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Structure and composition of tree and shrub species and their invasiveness in conservation areas of West Timor, Indonesia

MANGADAS LUMBAN-GAOL[1,♥], I WAYAN MUDITA[2]
[1]Department of Biology, Faculty of Science and Engineering, Universitas Nusa Cendana. Jl. Adisucipto Penfui, Kupang 85001, East Nusa Tenggara, Indonesia. Tel./fax.: +62-380-881580, ♥email: lumbanbio@yahoo.co.id
[2]Department of Agrotechnology, Faculty of Agriculture, Universitas Nusa Cendana. Jl. Adisucipto Penfui, Kupang 85001, East Nusa Tenggara, Indonesia

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Abstract. *Lumban-Gaol M, Mudita IW. 2023. Structure and composition of tree and shrub species and their invasiveness in conservation areas of West Timor, Indonesia. Asian J For 7: 134-146.* This study aimed to investigate the composition of vegetation of tree and shrub species and their invasiveness in West Timor conservation forests, Indonesia. Three conservation zones were purposefully chosen to showcase Timor Island's conservation forest. Baumata Nature Recreation Park (Baumata NRP), Camplong Nature Recreation Park (Campong NRP), and Herman Yohannes Grand Forest Park (Herman Yohannes GFP) are three such parks. The point-centered quarter approach was used to collect data. The Important Value Index (IVI) was established for each existing species. Each plant was classed as either invasive or non-invasive. Approximately 59 tree and shrub species were found in these three conservation zones. Based on IVI, the forest was dominated by *Cassia siamea* Lam. (23.53%), *Tectona grandis* L.f. (21.97%), *Schleichera oleosa* (Lour.) Oken (19.61%), and *Syzygium aqueum* (Burm.fil.) Alston (14.95%). More than 40% of the species present were potentially invasive. Based on the IVI, the potentially invasive species were dominated by *C. siamea* (23.53%), *Tamarindus indica* L. (11.69%), *Gmelina arborea* Roxb. ex Sm. (10.73%), *Swietenia macrophylla* G.King (10.30%), *Ficus benjamina* L. (7.45%), *Antidesma bunius* (L.) Spreng. (7.40%), and *Albizia* Durazz. (7.31%). The presence of invasive trees and shrubs in the conservation area of West Timor was relatively high. Therefore, it requires management actions to prevent further spread and dominance.

Keywords: Conservation, forest, Importance Value Index (IVI), invasive species, shrub, tree

INTRODUCTION

Timor Island is in the southern part of the Indonesian archipelago, divided between the independent state of Timor Leste and the territory of West Timor, part of the Indonesian Province of East Nusa Tenggara. With an area of about 30,777 km², Timor Island is the second-largest oceanic island in the archipelago and the largest island in the Lesser Sundas (Trainor 2010). The island was formed as a result of uplift caused by the movement of the Australo-Papuan plate to the north and the subsequent collision with the oriental plate about 4 million years ago, resulting in the hilly and mountainous topography, with the highest peak reaching 2500 m above sea level (Jouannic et al. 1988; van Marle 1991; Vita-Finzi and Hidayat 1991; Nguyen et al. 2013). Steep slopes (slope >40%) account for 44% of the total area (Monk et al. 1997). The island is part of the Wallacean biogeographic region where different Asian and Australian assemblages of plants, birds, mammals, reptiles, and insects mix (Braby and Pierce 2007). The climate in Timor Island is characterized by a short rainy and long dry season. The rainy season is mainly from December to March, and the dry season is from June to September yearly (Monk et al. 1997). The land cover of the West is dominated by savanna, seasonal lowland forest, and secondary vegetation, especially in the lowlands. The majority of the original forest has been removed, and the remaining primary and secondary forests are also under threat, leaving only a few scattered pockets of remnant woodland. These pockets of remaining forest vegetation are now threatened by loss due to forest clearing practices for shifting cultivation, timber exploitation, overgrazing, burning, and weed invasion, all of which affect species diversity (Cowie 2006).

One of the problems faced in forest management in East Nusa Tenggara is the high level of forest degradation. Many forest areas have been cleared and deforested, and as a result, the diversity of plant species has undergone many changes in structure and composition. This forest clearing will provide an entry site for invasive alien plants and threaten the existence of native plants. Invasion of alien species in forest areas, especially in conservation forests, has been reported by Siregar and Tjitrosoedirdjo (1999). The quality of the forest and the diversity of flora and fauna found in conservation forests can be threatened if such an invasion is not managed. Research on invasive species in Indonesia has become one of the popular topics related to species diversity, ecology, control, and utilization aspects (Tjitrosoedirdjo 2005; Setyawati et al. 2015; Sunaryo and Girmansyah 2015; Sutomo et al. 2016; Padmanaba et al. 2017; Utami et al. 2017; Tampubolon et al. 2018; Mukaromah and Imron 2020; Sayfulloh et al. 2020). Various plant life forms can be invasive, ranging from trees, shrubs, lianas, vines, grasses, herbs, and other types of succulents, including plants that have tubers and rhizomes, to aquatic plants (Sindel 2000). Many woody plants have recently been recognized as a new invasive species (Holm et al. 1977). In the last few centuries, humans have introduced many types of woody plants for various purposes, and many of these woody tree and shrub species have been naturalized from their natural habitats and become invasive (Binggeli et al. 1998; Richardson and Rejmánek 2004; Williams and Cameron 2006; Richardson 2011). In Indonesia, most alien plant species were introduced for cultivation, as experimental, and through a Botanic Garden collection (Tjitrosoedirdjo 2005). The alien species might also be introduced through plant propagules infecting imported agricultural products. Research on invasive plants by Lestari (2021) at the Bogor Botanic Gardens, Indonesia, found 69 species of invasive plants from 44 families. Of 69 species present, the most invasive species were shrubs (20 species), or around 28.99%, followed by trees (17 species), or around 24.64%. Reichard and Campbell (1996) noted that 85% of the 235 woody invasive plants in the United States were initially introduced as ornamentals and 14% as crops. Such woody plants are now considered invasive alien species in many locations, and they have caused significant damage in others. Among 235 woody plants, 21 species are on the list of the '100 worst invaders' in the World' (Boudjelas et al. 2000), seven species are on the list of Europe's '100 worst invaders species, and 20% of the most intensively studied invasive species are woody plant species (Pyšek et al. 2008). Invasion of woody plants has known to be able to inhibit and suppress the regeneration of native species, leading to overtaking the native species (Webster et al. 2006). Many traits of trees and shrubs allow them to be invasive, including fast growth, shade tolerance, drought, and resistance to fire. Invasive exotic trees and shrubs can outcompete native species for growing space (Webster et al. 2006). Invasive trees and shrubs are aggressive invaders of disturbed areas, and because they are fast-growing, some are well-adapted to relatively undisturbed forests. Consequently, if left unchecked, invasive trees and shrubs can potentially replace commercially and ecologically important native species (Webster et al. 2006).

The most crucial problem faced in forest conservation actions in West Timor is the need for more information regarding invasive plant species composition. In order to evaluate forest sustainability, determine conservation priorities, direct ecosystem management, and prioritize restoration activities, an understanding of invasive plant species, particularly woody trees and shrubs, is required. Therefore, this study was conducted to determine the structure and composition of tree and shrub species and their invasiveness in the conservation area of West Timor with a focus on measuring species density, dominance, and frequency needed to calculate the Importance Value Index (IVI), as a measure of the composition and structure of the forest.

MATERIALS AND METHODS

Study area

This study was carried out in Kupang District (Indonesia), a district located in the southwest part of Timor Island with a land area of about 7,178.26 km^2 and geographically located between 9º19'-10º57' South Latitude and 121º30'-124º11' East Longitude. The forest area in Kupang is 288,397 ha, consisting of 109,463.41 ha of Protected Forest and 831.92 ha of Conservation Forest (BPS Provinsi Nusa Tenggara Timur 2022). The research was conducted in its three conservation forests: Baumata Nature Recreation Park (Baumata NRP), Camplong Nature Recreation Park (Camplong NRP), and Herman Yohannes Grand Forest Park (Herman Yohannes GFP) (Figure 1).

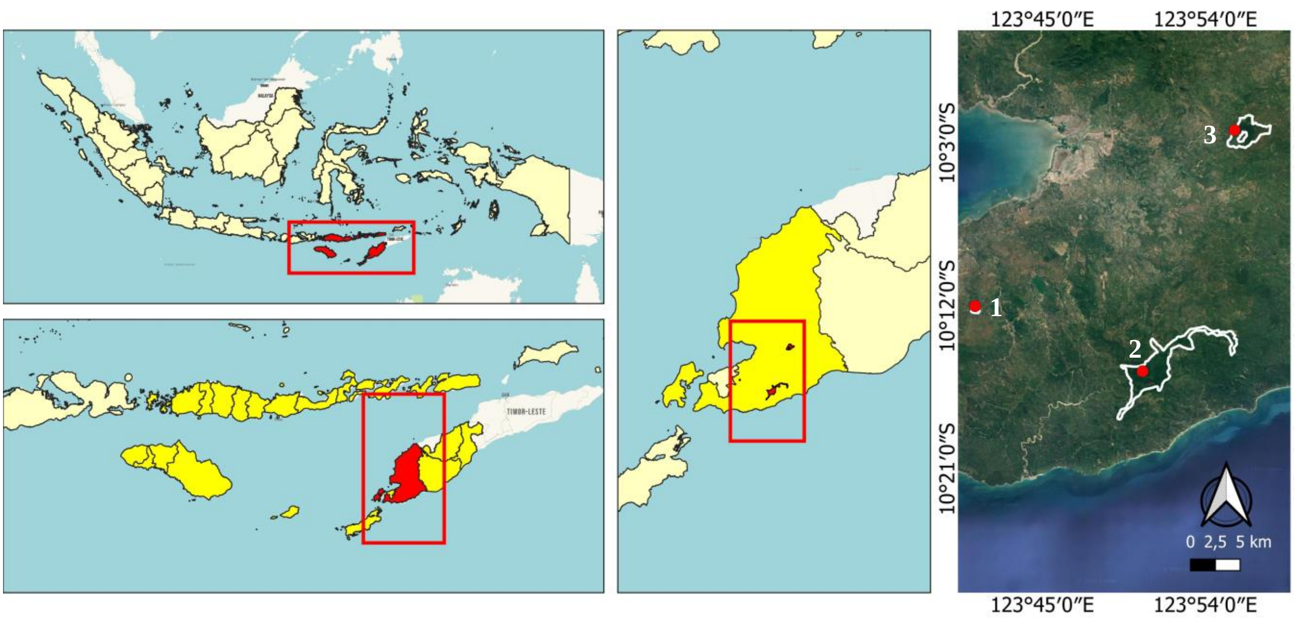

Figure 1. Map of the study area in (1) Camplong NRP, (2) Herman Yohannes GFP, and (3) Baumata NRP of East Nusa Tenggara, Indonesia

Baumata NRP has an area of 36.21 ha. The Baumata Forest area was located at 211-263 masl with a wavy and hilly topography with calcareous or karst soil conditions. Baumata NRP has vegetation that is representative of the type of medium land forest ecosystem (BBKSDA NTT 2022). This area has a wealth of natural resources, including the potential for natural tourism and environmental services, the potential for fauna, and the diversity of vegetation types. The Camplong NRP is located at 245-480 masl with sloping, wavy, hilly, or mountainous topography and calcareous or karst soil conditions. Camplong NRP has vegetation that is representative of the type of medium and forest ecosystem. The habitat type of Camplong NRP was classified as a semi-deciduous forest type because climatic conditions and local altitude strongly influenced the vegetation condition in this area. The above conditions show that the vegetation that could live in this area was generally dominated by vegetation that sheds its leaves in the long dry season. With an area of 1,900 ha, Herman Yohannes GFP was the only GFP located in West Timor. The GFP suffered severe damage from illegal logging, illegal grazing, wildlife hunting, encroachment, and other environmentally unsound activities.

Data collection and analysis

Three conservation areas were chosen purposively to represent conservation areas in Timor Island: one Grand Forest Park and two Nature Recreation Parks [(*Taman Wisata Alam* Baumata (Baumata NRP), *Taman Wisata Alam* Camplong (Camplong NRP), and *Taman Hutan Raya* Prof. Ir. Herman Yohanes (Herman Yohanes GFP)]. The selection of this Nature Recreation Park was carried out because, apart from being used for recreational purposes, the Nature Recreation Park is expected to be able to maintain the local biodiversity of plant species present in West Timor. The method used to collect data was the point-centered quarter method (Mueller-Dombois and Ellenberg 2003). In each selected conservation area, four 100 m long transects were placed in the direction of the compass. The first transect was placed randomly, and the second and third transects were placed at a distance of 100 m parallel to the first transect. Sample points were then determined in 10 m intervals across the 100 m transect (10 points in total per transect). To construct four quarters, a 1 m timber meter was placed perpendicular to the line transect at each sample point. In each quarter, the nearest tree or shrub (≥1 m height) was identified, and the distance from the sample point was measured (Figure 2). All plants belonging to the group of trees and shrubs present were recorded and identified. Trees were defined as perennial woody plants with a distinct main trunk. Woody plants without these criteria and with many small stems were classified as shrubs. The measurement did not include woody grasses, woody parasitic plants, woody cacti, herbaceous, seedlings, and all other plant statures. Basal area was obtained by measuring the diameter of the stem at a height of 0.5 m.

Plant density was calculated from the average distance, while the diameter or dominance and frequency were calculated from the presence of plants at each sample point. Every plant present was recorded, labeled, and sampled. The plant samples were dried and then identified in the laboratory of the Department of Biology, Faculty of Science and Engineering, Universitas Nusa Cendana, Indonesia. The identified name of each tree and shrub species was then subject to a scientific name search at the GBIF (https://www.gbif.org/) and WFO (http://www.worldfloraonline.org/) sites to ensure it was a current name. For each species present, the number of individuals (density), dominance, frequency, and Importance Value Index (IVI) were calculated (Mueller-Dombois and Ellenberg 2003). Species Density (DE) was estimated as the proportion of places where the species was found multiplied by the estimated density of all species. The Relative Density (RDE) of each species was calculated as the percentage of the total number of observations of that species. Each species' Dominance (DO) was expressed in stem diameter per hectare. The Relative Dominance (RDO) for a species was defined as the trunk diameter for that species divided by the total trunk diameter × 100. A Species' Frequency (FE) was the percentage of sample points at which a species was present. Relative frequency (RFE) was calculated by dividing the species frequency of each species by the total frequency of all species multiplied by 100. The IVI for trees and shrub species was defined as the sum of relative density, relative dominance, and relative frequency (IVI = RDE + RDO + RFE), while grass, herbaceous, seedling, and all other plant statures were not included in the measurement. Each type of plant present was checked for its invasiveness at the site of the CABI Invasive Species Compendium (https://www.cabi.org/ISC) and the site of IUCN Global Invasive Species (http://www.iucngisd.org/gisd/) and later was crosschecked with the list of invasive species for Indonesia as provided by the the Minister of Forestry Regulation (*Permenhut*) Number 94 of 2016 concerning Invasive Species and the list of invasive species provided in the guide book to invasive species in Indonesia (Setyawati et al. 2015).

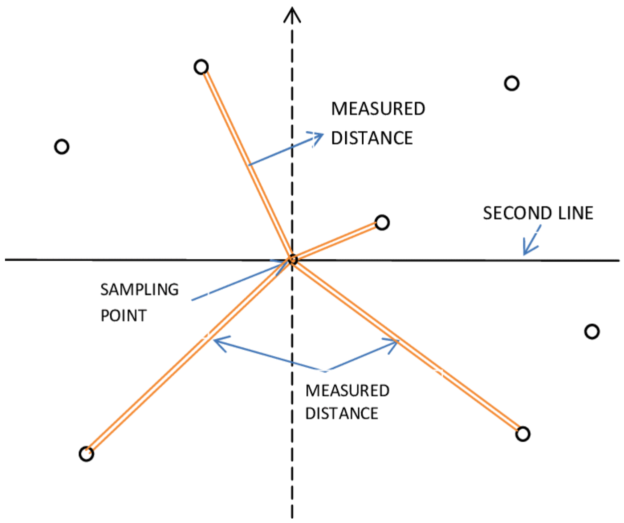

Figure 2. Graphic representation of points center quarter method (Okereke et al. 2016)

RESULTS AND DISCUSSION

Structure and composition of vegetation

In Camplong NRP, 22 species of trees and shrubs were found with a population density of 654 plants/ha. Based on density, the forest was dominated by *Syzygium aqueum* (Burm.fil.) Alston (18.74%), *Elaeocarpus petiolatus* (Jack) Wall. ex Kurz (15.66%), *Cananga odorata* (Lam.) Hook.f. & Thomson (12.63%), and *Senna siamea* (Lam.) H.S.Irwin & Barneby (11.36%). Based on dominance, the area was dominated by *Wrightia calycina* A.DC. (27.21%), *C. odorata* (13.72%), *Schleichera oleosa* (Lour.) Oken (9.90%), *Tetrameles nudiflora* R.Br. (8.10%), and *S. siamea* (7.71%). Based on frequency, the area was dominated by *S. agueum* (21.02%), *C. odorata* (13.81%), *S. siamea* (13.71%), and *Ziziphus timoriensis* DC. (12.20%). Based on IVI, the area was dominated by *S. agueum* (45.77%), *C. odorata* (40.16%), *W. calycina* (37.12%), *S. siamea* (32.79%), *Z. timoriensis* (26.34%), and *E. petiolatus* (22.28%) (Figure 3.A). Of the 22 species present, 16 (72.73%) were trees, and six (27.27%) were shrubs. The tree has a density of 80.89%, dominance of 82.93%, frequency of 78.81%, and IVI of 244.41 (81.47%). Therefore, the forest area was dominated by tree species. The shrub has a density of 19.10%, a dominance of 15.27%, a frequency of 21.19%, and an IVI of 55.58 (18.33%). The shrub species was *Broussonetia papyrifera* (L.) Vent., *Jatropha gossypiifolia* L., *Z. timoriensis*, *Ziziphus oenopolia* (L.) Mill., *Annona squamosa* L., and *Gliricidia sepium* (Jacq.) Kunth, while all other species were in the tree category.

In Herman Yohannes GFP, 24 trees and shrubs were present, with a 742 plants/ha density. Based on the density, the plants were dominated by *Neolitsea cassiifolia* (Blume) Merr. (10.00%), *Maesa junghuhniana* Scheff. (10.00%), *Aglaia teysmanniana* (Miq.) Miq. (8.30%), *Antidesma bunius* (L.) Spreng. (7.50%), and *Albizia* spp. (7.50%). Based on dominance, the forest area was dominated by *N. cassiifolia* (20.74%), *M. junghuhniana* (13.07%), *Ficus benjamina* L. (8.04%), *Miliusa horsfieldii* (Benn.) Pierre (7.47%), and *A. bunius* (7.20). Based on the frequency, the forest was dominated by *N. cassiifolia* (10.00%), *M. junghuhniana* (10.00%), *A. teysmanniana* (8.33%), *A. bunius* (7.50%), and *Albizia* Durazz. (7.50%). Based on IVI, the stand was dominated by *N. cassiifolia* (40.70%), *M. junghuhniana* (33.07%), *A. bunius* (22.20%), *Albizia* (21.92%), and *A. teysmanniana* (19.86%) (Figure 3.B). Of the 24 species present, about 18 (75.00%) species belong to the tree category and six (25.00%) species to the shrub category. The tree category has a density of 87.42%, dominance of 96.71%, frequency of 87.45%, and an IVI of 90.52%. The shrub category has a density of 12.48%, a dominance of 3.27%, a frequency of 12.48%, and an IVI of 9.41%. The shrubs were *A. squamosa*, *Maesa latifolia* (Blume) DC., *Harrisonia perforata* (Blanco) Merr., *Sambucus javanica* Reinw. ex Blume, *Daphniphyllum glaucescens* Blume, and *Coffea* sp., while all other species belong to the tree category.

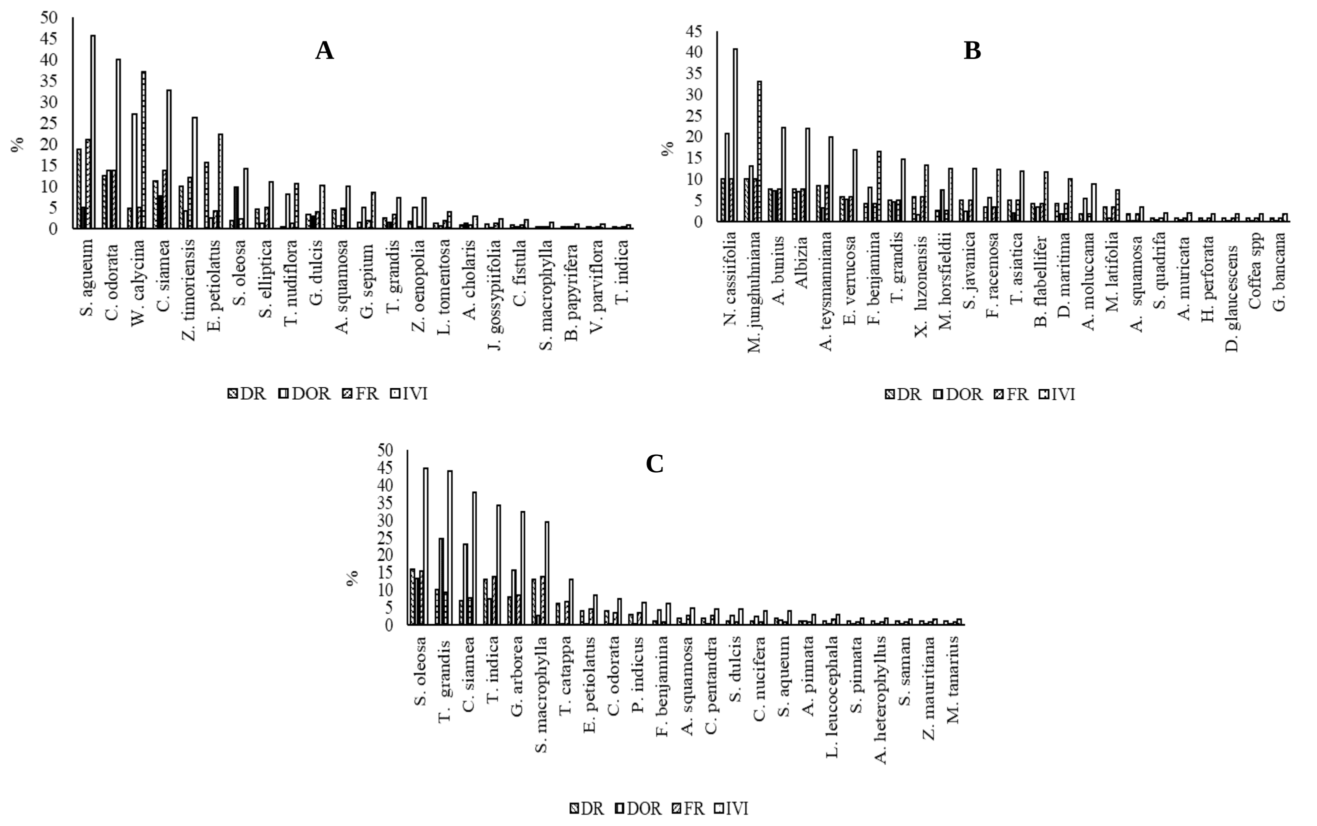

Figure 3. Plant composition on A. Camplong, B. Yohannes, C. Baumata Forest (DR: Relative Density, DOR: Relative Dominance, FR: Relative Frequency, IVI: Importance Value Index)

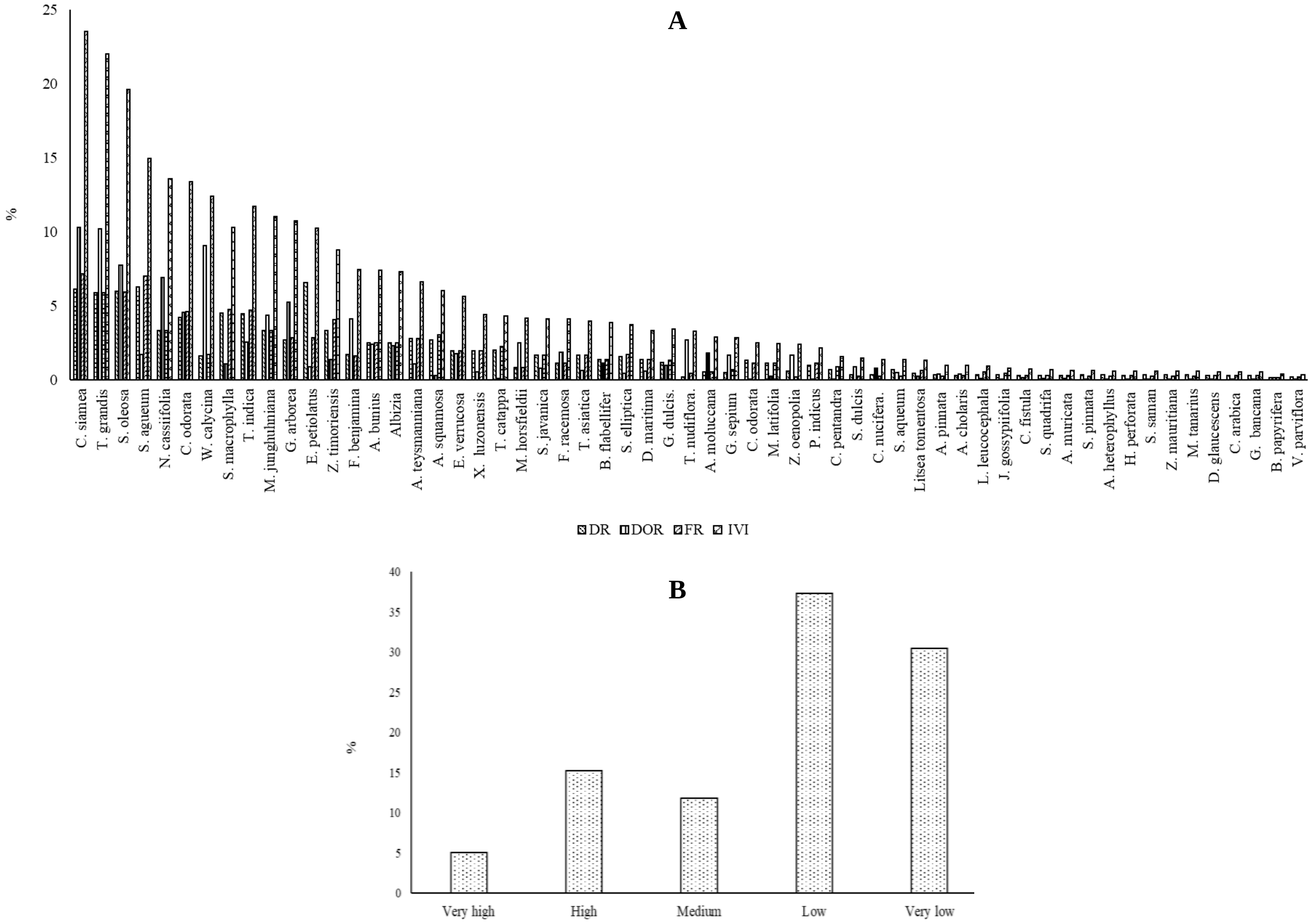

Figure 4. A. Composition and B. Categories of Importance Value Index (IVI) of plants in conservation areas of West Timor (DR: Relative Density, DOR: Relative Dominance, FR: Relative Frequency, IVI: Importance Value Index)

In Baumata NRP, 23 species of trees and shrubs were found, with a density of 408 plants/ha. Based on density, this area was dominated by *S. oleosa* (16.00%), followed by *Swietenia macrophylla* G.King (13.00%), *Tamarindus indica* L. (13.00%), and *Tectona grandis* L.f. (10.00%). Based on dominance, the plants were dominated by *T. grandis* (24.60%), *S. siamea* (23.10%), *Gmelina arborea* Roxb. ex Sm. (15.70%), and *S. oleosa* (13.30%). Based on frequency, the plants were dominated by *S. oleosa* (15.40%), followed by *S. macrophylla* (13.70%), *T. indica* (13.70%), and *T. grandis* (9.30%). Based on IVI, the plants were dominated by *S. oleosa* (44.70%), *T. grandis* (43.90%), *S. siamea* (37.80%), *T. indica* (34.20%), *G. arborea* (32.20%), and *S. macrophylla* (29.40%). Those six plants have a total IVI of 222.20 (74.07%) (Figure 3.C). Of the 23 species present, as many as 20 (86.96%) species belong to the tree stature category and three (13.04%) to the shrub category. Trees have a density of 93%, dominance of 99.90%, frequency of 93.30%, and IVI of 95.40%, while shrubs have a density of 7.00%, dominance of 0.10%, frequency of 6.70%, and IVI of 4.60%. Plants belonging to the shrub category were *Chromolaena odorata* (L.) R. King & H.Rob., *A. squamosa*, and *Ziziphus mauritiana* Lam., while all other plant species were of the tree category.

The plant population density was lower in Baumata NRP (4.08 plants/ha) than in Camplong NRP (6.54 plants/ha) and Herman Yohannes GFP (7.42 plants/ha). The dominance of the tree population in the Baumata NRP was higher (86.96% with an IVI of 95.40%) than in Herman Yohannes GFP (75.00% with an IVI of 90.52%) and Camplong NRP (72.73% with an IVI of 81.47%). The low plant population density in the Baumata NRP compared to the other two conservation areas can be due to the more disturbances of the former conservation area than in the other two conservation areas or can be due to the higher dominance of tree species in the former conservation area so that there was less opportunity for bush species to be present. However, further research was needed to confirm this. Of the three conservation areas, 59 trees and shrubs had a 601.33 plants/ha density. In general, the number of tree and shrub species found in the three conservation areas was relatively lower compared to that commonly found in rainforest communities where woody plant diversity can reach 150 tree species/ha (Kessler et al. 2005) and in the Amazon forest even reaches 283 tree species/ha (Gentry 1988). The relatively lower number of species found in West Timor can also be affected by forest health, where most of the forests are currently heavily disturbed, and forest areas are limited to small remnant vegetation (Lesmana et al. 2000). In addition, the dryland ecosystems in West Timor were generally relatively less stable than ecosystems in humid areas in the tropics which may also affect the number of species present (Monk et al. 1997). Kessler et al. (2005) stated that the number of native tree species was higher in natural forests than in unnatural forests, and the number of tree species gradually decreased with increasing intensity of forest disturbance.

The low number of species found in the forests of West Timor compared to those found in most areas of the rainforest may also be influenced by the geographical position of Timor Island in central Malesia, the transition zone called (Wallacea) located between the Sunda Shelf and the Sahul Shelf (van Welzen et al. 2005; Cowie 2006). Being located in the transition zone between these areas, Timor Island's flora lacks the diversity of much of the flora of the primary rainforest (van Steenis 1979; Cowie 2006). The geological history, climate, patterns of plant distribution, soil conditions, and topography can also influence the flora of Timor (van Steenis 1979; Cowie 2006). As the island of Timor is closer to Australia than West Malesia, the Timorese flora appears to have been more influenced by the Australian than the Malesian flora. During the ice ages, the northwest coast of Australia was some 100-200 km from Timor (Barlow 1981; Cowie 2006). This proximity also appears to facilitate the exchange of plant species between the two regions (van Steenis 1979; Cowie 2006). Timor also has a generally drier monsoon climate than the climate surrounding New Guinea and West Malesia, which may also limit the diversity of flora on the island of Timor. Timor is a relatively new island in terms of its geology, having been lifted from the seabed by the Australian tectonic plate drifting northward over the last 10 million years, and the time for the species to evolve thus was shorter than in many other parts of Malesia (Barlow 1981; van Welzen et al. 2005), and this may also affect the species diversity present in West Timor.

Of the 59 species present in the conservation areas of West Timor, based on the density, the forest area was dominated by *E. petiolatus* (6.55%), *S. aqueum* 6.25%), *S. siamea* (6.12%), *S. oleosa* (5.96%), and *T. grandis* (5.88 %). Based on the dominance, the forest was dominated by *Cassia siamea* Lam. (10.27%), *T. grandis* (10.21%), *W. calycina* (9.07%), and *S. oleosa* (7.73%). Based on the frequency, the area was dominated by *C. siamea* (7.14%), *S. agueum* (7.01%), *S. oleosa* (5.92%), and *T. grandis* (5.89%). Based on the IVI, the area was dominated by *C. siamea* (23.53%), *T. grandis* (21.97%), *S. oleosa* (19.61%), and *S. agueum* (14.95%). These four species had a total IVI of 80.06 (26.69%) or dominated almost 30.00% of the conservation areas (Figure 4.A). Species with high IVI indicate that they were more adaptive and able to adapt to changing environmental conditions better than other species in a forest community (Soerianegara and Indrawan 1998). They were able to make better use of available resources than other species and have a greater chance of sustaining their growth and reproduction. Species with high IVI could adapt to the environment by using what energy sources are available in the community, indicating that these species have an essential role in ecosystem sustainability (Soerianegara and Indrawan 1998).

Based on IVI, *S. siamea* was the most dominant plant in the conservation areas of West Timor. The *S. siamea* is an evergreen tropical plant that grows fast in various climatic conditions but prefers monsoon climates. This tree was often planted as roadside shade, as shade in tea, coffee, or cocoa plantations, as an ornamental tree, and as a pioneering tree in rehabilitating mining areas. In West Timor, this tree was introduced as part of the reforestation programs following the introduction of *T. grandis* to the island as part of the plantation forest program several decades ago. The presence of these two tree species in the conservation areas of West Timor was initially the result of planting and later the result of natural regeneration. *S. oleosa* was mainly found in Indonesia in areas with an extended and robust dry season, starting from the eastern hemisphere of Java, Bali, Nusa Tenggara, Sulawesi, and Maluku, growing either wild or planted (van Steenis 1979). This tree is also found outside West Timor in Sumba, Rote Ndao, Kalabahi, Alor, and others (van Steenis 1979). The wood of this plant was widely used as firewood for preparing a pork-based local delicacy called *Sei*. On the other hand, *S. aqueum* is a fruit-producing tree that is generally eaten fresh or used for preparing fruit salad.

The IVI of the above tree and shrub species was grouped based on their IVI into categories of very high (IVI>15), high (10<IVI<15), medium (5<IVI<10), low (1<IVI<5), and very low (IVI<1). Of the 59 trees and shrubs present, three (5.08%) species belonged to the category of very high importance; nine (15.25%) to the category of high; seven (11.86%) to the category of medium; 22 (37.29%) to the category of low, and 18 (30.51%) to the category of meager (Figure 4.B). Species of very high importance (NP>15) were *S. siamea*, *T. grandis*, and *S. oleosa*. The general pattern of forest community composition is that only a few species are categorized as abundant, and many others are categorized as locally rare. Most species (67.80%) in Timor Island forest communities belong to low and very low-importance categories. Many species in this category indicate that most species present are rare in this forest area. The large number of rare species encountered in this study confirms the general assumption that most species in the ecological communities are rare, not ordinary (Magurran 2003; Françoso et al. 2016). The scarcity of species can be due to various reasons, namely strong density-dependency in the forest, the existence of a resource gradient that causes species to occupy different positions resulting in variations in the distribution of abundance, the low ability of species to spread, the presence of natural or human-induced disturbances, and the process of competition taking place in the forest (Schwarz et al. 2003). The IVI is commonly used in ecological studies to indicate the ecological importance of a species in an ecosystem and to determine the conservation priority of species where species with low IVI values require a high conservation priority compared to those species with high IVI (Zegeye et al. 2006). Based on their low IVI values, *Arenga pinnata* (Wurmb) Merr., *Alstonia scholaris* (L.) R.Br., *Leucaena leucocephala*

(Lam.) de Wit, *J. gossypiifolia*, *Cassia fistula* L., *Sterculia quadrifida* R.Br., *Annona muricata* L., *Spondias pinnata* (L.fil.) Kurz, *Artocarpus heterophyllus* Lam., *H. perforata*, *Samanea saman* (Jacq.) Merr., *Z. mauritiana*, *Macaranga tanarius* (L.) Müll.Arg., *D. glaucescens*, *Coffea* spp, *Garcinia bancana* (Miq.) Miq., *Vitex parviflora* A.Juss., and *B. papyrifera* can be of high conservation priority in conservation areas.

Understanding tree species' composition and structure is a crucial instrument in assessing the sustainability of forest management, species conservation, and ecosystem management (Madoffe et al. 2006; Addo-Fordjour et al. 2009). Rapid human population growth has been shown to negatively impact forest size, species richness, and diversity (Kacholi 2014). If no action is taken, the remaining forest areas will continuously decrease and become more fragmented, leaving remnant forests that will lose their capacity to preserve the original biological diversity. Biodiversity conservation has become an increasingly important priority and essential issue in recent years, which, by describing the status of the structure and composition of tree and shrub species in the West Timor conservation areas, this study is expected to contribute. Using the available data, urgent intervention measures are needed to minimize further disturbances, primarily anthropogenic disturbances such as illegal logging, livestock grazing, fires, overexploitation, unsustainable agricultural practices, land conversion, and invasion by alien species as the primary driver of biodiversity loss.

Invasive trees and shrubs

In the Camplong NRP, of the 22 species of trees and shrubs present, nine species (40.91%) were potentially invasive. It is considered “potentially” invasive because a species is invasive in an area but has not been formally registered as an invasive species. Those potentially invasive species included *C. siamea*, *A. squamosa*, *G. sepium*, *J. gossypiifolia*, *C. fistula*, *B. papyrifera*, *V. parviflora*, *T. indica*, and *S. macrophylla*. Potentially invasive species had a density of 21.02%, a dominance of 14.86%, a frequency of 24.44%, and an IVI of 60.33 (20.11%). Potentially invasive species were dominated by *C. siamea* (IVI 32.79%), followed by *A. squamosa* (IVI 10.02%), *G. sepium* (IVI 8.51%), while other potentially invasive species only had relatively low importance (<3.00%) (Figure 5.A). Four of the nine potentially invasive species were shrubs (*A. squamosa*, *G. sepium*, *J. gossypiifolia*, and *B. papyrifera*), and the five remaining species were trees.

Seven of the 24 species of trees and shrubs present at Herman Yohannes GFP (29.17%) were potentially invasive. Based on density, dominance, frequency, and IVI, the potentially invasive species had a total density of 24.14%, dominance of 27.94%, frequency of 24.14%, and IVI of 25.41%. Those potentially invasive species included *A. bunius*, *Albizia*, *F. benjamina*, *Aleurites moluccanus* (L.) Willd., *A. squamosa*, *A. muricata*, and *Coffea* spp. Based on IVI, potentially invasive species were dominated by *A. bunius* (22.20%), *Albizia* (21.92%), and *F. benjamina* (16.37%), while other species had IVI<10.00% (Figure 5.B). Two of the seven potentially invasive species were shrubs (*A. squamosa* and *Coffea* spp.), and the five remaining species were trees.

In Baumata NRP, of the 23 species of trees and shrubs present, 16 (69.57%) species were potentially invasive, indicating that the number of invasive species was relatively large, at around 70.00%. Potentially invasive species included *C. siamea*, *T. indica*, *G. arborea*, *S. macrophylla*, *Terminalia catappa* L., *C. odorata*, *Pterocarpus indicus* Willd., *F. benjamina*, *A. squamosa*, *S. aqueum*, *A. pinnata*, *L. leucocephala*, *A. heterophyllus*, *S. saman*, *Z. mauritiana*, and *M. tanarius*. Potentially invasive species have a total density of 65.00%, dominance of 56.69%, frequency of 66.20%, and IVI of 62.63%. So, based on IVI, potentially invasive species have an IVI of more than 50.00%. Based on IVI, the potentially invasive species were dominated by *C. siamea* (37.80%), *T. indica* (34.20%), *G. arborea* (32.20%), and *S. macrophylla* (29.40), while other potentially invasive species had an IVI of <13%. (Figure 5.C). Of the 15 potentially invasive species present, three were shrubs (*C. odorata*, *A. squamosa*, and *Z. mauritiana*), and 13 remaining species were trees.

Based on the number of species potentially invasive, Baumata NRP has higher potentially invasive tree and shrub (69.57%), followed by Camplong NRP (40.91%) and Herman Yohannes GFP (29.17%) (Figure 6.A). Based on their IVI, potentially invasive species in Baumata NRP were significantly higher (paired T-Test) (62.63%) than in Camplong Forest (20.11%) (P <0.001), and Herman Yohannes Forest (25.41%) (P<0.001), while between Herman Yohannes and Camplong Forest were not different (P >0.001). Thus, the contribution of potentially invasive tree and shrub species to the Baumata NRP was relatively more significant than to the other two conservation areas. The high presence of potentially invasive species in the Baumata NRP indicates more significant damage to the conservation area than Camplong NRP dan Herman Yohannes GFP.

Of the 26 potentially invasive tree and shrub species present, based on density, the species were dominated by *C. siamea* (6.12%), *T. indica* (4.47%), *S. macrophylla* (4.50%), *A. squamosa* (2.70%), and *G. arborea* (2.67%). Based on the dominance, the potentially invasive species were dominated by *C. siamea* (10.27%), *G. arborea* (5.23%), *F. benjamina* (4.10%), and *T. indica* (2.53%). Based on the frequency, the potentially invasive species were dominated by *C. siamea* (7.14%), *T. indica* (4.69%), *S. macrophylla* (4.73%), *A. squamosa* (3.04%), and *G. arborea* (2.83%). Based on IVI, the potentially invasive species were dominated by *C. siamea* (23.53%), *T. indica* (11.69%), *G. arborea* (10.73%), *S. macrophylla* (10.30%), *F. benjamina* (7.45%), *A. bunius* (7.40%), and *Albizia* (7.31%) (Figure 6.B). Of the 26 potentially invasive species present, seven species (26.92%) were shrub (*J. gossypiifolia*, *A. squamosa*, *G. sepium*, *Coffea* spp, *B. papyrifera*, *C. odorata*, and *Z. mauritiana*), and 19 species (73.08%) were tree (*C. siamea*, *T. indica*, *G. arborea*, *F. benjamina*, *A. bunius*, *Albizia*, *T. catappa*, *A. moluccanus*, *P. indicus*, *S. aqueum*, *A. pinnata*, *L. leucocephala*, *C.*

fistula, *A. muricata*, *A. heterophyllus*, *S. saman*, *M. tanarius*, *S. macrophylla*, and *V. parviflora*). Invasive species can be present in various forms of habitus or form, ranging from the form of trees, shrubs, lianas, climbing or vines, grasses, herbs, and succulent plant species, including plants that have tubers, rhizomes, or aquatic plants (Sindel 2000). Each form of habitus can have a different effect on the ecosystem and its flora and fauna. Weeds in the form of shrubs can form dense and dense clumps when they successfully invade and dominate an area. This shrub will then directly prevent and inhibit the growth of seedlings of native plant species in the area.

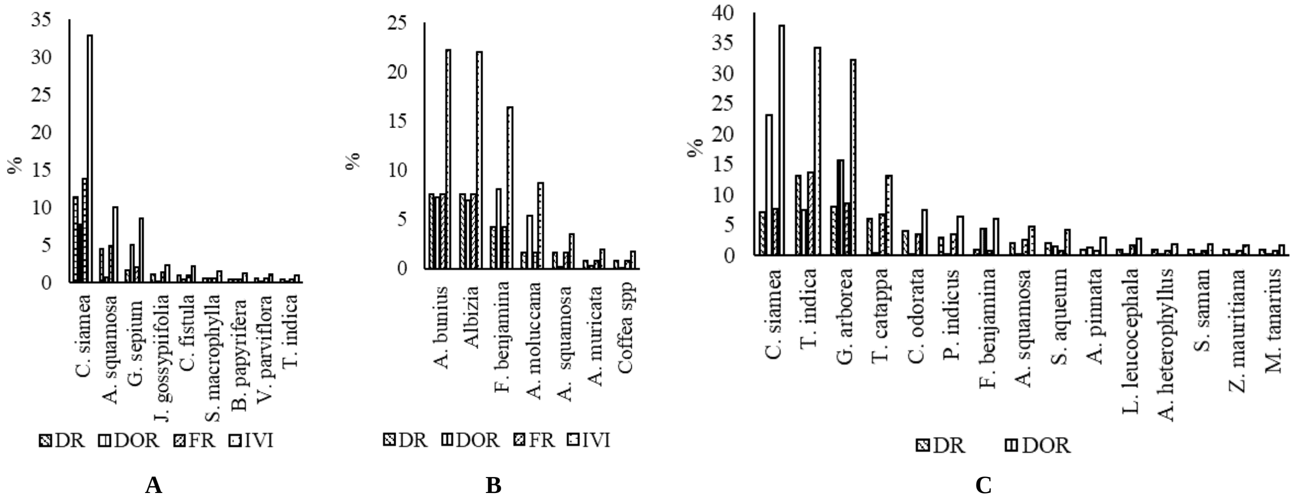

Figure 5. Potentially invasive species in three conservation forest areas on Timor Island. A. Camplong, B. Yohannes, and C. Baumata forest (DR: Relative Density, DOR: Relative Dominance, FR: Relative Frequency, IVI: Importance Value Index)

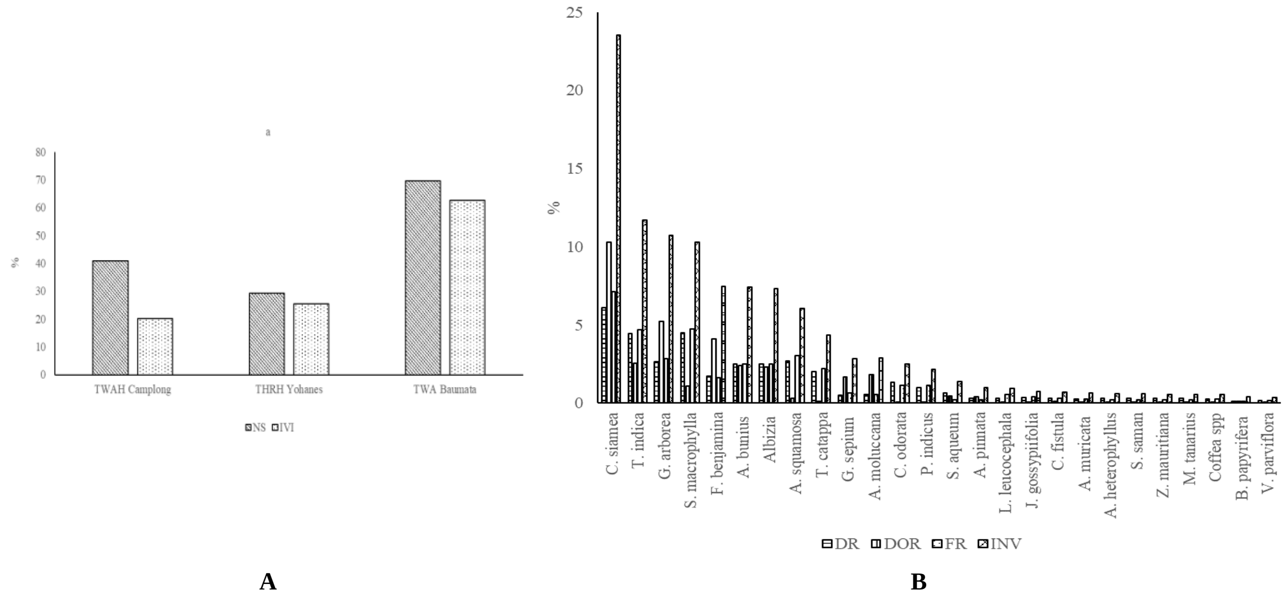

Figure 6. A. Number of species (NS) and Importance Value Index (IVI), B. Species composition of potentially invasive trees and shrubs in Timor conservation forest (DR: Relative Density, DOR: Relative Dominance, FR: Relative Frequency, IVI: Importance Value Index)

Table 1. The potential invasive species in Baumata NRP, Camplong NRP, and Herman Yohannes GFP after checking at the site of CABI Invasive Species Database and IUCN Global Invasive Species Database and crosschecking with the list of invasive species according to Permen LHK No. P.94/Menlhk/Setjen/Kum.1/12/2016 and Setyawati et al. (2015)

Species	Notes on Invasiveness on CABI Invasive Species Database	GISD	Permen LHK No. P.94 Year 2016	Setyawati et al. (2015)	Status of Introduction	Invasiveness to the Conservation areas
Albizia lebbeck and *Falcataria moluccana* (*Albizia falcataria*)	A nitrogen-fixing tree native to Southeast Asia and Papua New Guinea, listed as invasive elsewhere	-	Not listed	Not listed	Introduced	*A. lebbeck* is native, and *F. moluccana* is invasive only if mass-planted (1)
Aleurites moluccanus	A native species to Southeast Asia, listed as invasive outside Indo-Malaya region	Not Found	Not listed	Not listed	Local	Not invasive, part of native species
Annona muricata	A native species to Southeast Asia, listed as invasive in the Pacific Island	Not Found	Not listed	Not listed	Local	Not invasive, part of native species
Annona squamosa	A native species to Southeast Asia, listed as a "cultivation escape, naturalized weed" in the Global Compendium of Weeds	Found	Not listed	Not listed	Local	Not invasive, part of native species
Arenga pinnata	A native palm species of Southeast Asia. Listed as invasive to disturbed areas, forests, forest gaps/edges, riparian vegetation, and lowlands	Not Found	Not listed	Not listed	Local	Invasive only because its fruits are not utilized (2)
Artocarpus heterophyllus	Listed as invasive to roadsides, disturbed areas, urban open spaces, forest edges/gaps, and secondary forest	Not Found	Not listed	Not listed	Local	Not invasive, a cultivated species rarely escapes from cultivation
Broussonetia papyrifera	It is listed as a highly invasive species, becoming weedy and difficult to remove after its introduction.	Not Found	Not listed	Not listed	Local	Not invasive, part of native species
Cassia fistula	A native species to Southeast Asia, listed as an 'agricultural weed,' 'casual alien,' 'cultivation escape,' 'environmental weed,' 'garden thug,' 'naturalized,' and 'weed' in the Global Compendium of Weeds, listed as invasive only in Queensland, Australia.	Not Found	Not listed	Not listed	Local	Not invasive, part of native species
Chromolaena odorata	Listed as the world's worst weeds	Found	Listed	Listed	Introduced	Invasive, potentially replacing ground-cover species, high risk of fire (1)
Ficus benjamina	Listed as 'environmental weed, naturalized, weed' in the Global Compendium of Weeds, invasive in Cuba (Oviedo-Prieto et al. 2012), Pacific Island, USA, Galapagos, Australia, not in Malesia region	Not Found	Not listed	Not listed	Local	Not invasive, part of native species
Gliricidia sepium	A fast-growing tree for land rehabilitation, it is listed as invasive in Australia, Hawaii, the Philippines, Cook Islands, French Polynesia, Tonga, Singapore, Comoros, and Trinidad and Tobago.	Not Found	Not listed	Not listed	Introduced	Invasive, potentially replacing native species (2)
Jatropha gossypiifolia	It is considered invasive in Australia, Africa, Asia, and North and South America. In Australia, it is declared invasive in Queensland, the Northern Territory, and Western Australia.	Found	Not listed	Not listed	Introduced	Invasive, potentially replacing ground-cover species (3)
Gmelina arborea	Widely used in reforestation programs in tropical and subtropical regions of the world and as a source of commercial timber and cellulose, it entered wild habitats where it is now replacing native trees and becoming invasive, listed as invasive in Costa Rica, the Dominican Republic, Ghana, Australia, and the Cook Islands.	Not Found	Not listed	Not listed	Introduced	Invasive, potentially replacing native species (4)

Leucaena leucocephala	A 'miracle tree' to produce valuable animal fodder and firewood while also being fast-growing and tolerant to drought and poor soils, it is regarded as an invasive species in Asia, Australia, and Pacific islands, and elsewhere	http://www.iucngisd.org/gisd/speciesname/Leucaena+leucocephala	Listed	Listed	Introduced	Invasive, potentially replacing native species (5)
Macaranga tanarius	A fast-growing pioneer plant, it is often found growing in secondary forests, especially in cleared rainforests; the spread is favored by disturbance and so rapidly colonizes gaps or margins in well-developed rainforests (Australian Tropical Rainforest Plants 2010). It is also found in thickets, brushwood, village groves, coastal rainforest, and estuaries	Not Found	Not listed	Not listed	Local	Not invasive, help recover degraded part of the conservation areas
Pterocarpus indicus	Native to tropical and temperate Asia and parts of the Pacific region, a nitrogen-fixing species is invasive because of being introduced	Not Found	Not listed	Not listed	Local	Not invasive, part of native species
Samanea saman	A large nitrogen-fixing tree may be invasive because of prolific seeding and livestock as effective dispersers of seeds, conflicting reference sources about its invasiveness	Found	Not listed	Not listed	Local	Invasive only if it is mass-planted in the conservation area (3)
Senna siamea	A widespread forestry and ornamental tree native to Southeast Asia, listed as invasive in Australia (especially the Cape York Peninsula, Queensland), Mexico, the Caribbean (Dominican Republic and Puerto Rico), the Pacific (Fiji and French Polynesia), and Africa (CABI Invasive Species Database)	Not Found	Not listed	Not listed	Introduced	Invasive only if it is mass-planted in the conservation area (4)
Sizygium aqueum	No information	Not Found	Not listed	Not listed	Local	
Tamarindus indica	a large perennial nitrogen-fixing tree native to Southeast Asia, an invasive plant of environmental concern elsewhere because it has the potential to suppress and outcompete other plant species	Not Found	Not listed	Not listed	Local	Not invasive, part of native species
Terminalia catappa	A native species to Asia, Australia, the Pacific, Madagascar, and Seychelles, listed as invasive in the United States (Florida and Hawaii), Brazil, the Bahamas, Cuba, Dominican Republic, Trinidad and Tobago, Puerto Rico, and the Virgin Islands, where it is displacing native vegetation and altering coastal dynamics.	Found	Not listed	Not listed	Local	Not invasive, part of native species
Vitex parviflora	A tropical tree native to the Philippines and Indonesia, highly valued for its durable wood and ornamental potential, it is listed as invasive in Guam and Hawaii, USA, as a species of Least Concern in the IUCN Red List of Threatened Species.	Not Found	Not listed	Not listed	Local	Not invasive, part of native species
Ziziphus mauritiana	A fast-growing, spiny, drought-tolerant, thicket-forming shrub or tree, which can produce fruits prolifically and disperse seeds over a wide area using mammalian and avian vectors, declared a noxious weed in three Australian states and is noted as invasive in parts of southern Africa and on some Pacific and Indian Ocean islands	Found	Not listed	Not listed	Local	Invasive only if large trees are felled (5)

The summary of invasiveness, means of movement and dispersal, and risk of invasiveness available for each species were carefully reviewed to check the potential invasiveness of each species. In addition, the natural distribution of each species was also consulted, and whether the species was introduced for a particular purpose or not to West Timor was also taken into account. As a result, of the 26 initially considered invasive and 23 listed as potentially invasive, only five species were invasive, and five were invasive under certain conditions. The five species categorized as invasive were *C. odorata*, *G. sepium*, *J. gossypiifolia*, *G. arborea*, and *L. leucocephala*, all introduced species. *C. odorata* and *J. gossypiifolia* were introduced as weeds; *G. sepium* and *L. leucocephala* as fast-growing nitrogen-fixing species for land rehabilitation; and *G. arborea* as plantation forest trees for timber production. Of these five species, *C. odorata* and *L. leucocephala* were the only listed invasive species under the Permen LHK No. P.94/Menlhk/Setjen/Kum.1/12/2016.

Cananga odorata was listed as invasive because of its ability to produce many seeds that are easily dispersed with the help of the wind and animals due to the presence of palpable hairs that help them buoyant in the air and stick to animal fur. In dry areas such as West Timor, the above-ground part of the shrub dry up at the end of the dry season that was easy gets burnt, leaving the underground part remaining alive to produce new shoots at the onset of the rainy season, thereby disrupting the function of natural ecosystems (Den Breeyen et al. 2006). On the other hand, *L. leucocephala* was introduced as a fast-growing nitrogen-fixing species to produce feed and rehabilitate degraded land but was later considered a weed on arable lands. The five species categorized as invasive under certain conditions were *A. pinnata*, *F. moluccana*, *S. saman*, *S. siamea*, and *Z. mauritiana*. Of these five species, *F. moluccana*, *S. saman*, and *S. siamea* are nitrogen-fixing tree species introduced as part of land rehabilitation and could become invasive to the conservation areas only if they were intentionally planted. On the other hand, *A. pinnata* and *Z. mauritiana* were part of native vegetation; the first could become invasive if the fruits were not harvested, and the latter only if the existing trees were felled.

A study conducted in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia (Balai Taman Nasional Bantimurung Bulusaraung 2017) found 18 species of invasive plants belonging to 12 families. The number of invasive species in this National Park was relatively higher than that found in the conservation areas of West Timor. However, this study included all plant species, including herbs, shrubs, and tree species. Three species of woody plants (*C. siamea*, *C. odorata*, and *S. macrophylla*) considered invasive in this study were also found as invasive or invasive under certain conditions in the conservation areas of West Timor. Sitepu (2020) investigated invasive species in the Samboja forest in East Kalimantan, Indonesia, and found six species of invasive trees and 11 species of invasive shrubs. However, again, they included all groups of plants ranging from herbs, shrubs, and tree species. Four species considered invasive in this study (*C. odorata*, *L. leucocephala*, *S. siamea*, and *Swietenia mahagoni* (L.) Jacq.) were also found in the conservation areas of West Timor. The study by Yuliana and Lekitoo (2018) in the Gunung Meja Manokwari, West Papua Province, Indonesia, found 39 invasive plants, consisting of 6 invasive species of woody plants in the form of shrubs, while all the others were herbaceous or grasses. Yuliana and Lekitoo (2018) also investigated invasive alien plants in the Protected Forest Management Unit area of Sorong, West Papua, and found 23 invasive plant species ranging from shrubs, grasses, and lianas to trees. The tree and shrub species they considered invasive species were *C. odorata*, *Crotalaria juncea* L., *G. sepium*, *L. leucocephala*, *Lantana camara* L., *Melaleuca leucadendra* (L.) L., *Mimosa pudica* L., *Senna alata* (L.) Roxb., and *Spathodea campanulata* Beauverd, of which *C. odorata*, *G. sepium*, and *L. leucocephala* were also found as either invasive or invasive under certain conditions in the conservation areas of West Timor. Sunaryo and Girmansyah (2015) identified only three invasive species of woody plants (*Acacia mangium* Willd., tree form, *Melastoma malabathricum* L., and *Rhodomyrtus tomentosa* (Aiton) Hassk. in the form of shrubs) in Tanjung Puting National Park, Central Kalimantan, Indonesia, while the remaining invasive species were of non-grass herb species.

Ihsan et al. (2022) conducted a study in Sungai Buluh Peat Protection Forest, Jambi Province, Indonesia, and found 20 invasive species. However, only a few were woody tree and shrub species, such as *Mimosa pigra* L., *Clibadium surinamense* L., *Hyptis capitata* Jacq., *Clidemia hirta* (L.) D.Don, and *M. malabathricum*, while the remaining species were from the Asteraceae family who are generally herbaceous. Sulistiyowati et al. (2020) found 13 invasive species, of which one was a tree (*Schima wallichii* (DC.) Korth.), 3 were shrubs (*Agathis dammara* (Lamb.) Rich. & A.Rich., *Calliandra houstoniana* var. *calothyrsus* (Meisn.) Barneby, and *Brugmansia suaveolens* (Humb. & Bonpl. ex Willd.) Bercht. & J.Presl), and the remaining species were herbs and grasses. In Meru Betiri National Park, East Java, Indonesia, Susilo (2018) found six essential species that were included in the 100 most invasive plant species in the world, namely *C. odora*, *L. camara*, *Mikania micranta* Kunth, *Imperata cylindrica* (L.) Raeusch., *Sida rhombifolia* L., and *Stachtarpheta jamaicensis* (L.) Vahl, two of which, namely *C. odorata* and *L. camara* invaded the Pringtali grassland area, the feeding ground of banteng (*Bos javanicus* d'Alton). According to Sunaryo et al. (2012), currently, there are 74 foreign plant species in Gunung Gede Pangrango National Park, West Java, Indonesia, while in all regions in Indonesia, there were approximately 2000 foreign plant species (Kementerian Lingkungan Hidup dan Kehutanan 2003). Of the 74 foreign and potentially invasive species, the largest belong to the Asteraceae (22 species), then Solanaceae (7 species), Caryophyllaceae (five species), Euphorbiaceae, and Lamiaceae (four species each), while the other 20 families were of different families.

In general, the contribution of invasive tree and shrub (woody plants) species to the three conservation areas of West Timor indicated that the conservation areas have been severely degraded. The presence of invasive species further threatens the integrity and composition of native forest ecosystems. It inflicts various negative impacts on forest health, biodiversity, and ecosystem services, increases tree seedling mortality, inhibits regeneration, and reduces the growth of native plant species. Invasive species are known as species that threaten the integrity of the environment and have a significant impact on flora and fauna communities (Vilà et al. 2011). The presence of *A. moluccanus*, *Coffea* sp., and *A. heterophyllus* may indicate a high level of human intervention in the three conservation areas of West Timor. Those tree species are commonly grown on agricultural land and not commonly present in natural forests. Invasion of these woody plants poses various challenges to forest management because they inhibit and outperform desired native species regeneration to suffocate or remove native species. When such invasive tree species have become abundant, they can suppress native species' growth (Webster et al. 2006).

In conclusion, for the conservation of the West Timor conservation area, management actions are needed to prevent the further presence, spread, and dominance of invasive species; to detect early the presence of new invasive species; to determine the priority scale of which species will be eradicated and which species may occupy an area, and to eradicate invasive plant populations both physically, chemically and biologically. Restoration actions are also required to prevent further destruction of the remaining forest. Efforts to prevent the degradation, both naturally and anthropogenically caused, are also needed to minimize the opportunity for invasive species to dominate.

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