, mines, and industrial timber estates (Kartawinata, 2005; Kartawinata et al, 2008). At present, the remaining relatively intact, undisturbed primary forests occur on the lowland hills and montane forests of the interior of the island, with much of them are located in national parks, conservation areas, and protected forests. Degradation and loss of tropical forests have progressed rapidly. The Riau province is one of the areas on Sumatra that has seen rapid changes in land use over the last few decades. Mining, oil palm plantations, large-scale pulp and paper industry, and wood processing plants have transformed the province through the extraction of natural resources. Although beneficent for the economy, that have exerted extensive pressure on natural resource management efforts (Sargeant, 2001; Sheil et al, 2009). Conservation is thereby urgently needed. The region has the highest rank on lowland forest biodiversity and is one of the last habitats for the threatened Sumatran elephants (Gillison, 2001). Deforestation is a major cause of biological diversity loss and is of significant global concern (Wilson, 1988; Laurance, 2007) as it is estimated that more than half of the known terrestrial plant and animal species live in the forests (Millenium Ecosystem Assessment, 2005).

The Tesso Nilo National Park (TNNP), with an area of 190,000 ha, is one of the sites in Sumatra containing lowland forests (Prawiradilaga et al, 2014). With the TNNP forest exploited since 1979, immense adverse impacts have affected the national park's ecological balance and biodiversity.

The purpose of this study was to obtain quantitative data on the floristic composition and structure of a lowland forest in Riau, particularly TNNP. To date, such a study has not been conducted much in the area. The study focused on the descriptions of forests in terms of key structural parameters, species richness, relative abundance patterns, and family composition. These data are important for their many purposes, including measuring conservation suitability and priorities, for knowing the equilibrium conditions of forest communities, for explaining interactions within and between species, for predicting trends in the future composition of stands (Whittaker, 1974; Keel et al, 1993), for the provision of basic data for ecological restoration, for documenting tree flora, for analyzing species distribution patterns and for defining ecological classifications for forest mapping purposes.

METHODS

Species Composition

The TNNP is located ± 60 km from Pekanbaru, in Indragiri Hulu, Segati, Pelalawan Regency, Riau Province, with a range of altitudes from 100-200 m asl (above sea level) (Figure 1). It is situated at the coordinates of 0° 0'5.1 "- 0° 14'56" South and 101° 31'14.6 "- 101° 52'1.9" East. The topography is relatively flat. TNNP is located adjacent to Kerumutan Wildlife Park to the east, Bukit Rimbang Nature Reserve to the west, Bukit Tiga Puluh National Park to the southeast, and Kerinci Seblat National Park to the south. The forest consists of mixed dipterocarp stands, dominated by large trees of *Dipterocarpaceae, Moraceae, Annonaceae,* and *Anacardiaceae*. Gillison (2001) indicated a high plant species diversity in TNNP, whereby in plots of 1,800 m^2 he recorded 900 species, 267 genera, and 238 vascular plants. Audley-Charles (1987) and Hamilton (1979) have described the geological and vegetation histories of Sumatra. Gillison (2002) recorded that under the USDA soil classification system, the soils in TNNP were listed as Haplochemists and Paleodults, and ranged from swampy peats to dryland with elevation from 25-100 m asl, with peat of varying thickness overlaid by sands and sandy clays.

The climate of the central region of eastern Sumatra is super wet, with an annual rainfall of 2,000-3,000 mm (Gillison, 2001). Climatically TNNP belongs to the rainfall type C described by Schmidt & Ferguson (1951). The nearest rainfall station at Pekanbaru (9 m asl) showed a mean annual rainfall of 2, 870 mm (Figure 1), with two months of slightly dry period in June-July and ten-month of wet period in August-May. The mean monthly rainfall is >200 mm with highest in January

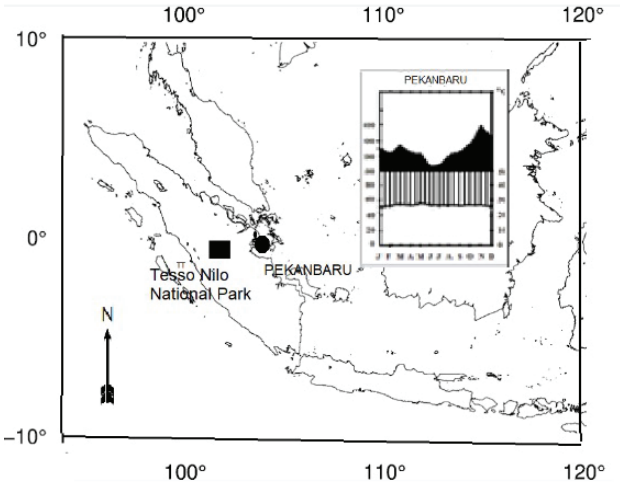

Figure 1. A map of the study site at Tesso Nilo National Park and a climate diagram for the meteorological station at Pekanbaru. The climate diagram shows the overwet climate with a slightly dry period in July (110 mm) and August (120 mm) and the ten-month wetter period in September-June with mean monthly rainfall > 1120 mm.

(400 mm). The mean temperature is between 26.2 ºC to 32.5 ºC, with only slight variation in average daily temperature.

Data Collection and Analysis

Field sampling was carried out in a lowland forest at the TNNP, using the quadrat method (Cox, 1967; Mueller-Dombois & Ellenberg, 1974, 2016). Plot size of 1 ha (100 m x 100 m) was selected to fit the topography. The plot was further divided into 100 subplots of 10 m x 10 m each. Within each subplot, trees with DBH (Diameter at Breast Height) ≥ 2 cm were counted and identified, and their positions recorded. Their diameters were measured, and their bole heights and tree heights were estimated. A forest profile diagram was constructed from a strip of 10 m x 50 m nested within the plot. Voucher specimens were collected and identified at the Herbarium Bogoriense, Center for Research in Biology, LIPI (now BRIN) Cibinong.

Definition and calculation of density, frequency, and dominance followed Cox (1967), Mueller-Dombois & Ellenberg (1974, 2016), and Rahmah et al (2016). Density is defined as the number of individuals per unit area obtained by counting individuals within subplots. The number of individuals per species is later calculated for one hectare. The Relative Density (RD) for each species is calculated using the following formula:

$$RD = \frac{\text{the number of individuals of a species}}{\text{the total number of individuals}} \times 100\%$$

Frequency is defined as the number of times a species occur in a given number of subplots within the plot and is expressed as a percentage of the total number of subplots. The Relative Frequency (RF) for each species is calculated using the following formula:

$$RF = \frac{\text{the frequency of a species}}{\text{the sum of the frequency of all species}} \times 100\%$$

Dominance for trees is defined as the stem cover, which is the same as the basal area. The basal area (BA) is obtained with the formula:

$$BA = (\tfrac{1}{2}d)^2 x\pi$$

where d stands for diameter. The Relative Dominance (RDo) is obtained with the following formula:

$$RD_o = \frac{\text{the dominance of a species}}{\text{the dominance of all species}} \times 100\%$$

The sum of density, frequency, and dominance is later used to indicate the importance of a species in the plot and this can be done only if they are expressed in terms of relative values. The Importance Value will then be computed with the formula:

$$IV = RD + RF + RD_o$$

RESULTS

Species composition

General observation showed that the forest at TNNP was relatively still in good condition as indicated by the occurrence of many primary forest species, including those of *Lauraceae*, *Dipterocarpaceae*, *Sapindaceae*, *Sapotaceae*, *Myristicaceae*, and *Burseraceae*. Further analysis, refers to Airy-Shaw (1975), Berg et al (2006), Keßler et al (2000), Whitmore (1986) shows that of 195 tree species recorded (Table 1) we identified 63 (32.3%) of them are secondary forest species (printed in boldface in Appendix 1). *Artocarpus heterophyllus*, *Pternandra galeata*, and *Scaphium macropodum* were secondary species with the highest Basal Area (Table 2), while *Artocarpus elasticus*, *Artocarpus scortechinii*, *Borassus* cf. *flabellifer*, and *Sloetia elongata* were four of the ten tree species with high Importance Value, *Sloetia elongata* having the highest (Table 3).

In the one-hectare plot, we recorded 1,303 individuals (diameter ≥2 cm) with a total basal area of 27.01 m², representing 304 tree species, 153 genera, and 62 families (Appendix 1, Table 1). They included 15 species of *Dipterocarpaceae*, but their density and frequency were low (Appendix 1): *Anisoptera megistocarpa*, *Hopea dryobalanoides*, *Hopea ferruginea*, *Hopea pachycarpa*, *Parashorea malaanonan*, *Shorea acuminata*, *Shorea atrinervosa*, *Shorea faguetiana*, *Shorea lepidota*, *Shorea leprosula*, *Shorea macroptera*, *Shorea parvifolia*, *Shorea retinodes*, *Vatica pauciflora*, and *Vatica ridleyana*.

Table 2 showed that big tree species with the highest mean basal area were *Dracaena* cf. *porteri* (mean BA= 0.32 m^2) and *Mangifera longipetiolata* (0.23 m^2). *Ctenolophon parvifolius* (0.20 m^2) was represented by two trees, and *Kokoona ochracea* (0.20 m^2) by one tree. *Dipterocarpaceae* was only represented by one big tree (*Shorea lepidota*) with a BA of 0.13 m^2.

Table 3 shows nine tree species with the highest IV and D in the plot. The data for IV and D are presented in Appendix 1. Based on IV the tree species could be classified into the following categories: (1) jointly dominant tree species with IV of 04.00-17.03, comprising nine species; (2) less important tree species with IV of 1.1-3.9, comprising 54 species; and (3) least important tree species with IV of ≤ 1.0. Among the jointly dominant species in category 1, *Sloetia elongata*, a secondary forest species, was the most prevalent, as indicated by IV of 17.09, while the rest of the group had low IV, ranging from 4.05 to 7.19.

Table 4 shows ten families with importance value >10, along with the number of species, density, and basal area. *Burseraceae*, *Dipterocarpaceae*, and *Moraceae* were the dominant families, and they have the highest importance value, density, and basal area. Large families containing many species were *Phyllanthaceae* (19), *Myristicaceae* (18), *Fabaceae* (17), and *Dipterocarpaceae* (16). The most common

families were *Burseraceae* (15) and *Dipterocarpaceae* (45). The contribution of the *Dipterocarpaceae* species was only 4%, while the non-dipterocarp (61 families) reached 96%.

Table 1. Vegetation characteristics of the plot at the TNNP.

Status	No. of species	No. of illegally traded individuals
Not protected, no harvest quotas	68	3,884
Not protected, exceeded harvest quotas	3	4,423
Protected	13	279*
TOTAL	**84**	**8,586**

Table 2. Species with the highest mean BA in one-hectare forest plot at the TNNP.

Species	Family	Density	Mean BA
Dracaena cf. *porteri*	*Asparagaceae*	2	0.32
Ormosia sumatrana	*Fabaceae*	1	0.16
Knema conferta	*Myristicaceae*	1	0.15
Castanopsis rhamnifolia	*Fagaceae*	2	0.14
Shorea lepidota	*Dipterocarpaceae*	1	0.13
Scaphium macropodum	*Malvaceae*	1	0.13
Artocarpus heterophyllus	*Moraceae*	3	0.11
Litsea tomentosa	*Lauraceae*	1	0.11
Pternandra galeata	*Melastomataceae*	1	0.10

Table 3. Tree species with highest Importance Value (IV) and Density in one hectare forest plot at the TNNP.

Species	Family	D	IV
Sloetia elongata	*Moraceae*	30	17.03
Pimelodendron griffithianum	*Euphorbiaceae*	15	07.19
Artocarpus elasticus	*Moraceae*	10	06.19
Santiria laevigata	*Burseraceae*	7	06.13
Artocarpus scortechinii	*Moraceae*	9	06.02
Xerospermum noronhianum	*Sapindaceae*	10	00.40
Horsfieldia polyspherula	*Myristicaceae*	11	05.09
Borassus cf. flabellifer	*Arecaceae*	7	04.54
Santiria oblongifolia	*Burseraceae*	8	04.05

The tree species regeneration could be reflected in the number of saplings recorded in the plot and could be classified into five categories (Appendix 2). Group 1 (Appendix 2) consisted of 13 species with very good regeneration as indicated by sapling density of 10-28 individuals/ha. *Sloetia elongata*, a secondary forest species with 28 individuals/ha was regenerating well. The regeneration of dipterocarp species was very poor. Of the 16 species present in the plot, only *Shorea macroptera* was registered in Group 1 (Appendix 2). There was only one species (*Hopea pachycarpa*) in Group 2 (Appendix 2), 11 species (*Anisoptera megistocarpa, Hopea dryobalanoides, Hopea ferruginea, Parashorea malaanonan, Shorea atrinervosa, Shorea faguetiana, Shorea leprosula, Shorea parvifolia, Shorea retinodes, Vatica pauciflora*, and *Vatica ridleyana*) in Group 3 (Appendix 2), one species (*Shorea lepidota*) in Group 4 (Appendix 2), and none in Group 5 (Appendix 2).

Structure

The structure of a forest can be indicated by its stratification (vertical distribution), individual distribution, and abundance of each plant species (Kershaw, 1964). Figure 2 shows the vertical and lateral distribution of the trees species presented in a profile diagram that was constructed from a strip of 10 m x 50 m nested within the plot, while Figure 3 indicates the tree distribution on the ground in the plot. The vertical distribution of trees in the entire plot consisted of three (3) layers. Layer A (top layer) was 35-45 meters in height. It was composed of 48 trees, 37 species, and 24 families, which were the primary forest species,

Table 4. Ten families with Importance Value > 10, Density and Basal Area in a lowland forest at Tesso Nilo National Park.

Family	Number of species	Density (individuals/ha)	Basal Area (m^2)	Family Importance Value
Moraceae	7	88	3.58	25.38
Burseraceae	14	115	2.30	24.14
Dipterocarpaceae	16	102	2.35	22.74
Myristicaceae	18	82	1.44	17.08
Phyllanthaceae	19	83	0.97	15.63
Myrtaceae	13	57	1.36	14.25
Sapindaceae	9	70	0.87	13.02
Annonaceae	13	61	0.81	12.22
Fabaceae	17	59	0.90	11.78
Lauraceae	14	45	1.05	11.15
Euphorbiaceae	8	47	0.81	10.52

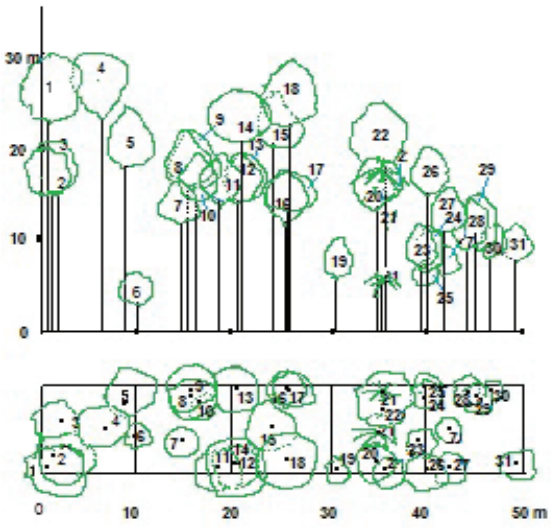

Figure 2. Profile diagram of forest in the plot. 1. *Hopea ferruginea*, 2. *Syzygium fastigiatum*, 3. *Urophyllum arboreum*, 4. *Hydnocarpus polypetalus*, 5. *Endiandra macrophylla*, 6. *Pternandra galeata*, 7. *Calophyllum macrocarpum*, 8. *Trigoniastrum hypoleucum*, 10. *Canarium littorale*, 11. *Pimelodendron griffithianum*, 12. *Canarium pilosum*, 13. *Porterandia anisophylla*, 14. *Dracaena* cf. *porteri*, 15. *Dacryodes rostrata*, 16. *Nephelium cuspidatum*, 17. *Parashorea malaanonan*, 18. *Baccaurea minor*, 19. *Mesua ferrea*, 20. *Maasia hypoleuca*, 21. *Oncosperma tigillarium*, 22. *Xylopia malayana*, 23. *Notaphoebe umbelliflora*, 24. *Triomma malaccensis*, 25. *Gymnacranthera forbessii*, 26. *Artocarpus scortechinii*, 27. *Garcinia maingayi*, 28. *Drypetes longifolia*, 29. *Dyera polypetala*, 30. *Syzygium hemsleyana*, 31. *Symplocos rubiginosa*.

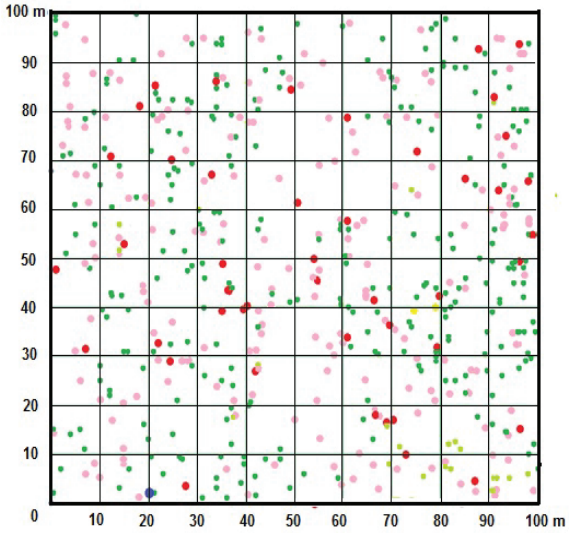

Figure 3. Map of all trees ≥ 10 cm dbh in the study plot at the Tesso Nilo National Park.

Legend:

- = 10.0-20.0 dbh
- = 30.0-40.0 ;
- = 50.0-60.0 ;
- = 70.0-80.0

including *Alseodaphne oblanceolata, Diospyros pyrrocarpa, Hopea dryobalanoides, Hopea ferruginea, Kokoona ochracea, Pouteria malaccensi, Santiria laevigata, Shorea ferruginea, Shorea lepidota,* and *Triomma malaccensis*. Layer B with the height of 20-30 m consisted of 148 species and 47 families, including 12 species of *Dipterocarpaceae* (30 trees), seven species of *Moraceae* (30 trees, of which 16 trees were *Sloetia elongata*), *Santiria spp.* (16 trees), *Xerospermum spp.* (13 trees) and *Xylopia caudata* (11 trees). Tree species in the layer with height <25 m constituted the largest share of the species in the plot. The above-mentioned canopy layers of trees reflected the structure of tropical forests and a common pattern of the dynamic process (Ogawa et al.. 1965). The largest number of individuals in the plot (80 %) was occupied by small trees (10-20 cm).

DISCUSSION

The species composition of the forest in the plot did not represent a typical undisturbed lowland forest of Sumatra. The structure, composition, and regeneration indicated that the forest had experienced various disturbances, including selective logging and harvesting by local inhabitants from the nearby villages. They frequent the forest and cut trees, which resulted in the formation of the open forest canopy. Dipterocarp species were not important as they contributed only 4% to the community, while non-dipterocarps, comprising 61 families, share 96 %. Using the dominance and density (Mueller-Dombois & Ellenberg, 1974, 2016) of the two tree species (Table 3), the forest community in the plot can be designated as ***Sloetia elongata-Pimelodendron griffithianum Association***.

Table 5 shows that the number of tree species in the present plot was comparable to those in many sites in the lowland forests of Sumatra, which were all secondary forests. It was lower than those in the Batang Gadis National Park, Ketambe, and Rimbo Panti, which were lowland primary forests. In addition to the data on regeneration in Appendix 2, our qualitative observations showed that tree regeneration took place under gaps, and the kind and density of seedlings and saplings present varied with gap size, as observed in various tropical forests elsewhere (Brokaw, 1985; Hartshorn, 1980; Poore,1968; Runkle, 1981; Whitmore, 1984). This indicated that the forest at TNNP was disturbed lowland forest, particularly a result of human activities, including commercial selective logging and tree poaching as well as harvesting by local people. Such a situation has stimulated the development of mixed forest with a high proportion of secondary forest species. The secondary forest species amounted to 63 (32.3 %), as printed in boldface and listed in Appendix 1. The most prominent species was *Sloetia elonggata* with the highest density and importance values, followed by *Artocarpus elasticus, Artocarpus scortechinii, Xerospermum noronhianum*, and *Borassus* cf *flabellifer* (Table 3). These species could grow on open sites in damaged forests as well as in small canopy gaps of primary and less disturbed forests. The occurrence of *Borassus* cf *flabellifer*, a tree palm that is typically dominant in seasonally dry forests and savannas, in the wet rain forest (Kartawinata, 2013) might be questionable, but Eagleton (2016), in his review of the genus *Borassus* and *Corypha*, stressed that *Borassus flabellifer* occurs in Sumatra naturally.

The secondary forest species occurring in the plots belonged to many families and the families that contained the highest number of secondary forest species were *Euphorbiaceae* (5), *Morceae* (6), and *Phyllanthaceae* (8). In Indonesia, they occurred in lowland to montane forests. The species of *Euphorbiaceae, Moraceae,* and *Phyllanthaceae* were dispersed by wind, birds and mammals (Berg & Corner, 2005; Berg et al, 2006; Pijl, 1982). These families can be found in the wet regions with altitudinal range of 0-1500 m asl, but they are particularly prominent in the lowland and they are very tolerant to direct solar radiation. They generally invade any open sites within and outside forests, even if mature tree individuals were present in the vicinity (Whitmore, 1984).

Because of various disturbances, the population of dipterocarp species, in general, has declined, and currently, in the plot, there were only 15 species with low density, basal area, and frequency (Appendix 1). Many species are becoming rare and threatened by extinction. Several dipterocarp species in TNNP have been listed in the IUCN Red List of Threatened Species, and they include *Anisoptera megistocarpa, Hopea ferruginea, Hopea pachycarpa. Shorea atrinervosa, Shorea faguetiana, Shorea lepidota, Vatica gamosepala.*

Most dipterocarp species were not regenerating well as shown in Appendix 2. They belonged to Group 3 (Appendix 2) and are of poorly regenerating species, and only two species, *Shorea acuminata*, and *Shorea macroptera*, occurred in Group 1 (Appendix 2) with very good regenerating species. Scarce and scattered big trees of diameters ≥ 10 cm with low regeneration and sparse structure reflected the heavily disturbed forest. Natural successions still took place but at a slow rate. Hence, the return of dipterocarp species to a population similar to that in an undisturbed forest would take a very long time. It is therefore recommended to enhance natural successions through ecological restoration by planting dipterocarp species, including the rare and threatened species, as well as non-dipterocarp species from the primary forests.

It should be noted that primary forest species of several families, including *Annonaceae, Dipterocarpaceae, Lauraceae, Myristica*, and *Sapindaceae* could reach large diameters. *Dracaena* cf. *porteri* could reach diameters of 70-80 cm, Ctenolophon parvifolius up to 60-70 cm, while *Hopea spp., Mangifera longifolia, Shorea spp.*, and *Santiria laevigata* could reach 50-60 cm. Dipterocarp species with small diameters present in the high number

indicated that they were the remnants of trees left after forest cutting and they have not been able to regenerate well.

The high number of primary forest species with small diameters was related to the presence of gaps. Dominant species in primary forest that could grow in gaps of various sizes included *Canarium pilosum, Cinnamomum javanicum, Dacryodes rostrata, Horsfieldia polyspherula, Magnolia liliifera, Santiria griffithii, Santiria oblongifolia, Shorea acuminata, Shorea macroptera, Xylopia caudata* and *Syzygium fastigiatum*. The overall regeneration in all subplots was indicated by the presence of a relatively large number of individuals with diameters of ≤ 20 cm. The number of individuals in the diameter classes of 5-10 cm and 10-20 cm may be used to indicate the regeneration status of a forest stand (Mueller-Dombois & Ellenberg, 1974; Richards, 1996). The presence of a large majority of trees with height of < 20 m (85 %) further confirmed the forest's dynamic status. There were only few trees with heights > 20 m (Figure 2). The percentage of trees with heights of 20-30 m was 11 % and those with heights > 30 m were 4 %. The tree species with the highest basal areas were *Dracaena* cf *porteri* (0.32 m^2). The presence of large numbers of small trees and a small number of trees with large diameters in a forest stand showed that the forest was regenerating after disturbances.

Figure 2 shows the profile diagram of the forest in a strip of 10 m x 50 m nested within the plot at TNNP. It shows the vertical and lateral distribution of the tree species. Figure 3 indicates the tree distribution that were ≥ 10 cm dbh in the plot. It was noted that in the TNNP forest gaps were present. High number of primary species intermediates between sapling and emergent sizes suggested that opening of canopy took place and formed small natural gaps. In the field, it was difficult to separate these forest gaps since they were seldom distinguishable (Richards, 1964; Wyatt-Smith, 1963) and the change from one unit to another was gradual.

Table 5. Comparison of the number of tree species in selected plots in several sites in Sumatra

Site	Plot size (Ha)	Number of tree species	Source
Tesso Nilo National Park, Jambi	1.0	195	**Present study**
Bukit Duabelas National Park 1, Jambi	1.0	113	Rahmah et al, 2016
Bukit Duabelas National Park 2, Jambi	1.0	89	Anas et al, 2021
Harapan Rainforest, Jambi	1.0	96	Mansur et al, 2010
Sei Lepan, Leuseur National Park, Aceh	1.0	110	Ismayadi & Heriyanto, 2010
Ketambe 1 Leuseur National Park, Aceh	1.6	116	Abdulhadi et al, 1989
Sekundur, Leuser National Park, North Sumatra	2.0	133	Priatna et al, 2004
Batang Gadis National Park, North Sumatra	1.0	184	Kartawinata et al, 2004
Rimbo Panti (diam. >5cm), West Sumatra	1.0	199	Yusuf et al, 2005

CONCLUSION

The number of species in a one-hectare plot at TNNP, comprising 1,303 individuals of trees and saplings, represented by 304 species, 153 genera, and 62 families, should not be representative of the species composition of forests in the area. The plot did not even represent a minimal area, but it sufficiently illustrated the species richness of the forest locally. Floristically the forest was a poor community with low species richness and dipterocarp species were not dominant. Structurally the forest in the plot was regenerating and developing after being heavily disturbed. It was heterogeneous, in which the floristic composition consisted of primary and secondary forest species. The heterogeneity was reflected also by the very low frequency and density of the species. The forest has experienced changes in tree species dominance from dipterocarps to non-dipterocarps due to various human activities. One of many ways to manage and improve the park is to allow the disturbed forest of TNNP to develop naturally following the processes of natural successions. This will lead to the formation of a forest similar to its original state. The rate of natural succession is very slow, but it could be accelerated and assisted by applying ecological restoration through planting tree species characteristics of the original undisturbed primary forests. In particular, rare and endemic species with multipurpose uses for the sustainable living of the indigenous communities and species with high conservation values, including species listed in the IUCN Red List, can be planted. Persistent species that would regenerate and can maintain themselves in the future were represented in almost all diameter classes in the forest, although with low density. Conservation and management of TNNP applying scientific principles should be supported by further research. Future research could cover basic aspects such as the structure and composition of forests over a wider area in the park to gain data and information on various biological and ecological characteristics, including

species distribution and variation in composition related to habitat factors.

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Appendix 1. Total Basal Area (BA in m^2), Total Density (D in trees/ha), Frequency (F in %), and Importance Value (IV in %) of trees and saplings recorded in the plot in the Tessonilo National Park, Riau. The secondary forest species are printed in boldface.

Species	Family	Tree				Sapling			
		D	F	BA	IV	D	F	BA	IV
Hydnocarpus kunstleri	Achariaceae	1	1	0.04	0.53	-	-	-	-
Hydnocarpus polypetalus	Achariaceae	3	3	0.31	2.31	-	-	-	-
Bouea oppositifolia	Anacardiaceae	3	3	0.21	1.93	2	2	0.00	0.62
Buchanania arborescens	Anacardiaceae	1	1	0.01	0.42	2	2	0.00	0.73
Gluta wallichii	Anacardiaceae	-	-	-	-	1	1	0.00	0.42
Mangifera longipetiolata	Anacardiaceae	2	2	0.45	2.51	7	7	0.01	2.72
Melanochyla caesia	Anacardiaceae	-	-	-	-	2	2	0.00	0.60
Melanochyla ferruginea	Anacardiaceae	-	-	-	-	1	1	0.00	0.35
Melanochyla fulvinervia	Anacardiaceae	3	3	0.18	1.82	1	1	0.00	0.37
Parishia insignis	Anacardiaceae	2	2	0.11	1.19	1	1	0.00	0.30
Semecarpus glauca	Anacardiaceae	-	-	-	-	2	2	0.00	0.64
***Swintonia* sp.**	Anacardiaceae	1	1	0.07	0.65	-	-	-	-
Anisophyllea disticha	Anisophylleaceae	-	-	-	-	2	2	0.00	0.67
Cyathocalyx sp.	Annonaceae	1	1	0.02	0.46	-	-	-	-
Goniothalamus macrophyllus	Annonaceae	-	-	-	-	8	8	0.00	2.39
Goniothalamus tapis	Annonaceae	-	-	-	-	7	7	0.01	2.58
Maasia hypoleuca	Annonaceae	3	3	0.08	1.46	1	1	0.00	0.31
Mezzettia parviflora	Annonaceae	-	-	-	-	2	2	0.00	0.64
Phaeanthus sumatrana	Annonaceae	-	-	-	-	1	1	0.00	0.31
Polyalthia lateriflora	Annonaceae	-	-	-	-	2	2	0.00	0.71
Polyalthia rumphii	Annonaceae	-	-	-	-	2	2	0.00	0.62
Polyalthia subcordata	Annonaceae	-	-	-	-	1	1	0.00	0.41
Xylopia caudata	Annonaceae	17	15	0.44	7.76	7	7	0.01	2.71
Xylopia fusca	Annonaceae	1	1	0.02	0.44	2	2	0.00	0.62
Xylopia malayana	Annonaceae	5	5	0.22	2.73	1	1	0.00	0.39
Dyera polyphylla	Apocynaceae	3	3	0.32	2.36	3	2	0.01	1.27
Ilex cymosa	Aquifoliaceae	-	-	-	-	5	5	0.00	1.7
Ilex macrophylla	Aquifoliaceae	-	-	-	-	1	1	0.00	0.3
Borassus* cf. *flabellifer	Arecaceae	7	7	0.49	4.54	-	-	-	-
Oncosperma tigillarium	Arecaceae	4	4	0.08	1.8	1	1	0.00	0.62
Dracaena cf. *porteri*	Asparagaceae	2	2	0.65	3.25	-	-	-	-
Dracaena elliptica	Asparagaceae	1	1	0.15	0.94	1	1	0.00	0.31
Deplanchea bancana	Bignoniaceae	1	1	0.05	0.58	-	-	-	-
Deplanchea glabra	Bignoniaceae	2	2	0.32	1.99	3	3	0.00	0.96
Canarium denticulatum	Burseraceae	3	3	0.04	1.27	6	5	0.01	2.53
Canarium littorale	Burseraceae	2	2	0.03	0.87	4	4	0.00	1.28
Canarium patentinervium	Burseraceae	-	-	-	-	3	3	0.00	1.2
Canarium pilosum	Burseraceae	5	5	0.07	2.16	9	9	0.01	3.28
Canarium pseudodecumanum	Burseraceae	-	-	-	-	3	3	0.00	0.93
Dacryodes incurvata	Burseraceae	7	7	0.27	3.68	3	3	0.01	1.4
Dacryodes rostrata	Burseraceae	-	-	-	-	9	9	0.01	2.98

Dacryodes rugosa	Burseraceae	4	4	0.11	1.93	3	3	0.00	0.92
Santiria apiculata	Burseraceae	4	4	0.09	1.87	4	4	0.00	1.38
Santiria griffithii	Burseraceae	3	3	0.06	1.38	6	5	0.01	1.99
Santiria laevigata	Burseraceae	7	7	0.90	6.13	7	6	0.01	2.53
Santiria oblongifolia	Burseraceae	8	8	0.26	4.05	5	5	0.01	1.84
Santiria rubiginosa	Burseraceae	2	2	0.11	1.19	2	2	0.01	1.89
Triomma malaccensis	Burseraceae	5	5	0.27	2.92	1	1	0.00	0.3
Gironniera hirta	Cannabaceae	-	-	-	-	2	2	0.01	1.39
Gironniera nervosa	Cannabaceae	3	3	0.08	1.46	2	2	0.01	1.02
Gironniera subaequalis	Cannabaceae	7	6	0.15	3.05	3	3	0.00	1.02
Gonocaryum gracile	Cardiopteridaceae	1	1	0.01	0.42	7	7	0.01	2.51
Euonymus indicus	Celastraceae	-	-	-	-	3	3	0.00	1.12
Lophopetalum javanum	Celastraceae	1	1	0.09	0.71	1	1	0.00	0.3
Calophyllum macrocarpum	Clusiaceae	5	5	0.15	2.45	4	4	0.00	1.23
Calophyllum pulcherrimum	Clusiaceae	2	2	0.08	1.07	-	-	-	-
Calophyllum rigidum	Clusiaceae	3	3	0.21	1.94	-	-	-	-
Garcinia bancana	Clusiaceae	-	-	-	-	2	2	0.00	0.97
Garcinia brevirostris	Clusiaceae	2	2	0.14	1.28	-	-	-	-
Garcinia celebica	Clusiaceae	2	2	0.08	1.06	1	1	0.00	0.47
Garcinia havilandii	Clusiaceae	2	2	0.05	0.95	-	-	-	-
Garcinia maingayi	Clusiaceae	2	2	0.03	0.88	1	1	0.00	0.31
Garcinia parvifolia	Clusiaceae	1	1	0.05	0.55	2	2	0.00	0.7
Mesua ferrea	Clusiaceae	1	1	0.03	0.5	2	2	0.00	1.02
Mesua lepidota	Clusiaceae	2	2	0.06	0.97	3	3	0.00	1.05
Ellipanthus tomentosus	Connaraceae	-	-	-	-	1	1	0.00	0.31
Mastixia pentandra	Cornaceae	1	1	0.04	0.54	8	8	0.03	5.01
Ctenolophon parvifolius	Ctenolophonaceae	2	2	0.40	2.3	14	11	0.02	5.52
Dillenia ovata	Dilleniaceae	5	4	0.42	3.32	-	-	-	-
Anisoptera megistocarpa	Dipterocarpaceae	2	2	0.05	0.95	1	1	0.00	0.3
Hopea dryobalanoides	Dipterocarpaceae	5	5	0.43	3.53	2	2	0.01	1.18
Hopea ferruginea	Dipterocarpaceae	8	6	0.57	4.84	2	2	0.01	1.66
Hopea pachycarpa	Dipterocarpaceae	4	4	0.05	1.72	7	6	0.01	2.86
Parashorea malaanonan	Dipterocarpaceae	1	1	0.02	0.44	2	2	0.00	0.75
Shorea acuminata	Dipterocarpaceae	3	3	0.07	1.41	18	17	0.02	6.24
Shorea atrinervosa	Dipterocarpaceae	1	1	0.02	0.45	2	2	0.00	0.88
Shorea faguetiana	Dipterocarpaceae	1	1	0.12	0.86	1	1	0.00	0.34
Shorea lepidota	Dipterocarpaceae	1	1	0.13	0.9	-	-	-	-
Shorea leprosula	Dipterocarpaceae	1	1	0.03	0.5	2	2	0.00	0.83
Shorea macroptera	Dipterocarpaceae	8	7	0.25	3.8	10	10	0.01	3.61
Shorea parvifolia	Dipterocarpaceae	3	3	0.06	1.35	2	2	0.00	0.68
Shorea retinodes	Dipterocarpaceae	2	2	0.06	0.98	3	3	0.00	1.07
Vatica pauciflora	Dipterocarpaceae	5	4	0.39	3.21	2	2	0.00	0.78
Vatica ridleyana	Dipterocarpaceae	2	2	0.03	0.86	1	1	0.00	0.31
Diospyros barteri	Ebenaceae	-	-	-	-	1	1	0.00	0.3
Diospyros buxifolia	Ebenaceae	-	-	-	-	2	2	0.00	0.61
Diospyros cf.*nutans*	Ebenaceae	-	-	-	-	1	1	0.00	0.35

Diospyros confertiflora	Ebenaceae	-	-	-	-	2	2	0.00	0.62
Diospyros oblonga	Ebenaceae	-	-	-	-	1	1	0.00	0.37
Diospyros oblongifolia	Ebenaceae	-	-	-	-	2	2	0.01	1.41
Diospyros pendula	Ebenaceae	1	1	0.02	0.46	1	1	0.00	0.36
Diospyros pyrrhocarpa	Ebenaceae	3	3	0.22	1.97	1	1	0.01	0.99
Diospyros rigida	Ebenaceae	-	-	-	-	2	2	0.00	0.66
Diospyros rostrata	Ebenaceae	-	-	-	-	1	1	0.00	0.54
Diospyros siamang	Ebenaceae	-	-	-	-	1	1	0.00	0.47
Diospyros sumatrana	Ebenaceae	3	3	0.07	1.42	3	3	0.00	0.96
Diospyros venosa	Ebenaceae	1	1	0.03	1.97	1	1	0.00	0.33
Diospyros virginiana	Ebenaceae	-	-	-	-	1	1	0.00	0.54
Elaeocarpus glaber	Elaeocarpaceae	-	-	-	-	2	2	0.00	0.65
Elaeocarpus palembanicus	Elaeocarpaceae	-	-	-	-	1	1	0.00	0.58
Elaeocarpus petiolatus	Elaeocarpaceae	-	-	-	-	1	1	0.00	0.49
Blumeodendron tokbrai	Euphorbiaceae	2	1	0.04	0.73	-	-	-	-
Macaranga caladiifolia	Euphorbiaceae	2	2	0.03	0.86	-	-	-	-
Macaranga denticulata	Euphorbiaceae	1	1	0.05	0.56	-	-	-	-
Macaranga tanarius	Euphorbiaceae	1	1	0.04	0.52	1	1	0.00	0.31
Macaranga triloba	Euphorbiaceae	-	-	-	-	1	1	0.00	0.33
Neoscortechinia kingii	Euphorbiaceae	2	2	0.21	1.57	2	2	0.01	1.31
Pimelodendron griffithianum	Euphorbiaceae	15	15	0.39	7.19	16	14	0.03	6.67
Ptychopyxis costata	Euphorbiaceae	1	1	0.01	0.41	3	3	0.01	1.46
Adenanthera pavonina	Fabaceae	1	1	0.03	0.51	1	1	0.00	0.5
Afzelia rhomboidea	Fabaceae	1	1	0.02	0.44	-	-	-	-
Albizia splendens	Fabaceae	1	1	0.03	0.49	-	-	-	-
Archidendron bubalinum	Fabaceae	1	1	0.03	0.48	2	2	0.00	0.6
Archidendron clypearia	Fabaceae	2	1	0.04	0.73	-	-	-	-
Archidendron microcarpum	Fabaceae	-	-	-	-	2	2	0.00	0.72
Callerya atropurpurea	Fabaceae	1	1	0.18	1.09	12	12	0.01	3.87
Dialium patens	Fabaceae	-	-	-	-	2	2	0.00	0.63
Dialium platysepalum	Fabaceae	1	1	0.03	0.5	-	-	-	-
Koompassia malaccensis	Fabaceae	1	1	0.11	0.82	3	3	0.01	2.08
Ormosia sumatrana	Fabaceae	1	1	0.16	0.98	-	-	-	-
Parkia speciosa	Fabaceae	1	1	0.06	0.61	1	1	0.00	0.3
Saraca declinata	Fabaceae	-	-	-	-	17	14	0.03	6.54
Sindora bruggemanii	Fabaceae	1	1	0.15	0.94	4	3	0.00	1.13
Sindora coriacea	Fabaceae	-	-	-	-	1	1	0.00	0.3
Sindora leiocarpa	Fabaceae	-	-	-	-	1	1	0.00	0.34
Sindora sumatrana	Fabaceae	-	-	-	-	1	1	0.00	0.67
Castanopsis costata	Fagaceae	-	-	-	-	1	1	0.00	0.54
Castanopsis megacarpa	Fagaceae	-	-	-	-	1	1	0.00	0.36
Castanopsis rhamnifolia	Fagaceae	2	2	0.28	1.83	-	-	-	-
Lithocarpus conocarpus	Fagaceae	-	-	-	-	1	1	0.00	0.59
Lithocarpus lucidus	Fagaceae	1	1	0.03	0.5	1	1	0.00	0.36
Lithocarpus wallichianus	Fagaceae	1	1	0.04	0.54	-	-	-	-
Ryparosa caesia	Flacourtiaceae	1	1	0.03	0.49	4	4	0.01	1.57

Ryparosa kunstleri	Flacourtiaceae	1	1	0.03	0.49	-	-	-	-
Fagraea racemosa	Gentianaceae	1	1	0.01	0.41	2	2	0.00	0.64
Ixonanthes icosandra	Ixonanthaceae	1	1	0.05	0.55	2	2	0.00	0.63
Teijsmanniodendron coriaceum	Lamiaceae	-	-	-	-	1	1	0.00	0.33
Vitex gamosepala	Lamiaceae	-	-	-	-	4	4	0.00	1.44
Actinodaphne gullavara	Lauraceae	-	-	-	-	1	1	0.00	0.31
Actinodaphne macrophylla	Lauraceae	-	-	-	-	1	1	0.00	0.3
Alseodaphne oblanceolata	Lauraceae	5	5	0.46	3.66	4	3	0.01	1.6
Beilschmiedia sp.	Lauraceae	1	1	0.01	0.42	2	2	0.00	0.66
Cinnamomum javanicum	Lauraceae	1	1	0.02	0.44	3	3	0.00	1.04
Cinnamomum porrectum	Lauraceae	1	1	0.07	0.63	-	-	-	-
Cryptocarya scortechinii	Lauraceae	1	1	0.01	0.41	2	2	0.00	0.85
Dehaasia caesia	Lauraceae	1	1	0.05	0.57	3	3	0.00	1.16
Dehaasia palembanica	Lauraceae	-	-	-	-	1	1	0.00	0.3
Endiandra macrophylla	Lauraceae	3	3	0.15	1.7	2	2	0.01	1.29
Litsea costalis var. *nidularis*	Lauraceae	1	1	0.02	0.44	3	3	0.01	1.28
Litsea noronhae	Lauraceae	-	-	-	-	2	2	0.00	0.65
Litsea resinosa	Lauraceae	3	3	0.10	1.52	-	-	-	-
Litsea tomentosa	Lauraceae	1	1	0.11	0.79	-	-	-	-
Notaphoebe umbelliflora	Lauraceae	3	3	0.03	1.25	-	-	-	-
Barringtonia cf *lanceolata*	Lecytidaceae	-	-	-	-	6	6	0.01	2.27
Barringtonia macrostachya	Lecytidaceae	1	1	0.01	0.41	18	17	0.03	7.29
Magnolia liliifera	Magnoliaceae	3	3	0.13	1.62	10	8	0.01	3.29
Coelostegia griffithii	Malvaceae	2	2	0.03	0.87	3	3	0.01	1.41
Durio excelsus	Malvaceae	2	2	0.05	0.93	-	-	-	-
Microcos paniculata	Malvaceae	1	1	0.03	0.49	6	6	0.00	2.04
Pentace erectinervia	Malvaceae	3	3	0.18	1.84	-	-	-	-
Scaphium macropodum	Malvaceae	1	1	0.13	0.87	-	-	-	-
Memecylon caeruleum	Melastomataceae	2	2	0.05	0.93	4	4	0.00	1.5
Memecylon edule	Melastomataceae	1	1	0.02	0.45	1	1	0.00	0.52
Memecylon excelsum	Melastomataceae	-	-	-	-	1	1	0.00	0.43
Memecylon garcinioides	Melastomataceae	-	-	-	-	1	1	0.00	0.3
Memecylon myrsinoides	Melastomataceae	3	3	0.11	1.55	3	3	0.00	1.02
Memecylon oligoneurum	Melastomataceae	-	-	-	-	1	1	0.00	0.35
Memecylon ovatum	Melastomataceae	-	-	-	-	1	1	0.00	0.37
Pternandra coerulescens	Melastomataceae	-	-	-	-	1	1	0.00	0.35
Pternandra galeata	Melastomataceae	1	1	0.10	0.78	-	-	-	-
Aglaia silvestris	Meliaceae	1	1	0.05	0.57	1	1	0.00	0.3
Aphanamixis borneensis	Meliaceae	1	1	0.07	0.66	1	1	0.00	0.3
Aphanamixis polystachya	Meliaceae	1	1	0.02	0.45	-	-	-	-
Aphanamixis sumatrana	Meliaceae	-	-	-	-	2	2	0.00	0.63
Chisocheton ceramicus	Meliaceae	-	-	-	-	2	2	0.00	0.66
Sandoricum koetjape	Meliaceae	-	-	-	-	3	2	0.01	1.46
Artocarpus elasticus	Moraceae	10	9	0.71	6.33	-	-	-	-
Artocarpus heterophyllus	Moraceae	2	2	0.34	2.08	1	1	0.00	0.39
Artocarpus kemando	Moraceae	1	1	0.03	0.51	-	-	-	-

Artocarpus nitidus	Moraceae	-	-	-	-	1	1	0.00	0.42
Artocarpus rigidus	Moraceae	-	-	-	-	1	1	0.00	0.31
Artocarpus scortechinii	Moraceae	9	9	0.68	6.02	5	4	0.01	2.3
Sloetia elongata	Moraceae	30	26	1.75	17.3	28	21	0.05	11.2
Gymnacranthera bancana	Myristicaceae	5	5	0.47	3.69	-	-	-	-
Gymnacranthera contracta	Myristicaceae	-	-	-	-	1	1	0.00	0.39
Gymnacranthera forbesii	Myristicaceae	2	1	0.14	1.12	8	8	0.02	3.97
Horsfieldia glabra	Myristicaceae	-	-	-	-	8	8	0.01	3.44
Horsfieldia grandis	Myristicaceae	1	1	0.01	0.42	-	-	-	-
Horsfieldia irya	Myristicaceae	-	-	-	-	1	1	0.00	0.3
Horsfieldia polyspherula	Myristicaceae	11	10	0.29	5.09	10	9	0.03	5.7
Horsfieldia subglobosa	Myristicaceae	2	2	0.09	1.09	1	1	0.00	0.3
Knema cinerea	Myristicaceae	-	-	-	-	1	1	0.00	0.35
Knema conferta	Myristicaceae	1	1	0.15	0.94	-	-	-	-
Knema curtisii	Myristicaceae	-	-	-	-	3	3	0.01	1.85
Knema intermedia	Myristicaceae	-	-	-	-	1	1	0.00	0.3
Knema latericia	Myristicaceae	1	1	0.01	0.42	2	2	0.00	1
Knema latifolia	Myristicaceae	4	4	0.05	1.7	3	3	0.00	1.18
Knema plumulosa	Myristicaceae	-	-	-	-	4	4	0.00	1.25
Knema pseudolaurina	Myristicaceae	-	-	-	-	1	1	0.01	0.79
Myristica iners	Myristicaceae	1	1	0.02	0.45	3	3	0.01	1.27
Myristica maxima	Myristicaceae	5	5	0.09	2.25	2	2	0.00	0.86
Rhodamnia cinerea	Myrtaceae	3	3	0.14	1.66	-	-	-	-
Syzygium cf. decipiens	Myrtaceae	1	1	0.03	0.5	-	-	-	-
Syzygium cf. grande	Myrtaceae	3	3	0.14	1.68	4	3	0.00	1.22
Syzygium fastigiatum	Myrtaceae	12	12	0.34	5.85	3	3	0.00	1.01
Syzygium hemsleyanum	Myrtaceae	4	4	0.12	1.97	-	-	-	-
Syzygium incarnatum	Myrtaceae	3	3	0.09	1.49	-	-	-	-
Syzygium lepidocarpum	Myrtaceae	1	1	0.02	0.47	2	2	0.01	1.21
Syzygium lineatum	Myrtaceae	-	-	-	-	2	2	0.00	0.61
Syzygium magnoliifolium	Myrtaceae	2	2	0.03	0.89	1	1	0.01	0.86
Syzygium palembanicum	Myrtaceae	4	4	0.28	2.61	-	-	-	-
Syzygium ridleyi	Myrtaceae	-	-	-	-	2	2	0.00	0.77
Syzygium zeylanicum	Myrtaceae	6	6	0.12	2.74	1	1	0.00	0.36
Syzygium zollingerianum	Myrtaceae	1	1	0.01	0.42	2	2	0.00	0.65
Gomphia serrata	Ochnaceae	2	2	0.04	0.91	1	1	0.00	0.31
Ochanostachys amentacea	Olacaceae	6	6	0.31	3.46	2	2	0.01	1.07
Chionanthus sp.	Oleaceae	1	1	0.01	0.43	1	1	0.00	0.3
Sarcotheca griffithii	Oxalidaceae	1	1	0.03	0.5	-	-	-	-
Galearia filiformis	Pandaceae	-	-	-	-	1	1	0.00	0.3
Galearia maingayi	Pandaceae	2	2	0.04	0.9	1	1	0.01	0.99
Adinandra sarosanthera	Pentaphylacaceae	2	2	0.09	1.1	5	5	0.00	1.62
Trigonopleura malayana	Peraceae	2	2	0.03	0.87	-	-	-	-
Antidesma cuspidatum	Phyllanthaceae	-	-	-	-	4	4	0.00	1.33
Antidesma neurocarpum	Phyllanthaceae	-	-	-	-	2	2	0.00	0.62
Aporosa frutescens	Phyllanthaceae	1	1	0.02	0.45	10	8	0.02	4.2

Aporosa grandistipula	Phyllanthaceae	-	-	-	-	1	1	0.00	0.51
Aporosa lucida	Phyllanthaceae	2	2	0.05	0.97	3	3	0.00	0.98
Aporosa nervosa	Phyllanthaceae	3	3	0.11	1.57	3	3	0.00	1
Aporosa nigricans	Phyllanthaceae	-	-	-	-	1	1	0.00	0.3
Aporosa nitida	Phyllanthaceae	1	1	0.1	0.44	14	12	0.02	5.22
Aporosa prainiana	Phyllanthaceae	-	-	-	-	5	5	0.01	2
Aporosa subcaudata	Phyllanthaceae	-	-	-	-	10	10	0.01	3.55
Baccaurea brevipes	Phyllanthaceae	-	-	-	-	1	1	0.00	0.51
Baccaurea deflexa	Phyllanthaceae	1	1	0.02	0.45	1	1	0.00	0.36
Baccaurea dulcis	Phyllanthaceae	-	-	-	-	1	1	0.00	0.4
Baccaurea macrocarpa	Phyllanthaceae	5	4	0.23	2.57	1	1	0.00	0.33
Baccaurea minor	Phyllanthaceae	3	3	0.27	2.17	1	1	0.00	0.34
Baccaurea polyneura	Phyllanthaceae	-	-	-	-	1	1	0.01	0.92
Baccaurea puberula	Phyllanthaceae	2	2	0.12	1.21	-	-	-	-
Baccaurea sumatrana	Phyllanthaceae	3	3	0.06	1.35	1	1	0.00	0.46
Glochidion rubrum	Phyllanthaceae	-	-	-	-	2	2	0.00	0.67
Austrobuxus nitidus	Picrodendraceae	3	3	0.31	2.34	5	5	0.01	1.84
Ryparosa javanica	Polygalaceae	-	-	-	-	1	1	0.00	0.33
Xanthophyllum curtisii	Polygalaceae	-	-	-	-	1	1	0.00	0.31
Xanthophyllum flavescens	Polygalaceae	1	1	0.02	0.45	6	6	0.02	3.32
Xanthophyllum rufum	Polygalaceae	6	6	0.13	2.78	4	4	0.00	1.37
Xanthophyllum scortechinii	Polygalaceae	1	1	0.07	0.64	1	1	0.00	0.3
Xanthophyllum stipitatum	Polygalaceae	1	1	0.04	0.53	0	0	0	0
Xanthophyllum vitellinum	Polygalaceae	1	1	0.03	0.51	1	1	0.00	0.31
Ardisia cf. lamponga	Primulaceae	-	-	-	-	1	1	0.00	0.3
Ardisia cf. macrocalyx	Primulaceae	-	-	-	-	2	2	0.00	0.67
Ardisia teysmanniana	Primulaceae	-	-	-	-	1	1	0.00	0.33
Kokoona ochracea	Primulaceae	1	1	0.20	1.14	1	1	0.00	0.63
Drypetes longifolia	Putranjivaceae	2	2	0.05	0.95	1	1	0.00	0.3
Carallia brachiata	Rhizoporaceae	1	1	0.03	0.48	1	1	0.00	0.31
Gynotroches axillaris	Rhizoporaceae	1	1	0.05	0.55	-	-	-	-
Parinari oblongifolia	Rosaceae	1	1	0.03	0.5	-	-	-	-
Prunus arborea	Rosaceae	3	3	0.10	1.54	1	1	0.00	0.36
Gardenia tubifera	Rubiaceae	-	-	-	-	1	1	0.00	0.35
Hypobathrum microcarpum	Rubiaceae	3	3	0.06	1.37	1	1	0.00	0.3
Ixora congesta	Rubiaceae	-	-	-	-	1	1	0.00	0.49
Lasianthus scabridus &	Rubiaceae	-	-	-	-	1	1	0.00	0.3
Lasianthus stercorarius	Rubiaceae	-	-	-	-	1	1	0.00	0.3
Porterandia anisophylla	Rubiaceae	2	2	0.05	0.94	1	1	0.01	0.9
Prismatomeris tetrandra	Rubiaceae	-	-	-	-	3	3	0.00	0.9
Psychotria viridiflora	Rubiaceae	-	-	-	-	1	1	0.00	0.37
Psydrax dicoccos	Rubiaceae	-	-	-	-	1	1	0.00	0.33
Saprosma arboreum	Rubiaceae	-	-	-	-	7	7	0.01	2.54
Timonius cf. bilitonensis	Rubiaceae	1	1	0.02	0.44	2	2	0.00	0.62
Timonius flavescens	Rubiaceae	3	3	0.06	1.36	1	1	0.00	0.4
Timonius stipulosus	Rubiaceae	1	1	0.01	0.42	3	3	0.01	1.68

Urophyllum arboreum	Rubiaceae	1	1	0.01	0.43	3	3	0.00	0.97
Urophyllum corymbosum	Rubiaceae	-	-	-	-	8	8	0.02	3.6
Urophyllum hirsutum	Rubiaceae	-	-	-	-	6	6	0.00	1.95
Evodia lunu-ankenda	Rutaceae	-	-	-	-	2	2	0.00	0.75
Tetractomia obovata	Rutaceae	1	1	0.09	0.71	-	-	-	-
Meliosma nitida	Sabiaceae	-	-	-	-	9	8	0.01	2.87
Allophylus cobbe	Sapindaceae	2	2	0.03	0.86	1	1	0.00	0.34
Mischocarpus pentapetalus	Sapindaceae	-	-	-	-	1	1	0.00	0.3
Nephelium cuspidatum	Sapindaceae	3	3	0.07	1.4	12	10	0.01	4.02
Nephelium juglandifolium	Sapindaceae	1	1	0.02	0.44	7	6	0.01	2.45
Nephelium mangayi	Sapindaceae	2	2	0.05	0.96	3	2	0.00	0.91
Nephelium ramboutan-ake	Sapindaceae	-	-	-	-	2	2	0.00	0.76
Rhysatoechia acuminata	Sapindaceae	-	-	-	-	4	4	0.01	2.07
Xerospermum laevigatum	Sapindaceae	7	7	0.24	3.58	10	8	0.01	3.55
Xerospermum noronhianum	Sapindaceae	10	10	0.40	5.33	5	5	0.01	2.32
Madhuca sericea	Sapotaceae	2	2	0.07	1.02	2	2	0.00	0.61
Palaquium calophyllum	Sapotaceae	-	-	-	-	1	1	0.00	0.58
Palaquium ridleyi	Sapotaceae	-	-	-	-	1	1	0.00	0.4
Palaquium rostratum	Sapotaceae	5	5	0.34	3.21	-	-	-	-
Payena leerii	Sapotaceae	1	1	0.02	0.45	1	1	0.00	0.3
Payena lucida	Sapotaceae	1	1	0.01	0.42	-	-	-	-
Pouteria malaccensis	Sapotaceae	3	3	0.35	2.48	3	3	0.01	1.4
Eurycoma longifolia	Simarubaceae	-	-	-	-	1	1	0.00	0.3
Symplocos lucida	Symplocaceae	1	1	0.02	0.46	1	1	0.00	0.3
Symplocos rubiginosa	Symplocaceae	1	1	0.02	0.45	4	3	0.00	1.1
Gordonia cf excelsa	Theaceae	-	-	-	-	3	2	0.01	1.92
Ternstroemia toquian	Theaceae	-	-	-	-	1	1	0.00	0.33
Tetramerista glabra	Theaceae	1	1	0.02	0.44	1	1	0.00	0.3
Aquilaria malaccensis	Thymelaceae	1	1	0.01	0.41	-	-	-	-
Gonystylus acuminatus	Thymelaceae	-	-	-	-	1	1	0.00	0.3
Gonystylus borneensis	Thymelaceae	1	1	0.03	0.5	-	-	-	-
Trigoniastrum hypoleucum	Trigoniaceae	2	2	0.13	1.27	1	1	0.00	0.3

Appendix 2. The saplings, as expressed in density (individuals/ha), indicating the regeneration in the plot of a lowland forest in TNNP are classified into five groups.

Group 1: Very good regenerating species; sapling density: 10-28 individuals/ha.

Species	Family	Density (individuals/ha)	
		Sapling	Tree
Sloetia elongata	Moraceae	28	30
Pimelodendron griffithianum	Euphorbiaceae	16	15
Shorea acuminata	Dipterocarpaceae	18	3
Barringtonia macrostachya	Lecytidaceae	18	1
Aporosa nitida	Phyllanthaceae	14	1
Ctenolophon parvifolius	Ctenolophonaceae	14	2
Nephelium cuspidatum	Sapindaceae	12	3
Callerya atropurpurea	Fabaceae	12	1
Horsfieldia polyspherula	Myristicaceae	10	11
Shorea macroptera	Dipterocarpaceae	10	8
Xerospermum laevigatum	Sapindaceae	10	7
Magnolia liliifera	Magnoliaceae	10	3
Aporosa frutescens	Phyllanthaceae	10	1

Group 2: Good regenerating species, Sapling density: 5-9/ha

Adinandra sarosanthera, Artocarpus scortechinii, Austrobuxus nitidus, Canarium denticulatum, Canarium pilosum, Gymnacranthera forbesii, Gonocaryum gracile, ***Hopea pachycarpa****, Mangifera longipetiolata, Mastixia pentandra, Microcos paniculata, Nephelium juglandifolium, Santiria griffithii, Santiria laevigata, Santiria oblongifolia, Xanthophyllum flavescens, Xerospermum noronhianum,* and *Xylopia caudata.*

Group 3. Poorly regenerating species; sapling density: 5-8/ha;

Adenanthera pavonina, Aglaia silvestris, Allophylus cobbe, Alseodaphne oblanceolata, ***Anisoptera megistocarpa,*** *Aphanamixis borneensis, Aporosa lucida, Archidendron bubalinum, Artocarpus heterophyllus, Baccaurea deflexa, Baccaurea macrocarpa, Baccaurea minor, Baccaurea sumatrana, Beilschmiedia* sp., *Bouea oppositifolia, Buchanania arborescens Canarium littorale, Calophyllum macrocarpum, Carallia brachiata, Chionanthus* sp., *Cinnamomum javanicum, Coelostegia griffithii, Cryptocarya scortechinii, Dacryodes incurvata, Dacryodes rugosa , Dehaasia caesia, Deplanchea glabra polyphylla, Diospyros pendula, Diospyros pyrrhocarpa, Diospyros sumatrana, Diospyros venosa, Dracaena elliptica, Drypetes longifolia, Dyera polyphylla, Endiandra macrophylla, Fagraea racemosa, Galearia maingayi, Garcinia celebica, Garcinia maingayi, Garcinia parvifolia, Gironniera nervosa, Gironniera subaequalis, Gomphia serrata,* ***Hopea dryobalanoides, Hopea ferruginea****, Horsfieldia subglobosa, Hypobathrum microcarpum, Ixonanthes icosandra, Knema latericia, Knema latifolia, Kokoona ochracea, Koompassia malaccensis, Lithocarpus lucidus, Litsea costalis* var. *nidularis, Maasia hypoleuca, Macaranga tanarius, Madhuca sericea, Melanochyla fulvinervia, Lophopetalum javanum, Memecylon caeruleum, Memecylon edule, Memecylon myrsinoides, Mesua ferrea, Mesua lepidota, Myristica iners, Myristica maxima, Neoscortechinia kingii, Nephelium mangayi, Ochanostachys amentacea, Oncosperma tigillarium,* ***Parashorea malaanonan,*** *Parishia insignis, Payena leerii, Porterandia anisophylla, Prunus arborea, Ptychopyxis costata, Ryparosa caesia, Santiria apiculata, Santiria rubiginosa,* ***Shorea atrinervosa, Shorea faguetiana, Shorea leprosula Shorea parvifolia, Shorea retinodes*** *Sindora bruggemanii, Symplocos lucida, Symplocos rubiginosa, Syzygium fastigiatum, Syzygium cf. grande, Syzygium lepidocarpum, Syzygium magnoliifolium, Syzygium zeylanicum, Syzygium zollingerianum, Tetramerista glabra, Timonius cf. bilitonensis, Timonius flavescen, s Timonius stipulosus, Trigoniastrum hypoleucum, Triomma malaccensi,s Urophyllum arboreum,* ***Vatica pauciflora, Vatica ridleyana,*** *Xanthophyllum rufum, Xanthophyllum scortechinii, Xanthophyllum vitellinum Xylopia malayana* and *Xylopia fusca.*

Group 4. Non-regenerating species; no saplings

Afzelia rhomboidea, Albizia splendens, Aphanamixis polystachya, Aquilaria malaccensis, Archidendron clypearia, Artocarpus elasticus, Artocarpus kemando, Baccaurea pubera, Blumeodendron tokbrai, Borassus sp. (cf *flabellifer*), *Calophyllum rigidum, Calophyllum pulcherrimum, Cinnamomum porrectum, Cyathocalyx* sp., *Deplanchea bancana, Dialium platysepalum, Dillenia ovata, Durio excelsus, Dracaena* cf. *porteri, Garcinia havilandii, Garcinia brevirostris, Gonystylus borneensis, Gymnacranthera bancana, Gynotroches axillaris, Horsfieldia grandis, Hydnocarpus kunstleri, Hydnocarpus polypetalus, Knema conferta, Lithocarpus wallichianus, Litsea resinosa, Litsea tomentosa, Macaranga caladiifolia, Macaranga denticulata, Notaphoebe umbelliflora, Ormosia sumatrana, Palaquium rostratum, Parinari oblongifolia, Payena lucida, Pentace erectinervia, Pternandra galeata, Rhodamnia cinerea, Ryparosa kunstleri, Sarcotheca griffithii, Scaphium macropodum,* ***Shorea lepidota***, *Swintonia* sp., *Syzygium cf. decipiens, Syzygium incarnatum, Syzygium palembanicum, Syzygium hemsleyanum, Tetractomia obovata, Trigonopleura malayana and Xanthophyllum stipitatum.*

Group 5. Developing saplings.

Actinodaphne gullavara, Actinodaphne macrophylla, Anisophyllea disticha, Antidesma cuspidatum, Antidesma neurocarpum, Aphanamixis sumatrana, Aporosa grandistipula, Aporosa nigricans, Aporosa prainiana, Aporosa subcaudata, Archidendron microcarpum, Ardisia cf. lamponga, Ardisia cf. macrocalyx, Ardisia teysmanniana, Artocarpus nitidus, Artocarpus rigidus, Baccaurea brevipes, Baccaurea dulcis, Baccaurea polyneura, Barringtonia cf *lanceolata, Canarium patentinervium, Canarium pseudodecumanum, Castanopsis costata, Castanopsis megacarpa, Chisocheton ceramicus, Dacryodes rostrata, Dehaasia palembanica, Dialium patens, Diospyros barteri, Diospyros buxifolia, Diospyros* cf.*nutans, Diospyros confertiflora, Diospyros oblonga, Diospyros oblongifolia, Diospyros rigida, Diospyros rostrata, Diospyros siamang, Diospyros virginiana, Elaeocarpus glaber, Elaeocarpus palembanicus, Elaeocarpus petiolatus, Ellipanthus tomentosus, Euonymus indicus, Eurycoma longifolia, Evodia lunu-ankenda, Galearia filiformis, Garcinia bancana, Gardenia tubifera, Gironniera hirta, Glochidion rubrum, Gluta wallichii, Goniothalamus macrophyllus, Goniothalamus tapis, Gonystylus acuminatus, Gordonia cf excelsa, Gymnacranthera contracta, Horsfieldia glabra, Horsfieldia irya, Ilex cymosa, Ilex macrophylla, Ixora congesta, Knema cinerea, Knema curtisii, Knema intermedia, Knema plumulosa, Knema pseudolaurina, Lasianthus scabridus, Lasianthus stercorarius, Lithocarpus conocarpus, Litsea noronhae, Macaranga triloba, Melanochyla caesia, Melanochyla ferruginea, Meliosma nitida, Memecylon excelsus, Memecylon garcinioides, Memecylon oligoneurum, Memecylon ovatum, Mezzettia parviflora, Mischocarpus pentapetalus, Nephelium ramboutan-ake, Palaquium calophyllum, Palaquium ridleyi, Phaeanthus sumatrana, Polyalthia lateriflora, Polyalthia rumphii, Polyalthia subcordata, Prismatomeris tetrandra, Psychotria viridiflora, Psydrax dicoccos, Pternandra caerulescens, Rhysatoechia acuminata, Ryparosa javanica, Sandoricum koetjape, Saprosma arboreum, Saraca declinata, Semecarpus glauca, Sindora coriacea, Sindora leiocarpa, Sindora sumatrana, Syzygium lineatum, Syzygium ridleyi, Teijsmanniodendron coriaceum, Ternstroemia toquian, Urophyllum corymbosum, Urophyllum hirsutum, Vitex gamosepala* and *Xanthophyllum curtisii.*