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The Structure, Composition, and Health of Remnant Forest Vegetation of West Timor, Indonesia

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Authors' contributions

This work was carried out in collaboration between both authors. Author MLG designed the study, collected the data, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author IWM checked the data analysis, conducted literature searches and managed the literature, and edited the first draft of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: The forest of West Timor has been cleared for different purposes for decades, leaving only small patches of remnant forest vegetation. Understanding tree-shrub composition and structure of this remnant forest vegetation is a vital instrument in assessing the sustainability of forest, species conservation, and management of forest ecosystems. This research was therefore conducted to investigate the current structure and composition pattern of tree-shrub species in such remnant forest vegetation.
Study Design: This research project was designed using a vegetation survey employing the Point Centered Quarter Method.
Place and Duration of Study: The research project was conducted in five sample stands of remnant forest vegetation, namely Oliana, Tablolong, Fatukoa, Oenesu, and Alak, the District of Kupang, West Timor, Indonesia, between April to July 2020.
Methodology: In each sample stand, the tree-shrub vegetation was surveyed using Point Centered

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Quarter Method by placing three 100-m-long transects. The first transect was placed at random and the second and third transects were placed parallel to the first, with a distance of 100 m between two transects. Sample points were then determined in an interval of 10 m along each transect to construct four quarters. In each quarter, the nearest tree or shrub (≥ 1 m height) to the sample point was identified and the distance measured. For each tree or shrub species, number of individual, dominance, frequency, Importance Value Index (IVI), stem diameter at 0.5 m height, and average value of plant height for each species were determined. Index Similarity (IS) between stands were also calculated using Sørensen Coefficient.

Results: Of the 600 invidual tree and shrub measured in a total of about 1,500-m-long line transect, about 28 tree-shrub species of 16 families were identified. The number of plant/hectare was 833 and the mean number of species/stand was 9.60 (*sd* = 1.94). Generally, the number of species and families found in the remnant vegetation community was relatively low compared to that of commonly found in rain forests. The IS between stand was 28.21 (*sd* = 14.40)%. The highest IS were between stand 1-2 (IS 55.56%) and between stand 1-4 *(*IS 47.62%). The lowest IS were between stand 3-4 and 3-5 (IS 10.53%). Based on the number of species, the five stands of remnant vegetation was dominated by families of Fabaceae, Arecaceae, and Anacardiaceae, but based on the IVI, they were dominated by families of Lamiaceae, Fabaceae, and Sapindaceae. On the basis of plant height, about 6.15% of the total individual was within the category of small plant (≤2 m) and 3.32% was of big tree (>14 m). However, on the basis of stem diameter, about 27.86% of the total individual was on the category of small plant (≤10 cm) and about 2.99% was of big tree (>130 cm). Most existing species were within the category of small and very small IVI, only about 14.26% of the existing species were within the category of very high IVI (>20%) and 71.43 were within the category of low and very low IVI (<10%). Four most prominent species, namely *Tectona grandis* Linn., *Schleichera oleosa* (Lour.), *Vachellia nilotica* (L.) P.J.H.Hurter & Mabb., and *Spondias pinnata* (L.f.) Kurz contributed to more than 50% IVI in the five stands of remnant vegetation. Among all species found, *Leucaena leucocephala* (Lam.) de Wit, *Caesalpinia pulcherrima* (L.) Sw., *Sesbania grandiflora* (L.) Poiret, *Syzygium cumini* (L.), *Pterocarpus indicus* Willd., *Pinus mercusii* Jungh. & de Vriese, and *Acacia auriculiformis* A.Cunn. ex Benth. were present in very small IVI. In general, the contribution of invasive species in the stands of remnant vegetation was relatively high (total IVI 56.96%), about a quarter of which were invasive weedy shrub species.

Conclusion: Based on this result it can be concluded that the five stands of remnant forest were in the state of poor health as indicated by the low number of species and families, the low species diversity, the heterogeneous floristic composition as most of species present were in the category of low occurrence, and the dominance of invasive non-native tree and shrub species. Therefore, the forest needs immediate intervention by taking conservation and restoration action to prevent further destruction.

Keywords: Forests health; importance value index; index of similarity; and invasive species.

1. INTRODUCTION

West Timor is an area covering the western part of Timor island, part of the Province of East Nusa Tenggara Province, Indonesia. Timor Island is the second largest oceanic island in Indonesian archipelago and the largest of the Lesser Sunda islands. The island spans about 470 km in length and about 95 km in width with an overall terrestrial area of 31,000 km^2. It was created by an uplifting caused by the northward movement of the Australo-Papuan plate and subsequent collision with the Oriental plate about 4 million years ago. The bedrock is primarily sedimentary calcareous rock, with fossil coral reefs can be found at high altitudes [1]. The topography is dominated by hills and mountains, with the highest peaks reaching as high as 2500 m asl. Steep slopes (those that have an incline >40%) characterize as much as 44% of the total area [1]. The island is part of the Wallacean biogeographic region in which divergent assemblages of Asian and Australian plants, birds, mammals, reptiles and insects in mixed [2].

The ecosystem of West Timor in general is relatively unstable compared to that of humid ecosystems of tropical areas. This is because of low rainfall; high wind speeds and solar radiation, generally steep slope of landform, and relatively young soil genesis, causing soil in the island sensitive to erosion and degradation and forming a unique bioenvironmental [1]. Land cover is dominated by savannah, seasonal lowland forest

and secondary vegetation, especially in the lowlands. Evergreen and semi-evergreen rain forests only occur in areas of high-rainfall, whereas deciduous forests and thorn forests occur where the climate is drier. Montane forest is found above 1,000 m asl. as mosaics with treeless areas and with those characterised by low vegetation. Some distinct vegetation types are also found along the coast, including coastal dune grasslands and shrublands [3]. The assessment conducted in 2017 concluded that about 2,245 km² (7%) of the total area of Timor ecoregion has been designated as protected areas and only about half of the unprotected area is still forested [4].

Despite much of the original forest has been cleared, the remaining primary and secondary forests continue of being under pressure, leaving only patches of remnant forest vegetation consisting of native trees or shrubs scattered only in limited areas of the island. Such patches of remnant forest vegetation are now rapidly disappearing due to forest clearing for shifting cultivation, wood exploitation, overgrazing, burning, and weed infestation, threatening the species diversity of the remaining patches [5,6]. Based on data of Statistics of Nusa Tenggara Timur Province [7], the area of forest in East Nusa Tenggara is about 1,808,990 ha (38.20% of terrestrial land), but only about 14% remains good and much larger areas, about 2,195,756 ha (46%), are critical. The government has struggled to do the necessary rehabilitation, but due to limited capacity and funding, is only able to do so about 4,516 ha (about one percent), much less compared to the cleared areas annually. Considering the illegal logging, land conversion, shifting cultivation, fires, free-roaming grazing, and land tenure dispute that continue to take place because of ineffective planning, inefficient and ineffective forest management, and low enforcement, West Timor currently is facing the risk of land degradation and desertification [7]. Like other tropical forests in the world, the remnant forest of West Timor suffers from extensive loss and degradation because of anthropogenic activities, which have a strong effect on the structure and species composition of the forest.

In order to protect and maintain the currently existing forest, evaluating the health status of forest as the basis for taking the necessary conservation action is needed. This is because the most crucial problem faced in take forest conservation action in West Timor is the minimal availability of information about forest structure and composition, especially those of natural forest remaining scattered as remnant vegetation. Understanding about structure and composition of an existing forest can help to evaluate forest sustainability, conservation priorities, ecosystem management, and restoration efforts [8,9]. To understand the distribution, composition and diversity of various species requires vegetation analysis [10]. Among all existing species, tree and shrub species are important since they provide resources and habitat for a number of other species. In addition, being the dominant life form, trees and shrub species are easy to locate and count and are comparatively better known from a taxonomic perspective [11]. Due to the population pressure and industrialization forests and its products have been over utilized. The native forest details are not available when it is over utilized. Hence, the remnant forest vegetation is a vital instrument in assessing the sustainability of forest, species conservation, and management of forest ecosystems. This research was therefore conducted to investigate the current structure and composition pattern of tree-shrub species in remnant forest vegetation of West Timor by focusing on measuring species density, dominance, and frequency needed to calculate Importance Value Index (IVI) and size class distribution as measures of forest composition and structure and vital instrument in assessing the sustainability of the forest for developing the required conservation and management strategy.

2. MATERIALS AND METHODS

2.1 The Study Area

The research was conducted in the District of Kupang of West Timor, Indonesia. Having a terrestrial area of about 7,178,26 km^2 located geographically between 9º19-10º57 South latitude and 121º30-124º11 East longitude. The climate in the District of Kupang is much affected by the Australian dry climate characterized by a very short (3-5 month) rainy season and dry season is relatively long (7-8 month) [12]. According to Oldeman agroclimate zona [13], the climate is belong to either D3 (3-4 month of wet months in a row and 4-6 months in a row), D4 (3-4 month of wet months in a row and 7-9 months in a row), or E4 (0-2 month of wet months in a row and 7-9 months in a row), where wet month is a month of rainfall over 200 mm and dry month is a month of rainfall less than 100 mm. The rainy season occurs from December to March

and the dry season from June to September annually.

The total forest areas of the District of Kupang is about 288,397 ha of which a total of 109,463.41 ha scattered remnant forests are designated as protection forest [14]. For this research, five stands of remnant forest vegetation were purposively selected to represent types of existing forest in the district, namely forest stand in Oliana, Tablolong, Fatukoa, Oenusu, and Alak (Fig. 1). These five stands were selected subjectively to represent the remaining dominant type of remnant forest vegetation of the district.

Fig. 1. Locations of the Five study areas (Oliana, Tablolong, Fatukoa, Oenusu, and Alak) selected subjectively to represent the dominant types of remnant forest vegetation in the District of Kupang, West Timor, Indonesia

2.2 Data Collection and Analysis

The method used to collect the filed data was point-centered quarter method [15]. On each selected stand in representative area, three 100-m-long transects were placed in compass direction. The first transect was place at random and the second and third transect were placed 100 m apart parallel to the first transect. Sample points were then determined in an interval of 10 m across 100 m transect (total of 10 points per transect). In each sample point, 1 m wood meter was place perpendicular to the line transect to construct 4 quarters. In each quarter, the nearest tree or shrub (≥ 1 m height) was identified and the distance from the sample point was measured. All other remaining plants stature were not including in measurement. Mean distance ($\bar{x}_d$) of all plant species were counted and converted to total density. Mean area (MA) was calculated as: $\mathrm{MA\ (area/plant)} = (\bar{x}_d)^2$ [15]. Plant density (number of plants/area) was measured by counting the inverse of MA. Basal area was obtained by measuring stem diameter at 0.5 m height.

Plant density was calculated from mean distance, while diameter or dominance and frequency were calculated from the presence of a plant in each sample point. Each plant present was noted, identified, and taken its sample. Plant sample was dried for later identification in laboratory of Department of Biology, Faculty of Science and Engineering, Nusa Cendana University. For each species present, number individual (density), dominance, frequency, and Importance Value Index (IVI) were counted [15]. The density (DE) of species was estimated as the proportion of quarters in which the species was found times the estimated density of all species. The relative density (RDE) of each species was the percentage of the total number observations of that species. The dominance (DO) of each species was expressed as its stem diameter per hectare. The relative dominance (RDO) for a species was defined to be the stem diameter for that species divided by the total stem diameter x 100. The frequency (FE) of a species was the percentage of sample points at which a species occurs. The relative frequency (RFE) = (frequency of a species/total frequency of all species) × 100. The Importance Value Index (IVI) for the species was determined as the sum of the relative density, relative dominance, and relative frequency (IVI = RDE + RDO + RFE). Index Similarity between stand was also calculated to investigate similarirty of flora composition between stands by using Coefficient Sørensen (Ss), with formula Ss = 2a/(2a + b + c), where a = number of species common to both stands, b = number of species unique to the first stand, and c = number of species unique to the second stand [15].

3. RESULTS AND DISCUSSION

3.1 Structure of Remnant Vegetation Forest of West Timor

Of the 600 individual tree and shrub measured in a total about 1,500 m line transect (5 stands x 3 of 100 m transect x 10 sample point/transect x 4 individual/sample point = 600), about 28 tree and shrub species were found. Mean distance between plant was 3.61 (*sd* = 0.66) m, number of plant per hectare was 833, and mean number of tree and shrub species present in each stand was 9.60 (*sd* = 1.94). Generally, the number of species present in each stand was relatively low compared to those found in rain forest

community where woody plant diversity may reach up to 150 tree species/ha [16] and in Amazonian forests up to 283 tree species/ha [17]. The relatively low number of species found here could be affected by forest health that most forest in West Timor now are intensively disturbed and forest area are limited to small remnant vegetation [6]. Ecosystem of West Timor in general is relatively unstable compared to that of humid ecosystem of tropical area [1]. Kessler et al. [16] stated that the number of native tree species was higher in natural forest than that in unnatural forest and tree species number was gradually decreased with the increase in intensity of forest disturbance.

The low number of species found in the forests of West Timor compared to that found in most rain forest area could also be affected by geographical position of West Timor. The composition flora of Timor Island is influenced by Timor location in central Malesia (Wallacea), a transition zone between the rainforests of the Sunda and Sahul shelves [18,5]. Timor flora is located in transitional zone between these areas, and it lacks the diversity of many of the major rainforest flora [19,5]. The geological history, climate, dispersal pathways, soils, and topography of Timor Island may also affect the flora of Timor [19,5]. The flora of Timor has been influenced more by its proximity to Australia than by West Malesia. During the ice ages, the northwest coast of Australia lay about 100-200 km from Timor [20,5]. This proximity appears to have facilitated the exchange of plants between the two regions [19,5]. Timor also has a generally drier monsoonal climate than those adjoining areas in New Guinea and West Malesia which has probably also limited the diversity of Timor flora. Timor is a geologically relatively recent island, having been uplifted from the ocean floor by the northwards drifting Australian tectonic plate over the last 10 my and the time for species to have evolved is thus less than in many other parts of Malesia [20,18] and this also probably affect the diversity of species present in West Timor.

Of 5 stands investigated, based on dominating species, stand one was referred to as *Schleichera oleosa* (Lour.)–*Spondias pinnata* (L.f.) Kurz community; stand two as *Tectona grandis* Linn community; stand three as *Vachellia nilotica* (L.) P.J.H.Hurter & Mabb. community; stand four as *S. oleosa* community, and stand five as *T. grandis* community. Based on Sørensen coefficient, mean Index of Similarity (IS) between stands were about 28.21 (*sd* = 14.40)%. The highest IS were between stand 1-2 (55.56%) and between stand 1-4 *(*47.62%). The lowest IS were between stand 3-4 and 3-5 (10.53%) (Table 1). The relatively high value of IS between stands 1-2 and 1-4 presume caused by homogenous communities between stand possibly due to similar ecological conditions. The relatively low value of IS between stands 3-4 and 3-5 caused by relatively low number of shared species among the stand or affected by high species turnover between sites because of irregular and heterogeneous nature of the environment within the communities due to natural or anthropogenic disturbance. Of all species, three species were present in all communities investigated, namely *S. pinnata*, *Tamarindus indica* L, and *T. grandis*. These three species are presumed to have a wide distribution in forest communities. One species was present in three community (*S. oleosa*) and seven species were present in two community [*Zizipus mauritiana* Lam*, Ficus benyamina* L, *Borassus flabellifer* L., *Leucaena leucocephala*de Wit., *Gliricidia sepium* (Jacq.) Kunth ex Walp, *Jatropha gossypifolia* L*,* and *Ceiba pentandra* (L.) Gaertn]*,* while all other species were only present in one community.

Of all species present, six were shrubs while all other species were trees. The shrub species were *V. nilotica*, *G. sepium*, *Caesalpinia pulcherrima* (L.) Sw., *Tecoma stans* (L.) Juss. ex Kunth, *J. gossypiifolia*, and *Chromolaena odorata* (L.) R.M.King & H.Rob. These shrub species contributed about 26.59% density, 15.77% dominance, 24.50% frequency, and 66.86 IVI, indicating a relatively high presence of shrubs in the composition of the forest community. Shrubs are woody plants which branch near the ground and do not have a leading shoot in contrast to trees that develop solitary trunks. In closed lowland evergreen rainforests, the presence of shrubs are generally scarce since they are usually outcompeted by the trees species in the race towards the light. They are more frequently found in early successional stages or in situations where sunlight can reach the understorey. Based on the resulting forest structure, all five stands of the remnant forest belong to a dry deciduous forest type of vegetation that presumably have developed specificaly in adaptation to local habitat of West Timor characterized by dry climate and rugged topography.

Of 600 trees and shrubs measured, the resulting mean plant height was 6.60 (*sd* = 0.16) m and the resulting stem diameter was 39.59 (*sd* = 1.57) cm. The distribution of plant height was right skewed (0.74) with a negative kurtosis (-0.09) while the distribution of plant stem diameter was right skewed (1.45) with a positive kurtosis (2.44). Based on plant size distribution, the population of tree and shrubs present was dominated by small plant stature, lower than mean plant height and stem diameter. Based on plant height, about 6.15% of the plant present in the community was of the category of saplings (2≤ m) or small plant and about 3.32% was of the categorize of big trees (>14 m). Based on plant height distribution, most plants present in the community were in the height of >2 - ≤ 8 m (Fig. 2a). Based on plant stem diameter, the community was also dominated by small plant stature, where plants with stem diameter ≤10 cm was about 27.86% (Fig. 2b). Based on plant stem diameter distribution, the presence of big trees (stem diameter >130 cm) in the forest community was relatively low (2.99%). The plant stature (height and stem diameter) of this forest community were dominated by small and medium trees and shrubs. This community structure was relatively different from that of commonly found in tropical rain forests where the presence of big trees in community is generally high [16].

Based on plant height and stem diameter distribution, the natural regeneration of plant in this forest community were presumably relatively good because the presence of small plant stature was relatively high. The presence of small plants or saplings on a forest community is an important determinant of forest regeneration. The successful regeneration of a tree species in a forest community depends on whether there are enough number of individuals found in each size class from small saplings to adult trees. The presence of individuals in all size classes indicates a successful regeneration process. In a forest community, tree species that were only

Table 1. Index similarity of tree-shrub species in 5 stands remnant forest vegetation of West Timor

Stand	1	2	3	4	5
1	0.00				
2	55.56	0.00			
3	21.05	26.67	0.00		
4	47.62	22.22	10.53	0.00	
5	27.27	33.33	10.53	27.27	0.00

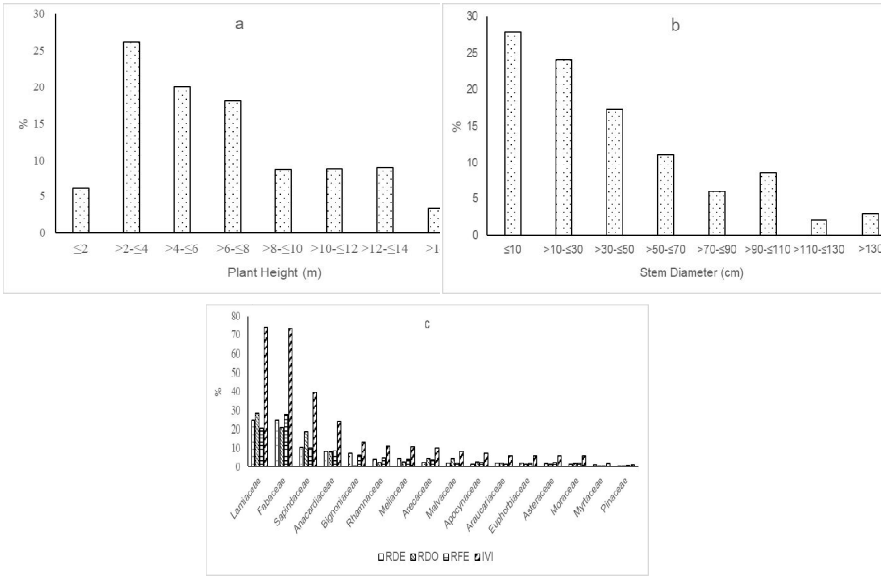

Fig. 2. The distribution of plant height (a), stem diameter (b), and family member (c) of tree-shrub species in the remnant forest vegetation of West Timor (RDE = Relative Density, RDO = Relative Dominancy, Relative Frequency (RFE), and IVI = Importance Value Index)

observed in the large sapling class might be an indication of the risk of extinction [21]. The low number of big trees present in the five remnant forest communities may be related to anthropogenic disturbances, especially logging of big trees. The low basal area values were related to high accessibility to the nearby community and lack of enough protection [22]. In any forest, lower basal area is mainly characterized by high abundance of young trees and sometimes by lacking of individuals in the larger size classes. In general, size class distribution of an undisturbed or less disturbed forest should fit the reverse J-shaped pattern, with most of the trees belong to the smaller size classes and fewer belong to the larger ones. The lack of individuals in the larger size classes could be due to illegal logging of bigger trees by local people for timber and construction purposes or the fact that the forest has limited species that grow in large diameters [23].

The upper canopy of the five remnant forest communities was dominated by *T. grandis*, *S. oleosa*, and *Alstonia scholaris*L. R. Br., while the lower canopy was dominated by *C. odorata* and *J. gossypiifolia.* The lower canopy consisted mostly of shrub species. Plants with high stem diameter were also dominated by *T. grandis, S. oleosa*and *A. scholaris* while plants with low stem diameter were dominated by *T. stans*, *J. gossypiifolia*, and *C. odorata*. The high number of small plants (low stem diameter and height) found in the five remnant forest communities are presumably contributed by the high presence of shrub species in the community. More than a quarter of the species present in the community was members of shrub species (density 26.59%). The canopy cover structure of the five remnant forest communities was different from that commonly found in tropical rain forest because the canopy cover was less diverse, less dense, and less homogenous than that found in tropical rainforest. This could be the result of nonoptimal growing conditions in West Timor, characterized by short unpredictable rainy season, where drought is generally more severe compare to that experienced in tropical rainforest [13]. Environmental stresses increase with seasonality of the environment and fewer plants can generate homeostatic mechanisms to cope with such a condition. Most of the taxonomic groups found in the dry forest are less diverse than those found in the rainforest. The tree canopy of the five remnant forest communities of West Timor was found less homogenous, less dense, and invariably lower species diversity than commonly found in tropical rainforests. A tropical *rainforest* is an ecosystem that is characterized by heavy rains and a dense tree canopy that allows very little light to pass through to the understory.

All species present were member of 16 families and based on the number of species present, the most dominant family was Fabaceae followed by Arecaceae and Anacardiaceae. Nine species present in the five remnant forest communities were of the family Fabaceae [*T. indica*, *G. sepium*, *L. leucocephala*, *C. pulcherrima*, *Sesbania grandiflora* (L.) Pers., *Acacia auriculiformis* A. Cunn. ex Benth, *Pterocarpus indicus* Willd., *V. nilotica*, and *Senna siamea* (Lam.) H.S. Irwin & Barneby], three of the family Arecaceae [*B. flabellifer*, *Areca catechu* L., and *Cocos nucifera* L.], two of the family Anacardiaceae (*S. pinnata* and *Anacardium occidentale* L.), and two of the family Malvaceae (*C. pentandra* and *Sterculia foetida* L) while all other families were represented only by one species. In general, the tree and shrub families present in this forest community were lower compare to those commonly found in tropical rainforests [16]. In the five remnant forest communities of West Timor, trees and shrubs of the family Fabaceae (legumes) seemed to be the most adaptable to the existing environmental conditions as species of this family are drought tolerant. However, based on the density, the dominance, the frequency and the IVI of all species present, the forest communities were dominated by family of Lamiaceae, Fabaceae, and Sapindaceae (Fig. 2c). In forest community, the density of Lamiaceae contributed 24.97%, Fabaceae 24.93%, and Sapindaceae 10.26%. The dominance of Lamiaceae contributed 28.46%, Fabaceae 20.68%, and Sapindaceae 18.99%. The frequency of Fabaceae contributed 27.65%, Lamiaceae 20.53%, and Sapindaceae 10.09%. Based on IVI, Lamiaceae contributed 73.96%, Fabaceae 73.28%, and Sapindaceae 39.34%. The most prominent species family of Lamiaceae was *T. grandis,* Fabaceae was *V. nilotica,* and Sapindaceae was *S. oleosa.*

3.2 Composition of Remnant Forest Vegetation of West Timor

Based on number of individual present (density), the remnant forest community was dominated by *T. grandis* (24.97%), followed by *V. nilotica* (12.19%), *S. oleosa* (10.26%), *S. pinnata* (6.60%), and *T. stans* (6.76%), while all other species were only present in small density (<5%)

(Fig. 3a). Based on plant dominance, it was also dominated by *T. grandis* (28.46%), *S. oleosa* (18.99%), *V. nilotica* (11.23%), *S. pinnata* (7.01%), and *T. indica* (5.59%), while all other species were only have small dominancy (<5%). The common composition pattern of the remnant forests communities was where few species were categorized as abundant and many other species were categorized as locally rare [24]. Three species with the highest relative density and dominance (*T. grandis V. nilotica* and *S. oleosa*) contributed about 50% to the living individuals in the remnant forest communities.

Based on the frequency, the forest was also dominated by *T. grandis* (20.53%), follow by *S. oleosa* (10.09%), *V. nilotica* (9.49%), *T. indica* (7.58%), *S. pinnata* (7.06%), and *T. stans* (5.93%), while all other species were only present in small frequency (<5%). The frequency class distributions showed (Fig. 3b) that about 78.57% of the total species present in forest community fell in the very low occurrence class distribution (<5%), about 14.29% was in 5-<10%, while in the higher frequency classes (>15%) only about 3.57% species were present. Such result suggests that most of species present in the remnant forest communities were in the category of low occurrence as would be expected in a typical species-abundance distribution. Normally, a tree species is considered homogeneously distributed when the number of individuals present was equal in all parts of the community. Thus, the frequency distribution analysis indicates the presence of high degree of floristic heterogeneity in all five remnant forest communities. Usually, frequency reflects the pattern of distribution and provides an approximate indication of the heterogeneity of the forest [25].

Based on IVI, we divided species into five categories, which are species with very high, high, medium, low, and very low IVI (Fig. 3c). In the five remnant forest communities, about 14.26% species present were in the category of very high IVI (>20%); 3.57% high IVI (15-<20%); 10.71% medium IVI (10-<15%), 32.14% low IVI (5-<10%), and 39.29% very low IVI (<5%).The four species with the highest IVI (*T. grandis*, *S. oleosa*, *V. nilotica*, and *S. pinnata*) contributed 54.02% density, 65.69% dominance, 47.17% frequency, and 166.89% IVI in the remnant forest communities. Therefore, those four most prominent species contributed more than 50% to the composition of individual present in the remnant forest communities. Species that have high IVI indicate that those species are more adaptive to and more capable of adjusting themself to changes in environmental conditions than other species in the remnant forest

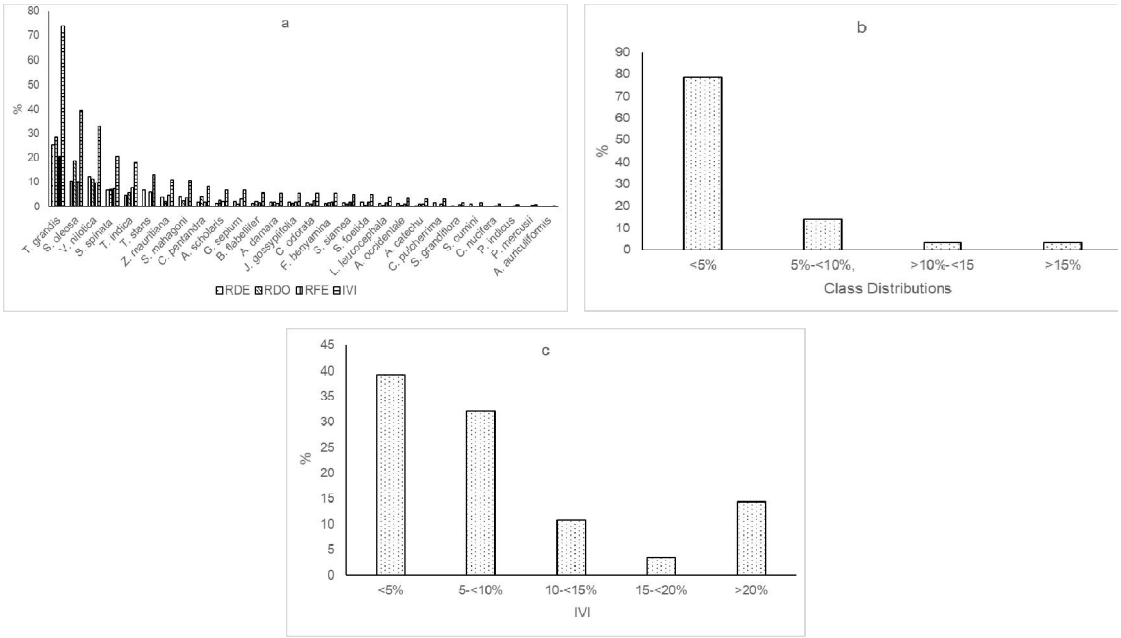

Fig. 3. Relative Density (RDE), Dominancy (RDO), Frequency (RFE), and Importance Value Index (IVI) (a); frequency class distributions (b), and class distribution of IVI (c) of tree-shrubs species at forest vegetation of West Timor

communities. They are able to utilize available resources better than other species and have greater opportunity to maintain their growth and reproduction. Species with high IVI are able to adapt to the environment using whatever energy sources available in the communities, indicating that those species have an important role in the sustainability of ecosystem at their communities [26].

Of all species present, *T. grandis* was the most prominent species in the remnant forest communities. This species is relatively adaptive and tolerant to the dry climate and therefore are able to dominate forest communities with similar climatic condition. *S. oleosa* was also prominent in this forest and this species was mainly found in dry areas [27]. In East Nusa Tenggara, this drought tolerant species is commonly dominate remnant forest communities in driest areas of Timor, Sumba, Rote Ndao, Kalabahi, and Alor islands. *V. nilotica* was also the prominent species in the five remnant forest communities. This species is common as an invasive species in savannah communities [28]. In West Timor, it invades and dominate grassland areas in lowland areas and reduces the quality of the grasslands for grazing. This species will be very likely to continue invading grassland areas of West Timor if no action is taken to reduce the expansion of this species. This species has recently invaded many similar forest communities in Indonesia, among others the grassland in Baluran National Park (BNP) since 1969 causing a significant reduction in other species abundance and biodiversity in the park [29]. *S. pinnata* was also prominently present in the five remnant forest communities. This tree species has been widely cultivated and naturalized in Bhutan, China, India, Myanmar, and Nepal [30]. In West Timor, this species is dry tolerant as they are able to grow in various unfertile and extremely dry areas.

Most of species present (71.43%) in the five remnant forest communities were within the category of small and very small IVI. The presence of many species within this category indicates that the majority of species present are rare in the forest. The large number of rare species encountered in this study confirms the commonly acclaimed notion that most of the species in the ecological community are rare, rather than common [31]. The rarity of species present may be due to various reasons, which include strong density-dependency in the forest, existence of a resource gradient, which causes species to occupy different positions within it resulting in abundance distribution variation, poor dispersal ability of species, natural or anthropogenic disturbances, and competition within the forest [32]. The IVI is commonly used in ecological studies to indicate ecological importance of a species in a given ecosystem. The IVI is also used for prioritizing species conservation whereby species with low IVI value need high conservation priority compared to ones with high IVI [25].

Due to their low IVI, *L. leucocephala*, *C. pulcherrima*, *S. grandiflora*, *Syzygium cumini* (L.), *P. indicus, Pinus mercusii* Jungh. & de Vriese, and *A. auriculiformis* were conservation priority in the five remnant forest communities of West Timor. In West Timor, *L. leucocephala* is commonly used as animal fodder, especially in dry season when grasses are unavailable, while *C. pulcherrima*, *S. grandiflora, S. cumini, P. merkusii,* and *A. auriculiformis* were not commonly utilized, although in some other countries they are commonly used as ornamental plant, medical plant, protective plant, alternative food source, or timber source [33,34]. Populations of *P. indicus* in the remnant forest communities need special attention since it is present in very low population and seriously threatened. It is extinct in Vietnam and possibly in Sri Lanka and Peninsular Malaysia [35] *and therefore, the conservation of this species in forest is high priority*. The presence of *A. occidentale*, *A. catechu* and *C. nucifera* in the remnant forest communities were likely a result of human intervention since that are agricultural trees commonly grown in agriculture land and therefore, although their presence in the remnant forest communities was in very small IVI, they are not of conservation priority.

Understanding tree species composition and structure is a vital instrument in assessing the sustainability of forest management, conservation of species, and management of the ecosystems [36,37]. This research describes the status of structure and composition of tree and shrub species in remnant forest vegetation forest of West Timor. Conservation of biodiversity has become an issue of increasing priority and importance in the recent years. Rapid human population growth has significant adverse impacts on forest size, species richness, and diversity [9] and if no action is taken, the remaining forests are likely to become more fragmented and the remnants will significantly lose their ability to sustain the original biological

diversity. Therefore, in order to maintain the sustainability of the remaining forests of West Timor, immediate intervention actions are needed to minimize further disturbances, particularly those of anthropogenic disturbance such as illegal logging, cattle grazing, fire, over exploitation, unsustainable agricultural practices, land conversion, and invasion by alien species as a main drivers of biodiversity loss.

3.3 Human Intervention, Invasive Species, and Implications for Conservation

The presence of non-native tree (*A. occidentale, A. catechu* and *C. nucifera*) in the remnant forest communities is very likely as resulting from deliberate or accidental introduction indicating the intensity of human intervention in the forests. Those tree species are commonly grown in agricultural land and not commonly present in natural forests. Because they are alien or non-native, they could cause various negative impacts to the local ecosystems. Unfortunate enough, such alien species are deliberately introduced as part of afforestation and reforestation programs, presumably because of lack of understanding among the local forestry staff, causing forest in the island and in many other islands in the Province of East Nusa Tenggara no longer natural but a result of alien species invasion resulting from human intervention. As a result, pristine natural forest is difficult to find or even no longer exists in the region.

Of 28 species present, four species were invasive weeds (*V. nilotica*, *T. stans*, *J. gossypiifolia*, and *C. odorata*). Of those species, the most invasive in the remnant forest communities was *V. nilotica* (IVI 32.92%), followed by *T. stans* (IVI 13.08%), *J. gossypiifolia* (IVI 5.52%), and *C. odorata* (IVI 5.44%). Invasive alien species are commonly found dominating various habitats in West Timor, however no attempt has been taken to control them and prevent their further spreads although such species has been widely recognized as harming local species, threatening local biodiversity, and replacing native species [38]. Its high growth rate and tolerance to various environmental conditions has made *V. nilotica* is an important invasive species in grassland and savannah ecosystem [28]. *V. nilotica* has been introduced to Indonesia in about 1850 [39] and ever since invaded grassland and savannah ecosystems in the country, including those in West Timor. *V. nilotica* invasion in West Timor has caused grassland productivity to decrease, causing significant decrease of grassland carrying capacity in supporting livestock grazing. The distribution and population of this species continue to increase and become serious weed in many countries [40].

In West Timor, *T. stans* is commonly found forming dense clump in grassland and disturbed lands, reducing growth of grass and other native species. Global Invasive Species Database (GISD, 2008) [41] has listed this species as a noxious weed in South Africa, Australia and America. This species serves no economic purpose and possesses characteristics that are harmful to animal, environment and even human beings, able to invade undisturbed environments and transform or degrade natural plant communities, and particularly difficult to control, causing serious financial losses to land owners [42]. *J. gossypifolia* is a vigorous invader of lowland savannah of West Timor, particularly in alluvial soil right down to the riverbed [43]. The economic impact of this species on the livestock industry has been reported in Australia [44]. In the long term, its restricts the growth of native and introduced grasses, ultimately displacing pasture species, making any land colonised by this weed entirely unproductive [45]. *C. odorata* has introduced to Indonesia since 1910 [46] and eversince invaded a wide range of soils, disturbed areas, fallow land, road sides, degraded forest margins and tree canopy gaps in the forests by forming dense stands preventing the establishment of other species, both due to competition and allelopathic effects [47]. It is reportedly one of the world's most invasive weeds [48].

In general, the contribution of invasive species in the five remnant forest communities was relatively high with the total density 22.71%, dominancy 14.39%, frequency 19.87%, and IVI 56.96%. Almost a quarter of trees and shrubs present in the remnant forest communities was weedy shrubs, indicating that the remnant forest communities has been severely invaded by weedy species resulting in poor health of forest ecosystem that requires immediate restoration. Those invasive species degrade and threaten the integrity and native composition of remnant forest ecosystems and have negative impacts to forest health, biodiversity, and ecosystem services, increase tree seedling mortality, inhibit regeneration, and reduce growth of native plant species. By changing disturbance regimes,

Table 2. Relative Density (RDE), Dominancy (RDO), Frequency (RFE), and Importance Value Index (IVI) of tree-shrubs species at forest vegetation of West Timor

No.	Species	Family	RDE	RDO	RFE	IVI
1	*Tectona grandis* Linn.	Lamiaceae	24.97	28.46	20.53	73.96
2	*Schleichera oleosa* (Lour.)	Sapindaceae	10.26	18.99	10.09	39.34
3	*Vachellia nilotica* (L.) P.J.H.Hurter & Mabb.	Fabaceae	12.19	11.23	9.49	32.92
4	*Spondias pinnata* (L.f.) Kurz	Anacardiaceae	6.60	7.01	7.06	20.67
5	*Tamarindus indica* L	Fabaceae	4.65	5.59	7.58	17.81
6	*Tecoma stans* (L.) Kunth	Bignoniaceae	6.76	0.39	5.93	13.08
7	*Ziziphus mauritiana* Lam.	Rhamnaceae	3.88	2.32	4.60	10.79
8	*Swietenia mahagoni* (L.) Jacq.	Meliaceae	4.33	2.52	3.84	10.68
9	*Ceiba pentandra* (L.) Gaertn.	Malvaceae	1.97	4.12	2.06	8.15
10	*Alstonia scholaris* L. R. Br.	Apocynaceae	1.53	2.81	2.39	6.74
11	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Fabaceae	2.20	1.27	3.25	6.72
12	*Borassus flabellifer* L.	Arecaceae	1.53	2.34	1.76	5.63
13	*Agathis damara* (Lamb.) Rich.	Araucariaceae	2.07	1.96	1.53	5.57
14	*Jatropha gossypiifolia* L	Euphorbiaceae	2.03	1.46	2.04	5.52
15	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Asteraceae	1.73	1.31	2.41	5.44
16	*Ficus benyamina* L	Moraceae	1.51	1.88	2.03	5.41
17	*Senna siamea* (Lam.) H.S.Irwin & Barneby	Fabaceae	1.68	1.24	2.11	5.03
18	*Sterculia foetida* L	Malvaceae	2.03	0.89	2.01	4.93
19	*Leucaena leucocephala* (Lam.) de Wit[	Fabaceae	1.48	0.80	1.76	4.04
20	*Anacardium occidentale* L.	Anacardiaceae	1.45	0.84	1.31	3.60
21	*Areca catechu* L.	Arecaceae	0.68	1.40	1.18	3.27
22	*Caesalpinia pulcherrima* (L.) Sw.	Fabaceae	1.68	0.11	1.38	3.18
23	*Sesbania grandiflora* (L.) Poiret	Fabaceae	0.67	0.02	1.14	1.83
24	*Syzygium cumini* (L.)	Myrtaceae	1.18	0.24	0.29	1.71
25	*Cocos nucifera* L.	Arecaceae	0.23	0.38	0.591	1.20
26	*Pterocarpus indicus* Willd.	Fabaceae	0.23	0.27	0.59	1.09
27	*Pinus mercusii* Jungh. & de Vriese	Pinaceae	0.32	0.02	0.70	1.03
28	*Acacia auriculiformis* A.Cunn. ex Benth.	Fabaceae	0.15	0.15	0.35	0.66
	Total		100	100	100	300

geomorphology, and soil chemistry, they reduce wildlife habitat diversity and quality, increase wildfire risk, change soil chemistry, and finally degrade natural hydrology. Invasive plants can drastically reduce biodiversity of native plants, which in turn can reduce biodiversity of wildlife by changing the structure and composition of vegetation communities [49]. This may lead to a decline in endangered, threatened, special concern or rare species or plant communities. Infiltration of invasive species into forested environments may disrupt forest ecosystem processes and functions by displacing native species, establish viable populations, and become highly invasive in their new environment [50]. These invasive species can reach a high level of dominance within their trophic level in their new community, and can exert powerful effects on ecosystem processes and properties in their new environment.

The remaining remnant native forest vegetation in West Timor is crucial for supporting local biodiversity and maintaining health of local environment. Forests provide the pathways for water capture, transport, and evaporation as it circulates throughout various systems at multiple scales [51]. Forest-derived processes also serve integral functions in determining plant and animal community compositions by influencing light levels, soil conditions, nutrient availability, and physical structures [52,53]. Forests play globally important roles in influencing other large-scale ecosystem patterns and processes such as the carbon and nutrient cycles [54]. Therefore, management strategies to prevent, reduce, control, and monitor invasive species are needed to maintain the remaining remnant forests sustainably and therefore minimize the economic, ecological, and human health impacts caused such invasive

species. The high forest conversion in the past and the proximity of most forest to human habitats make most remnant forests in West Timor increasingly vulnerable to further disturbances. Exploitation by local people through logging, harvesting forest product, grazing domestic animal, fires during the dry season, and introduction of unnatural plants are all contributed to disturbance and causing severe damage to the integrity of the local forest ecosystems [55].

4. CONCLUSION

The number of species and families present in the five remnant forest communities of West Timor was relatively low compared to those of commonly found in tropical rainforest areas. The diversity of species present was also low as indícated by Index of Similarity among stands. The low number of species and families, and the low diversity of species present indicated the poor growing conditions of West Timor that does not support high diversity of flora. Based on plant size distribution, the presence of big stature trees in the remnant forest communities was relatively low. Based on number of individuals present, the composition pattern of the remnant forest communities was characterised by abundance of few species and rarity of all other species. Based on their frequency, most of species present in the remnant forest communities were of low occurrence, indicating a high degree of floristic heterogeneity. Most species present in forest were category of small and very small IVI. Species within the category of very small IVI were of conservation priority since those species were more prone to extinction. In general, the contribution of invasive alien species to the composition of the remnant forest communities was relatively high with about a quarter of forest composition consisted of weedy shrubs. All of these conditions indicate that the remnant forest communities were in the state of poor quality or health and high anthropogenic disturbances. To prevent further degradation, management strategies to take conservation and restoration actions of the remaining remnant forests of West Timor are clearly required.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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