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Population and ecological study of agarwood producing tree (*Gyrinops versteegii*) in Manggarai District, Flores Island, Indonesia

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Abstract. *Rindyastuti R, Yulistyarini T, Darmayanti AS. 2019. Population and ecological study of agarwood producing tree* (Gyrinops versteegii) *in Manggarai District, Flores Island, Indonesia. Biodiversitas 20: 1180-1191. Gyrinops versteegii* (Gilg) Domke is one of very important tree species listed in Appendix II CITES because of its economical value as a source of agarwood. Since this commodity has been harvested in a significant volume, the natural population of *G. versteegii* is continuously decreasing in size. A remnant forest of Pongkor is one of fragmented habitat of *G. versteegii* in the rest of other land use for rice farming in Flores Island. The purpose of this study were to investigate the population structure and importance value rank of *G. versteegii* among plant species in Pongkor Community Forest. A semi-purposive random sampling were used in this study to investigate the population of *G. versteegii* in Pongkor, Manggarai District. The result showed that *G. versteegii* in Pongkor Community Forest was abundant, especially in seedlings stage. *G. versteegii* were found in four stratas i.e., trees, poles, saplings and seedlings with densities of 6, 4, 15 and 23 plants ha^{-1}, respectively. Seedlings of *G. versteegii* were abundant while larger plants were rare. Moreover, *G. versteegii* has scattered distribution and the highest important values (IVI) for trees, poles and saplings stratas, with IVI of 17.42, 25.75 and 44.42, respectively, while among the ground covers, *G. versteegii* ranked 22nd with an important value of 2.32. The abundant seedlings and the availability of adult trees as reproductive stages in the population of *G. versteegii* designated that population of *G. versteegii* in Pongkor could serve as a potential source of seed and young trees for plant enrichments in natural habitats and sustainable plantation in Manggarai District, Flores Island.

Keywords: Agarwood, CITES, *Gyrinops versteegii*, population structure

INTRODUCTION

Agarwood is one of the highest economic non-timber commodities in the world yielding aromatic resin that is produced under fungal infection (FAO 2002; Zich and Compton 2001). Agarwood is widely used for various purposes, therefore, it has been harvested in a significant volume. In infected form, agarwood were used as perfume and incense. The products of agarwood are generally exported in the form of chunks of wood, debris, powder or aloes oil to Arabian countries, Singapore and China (Zich and Compton 2001; Turjaman and Hidayat 2017; Mohamed 2016). As traditional medicine, agarwoods were investigated farmacologically and were found as a central nerve deppresant (Okugawa et al. 1993), anticancer (Hashim et al. 2014; Dahham et al. 2016), digestive medicine (Kakino et al. 2010), and antioxidant (Huda et al. 2009).

The most well-known plant groups which produce agarwood were the genera of *Aquilaria* and *Gyrinops* belonging to the family of Thymelaeaceae, subfamily of Aquilarioideae for their high quality resin production. There are eleven species of genera *Aquilaria* and seven species of genera *Gyrinops* which produce agarwood. Five of these species are *Gyrinops versteegii*, *G. ledermannii G. decipiens*, *G. podocarpus*, *G. caudate*, and *G. salicifolia* (natural habitat in Indonesia and Papua New Guinea) and *G. walla* (natural habitat in Sri Lanka) (Hou 1960; Schun and Cordell 1985). One of agarwood producing species which has been harvested hardly from its habitats is *Gyrinops versteegii* (Gilg) Domke (Zich and Compton 2001). *G. versteegii* is a tree that can reach a height of up to 10 m, 25-30 cm in diameter and has various leaf morphology (Siburian 2009; Surata and Soenarno 2011; Hou 1960). *G. versteegii* is divided into many various groups and varieties, however, it was still taxonomically intricated (Mulyaningsih et al. 2017; Mulyaningsih et al. 2017; Roemantyo and Partomihardjo 2010). *G. versteegii* is distributed from Lesser Sunda Island, especially Western Sumba, Alor Island, Lombok Island, Flores Island, to Sulawesi, Mollucas and Papua (Hou 1960).

The population of *G. versteegii* in its distribution area was reported to decline continously because of hard harvesting of mature plants especially in Nusa Tenggara Barat and Nusa Tenggara Timur Provinces. Because of its high demand, the harvesting of agarwood producing trees is oftenly carried out without distinguishing the producing and non-producing trees (Zich and Compton 2001; Barden et al. 2000). This harvesting model significantly threaten the natural population of the species by decreasing its population size. This major threat to the population of agarwood producing trees results in the issue of a trade rules of export under the CITES (Convention on International Trade in Endangered Species) regulation. In Indonesia, the export of *G. versteegii* in the form of chips is in a low quota, however, the export has increased from 1000 kg in 2014 to 4000 kg in 2015 (CITES Trade

Database 2018). Unfortunatelly, to meet the quota, the population of *G. versteegii* in its distribution region was very rare. The population of *G. versteegii* were reported to have been over-exploited for years, resulting in small population size and a rare source of seedling for plantation (Roemantyo and Partomihardjo 2010).

Populations study of agarwood producing tree in its distribution regions has been conducted in the areas of Lesser Sunda. Mulyaningsih et al. (2017) invesigated the presense of *G. versteegii* in the natural forest of West Lombok, Lombok Island and found that, in natural habitats, agarwood producing tree was only found in one location with very limited population which consisted of two stratas, i.e., sapling and seedling. Roemantyo and Partomihardjo (2010) assessed the ecological distribution of *G. versteegii* in Indonesian region based on the herbarium accessions from Herbarium Bogoriense (BO). It occured in Manggarai and East Manggarai District, Flores Island in the altitute of 50-900 m asl. The population of *G. versteegii* were recorded only in East Manggarai District, Flores Island (Komar et al. 2014). Current surveys showed that the population of *G. versteegii* were found in Manggarai District in two locations. One of remnant population of *G. versteegii* in Flores is located in Pongkor, Manggarai District. This area is a small and remnant forest of land used as large rice field outer Ruteng Nature Recreation Park (Yulistyarini et al. 2019).

The small and narrow forest areas are susceptible to ecosystem damage so that the research of the remaining *G. versteegii* population in the forest area is very urgently required. As the survey and modelling of small plant populations could serve as a basis for developing conservation strategies of a rare or endangered species, the information about *G. versteegii* population in its natural habitat should be well documented (Iriondo 1996). Recent information of natural population will be useful for the conservation of *G. versteegii* in both natural habitats and plantation. Regarding the CITES regulations, the information of population will be very useful for determining the trade quotas per year in an appropriate volume, therefore, the exploitation of this species in nature habitats will be limited.

Previous studies on agarwood producing tree in Indonesia have been conducted including genetic diversities (Toruan-Mathius et al. 2009; Mulyaningsih et al. 2017), the science of agarwood (Mohamed 2016), development of agarwood induction technology using endophytic fungi (Turjaman et al. 2016), species ecology and distribution of agarwood producing tree from herbarium records (Roemantyo and Partomihardjo 2010), infraspecific diversity of agarwood producing tree (Mulyaningsih et al. 2017), the inventory of agarwood-planted tree in Indonesia (Turjaman and Hidayat 2017), phylogeny relationship of agarwood producing trees (Lee et al. 2018), environment factors affecting the growth of agarwood producing tree (Rawana et al. 2018), and identification of chemical compounds in agarwood producing species (Nasution et al. 2019). However, the study on population structure of *G. versteegii* and its ranking amongs forest community in its natural habitas are still lacking, especially in Flores Island. Therefore, the purposes of this study were to investigate the population structure of *G. versteegii* in Pongkor Community Forest, Manggarai District, Flores Island, Nusa Tenggara Timur Province, to study the agarwood producing tree abundance, its ranking among plant species in the forest community and to discuss the implications for conservation of agarwood producing tree in small population.

MATERIALS AND METHODS

Study area

This research was conducted in Pongkor, Manggarai District, Flores Island, Nusa Tenggara Timur Province, Indonesia in April 8-18th, 2018, within a coordinate location of 8^{o}.69'40.54"S latitude and 120^{o}.39'62.44'E longitude (Figure 1). The site of this study is a community forest in Pongkor, Manggarai District, Flores Island. This forest was a small and hilly areas with a size of aproximately 12 hectares, the slope range of 45-75^{o} and altitute range of from 608 to 660 m asl. This area is a remnant and fragmented forest near the riverbank, the rest of land used by the local people for rice fields. The plant community in this forest are partly dense with the low abundance of large trees (Yulistiarini et al. 2019). The area is relatively opened, with the air temperature ranged from 28 ^{o}C to 32 ^{o}C, the light intensity ranged from 310 to 1951 lux and air humidity was 57-79%, while the soil acidity level was around normal (pH 6.4-7).

Procedures

Vegetation analyses in Pongkor Community Forest

The research was carried out from April 8th to18th, 2018, by conducting a survey to discover the natural population of agarwood producing trees *G. versteegii* in Manggarai District, Flores Island. A purposive random sampling method was used for determination of sampling area. At the study site, the identification of agarwood producing tree was carried out, along with interviews with local residents to determine the species target and sampling locations. This method was conducted to record the occurence of population of agarwood producing tree and collected the data of habitats, location, number of stands, stand height, age range, stand diameter, reproductive biology during research, etc.

Vegetation analysis was carried out to determine the population structure of *G. versteegii*, floristic composition of forest in Pongkor Community Forest using variable Important Value Index (IVI) (Barbour et al. 1987). Vegetation inventory was conducted using a random sampling method in the area of about 12 hectares, by making line transects and sampling plots with an area of 20 x 20 m^2 for 4 stratas, namely ground covers (dbh <1.5 cm), saplings (saplings with dbh <10 cm), poles (small trees with dbh 10-20 cm), and trees (trees with dbh at least 20 cm) (Soehartono and Newton, 2000; Barbour et al. 1987). Data collection was carried out in 3 transects, each transect had 4 plots, 12 plots in total.

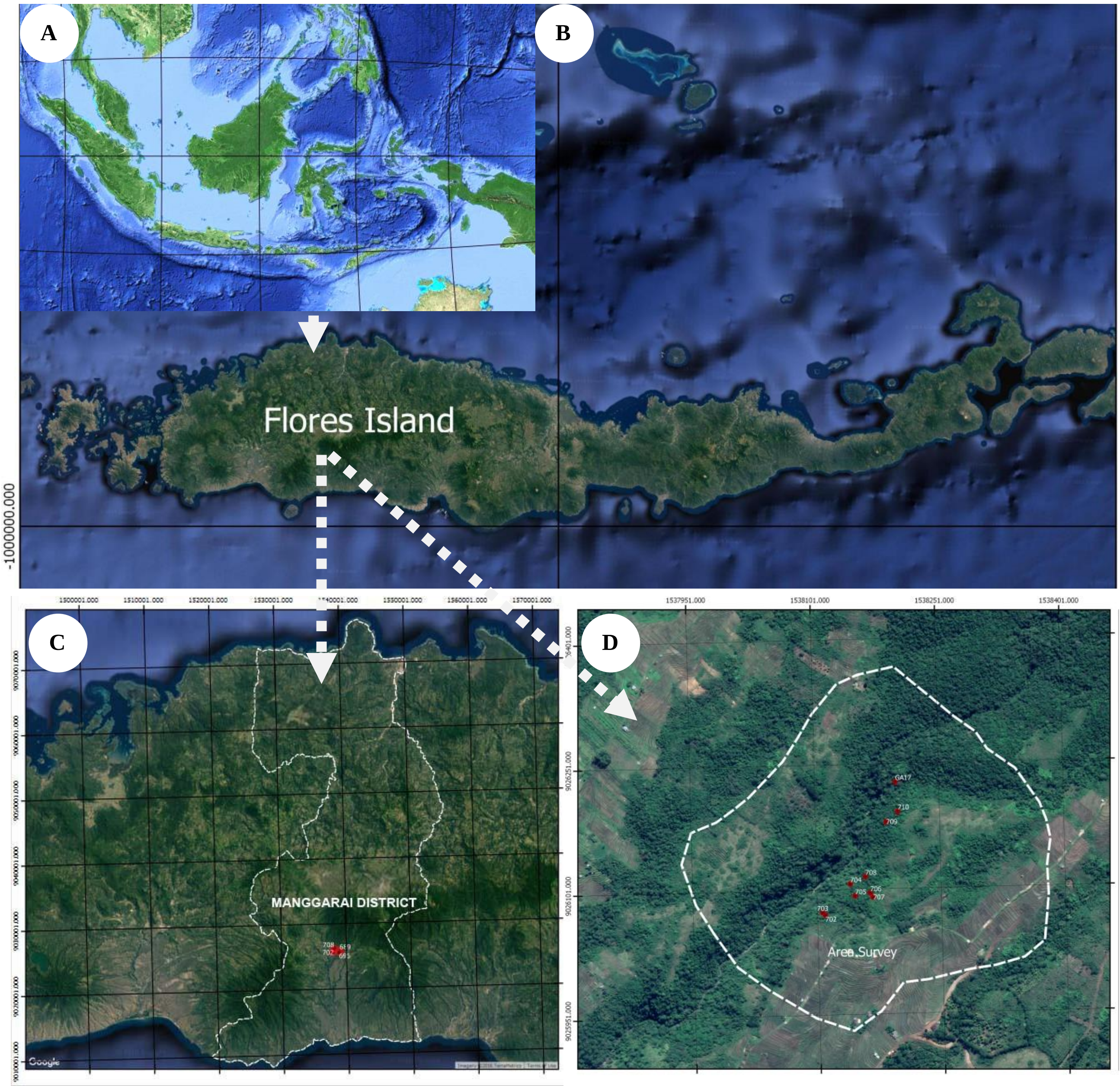

Figure 1. (A) Indonesian region. Map scale 1: 25,048,729, (B) Flores Island, East Nusa Tenggara Province, Indonesia. Map Scale 1: 1,981,263. (C) Location of the population study of agarwood producing trees (*G. versteegii*) in Pongkor, Manggarai District, Flores Island (red dots) Map Scale 1: 360,000 (D) The area and sampling plots of agarwood producing trees occured in Pongkor Community Forest, Manggarai District, Flores Island with the area of 12 hectares (white line). Map scale 1: 2,813

Data analysis

The floristic datas were analyzed to study the floristic composition of natural habitat of agarwood producing tree in Pongkor Community Forest, Manggarai District, Flores Island. The data recorded including ecological variables such as Important Value Index (IVI), Density (D), Relative Density (RD), Frequency (F), and Relative Frequency (RF), for each species. Important Value Index (IVI) was determined based on Relative Density (RD) and Relative Frequency (RF).

$$RD = \frac{\text{Number of individual of Species A}}{\text{Total number of individual}} \times 100\%$$

$$RF = \frac{\text{Number of plot containing Species A}}{\text{Total frequencies of plant species}} \times 100\%$$

$$IVI = RD + RF$$

(Barbour et al. 1987)

RESULTS AND DISCUSSION

Population structure of *G. versteegii* in Pongkor Community Forest

Agarwood producing trees *G. versteegii* were found in Pongkor Community Forest in four stratas, i.e. trees, poles, saplings and seedlings (Figure 2). The data of average diameter, maximum diameter, average height and maximum height of agarwood producing trees, are shown in Table 1. The average diameter of *G. versteegii* in tree, pole, sapling and seedling stratas found in the forest area was 29.35, 10.79, 5.91, and 0.47 cm, respectively. The average height of *G. versteegii* in trees, poles, saplings and seedlings stratas were 7.00, 6.15, 4.45, and 0.23 cm, respectively. The densities of trees, poles, saplings and seedlings of *G. versteegii* were 6, 4, 15 and 23 plants ha^{-1}, respectively. Generally, the higher the strata, the lower the density of agarwood producing trees. However, the result showed that the density of agarwood producing tree in pole strata is the lowest among all stratas.

Figure 3 showed a demographic structure of agarwood producing tree *G. versteegii* in various growth stages in Pongkor Community Forest i.e., flowering adults, vegetative adults, juvenils and seedlings. The per-hectare density of *G. versteegii* based on the growth stages were 8 plants in flowering adults, 2 plants in vegetative adults, 15 plants in juvenils and 23 plants in seedling stage. The higher the growth stages, the lower the densities of agarwood producing trees. The population has relatively larger numbers of seedlings and young trees (Figure 4C, 4D), compared to the number of adults (Figure 4A, 4B). The flowering adult stage showed the lowest density in this population. Moreover, the presence of flowering adult plant indicates that this population could produce the young generations by itself by performing seedling recruitments.

Table 1. Population of agarwood producing tree (*Gyrinops versteegii*). Its average diameter (cm dbh), maximum diameter (cm dbh), average height and maximum height of plants found in Pongkor Community Forest, Manggarai District, Flores Island, East Nusa Tenggara, Indonesia

Strata	Average diameter (cm)	Maximum diameter (cm)	Average height (m)	Maximum height (m)
Trees	29.35±0.24	29.62	7.00±0.50	7.00
Poles	10.79±0.09	12.74	6.15±2.29	12.00
Saplings	5.91±2.89	9.55	4.45±1.91	8.00
Seedlings	0.47±1.43	0.68	0.23±6.40	0.45

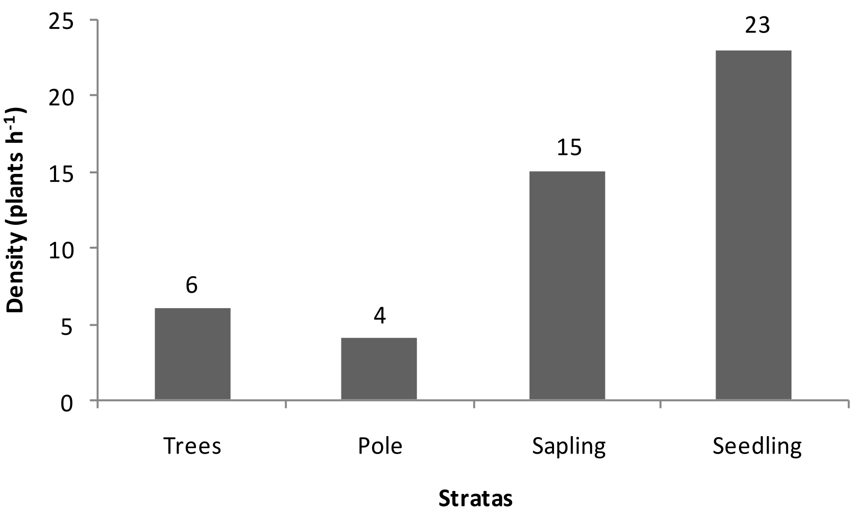

Figure 2. Population structure of agarwood producing tree (*Gyrinops versteegii*) in various stratas in Pongkor Community Forest, Manggarai District, Flores Island, East Nusa Tenggara, Indonesia

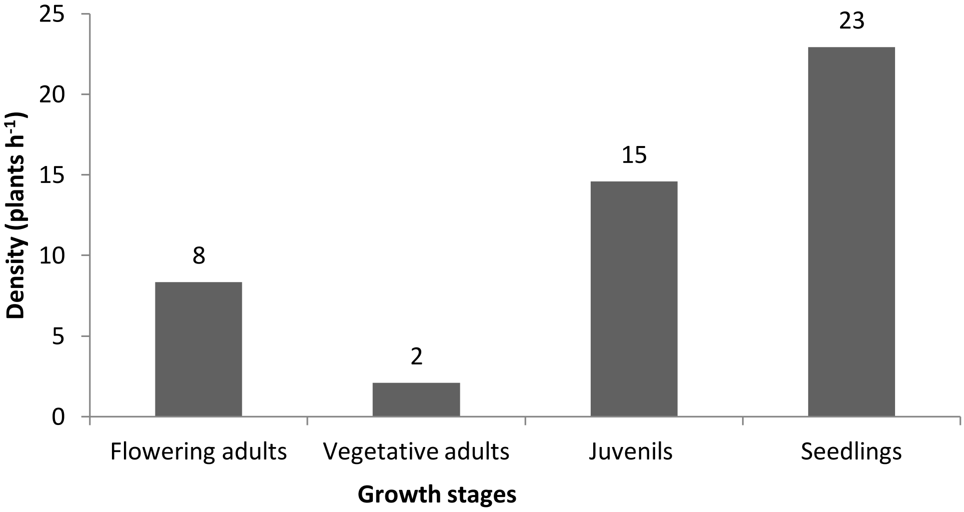

Figure 3. Demographic structure of agarwood producing tree (*Gyrinops versteegii*) in various growth stages in Pongkor Community Forest, Manggarai District, Flores Island, East Nusa Tenggara, Indonesia

Figure 4. Population of agarwood producing trees (*Gyrinops versteegii*) in Pongkor Community Forest, Manggarai District, Flores Island, East Nusa Tenggara, Indonesia. A. Plant habit, tree strata with the trunk diameter of up to 20 cm, B. Pole strata with the diameter of up to 10 cm (yellow arrow), C. Small sapling with the diameter of around 2 cm (yellow arrow), D. Seedling in the forest ground

The ranking of *G. versteegii* in the forest community of Pongkor

Pongkor Community Forest is a remaining forest of encroachment area with an area of only 12 hectares. The community structure in Pongkor Community Forest is dominated by small trees. Plants in the tree strata were very few. There were 39 tree plant species which were included in 26 plant families and 72 species of ground covers which were included in 47 plant families. From this composition, only 4 species of tree belong to 4 plant families, i.e., Euphorbiaceae, Burseraceae, Thymelaceae and Leguminosae. Of the pole strata, 12 species were found which are included in 10 plant families. In the sapling stage, there were 30 plant species which belong to 21 plant families.

The forest stucture indicates that Pongkor Community Forest has diverse species of young trees, especially saplings and groundcovers. Forest vegetation with stable conditions is indicated by more species in the younger stage than species in trees (Wirakusumah 2003). It suggests that the vegetation in this forest is quite stable. The stable and ideal forest is important to be conserved especially to preserve a rare and over-exploited species such as agarwood producing trees.

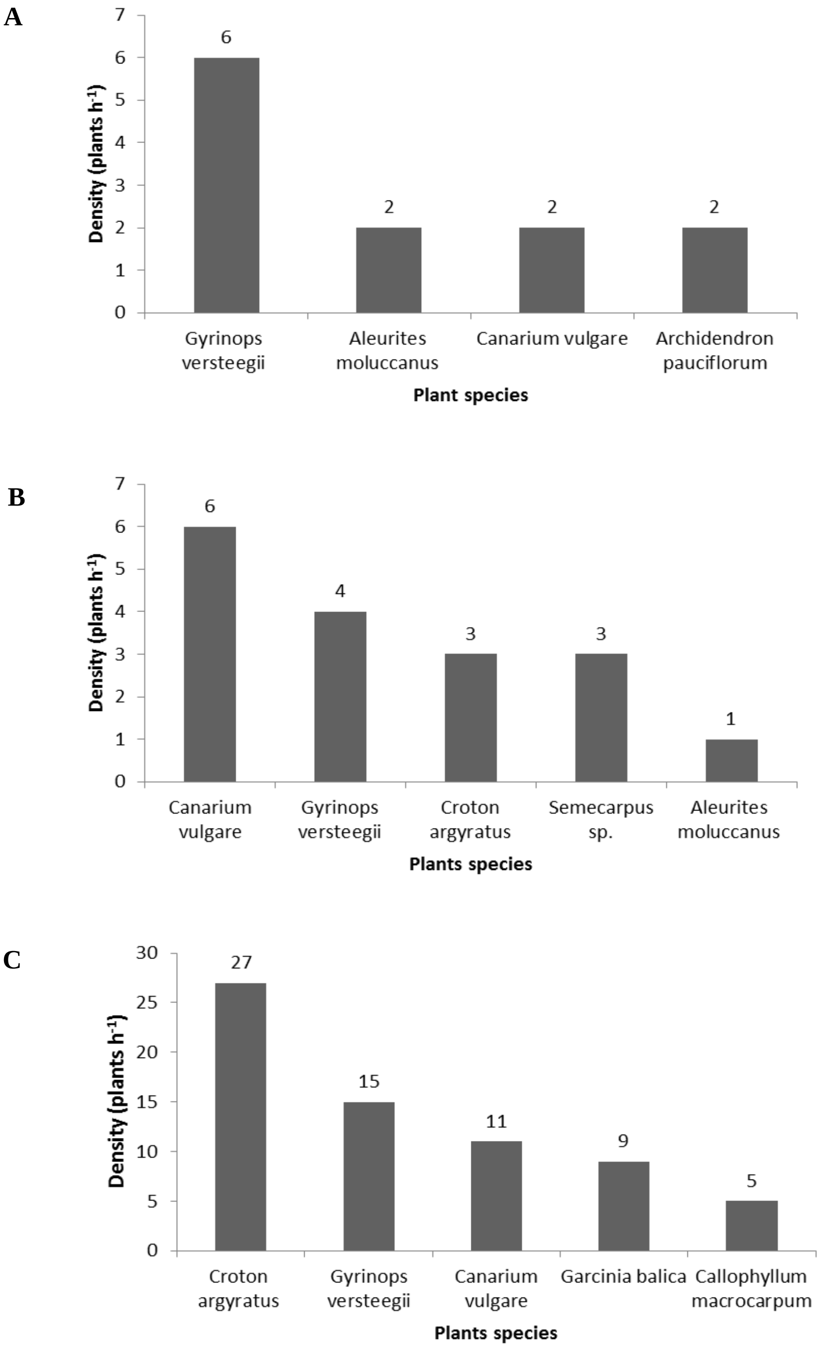

Figure 5. The density ranking of agarwood producing tree (*G. versteegii*) and other plant species in Pongkor Community Forest, Manggarai District, Flores Island, East Nusa Tenggara, Indonesia on the stratas of (A) tree (B) pole and (C) sapling

The comparison between the densities of agarwood producing tree (*G. versteegii*) per hectare to those of other plant species in Pongkor Community Forest in 3 stratas i.e., trees, saplings and poles are shown in Figure 5. There are four plant species in tree strata in Pongkor Community Forest, i.e., *G. versteegii*, *Aleurites mollucanus, Canarium vulgare*, and *Archidendron pauciflorum*. The density of *G. versteegii* was the highest among other species, i.e. 6 plants ha^{-1}. There are five species in the pole strata with the highest density in the forest i.e. *C. vulgare, G. versteegii, Croton agyratus, Semecarpus* sp., and *A. mollucanus.* In the pole strata, *G. versteegii* ranked the second after *C. vulgare* with the density of 4 plants ha^{-1}. In the saplings strata, five species with the highest densities were *C. agyratus, G. versteegii, C. vulgare, Garcinia balica* and *Callopyllum macrocarpum*. *C. argyratus,* which had very abundant saplings in the forest. The saplings of *G. versteegii* ranked the second after *C. argyratus* with the density of 15 plants ha^{-1}. There were 72 species of ground covers that dominated the forest floor, especially the plant group of shrub, grass and fern. Amongst all ground cover species, the seedling of *G. versteegii* ranked the 58th. The result for density ranking amongs the ground covers is not illustrated in this paper.

Table 2. Density (D), Relative Density (RD), Frequency (F), Relative Frequency (FR) and Important Value Index (IVI) of plant species in Pongkor Community Forest, Manggarai District, Flores Island, East Nusa Tenggara, Indonesia

Strata	D	DR (%)	F	FR (%)	IVI (%)
Trees					
Gyrinops versteegii	0.63	0.75	0.167	16.67	17.42
Aleurites moluccanus	0.21	0.25	0.083	8.33	8.58
Canarium vulgare	0.21	0.25	0.083	8.33	8.58
Archidendron pauciflorum	0.21	0.25	0.083	8.33	8.58
Poles					
Gyrinops versteegii	0.0075	0.75	0.25	25.00	25.75
Canarium vulgare	0.0125	1.25	0.167	16.67	17.92
Semecarpus sp.	0.005	0.50	0.167	16.67	17.17
Croton argyratus	0.005	0.50	0.167	16.67	17.17
Syzygium littorale	0.0025	0.25	0.083	8.33	8.58
Rhus taitensis	0.0025	0.25	0.083	8.33	8.58
Pouteria obovata	0.0025	0.25	0.083	8.33	8.58
Knema cinerea	0.0025	0.25	0.083	8.33	8.58
Dracontomelon dao	0.0025	0.25	0.083	8.33	8.58
Calophyllum macrocarpum	0.0025	0.25	0.083	8.33	8.58
Saplings					
Gyrinops versteegii	0.0275	2.75	0.417	41.66	44.42
Canarium vulgare	0.025	2.50	0.33	33.33	35.83
Canarium hirsutum	0.0075	0.75	0.25	25.00	25.75
Cordia bantamensis	0.0075	0.75	0.167	16.67	17.42
Gnetum gnemon	0.005	0.50	0.167	16.67	17.17
Knema cinerea	0.005	0.50	0.167	16.67	17.17
Tabernaemontana sphaerocarpa	0.005	0.50	0.167	16.67	17.17
Croton argyratus	0.05	5.00	0.083	8.33	13.33
Syzigium littorale	0.02	2.00	0.083	8.33	10.33
Polycias nodosa	0.015	1.50	0.083	8.33	9.83
Groundcovers					
Selaginella plana	0.16	16.38	0.64	12.00	27.43
Kyllinga brevifolia	0.10	10.19	0.36	6.00	16.51
Oplismenus compositus	0.11	11.15	0.27	4.74	15.88
Melastoma malabathricum	0.048	4.82	0.27	4.74	9.56
Kyllinga sp.	0.05	5.06	0.21	3.68	8.74
Garcinia balica	0.02	2.27	0.24	4.21	6.49
Cyperus sp.	0.038	3.86	0.12	2.10	5.97
Dracaena angustifolia	0.027	2.37	0.15	2.63	5.00
Christella arida	0.032	3.27	0.09	1.58	4.85
Radermachera gigantea	0.024	2.24	0.12	2.11	4.35

The population of agarwood producing trees in Pongkor Community Forest was small with rare plants in the tree strata. In comparison of IVI for plant species in the four stratas, the forest has partly dense vegetation with dominance of understorey and tree species in the sapling srata. *G. versteegii* were found in 4 stratas, i.e., trees, poles, saplings and seedlings. In the tree strata, there were only 4 plant species in this area, i.e., *G. versteegii*, *A. mollucanus*, *C. vulgare*, *A. pauciflorum* with the Important Value Index (IVI) of 17.41; 5.85; 5.85; 5.85 and 5.85, respectively (Table 2). In the tree strata, *G. versteegii* ranked first out of 4 plant tree species, with the IVI of 17.42.

Table 1 shows that, based on the IVI, *G. versteegii* ranked the first out of the total 12 plant species in the poles strata, with the important value of 25.7. Among the saplings, *G. versteegii* ranked the first out of the total 30 plant species with the important value of 44.42. Highly diverse ground covers are grown in the Pongkor Community Forest including tree seedlings, grasses, shrubs, herbs and ferns. Among 72 species of ground covers, the seedling of *G. versteegii* ranked 22nd out of the total ground cover species with the IVI of 2.32. The fern species, *Selaginella plana* showed the highest important value among the ground covers with the IVI of 27.43. In addition, *G. versteegii* in tree, poles and sapling stratas have high frequencies, which indicate that *G. versteegii* has a random or scatered spatial distribution in the forest area.

Discussion

The population structure of G. versteegii in Pongkor Community Forest

The average diameter (dbh) of agarwood producing trees *G. versteegii* in tree strata which were found in Pongkor Community Forest was 29.35 cm, while the maximum diameter (dbh) was 29.62 cm. There are few plants of *G. versteegii* in tree stratas and all trees have the diameter up to 29 cm. In the pole strata, the average diameter (dbh) of agarwood producing trees was 10.79 cm with maximum diameter (dbh) of 12.74 cm. The plant in this class diameter is classified as a large individual and in the harvesting stage, because agarwood producing trees (*Gyrinops* and *Aquilaria*) could be harvested in smaller size (Soehartono and Newton 2001; Zich and Compton 2001), i.e. in around 15 cm (Soehartono and Newton 2001). According to Soehartono and Newton (2001), agarwood producing trees are classified into class sizes differently from those of common tree species (tree strata has diameter of up to 20 cm). Agarwood producing trees are classified as adults plants in the diameter of up to 10 cm, and further clasified into adult 1 (>10±<30cm dbh), adult 2 (30±50 cm dbh) and adult 3 (>50 cm dbh). The trunk diameter of harvested agarwood could be various because the yield of agarwood does not correspond with tree diameter. There are two harvest methods to extract agarwood i.e. by felling down the trees and by slicing the part of the trunk of infected trees. In line with that, the farmers in Pongkor also checked the trunk of *G. versteegii* whether it was infected or not by slicing part of the trunk (pers. observation). This indicates that *G. versteegii* with the diameter of up to 10 cm are threatened by any harvesting method of agarwood in their natural habitat. Therefore, this small population of *G. versteegii* need to be protected.

G. versteegii in Pongkor showed the highest ranking of IVI among plant community on trees, poles and saplings stratas. Importance value reflects relative contribution of a species to the entire forest community (Barbour et al. 1987). In this study, Importance Value Index (IVI) was obtained from the sum of two ecological variables namely relative density (RD) and relative frequency (RF). The IVI shows the relative dominance of species to forest community. The first rank of IVI of *G. versteegii* on tree, poles and sapling stratas indicates that this species is dominant in the forest community. The first rank of IVI of *G. versteegii* was more determined by the relative frequency (RF), which are in the first rank for 3 stratas (tree, pole and sapling), than by relative density (RD). *G. versteegii* had the highest frequency and random spatial distribution. They were found in 8 plots out of total 12 plots (Figure 1). The density rank of *G. versteegii* in Pongkor was the first only for tree strata and the second for pole and sapling stratas. The study showed that *G. versteegii* in Pongkor is abundant in all stratas, especially in seedlings stage. The presence of agarwood producing tree in tree and pole stratas indicates that there is no massive logging for this species in this area and the trees are selectively logged or harvested by local people. The dominance of *G. versteegii* in the forest community indicates that Pongkor area is one of distribution centre of this species in Flores Island. Unfortunatelly, the forest cover was widely reduced by the rice farming and plantations, resulted in a fragmented habitats of *G. versteegii*.

Based on the previous study on the species of *G. versteegii*, the information of distribution pattern, population density and trends in population size in its natural habitats is inadequate and still lacking. Accordingly, Mulyaningsih et al. (2017) investigated the presense of *G. versteegii* in the natural forest of West Lombok, Lombok Island and found that natural habitat of agarwood producing trees was only found in one location with very limited population which consisted of two stratas i.e. sapling and seedling. However, the study did not show the density and important value of *G. versteegii* in the forest community. A species of agarwood producing trees which has very close taxonomical relationship, i.e., *Aquilaria* spp., is more oftenly investigated because it is more popular among the agarwood farmers and traders. Based on the study, the density of agarwood producing tree (*Aquilaria* spp.) in Kutai National Park was very low, with the abundance only 0.01 plants ha^{-1}. The abundance of agarwood producing tree in other regions were also small, i.e., 1.87 plants ha^{-1} in Sumatra, 3.37 plants ha^{-1} in Kalimantan and 4.33 plants ha^{-1} in Irian Jaya (Soehartono 1997 in Donovan and Puri 2002). Very low densities of agarwood producing tree in mostly natural habitats especially in large size (tree and pole stratas) indicates that many agarwood producing trees had experienced massive and unselective logging by collectors.

Population demographic data is related to species phenology and will be useful to increase the understanding of biological aspects of *G. versteegii* for species conservation. From demographic evidences, *G. versteegii* predically has a stable population in Pongkor Community Forest, because it occurs in four growth stages i.e. flowering adults, vegetative adults, juvenils and seedlings. On April 2018, when the study was conducted, is the end of rain season in Indonesian region. At these time, this species ended the flowering and fruiting period indicated by the mature fruits which was found abundantly. Moreover, the density of flowering adults stage (8 plants h^{-1}) was different from the densities of tree strata (6 plants h^{-1}), because agarwood producing species (*Gyrinops* spp., *Aquilaria* spp.) could bear flowers and fruits in the younger stage. Based on the trunk diameter, plant which reach diameter around 10 cm, will be able to produce flowers and fruits, while the tree stage was determined from the diameter of up to 20 cm. This result is in line with the demographic data of other species of agarwood producing plants i.e *Aquilaria* spp. (Soehartono and Newton 2001).

The study results also contribute to the information of plant pattern or spatial distribution of *G. versteegii* in Pongkor Community Forest, which could be arranged in 3 basic patterns i.e. random, clumped and regular. The value of relative densities and relative frequencies reflect that *G. versteegii* has a random or scatered distribution in the forest area. In a random pattern, the location of any one plant has no bearing on the location of another plant (Barbour et al. 1987). Pribadi (2009) reported the different result on spatial distribution study of other agarwood producing trees (*Aquilaria* spp.). The study revealed that the spatial distribution of *Aquilaria* spp. in Kutai National Park in the area of 4,883.75 hectares was clumped. Regarding to the small study area of Pongkor, the spatial distribution of this species should be further confirmed by conducting a study in broader areas in Flores Island.

Agarwood producing tree and forest community in Pongkor

Agarwood producing trees are reported to grow naturally in Pongkor Community Forest, however, the forest has received a lot of human intervention for plantation (Yulistyarini et al 2019), besides grazing for animal feeding and firewood hunting by local people (pers. observation). This is indicated by the presence of plant species in tree strata which are typically grown for plantations, namely "kemiri" (*Aleurites mollucanus*). *A. mollucanus* is a large tree belongs to Euphorbiaceae family (Orwa et al. 2009) which distributed in Brunei, Cambodia, China, Cook Islands, Fiji, and French Polynesia. This species has been distributed globally because of its beneficial properties. In Indonesia, the nuts of this species is commonly used as one of spice ingredients. Based on ecological study, *A. mollucanus* are known to have high plant density and index of important values in tree strata. In the pole strata, this species also has a high importance value index ranking (rank 4 with IVI of 8.58). This species has important ecological roles in this community forest because it was purposely planted by the community to meet the market demand of important component of food seasonings.

Aleurites moluccanus is a medium-sized tree with the height up to 20 m, which thrives in moist regions, ranging from subtropical dry to wet through tropical very dry to wet forest. The tree prefers full sun and can grow as a pioneer in open areas with suitable rainfall. *A. moluccanus* trees can be integrated into windbreaks, borders, and soil stabilisation. It also has leafy rounded crown which could provide shade for forest environment (Elevitch and Manner 2006; Krisnawati et al. 2011). *Aleurites moluccanus* which provides shade are very important to contribute ecological support especially environment shading for the growth of tree seedlings in the forest ground and shade for co-dominant tree which requires lower light intensity such as *G. versteegii*. In the canopy stratification, *G. versteegii* is placing the second stratum or is a co-dominant tree which receives sunlight from above canopy of *A. moluccanus*. Naturally, *G. versteegii* requires low light intensity and is considered as a shading tolerant species (Rawana et al. 2014). However, according to Rawana et al. (2018) *G. versteegii* cannot grow well under the very heavy shading environment, which are provided by the coverage of tree species such as *Tectona grandis, Eugenia aquea, Leucaena leucochepala, Mangifera indica*, and *Manilkara zapota.* The growth of stem diameter of *G. versteegii* are surpressed by the very shading environment. Regarding to this result, the plantation of domesticated species of *A. moluccanus* in Pongkor are good in contributing a forest cover, however should be limited to avoid the over population and over growing which could provide too tight shading trees in community forest.

A tree species of java almond which known locally as "kenari" (*Canarium vulgare*) belongs to the family of Burceraceae. This species are dominantly grown in the Pongkor Community Forest which is showed by the high ranking of plant density and IVI. Java almond is a local tree to Sunda region which oftenly growing naturally in dense primary forest on limestone or in rather dry rain forest, a similar typical area as Pongkor habitats. *Canarium vulgare* is a fast growing deciduous tree that can reach a height of 45 m. This species is a native plant distributed in Southeast Asia - Indonesia to New Guinea, adapted to an altitude up to 1200 m. It grows in primary lowland forests on limestone or in rather dry rain forest. It has a local canopy coverage which could provide shade and shelter (Fern 2014). Java almond is also dominant to Pongkor Community Forest in both pole and sapling stratas with the IVI of 17.93 and 35.83 respectively. The dominance of java almond in three stratas showed that this species is taking an important ecological role in the forest community. The occurence of this species showed that Pongkor Community Forest has natural vegetation which support the growth of a rare and protected species of agarwood producing tree such as *G. versteegii*.

Cordia bantamensis is dominant only in the sapling strata, beside of two species of *Canarium*, i.e. *C. vulgare* and *C. hirsutum. C. bantamensis* belongs to the family of Boraginaceae. With the local name of "kendal", this tree species is native to Indonesian region and distributed throughout South-East Asia, expanded to India, South China, Australia to New Caledonia. This tree species commonly grows from the hilly coastal, mangrove, opened forest areas to savanas in altitute around 500 m dpl (Heyne 1987). The dominance of this local species in sapling strata indicates that the vegetation of Pongkor Community Forest is still natural which is important for species preservation of *G. versteegii*.

Amongs the ground covers, *Selaginella plana* showed the highest important value with the IVI of 27.43. The fern group *Selaginella* is one of plant genera which grow mostly in mountanious and moist area. Setyawan et al. (2013) reported that some species of *Selaginella* could grow in relatively open areas and rarely grows under the dense clumps of herbs or shrubs. The forest ground of Pongkor Community Forest is dominated by many species of flowering graminoids from family of Cyperaceeae such as *Kyllinga brevifolia, Oplismenus compositus, Kyllinga* sp., and *Cyperus* sp. These graminoids are globally known as weeds. They have rapid growth because develop a vegetative propagation using stolon. They are adapted to open and sunny areas with reduced competition from shading trees and shrubs (Bryson and Carter 2008). The presence of graminoids indicates that mostly areas of Pongkor Community Forest are relatively opened. The relatively opened environment are suitable for growth of *G. versteegii* which is considered as a shading tolerant species which need a thin layer canopy to grow and regenerate in the forest ground.

Pongkor Community Forest is predically suitable for growth of *G. versteegii* in natural habitats. The forest has relatively natural vegetations with thin canopy layer which provide relatively opened forest cover. This is supported by Rawana et al. (2018)*;* Mulyaningsih et al. (2015) which suggest that, naturally, *G. versteegii* requires lower light intensity which can be obtained from natural forest habitats and is considered as a shading tolerant species. However, this species cannot grow well under the very heavy shading environment. Mulyaningsih et al. (2015) reported that this species is associated with the plants species with not so tight canopy layers such as *Heritiera* sp., *Diospyros sundaica, Planchonella nitida, Sandoricum koetjape, Harpullia cupanioides, Baccaurea racemosa, Erythrina orientalis, Artocarpus heterophyllus, Alstonia spectabilis, Gnetum gnemon, Durio zibethinus*, etc. Canopy layers could maintain air humidity and light intensity by protect sunlight which exposing the forest ground. The information about the limiting environment factors on the growth of agarwood producing trees and the plants species associated with it will be applicable for species preservation.

The information of association between agarwood producing trees with other plant species will be useful in terms of cultivation in various systems of plantation. Agarwood producing trees are cultivated in many kind of plantation, i.e. pure stand (monoculture) (Turjaman and Hidayat 2017), homegarden (Yulistyarini et al. 2019), homegarden with intercropping system (Surata and Soenarno 2011) and agroforestry mixed with cash crop such as citronella, banana, lemon, guava, soursop, durian (Turjaman and Hidayat 2017). Rawana et al. (2018) reported that in natural habitat, *G. versteegii* well grow in mixed plantation with compatible species and almost never grow in pure stand. In home garden, *G. versteegii* in Pongkor did not grow well while combine with the other woody plants such as *Canarium vulgare, Cocos nucifera, Gliricidia maculata* and *Cinnamomum* sp. which grow in open areas (Yulistyarini et al. 2019). However, *G. versteegii* grows well in co-existence with the other plant species in Pongkor Community Forest, such as *Aleurites moluccanus, Archidendron pauciflorum, Cordia bantamensis, Canarium vulgare* and *Canarium hirsutum.* Based on the result, it can be concluded that agroforestry which usually mixed with the diverse plant species has high similarity of vegetation with the community forest. Therefore, agroforestry which mixed with thin canopy layer species such as *A. pauciflorum, C. bantamensis, C. vulgare* and *C. hirsutum* will be the best plantation system of agarwood producing trees for obtaining the healthy tree stands for conservation and plantation.

The implication for conservation

Pongkor Community Forest with small and hilly area is a remnant and fragmented forest which are still protected by local residents. The local residents have been growing several species for wood production and other commodities, however, they are protecting the natural habitat of the forest (Yulistyarini et al. 2019). The narrow forest indicates that the population of *G. versteegii* in Manggarai District has been greatly reduced. The high abundance of *G. versteegii* in Pongkor Community Forest indicated that the population of agarwood producing tree in Pongkor is worth protected in terms of conservation of a rare and protected species. Protecting a rare species could be established by keeping the forest natural and intact to protect the species target and its ecosystem (Heywood and Dulloo 2005; Tuxill et al. 2001). To keep the forest ecosystem, human intervention especially plant species introduction should be limited. Logging of large trees should not be done because it will reduce the forest cover. The encroachment of ground covers by local people to look for firewood and cattle fodder should be avoided because it could damage the regeneration process mainly at the seedling stage.

The population of *G. versteegii* in Pongkor Community Forest was characterised by the presence of relatively larger numbers of seedlings and young trees than the number of adults. It indicates the occurence of natural regeneration of agarwood producing tree in Pongkor Community Forest. The higher abundance of *G. versteegii* on poles, saplings and seedlings shows that the population is quite stable. Moreover, productive mature individuals (flowering adults stage) in the population could produce a high potential seed crop and rapid germination rates (Soehartono and Newton 2001).

One of strategy for conserving the rare and protected species is to use them sustainably (Milner-Gulland and Mace 1998; Soehartono and Newton 2001). The extraction of a forest products may be considered sustainable if the harvest has no long-term harmful effect on the plant regeneration (Hall and Bawa 1993). Several growers in Pongkor are developing *G. versteegii* plantations, however they do not use a local plant source to regenerate their plantations (Yulistyarini et al. 2019). The presence of four stratas in the population *G. versteegii* in Pongkor could be functioning as the source of seed for plantations. The farmers could harvest the seeds and young plants to obtain a local source of agarwood producing trees. Beside the regeneration using seeds, the conventional vegetative propagation methods for woody plants such as shoot grafting, stem cuttings, hardwood cuttings marcotting (air-layering), and suckering could be applied to obtain new generation of agarwood producing trees (Lata, 2007). Nowadays, more advance technology i.e. tissue culture is also applicable for plant propagation which could produce huge amount of new young plants for mass cultivation (Daud et al. 2012; Van Minh 2001).

Agarwood was harvested by cutting down the trees in its natural habitats and plantation (Turjaman et al. 2016). Although agarwood producing tree *G. versteegii* has been widely cultivated in many regions in Indonesia (Turjaman and Hidayat 2017), the hunting and harvesting of agarwood from natural habitat was reported to be still massive (Zich and Compton 2001). Agarwood harvesting from natural habitats will threaten the population of agarwood producing species to extinction. To protect the agarwood producing species, the plant enrichments in natural habitats should be conducted and the production of agarwood in the cultivation and industrial level should be increased to meet the world’s agarwood market demand to avoid harvesting agarwood from natural habitats (Liu et al. 2013).

A small population of protected plant species deserves more attention in conservation to protect the population size. According to Iriondo (1996); Bradshaw and Doody (1978), it is important to conduct a study on population dynamic to record relevant demographic data which could be discussed in the context of conservation especially for the information about minimum population size. In addition, in small populations, genetic variation maintenance is important fo plant conservation, because in the long term it will affect plant species fitness (Frankham et al. 2002). To maintain the genetic diversity of small population, there should be an effort to increase population size by plant enrichments (Rindyastuti et al. 2015; Komar et al. 2014). For massive plantation, the vegetative propagation i.e. tissue culture or conventional propagation could be applied to obtain new regeneration of agarwood producing trees. For conservation of *G. versteegii*, the vegetative propagation couldnot be conducted because it will result in somaclonal individuals which represent low genetic variation of the population. The population which has low genetic variation will be more threatened by environmental changing and plant disease (Allendorf and Luikart 2007). Therefore, the generative propagation by sowing the seeds and growing the seedlings could be conducted to obtain plants with diverse genetic characters because the offspring will be the result of recombinations between two plant parents (Frankham et al. 2002).

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