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Distribution and Population Status of Critically Endangered *Aquilaria Malaccensis* Lamk. In The Forests of Arunachal Pradesh and Assam, India

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ABSTRACT: *Aquilaria malaccensis* Lamk. is an endangered but highly demanded tree species of sub-tropical rain forests of northeastern India. It has profound impact on socio-economic status of rural people owing to its highly priced resinous wood and wood oil valued for medicinal & aromatic properties. The species has come to the risk of extinction due to pressures for utilization. As a result, it has been included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and considered 'critically endangered, in India. Population ecology of this important species was investigated as a basis for its conservation. This paper presents results of survey conducted at thirty nine *Aquilaria* growing sites of Arunachal Pradesh and Assam. The present study records the existence of natural populations of *A. malaccensis Lamk.* but in very less numbers with alarming current population density. The species is mainly surviving in plantations. Urgent biotechnological interventions may be employed to conserve remaining natural genetic pool of *Aquilaria malaccensis* in natural state in this north eastern most state of India.

KEYWORDS: *Aquilaria malaccensis*, conservation, distribution, population status, natural forests, plantations

I. INTRODUCTION

Aquilaria malaccensis Lamk. (syn.: *A. agallocha* Roxb., Family: Thymeleaceae) commonly known as 'Agar' is an economically important native tree species of sub-tropical-tropical rainforests of northeast India. The species is valued for its enumerable medicinal and perfumery properties. Since the time immemorial, its resinous heart wood popularly known as 'agarwood' is highly demanded for medicine, incense and perfumes across Asia and the Middle East. Medicinally, the plant is used as stimulant tonic, diuretic, illness during and after childbirth, to treat small pox, rheumatism, spasms especially in the digestive and respiratory systems, abdominal pain, asthma, colic, chest congestion, diarrhea, hiccups, nausea, nerves and regurgitation (Kim et al., 1997). The plant is also reported to possess remarkable anti-cancer activity (Yumi et al., 2014). In Egypt, Arabia and throughout the northeast part of Bangladesh, agarwood is described as a stimulant, cardiac tonic and carminative (Bhuiyan et al., 2009; Donovan and Puri, 2004). In traditional Chinese and Japanese medicine, it is used as a traditional sedative, analgesic and digestive medicine (Liu et al., 2008). Its aromatic oil bears acrid, bitter, warm, aromatic properties and plays an important role in incense and perfume industries. It has been used for centuries as incense in Buddhist, Hindu and Islamic ceremonies (Neaf, 2011).

There are 27 *Aquilaria* species distributed worldwide, of which 24 are naturally found in 12 south-east Asian countries i.e. Bangladesh, Bhutan, Cambodia, India, Indonesia, Lao PRD, Malaysia, Myanmar, Philippines, Thailand, Vietnam and Papua New Guinea (Zich and Compton, 2001). About six species are reported to occur only in Indonesia and two in China (Saikia, 2014). India is the home of three *Aquilaria* species and *Aquilaria malaccensis* is considered endemic to north-east India (Kanjilal et al., 1982). Two species i.e. *A. malaccansis* Lamk. and *A. khasiana* Hall. are found in the evergreen rain forest of north eastern states whereas the third species i.e., *A. macrophylla* Miq. is found in the Nicobar Islands (Giri, 2003). In India, it is mainly confined to the north eastern states and mostly distributed in plains and foot hills of eastern Himalayan states (Chakrabarty et al., 2003). The natural population of *A. malaccensis* has almost been

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extinct in the north eastern India. Large scale harvesting from natural forests resulted in rapid depletion of the species from wild habitats and is listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 1994) to bring the international trade within sustainable levels. Its population has declined to the point that it is included in IUCN red data list as 'vulnerable' in 1998 and considered 'Critically Endangered in India' and almost 'Extinct in wild' in Assam (Anonymous, 2003).

Due to high medicinal and perfumery value, the species has great demand in national and international market hence the attempts are now being made to cultivate the species in plantations in India and other places around the world. Currently, the species is mainly surviving in plantations, home gardens and along tea plantations in Assam and its adjoining areas of northeast India and Bangladesh and significantly contributing to the local economy of the region (Saikia, 2014). 'Bhola sanchi' and 'Jati sanchi' are two distinct variants of *A. malaccensis* cultivated there in upper Assam, of which, former is fast growing and less agarwood yielding than the later variant which is slow growing but high yielding hence preferred for large scale cultivation (Saikia and Khan, 2013). *Aquilaria* is presently being cultivated on commercial scale mainly in upper Assam region, but even favorable topology, climatic conditions and soil types in Arunachal Pradesh, the commercial cultivation has not been initiated so far.

Keeping in view the importance of species, drastic decline in natural *A. malaccensis* population, commercial plantations, reforestation and biological conservation, a study was conducted with the objective to find out current population status of this precious species in natural and artificial plantations in Arunachal Pradesh and Assam and to identify factors responsible for its diminution. The associated vegetation was also analyzed to provide complete information about natural habitats of agar tree particularly in the northeastern parts India.

II. MATERIALS AND METHODS

The present study was conducted in *Aquilaria* growing sites of Arunachal Pradesh (27.0600° N, 93.3700° E) and Assam (26.1400° N, 91.7700° E), Northeast India during 2009-11 (Figure 1). The altitude of study sites ranges between 71 to 506 m amsl and the area harbors diverse vegetation and habitat ranges (Table 1). The region is characterized by an average annual rainfall of 42.1-353.2 cm, temperature range from 05 to 36^{o}C and relative humidity from 51.1-97.0 % respectively. The local people mostly fulfill their day-to-day needs from locally available bio-resources.

Description of study-sites

A total of 39 *Aquilaria* growing sites located in six districts (4 in Arunachal Pradesh and 2 in Assam) of North-east India were surveyed. The sites representing *Aquilaria* were namely Balijan (ARB), Itanagar (ARI), Midpu (ARM) and Nirjuli (ARJ) of Papum pare, Bhismaknagar (ARBH) and Roing (ARR) of Lower Dibang Valley, Wakro (ARW) and Bhekuliang (ARBE) of Lohit, Namdapha (ARN) and Miao (ARMO) of Changlang, Assam-Nagaland border (ASAN) and Majarbar Grave yard (ASG) of Golaghat and Hojai (ASH) of Nagaon (**Figure 1**) where from primary information

Table 1: Sites characteristics of *Aquilaria malaccensis* forests in Arunachal Pradesh and Assam

State	District	Name and code of study sites	Coordinates	Altitude (m)	Habitat	Topography
Arunachal Pradesh	Papum pare	Balijan (ARB)	N 26.96085° E 93.54648°	159	Natural	Hilly
	-do-	Itanagar (ARI)	N 27.10184° E 93.63708°	454	Plantation	Hilly
	-do-	Midpu (ARM)	N 27.50075° E 94.13174°	506	-do-	Hilly
	-do-	Nirjuli (ARJ)	N 27.11783° E 93.74859°	247	-do-	Valley
	Lower Dibang Valley	Bhismaknagar (ARBH)	N 28.06214° E 95.97678°	346	Natural	Hilly
	-do-	Roing (ARR)	N 28.14277° E 95.84391°	399	Plantation	Hilly
	Lohit	Bhekuliang (ARBE)	N 28.02665° E 96.09898°	347	Both	Hilly

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Assam	-do-	Wakro (ARW)	N 27.78257° E 96.34766°	424	Both	Hilly
	Changlang	Miao (ARMO)	N 27.48657° E 96.2093°	269	Plantation	Plain
	-do-	Namdapha (ARN)	N 27.53936° E 96.1°	207	Natural	Hilly
	Golaghat	Assam-Nagaland border (ASNB)	N 26.65263° E 94.32788°	119	Natural	Plain
	-do-	Golaghat (ASG)	N 26.51937° E 93.96933°	104	Both	Plain
	Nagoan	Hojai (ASH)	N 26° E 92.87°	71	Plantation	Plain

Source: http://elevationmap.net/

were collected (**Table 1**). Secondary information from all these sites was collected on the basis of available literature, through personal contacts and interviews with local people. The population studies, however, were carried out at two natural *Aquilaria* growing sites of Arunachal Pradesh only i.e. Balijan (ARB) of Papum Pare and Namdapha (ARN) of Changlang districts.

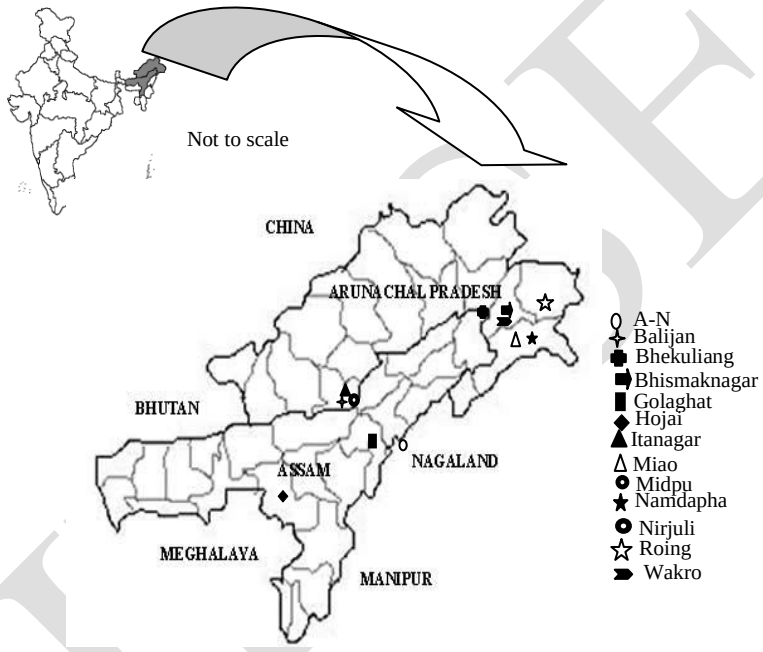

Figure 1: Map showing different study sites in Arunachal Pradesh and Assam, Northeast India

Survey for A. malaccensis Lamk. in forests and plantation sites

The field survey and samplings were conducted during 2009-11 in the selected study sites of Arunachal Pradesh and Assam states of NE India. All individuals of *A. malaccensis* were counted and categorized in different growth stages on the basis of tree height and girth. Population studies of *Aquilaria* were conducted at two natural forest sites following quadrate method (Mishra, 1968; Magurran, 2004). Phytosociological studies were also carried out to comprehend the composition of plant associates of *A. malaccensis* in nature. Ten quadrates of 25m × 50m size were randomly laid at each study site. All tree individuals of more than 1.5m height occurring within quadrates were counted and listed, diameter at breast height (DBH) and approximate tree height was measured, species density (trees ha^{-1}) and basal area were calculated (Ravindranath and Premnath, 1997). For associated vegetation of shrubs and herbs, the quadrates of 5m × 5m size and 1m × 1m size respectively were randomly laid at each study site. Quantitative analysis for determining herb, shrub and tree frequency, density and dominance were done (Mishra, 1968). The total number of individuals/quadrate were counted and identified. The plant species diversity was determined by using abundance values in Shannon's Index of General Diversity and calculated (Shannon, C.E. and Wiener, 1963) as per the following formula:

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Shannon-Wiener Index (H):
$H= -\sum (ni/N) \log (ni/N)$
Where, ni = total no. of individual species
N = Total number of all species.
The Dominance was determined by the following formula (Odum 1975):
Species Dominance Index (D):
$D=\sum (ni/N)^2$
The ni and N value is same as in Shannon-Wiener Index.

Based on feasibility and approachability of the area, seven out of thirteen study sites i.e. Balijan (ARB), Itanagar (ARI), Midphu (ARM), Nirjuli (ARJ) and Namdapha (ARN) in Arunachal Pradesh and Golaghat (ASG) and Hojai (ASH) in Assam were selected for studying *A. malaccensis* population and sample collection. The samples of all plant species were collected and brought to the lab, identified with the help of standard literature (Hajra et al., 1996) as well as by comparison with reference specimen available in departmental herbarium and the same were also deposited there. *A. malaccensis* supporting soils in natural and artificial habitats were also analyzed for their physical and chemical properties following standard procedures.

Data analysis
The total number of individuals of *A. malaccensis* and its associated plant species were used in calculating the Abundance, Frequency, Density, Basal Area, Relative Frequency (RF), Relative Density (RD), Relative Basal Area (RBA), Importance Value Index (IVI) of each types, Shannon-wiener index, Dominance and Abundance Frequency Ratio (AFR) in Microsoft Excel Spreadsheet and STATISTICA software.

III. RESULTS AND DISCUSSION

Distribution of A. malaccensis Lamk.
The present survey reports recurrence of natural *Aquilaria malaccensis* population **(Table 1, Plate 1)** after a long gap and updates its current distribution status in the forests of Arunachal Pradesh and Assam. The natural populace of *Aquilaria* was otherwise reported as totally vanished by earlier workers from Northeast India. This precious tree is regarded as 'Liquid Gold' in northeast India due to its high commercial values. Northeast Indian agarwood oil has high commercial value and graded as A+ oil with 100% purity, which is only found in Assam, India, (Anonymous, 2003) hence recurrence of natural population of *Aquilaria* plants in these area is worthy. Out of 39 *Aquilaria* growing sites surveyed, the target species was recorded only at 13 sites (**Figure 1**) of six districts (four from Arunachal Pradesh and two from Assam).

Aquilaria in natural forests was seen at only four sites i.e. Balijan (ARB), Bhismaknagar (ARBH), Namdapha (ARN) and Assam-Nagaland border (ASNB) contributing 30.7 % to the all sites surveyed. Only plantations were recorded at six sites i.e. Itanagar (ARI), Midpu (ARM), Nirjuli (ARJ), Roing (ARR), Miao (ARMO) and Hojai (ASH) contributing 46.1% where as at three sites i.e. Wakro (ARW), Bhekuliang (ARBE) and Golaghat (ASG), both natural as well as artificial plantations were observed with 23.1% share of total sites **(Table 1)**. The natural populations of *A. malaccensis* plants were observed specifically at Bangha Pahar (Balijan) of Papum Pare district; Lal pahar (Bhismaknagar) of Lower Dibang Valley district; Bhekuliang & Wakro of Lohit district and Namdapha of Changlang district in Arunachal Pradesh. The natural distribution was also observed in Majarbar grave yard (protected by Muslim NGO's and Forest department) and forests bordering to Nagaland of Golaghat district, Assam, where quite old aged trees were growing lavishly. The *A. malaccensis* in natural forest showed lesser population (12.8%) as compare to plantation sites (87.2 %) of the total surveyed population of north east India (**Figure 2**). The variations in distribution of agar tree might be due to the climatic condition, topography, ecosystem and disturbance gradients and altered soil conditions as a result of fast changing agricultural practices. The present status of wild pool of *Aquilaria* was very less, spatters and disappearing from forest at faster rate. The heavy exploitation took place between the late 1950s and the early 1980s (Chetpattananondh, 2012), burning, clearing practices for agriculture and shifting cultivation (Kobayashi 2004) were been the contributory factors for this depletion. This species faces a serious threat both from nature as well as by increasing anthropogenic activities which eventually led it to threatened or vulnerable. *Aquilaria* species was otherwise growing well in most of the above districts in higher densities (Barden et al., 2000).

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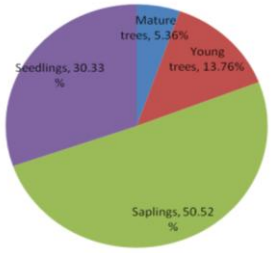

Figure 2: Percent occurrence of different growth stages of *Aquilaria malaccensis* in natural forests

Earlier in Arunachal Pradesh, the distribution of wild *Aquilaria* were reported from the evergreen forests at foothills of Kameng, Lower Subansiri, Siang, Changlang, Lohit and Tirap districts and Garo Hills of Meghalaya (Palit, 1996). The species is presently being cultivated artificially in many parts of Arunachal Pradesh and Assam. It has been raised artificially in Kakohi, Nirjuli, Itanagar, Midphu, Bordumsa, Geku, Roing, Pasighat areas of Arunachal Pradesh. The small scale artificial cultivation of this species has also been taken up at many places in the state due to knowledge about economic and medicinal values of this treasure tree species. In areas like, Itanagar, Midphu and Nirjuli of Papum Pare district, Arunachal Pradesh, a few scattered or small plantations, home gardens or roadside plantations have been raised**.** In Assam**,** wild *Aquilaria* was reported in Barak valley of upper Assam region (Chakrabarty, 1994), like Tinsukia, Jorhat, Dibrugarh, Silchar, Sibsagar, Golaghat, Nagaon, Lakhimpur, Sonitpur, Darrang, Goalpara, Kokrajhar, Karbi Anglong, North Cachar Hills and Cachar districts (Haridasan and Rao, 1985). In Assam, large scale commercial plantations and home gardens of *Aquilaria* have been reported at large in Hojai town, Golaghat and their out skirt foot hill terrains (Atal and Kapoor, 1982); although, it has not been widely established in artificial system because of the uncertainty of its agarwood production (Saikia and Khan, 2013).

Table 2: Abundance, Frequency, Relative density, Dominance and Plant population (%) of *A. malaccensis* Lamk. in two districts of Arunachal Pradesh.

Study site	Abundance	Relative Frequency	Relative Density	Dominance	Plant population (%)
Papum Pare	1.40	26.32	2.85	0.00081	40
Changlang	4.75	42.11	15.45	0.02386	60

On the basis of height, all *Aquilaria* individuals encountered during survey were categorized in four groups i.e. 1. Seedlings/New sprouts (individuals >1 m in height), 2. Saplings (<1 m - >6 m in height), 3. Young trees (< 6 m - > 10 m in height) and 4. matured trees (< 10 m in height). The target species was mostly seen as saplings contributed highest (50.52%) to the total agar population followed by seedlings/new sprouts (30.33%). Young trees were observed in a lesser number (13.76%); however, naturally growing matured trees were less or rarely observed contributing to 5.36% only to the total population (**Figure 3**). This could be an attribution of degree of overexploitations (Nath et al., 1999). At difficult rocky terrain slopes of Balijan (ARB) and hill top of Namdapha National Park (ARN), scattered young saplings were observed in small but pure blocks in natural forests **(Plate 1**). Less percentage of seedlings in forests may be due to more demand of natural *Aquilaria* variety as a result of collection of young seedlings by the agar growers from forests as revealed during questionnaire survey and personal interviews. The presence of low but significant number of young trees (13.76%) and a few matured trees (5.36%) shows the innate strength of this tree species to survive in harsh conditions hence provide an opportunity to adopt appropriate steps for conservation of these stands immediately.

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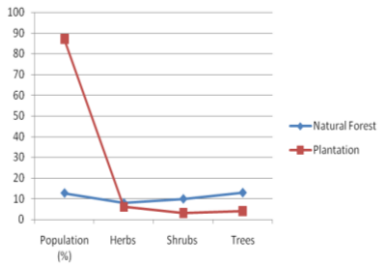

Figure 3: Diversity of herbs, shrubs and tree species with *A. malaccensis* population in natural forest and plantation sites

The naturally growing mature trees were observed only at Balijan, A-N border and Golaghat sites, however; large commercial plantations of *A. malaccensis* were observed in Hojai of Nagaon district of Assam where its essential oil is being extracted in small distillation units and sold to perfume industry. This area is considered as the commercial hub for perfumery distillation unit of *Aquilaria* woods. The plantations were also taken up as a part of research work and for extraction of agar oil by Research & Development Centre, AJMAL Group, Hojai, Assam. The success of regeneration can be predicted on the basis of current population structure, growth and fecundity (Soehartono and Newton, 2001b). At present, the species is mainly surviving in plantations. Many acres of plains, foot hills and paddy fields have been converted into *Aquilaria* plantation in and around Hojai town where as a number of private plantations as home gardens were being maintained in Golaghat district at large scale. Some small Agar plantations were also raised at Jorhat, Sivasagar, Tinsukia, and North Cachar Hill districts of Assam. As per the requirement, individual farmers also grow Agar tree in requisite locations; such as a shade provider to tea crop, a fence supporter and for aesthetic purposes.

Composition of Associated Vegetation of A. malaccensis Lamk.

On the basis of accessibility, topography and approachability of area, population studies of *A. malaccensis* and its associates were carried out at seven study sites i.e. ARB, ARI, ARJ, ARM, ARN, ASG and ASH. The comparison of natural *Aquilaria* population studies were done at two sites of Arunachal Pradesh i.e. Papum Pare and Changlang districts of Arunachal Pradesh. Of the total *Aquilaria* population, 60 % was recorded from Changlang and 40 % was recorded from Papum Pare district. The abundance (4.75), relative density (15.45) and dominance (0.024) of *A. malaccensis* were higher in Changlang than Papum Pare i.e. 1.40, 2.85 & 0.0008 % respectively **(Table 2)**. The occurrence frequency was also higher at Changlang (42.11 %) as compare to Papum Pare (26.32 %). *Aquilaria* associated vegetation was consisting of 40 different plant species (16 trees, 13 herbs and 11 shrubs) belonging to 30 families **(Table 3)**.

Table 3: Plants associates of *A. malaccensis* Lamk.

Sl. No	Herbs species (Family)	Shurbs species (Family)	Tree species (Family)
1.	*Adiantum pedatum* (Pteridaceae)	*Bidens bipinnata* (Asteraceae)	*Angiopteris evecta* (Marattiaceae)
2.	*Ageratum conyzoides* (Asteraceae)	*Borassus* sp. (Aracaceae)	*Bauhinia purpurea* (Fabaceae)
3.	*Alocasia indica* (Araceae)	*Calamus rotang* (Aracaceae)	*Canarium strictum* (Burseraceae)
4.	*Anaphalis contorta* (Asteraceae)	Clematis gouriana (Rununculaceae)	*Cyathea spinulosa* (Cyatheaceae)
5.	*Arisaema ringens* (Araceae)	*Dendrocalamus* sp. (Poaceae)	*Dillenia indica* (Dilleniaceae)
6.	*Artemesia maritima* (Asteraceae)	*Deschampsia cespitosa* (Poaceae)	*Duabanga grandiflora* (Lythraceae)
7.	*Chinopodium umbrosum* (Chenopodiaceae)	*Eupatorium adenophorum* (Asteraceae)	*Dysoxylum binectariferum* (Meliaceae)

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8.	*Coptis teeta* (Ranunculaceae)	*Fagaria nubicola* (Roseaceae)	*Ficus benghalensis* (Moraceae)
9.	*Curcuma longa* (Zingiberaceae)	*Osbeckia chinensis* (Melastomataceae)	*Glycosmis pentaphylla* (Rutaceae)
10.	*Dryopteris spp.* (Dryopteridaceae)	*Pandanus tectorius* (Pandanceae)	*Litsea cubeba* (Lauraceae)
11.	*Impatiens urticifolia* (Balsaminaceae)	*Strobilanthes coloratus* (Acanthaceae)	*Livistona jenkinsiana* (Aracaceae)
12.	*Mimosa pudica* (Fabaceae)		*Michelia* sp. (Magnoliaceae)
13.	*Musa balbisiana.* (Musaceae)		*Podophyllum hexandrum* (Berberidaceae)
14.			*Rhododendron reticulatum* (Ericaceae)
15.			*Shorea assamica* (Dipterocarpaceae)
16.			*Terminalia myriocarpa* (Combretaceae)

At natural sites, more species of herbs, shrubs and trees were recorded **(Figure 2)** as compare to plantation sites. Most of the plant species except *Adiantum pedatum, Arisaema ringens, Curcuma longa, Borassus sp. Bauhinia purpurea* and *Canarium strictum* were growing commonly in all seven study sites. *Adiantum pedatum, Bauhinia purpurea* and *Curcuma longa* were only growing at ARB whereas *Arisaema ringens, Borassus sp.* and *Canarium strictum* were restricted to ARN**.** *Dillenia indica, Duabanga grandiflora, Ficus benghalensis, Dysoxylum binectariferum, Michelia sp., Terminalia myriocarpa* and *Shorea assamica* were some of the dominant tree species found growing symbiotically with *Aquilaria* in the natural forest sites and formed main canopy for it. This verifies the fact that it is a shade loving tree (Guedje et al., 2003). The tall canopy forming tree species in the forest restrict light availability to members of the under-storey trees species (Gunn et al., 2003) and other ground level plant species which applies to *Aquilaria* too. There were few tree associates such as *Litsea cubeba* and *Podophyllum hexandrum* that appeared sporadically at these sites.

The statistical analysis of collected data shows that the most abundantly occurring plant species associated with agar tree were herbs followed by shrubs and trees. Among the herb species, *Curcuma longa* (8.80 %) was most common (**Table 4**) whereas *Dendrocalamus* sp. (7.80 %) was dominant among shrubs and *Duabanga grandiflora* (3.33 %) among trees respectively. The lowest abundance was recorded in case of *Alocasia indica* (2.33 %), *Deschampsia cespitosa* (2.20 %) and *Terminalia myriocarpa* (1.00 %) among herb, shrub and tree respectively. The highest frequency of occurrence was recorded in case of *Calamus rotang* (14.00 %), a shrub species followed by *Angioptris evecta* of tree species (10.00 %) and *Ageratum conyzoides, Artemesia maritima, Chinopodium umbrosum* and *Mimosa pudica* of herb species (8.75 % each). The lowest frequency was recorded of *Clematis gouriana* and *Pandanus tectorius* (6.00 % each) among shrubs followed by *Arisaema ringens* and *Coptis teeta* (5.00 % each) among herbs and *Terminalia myriocarpa* (2.68 %) in trees. In general, *Curcuma longa* (0.176 %) showed maximum abundance frequency ratio **(Table 4 & 5)** followed by *Deschampsia cespitosa* (0.156 %) and *Duabanga grandiflora* (0.110 %).

Table 4: Abundance, Relative frequency, Important Value Index (IVI), Shannon-Wiener Index (H'), Dominance (D), Abundance frequency Ratio (A/F) and Density of Herbs and Shrubs associated with *A. malaccensis* Lamk.

Sl.No	Name of species	Abundance	Relative frequency	IVI	H	D	A/F	Density (No./ha)
	Herbs							
1.	*Adiantum pedatum*	4.00	6.25	19.32	0.077	0.004	0.0800	200
2.	*Ageratum conyzoides*	7.14	8.75	36.44	0.111	0.023	0.1020	500
3.	*Alocasia indica*	2.33	7.50	15.84	0.067	0.002	0.0389	140
4.	*Anaphalis contorta*	3.00	7.50	18.22	0.074	0.003	0.0500	180
5.	*Arisaema ringens*	3.25	5.00	14.63	0.064	0.002	0.0813	130
6.	*Artemesia maritima*	2.43	8.75	18.16	0.074	0.003	0.0347	170
7.	*Chinopodium umbrosum*	5.00	8.75	28.13	0.096	0.011	0.0714	350

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8.	*Coptis teeta*	2.50	5.00	12.41	0.057	0.001	0.0625	100
9.	*Curcuma longa*	8.80	6.25	35.01	0.109	0.018	0.1760	440
10.	*Dryopteris* sp.	4.00	6.25	19.32	0.077	0.004	0.0800	200
11.	*Impatiens urticifolia*	3.00	7.50	18.22	0.074	0.003	0.0500	180
12.	*Mimosa pudica*	3.43	8.75	22.04	0.083	0.005	0.0490	240
13.	*Musa balbisiana*	3.80	6.25	18.67	0.075	0.003	0.0760	190
	Shrubs							
14.	*Bidens bipinnata*	2.50	12.00	26.65	0.093	0.006	0.0417	150
15.	*Borassus* sp.	4.00	8.00	27.16	0.094	0.007	0.1000	160
16.	*Calamus rotang*	3.29	14.00	35.01	0.109	0.015	0.0469	230
17.	*Clematis buchananiana*	4.67	6.00	25.86	0.092	0.006	0.1556	140
18.	*Dendrocalamus* sp.	7.80	10.00	51.53	0.131	0.043	0.1560	390
19.	*Deschampsia cespitosa*	2.20	10.00	21.71	0.083	0.003	0.0440	110
20.	*Eupatorium adenophorum*	3.83	12.00	34.46	0.108	0.015	0.0639	230
21.	*Fagaria nubicola*	4.17	12.00	36.42	0.111	0.018	0.0694	250
22.	*Osbeckia chinensis*	2.60	10.00	23.84	0.087	0.005	0.0520	130
23.	*Pandanus tectorius*	2.67	6.00	17.35	0.072	0.002	0.0889	80
24.	*Strobilanthes coloratus*	4.50	7.50	23.58	0.087	0.007	0.0750	270

The important value index (IVI) of associated plant species ranged from 10.41 to 55.00 % **(Table 4&5)**. The highest diversity and dominance of individual species using abundance values was obtained in case of *Dendrocalamus* sp. (0.135 & 0.043 %) whereas lowest diversity was recorded of *Ficus benghalensis* (0.035 %). *Terminalia myriocarpa* was found with lowest dominance (0.0002 %). The variation in species diversity varied between 0.035 to 0.135 % and dominance between 0.0002 to 0.043 %. The highest species density/ha was recorded of *Ageratum conyzoides* (500/ha) followed by *Curcuma longa* (440/ha) and *Dendrocalamus* sp. (390/ha). The basal area of associative tree species per hectare were measured **(Table 5)** and *Ficus benghalensis* (57.50 m^2/ha) recorded with maximum basal area followed by *Duabanga grandiflora* (19.98 m^2/ha), *Podophyllum* sp. and *Terminalia myriocarpa* (16.12 m^2/ha each). The lowest basal area/ha was measured in case of *Rhododendron* sp. (0.18 m^2/ha) followed by *Dillenia indica* (0.31 m^2/ha) and *Shorea assamica* (0.51 m^2/ha) respectively. The basal area of *Aquilaria malaccensis* was 0.45 m^2/ha with highest abundance (5.94) and relative frequency (21.42) as compare to other tree species. The associations of various plant species including palms like Licuala and Rattans with *Aquilaria* species have also been reported (Appanah, 1990).

Table 5: Abundance, Relative frequency, Important Value Index (IVI), Shannon-Wiener Index (H'), Dominance (D), Abundance frequency Ratio (A/F), Basal area (m^2)/ha and Density of Trees associated with *A. malaccensis* Lamk.

Sl. No.	Name of tree species	Abundance	Relative Frequency	IVI	H	D	A/F	Basal area (m^2)/ha	Density (No/ha)
1.	*Aquillaria agallocha*	5.94	21.42	27.76	0.029	0.0072	0.076	0.45	12
2.	*Angiopetris evecta*	2.57	10.00	25.04	0.090	0.0183	0.04	2.04	180
3.	*Bauhinia purpurea*	2.00	5.71	12.16	0.056	0.0036	0.05	0.58	80
4.	*Canarium strictum*	1.33	4.29	10.41	0.051	0.0009	0.04	4.21	40
5.	*Cyathea spinulosa*	1.83	8.57	19.70	0.078	0.0068	0.03	3.85	110
6.	*Dillenia indica*	2.00	5.71	11.96	0.056	0.0036	0.05	0.31	80
7.	*Duabanga grandiflora*	3.33	4.29	26.60	0.093	0.0057	0.11	19.98	100
8.	*Dysoxylum binectariferum*	1.67	4.29	10.90	0.052	0.0014	0.06	3.85	50
9.	*Ficus benghalensis*	1.40	7.14	55.00	0.135	0.0028	0.03	57.5	70
10.	*Glycosmis pentaphylla*	1.83	8.57	17.84	0.073	0.0068	0.03	1.35	110
11.	*Litsea cubeba*	1.20	7.14	12.37	0.057	0.002	0.02	0.96	60
12.	*Livistona jenkinsiana*	2.50	8.57	23.25	0.086	0.0127	0.04	4.59	150
13.	*Michelia sp.*	2.00	4.29	10.93	0.052	0.002	0.07	2.87	60
14.	*Podophyllum hexandrum*	1.25	5.71	21.41	0.082	0.0014	0.03	16.12	50
15.	*Rhododendron reticulatum*	2.00	7.14	14.79	0.064	0.0057	0.04	0.18	100
16.	*Shorea assamica*	1.75	5.71	11.35	0.054	0.0028	0.04	0.51	70
17.	*Terminalia myriocarpa*	1.00	2.86	16.30	0.069	0.0002	0.05	16.12	20

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The variation in occurrence of *A. malaccensis* along with different plant species in rocky terrain showed their wide range of tolerance to environmental factors and adaptability. *Aquilaria* grows well in high moisture contents and rich organic matter. More herb species being seasonal gradually die with the onset of winter season support mineralization and reappears. Singadan et al., 2002 have reported that the variation in species richness, composition and distribution of many plant species in the forest is mainly governed by a series of biological interaction, level of elevation, topography, climatic and historical factors etc.

The physic-chemical analysis (Data not shown) of *Aquilaria malaccensis* supporting soil of natural forest sites indicated that it prefers acidic soil (pH 5.2 to 5.3) and silty loams to silty clayey textures. High moisture contents (22.5 -30.1 %) with poor electrical conductivity, phosphorus, potassium contents and optimum organic carbon & nitrogen in soil appears to favour the growth of *Aquilaria* in natural sites of Arunachal Pradesh and Assam.

IV. CONCLUSION

As such, *Aquilaria* species has no hurdle in natural regeneration from seeds which proliferate profusely but the species has to come down to the status of 'Vulnerable', Red Data List of IUCN and considered critically endangered in India. The reasons for this depletion include irrational extraction, short seed viability period leading to lesser germination, insect infestation, mistaken fellings in search of resinous wood etc. At present, the species is mainly surviving in plantations however; in present studies, natural populace of *A. malaccensis* has been reported after a long gap. The wild genetic pool of Indian *Aquilaria* is most preferred source of world famous agar oil hence remaining natural population should be immediately and effectively be conserved by the participation of local people and by applying modern biotechnological approaches like plant tissue culture (Tabin et al., 2009; He et al., 2005). The indigenous knowledge of local tribes may also be helpful for sustainable management of this species.

REFERENCES

[1] Anonymous, "Review of significant trade *Aquilaria malaccensis"*. Available from URL: http://www.cites. org/eng/com/PC/14/E-PC14-09-02-02-A2.pdf. 2003.
[2] Appanah, S., "Plant-pollinator interactions in Malaysian rain forests", In: Bawa, K. S., Hadley, M (Eds.), Reproductive Ecology of Tropical Forest Plants, Man and the Biosphere Series, Vol. 7. UNESCO and the Parthenon Publishing Group, Paris, 1990.
[3] Atal, C. K. and Kapoor, B. M., "Cultivation and utilization of Aromatic Plants", RRL, CSIR, Jammu-Tawi, India, 1982.
[4] Barden, A., Awang, A., Mulliken, T. and Song, M., "Heart of the matter: agarwood use and trade and CITES implementation for *A. Malaccensis*" TRAFFIC International, Cambridge, UK. Rewritten copy of Chai, B. @http://www.traffic.org/news/agarwood.pdf., 2000.
[5] Bhuiyan, M.N.I., Begum, J. and Bhuiyan, M. N. H., "Analysis of essential oil of eaglewood tree (*Aqulilaria agallocha* Roxb.) by gas chromatography mass spectrometry", Bangladesh J Pharmacol, 4: 24–28, 2009.
[6] Chakrabarty, K., Kumar, A. and Menon, V., "Trade in Agarwood", WWF/TRAFFIC-India,New Delhi, 1994.
[7] Chetpattananondh, P., "Overview of the agarwood oil industry", In: International Conference Proceedings of IFEAT on 'Essential Asia' held at Singapore from 4 - 8 November, 2012 Pp. 131-138. 2012.
[8] CITES. Resolution of the Conference of the Parties. Ninth Meeting of the Conference of the Parties, Fort Lauderdale, USA, 7-18 November, 1994.
[9] Donovan, D. G., Puri, R. K., "Learning from traditional knowledge of non-timber forest products: Penan Benalui and the autecology of *Aquilaria* in Indonesian", Borneo Ecol Society, 9(3): 1-23, 2004.
[10] Giri, G. S., "Review of Significant Trade Aquilaria malaccensis. Agarwood: Trade and CITES Implementation in Southeast Asia" Unpublished report prepared for TRAFFIC Southeast Asia, Malaysia, 2003.
[11] Guedje, N. M., Lejoly, J., Nkongmeneck, B. A. and Jonkers, W. B. J., "Population dynamics of Garcinia lucida (Clusiaceae) in Cameroonian Atlantic forests". Forest Ecology and Management, 177: 231-241, 2003.
[12] Gunn, B. V., Stevens. P., Singadan, M., Sunari, L. and Chatterton, P. F., "Eaglewood in Papua New Guinea" In: First International Agarwood Conference, Vietnam. 2003
[13] Hajra, P. K, Verma, D.M. and Giri, G.S., "Materials for the Flora of Arunachal Pradesh" Botanical Survey of India, Calcutta, vol. I., 1996
[14] Haridasan, K., Rao, R. R., "Forest Flora of Meghalaya", Bishen Singh Mahendra Pal Singh, Dehra Dun, 1985, Vol. I and II, 1985.
[15] He, M. L., QI, S. Y. and Hu, L. J., "Rapid in vitro propagation of medicinally important *Aquilaria malaccensis"*. J Zhejiang Univ SCI, 6B (8):849-852, 2005.
[16] IUCN. In: IUCN Red List of Threatened Species. <http://www.iucnredlist.org>. Downloaded on 31st July, 2014.
[17] Kanjilal, U. N., Kanjilal, P. C., Dey, R. M. and Das, A., "Flora of Assam" , Vol IV. Government of Assam , Assam , India , reprinted 1982
[18] Kim, Y. C., Lee, E. H., Lee, Y. M., Kim, H. K., Song, B. K., Lee, E. J. and Kim, H. M., "The effect of the aqueous extract of *Aquilaria agallocha* stems on the immediate hypersensitivity reactions", *Journal of Ethnopharmacology*, 58: 31-38, 1997.
[19] Liu, J., Wu, J., Zhao, Y. X., Deng, Y. Y., Mei, W. L. and Dai, H. F., "A new cytotoxic 2-(2-phenylethyl) chromone from Chinese eaglewood", Chinese Chemical Letters, 19: 934–36, 2008.
[20] Magurran, A. E., "Measuring biological diversity". Blackwell publishing, UK, 2004.

ISSN: 2319-8753

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(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 11, November 2014

[21] Misra, R. S., "Ecology Work Book". Oxford and IBB publishing, co. pvt. Ltd. New Delhi, 1968.
[22] Naef, R. "The volatile and semi-volatile constituents of agarwood, the infected heartwood of *Aquilaria* species: A review". Flavour Frag Journal, 26: 73-87, 2011.
[23] Nath, S. C., Kalita, J. and Saikia, N., "Germination studies on the seeds of *Aquilaria malaccensis* Lamk. A potential crop for fragrance industry", Indian Perfumery Essential Oil Association of India, 43 (3): 159-163, 1999.
[24] Palit, M. K., "*Aquilaria malaccensis* Roxb.-A commercial agar oil yielding tree of the north east India", Arunachal Forest News, 14 (4): 30-33, 1996.
[25] Ravindranath, S. and Premnath, S., "Biomass studies: Field methods for monitoring biomass", Oxford & IBH Publishing Co. PVT. Ltd., New Delhi, 1997.
[26] Saikia, M., "*In-Vitro* regeneration of *Aquilaria malaccensis* Lam. and acclimatization with endomycorrhizal symbiosis for enhanced field establishment", Ph.D. Dissertation. NERIST (Deemed University), Arunachal Pradesh, India, 2014.
[27] Saikia, P. and Khan, M. L., "Population structure and regeneration status of *Aquilaria malaccensis* Lam. in homegardens of Upper Assam, northeast India", *Tropical Ecology*, 54 (1): 1-13, 2013.
[28] Shannon, C.E. and Wiener, W., "The Mathematical Theory of Communities", University of Illinois Press, Urbana, Illinois, pp. 117, 1963.
[29] Singadan, M., Sunari, L. and Fazang, K., "Gaharu trade on the Keram River area of Madang Province Papua New Guinea" Part of the 'Domestication of Papua New Guinea's Indigenous Forest Species' Project managed by CSIRO, Forestry and Forest Products, Canberra, Australia in conjunction with WWF South Pacific Programme, Madang, PNG and PNG Forest Research Institute, Lae, PNG, 2002.
[30] Soehartono, T., and Newton, A. C., "Conservation and sustainable use of tropical trees in the genus *Aquilaria* II. The impact of Gaharu harvesting in Indonesia", Biological Conservation, 97: 29-41, 2001b.
[31] Tabin, T., Arunachalam, A., Shrivastava, Karuna and Arunachalam, K., "Effect of arbuscular mycorrhizal fungi on damping-off disease in *Aquilaria agallocha* Roxb. Seedlings", Tropical Ecology, 50 (2): 243-248, 2009.
[32] Yumi, Z. Has-Yun, Hashim, A. and Phirdaous, A. A., "Screening of anticancer activity from agarwood essential oil", Pharmacognosy Research, 6(3): 191-194**,** 2014.
[33] Zich, F.A. and Compton, J. "The Final Frontier: Towards Sustainable Management of Papua New Guinea's Gaharu" Resource TRAFFIC Oceania-WWF South Pacific Programm, 2001.