Species Composition and Structure of Forests in the Muara Kendawangan Nature Reserve, West-Kalimantan, Indonesia

Purwaningsih¹, and K Kartawinata²

¹Botany Division, Research Center for Biology, Indonesian Institute of Sciences (LIPI)
²Integrative Research Center, The Field Museum
1400 Lake Shore Drive, Chicago, IL 60605. USA

E-mail: purazali@yahoo.co.id

Abstract. Indonesia’s forests are globally known for their high species diversity but many regions remain little known and so are floristic compositions of many conservation areas. This study investigated the tree communities in the heath, peat swamp, dryland dipterocarp and seasonal peat swamp forests at the Muara Kendawangan Nature Reserve, West Kalimantan. We established a plot size of (50mx60 m) in each forest type, thus the total area sampled was 1.2 ha. We enumerated trees with stem diameter ≥7cm on dryland dipterocarp and swamp forests as well as individuals with stem diameter ≥2 cm in heath forest. In the plot of 1.2 ha, we recorded 1.416 trees, representing 87 species, 57 genera and 28 families. Floristically the entire sampled forests consisted of Schima wallichii-Shorea balangeran association and Baeckea frutescens-Rhodomyrtus tomentosa association. The Schima wallichii-Shorea balangeran association consists of Rhodamnia cinerea-Diospyros hermaphroditica subassociation, Baccacuera lanceolata-Calophyllum inophyllum subassociation and Syzygium fusticuliferum-Adinandra dumosa subassociation. The forest communities investigated along the habitat gradient have low species richness. Further intensive studies in the above forest types as well as in the other community types present in the Muara Kendawangan Nature Reserve are necessary to provide data for better management of the reserve.

1. Introduction
The lowland forest of West Kalimantan covers mangrove, freshwater swamp, peat swamp, dryland dipterocarp and heath forests [1]. Much of these forests have been exploited for timber and converted into oil palm plantation. The remaining good undisturbed natural forests occur in national parks and nature reserves. One of these reserves is the Muara Kendawangan Nature Reserve (MKNR) in the Ketapang Regency, West Kalimantan.

Unlike the nearby Gunung Palung National Park, the species composition of forests within MKNR is less known. So far, the earlier floristic and vegetation studies have been carried out by [2-3]. Several surveys on ecological potentials have been carried out around the reserve, including in the Panggok, Bintan, Nata Lembawang and Bukit Marau forest regions [4-5]. MKNR comprised several ecosystems, including coastal, peat swamp, heath and lowland forests [6].
The MKNR was established on 12 October 1982 with a total area of ± 175,000 ha by the Decree of the Minister of Agriculture (Surat Keputusan Menteri Pertanian Nomor 575/Kpts/Um/10/1982). The area was further reduced to 149,079 ha by the Decree of the Minister of Forestry (Surat Keputusan Menteri Kehutanan Nomor 174/Kpts-II/1993 tanggal 4 November 1993). MKNR is the largest among six nature reserves in West Kalimantan [6-7]. MNKR comprised coastal forest, peat swamp forest, seasonal peat swamp forest, heath forest, grassland, and dryland dipterocarp forest. Economically important species can be found in MNKR, including meranti (Shorea spp.), ulin (Eusideroxylon zwageri) and jelutung (Dyera lowii) [2-3].

It was indicated that various ecosystems in MNKR were the habitat and breeding ground of primates, turtles and birds [6-7]. The coastal forest constitutes the hatching ground of a turtle species known locally as penyu belimbing (Dermochelys coriacea) and kuragading (Orlitia borneensis) as well as breeding site for various bird species. The peat swamp forest was the habitat of several primate species, including bekantan (Nasalis larvatus).

The presence of the above plant and animal species made MNKR unique, but the uniqueness of MNKR has been steadily disappearing due to intensive human disturbances, including uncontrolled illegal logging, conversion to other uses, and forest fire. During the period of January-October 2001, hotspots were recorded in 11 districts (kecamatan) with the highest (100 spots) occurred in Kendawangan district. The highest occurrence of hotspots was recorded in August 2001, especially in Dusun Hilir district.

The objective of the present study was to perform quantitative measurements of species composition and structure of the peat swamp, seasonal peat swamp, dryland and heath forests. The scope of this paper is limited to the description of the forest in terms of the main structural characteristic, species richness, pattern of relative abundance and family composition. Such data are important for measuring the suitability and the priority of conservation [8] as well as for ecological restoration of disturbed forests.

2. Study Site
The study site was located on the side of the Membuluh River at 2°32.418’ South and 110°20.992’ East in the Tiang Balai subdistrict (desa) with the altitude of 0-30 m asl (above sea level). An areal photo with a scale of 1:50,000 showed that the grassland covered larger area than the forests. Several extensive grasslands dominated by Hymenachme sp. Scleria sp. and Fimbristylis sp. could be found in the Tiang Balai region, including the area of Kakora Lake and Arang-Arang Lake. MNKR consisted mainly of grasslands and a few islands covered by peat swamp and heath forests on sandy soils. Stagnant water occurred on many sites. The seasonal swamp forest was located in the Kampas Menali forest area, where the Bengkuang River tributary was flowing and was bordering with the Kakora Lake. It was flooded during wet season and dry during dry season. The Kampas Menali forest is situated at 2°34.776’ South and 110°22.402’ East with the altitude of 20 m asl. The dryland forest at Tiang Balai was smaller in area compared to the peat swamp forest and the species composition differed from that of other vegetation types. It was an old secondary forest, consisting of young trees with sparse herbaceous undergrowth. The plot on the dryland forest is located at 2°34.656’ South and 110°22.184’ East, at the elevation of 30 m asl, where the topography was relatively flat and the soil was dry. The heath forests were small patches of less than one ha and occurred sparingly. The soil consisted of sand on the top overlying black dry layer. The plot is located at 2°35.085’ South and 110°22.029’ East with flat topography and the altitude of 10 m asl, about ±5.5 km from the Tiang Balai subdistrict.

The study site was located in the rainfall type A according to [9]. The climate diagram (Figure 1) of the nearest rainfall station at Pangkalanbun (19 m asl) shows the mean annual rainfall of 2,679 mm and wet throughout the year, where the mean monthly rainfall was > 100 mm with the highest mean in January (425 mm) (LMG 1969).
3. Methods

Field sampling was carried out in the Muara Kendawangan forests, using the quadrat method [10-11]. Forest investigation was done by establishing plots of 0.3 ha (50x60 m) each in dryland forest (Plot 1), seasonal swamp forest (Plot 2), peat swamp forest (Plot 3) and heath forest (Plot 4). Their orientations were fitted into the topographic conditions of each forest type. Thus the total sampled area of forest was 1.2 ha. Each plot was divided into 30 quadrats of 10 m x 10 m each. Within each quadrat, DBH (Diameter at Breast Height) of each tree with stem diameter ≥ 7 cm (≥ 2 cm for heath forest) was measured, its bole and total tree heights were estimated, its identity was identified, and its position was recorded. Woody lianas with DBH ≥ 10 cm were treated as trees. A forest profile diagram for each plot was constructed from a strip of 10 m x 50 m nested within each plot.

We used the standard method [10-12] in defining density, frequency and dominance. Density is defined as the number of individuals per unit area. The number of individuals per species was later calculated for the total area of the plot, which was 0.30 hectare. The density in the plot is the sum of the individuals of all species and is expressed in terms of the number of individuals per hectare. The Relative Density (RD) for each species was calculated as follows:

\[
RD = \frac{\text{number of individuals of a species}}{\text{total number of individuals}} \times 100\% \tag{1}
\]

Frequency was the number of times a species occurred in quadrats in the plot and was expressed as the percentage of the total number of quadrats. Relative Frequency (RF) was obtained as follows.

\[
RF = \frac{\text{frequency of a species}}{\text{sum frequency of all species}} \times 100\% \tag{2}
\]
Tree dominance was usually determined by the stem cover, which was expressed as basal area. The basal area (BA) was calculated with the formula:

$$BA = \left(\frac{1}{2}d\right)^2 \pi$$

(3)

Where $d$ stands for diameter. The dominance of a species was measured by summing the BA values for all individuals in the species. The Relative Dominance (RDo) was calculated as follows:

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

(4)

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

$$IV = RD + RF + RDo$$

(5)

The Family Important Value (FIV) was calculated by summing up Importance Values of all species in a family [13].

Shannon’s index of diversity was calculated using the formula [14]:

$$H = -\sum_{i=1}^{S} \hat{P}_i \ln \hat{P}_i$$

(6)

In each subplot percentage of canopy gaps and the projected tree crown coverage were estimated, and topography and soil type were noted. Herbarium specimens for each species within the plot were collected and identified at the Herbarium Bogoriense, Research Center for Biology‒LIPI, Cibinong. The identity and nomenclature of each tree species are conducted by follow the plant list.

4. Results

4.1. Species composition

The total number of tree species in four plots of 1.2 ha were 1180 individuals representing 87 species, 57 genera and 28 families (Table 1). The highest number of species (55) occurred in the seasonal swamp forest with the Shannon’s diversity index of 3.64. It was followed by the dryland forest (38 species), peat swamp forest (17) and heath forest (8 species). Table 2 shows the species with IV > 10 in four plots in the dryland, peat swamp, seasonal swamp and heath forests, showing that *Shorea balangeran* and *Syzygium griffithii* were the prevalent species with IV of 29.39 and 24.74, respectively.

Density and basal area in the dryland forest plot was higher than those in the three other plots, but the Shannon’s diversity index (2.7) was lower than plot seasonal swamp forest (Table 1). The dominant species in each plot differed. In the dryland forest, the dominant species as indicated by the IVs (Table 3) were *Schima wallichii*, *Vatica pauciflora*, *Calophyllum pulcherrimum* and *Rhodamnia cinerea*; in heath forest they were *Baeckea frutescens*, *Calophyllum pulcherrimum*, *Tristaniopsis whiteana* and species of Myrtaceae dan Clusiaceae; in the peat swamp forest it was *Shorea balangeran*; and in the seasonal forest they were *Madhuca motleyana* and *Pterandra azurea*. 
Table 1. Vegetation characteristics of forests in MKNR

| Vegetation characteristics | All plots (plot 1-4) | Dryland forest (Plot 1) | Seasonal peat swamp forest (Plot 2) | Peat swamp forest (Plot 3) | Heath forest (Plot 4) |
|---------------------------|----------------------|------------------------|-------------------------------|----------------------|---------------------|
| Plot size (ha)            | 1.2                  | 0.3                    | 0.3                           | 0.3                  | 0.3                 |
| Number of species         | 87                   | 38                     | 55                            | 21                   | 8                   |
| Number of genera          | 57                   | 33                     | 39                            | 17                   | 6                   |
| Number of families        | 28                   | 19                     | 23                            | 11                   | 2                   |
| Number of trees per hectare | 1180          | 1073                   | 516                           | 786                  | 2343                |
| Number of basal Area (m²/ha) | 20.85         | 29.01                  | 26.13                         | 25.59                | 2.69                |
| Shannon Index of diversity (H’) | 3.21            | 2.7                    | 3.64                          | 2.39                 | 1.58                |

The synthesis table (Table 3) shows the grouping of species that can be designated as associations based on the 100% constancy [11] (of species in dryland, peat swamp, seasonal swamp and heath forest plots. The synthesis table method was used to designate the association and subassociations, which was purely based on floristic distribution [11]. Two associations can be identified:

(i) Schima wallichii-Shorea balangeran association, or for short Schima-Shorea association. Six species in Group 1 (Table 3) characterized the association. Two prevalent species, Schima wallichii and Shorea balangeran, with high IVs in dryland and swamp forests, respectively, can be used to name the association. Within the Schima-Shorea association three subassociations could be recognized, including:

(1) Rhodamnia cinerea-Diospyros hermaphroditica subassociation or Rhodamnia-Diospyros subassociation, whose character species are listed in Group 3 (Table 3). This subassociation constituted the forest on the dryland, where the soil was dry. It differed from other forest by the 15 species that form the character species whose distribution were restricted to the dry soil habitat. Other component species were listed in Group 1 (character species of the Schima-Shorea association), 6, 7 and 8, which occurred also in other subassociations. Overall, we recorded 38 species, 33 genera and 19 families with density of 1073 trees/ha and basal area of 29.01 m²/ha. The density and basal area were higher than those in the other subassociations. The dominant species included Schima wallichii (IV=46.22), Vatica pauciflora (IV=40.14), Calophyllum pulcherrimum (IV=34.22) and Rhodamnia cinerea. (IV=32.93). Undergrowth species were common and shrub species rarely present. Regeneration was dominated by primary forest species, including those of Lauraceae, Ebenaceae, Burseraceae and Sapindaceae.

(2) Baccaurea lanceolata-Calophyllum inophyllum subassociation or Baccaurea-Calophyllum subassociation. Thirty species constitute the character species as listed in Group 4 (Table 3). The subassociation formed the seasonally flooded swamp forest, whose character species were restricted in distribution to their habitat. Other species composing the subassociation are listed in
Groups 1, 7 and 9. We recorded 55 species with density of 516 trees/ha and basal area of 26.13 m²/ha. The species richness was the highest compared to the other subassociation. The prevalent species with relatively high IV included *Madhuca motleyana* (IV=25.3) and *Pterandra rostrata* (IV=21.62). In this forest, *Shorea rugosa* (IV=3.15) and *Aquilaria malaccensis* (IV= 3.12) were recorded but with low density. The dry section of the forest was occupied by species of Burseraceae, Ebenaceae, Sapotaceae and Euphorbiaceae while the swamp section was dominated by species of Myrtaceae.

(3) *Syzygium fusticuliferum-Adinandra dumosa subassociation* or *Syzygium-Adinandra association*. The character species are listed in Group 5 (Table 3). Other component species are listed in Groups 1, 6, 8, 9 and 10. This subassociation formed the peat swamp forest, which could be found on the edge of Arang-arang Lake. Within the plot of 0.3 ha we recorded 21 species, 17 genera and 11 families, with density of 590 trees/ha and BA of 24.43 m²/ha (Table 1). The species richness is small. The dominant species was *Shorea balangeran* (IV=101.6), with mean height of 15 m and diameter of 15-20 cm. Other prevalent species included *Haemocharis ovalis* (IV= 33.89) *Combretocarpus rotundus* (IV=30.12) *Eugenia fusticuliferum* IV=32.66) and *Pterandra rostrata* (IV=24.94). Climbing species were quite common in the undergrowth layer in the swamp forest. It appears that it was related to the gaps resulted by tree removal. The regeneration in the swamp forest was dominated by species of Myrtaceae and Clusiaceae.

(ii) The *Baeckea frutescens-Rhodomyrtus tomentosa association* or *Baeckea frutescens-Rhodomyrtus association*. The character species whose presence was restricted to this community were *Baeckea frutescens*, *Rhodomyrtus tomentosa*, *Syzygium bankense* and *Eugenia* sp. as listed in Group 2 (Table 3). Other component species are listed in Groups 6 and 10. This association formed the heath forest over the sandy soil. The heath forest plot is the poorest, containing only 8 tree species with the species richness index of 0.30. It was dominated by small trees with diameters of 2-5 cm height of 3-5 m occurring on sandy soil. The BA was only 2.69 m²/ha, which was the lowest in comparison to those of the other three plots. The density was 2343 individuals/ha, which made the vegetation looked more like a scrub rather than a forest. The dominant species belong to Myrtaceae (Table 3). The most prominent species was) *Syzygium griffithii* (IV = 96.82) and *Baeckea frutescens* (IV=91.83). The leaves of *B. frutescens* are sclerophyllous emitting the fragrance of cayuput oil when crushed and reported to be good for curing stomach disorder. Other species with high IVs but present also in other forests were *Syzygium griffithii* (IV=86.82), *Calophyllum pulcherrimum* (IV=45.62) and *Tristaniopsis whiteana* (IV=42.01). Undergrowth community was relatively sparse and is mostly of the seedlings and saplings of the tree species which were mostly species of Myrtaceae. They were also common in the peat swamp forest and seasonal peat swamp forest.

**Table 3.** Grouping of species based on their presence in the plots at MKNR; D = Density (trees/ha), BA = Basal Area /ha, and IV = Importance Value.

| Group | Species | Dryland Forest Plot | Seasonal Peat Swamp Forest | Peat Swamp Forest | Heath Forest |
|-------|---------|---------------------|---------------------------|------------------|--------------|
|       |         | D  | BA  | IV | D | BA | IV | D | BA | IV | D | BA | IV |
| GROUP 1 |         |    |     |    |   |     |    |   |     |    |   |     |    |
| 1     | Baeckea polycarpa | 3  | 0.02 | 0.96 | 7 | 0.15 | 3.48 | 3   | 0.26 | 2.19 |    |     |    |    |
| 2     | Gordonia ovalis | 37 | 1.08 | 11.2 | 3 | 0.01 | 1.51 | 103 | 1.93 | 31.2 |    |     |    |    |
| 3     | Pterandra azurea | 3  | 0.02 | 0.95 | 50 | 1.01 | 21.62 | 97  | 1.49 | 30.1 |    |     |    |    |
| 4     | Schima wallisii | 130 | 5.79 | 43 | 7 | 0.2 | 3.66 | 17   | 0.44 | 6.1 |    |     |    |    |
| 5     | Shorea balangeran | 3  | 0.34 | 2.07 | 7 | 1.59 | 8.2 | 200 | 15.3 | 102 |    |     |    |    |
| 6     | Syzygium chiloranthum | 17 | 0.17 | 5.03 | 17 | 1.95 | 11.29 | 20 | 0.41 | 7.14 |    |     |    |    |
| GROUP 2 |         |    |     |    |   |     |    |   |     |    |   |     |    |
| 7     | Baeckea frutescens | 617 | 12.2 | 91.8 |    |     |    |    |     |    |    |     |    |    |
| 8     | Syzygium bankense | 30 | 0.01 | 7.31 |    |     |    |    |     |    |    |     |    |    |
| 9     | Eugenia sp. | 3  | 0 | 0.98 |    |     |    |    |     |    |    |     |    |    |
| 10    | Rhodomyrtus tomentosa | 137 | 0.06 | 20.9 |    |     |    |    |     |    |    |     |    |    |
| GROUP 3 |         |    |     |    |   |     |    |   |     |    |   |     |    |    |
| 11    | Antidesma cuspidatum | 10 | 0.57 | 4.61 |    |     |    |    |     |    |    |     |    |    |
| 12    | Artocarpus mitius | 13 | 0.37 | 4.23 |    |     |    |    |     |    |    |     |    |    |
| 13    | Cratoxylum formosum | 10 | 0.13 | 3.1 |    |     |    |    |     |    |    |     |    |    |
| No. | Species Name                | GROUP | Width (mm) | Height (mm) |
|-----|-----------------------------|-------|------------|-------------|
| 14  | Cryptocarya ferrea          | 4     | 3          | 63          | 3.05       |
| 15  | Diospyros hermaphroditica   | 30    | 0.76       | 10          |
| 16  | Garcinia diotica            | 23    | 0.68       | 7.95        |
| 17  | Guioa diplopetala           | 3     | 0.01       | 0.93        |
| 18  | Helicia moluccana           | 7     | 0.38       | 3.07        |
| 19  | Horsfieldia wallachii       | 7     | 0.06       | 1.99        |
| 20  | Licaria splendens           | 3     | 0.1        | 1.21        |
| 21  | Litsea umbellifora          | 3     | 0.02       | 0.94        |
| 22  | Nephelium cuspidatum        | 3     | 0.03       | 0.98        |
| 23  | Rhododendron dinerea        | 217   | 2.23       | 39.9        |
| 24  | Gymnadenia boreoensis       | 3     | 0.11       | 1.26        |
| 25  | Xylopia ferruginea          | 10    | 0.23       | 3.45        |

GROUP 4

| No. | Species Name                | Width (mm) | Height (mm) |
|-----|-----------------------------|------------|-------------|
| 26  | Agathis alba                 | 7          | 0.38       | 4.35       |
| 27  | Alseodaphne umbelíflora      | 10         | 0.38       | 4.99       |
| 28  | Aporosa frutescens          | 17         | 0.26       | 7.44       |
| 29  | Aquilaria malaccensis       | 7          | 6.67       | 3.12       |
| 30  | Arctocarpus lanceifolius    | 3          | 0.01       | 1.5        |
| 31  | Baccocarca macracarpa       | 3          | 0.24       | 2.37       |
| 32  | Baccocarca javanica         | 7          | 6.67       | 3.13       |
| 33  | Baccocarca lanceolata       | 13         | 2.14       | 13.19      |
| 34  | Barringtonia reticulata     | 3          | 0.15       | 2.02       |
| 35  | Broue oppositifolia        | 7          | 0.08       | 3.19       |
| 36  | Calophyllum inophyllum      | 13         | 1.6        | 11.92      |
| 37  | Camarium hirsutum           | 10         | 0.44       | 6.03       |
| 38  | Chiocheton patens           | 3          | 0.04       | 1.59       |
| 39  | Cryptocarya lucida          | 17         | 0.1        | 6.84       |
| 40  | Dysoxylum rostrata          | 10         | 0.64       | 6.79       |
| 41  | Diospyros cf. confertiflora| 3          | 0.02       | 1.53       |
| 42  | Elaeocarpus stipularis var. brevipes | 7 | 0.05 | 3.08 |
| 43  | Elaeocarpus glaber          | 3          | 0.03       | 1.58       |
| 44  | Cryptocarya agathophylla    | 7          | 0.03       | 3          |
| 45  | Ficus sp.                   | 3          | 2.55       | 11.21      |
| 46  | Gomphia serrata             | 3          | 0.13       | 1.93       |
| 47  | Haegiolasbus floribundus    | 3          | 0.66       | 1.67       |
| 48  | Hopna nigra                 | 7          | 0.08       | 2.4        |
| 49  | Koordersidendron pinnatum   | 3          | 0.86       | 1.68       |
| 50  | Litesa firma                | 3          | 0.05       | 1.63       |
| 51  | Litesa contalis van nuidlaris| 3       | 0.02       | 1.53       |
| 52  | Litesa restoma              | 3          | 0.06       | 1.68       |
| 53  | Litesa robusta              | 3          | 0.95       | 5.08       |
| 54  | Macaranga depressa          | 20         | 0.16       | 7.71       |
| 55  | Macaranga triloba           | 40         | 0.38       | 13.65      |
| 56  | Ochanostachys amentacea     | 10         | 0.5        | 6.28       |
| 57  | Polyalthea lateriflora      | 3          | 0.06       | 1.69       |
| 58  | Sandoricum borneensis       | 3          | 0.68       | 4.05       |
| 59  | Schroedercarpus borneensis  | 13         | 1.26       | 10.64      |
| 60  | Shorea rugosa               | 7          | 6.67       | 3.15       |
| 61  | Syzygium claviflorum        | 7          | 0.06       | 2.33       |
| 62  | Syzygium valdensiflorum     | 27         | 0.75       | 11.25      |

GROUP 5

| No. | Species Name                | Width (mm) | Height (mm) |
|-----|-----------------------------|------------|-------------|
| 63  | Adinandra dumosa            | 23         | 0.34       | 7.32       |
| 64  | Parastemon urophyllus       | 7          | 0.05       | 1.79       |
| 65  | Symphocos fasciculata       | 10         | 0.07       | 3.79       |
| 66  | Syzygium fasticaliferum     | 107        | 1.43       | 32.7       |

GROUP 6

| No. | Species Name                | Width (mm) | Height (mm) |
|-----|-----------------------------|------------|-------------|
| 67  | Calophyllum pulcherrimum    | 140        | 3.68       | 33.2       |
| 68  | Tristaniopsis whiteana      | 30         | 0.97       | 9.6        |

GROUP 7

| No. | Species Name                | Width (mm) | Height (mm) |
|-----|-----------------------------|------------|-------------|
| 69  | Aglaia edulis               | 7          | 0.06       | 1.98       |
| 70  | Arctocarpus tamaran         | 17         | 0.56       | 6.36       |
| 71  | Barringtonia samoensis      | 3          | 0.01       | 0.93       |
| 72  | Daecyodoris kava            | 3          | 0.07       | 1.14       |
| 73  | Dilienia serrata           | 3          | 0.15       | 1.4        |
| 74  | Endospernum peltatum       | 3          | 0.51       | 2.63       |
| 75  | Nephelium uncinatum        | 3          | 0.07       | 1.11       |
| 76  | Fereonrivista glabra       | 10         | 0.36       | 3.33       |
| 77  | Fatica pauciflora          | 117        | 4.38       | 40.1       |

GROUP 8

| No. | Species Name                | Width (mm) | Height (mm) |
|-----|-----------------------------|------------|-------------|
| 78  | Calophyllum rigidum         | 30         | 0.86       | 9.23       |
| 79  | Cembretocarpus rotundatus   | 80         | 2.64       | 25.7       |
| 80  | Eupeyna lineata             | 47         | 0.77       | 13.3       |

GROUP 9

| No. | Species Name                | Width (mm) | Height (mm) |
|-----|-----------------------------|------------|-------------|
| 81  | Diospyros maingayi          | 17         | 1.4        | 12.61      |
| 82  | Garcinia tetrandra          | 3          | 0.67       | 1.71       |
| 83  | Madhuca molleiana           | 33         | 4.08       | 25.3       |
Based on the calculation of the FIV (Family Importance Value) in all plots, Myrtaceae was recorded to be the family with highest number of species (14 species), followed by Euphorbiaceae (9 species). Dipterocarpaceae was not important in terms of the number of species (4), but had relatively high IV (104.38) mainly in the peat swamp forest (FIV=104.38). In the heath forest, only Myrtaceae (FIV=213.82) and Clusiaceae (FIV=86.18) were present. Myrtaceae practically dominated the community, including Baeckea frutescens, Syzygium griffithii and Tristaniopsis whiteana, amounted to 83%.

4.2 Structure

The forest structure refers to the size, density and horizontal as well as vertical distribution of trees (Kershaw 196415). Graphs (Figures 2 and 3) and profile diagrams (Figures 4a-e) show the structure of forests in the study sites. Diameter classes show the dominance of trees with small diameter (> 30 cm) and only a few trees having diameters > 30 cm (Figure 2). In the heath forest plot, all trees in the plot were small with the range of 10-14 cm consisting of Baeckea frutescens. In the peat swamp forest plot, the 90 % of the trees having diameters of ≤ 30 cm and 13 trees had diameters of 40-50 cm consisting of Shorea balangeran. In the seasonal peat swamp forest plot, a total of 16 trees (10 %) had diameters of ≥ 40 cm and 83 % of the trees had diameters of ≤ 30 cm. Trees with diameters > 50 cm included Ficus sp. and Madhuca motleyana. In the dryland forest 92 % of the trees had small diameters and only 7% had diameters of 45-55 cm including Combretocarpus rotundatus, Cryptocarya ferrea and Schima wallichii (Table 4).

Figures 4a-d show the profile diagrams of the four forest types. Figure 4d is the profile diagram of the heath forest where the tree height did not exceed 8 m and the mean height was only 3.5 m, with very high tree density. In the peat swamp forest the tree height reached 25 m with the mean height of 12. In the dryland forest and the seasonal swamp forest the tree height was almost the same with the highest was recorded to be 35 m but the mean height was 15 m.

High population of trees with small diameters indicates the regeneration status of the forest. Tree species with small diameters included Combretocarpus rotundatus, Syzygium spp., Gordonia ovalis, Pterandra azurea, Macaranga triloba, Aporosa frutescens, Madhuca motleyana, Schima wallichii, Rhodamnia cinerea, Calophyllum pulcherrimum, Diospyros hermaphroditica was fitly regenerating. In the heath forest, the species with good regeneration included Baeckea frutescens, Calophyllum pulcherrimum, Cratoxylum glaucum, Eugenia spp., Rhodomyrtus tomentosa and Tristaniopsis whiteana. The pattern of diameter class distribution of the other species is as follows:

1. Species that were represented in diameter classes up to 40 cm but with low density were Calophyllum pulcherrimum, Schima wallichii, Pterandra azurea, Syzygium chlotanthum, Combretocapus rotodatus, Shorea balangeran and Vatica pauciflora.
2. Species with diameters of 10-40 cm but its distributional pattern was irregular and low density (1-14 trees/ha) were Calophyllum rigidum, Diospyros maingayi, Diospyros hermaphroditica, Xylopia ferruginea, Baccarea lanceolata, Calophyllum inophyllum, Cratoxylon formosum, Artocarpus tamaran, and Ochanostachys amentacea.
3. Species that were represented in high diameter classes (>50 cm) but its occurrence in lower diameter classes was low were Ficus sp. (80.0-100 cm), Litsea robusta (50-70 cm), Sandoricum borneense (50-70 cm) and Aglaia edulis (50-70 cm).
4. Vertical distribution in the plots except the heath forest plot shows three strata, the lowest stratum consisted of trees with height of 8-15 m, the height of next stratum was 15–25 m and the height of the uppermost stratum was 25–35 m. Some tree species had height of more than 30 m, including Madhuca motleyana (in seasonal peat swamp forest), Shorea balangeran (in
peat swamp forest) and *Schima wallichii* (in dryland forest). In the heath forest the tree height was less than 10 m with the average height of 6 m.

Table 4. Species with large diameters in each plot in MKNR

| Species             | Family          | Seasonal peat swamp forest | Peat swamp forest | Dryland forest | Heath forest |
|---------------------|-----------------|----------------------------|-------------------|----------------|--------------|
| *Aglaia edulis*     | Meliaceae       | 51                         | -                 | 0              | 0            |
| *Artocarpus tamarae*| Moraceae        | 41                         | 0                 | 0              | 0            |
| *Baccaurea lanceolata* | Euphorbiaceae   | 75                         | 0                 | 0              | 0            |
| *Baeckea frutescens* | Myrtaceae       | 0                          | 0                 | 0              | 10-14        |
| *Calophyllum inophyllum* | Clusiaceae  | 45-60                      | 0                 | 0              | 0            |
| *Combretocarpus rotundatus* | Rutaceae  | 0                          | 0                 | 55             | 0            |
| *Cryptocarya feree* | Lauraceae       | 0                          | 0                 | 49             | 0            |
| *Diospyros hermaphroditica* | Ebenaceae | 0                          | 0                 | 45             | 0            |
| *Diospyros maingayi* | Ebenaceae       | 42                         | 0                 | 0              | 0            |
| *Endospermum peltatum* | Euphorbiaceae | 0                          | 0                 | 44             | 0            |
| *Ficus* sp.         | Moraceae        | 99                         | 0                 | 0              | 0            |
| *Lisea robusta*     | Lauraceae       | 60                         | 0                 | 0              | 0            |
| *Madhuca molloyana* | Sapotaceae      | 43-66                      | 0                 | 0              | 0            |
| *Sandoricum borneense* | Meliaceae | 51                         | 0                 | 0              | 0            |
| *Schima wallichii*  | Theaceae        | 0                          | 0                 | 45-48          | 0            |
| *Scordocarpus borneensis* | Olacaceae | 42                         | 0                 | 0              | 0            |
| *Shorea balangeran* | Dipterocarpaceae | 76                      | 40-52             | 0              | 0            |
| *Syzygium chloranthum* | Myrtaceae    | 42                         | 0                 | 0              | 0            |

Figure 2. Number of trees according to the three diameter classes in the four plots in Muara Kendawangan Nature Reserve
Figure 3. Number of trees according to the height classes in the four plots in Muara Kendawangan Nature Reserve.
**Figure 4a.** The profile diagram of dryland forest (plot 1.): 1. *Artocarpus nitidus*; 2. *Rhodamnia cinerea*; 3. *Schima wallichii*; 4. *Combretocarpus rotundatus*; 5. *Vatica pauciflora*; 6. *Barringtonia samoensis*; 7. *Cryptocarya ferrea*; 8. *Gymnanthes borneensis*; 9. *Tristaniopsis whiteana*; 10. *Aglaia edulis*; 11. *Licania splendens*; 12. *Litsea umbelliflora*.

**Figure 4b.** The profile diagram of seasonal peat swamp forest (plot 2.): 1. *Cryptocarya lucida*; 2. *Gomphia serrata*; 3. *Ochanostachys amentacea*; 4. *Dacryodes rostrata*; 5. *Scorodocarpus borneensis*; 6. *Macaranga triloba*; 7. *Canarium hirsutum*; 8. *Schima wallichii*; 9. *Litsea firma*; 10. *Baccaurea macrocarpa*; 11. *Cryptocarya agathophylla*; 12. *Baccaurea polyneura*; 13. *Shorea rugosa*; 14. *Hopea nigra*; 15. *Aporosa frutescens*; 16. *Agathis alba*; 17. *Diospyros maingayi*; 18. *Alseodaphne umbelliflorum*; 19. *Baccaurea javanica*; 20. *Syzygium chloranthum*.
Figure 4c. The profile diagram of the peat swamp forest (Plot 3.): 1. *Cratoxylum glaucum*; 2. *Gordonia ovalis*; 3. *Pterandra azurea*; 4. *Syzygium* sp; 5. *Schima wallichii*; 6. *Parastemon urophyllus*; 7. *Syzygium griffithii*; 8. *Syzygium fusticuliferum*; 9. *Shorea balangeran*; 10.

5. Discussion
The MNKR forests were rain forests with high rainfall and could be included in the rainfall type A of Schmidt & Ferguson (1951) [9] Forest with type A is characterized by everwet conditions, evergreen and thick canopy. The species composition of the forest consisted mainly of primary forest species (80%) including species of Myrtaceae (14 species), Lauraceae (8), Burseraceae (4), Dipterocarpaceae (4), Theaceae (4), Ebenaceae (3), Meliaceae (3), Sapindaceae (3). *Shorea balangeran*, which is a member of the character species of the *Shorea-Schima* association gained dominance in the swampy
habitat, which could be designated as swamp forest indicator. Meanwhile *Schima wallichii* distinguished the dryland forest and *Baeckea frutescens* typified heath forest.

The density (trees/ha) in the dryland forest was higher than in the peat swamp forest. Similarly with the BA, the dryland forest was the highest (29.0 m²/ha). In the seasonal swamp forest the mean diameter was 20.1 cm, while in the dryland forest it was 16.37 cm (**Table 1**). The trees with big diameters were more common in the seasonal swamp forest, including a *Ficus* sp. which could reach a diameter of > 80 cm and in the peat swamp forest *Shorea balangeran* which could have diameter of up to 75 cm. Myrtaceae and Dipterocarpaceae contributed the trees with large diameters including *Shorea balangeran* (Dipterocarpaceae) with a total BA=5.16) from 63 trees and *Syzygium grifithii* (Myrtaceae) with a total BA= 0.31 contributed by 249 trees. Other species with high BA included *Schima wallichii, Vatica pauciflora, Combretocarpus rotundus, Madhuca motleyana* dan *Calophyllum pulcherrimum*.

In heath forest, 98.7% of trees were small with mean diameter of 3.51 cm but we observed *Syzygium bankense* having diameter of 42 cm. Small trees were also dominant in the other forest types. A total of 73 tree species had diameters <20 cm (**Figure 2**). Such pattern characterizes disturbed tropical rain forests [16-17].

The diversity of tree species in seasonal swamp forest according to diversity index shows the highest value (3.64). The high number of tree species in seasonal swamp forest area is suspected to be more influenced by land factor. The forest experienced longer dry period compared to swamp forest and when with dryland forest can still hold water during dry season. The area of the swamp forest in MKNR has been decreasing due to illegal logging, Species that have been disappearing because of illegal logging included belangir (*Shorea balangeran*), gembor wood (*Nothaphoebe umbelliflora*), ramin wood (*Gonystylus bancanus*) and gaharu (*Aquilaria malaccensis*). Currently, the population of these species were very small and even ramin and gembor were no longer present in the research sites. On the other hand, *Shorea balangeran* was one of the most abundant species of the Dipterocarpaceae occurring in the peat swamp plot (D = 200 trees/ha) but not so in seasonal peat swamp forest and dryland where there were only seven trees in each plot. The abundance and high occurrence of this species (Frequency =100%) led to lower species heterogeneity compared to the seasonal swamp forest and dryland forest plots. This species is endemic to Borneo and has been listed in the critical category in the IUCN [18-20].

The density of *Schima wallichii* was relatively low in seasonal swamp and peat swamp forests but it was high and dominant in hill forest plots. It was one of the five big species in the dryland forest research site. In Indonesia, it is widely distributed from lowland to montane forests [21-23].

The peat swamp forest was mostly inhabited by trees with small diameters of 10-20 cm, with a density of 590 trees/ha and BA of 24.43 m²/ha. The common species included *Shorea balangneran, Syzygium fusiculiferum, Gordonia ovalis, Garcinia dioica* and *Calophyllum pulcherrimum*. The forest at Kempas Menali has been much disturbed as it is located adjacent to native agricultural fields. The disturbance led to the formation of canopy gaps, which were usually occupied by scrubs overgrown by rattans and vines. In the parts of the forest where there were still many large trees, the undergrowth was dominated by the species of Myrtaceae, Clusiaceae, Ebenaceae, and Sapotaceae.

Along with the rapid rate of regional development and population growth, disruption to wetland ecosystems has been also increasing. It has been threatening the integrity of the wetlands. The degradation of the area has been partly due to forest conversion to non-forest uses, including oil palm plantations, rice fields, settlements, and transmigration area.

In the heath forest plots, 98.7% of trees were small in size with an average diameter of 3.51 cm and average height of 6 m. But elsewhere, *Syzygium bankense* could reach a diameter of 42 cm [24]. Myrtaceae was one of the families that had the highest number of species in the heath forest. The forest in the plot was almost entirely dominated (83%) by *Baeckea frutescens, Syzygium subrufum*, and *Tristaniopsis whiteana*. In the Malesian forests [16] [25-27], including in riparian and swamp forests [28-29], Myrtaceae is known to be rich in species. Heath forest is one of the important forest types in Indonesia developed on podsol and quartz sandy soils, which are poor in nutrients and low pH.
The heath forest at MKNR occurred as scattered mosaic of small areas, sand in places they were planted to pineapple. The density of trees in the three plots of research was quite high. Dryland forests were noted to have a higher density compared to the peat swamp and seasonal swamp forests. However, large diameter trees were more prevalent in seasonal swamp forests. In the seasonal swamp forest, *Baccaurea lanceolata* and *Shorea balangeran* stem diameters reached > 70 cm, but if in the peat swamp forest *Shorea balangeran* mostly had diameters of 40-60 cm. Myrtaceae and Dipterocarpaceae were the largest contributors to the Basal area. The trees with largest basal area were *Shorea balangeran* (BA = 5.16 m²; density n = 63 trees/ha) and *Syzygium griffithii* (BA = 0.52 m²; density = 262 trees/ha) (Table 2). Other species with relatively high BAs included *Calophyllum pulcherrimum*, *Combretocarpus rotundatus*, *Madhuca motleyana*, *Schima wallichii* and *Vatica pauciflora*.

6. Conclusion
The forests at MNKR could be included as the disturbed primary forest where 80% of the species were primary forest species. The small statured heath forest was almost entirely dominated by species of Myrtaceae. High population of trees with small diameters indicates the regeneration status of the forest. The forest communities had low species richness and were designated as the *Schima wallichii-Shorea balangeran* association, composed of three subassociations, and the *Baeckea frutescens-Rhodomyrtus tomentosa*. The associations and subassociations were related to dryland, peat swamp, seasonal peat swamp and sandy dryland. It is predicted that the species composition of the associations and subassociations will not change in the coming years. The recovery of the disturbed sites and degraded lands to conditions similar to the original forests prior to disturbances would take a very long time. The recovery could be enhanced by applying ecological restoration through planting tree species native to the sites, complemented with actions to prevent tree poaching and forest encroachment. The ecological restoration will help in increasing species diversity, improving forest conditions and expanding the coverage of forest to satisfy the requirements stipulated in Forestry Law (UU no.41 Tahun 1999 tentang Kehutanan Pasal 18 Ayat 2) and Spatial Arrangement Law (UU26/2007 tentang Tata Ruang) to preserve 30% of the total land area of a region as forests in order to maintain various ecosystem functions [12]. Species that will survive and maintain themselves in the forest in the future are currently represented in almost all diameter classes, although with low density. They included the *Schima wallichii, Shorea balangeran, Baeckea frutescens* and *Rhodomyrtus tomentosa*. Further intensive studies in the above forest types as well as in the other community types present in MNKR are needed to provide data for better management of the reserve.

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