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Tree species composition and structure of dry forest in Mutis Timau Protected Forest Management Unit of East Nusa Tenggara, Indonesia

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Abstract. *Almulqu AA, Arpornpong N, Boonyanuphap J. 2018. Tree species composition and structure of dry forest in Mutis Timau Protected Forest Management Unit of East Nusa Tenggara, Indonesia. Biodiversitas 19: 496-503.* Plots 10,000 m^2 were established in four sites of Mutis Timau Protected Forest Management Unit (Mutis Timau PFMU), in order to determine tree species density, basal area, importance value index, species richness and to identify the relationship betwen species richness and abundance of trees. A total of 94 species belonging to 72 genera and 45 families were recorded. Species richness and forest structure were different between sites. Moraceae was the dominant tree family at most sites, particulary for *Eucalyptus urophylla*. The results suggest controlling the number of species, level on species distribution pattern, silvicultural interventions to pioneer species through thinning liberation, seeding and planting (pioneer species) could accelerate the tree regeneration of Mutis Timau PFMU in Kupang District, East Nusa Tenggara Province, Indonesia.

Keywords: Forest structure, Mutis Timau PFMU, silvicultural interventions, species diversity, species richness, species abundance

INTRODUCTION

Dry tropical forest communities are among the world's most threatened systems and urgent measures are required to protect and restore them in degraded landscapes (Sagar and Singh 2006). Tropical dry forests, the most endangered and probably the most fragmented lowland forest in the tropics (Janzen 1988), have relatively low species diversity (Gentry 1995) and the trees are particularly vulnerable compared with other plant forms because they take a long time to reach reproductive age. They are also associated with low productivity, high mortality rates, increasing demand for food and energy and declining land productivity (FAO 2009). For planning conservation strategies, there is a need to determine the few essential measurable properties, such as number of species and basal area, that best describe the dry forest vegetation and its environment, and to document quantitative relationships among them (Sagar and Singh 2006).

According to Sagar et al. (2003), biodiversity inventories are used to determine the nature and distribution of biodiversity resources of the forests to be managed. Information from this quantitative inventory will provide a valuable reference for forest assessment and improve our knowledge by the identification of ecologically, useful species as well as species of special concern, thus identifying conservation efforts for sustainability of forest biodiversity (Naidu and Kumar 2016).

Information on composition, diversity of tree species and species-rich communities is primary importance in the planning and implementation of biodiversity conservation efforts (Suratman 2012). For a good forest conservation plan, understanding tree species composition and knowledge of the forest stand structure is necessary (Farhadi et al. 2013). Because trees, an important component of vegetation, must be constantly monitored and managed in order to direct successional processes towards maintaining species and habitat diversity (Attua and Pabi 2013). Variables that influence the tree species diversity are climate, stand structure, species composition, and geomorphology. Forest stand structure is a key element in understanding forest ecosystems and also an important element of stand biodiversity (Ozcelik 2009).

Until today, only little published scientific information on the tree species composition and structure in the dry forest of Mutis Timau Protected Forest Management Unit (Mutis Timau PFMU), although biodiversity conservation in Mutis Timau PFMU received attention from the central government, local government and international conservation agencies. Such surveys by the Food and Agriculture Organization of the United Nations, in collaboration with the Department of Forestry's Directorate General of Forest Protection and Nature Conservation, identified priority areas for conservation in 1980 (MacKinnon et al. 1982). Only one detailed study on *Eucalyptus urophylla* forests, using floristic and structural data, was conducted at Mutis Timau dry forest (Robinson and Supriadi 1981).

Here, we report on the tree species community and forest structure of dry forest in Mutis Timau PFMU. The study aims (i) to identify and inventory tree species in

Mutis Timau PFMU, (ii) detail forest structure and composition of tree species (in terms of density, basal area and importance value index) Mutis Timau PFMU in Kupang District, East Nusa Tenggara Province, Indonesia.

MATERIALS AND METHODS

Study area

The study was carried out at the Mutis Timau Protected Forest Management Unit (Mutis Timau PFMU) of East Nusa Tenggara Province, Indonesia. This area includes Kupang District, Timor Tengah Selatan District and Timor Tengah Utara District (Lat. 90 20' 00" - 90 45' 10" South and long. 123.042'30" - 124.0 20' 00" E) (Figure 1). Data for this study were collected from 4 dry forest study sites in Kupang District, named Binafun, Bonmuti, Letkole and Oelbanu, each study site consisting of two 10.000 m² plots. The detail description of the study sites is given in Table 1.

The research sites represent the dry forests of East Nusa Tenggara, Indonesia, and surrounding areas are the wettest areas on the island of Timor, the rain fell almost every month with the highest frequency of rainfall occurs during November to July, temperatures range between 14^0C - 29^0C, and in extreme conditions can decrease up to 9^0C. High-speed winds occurred in November until March. About 71% areas are hilly (15-30% slope) to mountainous (>30% slope). The high-intensity rainfall (2000-3000 mm/year) during the rainy season (Fisher et al. 1999).

Plot setting

The fieldwork was carried out during 7 months on May 2016 to November 2016. In that time, the study of tree diversity and community structure were conducted from the four study sites. To obtain data on the composition and diversity of vegetation we used sampling plots in a rectangular shape, with a size of 100 m x 100 m (1 ha). The plot design consists of two 1-ha plots per site. In each plot, all tree species were measured for species name, height, and diameter at breast height (DBH) ≥ 20 cm (1.3 meters).

Data analysis

The tree species richness was calculated as the number of tree species per 1-ha plot, and the total tree species richness was calculated as the number of tree species per site. The density of a species was the number of trees of that species per hectare. The relative density of a species was calculated as its density divided by the total density of all species and multiplied by 100. The frequency of a species was the number of plots in which that species was found. The relative frequency of a species was calculated as the frequency of a species divided by the total number of sampling plots and multiplied by 100 (Koonkhunthod et al. 2007).

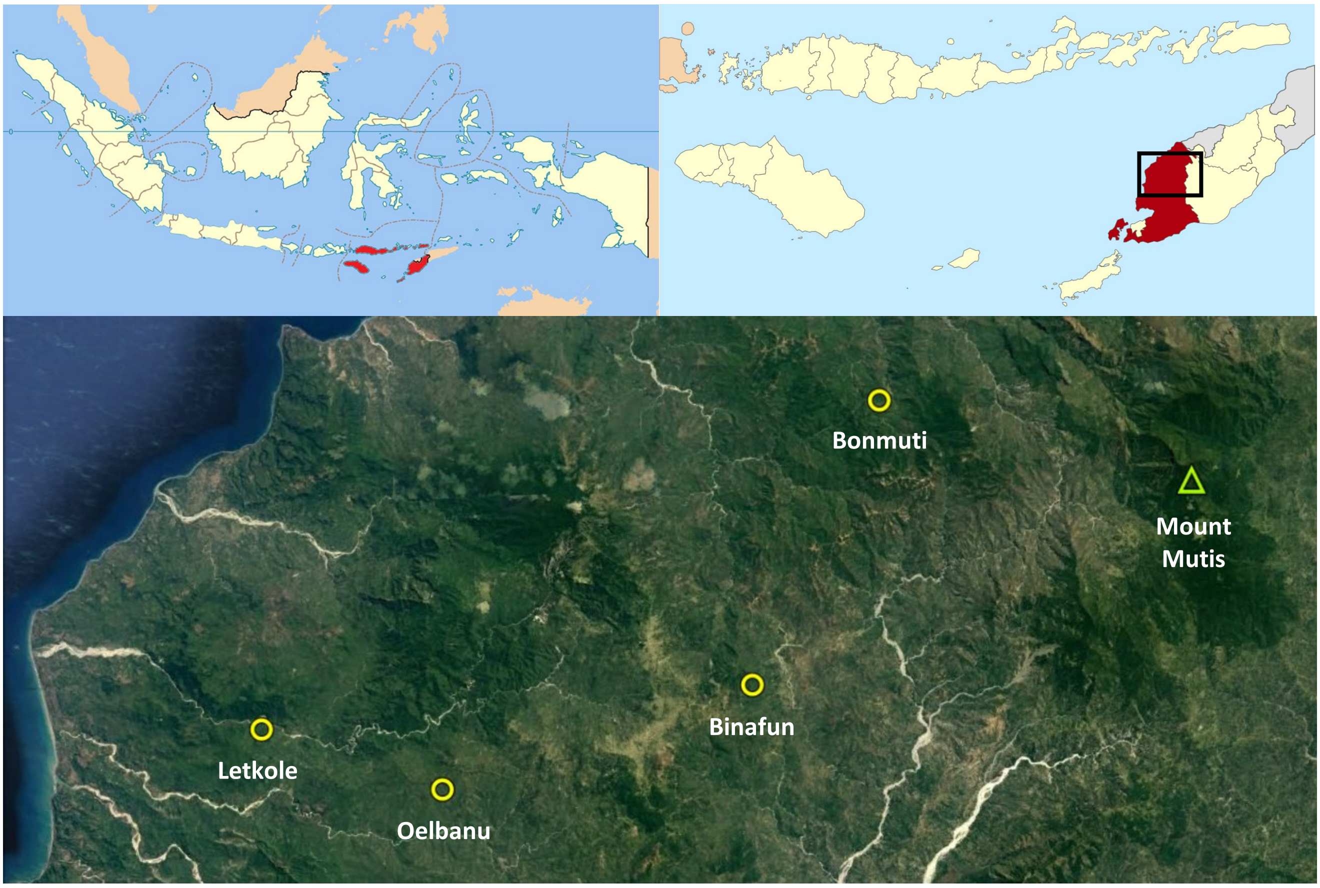

Figure 1. Location of research sites at Mutis Timau PFMU, East Nusa Tenggara Province, Indonesia

Table 1. Description of research sites at Mutis Timau PFMU, Kupang District, East Nusa Tenggara Province, Indonesia

	Site			
	1	2	3	4
Village	Binafun	Bonmuti	Letkole	Oelbanu
Sub-district	Amfoang Tengah	Amfoang Tengah	Amfoang Barat Daya	Amfoang Selatan
District	Kupang	Kupang	Kupang	Kupang
Longitude	S 09⁰39’12 9.22’’	S 09⁰37’46.50’’	S 09⁰41’02.62’’	S 09⁰42’28.59’’
Latitude	E 124⁰01’421.16’’	E 124⁰9127.92’’	E 123⁰48’	E 123⁰53’04.82’’
Geology[a]	Mixed volcanic and limestone rock	Mixed volcanic and limestone rock	Mixed volcanic and limestone rock	Mixed volcanic and limestone rock
Rainfall ($mm.year^{-1}$)[b]	1301	1405	1203	1254
Temperature (°C) [b]	24.1	21.4	26.4	25.3
Slope (°)	0-14	0-26	0-10	0-12
Elevation (m)	513-635	631-1007	122-125	310-636
Driest month [b]	September (5mm)	August (12mm)	September (3mm)	September (4mm)
Wettest month [b]	January (280mm)	January (263mm)	January (307mm)	January (301mm)
Highest temperature[b]	25.4⁰C (November)	22.7⁰C (November)	27.6⁰C (November)	26.6⁰C (November)
Lowest temperature[b]	22.6⁰C (July)	19.7⁰C (July)	25.0⁰C (July)	23.9⁰C (July)
Dry periods	June-October	June-September	May-October	May-October
Rain periods	December-May	October-May	September-April	December-April

Note: [a)]Fisher et al. (1999), [b)] BPS (2016)

The Importance value Index for a species is a composite of three ecological parameters including density, frequency and basal area, which measure different features and characteristics of a species in its habitat. Basal area per tree is the cross-sectional area of a tree at breast height. It was calculated from the diameter at breast height. Ecologically, density and frequency of a species measure the distribution of a species within the population while basal area measures the area occupied by the stems of trees.

RESULTS AND DISCUSSION

Tree species composition in research sites

A total of 2097 trees, representing 94 species, 72 genera and 45 families, were identified within the 8.0 ha survey area. In this study, species number reaches its maximum value (74) at Letkole (tree) and minimum (6) at Oelbanu (sapling). The 4 sites are ranked in the same order according to the highest and the lowest observed values of species richness, i.e. species number is maximum value (36, 36, 22, 22, 53, 74, 18, 23, respectively) at Binafun (pole and tree), Bonmuti (pole and tree), Letkole (pole and tree) and Oelbanu (pole and tree) while minimum (16, 15, 30, 6, respectively) at Binafun (sapling), Bonmuti (sapling), Letkole (seedling) and Oelbanu (sapling) (Figure 2).

The composition of the forest is diverse and varies from place to place because of varying topography such as plains, foothills and upper mountains (Singh 2006). The different changing site conditions, from the base to the summit of mountains, originates the diversification of habitats. Changes in structure and species composition along elevational gradients were described in the Andes (Smith and Killeen 1998) and Central America (Vásquez and Givnish 1998). Altitudinal changes in biogeographical patterns were reported in Sulawesi in Indonesia (Culmsee and Pitopang 2009), where there is a progression from dominant tropical families in the submontane zone to tropical Fagaceae (*Castanopsis, Lithocarpus*) in the lower/mid-montane. Sapotaceae, in particular, make a significant contribution to submontane forest and Magnoliaceae to mid-montane forest. Our studies show similar biogeographical patterns with altitude. Myrtaceae has the highest species richness in the Binafun, Bonmuti, Oelbanu forests, and Meliaceae in Letkole dry forest. If we rank the sites by their compositions, the dominance of Meliaceae decreased according to this scheme: Oelbanu > binafun > Bonmuti.

In this study, the tree species of dry forest was characterized by differences in DBH size classes (Figure 3). Generally, the numbers of stems in the >25.5 cm DBH size classes were higher in all research sites compared to others DBH class. Within the vegetation, the tree (>25.5cm) was dominated by dry forest with high DBH. Binafun had the highest number of stems in the 4.5-11.5 and >25.5 cm DBH size classes (133 and 174 stems, respectively). The highest number of stems in the 4.5-11.5 and >25.5 cm DBH size classes were in Bonmuti (60 and 95 stems, respectively). Letkole and Oelbanu had the highest number of stems in the 18.5-25.5 and >25.5 cm DBH size classes (64,199 and 87, 221 stems, respectively).

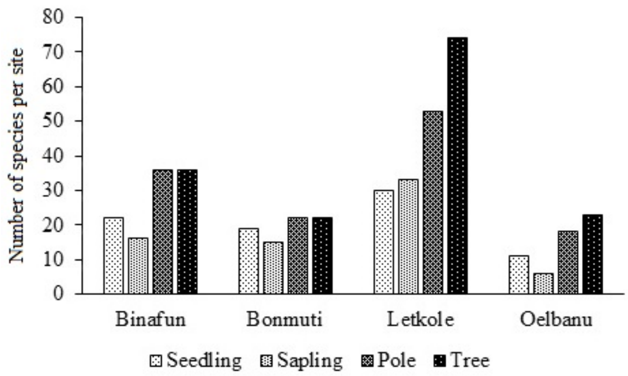

Figure 2.Species number of plant species in the research sites

Density and species richness

The mean stand density was 353.62 individuals/ha. The highest stand density was observed in plot 2 of Oelbanu (545 individuals/ha), whereas the lowest stand density was observed in plot 1 of Oelbanu (166 individual/ha), and the other six plots showed moderate densities (Figure 4). The basal area in all the study plots ranged from 5.78 m^2/ha (plot 2 of Bonmuti) to 27.79 m^2/ha (plot 1 of Binafun) and the mean basal area for the four plots was 19.97 m^2/ha (Figure 5). The basal area was highest in Binafun and lowest in Bonmuti (plot 2).

Eucalyptus urophylla had higher densities than other species in Binafun (51 stem ha^{-1}), Bonmuti (46 stem ha^{-1}) and Oelbanu (127 stem ha^{-1}). The density value of a tree species is very important because it can show the number of occurrences for this species concerned on a particular unit area, the density value is an idea of vegetation amount at each research site. The representation of individual distribution of particular species of vegetation can be seen in the value of frequency. The highest (19.480 %) value of all research sites was found for *Eucalyptus urophylla*. But, in the dry forest of Bonmuti and Binafun, *Elattostachys verrucosa*, potentially could change the domination of *Eucalyptus urophylla* at tree stage because consistently, this species had high IVI (18.4-88.8%) on seedling, sapling, and pole.

The tree density in Letkole was higher than in other sites, except for Oelbanu plot 2 (545 stems ha^{-1}), which showed the greatest density, while plot 1 of Oelbanu had the lowest density. At plot 2 of Oelbanu showed the greatest density; while at site 1 of Oelbanu, density was the lowest. This different may be related to the topographic variable aspect that influences parameters such as exposure to sunlight, drying winds and evapotranspiration. Therefore, aspect has implications to physiological of the species and ecological requirements such as community structure and species distribution of trees (Tagil 2015). However, further study on topographic factors is necessary.

The highest rank of density was measured for all research sites (Figure 6). This graph ranks, for each site, the number of species by decreasing density. For example in Binafun, only 1 species (*Eucalyptus urophylla*) have a density of more than 50 stems ha^{-1}, and only 3 species (*Syzygium javanica, Prunus* sp. and *Elattostachys verrucosa*) have a density of more than 30 stems ha^{-1}. The graph shows that in Binafun 2 species (*Eucalyptus urophylla*) are dominant in terms of stem density, 5 species (*Celtis cinnamomea, Hibiscus timoriensis, Phaleria laurifolia, Elattostachys verrucosa* and *Eucalyptus urophylla*) in Bonmuti, 7 species (*Ficus ampelos, Celtis cinnamomea, Dysoxylum gaudichaudianum, Wikstroemia androsaemifolia, Drypetes macrophylla, Aglaia heptandra* and *Melaleuca leucadendron*) in Letkole, 5 species (*Vitex parviflora, Dryobalanops aromatic, Schleichera oleosa, Ceriops tagal* and *Eucalyptus urophylla*) in Oelbanu.

In this research, we found 74 species of trees that occurred only at level of trees (DBH > 25.5 cm), most of them provided in Letkole dry forest i.e. 27 species in Binafun, 17 species in Bonmuti, 46 species in Letkole and 20 species in Oelbanu (Table 2).

The most common family in the research sites was Moraceae which was composed of 14 species (Table 2). Figure 7 show the ten most common species on density criteria in each sites, where its around 97.28% of a total of 365 stands, 96.90% of 373 stands, 83.50% of a total 759 stands and 93.05% of a total of 600 stands for Binafun, Bonmuti, Letkole and Oelbanu, respectively.

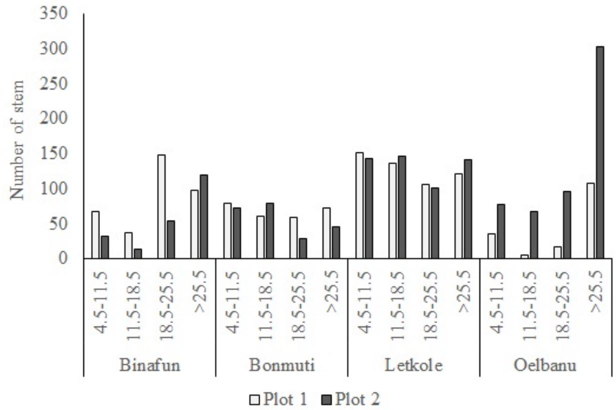

Figure 3. Stem number of plant species in the research sites

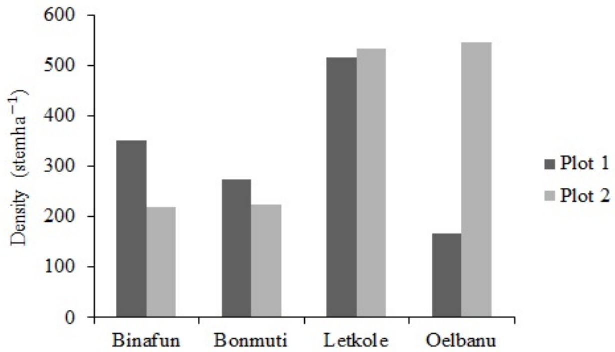

Figure 4. Density of plant species in the research sites

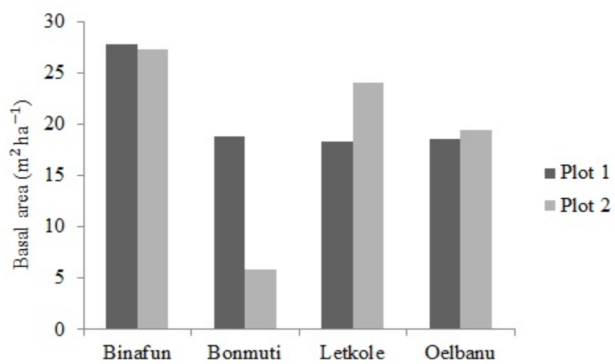

Figure 5. Basal area of tree species in the research sites

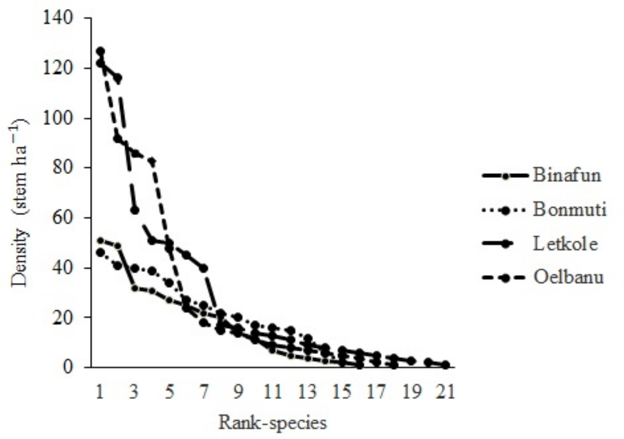

Figure 6. Cumulative ranked abundance curves of tree species in the research sites

Table 2. Density for each tree species which have DBH >25.5 cm in the research sites

		Number of stand			
Species	**Family**	**Binafun**	**Bonmuti**	**Letkole**	**Oelbanu**
Acacia oraria	Mimosaceae			2	
Aglaia heptandra	Meliaceae		1	15	
Albizia lebekioides	Fabaceae				
Albizia procera	Fabaceae			1	
Albizia saponaria	Fabaceae			2	
Albizzia chinensis	Fabaceae	5	5	3	
Alstonia scholaris	Apocynaceae			4	
Alstonia villosa	Apocynaceae	1			
Bambusa spinosa	Poaceae				1
Bauhinia malabarica	Leguminosae				
Broussonetia papyrifera	Moraceae			1	
Canarium asperum	Burseraceae				
Casuarina junghuhniana	Casuarinaceae				1
Celtis cinnamomea	Ulmaceae	1	17		
Celtis wightii	Ulmaceae	6		1	
Ceriops tagal	Rhizophoraceae				
Cordia spp.	Boraginaceae	1			8
Cudrania cochinchinensis	Moraceae.			1	
Desmodium cephalotis	Cephalotaceae				
Dryobalanops aromatica	Dipterocarpaceae				22
Drypetes longifolia	Putranjivaceae				
Drypetes macrophylla	Putranjivaceae			20	
Dysoxylum gaudichaudianum	Meliaceae	3		4	
Elattostachys verrucosa	Sapindaceae			1	
Eleocarpus peyiolatus	Elaeocarpaceae				
Eucalyptus urophylla	Myrtaceae	50	21		87
Eugenia littorale	Myrtaceae		4		
Eugenia polyantha	Myrtaceae			2	
Euodia macrophylla	Rutaceae	2	1		
Exocarpus latifolia	Santalaceae			1	
Ficus ampelos	Moraceae	1	1	27	
Ficus benjamina	Moraceae			1	8
Ficus callosa	Moraceae	1			
Ficus flaveola	Moraceae		4		
Ficus fulva	Moraceae	1			1
Ficus gibbosa	Moraceae			1	
Ficus glomerata	Moraceae	1		14	10
Ficus hispida	Moraceae			3	
Ficus nervosa	Moraceae	6	1		
Ficus racemosa	Moraceae			4	
Ficus spp.	Moraceae	2		1	
Ficus variegata	Moraceae	3	1	2	
Garuga floribunda	Burseraceae			2	17
Gnetum gnemon	Gnetaceae				
Gyrocarpus americanus	Hernandiaceae	1	2	12	11
Harissonia perforata	Simaroubaceae	2			
Hibiscus tiliaceus	Malvaceae				2
Hibiscus timoriensis	Malvaceae				
Homalium tomantosum	Salicaceae			1	
Hymenodictyon excelsum	Rubiaceae			2	
Jambolifera trifoliata	Rutaceae				2
Kleinhovia hospita	Malvaceae			1	
Lagerstroemia sp.	Lythraceae		7	1	
Lantana camara	Verbenaceae				
Leea sp..	Vitaceae				
Litsea difersifolia	Lauraceae			3	
Macaranga tanarius	Euphorbiaceae	2		1	
Maesa latifolia	Primulaceae			1	
Mallotus philippinensis	Euphorbiaceae			1	
Mangifera indica	Anacardiaceae				
Melaleuca cajuputi	Myrtaceae		15		15
Melaleuca leucadendron	Myrtaceae			1	
Mischocarphus sundaicus	Sapindaceae				
Nauclea orientalis	Rubiaceae			3	
Nephelium juglandifolium	Sapindaceae			2	
Omalanthus populneus	Euphorbiaceae				
Oroxylum indicum	Bignoniaceae				
Peltophorum inerma	Fabaceae			3	5
Phaleria laurifolia	Thymelaeaceae	6	8	5	
Photinia sp.	Rosaceae				
Phyllanthus sp..	Phyllanthaceae				
Pipturus argenteus	Urticaceae	3			
Pittosporum timorense	Pittosporaceae				1
Podocarpus amara	Podocarpaceae	1			
Podocarpus imbricata	Podocarpaceae	1			
Polyscias rumphiana	Araliaceae				
Prunus sp.	Rosaceae	5		1	
Pterocarpus indicus	Fabaceae		2		
Pterocymium tinetorium	Malvaceae				
Pygeum parviflorum	Rosaceae			3	
Schleichera oleosa	Sapindaceae			2	63
Sesbania grandiflora	Fabaceae		1		
Sterculia foetida	Sterculiaceae			2	
Syzygium javanica	Myrtaceae	12			
Tamarindus indica	Fabaceae				6
Tarenna pubiflora	Rubiaceae			3	
Terminalia catappa	Combretaceae			2	
Terminalia mollis	Combretaceae	2		1	
Timonius sericaus	Rubiaceae			2	1
Viburnum sp.	Adoxaceae	1			1
Vitex parviflora	Verbenaceae				40
Wikstroemia androsaemifolia	Thymelaeaceae			1	
Wrightia calysina	Apocynaceae				
Zizyphus timoriensis	Rhamnaceae	9	1		

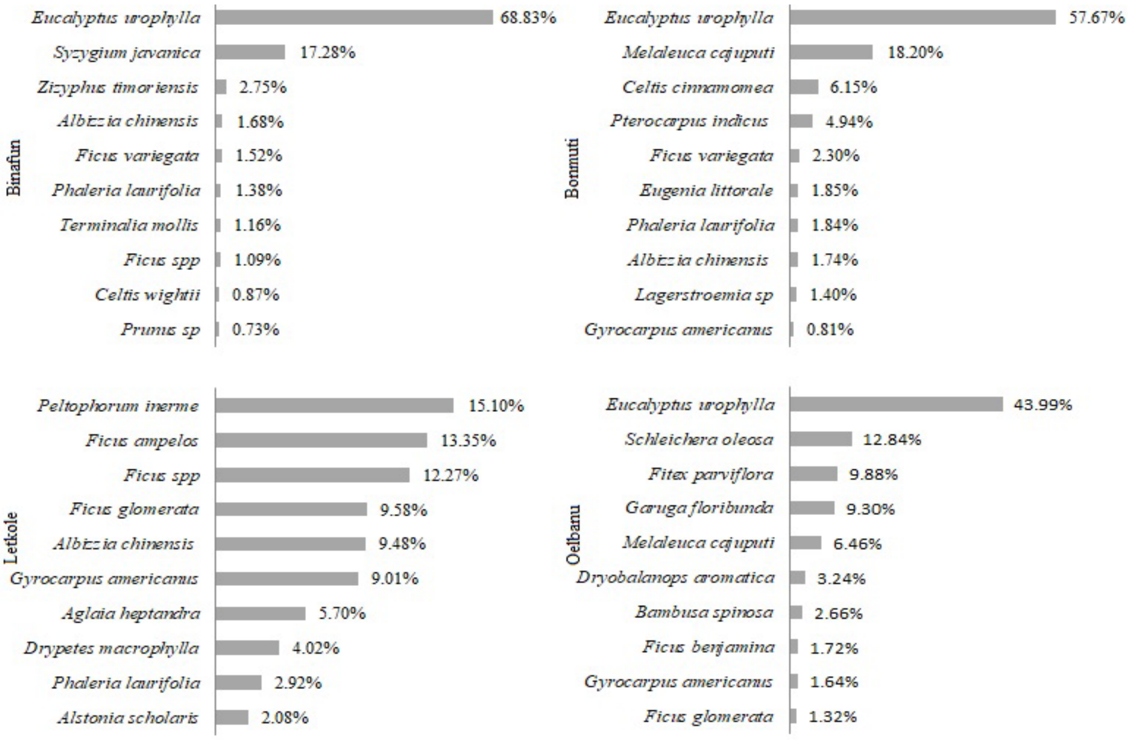

Figure 7. The ten most common species on density criteria in each sites

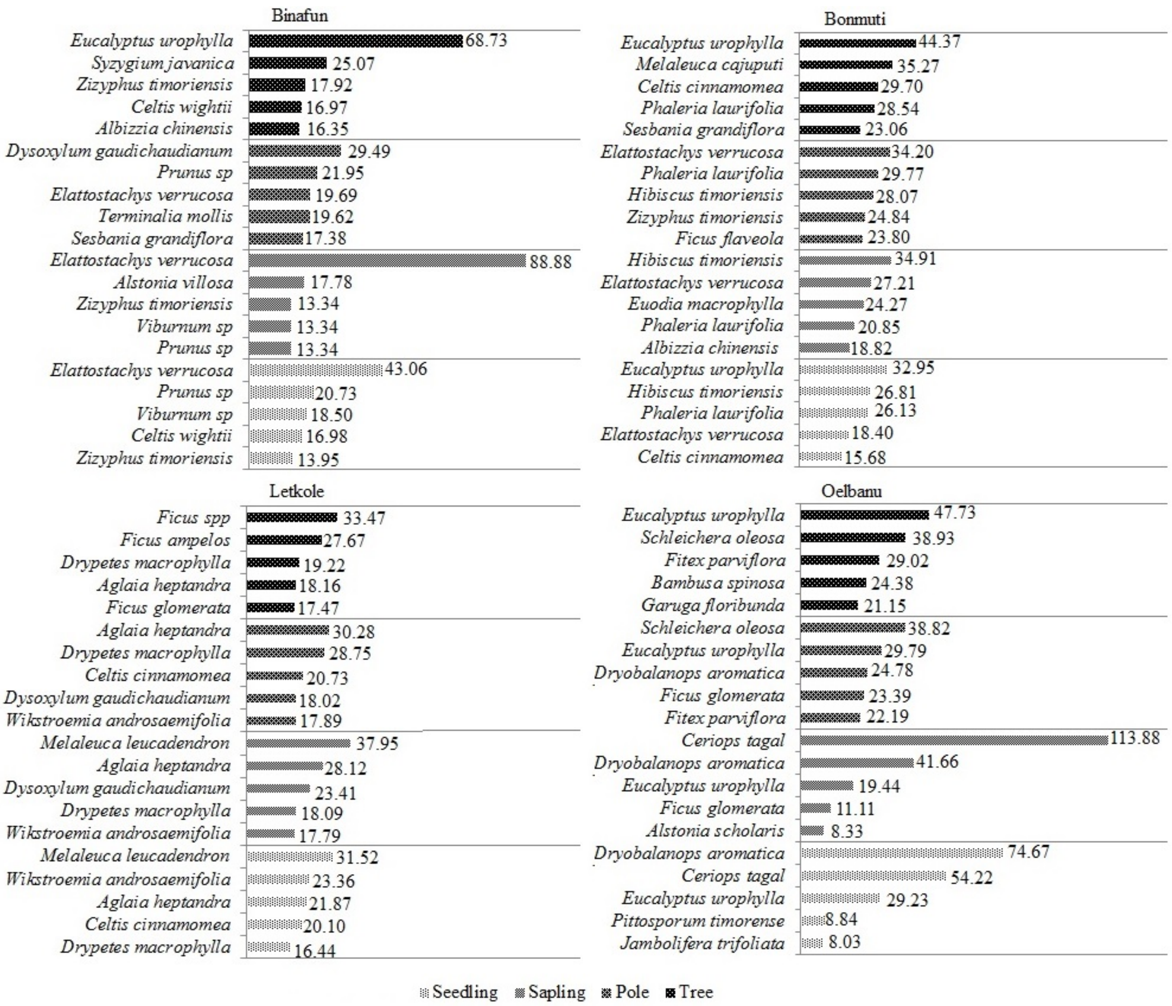

Figure 8. The five highest value of important index

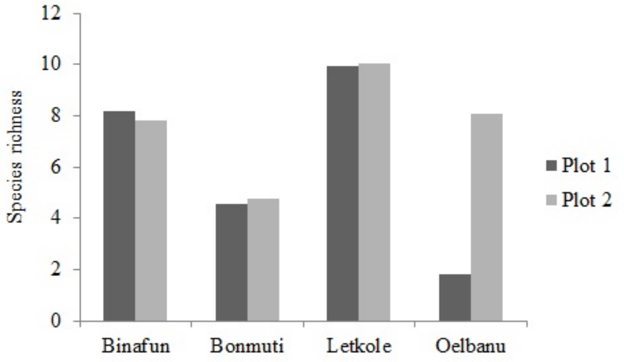

Figure 9. Species richness of tree species in the research sites

In respect to heterogeneity, there were differences in vegetation composition among the four research sites (Figure 8). Based on the IVI the dominant species at each site differed. Ranked by IVI; Binafun was dominated by *Elattostachys verrucosa* (151.64%), *Eucalyptus urophylla* (79.13%) and *Prunus* sp. (65.71%); Bonmuti by *Phaleria laurifolia* (105.31%), *Eucalyptus urophylla* (103.78%) and *Hibiscus timoriensis* (89.81%); Letkole by *Aglaia heptandra* (98.44%), *Melaleuca leucadendron* (87.90%) and *Drypetes macrophylla* (82.52%); Oelbanu by *Ceriops tagal* (188.28%), *Dryobalanops aromatic* (159.09%) and *Eucalyptus urophylla* (126.2%) (Figure 8).

The species richness per sampled sites ranged from 7.81 to 8.18 in Binafun, 4.56 to 4.75 in Bonmuti, 9.93 to 10.06 in Letkole, 1.81 to 8.06 in Oelbanu dry forest (Figure 9). The lowest value of species richness in Letkole dry forest (1.81) may be caused by the fact that seedlings, saplings, and poles of the pioneer species tended to be absent in this site.

Species richness in research sites was 8.18 (plot 1) and 7.81 (plot 2) in Binafun, 4.56 (plot 1) and 4.75 (plot 2) in Bonmuti, 9.93 (plot 1) and 10.06 (plot 2) in Letkole, 1.81 (plot 1) and 8.06 (plot 2) in Oelbanu. This variation in species richness between the sites may be explained by the elevation factor. In the present study, the elevation was recorded from 125-636m. The minimum species richness (1.81) was recorded at the highest elevation (636 m). According to McCain et al. (2000), decreasing richness patterns are those in which species numbers generally decline monotonic with increasing elevation. Low plateau patterns have consecutively high richness across the lower portion of the gradient (<300 m) and after that decreasing species richness. Low plateau patterns with a mid-elevational peak have high richness across low elevations (> 300 m) with a diversity maximum found more than 300 m from the base. Mid-elevation peaks have a unimodal peak in diversity at intermediate elevations (<300 m) with 25% or more species than at the base and top of the mountain. The dispersal limitation is an important ecological factor for controlling species distribution pattern and a connection between biotic and abiotic ecological factors. A number of tree species found in the Himalaya showed varying patterns of distribution. The extension of climate gradient enabled several species to realize their fullest range of elevational adaptability (Hubbell et al. 1999).

The lowest value of species richness in Letkole dry forest (1.81) may be caused by the fact that seedlings, saplings, and poles of the pioneer species tended to be absent in this site because of light deficiency on the forest floor (Table 2), it may result from the limitation of seed rain and/or light deficiency (Wangpakapattanawong et al. 2010). This indicates that the tree species (DBH>25.5cm) suppressed the growth of seedlings, saplings, probably due to low light intensity (Chuntanapapb 1969). We propose that seed limitation should be particularly strong for pioneer species given their low population densities and the infrequency with which their recruitment sites become available (Dalling and John 2008). Woody pioneers, including trees, shrubs and lianas, are fast-growing species whose abundant and widely dispersed seeds require high-light conditions for germination and establishment (Swaine and Whitmore 1988).

In this research, silviculture treatment with harvesting on tree species may improve conditions for regeneration of pioneer species through a reduction in competition. Nevertheless, silvicultural interventions should be oriented towards the liberation of future crop trees (i.e., liberation thinning) and avoid substantial changes in forest structure, which may lead to high recruitment of pioneer species in the forest stand as already observed in the study area (de Avila et al. 2015). Oliveira-Filho et al. (1998) found in a tropical dry forest in Brazil five scrubs species that were exclusive to gaps and only two of them were occasionally detected outside the gaps.

For the development of pioneer species in research sites, several valuable species of shrubs and tree species (*Nauclea orientalis, Pipturus argenteus, and Pterocarpus indicus*) can be established in the field directly from seed. Direct seeding involves collecting seeds from local sources, storing them until sowing, identifying the germination niches or preparation of seed-beds to optimize the germination, and sowing seeds at the onset of monsoon season. In general, world-wide experience suggests that direct seeding is a useful method for restoration of tropical dry forests (Pandey and Prakash 2014).

It is clear that understory development will depend on the active intervention of managers through seeding and planting (Denslow et al. 2006) and adequate knowledge about the autecology of target species is important to guide silvicultural interventions (Gómez-Pompa and Burley 1991). Because of climate change and rampant movement of non-native species, native ecosystems are under siege worldwide, and restoration, already difficult, has become increasingly complicated (Harris et al. 2006).

In conclusion, although the regeneration of tree species was low in several research sites, it potentially appears that the silvicultural interventions to pioneer species through thinning liberation, seeding and planting (pioneer species) could accelerate the tree species regeneration of Mutis Timau PFMU in Kupang District, East Nusa Tenggara Province, Indonesia.

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