

# Karst vegetation in the natural habitat of sandalwood (*Santalum album*) at various altitude places in Timor Island, Indonesia

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**Abstract.** Lio FXS, Dewi MPS. 2018. Karst vegetation in the natural habitat of sandalwood (*Santalum album*) at various altitude places in Timor Island, Indonesia. *Biodiversitas* 19: 1703-1713. Sandalwood (*Santalum album* L.) was the superior commodity in South Central Timor District, but it tends to decrease in number at present. South Central Timor has been highly regarded for the quality and former abundance of its sandalwood stocks and it has been one of the most productive sources for sandalwood on Timor Island. It grows in the karst ecosystem at altitude of 450-1044 m asl. This study aims to assess karst vegetation in the natural habitat of sandalwood at three elevation sites in South Central Timor. A total of 4 plots were placed in the middle land zone (307-382 m asl.), 7 plots in the upland zone (784-1031 m asl.), and 4 plots in the highland zone (1665-1782 m asl.). Data were sampled using a square plot measuring 20 x 20m for tree, and the sub-plot of 1 x 1m for the ground vegetation category. Ecological data were measured together with the sampling of vegetation data, while the soil quality was assessed in the laboratory of Nusa Cendana University. The results showed that the higher a place from the sea surface, the less number of species was found. The highest number of species was found in the upland zone, but it tended to decrease in the highland zone. Dominant species placed at each zone were also different, which in the middleland zone the dominant species were *Acacia mangium*, *Tectona grandis*, and *Eleusine indica*; in the upland zone, they were *Lantana camara*, *Gmelina arborea*, *Senna siamea* and *Cyperus rotundus*, whereas in highland zone was dominated by *Senna occidentalis*, *Portulaca oleracea*, *Eucalyptus urophylla*, and *C. rotundus*. The results of multiple regression analysis also showed that environmental factors did not affect the species number in research sites. Ecological condition and soil quality in research sites indicated that those conditions are suitable for sandalwood's growth.

**Keywords:** vegetation, karst, sandalwood forest, South Central Timor

## INTRODUCTION

The sandalwood (*S. album* L.) grows in karst ecosystem with the thin layer of soil and poor nutrients. Karst has a unique topography as a result of the dissolution of soluble rocks and characterized by the presence of grooves and strains, had a high porosity of rocks that could not accommodate large amounts of water (Heilman et al. 2009; Liu et al. 2012; Lu et al. 2014). It was very susceptible to annoyance. Sandalwood was an endemic plant species to East Nusa Tenggara which had high economic value, and also as a symbol of community unification and local wisdom. Currently, sandalwood grows both wild and cultivated status in Timor Island (Kupang, South Central Timor and North Central Timor Districts) and Sumba Island (East Sumba and West Sumba Districts) at a dry region with agro-climate condition of D3, D4 and E4 (McWilliam 2005).

Sandalwood was the superior commodity in the past, but it tends to decrease at present in South Central Timor. The district had been highly regarded for the quality and former abundance of its sandalwood stocks and it has been one of the most productive sources for sandalwood on Timor Island (Pulongo 1995; McWilliam 2005). According to the Government of East Nusa Tenggara, there were 300,000 sandalwood trees in Timor, Alor, and Sumba

in 2010. In fact, in 2000 there were still around 1,000,000 sandalwood trees in the area (Nurcahyani 2017).

Kaho (2011) conducted a study on the distribution of sandalwood at various altitude places in South Central Timor, and his research area was only in Kuanfatu Village, Kuanfatu Sub-district at altitude 450 m asl.; Haunobenak Village, Kolbano Sub-district at altitude 750 m asl.; Anin Village, South Amanatun Sub-district at altitude 755 m asl.; Oelbubuk Village, Central Mollo Sub-district at altitude 997 m asl., and Eonbesi Village, North Mollo Sub-district at altitude 1044 m asl. In North Central Timor District, sandalwood grows at altitude of 100-730 m asl. At least, 21 species of associated species of sandalwood were found in lowland, 34 species in middleland and 68 species in upland (Lio 2015).

Plant species are associated with sandalwood include: *Acacia leucophloea*, *Amorphophallus variabilis*, *Annona squamosa*, *Artocarpus heterophyllus*, *Brucea javanica*, *Cajanus cajan*, *Capsicum annum*, *Chromolaena odorata*, *Euphorbia hirta*, *Imperata cylindrica*, *Lantana camara*, *Leucaena leucocephala*, *Oryza sativa*, *Pleiogynium timoriense*, *Psidium guajava*, *Pterocarpus indicus*, *Schleichera oleosa*, *Senna siamea*, *Sesbania grandiflora*, *Swietenia macrophylla*, *Tectona grandis*, *Tridax procumbens*, and *Ziziphus mauritiana* (Kaho 2011). According to Surata (2006) sandalwood is a hemiparasite

plant that requires other plants as hosts. The primary host species are *C. cajan*, *Capsicum annum*, *L. leucocephala* and *S. grandiflora*. The secondary host species include *Acacia villosa*, *Casuarina equisetifolia*, *I. cylindrica*, and *S. siamea*.

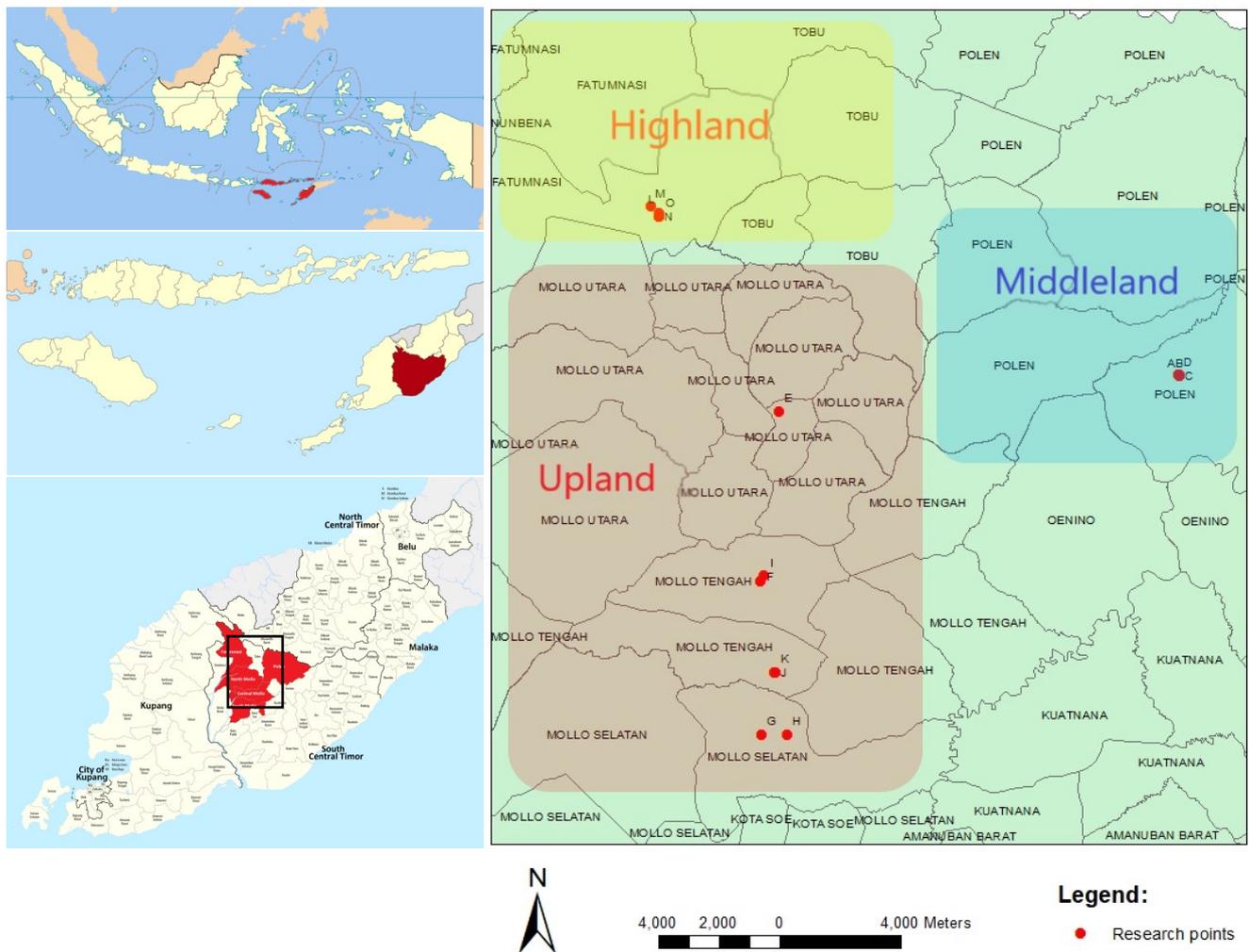
The number of vegetation species that compiled sandalwood forest community showed that the higher a site from the sea level, the more number of associated species were found. There were several different patterns of plant species diversity due to varying responses to altitude i.e. (i) plant diversity decreased with increasing altitude; (ii) plant diversity increased with increasing altitude; (iii) "swells" in the middle-altitude; (iv) plant diversity decreased in the middle-altitude; or (v) no relationship with altitude (MacArthur 1972). The present study aimed to assess karst vegetation in the natural habitat of sandalwood at three elevation sites in South Central Timor.

**MATERIALS DAN METHODS**

**Study areas**

The research has been carried out from January to February 2018. The research sites were divided into 3 zones in South Central Timor District, East Nusa Tenggara Province, Indonesia, i.e., zones of middle land, upland, and highland (Figure 1). According to Degroot (2009), the lowland ranges at 0-199 m asl., middle land at 200-499 m asl., upland at 500-1499 m asl., and highland at >1499 m asl.

The middle land zone was located in Puna Village, Polen Sub-district at altitude of 307-382 m asl. The upland zone was located in Villages of Eonbesi, Oelbukuk, Oehala, and Binaus at altitude of 784-1031 m asl. Gunung Mutis Natural Reservation in Fatumnasi Village at altitude of 1665-1782 m asl. The data were not collected in lowland, because the sandalwood was found only in the middle to highland zones (Kaho 2011).



**Figure 1.** Study sites in South Central Timor District, East Nusa Tenggara Province, Indonesia. The ABCD points, representing 4 plots were placed in the middle land zone. The EFGHIJK points, representing 7 plots were placed in the upland zone, and the LMNO points, representing 4 plots were placed in the highland zone

## Procedures

### Vegetation

Vegetation data were recorded using a plot of size 20 x 20m (Barbour et al. 1987). The data sampled on each plot were vegetation (stand, shrubs, herbs and floor vegetation), ecological condition, and soil chemistry. Herbs are plants with soft trunk (not woody) (Brewer 1993). Shrubs are clumping plants with short stems, creeping, a few centimeters to approximately 1.5 m (Lenard 2008). The stand is a distribution of the number of trees per unit area (ha) in various layers of its diameter class (Meyer et al. 1961). The stand consisted of a tree (clump circular > 31.4 cm), sapling (clump circular between 6.28-31.4 cm), and seedling (clump circular < 6.28 cm). It categorized as the stand if a species had 1 m height above, meanwhile if it was 1 m height under, it categorized as floor vegetation (Relva et al. 2008). Growth form parameter of stand, shrub, herbs, and floor vegetation measured the involved number of plant species, individual number of each plant species, each species density, stem circular, a canopy length and width, and clump circular (Zhao et al. 2005). To record the data of floor vegetation, it used subplot of 1m x 1m (Figure 2). Vegetation data ecological condition and soil quality in the highland zone were taken from 4 plots; 7 plots in upland zones, while in the middle land zone was placed 4 plots.

### Ecological condition and soil quality

Ecological condition such as air temperature and humidity, light intensity, soil temperature, moisture, and pH were measured and recorded in research sites. Those parameters of each quadrant in the plot were measured with 5 replications. Data of soil quality were obtained in 5 replications (Figure 3). Each replication will be taken as much as 100 g and then mixed until homogeneous. The layer of soil was taken at a layer of 0-20 cm. Each zone would be obtained 1 composite soil derived from the composite soil of the whole plot (Mahler and Tindal 1990). For analysis, 200 gr (composite soil per zone) were taken to the laboratory for the study of Nitrogen, P<sub>2</sub>O<sub>5</sub>, Fe, potassium, and calcium concentrate.

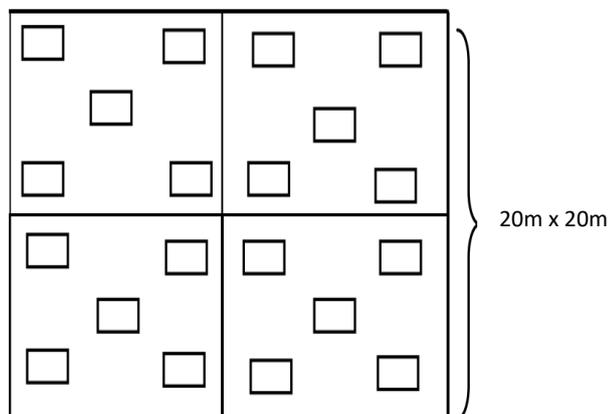


Figure 2. Sub-plot to calculate the floor vegetation (Bexter 2014)

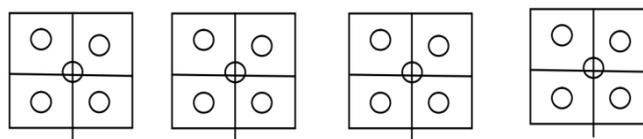


Figure 3. Soil composite sampling (Mylavarapu and Won 2002)

## Data analysis

Vegetation data were tabulated and inserted into MS Excel as a calculating tool. The calculations for obtaining the Important Value (IV) (Barbour et al. 1987) were as followed:

$$\text{Density of species A} = \frac{\text{individual count of species A}}{\text{Area wide}}$$

$$\text{Relative density of species A} = \frac{\text{a total count of species A}}{\text{density of whole species}} \times 100 \%$$

$$\text{Frequency of species A} = \frac{\text{number of plots found species A}}{\text{number of whole plot}}$$

$$\text{Frequency relative of species A} = \frac{\text{frequency of species A}}{\text{frequency of whole species}} \times 100 \%$$

$$\text{Wide of basal area of species A} = \pi(\text{stem radius of species A})^2$$

$$\text{Wide of relative basal area of species A} = \frac{\text{wide of basal area of species A}}{\text{wide of basal area of whole species}} \times 100\%$$

$$\text{Canopy wide of species A} = \pi(\text{length} \times \text{width}) \text{ canopy}$$

$$\text{Relative canopy wide of species A} = \frac{\text{canopy wide of species A}}{\text{canopy wide of whole species}} \times 100\%$$

IV of species A = Relative density of species A + Relative frequency of species A + Wide of basal area of species A + Relative canopy wide of species A

To examine the effect of environmental physical factors on the number of species found in each study plot, a multiple regression analysis was conducted with the help of SPSS software.

The formula of it described as follow (Uyanik and Nese 2013):

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \dots + b_6X_6 + \varepsilon$$

Where :

- Y : Number of plant species in each plot
- b<sub>0</sub> : The value of plant species number when whole free variable counted as zero
- b<sub>1</sub>-b<sub>6</sub> : The coefficient of regression variable
- ε : Error
- X<sub>1</sub> : Air temperature
- X<sub>2</sub> : Air humidity
- X<sub>3</sub> : Soil temperature
- X<sub>4</sub> : Soil moisture
- X<sub>5</sub> : Soil pH
- X<sub>6</sub> : Light intensity

**RESULTS AND DISCUSSION**

**The number of species on each elevation**

Twenty-seven species were recorded in the middle land zone, 79 species in the upland zone, and 35 species in the highland zone. The results indicated that altitude was not affecting to the number of species in South Central Timor. If it had reached the highland zone, then the number of species tended to decrease. This result might be due to temperature being the limiting factor of the presence of various species of vegetation. According to Lio (2015), there were 21 species found in the lowland zone. Based on the present study, there were 27 species found in middle land, 79 species in upland, and 35 species in highland (Figure 4).

The diversity of plant species due to altitude patterns had been the focus of attention from ecologists such as Whittaker (1960), Mac Arthur (1972), and Walter (1979). The altitude and slopes primarily determined microclimate conditions and in the broader scale determined the spatial distribution and vegetation pattern and cover (Jin et al. 2008). There were several varying patterns of plant species diversity due to different responses to altitude i.e. (i) plant diversity decreased with increasing altitude; (ii) plant diversity increased with increasing altitude; (iii) "swells" in the middle-altitude; (iv) plant diversity decreased in the middle-altitude; or (v) no relationship with altitude. MacArthur (1972) revealed lowland regions in the tropics and sub-tropics had the highest biodiversity, in where species diversity decreased with increasing altitude. However, the hypothesis lacked of evidence (Colwell and Hurr 1994). More references of the effect of altitude on species diversity in tropical and sub-tropical mountain ecosystems suggested that the elevation gradients had a significant impact on plant distribution; the highest diversity tended to be in the middle land zone (Lomolino 2001). However, there was another study reported that there was no diversity differentiation with increasing altitude (Wilson and Sydes 1988). At different altitude, growth form as shrub and herb had different diversity (Whittaker 1960).

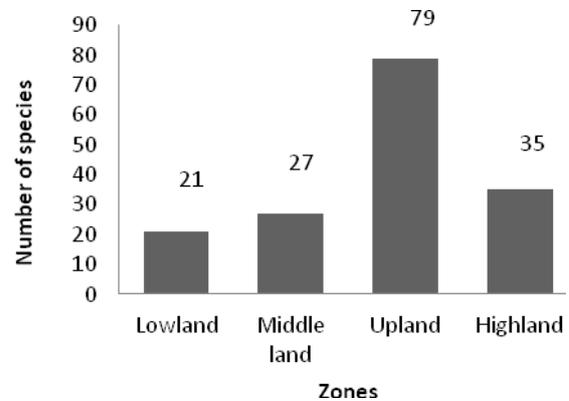
Based on those studies, it assumed that the number of species did not increase with increasing of altitude. Climate change due to deforestation caused various species adapted

to a variety of habitat conditions and the highest number of species found at upland (Zhao et al. 2005). Present study showed that the upland zone is an optimal habitat for the growth of various species. It means habitat conditions in upland zones with a variety of environmental factors exist were still able being tolerated by the species. Areas below and above the upland zone were only be occupied by species that had wide tolerance ranges with habitat conditions that might be said to be a little bit extreme. However, it needed to be further studies, especially for tropical monsoon climatic regions such as Timor in particular and East Nusa Tenggara in general.

**The influence of ecological factors on the number of species**

Number of species and ecological conditions, such as air temperature and humidity, soil temperature, moisture, and pH, and light intensity were performed in Table 2.

The relationship between species number and environmental factors (eliminate the interactive effects among species number and environmental factors) that used F test and t-test analysis were presented in Table 3 and 4. F test analysis used to understand the simultaneously ecological factors with the appearance of species number in each plot, whereas t-test analysis used to understand the effect of ecological factors partially on the number of species (Zhao et al. 2005).



**Figure 4.** Number of species found in the study sites

**Table 1.** Ecological data and number of plant species

Environmental physical factors	Middle land				Zones Upland Plots							Highland			
	1	2	3	4	1	2	3	4	5	6	7	1	2	3	4
	Altitude (m asl.)														
	307	364	377	382	948	1031	784	790	1005	832	825	1655	1702	1662	1683
Air Temp. (°C)	37.5	36.75	42.25	41	26.13	24.75	24.88	25.38	27.88	32.88	32.75	17	18.75	19.75	19.75
Air Humidity (%)	49.75	45.5	44	48.8	81	85.13	87.38	86.5	59	59.75	66.25	95.5	92.75	92	95.25
Soil Temp. (°C)	32.5	33.5	32.5	31.5	23.88	20.63	24.88	24.25	22.63	27.13	26.13	17.5	17.25	17.5	17.75
Soil Moisture (%)	4.1	4.15	4	4.1	7.8	8.525	6	6.625	7.975	7.975	8.05	7.025	6.05	6.975	7.05
Soil pH	7.5	7.125	7.175	7	7	7.05	6.6	7.05	7.05	6.975	7.025	7	6.88	6.98	6.78
Light Intensity (Cd)	325	40	45	375	10	22.5	10	25	25	37.5	32.5	0	0	0	0
Number of species	17	20	17	20	20	13	20	21	32	26	24	10	13	16	22

Note: Light intensity valued zero in the highland zone because there were fogs during the sampling data taken

**Table 2.** F test analysis result of environmental factors to species number

ANOVA						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	220.989	6	36.831	1.426	.313b
	Residual	206.611	8	25.826		
	Total	427.600	14			

Note: a. Dependent Variable: Species Number (Y); b. Predictors: (Constant), Light intensity (X6), Soil pH (X5), Soil moisture (X4), Air moisture (X2), Soil temperature (X3), Air temperature (X1)

**Table 3.** The result of t-test analysis of environmental factors to species number

Coefficients <sup>a</sup>						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	SE	Beta		
1	(Constant)	101.879	83.817		1.215	.259
	Air temp. (X1)	-.436	.856	-.652	-.510	.624
	Air moisture (X2)	-.354	.253	-1.267	-	.199
	Soil temp. (X3)	.310	.908	.330	.342	.741
	Soil moisture (X4)	2.318	1.260	.682	1.839	.103
	Soil pH (X5)	-9.566	9.433	-.337	-	.340
	Light intensity (X6)	.002	.017	.050	.134	.896

Note: a. Dependent Variable: Species number (Y)

Ecological data and number of plant species were performed in Table 1. F test analysis showed that the sig value is  $0.313 > 0.05$ , it means, there was not any influence of environmental factors simultaneously (together) to the number of species in each plot (Table 2). The results of t-test analysis showed that each environmental factor, which consists of: (1) the air temperature had a sig value of  $0.624 > 0.05$ ; (2) the air humidity had a sig value.  $0.199 > 0.05$ ; (3) the soil temperature had a sig value of  $0.741 > 0.05$ ; (4) soil moisture had sig value of  $0.103 > 0.05$ ; (5) soil pH had sig value of  $0.340 > 0.05$ ; and (6) the light intensity had a sig value of  $0.896 > 0.05$ , had not any significant effect to number of species (Table 3).

Plant species diversity might be affected by air temperature and precipitation, which highly depended on altitude and sunlight. The distribution of species had a significant association with spatial location, where altitude showed a lot of vegetation data, followed by latitude and longitude. The largest number of species was found at 1200 m asl, and fewer were found at altitude below 1200 m asl or above 1200 m asl (Zhao et al. 2005). The number of plant species in a particular community was also influenced by the availability of resources on a broad scale, the broad ecological niche of a species, or also affected by the time of

evolution and the environmental succession (Pianka 1966). Environmental factors were the main factors caused biodiversity compared to biological factors (Huang 1994). The alteration of altitude, together with the changing in temperature, rainfall and sunlight conditions changed the distribution of vegetation (Jhonson et al. 1986). Habitat diversity and human activity were able to change water and temperature and caused vegetation diversity regarding altitude patterns. Since flora in the tropics was generally tropical, low temperatures limited the distribution of tropical plants along with increasing altitude, therefore plant species diversity decreased with increasing altitude (Zhao et al. 2005).

According to Rohde (1992), there was no a consistent correlation between species diversity, environmental stability, environmental predictability, productivity, abiotic rarefaction, physical heterogeneity, aridity, seasonality, number of habitats, and latitudinal ranges. The ecological and evolutionary time hypotheses, as usually understood, also could not explain the gradients, nor did the temperature dependence of chemical reactions permit predictions on species richness. Only differences in solar energy were consistently correlated with diversity gradients along latitude and altitude. It was concluded that greater species diversity is due to higher "effective" evolutionary time (evolutionary speed) in the tropics, probably as the result of shorter generation times, faster mutation rates and selection at higher temperatures.

### The habitat condition of sandalwood

The total of 208 individuals grouped into the category of the stand and 4105 individuals categorized of floor vegetation of 27 species (both stand and floor vegetation) grouping to 13 families were found in the natural habitat of sandalwood in the middle land zone. The highest density for the seedling category was *Acacia mangium* with density of 27 individuals/ 0.24 ha; the highest Importance Value (IV) was *A. mangium* with IV of 20.9%. For the sapling category, the highest density was *Tectona grandis* with the density of 77 individuals/ 0.24 ha, which was also the species with the highest IV of 77.9%. While for the tree category was *T. grandis* with density of 22 individuals/0.24 ha, with IV equal to 60.4%. For the group of ground vegetation was occupied by *Eleusine indica* with density of 2267 individuals/0.24 ha and IV equal to 60.9%. All species were recorded in study sites were performed in Table 4.

*Acacia mangium* was planted as a marginal land plant. It could fix nitrogen significantly that helped to rehabilitate the soil. It was suitable to grow at an altitude of 0-400 m asl, at warm temperatures with very low to high rainfall and soil conditions with the range of pH 4-9. It could grow well under degraded soil conditions, tolerant to environmental stress, on barren land, clay, high salt soil or inundated soil; and suitable to be raised in various tropical and sub-humid regions (Aguiar et al. 2014; Tanaka et al. 2015). *T. grandis* could grow and develop well in moist areas compared with dry areas, with average temperatures during the daylight was 27-36°C and at night it was from 20-30°C. It also required soil with high calcium level with

the range of pH 6.5-7.5 (Kaosa-Ard 1989). According to An et al. (2014), *E. indica* was one of the herbs that had a high level of fecundity and a wide tolerance to various environmental factors that vary in certain habitat. The total species found in study sites were the list in Table 5.

In the upland zones were recorded 379 individuals of stand category, and 8462 individuals of floor vegetation from 79 species grouped into 31 families. The highest density and IV for seedling category were *Lantana camara* with density of 24 individuals/0.28 ha and IV of 10.4% respectively. For the sapling category was *Gmelina arborea* with density of 39 individuals/0.28 ha and IV of 28% respectively. While for the category of trees was *Senna siamea* with density of 27 individuals/ 0.24 ha and IV of 40.6% respectively. For the group of floor vegetation was *Cyperus rotundus* with density of 2889 individuals/0.28 ha and IV of 40.0% respectively. Priyanka and Joshi (2013) suggested that *L. camara* had the wide distribution in various habitat conditions and on various soil types (Sharma et al. 2005; Sankaran 2007). It was found from open areas, vacant lots, coastal ridges, tropical rainforests, and disturbed forests due to human activities such as burning and logging. Human activities further exacerbated the spread widely of the species. Sulaiman and Lim (1989) revealed that *G. arborea* could survive, easily reproduced, and its seed could grow in various climatic conditions. According to Joker (2000), *S. siamea* was a species that able to grow in various climatic conditions, from lowland areas with monsoon climate. It was also growing in degraded habitats, infertile soil and resistant to wind shocks because it had a shallow root system.

In the highland zone were recorded 63 individuals of stand category and 7201 individuals of floor vegetation from 35 species and grouped into 20 families. For seedling category, *Portulaca oleracea* had the highest density of 3 individuals/0.24 ha and *Senna occidentalis* had the highest IV of 12.8%. For the sapling category, *Spondias pinnata* had the highest density and IV of 10 individuals/0.24 ha and 23.3% respectively. The highest density and IV for tree category was *Eucalyptus urophylla* with a value of 27 individuals/0.24 ha and IV of 249.9% respectively. While for the group of floor vegetation was occupied by *C. rotundus* with density and IV of 2253 individuals/0.24 ha and 29.69% respectively. According to Sein and Mitlöhner (2011), *E. urophylla* was naturally found in Adonara, Alor, Flores, Lembata, Pantar, Timor and Wetar at an altitude of 180-3000 m asl. It was also found in hilly, clay areas, in open areas, secondary forests, and mountain forests with deep soil conditions, moisture, and well-drained soils. It also did not require so much soil nutrition. So, it was suitable for reforestation both on floodplains and dry lands in tropical lowland areas. Important value is needed to determine the composition of a forest community. According to Barbour et al. (1987), IV was a relative contribution within a community. The IV described the importance of the role of a vegetation species in the ecosystem (Kalaba et al. 2013). The IV at each growth rate would describe the important species at that level.

The dominant species at study sites were different. This difference was due to each species dominating a different

region. The dominating species meant having a more extensive range tolerance of environmental factors if compared to the other species (Barbour et al. 1987). The environmental conditions led to competing among species with other species. Competition would increase the fighting power to alive, so that strong species will prevail and suppress other species. Losing species became less adaptive and caused low reproductive rates and were found in small amounts (Aerts 1999). Each plant species had a minimum, maximum and optimum condition of the existing environmental factors.

In the highland zone was recorded several species of orchids, fungi, mosses, and lichens. Fungi species was found included *Pleurotu sostreatus*, *Ganoderma applanatum*, and *Pleurotus cystidiosus*. Species of moss were found highlands such as *Pellia endiviifolia*, *Anthoceros punctatus*, and *Polytrichum abbreviatum*. *Usnea* sp. and *Parmalia* sp. were found too. The orchid species was found living commensalism to ampupu plants, as well as with moss and lichens. Solikin (2015) revealed that the vegetation in the Gunung Mutis Natural Reservation was dominated by ampupu, especially in the savannas. The orchid species found in the Gunung Mutis Natural Reservation included *Bulbophyllum ovalifolium*, *Bulbophyllum odoratum*, *Ceratostylis radiate*, *Dendrobium kuhlii*, *Eria retusa*, *Eria rhynchostyloides*, and *Pholidota rubra*.

Sandalwood was found in all research sites. This finding is supported by the living species associated with sandalwood such as *A. leucophloea*, *A. variabilis*, *A. squamosa*, *A. heterophyllus*, *B. javanica*, *C. cajan*, *C. annum*, *C. odorata*, *E. hirta*, *I. cylindrica*, *L. camara*, *L. leucocephala*, *O. sativa*, *P. Timoriensis*, *P. guajava*, *P. indicus*, *S. oleosa*, *S. siamea*, *S. grandiflora*, *S. macrophylla*, *T. grandis*, *T. procumbens*, and *Z. mauritiana* (Kaho 2011). The results are similar as expressed by Surata (2006) that sandalwood is a hemiparasite plant that requires other plants as hosts. The primary host species are *C. cajan*, *C. annum*, *L. leucocephala*, and *S. grandiflora*. The secondary host species include *A. villosa*, *C. equisetifolia*, *I. cylindrica*, and *S. siamea*.

Based on the analysis, it is known that the number of species found on each plot in the middle land zone was 17 and 20 species (Figure 5). It means that the number of species found in the four observation plots was not different. In the upland zone, the smallest amount of species was found 13 species on plot 2, whereas the most was on plot 5. While in the highland zone was found 10 species on plot 1 and the most were found 22 species on plot 4. According to Pausas and Austin (2001), the variety of environment condition such as physical, chemical and interactions between species along the gradient of research sites caused the variety of species that live in it. This phenomenon would turn different if the environmental condition relatively homogeny. A relative homogeny of micro situ condition would be lived by individual from same species because it naturally developed adaptation mechanism tolerant to its habitat (Barbour et al. 1987). The number of species most commonly found was floor vegetation. It was because the study area was a savanna,

with rare stand condition and more found in floor vegetation. This condition was also supported because the vegetation is in a position with less density. The gaps formation created a microhabitat for underlying vegetation and provided opportunities for sapling, seedling, and floor vegetation to develop (Whitmore and Burnham 1984; Barbour et al. 1987; Campello et al. 2007; Naaf and Wulf. 2007). This condition also caused sunlight able to penetrate the forest floor so floor vegetation that generally light-requiring able to grow and develop (Campello et al. 2007).

### Ecological condition

The average of ecological conditions was recorded in 15 plots presented in Table 5. The measurement result was a description of the condition in the field during the research.

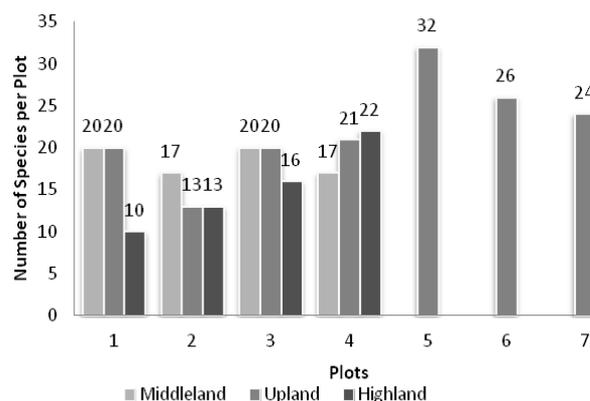


Figure 5. Number of species on each plot in study sites

Table 4. Species were recorded in study sites

Local name	Species	Family	Location			Habit
			Middle land	Upland	High land	
Akasia	<i>Acacia mangium</i> Wild.	Leguminosae	+	+	-	Stand
Alang-alang	<i>Imperata cylindrica</i> (L.) Raeusch	Poaceae	-	+	+	Shrub
Alpukat	<i>Persea americana</i> Mill.	Lauraceae	-	+	+	Stand
Ampupu	<i>Eucalyptus urophylla</i> S.T.Blake	Myrtaceae	-	+	-	Stand
Bakoma'a	<i>Hyptis capitata</i> Jacq.	Lamiaceae	-	+	-	Herb
Bandotan	<i>Ageratum conyzoides</i> (L.) L.	Compositae	-	+	+	Herb
Batang sirih hutan	<i>Peperomia luisana</i> Trel. & Standl.	Piperaceae	-	-	+	Herb
Baunoet	<i>Spigelia anthelmia</i> L.	Loganiaceae	-	+	-	Herb
Biduri	<i>Calotropis gigantea</i> (L.) Dryand	Apocynaceae	+	+	-	Herb
Bonsai	<i>Duranta erecta</i> L.	Verbenaceae	-	+	-	Shrub
Bunga kuning	<i>Tribulus terrestris</i> L.	Zygophyllaceae	-	+	-	Herb
Bunga mayana	<i>Coleus aromaticus</i> Benth.	Lamiaceae	-	-	+	Herb
Bunga putih	<i>Hippobroma longiflora</i> (L.) G.Don	Campanulaceae	+	+	+	Herb
Bunga putih terompet	<i>Hymenocallis acutifolia</i> (Herb. ex Sims) Sweet	Amarylidaceae	-	+	-	Herb
Bunga ungu	<i>Stachytarpheta acuminata</i> DC. ex Schauer	Verbenaceae	+	+	+	Herb
Caliandra	<i>Calliandra biflora</i> Tharp	Leguminosae	+	+	-	Stand
Cemara	<i>Casuarina junghuhniana</i> Miq.	Casuarinaceae	-	+	-	Stand
Cendana	<i>Santalum album</i> L.	Santalaceae	+	+	+	Stand
Ceri hutan	<i>Syzygium cumini</i> (L.) Skeels	Myrtaceae	-	-	+	Stand
Cocor bebek	<i>Bryophyllum pinnatum</i> (Lam.) Oken	Crassulaceae	-	-	+	Herb
Cyperus	<i>Cyperus rotundus</i> L.	Cyperaceae	-	+	+	Herb
Damar hutan	<i>Agathis dammara</i> (Lamb.) Rich. & A.Rich.	Araucariaceae	-	+	-	Herb
Daun bentuk jantung	<i>Mikania micrantha</i> Kunth	Compositae	-	+	-	Herb
Daun dewa	<i>Gynura divaricata</i> (L.) DC	Compositae	-	-	+	Herb
Daun mint	<i>Plectranthus amboinicus</i> (Lour.) Spreng	Lamiaceae	+	+	+	Herb
Daun sendokan	<i>Plantago major</i> L.	Plantaginaceae	-	+	+	Herb
Daun tempel baju	<i>Desmodium rhytidophyllum</i> Benth.	Leguminosae	+	-	-	Shrub
Daun Ubi	<i>Manihot esculenta</i> Crantz	Euphorbiaceae	-	+	-	Herb
Delima	<i>Punica granatum</i> L.	Lythraceae	-	-	+	Stand
Euporbia	<i>Euphorbia heterophylla</i> L.	Euphorbiaceae	-	+	-	Herb
Fua koti	<i>Phyllanthus urinaria</i> L.	Phyllanthaceae	-	+	-	Herb
Gamal	<i>Gliricidia sepium</i> (Jacq.) Kunth ex Walp.	Leguminosae	-	+	-	Herb
Haukase	<i>Sambucus javanica</i> Blume	Caprifoliaceae	-	+	-	Herb
Huk kau	<i>Eleusine indica</i> (L.) Gaertn.	Poaceae	+	-	-	Herb
Huk pisu	<i>Axonopus compressus</i> (Sw.) P.Beauv.	Poaceae	+	+	+	Herb
Ito	<i>Barringtonia asiatica</i> (L.) Kurz	Lecythidaceae	-	+	-	Stand
Jahe merah	<i>Zingiber officinale</i> Roscoe	Zingiberaceae	-	+	-	Herb
Jambu	<i>Psidium guajava</i> L.	Myrtaceae	+	+	-	Stand
Jambu air	<i>Syzygium aqueum</i> (Burm.f.) Alston	Myrtaceae	-	+	-	Stand
Jamur kayu	<i>Ganoderma applanatum</i> (Pers.) Pat.	Ganodermataceae	-	-	+	Fungi
Jamur payung cokelat	<i>Pleurotus cystidiosus</i> O.K.Mill.	Pleurotaceae	-	-	+	Fungi
Jamur payung putih	<i>Pleurotus ostreatus</i> (Jacq.) P. Kumm.	Pleurotaceae	-	-	+	Fungi

Jati	<i>Tectona grandis</i> L.f.	Lamiaceae	+	+	-	Stand
Jati putih	<i>Gmelina arborea</i> Roxb.	Lamiaceae	+	+	-	Stand
Johar	<i>Senna siamea</i> (Lam.) H.S.Irwin & Barneby	Leguminosae	-	+	-	Stand
Kabesak	<i>Acacia leucophloea</i> (Roxb.) Willd	Leguminosae	+	+	-	Stand
Kacang hutan	<i>Senna occidentalis</i> (L.) Link	Leguminosae	-	-	+	Stand
Kangkung hutan	<i>Ipomoea pes-caprae</i> (L.) R.Br.	Convolvulaceae	-	-	+	Herb
Kapok	<i>Ceiba pentandra</i> (L.) Gaertn.	Convolvulaceae	-	+	-	Stand
Kate emas	<i>Euphorbia heterophylla</i> L.	Euphorbiaceae	-	+	-	Herb
Kayu putih	<i>Melaleuca leucadendra</i> (L.) L.	Myrtaceae	+	+	+	Stand
Kedondong hutan	<i>Spondias pinnata</i> (L.F.) Kurz	Anacardiaceae	-	-	+	Stand
Keladi	<i>Colocasia esculenta</i> (L.) Schott	Araceae	-	+	+	Herb
Kemiri	<i>Aleurites moluccanus</i> (L.) Willd.	Euphorbiaceae	-	+	-	Stand
King rass	<i>Pennisetum purpureum</i> Schumach.	Poaceae	-	+	-	Herb
Kiun'ut	<i>Cosmos caudatus</i> Kunth.	Compositae	-	+	+	Herb
Kuk nefo	<i>Tridax procumbens</i> (L.) L.	Compositae	-	+	-	Herb
Kunyit	<i>Curcuma longa</i> L.	Zingiberaceae	-	+	-	Herb
Kusambi	<i>Schleichera oleosa</i> (Lour.) Merr.	Sapindaceae	+	+	-	Stand
Lengkeng	<i>Dimocarpus longan</i> Lour.	Sapindaceae	-	+	-	Stand
Mahoni	<i>Swietenia macrophylla</i> King	Meliaceae	+	-	-	Stand
Mahoni hutan	<i>Swietenia</i> sp	Meliaceae	-	+	-	Stand
Maleku	<i>Oxalis corniculata</i> L.	Oxalidaceae	-	+	-	Herb
Masi	<i>Bauhinia purpurea</i> L.	Leguminosae	+	+	-	Stand
Nabasbot	<i>Hibiscus trionum</i> L.	Malvaceae	-	+	-	Herb
Name	<i>Diospyros abyssinica</i> (Hiern.) F. White	Ebenaceae	-	+	-	Stand
Nangka	<i>Artocarpus heterophyllus</i> Lam.	Moraceae	-	+	-	Stand
Nombesa	<i>Talinum fruticosum</i> (L.) Juss.	Talinaceae	-	+	-	Herb
Paku tanduk rusa	<i>Platyserium bifurcatum</i> (Cav.) C.Chr.	Polypodiaceae	-	+	-	Fern
Pangkase	<i>Lantana camara</i> L.	Verbenaceae	-	+	-	Shrub
Papa'i	<i>Sida cordifolia</i> L.	Malvaceae	-	+	-	Herb
Papo'e	<i>Arachis pintoi</i> Krapov. & W.C Greg	Leguminosae	-	+	+	Herb
Paria hutan	<i>Tithonia diversifolia</i> (Hemsl.) A.Gray	Compositae	-	+	-	Herb
Pegagan	<i>Centella asiatica</i> (L.) Urb.	Apiaceae	-	+	+	Herb
Papih	<i>Syzygium aromaticum</i> (L.) Merr. & L.M. Perry	Myrtaceae	+	-	-	Stand
Petes	<i>Leucaena leucocephala</i> (Lam.) de Wit	Leguminosae	+	+	-	Stand
Petikan Kebo	<i>Euphorbia hirta</i> L.	Euphorbiaceae	+	+	+	Herb
Pohon A	<i>Saraca indica</i> L.	Caesalpinaceae	-	-	+	Stand
Pohon B	<i>Pachystachys lutea</i> Nees	Acanthaceae	-	-	+	Stand
Pohon daun sirih	<i>Melastoma malabathricum</i> L.	Melastomataceae	-	-	+	Stand
Pulai	<i>Alstonia scholaris</i> (L.) R.Br.	Apocynaceae	-	+	-	Herb
Put'puta	<i>Polygala paniculata</i> L.	Polygalaceae	-	+	-	Herb
Putri malu	<i>Mimosa pudica</i> L.	Fabaceae	+	+	-	Shrub
Reo	<i>Pleiogonium timoriense</i> (A. DC.) Leenh.	Anacardiaceae	-	+	-	Stand
Rumput gajah	<i>Poa trivialis</i> L.	Poaceae	-	+	+	Herb
Rumput mutiara	<i>Oldenlandia corymbosa</i> L.	Rubiaceae	-	+	-	Herb
Rumput sarang buaya	<i>Lophatherum gracile</i> Brongn.	Poaceae	-	+	+	Herb
Sapotili	<i>Ficus natalensis</i> Hochst.	Moraceae	-	+	-	Stand
Spesies A	<i>Portulaca oleracea</i> L.	Portulacaceae	+	+	+	Herb
Spesies C	<i>Emilia sonchifolia</i> (L.) DC. ex DC.	Compositae	-	+	-	Herb
Spesies E	<i>Sida rhombifolia</i> L.	Malvaceae	-	+	-	Herb
Suf muti	<i>Chromolaena odorata</i> (L.) R.M.King & H.Rob.	Compositae	+	+	-	Shrub
Taduk	<i>Brucea javanica</i> (L.) Merr.	Simaroubaceae	-	+	-	Shrub
Tapak liman	<i>Elephantopus scaber</i> L.	Compositae	+	+	+	Herb
Temulawak	<i>Curcuma aeruginosa</i> Roxb.	Zingiberaceae	+	-	-	Herb
Terong	<i>Solanum melongena</i> L.	Solanaceae	-	+	-	Herb
Timu	<i>Timonius timon</i> (Spreng.) Merr.	Rubiaceae	+	+	-	Stand
Usmusi	<i>Aleurites moluccanus</i> (L.) Willd.	Euphorbiaceae	-	+	-	Stand

Note: + = exist, = not exist

**Table 5.** The analysis results of physical parameter

Zone	Parameters					
	Air temp. (°C)	Air humidity (%)	Soil temp. (°C)	Soil moisture	Light intensity (Cd)	Soil pH
Middle	39.4	47	32.5	4.1	380 lux	7.2
Upland	27.8	75	24.2	7.5	21.78 lux	7.8
Highland	18.8	93.8	17.5	6.7	-	6.9

The analysis result of physical condition showed that the air temperature in study sites was in the range of 39.4-18.8°C; Air humidity was in the range of 47.0-93.8%; (Table 5). Surata (2006) revealed that the air temperature that supports the growth of sandalwood was 10-35°C with air humidity conditions ranging from 50-60%.

The air humidity in the upland and highland zones were in the range of 75-93% due to the position of the existing location with an altitude of more than 500 m asl. Humidity would be high if the air temperature decreased and the light intensity was low. It also due to the density of the canopy that made few light intensity so that the air temperature was also low and the air humidity became high. According to Barbour et al. (1987), in the shade, temperature turned low than outside the shade. The lowest air humidity and temperature were found in the middle land zone. Since the location was only in the range of 300 m asl., the canopy was not tight and light intensity was high. The high light intensity was caused the air temperature increased so that the humidity was decreased. Withmore and Burnham (1984) revealed that the moisture was affected by air temperature and light intensity. If the light intensity was low, then the air temperature was low and the air humidity would be high. The analysis results showed that the air temperature and humidity in the middle land and highland zones were above the optimal range of sandalwood growth.

Soil pH analysis showed that the study sites had soil pH ranged from 6.9 to 7.8. It means that soil conditions in it were in a neutral condition. According to Surata (2006), soil pH conditions suitable for sandalwood growth were neutral-alkalis. These results were in line with Lio (2015) in which the soil pH of the natural forest of sandalwood in North Central Timor ranged from 6.56 to 6.9. Soil conditions were at a slightly acidic pH to neutral, in which under such circumstances sandalwood was able to live naturally. Other physical condition such as soil temperature, soil moisture, and light intensity respectively were 17.5-32.5°C; 4.1-7.5; 21.78-380 lux. This condition

was allegedly optimal for sandalwood growth because it was still found in all study sites with soil temperature conditions classified as moist to heat, dry soil, and low to high light intensity. In North Central Timor, on soil conditions with hot soil temperature, wet soil, and high light intensity, sandalwood still found (Lio 2015).

In the highland zone, the light intensity was undetectable due to the fog that covers the forest and the tight canopy cover and the broad basal area of *E. urophylla*. According to Ediriweera et al. (2008), light intensity decreased with increasing canopy cover and basal area of the tree. Diaz et al. (2017) revealed that the fog (natural) as a water form of condensed water presence had a very significant impact on various environmental factors such as climate globally and regionally, air quality, water, flora, fauna, and others. It also caused the air humidity relatively high and the air temperature became low. It would appear along with altitude and slowly disappear in the sunshine, so that the heat raised.

### Soil quality

Middle and upland zones had a soil texture class in the form of sandy clay while in the highland zone was clay sandy loam (Table 6). Almulqu et al. (2018) explained that the Gunung Mutis Natural Reservation is the wettest area on the Timor Island with rainfall almost every month throughout the year, with an average of 1500 up to 3000 mm/year. the soil texture in the nature reserve is also different from the other zones in East Nusa Tenggara, and sandalwood grew primarily in volcanic calcareous rocky terrain, shallow rocky soil, texture of clay soil from lime parent material, black soil color and red-brown. Soil types were generally lithosol, Mediterranean and complex soil (Hamzah 1976 in Surata 2006). Sandalwood requires fertile soil with good drainage (generally in dry land), and deep-souled soil solum (In shallow, rocky and under-fertile, it grew and produced wood with good quality ( Surata 2006).

**Table 6.** Analysis result of soil quality

Zone	N (%)	P <sub>2</sub> O <sub>5</sub> (ppm)	Fe	K (me/100g)	Ca	Fraction composition (%)			Texture class
						Sand	Dust	Clay	
Middle land	0.35	101.01	14.23	1.12	37.55	72.00	12.00	16.00	Sandy clay
Upland	0.26	99.75	17.61	0.89	30.07	73.00	11.00	16.00	Sandy clay
Highland	0.30	85.13	15.88	0.97	32.23	68.00	11.00	21.00	Clay sandy clay

**Table 7.** Criteria of soil chemistry assessment according to the Bogor Research Center (Soepraptoharjo 1983)

Nature of the soil	Very low	Low	Moderate	High	Very high
N (%)	< 0.10	0.10-0.20	0.21-0.50	0.51-0.75	> 0.75
P <sub>2</sub> O <sub>5</sub> HCl (me/100 g)	< 10	10-20	21-40	41-60	> 60
K <sub>2</sub> O HCL 25% (me/100 g)	< 10	10-20	21-40	41-60	> 60
Ca (me/100 g)	< 2	2-5	6-10	11-20	> 20
Mg (me/100 g)	< 0.4	0.4-1.0	1.1-2.0	2.1-8.0	> 8.0

Sandalwood required high of Fe, Calcium, and Potassium from the soil (Nasi 1994 in Surata 2006). Based on the Criteria of soil chemistry assessment according to the Bogor Research Center (Soepraptoharjo 1983), the results of this study indicated that all study sites had a medium category of N and very high of P<sub>2</sub>O<sub>5</sub> (Table 7). According to Kaho (2011), sandalwood could grow under low of N level and able to survive on high P level soil. To produce good sandalwood, it required moderate levels of N, medium-high P<sub>2</sub>O<sub>5</sub> and high amounts of Fe, Ca and K. According to McWilliam (2005), it was known as hemiparasitic plants or had semi-parasitic roots and required host suitable for nutrition and moisture intake for its self. Its seedling will only live if its roots were attached to the roots of the host plant, while the sandalwood tree was able directly to obtain nutrients from the soil (Fallick 2009).

According to Lio (2015). In the lowland, middle land and upland zones of North Central Timor included total N, total P, and total K at the ranged of 0.1-0.78%; 77.11-101.12 ppm; and 0.87-1.01 me/100g respectively and sandalwood was also still found that grew naturally. Based on those studies above, it could be concluded that all study sites are suitable and had an optimal soil nutrient condition for sandalwood growth.

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