Multistoried agroforestry system of Gaharu (*Gyrinops verstegii* (Gilg.) Domke) in Flores Island East Nusa Tenggara

R Iryadi, Sutomo and I D P Darma

Research Centre for Plant Conservation and Botanic Garden - Indonesian Institute of Sciences (LIPI): Research Station Bali Botanical Garden, Candikuning, Baturiti, Tabanan, Bali, Indonesia

E-mail: masrajifgeo@gmail.com

**Abstract.** Flores is one of islands that the producing agarwood from *Gyrinops verstegii* (Gilg.) Domke. The plant population in nature has been threatened due to over extraction and poaching. Therefore, the plant is cultivated in a cropping system with other crops by some local communities. This study examined the agroforestry pattern of agarwood cultivation in Flores. The purposive sampling plots (20m x 20m) were used to record the composition and structure of vegetation, as well as the environmental conditions in five districts (East Manggarai, Nagekeo, Ende, Sikka, and East Flores) of Flores. The agroforestry species of agarwood in the study areas consisted of 23 species. Cacao, Robusta coffee, clove, and coconut were the most dominant species in agroforestry patterns of *Gyrinops verstegii* plantation. The growing of agarwood in the intercropping patterns with estate crops in agroforestry conditions in Flores Island should be maintained to sustain its production. This study could have an implication as to inform conservation managers to maintain agarwood sustainability and thus further study is required to improve a better cropping system of the agarwood under the natural conditions of Flores Island.

**1. Introduction**

Population growth over the past few decades in Indonesia has been one of the causes of land use change areas from forest to residential, agricultural lands and plantations. The diminished forest areas brought threats to plant species including gaharu (agarwood). This threat is doubled when considering illegal poaching and over extraction of the gaharu has been going on for several decades. To overcome this problem, we must first agree that the lost forest function must be returned without having to sacrifice the peasant population whose lives depend on the former forest area. The way to do this is to promote mixed farming by growing trees among annual crops on agricultural land, known as the Agroforestry System. On the one hand, agroforestry can produce food and, on the other hand, is expected to improve soil and environmental quality.

One of Indonesia's rich biodiversities is agarwood. Because of its economic value, agarwood is also known as green gold. However, agarwood trading was determined with quota because this plant in 2004 was included in CITES (Convention on International Trade in Endangered Species of wild flora and fauna) Appendix II [1]. There are several types of agarwood producing trees found in Indonesia, namely *Gyrinops* spp. and *Aquilaria* spp., these two kinds of plants are prevalent and have been cultivated. *Gyrinops verstegii* (Gilg.) Domke is one example of agarwood-producing plant that is native to Indonesia and has different characteristics from other types so that it is preferred by
consumers [2]. According to Mogea et al. [3], in the list of forty rare Indonesian plants, \textit{G. versteegii} is one of the species included in it.

Efforts to preserve a plant species can be made in-situ conservation in their natural habitat and ex-situ outside their natural habitat. \textit{G. versteegii} is known for its distribution area, including the islands of Lombok, Sumbawa, and Flores [4,5]. In-situ conservation efforts become evident by the existence of farmers who plant this species of agarwood in their home garden, on upland or plantation land on Flores Island. In Flores, East Nusa Tenggara (NTT), many people have found agarwood-producing plants derived from the \textit{Gyrinops versteegii} type [6,7]. Therefore, by intercropping gaharu with other fast growing plants that could give relatively fast income to farmers is seen as one way to overcome the lengthy processes to gain economic value from the gaharu.

The intercropping system is one form of agroforestry. Indeed it has long been known, wherein this pattern, the system is to plant another intercropping that fills the space between planting distances [8]. It is interesting to study whether in addition to planting and cultivating agarwood, there are other species that are also planted together with agarwood on Flores Island. The study aims to analyze the intercropping pattern of agarwood and estate crops in agroforestry conditions in Flores.

2. Methods

2.1. Study area
The study was conducted on the island of Flores, NTT, from 18 June to 1 July 2019. The name Flores comes from the Portuguese language "Cabo de Flores," which means "Cape of flowers." Flores is included in the Lesser Sunda Islands group with Bali and NTB, with an area of around 14,300 km². The population in Flores, in 2007, reached 1.6 million. The highest peak is Mount Ranaka (2,350 m above sea level). At the western and eastern ends of Flores Island, there are several small islands, such as Lembata, Adonara, and Solor, in the east and Komodo and Rinca in the west. The other islands are Sumbawa (NTB) and Alor archipelago. To the southeast is the island of Timor. In the southwest, there is the island of Sumba; in the south, there is the Savu Sea. In the north, across the Flores Sea, there is Sulawesi. Literature study and information retrieval of the existence of \textit{Gyrinops versteegii} were carried out before going to the field. The secondary data on the presence of \textit{G. versteegii} was obtained from published papers in journals or proceedings, as well as from the KPH of Ngada and Nagekeo, Flores. The research locations were East Manggarai (Borong), Nagekeo (Mbay), Ende (Ende), Sikka (Maumere), and East Flores (Larantuka) Districts in figure 1.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{\textit{Gyrinops versteegii} research area in Flores, East Nusa Tenggara (NTT) Province, Indonesia.}
\end{figure}
2.2. Data analysis
Interview to obtain additional information regarding the gaharu was conducted. The approach used is an open interview by approaching the key informants in each of the sampling location. In each of the sampling location, field measurement was also conducted. The plot was made with a size of 20 m x 20 m. Each species in the observation plots was recorded by the name of the area and samples taken for the herbarium for the purpose of species identification in the laboratory at the Bali Botanic Garden. A profile diagram is also drawn. The tree canopy appearance scheme, the position of the tree in the plot, is marked on millimeter block paper. The tree height, the trunk free branches, and the length and thickness of the crown were recorded [9] and then be redrawn on tracing paper in the laboratory.

Topographic and microclimate data retrieval was carried out while in the field. Elevation or altitude is recorded from the GPS, while the slope was recorded with a clinometer. Soil acidity data is measured with pH meter, while information on irradiation intensity, temperature, and humidity are carried out with Lutron [10].

3. Results and discussion
Agroforestry is a land use system (farming) that combines trees with crops to increase profits, both economically and environmentally. In this system, plant diversity is created in an area of land so that it will reduce the risk of failure and protect the soil from erosion and reduce the need for fertilizers or nutrients from outside the garden due to the recycling of plant residues [11]. This system has been practiced traditionally by farmers in various places in Indonesia in the last three decades [12], for example the existence of local wisdom known as the shifting cultivation system on the island of Borneo, mixed gardens on land around the house (home garden) and grazing land.

Flores areas in agroforestry activities for land development, is categorized as in dry zone agroforestry (semi-arid, or semi-framed zones) where contrast conditions during the high-intensity rainy season cause erosion and weeds to grow fast and in dry seasons with the potential for fires it needs shade and fire suppression plants [12]. Referring to Sardjono et al. [12] explained that generally farmers in NTT cultivate food crops only in the rainy season while in the dry season they usually tries to raise livestock so that they prioritize plants or trees that produce fodder.

3.1. Agarwood in Flores
Gyrinops verstegii agarwood is thought to have been easily found in the forests of Flores Island. According to Setyaningrum and Saparinto [13] Gyrinops verstegii species spread in NTB and NTT. It is difficult to find natural agarwood in Flores, where the species of G. verstegii in NTT Manggarai Regency were found to be limited in number and location [14], then agarwood cultivation had been carried out in NTT, including in East Manggarai, Bajawa, and Ende [15]. We found one site where agarwood trees grow naturally on the edge of the forest located precisely in the Bukit Sandang Forest, Mbengan Village, and East Manggarai Regency. Indeed, since the late 1990s, the natural population of agarwood has declined due to massive exports [13]. Now began to emerge agarwood/aloes farmers who try to cultivate aloes in their gardens or their yards. Not only merely agarwood but farmers also plant it with other crops, following the concept of agroforestry. Furthermore, agarwood growth in the Rarung West Nusa Tenggara showed better performance when grown together with a shade tree [16]. In general, the condition of agarwood plants and the environmental conditions of the community gardens we have explored can be seen in table 1 below.

The agarwood trees found at the study site have an averaged diameter of 7 to 16 cm, 4 to 10 m of height. The soil pH ranged from 5.9 to 6.9, the average sunlight intensity ranged from 150 to 4,000 Flux, the altitude or elevation ranged from 300 to 1,100 m above sea level, and the slopes ranged from 4 to 22°. Based on Table 1, it can be seen that the people in the Nageko District manage agarwood plants better than those in other areas. This can be seen from the average stem diameter, height, and a number of agarwood plants cultivated as well. From the results of the research in the field, information was also obtained that the observation plot in the Nageko Regency was used as a source of seeds for the development of G. verstegii by the Bali Forest Plant Seedling Agency (BPTH).
The number of plant species planted in land does not affect the growth of cultivated agarwood. The study showed that in the Nageko District, which has some variations in species of 6 plants, has the highest tree diameter and height compared to those in Ende Regency with two species of plant variations, but has a trunk diameter and tree height, respectively 7 cm and 4 m. This indicates that there was no competition for nutrients, water, or sunlight in the agroforestry system. Furthermore, planting agarwood in community forest areas with a variety of plant species (fruits, woods) as an enrichment planting pattern showed good growth and can provide hope for future community income [16].

Table 1. Height-diameter and environmental data of agarwood habitat (*Gyrinops verstegii*) in Flores

| Information                        | East Manggarai | Nagekeo | Sikka | East Flores | Ende |
|------------------------------------|----------------|---------|-------|-------------|------|
| Average diameter (cm)              | 9              | 16      | 9     | 14          | 7    |
| Average height (m)                 | 5.5            | 10      | 6     | 8           | 4    |
| Average plant age (year)           | 18             | 15      | 10    | 16          | 7    |
| Density per-400m²                  | 0.015          | 0.031   | 0.016 | 0.019       | 0.017|
| Sum of agroforestry species        | 11             | 6       | 7     | 10          | 2    |
| Average years (year)               | 18             | 15      | 10    | 16          | 7    |
| Average pH                         | 6.5            | 6       | 6.9   | 6.6         | 5.9  |
| Average slope (°)                  | 22.5           | 10      | 4.2   | 13.8        | 20   |
| Average altitude (masl)            | 699.5          | 499     | 345.8 | 751.7       | 1,104|
| Average light intensity (lux)      | 367            | 150     | 911.4 | 1,708.2     | 4,000|

where: Gv: *Gyrinops verstegii*; Sa: *Syzygium aromaticum*; Tc: *Theobroma cacao*

Figure 2. Profile illustration of various intercropping patterns in Pongruan Village, East Manggarai, Flores NTT

Figure 3. Profile illustration of various intercropping patterns in Jawapogo Village, Nagekeo, Flores NTT
where: Ac: Areca catechu; Gv: Gyrinops verstegii; Nl: Nephelium laplaceum; Mg: Mangifera sp.; Tc: Theobroma cacao

Figure 4. Profile illustration of various intercropping patterns in Mok Village, East Manggarai Flores NTT

where: Cn: Cocos nucifera; Dz: Durio zibethinus; Gv: Gyrinops verstegii; Mp: Musa paradisica; Nl: Nephelium laplaceum; Tc: Theobroma cacao

Figure 5. Profile illustration of various intercropping patterns in Mbengan Village, East Manggarai, Flores NTT

3.2. Agroforestry pattern in Flores

The study showed that the agarwood growing patterns found in 5 districts in Flores were random agroforestry where agarwood plants were grown with other plantation crops. The number of different plants cultivated in agarwood agroforestry is 23 kinds of plants. Most plant variations were found in the Manggarai Timur and Flores Timur districts with 11 plants, while the least was found in Ende District with two plants. This agroforestry system is very suitable to be applied in the area, considering that this land is classified as sloping land. Of the many types of intercropping, there are only two types that are abundant or more widely planted by the community, namely chocolate (Theobroma cacao) and Clove (Syzygium aromaticum). Most of the farmers choose various species types of fillers with multi-purpose tree species because it can be harvested and sold directly to get money. This result also in line with the agroforestry system in the Wan Abdul Rachman Grand forest park [17]. Theobroma cacao is also found as prominent intercropping plants with agarwood in NTB who give high survival percentage compared with cassava and corn [18]. The study showed that a stratification growing pattern of agarwood-estate crops, which gives an advantage for the tree to maximize sunlight absorption for photosynthesis. In other areas of Indonesia, agarwood was intercropped with rubber and fruit trees [19], a mixture of Aquilaria spp., and rubber or cocoa plants in Bengku Province [20], and a mixture of Aquilaria malaccensis and oil palm is found in the Rokan Hulu District, Riau [21].

Based on the results of interviews with agarwood farmers in Flores, the planting pattern was randomized (random planting), and the spatial arrangement was irregular. Plants are planted at uneven spacing but form a productive multistoried system, as seen in figure 1. The tight canopy conditions on agroforestry land can protect the soil surface from a direct hit by rainwater. The interception of rain by heterogeneous and multi-layered vegetation causes a reduction in the raindrop type energy so that the dispersion power of soil aggregates is reduced [22].

The study shows that the actual ecological processes had been managed by farmer to include in the implementation of this agroforestry system. The activities in it refer to a foundation of environmental theories that are not yet widely known and so far, have only departed from trial and error. Diversification within an agroforestry system is also needed to maintain ecosystem resilience within
agroforestry. The agarwood domestication in agroforestry systems is expected to sustain its productivity. This is in line with one of the pillars of the world's agroforestry [23, 24].

Table 2. Types of intercropping in agarwood plantations in East Manggarai, Nagekeo, East Flores and Sikka Regencies

| East Manggarai | Nagekeo | Sikka | East Flores | Ende |
|----------------|---------|-------|-------------|------|
| Aleurites moluccanus | Areca catechu | Aleurites moluccanus | Areca catechu | Citrus spp. |
| Annona muricata | Cocos nucifera | Areca catechu | Mangifera indica |
| Cinnamomum burmannii | Coffea robusta | Artocarpus heterophyllus | Cocos nucifera |
| Coffea arabica | Durio zibethinus | Hyophorbe lagenicaulis | Coffea robusta |
| Gliricidia sepium | Syzygium aromaticum | Nephelium lappaceum | | |
| Gmelina arborea | Theobroma cacao | Santalum album | | |
| Mangifera indica | Pinanga sp. | Theobroma cacao | | |
| Syzygium aromaticum | | | | |
| Theobroma cacao | | | | |
| Nephelium lappaceum | | | | |

Figure 6. Proportion of *G. verstegii* intercropping with other crops in East Manggarai, Nagekeo, Ende, East Flores and Sikka Regencies
This agroforestry cropping pattern is an effort to conserve and protect ecosystems. The focus of agro-ecosystem management efforts has shifted in recent years, not only to increase the number and enrichment of species and improvement of ecosystem habitat but also to offer better environmental services provided by the ecosystem or agroecosystem [25]. The results of the research by [26] revealed that the denser the vegetation cover of land would provide an abundant distribution of organic matter. Furthermore, organic matter has a positive effect on soil physical properties such as increasing water retention capacity, stimulating the formation of soil aggregates, decreasing plasticity and cohesion as well as other harmful properties of clay [26]. It is also argued that agroforestry, besides having biophysical benefits (soil and water quality, conservation, biodiversity, carbon storage), also has socioeconomic and cultural benefits that always change from time to time [27].

4. Conclusions
The study shows that farmers on the Flores Island have cultivated agarwood following the concept of intercropping with mixed cropping systems with several estate crops. However, the intercropping planting did not have clear rules or practices, meaning that they were irregular or did not have uniform spacing. The types used in the intercropping also varied and differed in the four districts sampled in this study. The concept of diversity of the agarwood at present condition has been able to increase plant resilience in an ecosystem based on the one of the pillars of agroforestry. This study could have an implication as to inform conservation managers to maintain agarwood sustainability and further study is required to improve a better cropping system of the agarwood under the natural conditions of Flores Island.

Acknowledgments
We thank the LIPI Biology Research Center for providing funding for research trips. We also thank the forestry services in five regencies in Flores, namely East Manggarai, Nagekeo, Ende, Sikka and East Flores. We thank I Made Sumerta for assisting in illustrating the profile of vegetation composition in the field. We also thank Siti Fatimah Hanum and Ayyu Rahayu who are members of Spatial Ecology Laboratory.

References
[1] CITES 2004 Convention on International trade in endangered species of wild fauna and flora: Amandements to Appendices I and II of CITES Thirteenth Meeting of the Conference of the Parties 3-14 Oct 2004 Bangkok
[2] Parman S and Mulyaningsih T 2001 Teknologi pembudidayaan tanaman gaharu (in Bahasa). Preseted in Lokakarya Pengembangan Tanaman Gaharu (Jakarta: Dirjen Rehabilitasi Lahan dan Perhutanan Sosial)
[3] Mogeja J, Gandawidjaya J, Wiriaidnata H, Nasution R and Irawati 2001 Daftar empat puluh jenis tumbuhan langka (in Bahasa) Tumbuhan Langka Indonesia (Bogor: Puslitbang Biologi, LIPI)
[4] Mulyaningsih T and Yamada I 2007 Notes on some species of agarwood in Nusa Tenggara, Celebes and West Papua (Mataram: Mataram University)
[5] Mulyaningsih T, Marsono D, Sumardi S and Yamada I 2017 Keragaman Infraspesifik Gaharu Gyrinops versteegii (gilg.) Domke di Pulau Lombok Bagian Barat (in Bahasa) J. Penelit. Hutan dan Konserv. Alam 14 57
[6] Pamungkas D, Banani F and Lalus M 2015 Pengembangan tanaman penghasil gaharu (Gyrinops versteegii (Gilg.) Domke) oleh masyarakat di flores nusa tenggara timur (Malaka: Paper presented at the Gelar Teknologi Hasil Hutan Bukan Kayu)
[7] Sukenti K and Mulyaningsih T 2019 Gaharu (Gyrinops versteegii (Gilg.) Domke) di Pulau Sumbawa: Sebuah Tinjuan Etnobotani (in Bahasa) BioWallacea 5 62
[8] Malezieux E et al. 2009 Mixing plant species in cropping systems: concepts, tools and models A review Agron. Sustain. Dev 29 43
[9] Indriyanto 2010 Ekologi Hutan (in Bahasa) 3rd ed. (Jakarta: Bumi Aksara)
[10] Sutomo and Fardila D 2015 Autecology Of Invasive Species Cyperus rotundus L. In Forest Edge Of Pohen Mountain, Batutuhu Nature Reserve, Bali, Indonesia J. Metamorf 2 50
[11] Ruijter J and Agus F 2004 Sistem Agroforestri, Particip. Integr. Dev. Rainfed Areas (Pidra) World Agrofor. Cent.
[12] Sardjono M A, Djogo T, Arifin H S and Wijayanto N 2003 Klasifikasi dan pola kombinasi komponen agroforestri (in Bahasa) (Bogor: ICRAF)
[13] Sutomo and Iryadi R 2019 Prosising Seminar Nasional Konservasi dan Pemanfaataan Tumbuhan dan Satwa Liar (in Bahasa) vol 1 (Bogor: CITES) p 360
[14] Minarningsih and Murniati 2020 Complex agroforestry system in Wan Abdul Rachman Grand Forest Park: composition and charactersitic of food-producing plants in IOP Conf. Series : Earth and Environmental Science p 533
[15] ICRAF 2000 International Centre for Research in Agroforestry, Agroforestree Database 2000
[16] van Noordwijk M, Agus F, Suprayogo D, Hairiah K, and Pasya G 2004 Peranan agroforestri dalam mempertahankan fungsi hidrologi peranan agroforestri dalam mempertahankan fungsi hidrologi daerah aliran sungai ( DAS ) (in Bahasa) Agrivita 26 1
[17] Endarwati M A, K. Sugriwan and D Suprayogo D 2017 Biodiversitas vegetasi dan fungsi ekosistem: hubungan antara kerapatan, keragaman vegetasi, dan infiltrasi tanah pada inceptisol lereng Gunung Kawi, Malang (in Bahasa) J. Tanah dan Sumberd. Lahan 4 45