Research article

Conservation and Ecological Threats of Agarwood (*Aquilaria* sp.) on Leyte Island, Philippines

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Abstract *Aquilaria* is a genus of about 20 species distributed mainly in the Indo-Malesian region. The genus *Aquilaria* belongs to the Thymelacaceae family of Indo-Malayan trees known for producing the world's most expensive oils, which are naturally occurring throughout the Philippines. *Aquilaria* is well known for the production of agarwood which is a highly wanted forest product of substantial economic value. In the Philippines, there is limited published information on the physical condition, habitat structure, and ecological threats of *Aquilaria*, which is a crucial factor to determine the optimum requirements to develop *Aquilaria* production system. Hence, this study was conceptualized to assess the habitat structure of *Aquilaria* as well as its conservation and ecological threats in the wild. Assessment, surveys and interview were conducted to gather on-site atmospheric data as well as ecological threats of *Aquilaria* in the wild. Soil collection was also gathered to analyzed soil properties. The results revealed that there were two species of *Aquilaria* documented in the study site, namely: *A. malaccensis* and *A. cumingiana*. Moreover, the soil chemical properties are not significant between different topographic expositions, but it is acidic and generally have low nutrient status. Furthermore, the conservation and ecological threats documented in the study site are unsustainable harvesting, a massive collection of regenerant, and inflecting damage of *Aquilaria* by punching nails or drilling holes in the trunk of standing mature tree. Therefore, it is highly recommended that *Aquilaria* should be protected, particularly *A. malaccensis*, since it is rare and considered a new record of occurrence to Leyte Island as one of the major findings of the study. The establishment of *Aquilaria* based production system is necessary as an option to reduce the rampant illegal poaching of agarwood in the wild but should be established on private land and registered with the Department of Environment and Natural Resources (DENR).

Keywords *Aquilaria*, topographic expositions, ecological threats, habitat structure

INTRODUCTION

Aquilaria is a genus of about 20 species (International Plant Names Index, 2015), distributed mainly in the Indo-Malesian region. Agarwood also known as *gaharu* in the South East Asia, *oud* in the Middle

East, *chen xiang* in China, *jinkoh* in Japan and *agar* in India is a highly valuable aromatic dark resinous heartwood of *Aquilaria* species (Liu et al., 2017). The genus *Aquilaria* belongs to the Thymelacaceae family of Indo-Malayan trees known for producing the world's most expensive oils (Lee & Mohamed, 2016). Fernando et al. (2018) reported that *Aquilaria apiculata, A. filarial*, *A. malaccensis, A. brachyantha*, *A. cumingiana, A. urdanetensis, A. citrinaecarpa*, and *A. parvifolia* are just eight out of the 24 species of agarwood oil-producing trees in the world that are naturally occurring in the Philippines. In Leyte, Biliran, Samar, and Negros, *Aquilaria* sp. is locally known as *lapnisan* and *laneti*.

Agarwood is traded in several raw forms, ranging from large sections of the trunk to finished products such as incense and perfumes (Barden et al., 2000). They reported that natural stocks are largely depleted by overexploitation, and the demand for agarwood is higher. Foreign nationals are now searching agarwood in the Philippines, specifically Leyte, Biliran, Samar, and Negros. There have been reports in the field that sometimes these nationals are impatient to find *Aquilaria* since it was reported by Abdin (2014) that global agarwood prices can be ranging from US$ 20 – 6,000 per kilogram for the wood chips depending on its quality or US$ 10,000 per kilogram for the wood itself. There was a destructive exploitation of agarwood that has badly affected the wild population of all *Aquilaria* species due to widely used as therapeutic perfumes, traditional medicine, religious purposes and aromatic food ingredient (Tan et al., 2019).

There is a scarcity of information on the physical condition, habitat structure and ecological threats of *Aquilaria* which is crucial factor to determine the optimum requirements to develop *Aquilaria* based production system. This study was conceptualized to assess the habitat structure of *Aquilaria* and its conservation and ecological threats in the wild.

OBJECTIVES

1. To characterize the habitat condition and structure of *Aquilaria* on Leyte Island; and
2. To determine the ecological threats of *Aquilaria* in the natural habitat.

METHODOLOGY

Selection of the Study and Sampling Site

The study was conducted at the selected site of Leyte Island. The major criteria in selecting the sampling site were the presence of *Aquilaria* in the area which was selected through a preliminary survey by directly collecting information from reliable individuals (i.e., poachers, a buyer of agarwood) further identify the exact location of *Aquilaria* trees in the wild. Furthermore, the study site was selected based on the incidence of rapid and over-harvesting of the *Aquilaria* matured trees and regenerant, respectively, during the pre-assessment.

Data Collection

The atmospheric data, i.e., light intensity (lux), temperature (°C), and relative humidity (%) were collected on-site to determine the climatic factor that may affects the habitat structure of *Aquilaria* under natural condition. The data was collected in each exposition at an interval of two hours, starting from seven o'clock in the morning until five o'clock in the afternoon.

Soil samples were collected in the study site. The soil samples were then brought to the laboratory to analyze soil chemical properties such as soil pH, soil organic matter, total nitrogen, and available phosphorus.

To determine ecological threats, an actual field survey and photo documentation of poached *Aquilaria* trees were done. Likewise, an interview was conducted to collect information from seedling-growers, poachers, and agarwood buyers.

Data Encoding and Statistical Analysis

All data gathered were collated, encoded, and summarized using an electronic spreadsheet editor, Microsoft Excel 2013. The data were analyzed using the Statistical Package for Social Science (SPSS version 20).

The atmospheric data were analyzed descriptively. The variability of the mean of soil chemical properties was analyzed using the one-way analysis of variance (ANOVA). Moreover, in a case where the significant variations at $p \leq 0.05$ was identified, Tukey and Least Squares Differences (LSD) was carried out to compare means.

RESULTS AND DISCUSSION

Microclimatic Conditions in the Study Site

The data on atmospheric parameters such as light intensity, air temperature, relative humidity, and rainfall are presented in the figure below to describe the on-site condition of the study area.

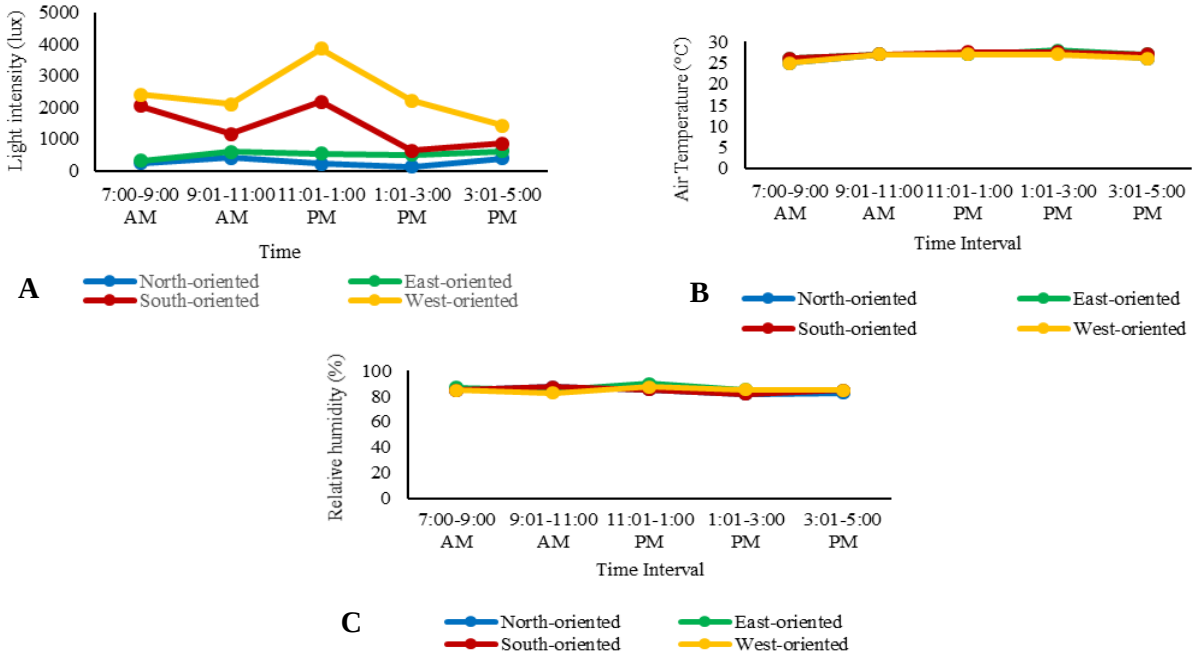

Fig. 1 Microclimatic conditions between different expositions of the study site at different time intervals

Results show that west-oriented topographic exposition had higher light intensity compared to other topographic expositions (Fig. 1A). Meanwhile, the average temperature at all periods of data collection had an increasing trend from seven o'clock in the morning until three o'clock in the

afternoon but had a slight drop at five o'clock in the afternoon (Fig. 2B). On the other hand, the result of the relative humidity had a slight variation (Fig.1C).

Soil Chemical Properties

Table 1 shows the chemical properties of the study site. Statistical analysis showed no significant difference between soil chemical properties of the study site between different topographic expositions. Soil pH was very strongly acidic, and soil organic matter content was moderate. The total nitrogen in the study site is medium, as interpreted by Landon (1991). According to Krofranek et al. (2007), total N is deficient mostly in the tropics since it undergoes various losses such as leaching and volatilization. The results on total N can therefore, be attributed to the lower soil organic matter in the study site.

Table 1 Soil chemical properties within study site between different topographic expositions

Expositions	pH	Soil Organic Matter (%)	Total Nitrogen (g/kg)	Available Phosphorus (mg/kg)
North-oriented	4.90 ± 0.18	4.27 ± 0.63	0.21 ± .03	0.96 ± 0.16
East-oriented	4.85 ± 0.18	4.11 ± 0.63	0.21 ± .03	0.59 ± 0.16
South-oriented	4.90 ± 0.18	4.46 ± 0.63	0.22 ± .03	0.92 ± 0.16
West-oriented	4.74 ± 0.18	4.01 ± 0.63	0.20 ± .03	0.63 ± 0.16

On the other hand, according to the sufficiency ranges of soil of Landon (1991) the available P in the study site is very low.

Therefore, the result of this study supports the findings of Piamonte et al. (2014), where they found out that the soil in Mt. Nacolod Mountain Range (Abuyog-Silago-Hinunangan-St. Bernard-Libagon-Mahaplag) is classified as Ultisols, which is characterized as acidic and generally have low nutrients status.

Conservation and Ecological Threats

Unsustainable harvesting:

In the study site, five illegally-cut matured *Aquilaria* were documented and recorded. Meanwhile, a community resident began harvesting *Aquilaria* in the forest in June 2019. According to the respondent, since it was difficult for them to identify the exact *Aquilaria* trees, they would randomly cut trees without properly distinguishing them and chopping them into pieces (Fig. 2A). Until eventually, traders from other countries (China and Taiwan) and other places within the Philippines (Mindanao and Samar) came and trained them to identify and distinguish the *Aquilaria* tree.

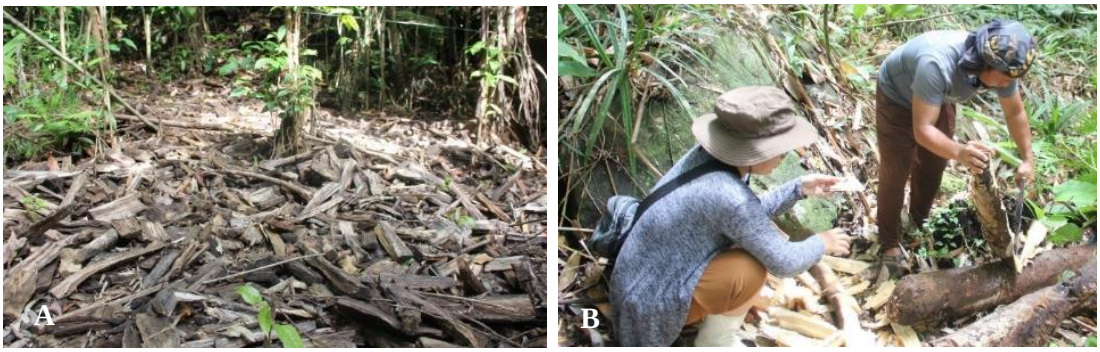

Fig. 2 Local practice in harvesting *Aquilaria* in the study site

The traders instructed them that a matured *Aquilaria* tree that looks rotten or unhealthy has most likely agar in it, whereas those that look firm and healthy are not good. This information was confirmed by the study of Rasool and Mohamed (2016) that agarwood formation is often linked to the physical wounding or damage of *Aquilaria* trees caused by thunder strike, animal grazing, and pest and disease infestations.

According to the respondents, *Aquilaria* is cut into pieces from trees to reveal the resinous product (Fig. 2B). Apparently, poachers are chopping down trees faster than they can grow, including forest across neighboring towns. According to Ng et al. (1997), not all *Aquilaria* trees produce agarwood, estimating that only approximately 10% of wild *Aquilaria* spp. produce resin.

Furthermore, respondents stated that they are more eager to search for agarwood than work as a hired labor or harvest copra because of its immense value. They further explained that they earn higher income from agarwood than farming and working as laborers. Harvesting *Aquilaria* and selling agarwood enable them to triple their income, which consequently improved their living condition. For instance, most of the respondents could buy new motorbikes, repair or enhance their houses and buy property (such as land).

Massive collection of regenerant:

Based on the interview results, in 2019, when *Aquilaria* became widely known, the value of seedling rose to 500 to 1000 Pesos. The seedling, particularly from *Aquilaria malaccensis* (Fig. 3A), generates higher income since wildlings are abundant in the forest. According to Chua (2008), *Aquilaria malaccensis* produces seeds after 7-9 years, while some other species produce seeds only once in their life cycle.

Fig. 3 *Aquialaria malaccensis* seedlings (A) and *Aquilaria cumingiana* seeds (B) owned by one of the respondents

As for *Aquilaria cumingiana* regenerant (Fig. 3B), only few are being propagated after collecting seeds. According to the seedling growers, its value is worth 40,000 Pesos per kilo. The seedling grower clarified that none of the seeds survived due to insufficient knowledge on how to properly propagate *Aquilaria* seeds and the appropriate time of collecting the matured fruits.

Inflecting damage to the matured Aquilaria trees:

In the study site, landowners and poachers have created an illegal method of inflecting matured *Aquilaria*. This is by punching nails or drilling holes on the trunk of standing matured *Aquilaria* (Fig. 4). They believe that by damaging the trunk using nails, it will gradually trigger infection and eventually develop agar inside. This method is widely visible on the study site.

Moreover, according to Ng et al. (1997), the age of the tree, differences in the tree caused by seasonal variation, environmental variation and genetic variation of *Aquilaria* spp. may also play an essential role in agarwood formation.

Fig. 4 Locally practiced method of inflecting (by punching nails and drilling holes at the trunk) matured *Aquilaria* species in the community

CONCLUSION

The results show that west-oriented topographic exposition had higher light intensity, while the average temperature during the conduct of the study had an increasing trend from seven o'clock in the morning until three o'clock in the afternoon but had a slight drop at five o'clock in the afternoon.
The result of the relative humidity showed that the east-oriented and north-oriented topographic location got the highest and lowest average of 86.29% and 84.26%, respectively.

The soil chemical properties are not significant between different topographic expositions. However, the soil on the study site is acidic and has a generally low nutrient status. The ecological threats recorded in the study site were unsustainable harvesting, a massive collection of regenerants, and inflecting damage of *Aquilaria* by punching nails or drilling holes in the trunk of a mature standing tree.

Therefore, it is highly recommended that *Aquilaria* should be protected particularly *Aquilaria malaccensis* since it is rare and is considered a new record of occurrence to Leyte Island. The establishment and development of an *Aquilaria*-based production system are necessary as an alternative option to reduce the rampant illegal poaching of agarwood in the wild. Furthermore, the *Aquilaria*-based production system should be established in private land and registered with the Department of Environment and Natural Resources.

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