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Agarwood practice and rural livelihoods in Naharani area of Golaghat District, Assam, North-East India

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Agarwood is a highly valuable aromatic plant variety mostly found in the tropical forest. The people of Assam have been practicing Agarwood cultivation and its trade for several decades. In this paper, an attempt has been made to investigate the indigenous knowledge system associated with the agar trade, i.e., detection of agar bearing plants, collection, processing, extraction of oil, and marketing of agarwood and its livelihood opportunities for the rural people. Naharani, a micro area with a few revenue villages located in the Golaghat district of Assam, has been selected for the study. This area is the hub of the Agar trade, and the local people have inherited this tradition from their ancestors. For this study, visit to different household industries, site observation, interviews with the people engaged in agar trade, and household surveys were carried out during 2016 and 2018. A simple random sampling technique was used for the selection of the sample household. Data have been collected from the randomly selected 975 households with a well-structured schedule-cum-questionnaire. Sustainable livelihood framework analysis was done to measure the livelihood assets of the people. It has been found that the agar trade and its associated practices have a significant contribution to the socio-economic condition of the rural people. As agarwood is now rarely found in the wild state, people have used to plant it in their homesteads and also developed plantation sites for its sustainable production. The homestead cultivation of agarwood and its trade alone contributes about 15-60% to the total annual income of the households. Although agarwood cultivation is commercially viable and sustainable, the farmers and traders are currently facing lots of hurdles to properly carry out their business in Assam.

Keywords: Agarwood, Processing of agar, Rural livelihood, Sustainability

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Agarwood is a tree with high economic value for its fragrant dark resinous content. It has different names in different cultures-*oud, oude* and *oodh* in Arabian countries, *agaru* in Bangladesh and Tibet, *chenxiang* (sinking incense) in China, *gaharu* in Malaysia and Indonesia, *jinko* or *jinkoh* in Japan, *mai ketsana* in Laos, *agar* in Pakistan, *ghara* in Papua New Guinea, *mai kritsana* in Thailand, *tram huong* in Vietnam, *adlerholz* in Germany, *lignum aquila* in Europe and generally *agilawood*, *agarwood* and *eaglewood* in English[1-3]. In India, it is known under different names- *agar* in Hindi, *aguru* in Sanskrit, *akil* in Tamil[1-3] and *Sanchi* in the Assamese. Agarwood is the source of an enigmatic aroma and is globally famous for its fragrant resinous content, which is used in perfume, cosmetic and pharmaceutical products. It is produced only from the infected heartwood of species of the genus *Aquilaria*, *Aetoxylon*[4] and *Gyrinops* of the *Thymelaeaceae* plant family[5]. *Aquilaria* is the primary source of valuable agarwood. There are 21 recognized species in the genus *Aquilaria* so far, of which 13 are known to produce fragrant resin content agarwood and the status of the remaining eight *Aquilaria* species is yet to be investigated[6]. Different kinds of *Aquilaria* are found in the tropical forests of Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Laos, Malaysia, Papua New Guinea, Thailand and Vietnam[7]. In India, three species of genus *Aquilaria* are found, namely *A. khasiana* Hallier f., *A. macrophylla* Miq. and *A. malaccensis* Lam[8].

North -East India is the home to Agar producing *A. malaccensis*, and Assam, a North-East Indian state, is famous for its utilitarian aspects. The use of agarwood is historically important in Assam. In *Harshacharita*, the biography of Indian emperor Harsha, written by Banbhatta (7th century Sanskrit prose writer and poet of India) states that the presents

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sent by Bhaskaravarman (King of ancient Kamrup) to Harsha included among other things "black aloe oil"[9]. The bark of the aloe tree, locally known as *Sanchi Pat*, was used to write manuscript in ancient times. The Hindus of Ancient India used agarwood in the form of a fragrant paste like sandalwood paste, but not in the form of essence[9]. The resinous wood and essence oil extracted are highly regarded for use during Buddhist and Islamic cultural activities, as well as an essential ingredient in many traditional medicines[10]. In the Middle-Eastern countries, the aloe oil is used as essence and also used for preparing medicinal products and they even burn the fragrant resinous agarwood. It is also used as bakhoor (scented brick), scented chips, Arabian perfumes in sprays and French-style perfumes as clothes fragrance, sprays as house fragrance and scented chips to receive honored guests[11]. Thus, the miscellaneous use of aloe wood and the extracted oil have high demand in all over the world. Due to its high economic value, people used to harvest this plant without considering its sustainability. As a result, this naturally grown agarwood tree has declined in number and extent, especially *A. malaccensis* in tropical forests[12].

Smuggling and poaching of agarwood were rising rapidly in some countries due to its high commercial value. Consequently, in 1995, it is listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to ensure its sustainable harvesting[13]. The species is globally vulnerable according to the IUCN red data list and has been included in the World List of Threatened Trees[14]. This species is considered critically endangered in India[15,16]. The export of agarwood, however, was prohibited in 1991, when the export of all wood products including log, timber, chip, powder, flake, dust, etc. of all species was banned through the EXIM policy in force at that time[17]. According to the EXIM policy (2009-2014) published by the Directorate General of Foreign Trade, Government of India, the import of agarwood is restricted, and this will be subject to the provisions of the convention of International Trade in Endangered Species of Wild Fauna and Flora[17]. Regarding the export provision of agarwood, the export of agarwood is regulated under chapter 12 (S.No. 80 to 83) of ITC (HS) Classification of Export and Import items[17]. After that, lakhs of people were affected related to the trading of agarwood. Imported agarwood, instead, can be re-exported as value-added herbal formulations. However, this will allow only if the herbal products are manufactured from imported raw material.

Hereafter, different countries have undertaken some measures for sustainable use of agarwood and encouraged the people for its plantation. International agreement, such as CITES, accepted by 169 countries, is designed to ensure trade in agarwood products[10]. There must be a license issued by CITES to export the logs or chips of agarwood. In Assam, the forest department used to cease the log from the traders. But gradually, people have understood the problem and given stress on the plantation of agarwood for its sustainable use. It is a promising wood even at the homestead level[12]. Unfortunately, little attention has so far been paid to its homestead cultivation. Nath and Saikia[18] in their work, considered the indigenous knowledge on the utilitarian aspects of agarwood in North-East India. Uddin *et al.*[19] explored the production, marketing, and processing problems of agar-based enterprises and their potential contribution to socio-economic development in Maulvibazar district of Bangladesh. Recently, a scientific study was also done on the processing of oil using bio-chemical analysis[20]. However, in North East India, very little attention has so far been paid to its contribution to rural livelihoods on the one hand and various stages of agar trade and the problems associated with it on the other. In this paper, an attempt has been made to explore the production, processing and trading of agarwood in Assam. Although Aloe wood is a tree with high economic value, the traders, growers and the people engaged in the processing of chips or oil have to tackle many problems in its trade. In Assam, Naharani (Golaghat District), Kakojan and Kabaru Gaon (Jorhat District), Nazira and Namti (Sivsagar District), Hojai District and Cachar District are known for the agar trade. Here, Naharani has been selected as the study area, which serves as the hub of the agar trade in Assam.

Methodology

Study area

The study area Naharani is located in the north-eastern part of Golaghat District, Assam, and characterised basically by physiographic homogeneity. The river Kakadonga flows along the north-western boundary of the area (Fig. 1). Naharani is the home of different castes and communities like Ahom, Koch, Kalita, Brahmin, Kachari, Muslim, etc.

with different cultural backgrounds, where agriculture is the mainstay of the economy of the people living in the area. Tea, rice and sugarcane are the major crops grown in the area. People also rear livestock for their livelihood. The availability of naturally grown indigenous agarwood plants (*Aquilaria malaccensis* Lam syn. *A. agallocha* Roxb.) helps in the growth of agro-based household industries for processing dark wood chips and essence oil.

The study area Naharani covers ten revenue villages with an area of 44.01 sq. km. The total population of the area is 22,810[21] with 51.28% male and 48.72% female. Mostly Hindus and Muslims constitute the population of the area. According to the Census of India report 2011, the literacy rate of Naharani is 89.87%. The occupations of the people include agriculture, business (mainly agar trade), service and daily wage labour. Microfinance (e.g., Bandhan, RGVM, AROHAN) groups play a significant role, particularly in women empowerment. This trade was initially led by Muslim people. But nowadays, people from other communities also have opted for this business.

Data collection

The study is based on both primary and secondary data. A literature review was done for detailed information on the nature, characteristics, status, and distribution of agarwood trees. The secondary data were collected from the Directorate of Census Operations, Assam. A sample survey was conducted to collect primary data. The data collection process was taken up between January 2016 and September 2018. The following procedures were used to collect and analyze the primary data:

From the Naharani area, ten villages were selected purposively for the study, where agar trade is widely practiced. A household survey was conducted in 975 randomly selected households using a well-structured schedule-cum-questionnaire. Interviews were conducted with the people engaged in cultivation, processing and trading of agarwood. Moreover, during the field study, visit plantation sites and oil processing industries were carried out. Data and information were collected on the indigenous knowledge and skills relating to the detection of agar-bearing plants, processing of chips and oil, marketing and also on the socio-economic background of the people associated

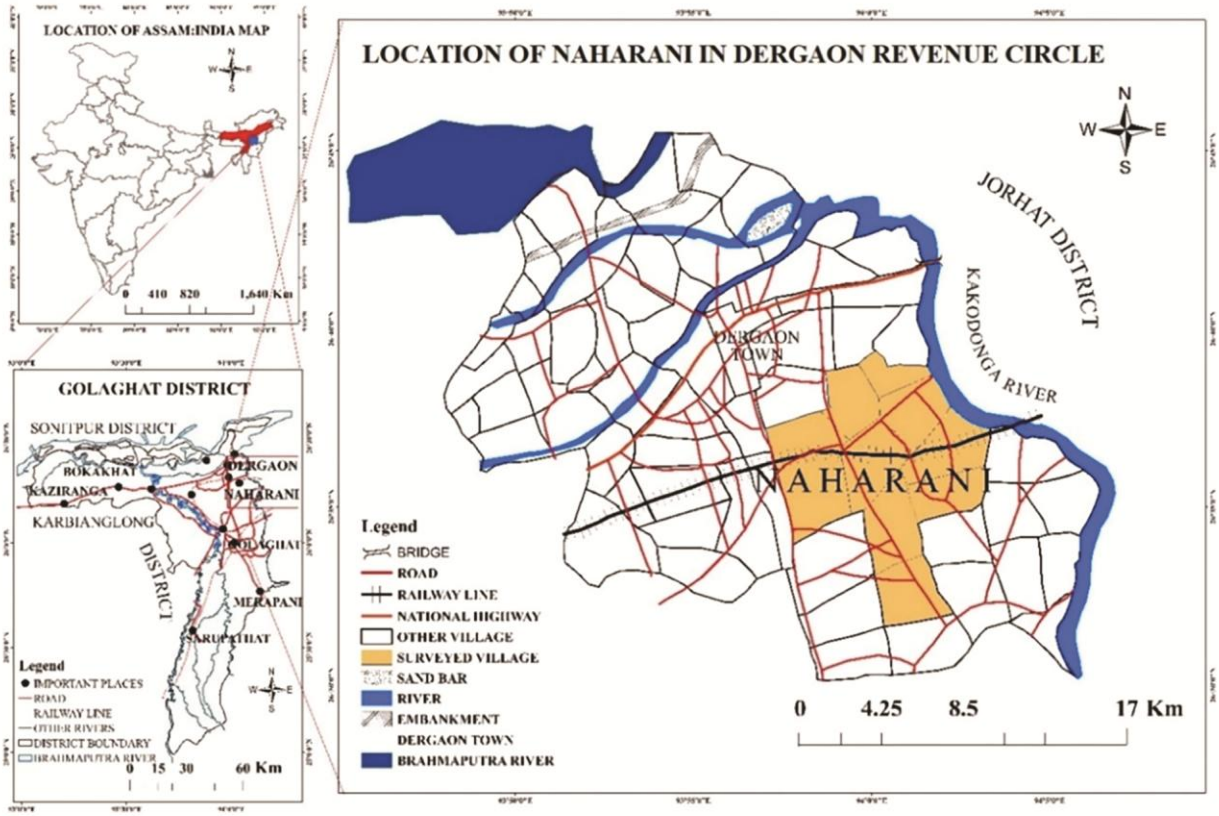

Fig. 1 — Location of the study area

with the trade. Besides, information on the period of Agarwood plantation, number of harvested trees in the homesteads and plantation sites, price of the trees, procedures of logs, chips and oil processing are also collected and summarized for discussion.

Analytical framework

The sustainable livelihoods approach was adopted for the study to assess the livelihood opportunity of the people from the cultivated agarwood and its trade. The framework developed as a form of livelihood analysis has been used by several development organizations, including the Department for International Development of the United Kingdom (DFID), the United Nations Development Program, CARE and Oxfam[22,23]. This approach states that livelihoods should be considered in terms of people's access to capital assets, i.e., financial, physical, natural, human, and social, how people combine these capital assets to create livelihoods[24-28].

Five types of livelihood asset capital and relevant indicators have been designed and presented. Therefore, various scaling and indexing methods were adopted to make them comparable and to allow meaningful interpretation. For developing the index, the survey results of each indicator questions were converted to a scale of 0 to 1. The results were assigned 1 to represent the most desirable response and 0 to represent the least desirable response. For the question of any household member engaged in agar trade, the answer 'yes' was assigned a 1 and any 'no' answer was assigned a 0. Most of the indicators were determined using rating scale methods in terms of different weights: 0.33, 0.66 and 1 to replace Poor, Average and Good, respectively[29-31]. Thus, it was assumed that higher scores should indicate higher levels of livelihood assets. The scoring methods were mainly plotted in three ways, all of which were based on the design features of the questionnaire. The first involves questions in the form of "house type" including three answer choices: *kutcha, semi-pucca and pucca*; which is replaced by "Poor, Average and Good":

$$I=Good\%\times 1+Average\%\times 0.66+Poor\%\times 0.33$$

The second method addresses questions in the form of "whether or Do.. " including two choices: Yes and No.

$$I=Yes\%\times 1+No\%\times 0$$

After calculating the weight of each indicator, the integrated measurement of each capital was done following the given formula:

$$C=\sum_{n=0}^{n}\left(\frac{In}{Tn}\right)$$

Where C is the criteria score for each asset or capital ($0 \le C \le 1$), n denotes n^{th} indicator of criteria (n = 1, 2, 3,. n); I denotes indicator; T denotes the total number of indicators.

Results and Discussion

Distribution and plantation of agarwood

Aquilaria is one of the most promising tree species that grows throughout South and South-East Asia, producing valuable non-timber forest products (NTFPs). *Aquilaria* is a fast-growing tree and can achieve a 10 cm diameter in breast height (DBH) in 4 to 6 years under favorable ecological and climatic conditions[32]. It is found to occur up to an altitude of 1200 m from the MSL. It needs a humid subtropical climate with an average annual rainfall of around 180-350 cm and also requires a lot of sunlight to attain a height of 40 m. In India, three types of *Aquilaria* species are found- *A. khasiana* which is restricted to Khasi hills of Meghalaya state, *A. macrophylla* in Andaman and Nicobar Islands and *A. malaccensis* in north-eastern states[8]. The distribution of different species of *Aquilaria* are presented in the Table 1.

There is an abundance of three intraspecific variants of *Aquilaria malaccensis* Lam. in North-East India and these exhibit variations in the resin content and growth of agar. The salient characteristics and distribution of the three variants are presented in Table 2.

The CITES member countries, those who are in the agarwood trade, have diverted their attention to cultivated *Aquilaria.* They are promoting *Aquilaria* cultivation to ensure a continuous supply of agarwood and sustainable harvesting[7]. Efforts have been taken by different countries, e.g., in Malaysia *Aquilaria* planting cover a total of 1300 hectares and 1.2 million trees at present[34], in Indonesia 3.4 million[35], in China estimated over 20 million[36]. In Bangladesh alone, almost 800,000 *Aquilaria* seedlings were planted in 2007. Bhutan and India have approximately 20,000 and 10 million trees, respectively[37]. These kinds of large scale plantations are developed by enterprising individuals or with trade interests who put hopes on high returns on their investment. Other plantations are run by private companies and government agencies. However, in Assam, efforts taken by the government

Table 1 — Distribution of *Aquilaria* species

Sl. no	Species name	Distribution
1	*Aquilaria malaccensis*	India, Indonesia, and Malaysia
2	*Aquilaria crassna*	Cambodia, Malaysia, Thailand and Vietnam
3	*Aquilaria apiculina*	Phillippines
4	*Aquilaria acuminata*	Papua New Guinea, Indonesia and Phillippines
5	*Aquilaria baillonil*	Thailand and Cambodia
6	*Aquilaria baneonsis*	Vietnam
7	*Aquilaria beccariana*	Indonesia
8	*Aquilaria brachyantha*	Malaysia
9	*Aquilaria cumingiana*	Indonesia and Malaysia
10	*Aquilaria filaria*	New Guinea, the Moluccas and Mindanao(Phillippines)
11	*Aquilaria grandiflora*	China
12	*Aquilaria hirta*	Thailand, Indonesia and Malaysia
13	*Aquilaria microcapa*	Indonesia and Malaysia
14	*Aquilaria rostrata*	Malaysia
15	*Aquilaria sinensis*	China
16	*Aquilaria subintegra*	Thailand
17	*Aquilaria spp.*	South and South-East Asia; from the foothills of the Himalayas to the rainforests of Papua New Guinea
18	*Aquilaria khasiana*	Khasi Hills of Meghalaya, North-East India

Source: Akter et al.[10];Mir et al.[33]

agencies for the plantation of the agar tree are negligible. Some plantations have been set up by the individuals in the districts of Golaghat, Jorhat, Sivsagar and Nagaon.

Agarwood is not abundant in the wild state; a noted Botanist in Assam stated that *Sanchi* tree is no longer a wild plant in Assam[38]. Sustainable agarwood production to support socio-economic development and conservation of the species in its natural habitat is possible only through domestication of the wild species[39]. Hence, most of the people used to plant it in their homesteads and also created plantation sites for more production (Photo 1, Photo 2). In the study area, the home gardens vary in size (0.03-0.4 hectares), and 100% of the surveyed households have planted agar trees in their homesteads, and 11% of households have separate plantation sites. Monocropping of the agar tree is introduced in the plantation sites. The number and age (1 to 20 years) of the trees, however, are different from one household to another. Saikia and Khan[12] stated that the density of agar in the home garden was not related to size, but was dependent on the owner's preference. However, in this study, it has been found that the size of the home garden determines the number of trees grown by the farmers.

The households having a small home garden (below 0.05 hectare) have less number of agarwood trees. Most of the households (46.48%) have small home gardens. Only 8.73% of the total households have large homesteads (Table 3). Moreover, some households also cultivate tea within the compounds of their residences. The villages located in the interior part have large homesteads.

Apart from the homesteads or residences, the villagers planted the agar trees in the compounds of Mosque, *Namghar* (Prayer hall in Assam), school, etc. The small tea growers also planted the agar tree in the boundaries of the tea garden. The tea-growing condition is also ideal for the agar tree and the canopy of the agar tree partly allows sunshine penetration. Thus, it can be used as a shade tree in tea plantation[32]. From the field survey, it has been found that 15 years before only 11% of the total small tea growers planted agarwood in their tea gardens, which is increased to 23.2% in 2016-18. The small tea growers have intercropped the agarwood tree with the tea cultivation for dual economic benefit. According to them, the agarwood tree will give shade to the tea leaves, and also, they can sell the mature agarwood tree for economic benefit. The growers generally collect saplings from the nurseries or the nearby villagers and plant them in separate plantation sites or within the homesteads. For the growth of the agar trees (saplings), the growers use some chemical fertilizer, mainly urea. However, only 20% of the total growers reported using chemical fertilizer, while others generally use bio-fertilizers (cow dung, plant debris), which is ecologically sustainable[12].

The cultivation of agarwood has a significant impact on the micro-level land-use change in this region. This area once used to be a major sugarcane producing area in Assam. But presently, the

Table 2 — Nature and distribution of agarwood variants

Variant	Local Name	Nature and Characteristics	Distribution
Aquilaria malaccensis Lamk.Variant I *RRLJ2729	Bhola Sanchi	Medium to large-sized tree; leaves oblong, lanceolate, apex caudate-acuminate, base acute; rarely susceptible to the development of disease and formation of agar	Distributed sporadically in some parts of Upper and Middle Assam and rarely in Lower Assam and Meghalaya up to an altitude of 900 m.
Aquilaria malaccensis Lamk.Variant II *RRLJ2726	Sanchi	Large-sized tree; leaves obovate-lanceolate, apex aristate-acuminate, base elliptic; development of disease and formation of agar is sporadic	Rarely found in Assam Hills and Barak Valley up to an altitude of 400 m.
Aquilaria malaccensis Lamk.Variant III *RRLJ2731	Jati Sanchi	Small to a medium-sized tree; leaves lanceolate, apex acuminate, base acute; mostly susceptible to the development of disease and formation of agar	Abundant in the Upper Brahmaputra Valley region of Assam and Arunachal Pradesh up to an altitude of 150 m.

*Source: Nath and Saikia (2002)[18], *Regional Research Laboratory, Jorhat, Assam,*

Table 3 — Percentage of the household having agarwood trees in their homesteads

Size of homestead (in hectare)	Agarwood trees in homestead(in number)	Household (in %)
Below 0.05	Below 100	46.48
0.05-0.10	100-150	20
0.10-0.26	151-200	24.79
Above 0.26	Above 200	8.73

Source: Primary survey, 2016-18

cultivators have given more importance to the production of tea and agarwood for maximizing their profit[40]. As agarwood is a forest tree, it does not require much care and expenditure and it is less labour dependent commercial crop. Like this, in some parts of the world also, people used to cultivate agarwood instead of traditional cultivation. A study by Jha[41] found that agarwood plantation was adopted as a livelihood strategy against the traditional cultivation of cassava and maize in some villages of North-East Thailand. Due to the frequent drought and poor soil quality, people retreat the cassava and maize cultivation.

The agar is formed due to some infection in the tree. The infection is caused when an injured or wounded tree is attacked by fungus or certain insects[42]. As a response to this, the tree produces a resin high in volatile organic compounds that aids in suppressing or retarding the infection, a process called tylosis. While the unaffected wood of the tree is relatively light in colour, the resin dramatically increases the mass and density of the affected wood, changing its colour from pale beige to dark brown or black[42].The natural maturation process takes a longtime (15-20 years) to form the resin content, and the best yields are obtained from trees aged 50 years and over. Only about 7-10% of the naturally infected trees produce resin. Therefore, to increase the rate of agar formation in a short period, patent-based inoculation techniques were introduced by the University of Minnesota[43].

Moreover, various conventional and non-conventional methods are used for the formation of agar. The conventional methods are-Nailing Method, Drilling Method, Partly-Trunk-Pruning Method (PTP), Burning-Chisel-Drilling Method (BCD), Fungi-Inoculation Method (FI) etc[44]. In Bangladesh, artificial induction of the larvae of the stem borer is made for the infection of the trees to get the resin content within a short period of time[10]. From the field study, it has been confirmed that no such types of conventional and non-conventional methods are used by the people of Naharani and its adjacent areas. It has been observed that only 2.12% of the surveyed households partially wounding the trees using an axe for the formation of agar as many of them do not have the knowledge and skill for artificial induction. The growers have to wait for a long time to sell the naturally matured trees which contain best grade agaru products. Many of the growers are compelled to sell the immature trees at a meager price due to their poor economic condition.

Processing

Agarwood processing refers to different stages from the detection of agar bearing plants to the raw oil processing. People are engaged in various stages according to their skills. Agar is formed as a result of infection of the trees either by natural or mechanical means. The formation of agar in agarwood is often related to natural factors like broken branches due to strong winds, thunder strikes, and pest and disease infiltrations. Due to these factors, wounds occur and the pathogenic microbes enter into the tree and trigger the resistance system[45]. The visible wound (locally referred to as *futi*), stem distortions, decayed

branches, and odoriferous property provide shreds of evidence of agar formation inside the tree[18]. Based on these symptoms and also by extracting the wood samples with the help of screw augurs or *dao* (a large knife), the local people and traders detect the agar bearing plants in the field. This process is not harmful to the further growth of the tree. People collect the agar bearing plants of different sizes from the field as a log. The best season for collecting the logs is from January to April, because in this season the fine grade dark wood is formed, from which high-quality oil can be processed with less waxy contents.

The collected logs are cut into different sizes, and the chips are processed in various forms. *Botali* (screw) is used to remove the unwanted parts from the chips. Every single piece of agarwood is processed in various sizes using indigenous techniques, which are known under different names in the market. The processed chips are graded and sold according to the darkness and scent. The chips are locally named as *churan, chipping, kash, bangtang, sem, kalagasi*, etc. according to their size, shape, fragrance and darkness (Photo 3a, Photo 3b, Photo 4).

In the case of oil extraction from different grades of processed chips, one has to establish a household industry which is quite expensive in the context of the local economy. The small processed chips, i.e., *churan*, *kash*, and *chipping*, are distilled to extract oil. Before distilling it, the chips are soaked in water for 15-30 days. The distillation tools include a stainless steel vessel, locally known as *deg* (Photo 5a). The capacity of the vessel varies from 25 to 700 kg. It is fixed on a concrete oven (Photo 5b). The stainless steel lid is called *sarposh* and it is tightly fixed with clay over the deg. One side of the *sarposh* is fixed with a straight steel tube, which is further attached to a removable bent steel tube of smaller diameter. The bent pipe is connected to a stainless steel condenser, which contains a coil of steel pipe inside it (Photo 5c).

After that, the *churan* or *chipping* is placed in the *deg* and water is added in the ratio of 1:2 by weight. The *deg* is then heated and distilled continuously for 15-20 days. The heat is generated using firewood. Nowadays, *falia* (the coarse husk of paddy) is used as fuel (Photo 5d). When the chips are boiled, the vapour containing oil or agar *attar* is condensed in the condensers. Cold water is continuously added to the condenser and the hot water is released out. The oil floats on the surface of the water and is then separated. After that, it goes to a steel pot called *Bokhba*. From the *Bokhba*, oil is captured after a gap of five days and stored in glass bottles (Photo 6). The extracted oil is sold to the traders and the price is fixed according to the grade. The cost of the whole set of a *deg* is approximately ₹ 1,00,000-₹ 1,50,000, which contains steel vessel (1), condenser with the coil pipe (1) and *Bokhba* (1).

Marketing of processed chips and raw oil

Agar oil and agar chips have great importance in the international market. The traders from the Middle-East countries and also from Europe import the raw oil from India, Bangladesh, Malaysia and Indonesia and other agar producing South-East Asian countries[13]. They use it in perfumery and medicinal products. In India, Mumbai is the hub for marketing best grade agar oil and chips. Hojai is the hub of agar trade in Assam. Naharani is the major supplier of agarwood and extracted oil. The hierarchy of the marketing system for agarwood and raw oil is as presented in Figure 2.

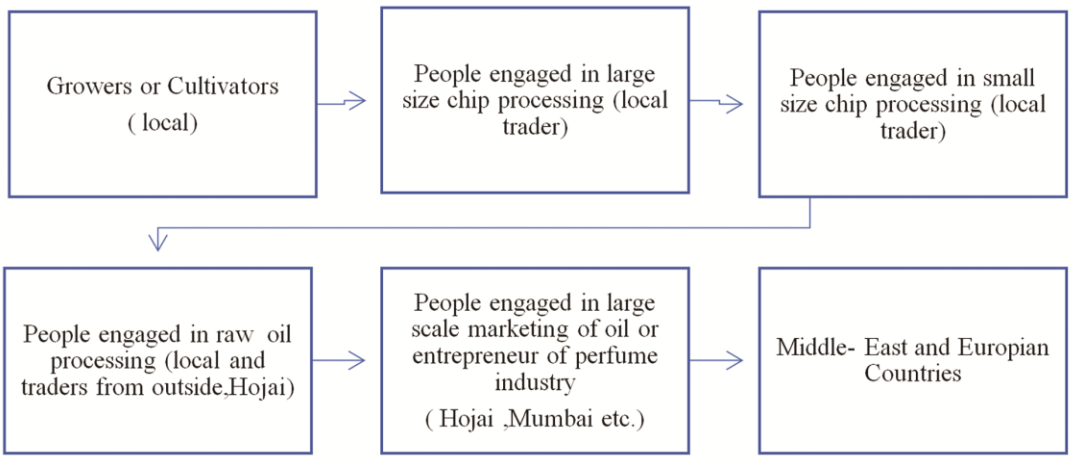

Fig. 2 — Marketing system of agarwood and raw oil

The role of the mediator is significant in the marketing of agarwood chips. The mediators are generally from among the local people. They help the traders from outside (e.g., from Hojai) to find out the best grade processed chips in the village. There are a few mediators in the study area who take money as commission from both the sellers and the buyers.

The price of agarwood varies according to its grade. There is no standard method of grading the quality of agarwood and oil; however, some sourcing and consuming countries have made an effort to grade their agarwood according to their local market[46]. The darker the colour of the chips and oil, the higher is the grade and price. The price of the tree also varies according to its maturity and dark resinous wood content. The traders opine that the price fluctuates according to its demand in the global market. Furthermore, like other commodities, the international market of agarwood has also experienced several booms and crashes over the years. In 1880, high grade agarwood was sold for up to US$1/ kg. The price doubled up to US$2.20/ kg by 1905. Due to overproduction by Indonesia, later, it crashed to US$0.30 in 1925. In the 1970s, best quality agarwood reached a price of US$42.50/ kg. The price continued to increase to US$1,250 in 2000 and US$2,500 in 2005[47,48]. The price of agarwood chips in international market varies currently between US$20 to US$6,000/ kg, based on its quality[10]. Distilled agar oil is valued at as high as US$30,000/ kg and the wood chips itself is worth up to US$10,000/kg[10]. The quantity of oil is measured in terms of Tola (1 tola =11.6g)[18]. The price of oil and agarwood chips differ according to its grade (Supplementary Table S1).

A choice for rural livelihood

Agarwood and its products have a significant contribution to the livelihoods of the people of this region. It has been taken as a feasible strategy for rural livelihood, and people are attracted to this activity in the interest of earning more money[49]. In Naharani, as well as in Assam, the origin of agarwood business dates back to the 1930s[12]. The oral history says that an Afghan *Mahaldar* (a leaseholder or bidder) made the agar trade in Dimapur along with his business of bidding elephant used for working in the hills. For making the agar trade, he brought some labourer from the Sylhet district of Bangladesh (erstwhile East Pakistan).

Along with the labourer, an Islamic saint, named *Munchi Atar Ali Sahab,* came to Dimapur. Later on, he came to Naharani and introduced the trading of agarwood here. Before that, the local people were not aware of the trading of agarwood; instead, they were using this as fuelwood. The saint married an Assamese Muslim girl and stayed back in Naharani and popularized the skill of processing of chips and oil from agarwood. Later on, his four sons developed the business in Assam. In 1972, 'Naharani Co-operative Agarwood and Atar Society' (Reg.no.GLT40/73) were established to run the business in organised manner[38]. After CITES declaration it as an endangered species in 1994, the government of India banned the trading of agarwood and its products also. The government also did not allow keeping the raw chips in the auction center. However, the agar trade is continued, and the agarwood society promotes the plantation of the agar tree in the homestead and also encourages developing plantation sites in their *patta* land (revenue land). Gradually, the business spread to Kakojan in Jorhat district and Namti in Sivsagar district of Assam. Currently, it becomes a small scale agro-based industry and choice of livelihood for more than lakhs families in Assam.

Approximately 47% of the households of the study area have preferred agar trade as their livelihood. People participate in different stages of agarwood production, i.e., plantation, processing chips, processing oil, marketing and distribution of products. The availability of raw materials encourages the inhabitants of this area to opt for this as a livelihood opportunity. Out of a total of 975 households, 456 households are engaged in agar trade. The total population of the area is 4438. Among them, 50.10% are male, and the rest, 49.90%, are female. It has been found that 51.68%of the people are in the working-age group (15-59 years) and 41.73% of them are engaged in this trade.

People have been doing this business, along with some other economic activities. Agriculture is the prime source of income and most of the agarwood traders are also engaged in agricultural activities. Cultivation of rice and small-scale tea garden are common among the villagers. Some of the public sector employees are also involved in agar trade (8.24%). Before getting a job, most of them were engaged in agar trade and later on, they have continued the trade along with their job. Most of them are, however, involved in oil processing. Generally, they use wage labourers for looking after their household industries. Currently, the young people,

who have got a job in government sector, are not generally ready to continue the agarwood trade. Private sector employees are also engaged in the trade. They typically go for partnership business. The agar traders are also found to be interested in agricultural activities. They also participate in other activities like driving, masonry, shopkeeping, etc. (Supplementary Fig. S1).

Most of the people (52.99%) engaged in agar trade have only high school level education (Supplementary Fig. S2). Many school dropouts are also there in this trade. The reason behind the popularity of the agar trade among young people is that the daily wage for processing chips is quite high, and the physical labour needed for this is not at all hard. However, one has to be skilled in handling different techniques associated with the processing of chips. Some of them got engaged after completion of their higher secondary education. Very few with a master degree are involved in this trade. Notably, there is a negative impact of agar trade on the educational scenario of this area. Most of the boys opt for this business after completing their high school education, as it is economically beneficial. They do not prefer to go for further study. Those who are from poor backgrounds do not want to pursue further study, and instead, they prefer to get engaged in this trade to support their family. There are also instances of boys involved in agar trade who are pursuing higher studies in the local colleges. They are employed as daily wage labourer particularly in the night shift or holidays.

To get engaged in this trade, one has to be skilled in agarwood processing techniques, although the techniques are traditional. The percentage of people engaged in different agar trade activities are shown in the Fig. 3. The majority of the people (55.56% of the total engaged) are engaged in the processing of the chips (semi). Full processing of the chips involves complete removal of the white part of the wood, which is quite laborious and time-consuming. Therefore, most of the people are interested in selling semi-processed chips. Oil processing is capital intensive, and only a few people (5.9%) have such kinds of processing industries. The works of the daily wage labourer remain confined to the processing of chips and extending help to the oil processing industry. The majority of them are of the age group of 18-35 years. The mediators reap benefits from both the buyers (traders from outside Naharani) and sellers (the local people). The traders stay with the mediators as paying guests. The duration of stay, however, varies according to their needs (1 week to 4 months). The traders collect the agar chips or oil from the villagers with the help of the mediators and then return to their respective places. Some of them are also involved in processing chips and oil (6%). Interestingly, 14.2% of the traders are engaged in the business in partnership. The female labourers are mostly engaged in chipping of agarwood and separating the black dust (*churan*) from the white dust for grading.

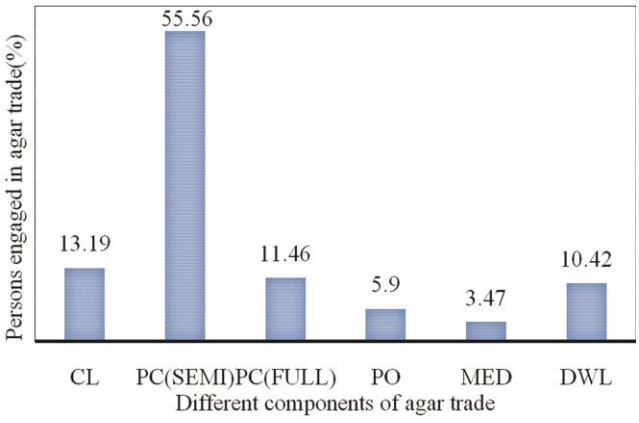

Fig. 3 — Percentage of people engaged in different agar trade activities

The duration of the work of the people engaged in different phases of agar trade varies greatly (Fig. 4). It is found that the tenure of their engagement varies from a minimum one year to a maximum of 40 years. Most of the people engaged in agar trade during the last 15 years are of the age group of 20-40 years (Fig. 5). There is a notable relationship between the age of the people and the tenure of engagement in this trade. The number of people involved in this trade for a long time is quite less (2 -4%). The proportion of people who have been doing this business for the last 1-5 years is 14.67%. It is quite high because these are the young age group of 18-25 years who have been in work since the previous 1 - 5 years.

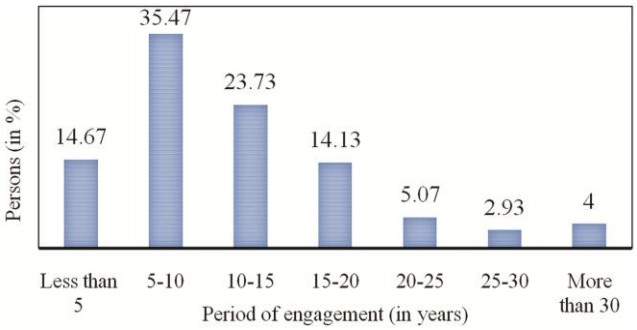

Fig. 4 — Period of engagement in agar trade

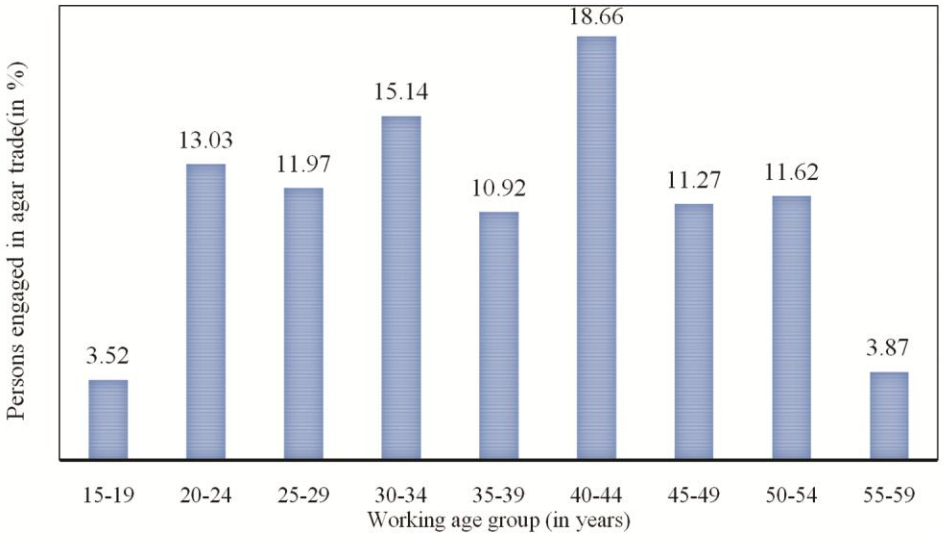

Fig. 5 — Participation of people of different age groups in agar trade *Data Source-Field Survey, 2016-18*

So far, the income from agar trade is concerned; it is difficult to assess the income of the households mainly due to the fluctuation of the price of the chips or oil. Most of the households have a monthly income ranging between Rs. 3,000, and Rs. 50,000 (Supplementary Fig. S3). The income of a household from agar trade depends upon the number of family members associated with the trade and also the sector in which they are engaged. Household income also varies according to the grade of the processed chips and oil. People who earn below Rs. 5000/ month are mostly the daily wage labours. However, the people associated with the processing of oil and chips have a higher income than that of the daily wage labours and the mediators. Households engaged in full processing of chips and oil has an income of more than Rs. 40,000/ month. Monthly income also varies according to the grade of chips and oil which have been processed in the household and in which stage the people are engaged in.

Sustainable livelihood analysis

The results depicts the impact of agarwood cultivation and its trade on livelihood assets (Table 4). For the physical capital, five livelihood indicators have been selected- 'house type', 'household energy structure,''household fixed assets condition,''access to market and transportation facility.' The physical capital value of 0.7 indicates good condition (i.e.,>0.66) of the physical livelihood assets. However, among the five indicators of the physical capital 'household energy structure' shows a good score of 0.82, which depicts the application of LPG as

Table 4 — Total value of livelihood capital index

Capital	Indicators	Weightage	Capital value
Physical capital	House type	0.68	
	Household energy structure	0.82	
	Household fixed assets condition	0.68	0.70
	Access to market	0.66	
	Transportation facility	0.68	
Natural capital	Size of home garden	0.68	
	Number of livestock	0.69	0.72
	Number of agarwood in the home garden	0.82	
	Landholding size	0.69	
Human capital	Number of a household member engaged in agar trade age between 18-59	0.88	
		0.65	
	Level of education of the respondent	0.77	0.66
	Skill & knowledge about agarwood trade	0.82	
	Health status		
	Female work participation	0.18	
Financial capital	Household income	0.88	
	Access to bank account	1.00	0.86
	Credit from microfinance or bank	0.89	
	Oil processing unit capacity	0.69	
Social capital	Strength of relationship with the traders from outside	0.98	
	Strength of relationship with neighbors	0.95	
	Political influence or power		0.68
	Participation in groups (planting group or trade society)	0.27	
		0.25	
	Strength of relationship in partnership business	0.97	

fuel instead of fuelwood. The use of renewable energy, such as electricity, is also high in households. The weightage of the other indicators of the physical capital ranges between 0.66-0.68, indicating 'average' to 'good' condition of the livelihood assets. The indicators of natural capital are selected 'size of the home garden,' 'number of livestock,' 'number of agarwood tree in the home garden' and 'landholding size.' Although the aggregate natural capital value of 0.72 depicts a good score, the indicator 'number of agarwood trees in the home garden' only reflects a significant controlling over livelihood status. The other indicators show an average weightage. The size of the home garden determines the number of agarwood trees in the home garden.

In addition to the common indicators like 'health status,' 'level of education,' and 'skill and knowledge,' 'female work participation' is taken an essential indicator of human capital. The female work participation is significant in determining the development of a society. However, in this study, it has been observed that only 18 percent of the total female under the working-age group participate in different activities of agar trade. The participation of the members of the household (age group 18-59) in agar trade is also noteworthy. The more members participate in the agarwood from a household, and the more will be the income. The skill and knowledge of the household members also indicate a significant score. Hence, most of the school dropouts, especially boys, engage in agarwood trade, which ultimately leads to poor scores in the level of education of the participants. The overall health status of the household members is showing a good status with a score of 0.82. However, the collective human capital score depicts an average condition of sustainable livelihood.

The results of the analysis show the impact of agarwood cultivation and its trade on the household income of the villagers. Although it is difficult to ascertain the household income of the people engaged in agar trade due to its fluctuating rate, during the survey, the respondents give a good weightage to the household income. All the cultivators and traders have bank accounts and 89% of them take credit from the microfinance organization or the bank to properly carry out their business. In most of the cases, the female of the households below age 60 generally take credit from the Bandhan Bank, RGVM, AROHAN, etc. and help the male members of the family to carry out the trade. Moreover, to access the financial capital of the household, the weightage has been given to the capacity of the oil processing unit. A weightage of 0.33 has been given to the oven size below 500 kg, 0.66 to the size of 500 kg and 1 to the size above 1000 kg. The results show that although the oil processing unit score 0.69 (i.e.,>0.66), it represents an average impact on the livelihood of the household. However, the aggregate financial capital earns a good score of 0.86, which directly reflects the livelihood impact of the household.

Regarding social capital, the strength of the relationship of the cultivators and local traders with the traders from outside has been accessed, which show a good relationship. It is the utmost concern of the cultivators and the local traders to maintain a good relationship with the traders from outside for selling their agarwood chips and oil. The cultivators and traders are also asked about their relationship with the neighbors, and the indicator shows a good weightage of 0.95. They said that the neighbours help them during their crisis, which represents a sustainable social relationship of the people for their livelihood. The influence of political power is less in their livelihood. Most of the cultivators and traders single-handedly carry out their activities for their livelihood. However, the traders who are engaged in partnership business of collecting and processing of the agar chips and oil, maintain a good relationship with the partners.

Constraints

Although the agarwood cultivation and its trade seem to be ecologically and economically sustainable, the cultivators and traders are facing lots of hurdles to carry out their activities properly. Due to the rigid legislation, the traders find it difficult to sell and to transport the agarwood products outside their region. Sometimes, the forest department and the police personal cease the logs, although the traders collect it from the cultivators who sell their trees from their *Patta* land. There is also no permanent rural market facility for selling and buying of agarwood logs and chips. The cultivators and the local traders have to depend on the traders from outside to sell the agarwood chips and oil. In an interview with the traders said that the fluctuating price of the agarwood products in the market impact on their livelihood earnings. Most of the traders (52.6%) still use a bicycle or bike to carry the logs from the cultivators.

Due to these constraints, people sometimes find it difficult to adapt it as a livelihood strategy for the long term.

Conclusions

Aquilaria malaccensis Lam. is the most promising tree species to develop agroforestry based industry. It has a significant contribution towards the rural economy of Assam, particularly in its upper part. The traditional skills of the people in the detection of agar bearing plants, processing of wood chips and oil encourage the local people to involve in these kinds of activities. In conclusion, it can be said that the cultivated agarwood and its trade has an impact on livelihood assets of rural households, including each aspect of the five types of livelihood asset capital. Importantly, the people of the Naharani area have been practicing this activity for the last 80-90 years, which provides employment opportunities to most of the local people. The participation of the female folk in this activity is also noteworthy (18%). The tradition of cultivation of agarwood and the process of natural agar formation in the area seem to be economically and ecologically sustainable. However, people are facing many problems for financial assistance, collection of logs, and marketing of the products. The elimination of the constraints might have an additional advantage in the further development of this livelihood strategy. Therefore, proper attention should be given to the management and marketing of agar products. Care should be taken to make the people aware of the problems, conducting workshops, training programs on the rules and regulations followed by different national and international organizations in connection with the cultivation, and trading of agarwood.

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Conflict of Interests

Authors declare no conflict of interest

Author Contributions

Data collection, analysis and interpretation: FRS Ahmed; Writing original draft and writing reviewing draft: FRS Ahmed; Supervised the work and editing: AK Bhagabati. All authors discussed the results and contributed to the final manuscript.

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