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THE POPULATION AND DISTRIBUTION OF AGARWOOD PRODUCING TREE (*AQUILARIA MALACCENSIS*) IN RIAU PROVINCE

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ABSTRACT
YULIZAH, RAHAJOE, J. S., FEFIRENTA, A. D. & NUGROHO, A. D. 2022. The population and distribution of agarwood producing tree (*Aquilaria malaccensis*) in Riau Province. *Reinwardtia* 21(1): 1–11. — Riau is recorded as one of the distribution areas of *Aquilaria malaccensis*, and has the largest export quota of agarwood in Indonesia. In this study, we identified the species distribution and abundance of the population of agarwood producing trees in the nature. The aims of the research were (i) to determine the distribution and abundance of *A. malaccensis* (ii) identification of ecological factors (microclimate and soil nutrients) and analysis of their relationship to abundance. Seven locations of agarwood producing trees were selected: Taman Hutan Raya (TAHURA: Forest Park Garden) Sultan Syarif Hasyim (SSH), three community forests in Siak Sri Indrapura Regency (Gosib, Perincit, and Dosan), and three community forests in Bengkalis Regency (Langkat, Pangkalan Jambi, and Duri Km 13). Random plots were established in the study sites and environmental parameters such as soil moisture, soil pH, temperature, humidity, and the soil macronutrients data were recorded. *Aquilaria malaccensis* planted at TAHURA SSH recorded about 38 individual ha^{-1}, with an average diameter was 15 cm, and the average tree height was 9.51 m. Perincit showed the highest density in wild condition with 8.13 individual ha^{-1}, with an average diameter was recorded for 20.8 cm and the average tree height was 9.11 m. While the lowest tree density was recorded of 0.58 individual ha^{-1} in Gosib; the average diameter and tree height were recorded of 40.15 cm and 14.70 m, respectively. The results of the study provide information in the conservation efforts of *A. malaccensis* through the possibility of planting it in various environmental conditions in Riau Province and land management such as being planted in monoculture or agroforestry systems as well as the ability to be reintroduced into species-rich natural forest. The supporting data gained from this study was used to provide information on location of potential seeds source and seedling. Moreover, the nutrient content as reviewed in this research will also be essential information about the needs of nutrient content in agarwood plantations.

Key words: Agarwood, *Aquilaria malaccensis*, Riau, TAHURA Sultan Syarif Hasyim.

ABSTRAK
YULIZAH, RAHAJOE, J. S., FEFIRENTA, A. D. & NUGROHO, A. D. 2022. Populasi dan distribusi pohon penghasil gaharu (*Aquilaria malaccensis*) di Provinsi Riau. *Reinwardtia* 21(1): 1–11. — Riau tercatat sebagai salah satu daerah distribusi *A. malaccensis*, dan memiliki kuota ekspor gaharu terbesar di Indonesia. Dalam studi ini, kami mengidentifikasi distribusi jenis dan kelimpahan populasi pohon penghasil gaharu di alam. Tujuan dari penelitian ini adalah (i) menentukan distribusi dan kelimpahan *A. malaccensis*, (ii) identifikasi faktor ekologi (iklim mikro dan unsur hara tanah) dan analisis hubungannya dengan kelimpahan. Tujuh lokasi pohon penghasil gaharu dipilih: Taman Hutan Raya (TAHURA: Taman Hutan Raya) Sultan Syarif Hasyim (SSH), tiga hutan masyarakat di Kabupaten Siak Sri Indrapura (Gosib, Perincit, dan Dosan), dan tiga hutan masyarakat di Kabupaten Bengkalis (Langkat, Pangkalan Jambi, dan Duri Km 13). Pembuatan plot secara acak dilakukan di lokasi penelitian dan mengukur parameter lingkungan seperti kelembaban tanah, pH tanah, suhu, kelembaban serta data makronutrien tanah. *Aquilaria malaccensis* yang ditanam di TAHURA SSH tercatat sekitar 38 tanaman ha^{-1}, dengan diameter rata-rata 15 cm, dan tinggi pohon rata-rata 9,51 m. Desa Perincit menunjukkan kepadatan *A. malaccensis* tertinggi dalam kondisi alam,

dengan 8,13 individu ha^{-1} dan diameter rata-rata tercatat 20,8 cm serta tinggi pohon rata-rata 9,11 m. Sedangkan kepadatan pohon terendah tercatat 0,58 individu ha^{-1} di Gosib; diameter rata-rata dan tinggi pohon tercatat masing-masing 40,15 cm dan 14,70 m. Hasil penelitian ini memberikan informasi dalam upaya konservasi *A. malaccensis* melalui kemungkinan penanamannya di berbagai kondisi lingkungan di Propinsi Riau dan pengelolaan lahan seperti ditanam dalam sistem monokultur ataupun agroforestri serta ditanam kembali ke hutan alam yang kaya jenis. Data penelitian juga mendukung informasi lokasi benih dan bibit yang potensial. Selain itu, kandungan nutrisi seperti yang diulas dalam penelitian ini juga akan menjadi informasi penting tentang kebutuhan kandungan nutrisi di perkebunan gaharu.

Kata kunci: *Aquilaria malaccensis*, gaharu, Riau, TAHURA Sultan Syarif Hasyim.

INTRODUCTION

Agarwood trees, belong to Thymelaeaceae (Hou, 1960) and grow well in the tropical forests (Sumarna, 2002). The most well known of agarwood producing genera are *Aquilaria* and *Gyrinops*. There are at least 13 species of agarwood producing trees which belong to *Aquilaria* and *Gyrinops*. The herbarium specimen collection indicates that *Aquilaria* spp. and *Gyrinops* spp. were distributed in the Western and Eastern parts of Indonesia (Roemantyo & Partomihardjo, 2010; Zich & Compton, 2001). Moreover, recent studies found that *Gyrinops verstegii* grows well in the natural habitats and becomes a potential source of seed for young trees for the plant enrichments in Manggarai District, Flores Island (Rindyastuti *et al.*, 2019).

Agarwood is Non Timber Forest Product (NTFP) produced as a product of secondary metabolites from the plant's defense in response to physical disorders or microorganism infections. The secondary metabolites are produced in the form of agarwood resin in agarwood tissue, which subsequently changes its colour from white to dark brown or dark black; this dark part has high economic value and named agarwood sapwood. Due to the high economic value of agarwood products, these trees are declared as one of five product priorities of NTFPs, while the other products are bamboo, rattan, honey, and bees (Santoso *et al.*, 2011). Agarwood is widely used for many purposes such as perfume and incense; therefore, it has been harvested in significant volume in nature.

The export of agarwood producing trees from Indonesia and Malaysia is leading among other countries. CITES export data from 1995 to 1997 recorded that Indonesia became the highest exporting agarwood with a range of 920 tons (Barden *et al.*, 2000). It was supported by the data of agarwood population in the forest; those were recorded for 61,000 from the period of 1991 to 1996. Sumatra is a distribution area of *A. malaccensis*, and one of the places to produce the best agarwood is Riau Province (Soehartono & Newton, 2001). In Riau Province, agarwood was famous since the era of Sultan Syarif Hasyim in the Siak Sri Indrapura Regency. The Sultan and his family used agarwood as fragrance, medicinal plant, and trading commodity. At present, Riau was no longer the center of agarwood trade, which causes the reduction of agarwood producing trees due to the unsustainable harvesting process. The reduction of agarwood trees in nature was mostly caused by land clearing, land use changed for plantations, and annual forest fires. In 2018, about 1,700 ha of forest was burnt and had an impact on the damage of the ecosystem (WALHI Riau, 2019). It also reduced the forest area and affected on the abundance of agarwood in nature, especially *A. malaccensis* in Riau Province.

The Directorate General of Conservation and Natural Resources and Ecosystems from the Ministry of Environment and Forestry has a role in regulating the export quotas of wild plants and animals. This quota regulation greatly influences the sustainable use of plant and animal populations in nature. In 2018, the total quota of *A. malaccensis* was 151,725 kg, with the highest quota recorded around 50,000 kg for Riau Province (KLHK, 2018). Therefore, Riau Province has to improve cultivation technology to produce good quality agarwood resins. There were some studies of agarwood cultivation, including the ecology of agarwood and conservation for sustainable use (Barden *et al.*, 2000; Soehartono & Newton, 2000, 2001; Paoli *et al.*, 2001; Sumarna, 2008), and the technology for producing good quality of agarwood resin by using selected microorganisms (Budi *et al.*, 2010; Santoso *et al.*, 2011). Important information regarding the population studies of *Aquilaria* spp. becomes an essential stage in determining quotas and maintaining the sustainability of the conservation plans. Hence, monitoring and mapping activities of natural agarwood habitats are essential to know the distribution of the population, to maintain the sustainable use of agarwood, and to ensure that there are no threats in nature. The study aimed to determine the distribution and abundance of agarwood populations and the relationship with

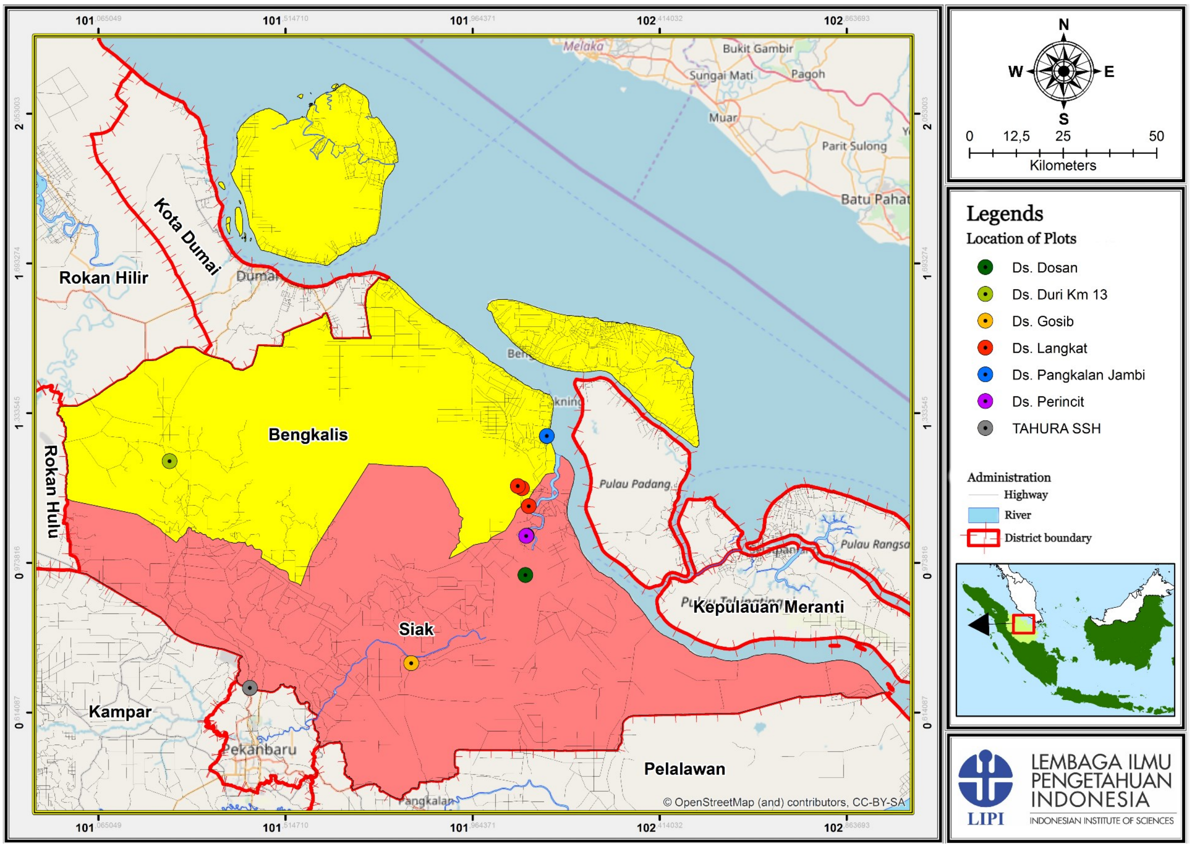

Fig. 1. Research sites of the population of agarwood producing trees in Riau Province.

some environmental properties of wild agarwood producing trees in Riau Province, to find out some of the basic information for cultivation strategy based on their natural habitat, and to support the conservation with cultivation program of agarwood in that region.

MATERIALS AND METHODS

Study Area

The research was conducted in Siak Sri Indrapura and Bengkalis Regencies, Riau Province in April 2019. In Siak Sri Indrapura Regency, the research area were located in the upstream area, *i.e.*, TAHURA Sultan Syarif Hasyim, Gosib, Dosan, and Perincit. While in Bengkalis Regency, they were located in Langkat, Pangkalan Jambi, and Duri Km 13 (Fig.1).

Methods

Analysis of composition was carried out to determine the population of agarwood-producing trees in Riau Province. Interviews with residents were conducted to determine the agarwood species targets and sampling locations. We selected agarwood populations that grow naturally without human interferences such as in conservation areas and community forests and those were planted without special treatment as found in TAHURA Sultan Syarif Hasyim. Vegetation study was carried out with adaptive cluster sampling method with plot of 30 × 30 m which was divided into 10 × 10 m subplots. The tree diameter at 1.3 m above the ground (DBH) and height was measured with hagameter for trees with DBH equal to or bigger than 10 cm. In addition to agarwood species, other plant species in the plots were also recorded and identified. Herbarium samples were collected for identification and validation of agarwood producing tree species at Herbarium Bogoriense, Research Center for Biology.

Soil pH, soil nutrients, air temperature, relative humidity, and light intensity were measured in each subplot. The parameters were measured by using a soil analyzer tester meter for soil pH; meanwhile, relative humidity and air temperature were measured by using a thermo-hygrometer and lux meter equipment. The measurements have been done in each location mainly in the morning at about 10 a.m. to 2 p.m in a base of a tree with two repetitions. Soil samples were then randomly collected at 10 cm depth in each selected subplot with two sampling points and were analyzed for C, N, P, K, Ca, Na, and Mg. Soil samples were taken on three subplots diagonally in each plot with two repetitions. The soil samples were digested by using an acid mixture and the nutrients contents were measured by using Atomic Absorption Spectrophotometry (AAS) Shimadzu Type AA-6800, UV-Vis Spectrophotometer 1240 Shimadzu, and CN Analyzer Yanaco JM 1000. All soil samples were analyzed in Plant Ecology Laboratory, National Research and Innovation Agency.

Data analysis

Tree density and basal area were determined by using basic ecological calculation. The dispersion of *A. malaccensis* was determined using Morisita Index (Id) (Krebs, 2009):

$$\mathrm{Id} = \mathrm{n}\frac{(\sum {x_i}^2 - \sum x_i)}{(\sum x_i)^2 - \sum x_i}$$

n : the number of sample in plots
x : the number of individuals in each plot

Then its dispersion pattern was determined as follows :

$$\mathrm{Mu} = \frac{X^2_{0,975} - n + \sum x_i}{(\sum x_i) - 1}$$

$$\mathrm{Mc} = \frac{X^2_{0,025} - n - \sum x_i}{(\sum x_i) - 1}$$

Mu : morisita index for regular dispersion patterns
Mc : morisita index for cluster dispersion patterns
$X^2_{0,0975}$: value of Chi Square table with confidence interval 97.5%
$X^2_{0,025}$: value of Chi Square table with confidence interval 2.5%

Then the standard degree of Morisita as calculated using following formula:

$$Ip = 0{,}5 + 0{,}5\left(\frac{Id - Mc}{n - Mc}\right) \quad \text{If Id} \geq \text{Mc} > 1$$

$$Ip = 0{,}5\left(\frac{Id - 1}{Mc - 1}\right) \quad \text{If Mc} > \text{Id} \geq 1$$

$$Ip = -0{,}5\left(\frac{Id - 1}{Mu - 1}\right) \quad \text{If 1} > \text{Id} > \text{Mu}$$

$$Ip = -0{,}5 + 0{,}5\left(\frac{Id - Mu}{Mu}\right) \quad \text{If 1} > \text{Mu} > \text{Id}$$

If Ip = 0 = distribution pattern is random, Ip < 0 = distribution pattern is uniform, and Ip > 0 = distribution pattern is clumped.

The relationship between abundance of *A. malaccensis* and environmental properties was analyses using Canonical Correspondence Analysis (CCA) (Ter Braak, 1987), mainly by using PAST software version 3.

RESULTS

The population and dispersion pattern of *Aquilaria malaccensis* in Riau Province

The study of agarwood natural habitat populations was conducted in the community forests managed by villagers; this location was surrounded by oil palm, rubber, and coffee plantations. Because of the high economic value of agarwood resin well known by the community, therefore agarwood trees were not cut down during the land clearing. Based on the information from villagers in the study site, an old tree of agarwood was still recorded with the age of about 70 years old with the tree diameter was recorded for 75.09 cm. Agarwood producing trees *A. malaccensis* were found in some locations in Riau such as in Siak Sri Indrapura and Bengkalis Regency.

The seven locations are the native habitat of *A. malaccensis*. Although *A. malaccensis* was planted in 2005 for conservation purpose, it has previously been recorded as agarwood plants found in TAHURA SSH. Based on the density of stands, the population in TAHURA SSH is higher than that in other locations, in addition to being in protected forest area, the vegetation conditions strongly support the growth of *A. malaccensis*. Dense vegetation communities and diverse species such as, *Sloetia elongata*, *Rhodamnia cinerea*, *Endospermum diadenum*, *Shorea parvifolia*, *Elaeocarpus griffithi*, *Dillenia reticulata*, *Gironniera parvifolia*, *Randia anisophylla*, and *Nephelium cuspidatum*. Those trees were widely distributed in TAHURA SSH. The results recorded that the highest individual density in the community forest was in Perincit village, Siak Sri Indrapura Regency with the individual density was 8.13 ha^{-1}, and the average tree diameter was 20.8 cm, and the tree height was recorded for 9.11 m (Table 1; Figs. 2 & 3). *Aquilaria malaccensis* can be found around home gardens and plantations around the village of Perincit. Agarwood was in high demand by traders and poachers; therefore, residents initiative to move their houses to the nearest place from the agarwood. Fig. 2 shows a high standard deviation in Gosib Village for the diameter and height of the tree. This result was due to the existence of old trees at Gosib. The

Table 1. Population and density of *A. malaccensis* in Riau Province

Locations	Max diameter (cm)	Max height (m)	Average BA (cm^2)	Stand Density (ind. ha^{-1})	Number of Plots
TAHURA SSH	44.98 ± 7.65	22.0 ± 2.72	232.84 ± 304.62	38.00	10
Gosib	59.71 ± 27.66	21.6 ± 9.75	1,566.08 ±1,743.91	5.80	4
Dosan	75.09 ± 18.98	23.7 ± 5.25	1,181.86 ± 1,371.91	4.50	10
Perincit	30.14 ± 7.57	12.7 ± 2.91	355.81 ± 241.43	8.13	10
Langkat	53.38 ± 18.92	16.3 ± 3.05	1,381.28 ± 924.90	1.25	7
Pangkalan Jambi	50.96 ± 12.69	10.9 ± 7.20	1,345.76 ± 758.06	2.50	8
Duri Km 13	17.25 ± 5.57	8.1 ± 1.07	218.73 ± 151.47	4.15	10

interesting phenomenon was that the agarwood trees of Dosan and Gosib in the peat swamp areas had a bigger diameter.

More common plants are found in community forest areas, namely *Elaeis guineensis*, *Hevea brasiliensis*, *Coffea* sp., and some species of fruit such as *Theobroma cacao*, *Garcinia mangostana*, *Durio zibethinus*, *Mangifera* sp., *Nephelium lappaceum*, *Syzygium* sp., *Artocarpus rigidus*, and other wood plants like *Palaquium hexandrum*, *Ixonanthes icosandra*, and *Artocarpus elasticus*. Conditions on the ground as in Fig. 3. In addition, the development of plantations around people's forest causes native species to degrade. The potential for the speed of growth and wide spread of seeds causes plantation crops to dominate community forest. This is evident from the many seedlings of *Coffea* sp. and *H. brasiliensis* in each location.

The distribution of diameter and height of *A. malaccensis* at each location shows that conditions do not support for the natural regeneration process. No seedlings were found at each location, it was also seen in the conservation area. TAHURA SSH officials said there had never been a flowering *A. malaccensis* tree. Dispersion pattern can explain how population conditions in their habitat (Amaral *et al.*, 2015). Morisita dispersion index (Id) of *A. malaccensis* in TAHURA has Id of 10 and Mc (Morisita Index for cluster distribution patterns) of 1.43, while the value of Ip (standard degree Morisita) is 1,02. Since Id ≥ Mc ≥1, and Ip > 0, therefore it can be concluded that dispersion pattern of *A. malaccensis* in TAHURA SSH is clumped. Similarity, the dispersion pattern of *A. malaccensis* in community forest is also clumped (Gosib (Ip= 0.13), Dosan (Ip = 0,99), Perincit (Ip = 1), Langkat (Ip = 1), Pangkalan Jambi (Ip = 0.91) dan Duri Km 13 (Ip = 1.03).

The relationship between distribution and the ecological factors variables

The influence of environmental factors on agarwood plant growth is very important, such as light intensity during sapling. These environmental factors might give different effects on the tree level growth. The highest average temperature during the study was in Dosan area (38°C) and the lowest in Duri Km 13 (33°C). In addition, the average humidity was 57%, and the light intensity was 287 at all locations (Table 2). The measurement result of this environmental data can not support information on the growth of *A. malaccensis* in the natural habitat but can provide an overview of the environmental conditions where *A. malaccensis* is found.

Based on the mapping of soil types, Gosib, Dosan, Perincit, Langkat dan Pangkalan Jambi were classified as peat soils (belonging to hemic arganosol and gleisol classes). Meanwhile, TAHURA SSH and Duri Km 13 were classified as mineral soil types (Cambic nitosols, cambic arenosol, gleic latosol, oxic latosol, and cambisol) (Balai Tanah Indonesia, 2011). Soil samples from the study sites were analyzed to determine the nutrient content. The nutrient content of P, Ca, and Mg was very low compared to other nutrients in all locations based on the criteria from Balai Penelitian Tanah (2009). The nutrient contents were in the range of 0.003–0.768%, 0.134–0.225%, and 0.035–0.114% for P, Ca, and Mg, respectively. K content was lower in the mineral soils than in the peat soils (Table 3). Sodium (Na) content was categorized from high to very high, with a range of Na being 0.981–1.00%. Nitrogen

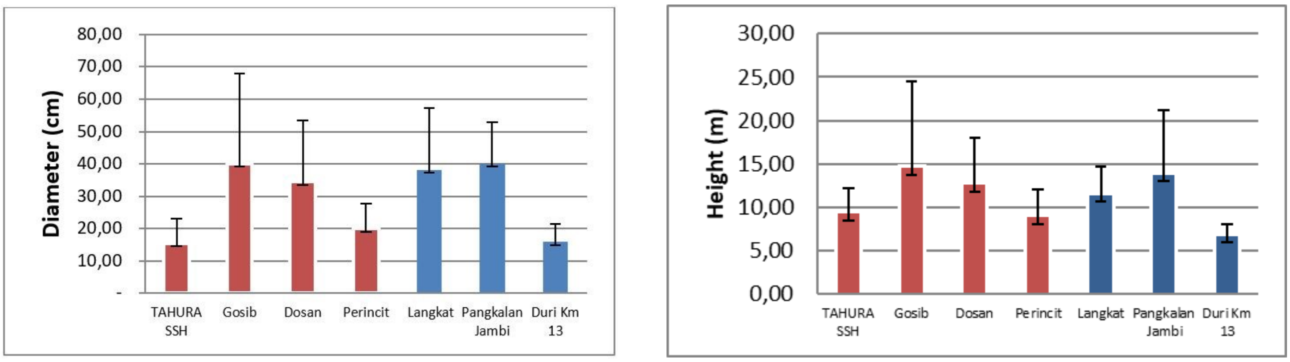

Fig. 2. Average distribution of diameter and height of *A. malaccenssis* in the study site, red bars were agarwood populations in Siak Sri Indrapura Regency, blue bars were in Bengkalis Regency.

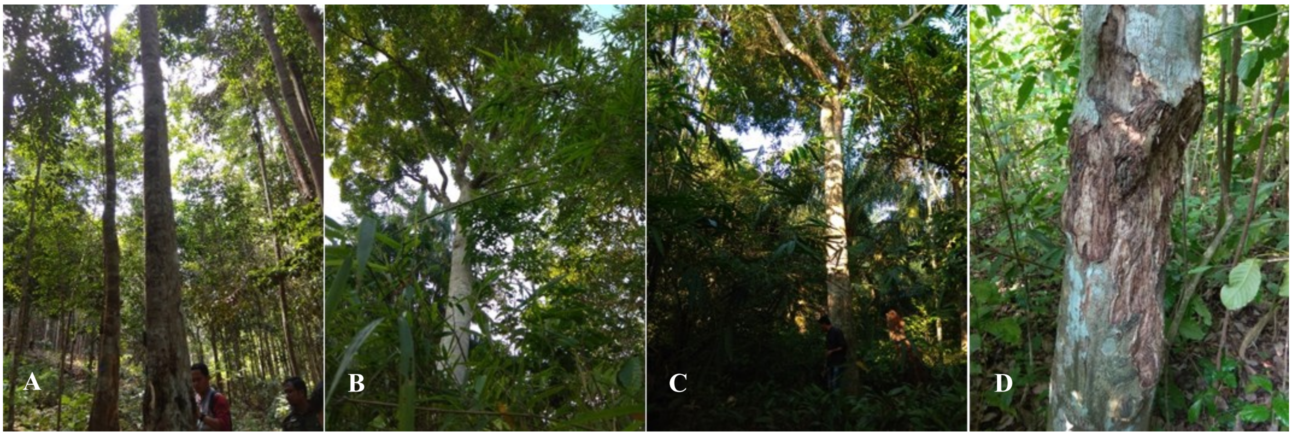

Fig. 3. Agarwood producing trees (*A. malaccensis*) in the conservation area. A. TAHURA Sultan Syarif Hasyim, community forest. B. Gosib, Siak Sri Indrapura Regency, C. Perincit, Siak Sri Indrapura Regency, D. Pangkalan Jambi, Bengkalis Regency. Photos by Yulizah.

content has a very wide range from low, medium, high to very high, with a range of 0.12–0.926%; the lowest and highest N were recorded in the mineral soil. Carbon content in mineral soil was recorded from low to moderate, those were 1.606 and 2.198% in TAHURA and Duri Km 13, respectively, while the carbon contents were recorded from high to very high ranging between 3.787–6.374% in the peat soils, an exception in Langkat, it was recorded in a very low criterion (0.655%).

Outputs of ordination analysis using Canonical Correspondence Analysis (CCA) of PAST version 3 software were in the form of Eigenvalue and ordination diagrams. The Eigenvalue shows the level of distribution of species or plots in the ordination diagram. The results of CCA ordination analysis obtained an eigenvalue of 0.412 which show the population represented by the location is not evenly distributed (Fig. 4).

DISCUSSION

The population and dispersion pattern of *Aquilaria malaccensis*

Riau Province is one of the best agarwood producing areas and has been a trading center for agarwood. In 2016 to 2019 the export quota of *A. malaccensis* in Riau Province has always increased from 35,000 kg to 50,000 kg, but in 2020 the export quota of *A. malaccensis* has decreased to 40,000 kg. Although there is a decrease, the highest export quota of agarwood was in Riau Province. Based on these data, it should be shown that the agarwood population was still quite high with a high utilization as well. However, when we see the condition of the forest in Riau Province, not all forest areas in Riau Province are covered by forest vegetation. The main factor causing the reduction of forest cover was the increasing

Table 2. Average value of environmental factors measured at each location

Locations	Temperature (°C)	Humidity (%)	Light (Lux)	pH
Tahura SSH	29 ± 0.92	79 ± 4.2	340 ± 10.5	6.2 ± 0.50
Gosib	34 ± 0.50	59 ± 3.46	280 ± 5.77	6.4 ± 0.23
Dosan	38 ± 0.53	44 ± 0.46	290 ± 4.62	6.0 ± 0.38
Perincit	35 ± 0.91	54 ± 4.18	210 ± 13.2	5.6 ± 0.28
Langkat	35 ± 0.51	50 ± 1.67	380 ± 0.12	5.6 ± 0.12
Pangkalan Jambi	35 ± 0.00	50 ± 0.57	270 ± 10.5	6.2 ± 0.51
Duri Km 13	33 ± 0.50	57 ± 0.17	240 ± 0.00	5.0 ± 0.25

Table 3. The test of the soil chemical content at each location

Test component (%)	Location						
	Tahura SSH	Gosib	Dosan	Perincit	Langkat	Pangkalan Jambi	Duri Km 13
Ca	0.160±0.018^{VL}	0.134±0.026^{VL}	0.199±0.018^{VL}	0.161±0.006^{VL}	0.18±0.001^{VL}	0.177±0.004^{VL}	0.255±0.010^{VL}
Mg	0.047±0.013^{VL}	0.123±0.009^{VL}	0.074±0.021^{VL}	0.114±0.009^{VL}	0.094±0.008^{VL}	0.110±0.015^{VL}	0.035±0.042^{VL}
Na	0.981±0.036^{H}	1.048±0.042^{VH}	1.000±0.013^{VH}	0.984±0.029^{H}	0.992±0.013^{H}	0.989±0.024^{H}	0.984±0.001^{H}
K	0.103±0.074^{L}	0.442±0.054^{M}	0.217±0.076^{L}	0.376±0.067^{M}	0.543±0.089^{M}	0.445±0.022^{M}	0.011±0.024^{VL}
P	0.003±0.002^{VL}	0.044±0.040^{VL}	0.010±0.009^{VL}	0.017±0.006^{VL}	0.768±0.001^{VL}	0.017±0.149^{VL}	0.005±0.01^{VL}
C	1.606±0.623^{L}	6.374±2.822^{VH}	3.374±0.650^{H}	3.787±0.53^{H}	0.655±1.466^{VL}	6.020±2.621^{VH}	24.20±21.109^{M}
N	0.126±0.032^{L}	0.483± 0.200^{M}	0.231±0.079^{M}	0.301±0.042^{M}	0.711±0.051^{H}	0.334±0.114^{M}	0.926±0.770^{VH}
C/N	12.384±2.771^{M}	13.111± 0.417^{M}	14.575±1.473^{M}	12.600±0.151^{M}	13.588±2.035^{M}	18.017±3.246^{H}	26.134±0.485^{VH}

*VL (Very Low), L (Low), M (Medium), H (high), VH (Very High)
**assessment criteria for the result of soil chemical analysis by Balai Penelitian Tanah, 2009.

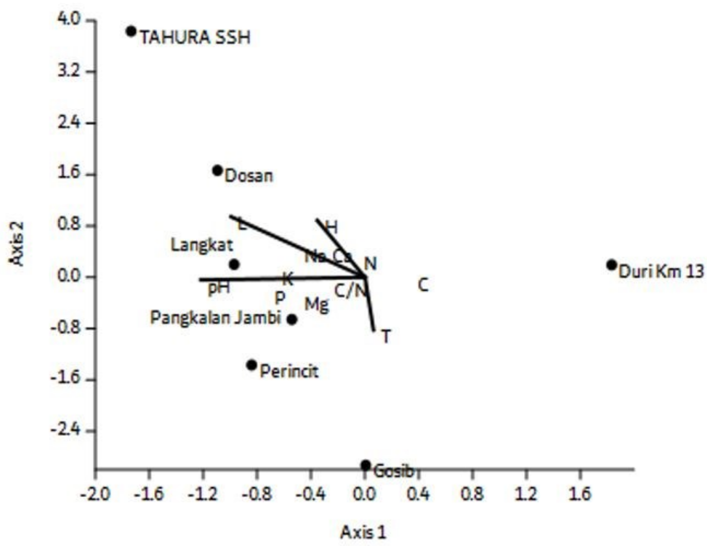

Fig. 4. Result of ordination CCA shows the distribution of sample locations and soil nutrient content on the gradients of an environmental factors (T= Temperature, H= Humidity, L=Light) .

deforestation, one of which is for oil palm plantations. Conversion of land to palm oil plantations and forest fires almost every year certainly disrupt the habitat of agarwood producing trees in nature. In addition, the increasing number of agarwood hunting in nature has decreased the agarwood population in Riau Province.

The population density of *A. malaccensis* in community forest locations was high compared to studies that have been carried out in other locations. Based on some researches, the density of agarwood producing trees (*Aquilaria* spp.) was very low, with an abundance of only 0.01 and 0.2 individuals ha^{-1} in Kutai National Park, and Gunung Palung, respectively (Donovan & Puri, 2004; Pribadi, 2009). The dispersion pattern of *A. malaccensis* in study areas was clumped. This can be stated that all research site has almost the same ecological conditions. *Aquilaria* spp. showed clumped distribution also in Sumatra and Kalimantan (Soehartono & Newton, 2000). Conservation areas such as TAHURA SSH have a high density with dispersion pattern was clumped and average diameter of 18 cm.

In study site, the tree diameter of *A. malaccensis* in some locations was recorded as more than 20 cm (Fig. 2). It was predicted that the harvestable agarwood tree was at about 20 cm DBH, far below the reproductive threshold, which was estimated at 35 cm DBH (Paoli, 2001). This indicates that the diameter of agarwood producing trees in several study sites was still below the harvest threshold, so it was estimated that study sites such as Perincit, and Duri Km 13, still maintain a population of agarwood producing trees. The community and agarwood hunters still maintain large-diameter agarwood trees as the mother tree. This finding was support by the abundance of the seed in Gosib as the source of the seedling of the agarwood tree which will be planted.

The differences in *A. malaccensis* density in each location might be due to the forest degradation, illegal hunting, and destruction of agarwood habitat in Riau Province. In consequence, it reduced or limited shading trees for *A. malaccensis* sapling. At the time of the study, several trees were flowering and bearing fruit. According to local community information, the *A. malaccensis* flowers almost every year, but at the time of the study, the seedlings or saplings were not found under the mother tree and in the plots. It was similar to the research in Gunung Palung National Park, where the distance of agarwood sapling (with the height of > 15 cm) was found about 3–7 m from mature trees, and the sapling density was only recorded about 10 sampling ha^{-1} (Paoli *et al.*, 2001). Based on the information from the local community, Dosan and Gosib areas are a source of seedlings, and those are often visited by agarwood hunters to collect seeds and seedlings. In the Perincit, Pangkalan Jambi, Langkat, and Duri Km 13 areas, *A. malaccensis* populations were found in the middle of rubber and oil palm plantations. The area has been cleared, and there was no shade for the seedling to grow. As well known that the shade from agarwood and surrounding trees were important for the growth of the seedling. Therefore, the shade was one of the reasons for determined the distance between seedlings and saplings from the mother tree.

Sumarna (2008) described the relationship between the tree diameter and tree canopy; this related to the ability of natural regeneration.

In Siak Sri Indrapura Regency, the location of the discovery of *A. malaccensis* is a peat area. Previously, there was not recorded that *A. malaccensis* had ever been found in peat areas. Partomihardjo *et al.* (2008) explained that several *Aquilaria* species can be grown well on peat swamp forest areas, one of which was *A. beccariana* which grows in peat swamp forest at Merang, South Sumatra. At this time, the Siak Sri Indrapura Regency Government has planted agarwood producing trees from *A. malaccenssis*, *A. macrocarpa* and *A. beccariana* in the peat area to prevent forest fires. However, this instance has not been supported by more instensive research.

The relationship between distribution and the ecological factors variables

Based on information from local villagers, agarwood trees have been growing for more than 20 years at the research site. Tables 3 and 4 show ecological variables in the habitats of *A. malaccensis* at seven research sites. *Aquilaria malaccensis* trees grow at altitudes of 0–2,400 m above sea level, in a high temperature range 28–34°C, humidity from low to 80%, and rainfall of 1,000–2,000 mm/year (Sumarna, 2012; Pribadi, 2009). *Aquilaria* spp. are also grow well in dry soils with a high sand content, with soil pH ranging from acidic pH to almost neutral, and tree growth requires shade associated with low light intensity (Pribadi, 2009). That's in line with the results of this study where temperatures at the study site ranged from 29–33°C, with soil pH of 5.4 to 6.8, and humidity ranging from 50 to 79%. Based on soil chemical properties, the population of *A. malaccensis* can be found in infertile to very fertile soil conditions with C organic range 0.655–0.768% which categorized as very low until very high. Forest floor cover is not too thick with litter, especially in Gosib and Dosan which are adjacent to oil palm plantations. Some other types of agarwood research such as *Gyrinops versteegii* in Lombok, light intensity is the main factor affecting the occurrence of *G. versteegii* (Mulyaningsih *et al.*, 2017; Sutomo & Oktaviani, 2019).

Soil pH from acid (5.0) to neutral (6.4) shows of *A. malaccensis* can be found in a variety of environmental conditions. It can be seen in the CCA diagram where variable light intensity and pH form a sharp angle (Fig. 4), this shows that both ecological variables are the primary ecological factors at each location. Variations of vegetation and tree canopy will affect the light intensity on the forest floor and will affect soil moisture levels. In soil nutrients, showing that the nutrient component of the soil is not a contributing factor to the distribution of *A. malaccensis* in Riau, it can be seen in the chemical composition of the soil scattered in the middle of the ordination diagram.

The relationship between distribution of *A. malaccensis* and ecological factor is uneven on the diagram CCA (Eigenvalue <1) (Fig. 4). Ecological variables converge at the center of ordination, while the populations at each location are scattered far away, such as Duri Km 13 (mineral soil) and Gosib (peat soil). Uneven distribution of *A. malaccensis* populations on CCA diagrams, suggests there are other factors have a high role in the distribution of *A. malaccensis* but they were not measured in the study. One of the most high-impact factors is human activities such as hunting and plantations. Winarni (2011) states that disruption of logging and forest management systems causes differences in the population structure of agarwood producing trees. Human activities such as hunting and unsustainable harvesting are major factors in the loss of agarwood populations in nature.

The populations of protected plant species such as *A. malaccensis* need more consideration to keep their populations in nature, so research on population dynamics is important to support conservation programs, especially in providing information about the minimum population sizes. Riau Province, as the conservation of agarwood producing trees was potential as the natural habitat of *Aquilaria* spp. Seedlings of *A. malaccensis* can also be obtained from Dosan and Gosib to produce high quality agarwood trees. Seedlings of agarwood in both villages are always available throughout the year; those were scattered near the mother tree. However, sapling level of agarwood trees was not found because it could not survive without shading and the distance close to the mother tree.

The potential in the conservation development of *A. malaccensis* is very likely, because *A. malaccensis* can be found in various of environmental conditions. In addition, there is support from the provincial government that supports conservation program by including *A. malaccensis* in the list of restoration plants that can be developed in various types of land and cultivation systems. However, this effort was still not enough because there were still many problems faced by farmers, mainly how to produce high quality of agarwood and the stability of agarwood price. Until now, the quality of cultivated agarwood product was low, so this causes the hunting of agarwood in nature is still on going due to the high selling price. Harvesting agarwood by cutting down the trees in natural habitats or plantations was about 75% of the total trees, with crop intensities ranging from 50–100% (Paoli *et al.*, 2001; Turjaman *et al.*, 2016). To protect agarwood producing species, planting trees in natural habitats has to be carried out, and the production of cultivated agarwood needs to be increased (Liu *et al.*, 2013). This was supported by the quality of the growth rate of natural regeneration of seedlings to provide good quality seedling (Sumarna, 2012).

CONCLUSION

This study revealed that *A. malaccensis* is spread from upstream to downstream of Riau Province and spread across various habitat characteristics with various soil type, soil nutrients and micro climate. The local or metapopulation of *A. malaccensis* at each location is scattered in a clumped. Some ecological variables might be important for the abundance of this species are light intensity and pH. The tolerance of *A. malaccensis* to ecological factors is very wide, especially soil nutrients, providing opportunities for conservation of *A. malaccensis* in various environmental conditions and development with monoculture and agroforestry plantation system.

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