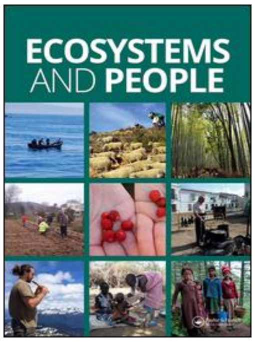

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SHORT RESEARCH PAPER

Homegardens of upper Assam, northeast India: a typical example of on farm conservation of Agarwood (*Aquilaria malaccensis* Lam.)

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This study has investigated the potential of homegardens in conservation of Agarwood (*Aquilaria malaccensis* Lam.), a critically endangered tree species of northeast India with great economic value. Agarwood is the most dominant tree species in the studied homegardens of upper Assam as it has the highest frequency (98%) and density (1443 individuals ha^{-1}) and it contributes 34% of the total tree density. It contributes significantly to the economy of the local people and income generation from Agarwood by individual family ranges from ₹ 3000.00 (US$ 600.00) to ₹ 9,00,000.00 (US$ 18,000.00) with an average of ₹ 1,14,393.00 (US$ 2287.86) per year. Besides its economic potential, it is also on the verge of extinction and needs proper conservation and management for further existence. Agarwood shows good regeneration and population status in studied homegardens of upper Assam. Therefore, homegardens can save the species from the risk of extinction and thus can be considered as a tool of on farm conservation of Agarwood.

Keywords: *Aquilaria malaccensis*; homegarden; species diversity; population structure; regeneration status; socio-economic prospects

Introduction

Homegardens are typical traditional agroecosystems close to human dwellings, managed intensively for everyday needs. They harbor unique and sometimes rare genetic diversity of crop plants and their wild relatives. They have attained international importance due to their basic objective of ensuring sustained availability of multiple products (Michon et al. 1983), besides generating employment and cash income (Padoch & De Jong 1991). They have been receiving enormous attention from scientists, researchers, especially ethnobotanists because of their great contribution to biodiversity conservation, ecological and socio-economic functions, indigenous peoples' livelihoods and soil conservation potential. Several studies throughout the world and India showed that homegardens are the sites of highest plant diversity including crop and non-crop species (Coomes & Ban 2004). Homegardens also serve as repositories of genetic resources and biodiversity to a greater extent (Ouinsavi & Sokpon 2008).

Though the practice of homegarden in Assam and northeast India is very common, very few studies have been undertaken on the traditional homegardens in this region (Ramakrishnan et al. 1996; Shrivastava & Heinen 2005; Sahoo 2009; Tangjang & Arunachalam 2009; Saikia & Khan 2011, 2014). Study on plant biodiversity in homegardens of Barak valley, Assam, by Das and Das (2005) showed homegarden as a reservoir of crop and other economic plant diversity for future use. Similarly, Saikia et al. (2012) also reported high plant diversity and its perspective to conserve species with great economic potential in the homegardens of upper Assam. On the other hand, Borthakur et al. (1998) stressed the role of homegardens, traditional Indian experience of management and conservation of biodiversity in Assam. One such example is the conservation of Agarwood (*Aquilaria malaccensis* Lam.) in homegardens of upper Assam. It is a fast growing tropical forest tree belonging to family Thymelaeaceae. It produces resin as a defense mechanism against infection or injury which is extensively used in incense and perfume and in traditional medicine (Anonymous 2003). Natural populations of Agarwood are widely distributed in south and south-East Asia and in India; it is found mostly in foothills of northeastern region and West Bengal. Large-scale harvesting of the species from natural forests resulted in rapid depletion of the species in the wild and its insertion in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1994) to scale the international trade within sustainable levels. The species is classified as 'Vulnerable' globally, 'Critically Endangered' in India (IUCN 2009) and almost 'Extinct in wild' in Assam (Anonymous 2003).

Agarwood has not been widely established in plantations because of the uncertainty of agarwood oil production as it used to produce oil as a defense mechanism

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against infection or injury. Because of the high economic potential, attempts are now being made to cultivate it in Assam, adjoining areas in northeast India and other parts around the world. In Assam, it is cultivated extensively in the homegardens of upper Assam along with other plant species as it contributes significantly to the economy of the local people of the region. In this paper, we studied the ecology and status of *A. malaccensis* in homegardens and its contribution to the rural economy of upper Assam.

Materials and methods

Study sites

The study was conducted in 135 randomly selected homegardens of Golaghat and Jorhat districts of Upper Assam, northeast India (25° 48′ to 27° 10′ N and 93° 17′ to 94° 36′ E), covering *ca*. 6400 square kilometer area (Figure 1). The area is surrounded by Sibsagar and Dibrugarh districts in the east, Karbi Anglong and Nagaon districts to the west, Lakhimpur and Sonitpur districts in the north and the bordering state of Nagaland in the south. The climate is tropical having hot and humid summers (39°C during June–July) and cool winters (9°C during December–January). Annual average rainfall of Golaghat and Jorhat districts is 1300 and 2244 mm, respectively. The area experiences maximum precipitation during June and July. The population density of Golaghat and Jorhat districts are 236 and 354 people per square kilometer (Census of India 2001). The Assamese people are rich in cultural activities and maintain homegardens of different sizes. The economy of upper Assam is mainly agro-based and homegarden also contributes a share.

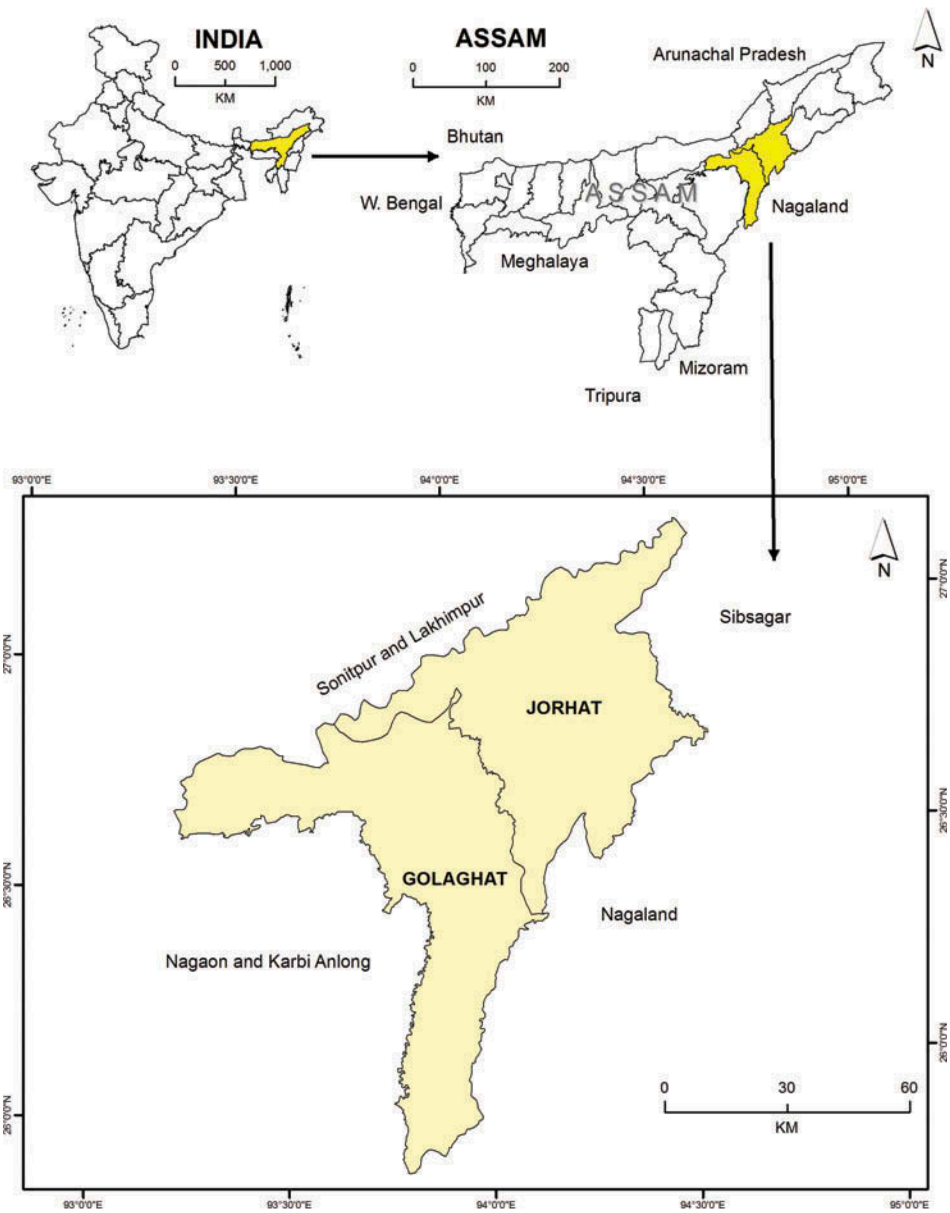

Figure 1. Map of the study site (Golaghat and Jorhat districts of upper Assam).

Methodology

An extensive field survey was undertaken in a total of 135 randomly selected homegardens from 27 villages of Jorhat and Golaghat districts of upper Assam during 2007–2010 for vegetation analysis as well as for socio-economic data. First, preliminary survey was done to gather the information about agarwood cultivating areas of both the districts. Then, 27 villages were selected randomly from the hub of agarwood cultivating areas and similarly 135 homegardens selected from those villages in an average of five homegardens per village. Socio-economic information was collected through interview-based fieldwork with 135 household owners using datasheets of fixed queries including number of harvested trees, income from individual trees, total income generated from agarwood, year of agarwood cultivation, etc. following the methodology of Vogl et al. (2004). Vegetation was studied using quadrat method covering a minimum of 30% area in each homegarden, and random quadrats of 10 m × 10 m size were laid for trees and within each of these quadrat, and one 5 m × 5 m quadrat for shrubs and two 1 m × 1 m quadrats for herbs were laid in each homegarden. Diameter at breast height (1.37 m above ground) of all the individual trees was recorded. Individuals were grouped into seedlings (≤20 cm height), saplings (≤3.18 cm DBH and >20 cm height) and trees (>3.18 cm DBH) for analysis of population structure. Regeneration was considered as (1) good, if number of seedlings > number of saplings > number of adult; (2) fair, if number of seedling > number of sapling ≤ number of adult; (3) poor, if species survived in only sapling stage or sapling population was less than that of adult; and (4) no regeneration, if only adult individuals were present in the population (Uma 2001). Out of the total 135 studied homegardens, eight homegardens (four from each district) were selected based on homegarden size (at least 0.13 ha size), location (easily accessible and easy for communication, so that periodic visit should possible) and vegetation (mixed culture with complex multi layered structure) to evaluate the seedling survival and growth of Agarwood and were studied in permanent quadrats from March 2008 to March 2010 by enumerating the population size of seedlings, saplings and trees at 3-month interval following Khumbongmayum (2004). Sufficient number of seedlings based on the availability (ranging 20 to 95) per homegarden was tagged with aluminum labels, and growth of the tagged seedlings was measured in terms of collar diameter, height, and leaf number.

Data analysis

Quantitative analysis of vegetation was done following Misra (1968). Importance Value Index (IVI) was computed separately for tree, shrub, and herb species. IVI was calculated by summing up relative density, relative frequency, and relative dominance for tree species and summing up relative frequency and relative density values for bamboos, shrubs, and herbs species. The species richness was calculated by using the 'Margalef's index of richness' (Dmg) (Magurran 1988) to give an idea about the species richness of the studied homegardens.

$$\mathrm{Dmg} = (S - 1)/\mathrm{In}(n) \tag{1}$$

where S = Total number of species.
n = Total number of individuals.

The Shannon–Wiener Diversity Index (Shannon & Wiener 1963) was calculated to give a clear picture of the species composition of the studied homegardens from the IVI values using the formula given by Magurran (1988).

$$\mathrm{H} = -\sum_{i=1}^{s} pi \ln pi \tag{2}$$

where p_i is the proportion of the IVI of ith species and the IVI of all the species (n_i/N) (N is number of species).

Concentration of dominance was assessed to get an idea about the species dominance in the studied homegardens by Simpson's Index (Simpson 1949)

$$\mathrm{CD} = \sum_{i=1}^{s} (pi)^2 \tag{3}$$

where p_i is the same as for the Shannon–Wiener information function.

An evenness index was calculated from Shannon–Wiener Diversity Index using the below mentioned formula to get an idea about how close in numbers each species in the studied homegardens.

$$\mathrm{E} = \mathrm{H}'/\mathrm{H}'\mathrm{max} \tag{4}$$

where, H' is Shannon–Wiener Diversity Index and H'max = lnS (where S = total number of species).

The ratio of abundance to frequency was used to interpret the distribution pattern of the species (Whitford 1949). The ratio of abundance to frequency indicates regular distribution if below 0.025, random distribution between 0.025 and 0.05 and contagious if >0.05 (Curtis & Cottam 1956).

Different statistical analysis (Standard error and F-test of ANOVA) has been done using different statistical software like MS-excel and SYSTAT.

Results

Plant species diversity in homegardens of upper Assam

People of upper Assam maintained homegardens of varied size ranging from 535.1 to 4013.4 m^2 (mean 1724.9 m^2; SE ± 64.6). Our study shows that

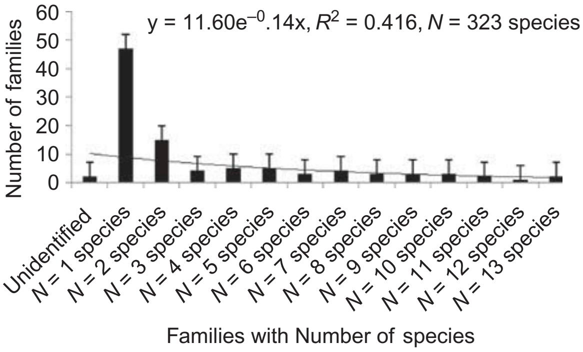

Figure 2. Distribution of families according to species number in the studied homegardens.

homegardens of upper Assam are very rich in plant diversity. Altogether 323 plant species belonging to 241 genera under 97 families consisting of 106 herbs, 61 shrubs and 156 trees were recorded. Highest diversity is contributed by the family Euphorbiaceae and Moraceae with 13 species each followed by Poaceae with 12 different plant species. Distributions of families according to species number in the studied homegardens are presented in Figure 2, and most frequently occurring important homegarden plants of upper Assam are mentioned in Table 1. The present study reported 17 to 108 species (with a mean of 48 ± 1.04) per homegarden. The ratio of abundance to frequency indicated contagious distribution of plant species in homegardens of upper Assam except *Mangifera indica* L. which showed random distribution with abundance to frequency ratio of 0.049. Although tree density (4259 individuals ha^{-1}) in homegardens of upper Assam was much higher, the basal area of tree species (6.01 m^2 ha^{-1}) was very low. Vegetation study revealed that Agarwood has the highest frequency (98%) and density (1443 individuals ha^{-1}) contributing 34% of total tree density ranking as the most dominant tree species thereby showing the trend of monoculture in the homegardens of upper Assam. The Shannon–Wiener diversity indices and all other community parameters of herbs, shrubs and trees in homegardens of upper Assam are shown in Table 2. The values of species diversity showed the trend that diversity of trees is greater than herbs which are greater than shrubs (tree > herb > shrub), while the concentration dominance showed the opposite trend that concentration of dominance for shrub is greater than trees which are greater herbs (shrub > tree > herb) in the homegardens of upper Assam.

Table 2. Community characteristics of all the studied homegardens of upper Assam, northeast India.

Parameters	Tree	Shrub	Herb
Number of families	53	28	43
Number of genera	109	49	88
Species richness	156	61	106
Species richness index	18.31	17.10	11.24
Density (ha^{-1})	4259	11581	478884
Basal area (m^2 ha^{-1})	6.01	-	-
Diversity (Shannon's H')	4.00	3.48	3.81
Concentration of dominance	0.05	0.09	0.04
Evenness Index	0.79	0.68	0.76

Table 1. List of most frequently occurring important tree species of homegarden of upper Assam; their local name, density (ha^{-1}), frequency, IVI, habit, status and uses.

Species	Local name	Density (ha^{-1})	Frequency	IVI	Present in HG	Habit	Status	Uses
Alstonia scholaris (L.) R.Br.	Chatiyana	16	12	2.90	66	Tree	Native	Timber
Aquilaria malaccensis Lam.	Agaru	1443	98	49.50	135	Tree	Native	Cash crop
Areca catechu L.	Tamul	554	74	24.94	133	Tree	Exotic	Masticator, cash crop
Artocarpus heterophyllus Lam.	Kothal	35	25	5.49	100	Tree	Native	Fruit, timber
Bambusa pallida Munro.	Jatibanh	1158	11	28.96	61	Tree	Native	Building material, cash crop
Carica papaya L.	Amita	34	19	3.95	89	Tree	Exotic	Fruit, vegetable
Citrus limon (L.) Burm.f.	Kazinemu	79	10	2.65	55	Tree	Native	Fruit
Cocos nucifera L.	Narikol	26	18	4.38	87	Tree	Exotic	Fruit
Mangifera indica L.	Aam	62	36	7.79	122	Tree	Native	Fruit, timber
Musa acuminata Colla.	Jahajikol	64	12	3.64	60	Tree	Native	Fruit
Musa balbisiana Colla.	Bhimkol	137	25	7.40	92	Tree	Native	Fruit
Musa calosperma F. Muell.	Senikol	72	14	4.14	65	Tree	Native	Fruit
Psidium guyava L.	Madhuri	17	12	2.50	75	Tree	Exotic	Fruit
Tectona grandis L.	Segun	25	10	2.83	41	Tree	Native	Timber
Terminalia chebula Retz.	Hilikha	15	12	2.95	72	Tree	Native	Timber
Toona ciliata M. Roem.	Poma	14	10	2.88	48	Tree	Native	Timber

Socio-economic prospects of Agarwood in homegardens of upper Assam

Agarwood contributes significantly to the economy of the local people, and the price of a single tree may vary from ₹ 150.00 ([1]US$ 3.00) to ₹ 40,000.00 (US$ 800.00) or even ₹ 1,00,000.00 (US$ 2000.00) based on its resin quantity. The income from Agarwood by individual family ranges from ₹ 3000.00 (US$ 600.00; from 10 trees after 10 years) to ₹ 9,00,000.00 (US$ 18,000.00; 500 trees after 20 years) with an average of ₹ 1,14,393.00 (US$ 2287.86; 106 trees after 13 years). Hence, the average cost of individual tree also varied in different families and it ranged from ₹ 270.00 (US$ 5.40) to ₹ 2000.00 (US$ 40.00) with an average of ₹ 949.53 (US$ 18.99). Future prospect of Agarwood in homegardens of upper Assam is calculated based on tree density and average cost of a mature tree, and it may range from ₹ 28,986.00 (US$ 579.72) to ₹ 20,08,238.00 (US$ 40,164.76) with an average of ₹ 2,49,090.00 (US$ 4981.79). People are benefitting from its lower inputs in terms of labor and fertilizer for its management in comparison with other cultivated economic crops of upper Assam like tea (*Camellia sinensis* (L.) O. Kuntze). People of Golaghat and Jorhat districts, especially Agarwood growers, are getting significant economic support from such a promising tree species of the region. Inequalities in returns from Agarwood were shown to be significant between the growers and traders in the present investigation. Traders earn considerably more than the growers.

Population structure and regeneration status of Agarwood in homegardens of upper Assam

The population density of Agarwood trees (>3.18 cm DBH), saplings, and seedlings was 1443, 4060, and 33,917 individuals per hectare, respectively, in the studied homegardens of upper Assam. Population structure of Agarwood showed good regeneration status in the studied homegardens of upper Assam with density of seedlings greater than saplings and trees (seedlings > saplings > trees) (Figure 3), which signifies the sustainability of the species in the future. Stand density for trees (>3.18 cm DBH) varied among different homegardens and ranged from 7913 (individuals ha^{-1}) to 260 (individuals ha^{-1}) with an average of 1466 (individuals ha^{-1}). Similarly, seedling and sapling densities ranged from 4,13,000 (individuals ha^{-1}) to 1667 (individuals ha^{-1}) and 14,500 (individuals ha^{-1}) to 320 (individuals ha^{-1}), respectively. Out of the total 135 studied homegarden, in 52% homegardens Agarwood have good regeneration, in 8% have fair regeneration, and in 40% have poor regeneration leaving only 1% having no regeneration of Agarwood.

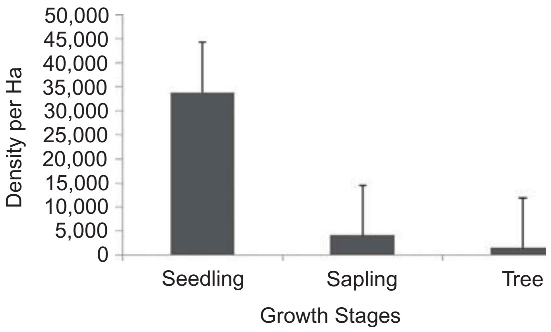

Figure 3. Seedling, sapling, and tree density ha^{-1} of Agarwood in all the studied homegardens of upper Assam, northeast India.

Seedling survival and growth of Agarwood in eight selected homegardens of upper Assam

Seasonal seedling survival rate of Agarwood was not significantly different among the eight selected homegardens during four different seasons of the year. Mean seasonal survival rate of seedling ranged from 98% ± 2.50 to 81% ± 6.35, and it was highest during February to April (96% ± 1.68) followed by May to July (92% ± 3.82) and lowest during November to January (78% ± 2.99). On the other hand, mean seasonal (per three months) growth rate of seedlings in terms of collar diameter varied significantly among the eight selected homegardens ($F_{7532} = 15.35$, $P < 0.001$) as well as during four different seasons ($F_{3532} = 19.51$, $P < 0.001$) of the year. It also differed significantly among the individuals growing in homegardens 1, 5, 6, and 8 (HG1: $F_{3,60} = 6.48$, $P < 0.01$; HG5: $F_{3,52} = 3.59$, $P < 0.05$; HG6: $F_{3156} = 9.08$, $P < 0.001$; HG8: $F_{3100} = 8.09$, $P < 0.001$) during four different seasons of the year but not in the remaining four homegardens (homegarden 2, 3, 4 and 7). However, mean seasonal growth rate ranged from 19.86% ± 1.42 to 4.73% ± 0.44, and it was highest during rainy season (May to July) (18.15% ± 2.23) and lowest during dry winter (November to January) (7.64% ± 1.49). Growth rate in terms of height and number of leaves was also higher during rainy seasons and decreased substantially during the beginning of dry season and was lowest during entire winter (November to January).

Discussion

People of upper Assam maintained homegardens of varied size ranging from 535.1 to 4013.4 m^2 (mean 1724.9 m^2; SE ± 64.6) which falls within the global inventory range of other tropical homegardens (Fernandes & Nair 1986). The present study reported significantly higher number of plant species compared to the earlier reports from Assam (Das & Das 2005; Saikia et al. 2012) as well as other parts of India (Kumar et al. 1994; Zimik et al. 2012) and the world (Soemarwoto 1987; Padoch & De Jong 1991). This may be due to the prevailing favorable microclimatic conditions of upper Assam which provide suitable growing conditions for different plant species. Diverse cultural practices may also have a greater effect in such high species diversity in the region. The present study reported

17 to 108 species (with a mean of 48 ± 1.04) per homegarden which is in conformity with earlier reports (Trinh et al. 2003; Saikia et al. 2012; Zimik et al. 2012). The ratio of abundance to frequency indicated contagious distribution of plant species in homegardens of upper Assam except *Mangifera indica* which showed random distribution with abundance to frequency ratio of 0.049. Contagious distribution has been accepted as a characteristic pattern of plant occurrence in nature (Odum 1971). Contagious distribution of species is an indication of clusteredness of species throughout the indigenous homegardens. Sahoo et al. (2010) also reported contagious distribution of all the species irrespective of their habit in all the studied homegardens of northeast India.

Although tree density (4259 individuals ha^{-1}) in homegardens of upper Assam was much higher than the recorded tree density in homegardens of other parts of India (Kumar et al. 1994; Das & Das 2005), the basal area of tree species (6.01 m^2 ha^{-1}) was lower than in homegardens of Barak valley, Assam (Das & Das 2005). This may be due to the dominance of narrow range girth class species in homegardens of upper Assam. In general, monoculture has a great impact on species diversity (Jose 1992). But this was not evident in the present study and may be due to the fact that owners try to cultivate all possible species of common household utilities in their homegarden. Diversity indices serve as valuable tools that help to quantify diversity in a community and describe its numerical structure. Shannon–Wiener diversity index is generally high for tropical forests of Indian subcontinent and ranged from 0.81 to 4.1 (Singh et al. 1984; Parthasarathy et al. 1992; Visalakshi 1995; Bhuyan et al. 2003). Shannon–Wiener diversity indices signify the similar structure of homegardens of upper Assam and tropical forests of Indian subcontinent. In general, species diversity and concentration dominance show an inverse relationship (Singh & Misra 1969; Joshi & Behera 1991).

The economic potential of Agarwood is very high compared to other homegarden products, and it depends on the age of trees, amount of products and rate of infection. Because, oil production is perceived by a defense mechanism of the tree against fungal infection or injuries caused by boring insects or even manmade wounds. Artificial wounding of tree trunk by nails or by cutting is common in Upper Assam by the traditional growers to promote rapid oil formation. Factors such as tree age, seasonal variations in growth, and environmental and genetic factors may also play an important role in oil formation (Ng et al. 1997). The variability in financial superiority of Agarwood in different homegardens is the result of complex interactions between many factors, including yield, cost, age of the tree or year of cultivation, transport, better deal or influence over markets. Though an individual Agarwood tree gives only one time income to the family and a few homegardens having tea plantations earn more than Agarwood-based homegardens, the low input for management, growth, lack of site specificity and intercropping adaptation make Agarwood a preferred cash crop in the homegardens of the region.

India is one of the earliest sources of Agarwood for foreign markets and the trade dates back as early as 600 A. D. (Chakrabarty et al. 1994). According to them, Agarwood business and its products including oil is the monopoly of a few families in and around Hojai and Nilbagan in Nagaon district of Assam in India. However, people of Golaghat and Jorhat districts, especially Agarwood growers, are getting significant economic support from such a promising tree species of the region. Inequalities in returns from Agarwood were shown to be significant between the growers and traders in the present investigation and traders earn considerably more than the growers. Uddin et al. (2008) also reported international traders as the most influential actors in the marketing channel of agar products and receive the greatest share of revenue in the product distribution chain.

Tree density of Agarwood was varied among different homegardens and ranged from 260 to 7913 (individuals ha^{-1}) with an average of 1466 (individuals ha^{-1}). The fluctuation in population density of the species in different homegardens may be attributed to the differences in their habitat and prevailing microenvironmental conditions. Size distributions may be informative of population trends at the local scale but not for broader spatial scales, such as the effects of global change on population dynamics (Wright 2005). Size distribution failed to correctly predict directions of change and is inadequate to measure the actual rates of population change (Feeley et al. 2007). The satisfactory natural regeneration of species is largely dependent on population structure characterized by the production and germination of seed and establishment of seedlings and saplings (Rao 1988). Presence of adequate number of seedlings and saplings reveals good regeneration status, in spite of competition with the associated vegetation (Bhuyan et al. 2003). Good regeneration potential shows suitability of a species to the environment. Microsite characteristics and microenvironmental conditions also influence the regeneration of trees through seeds (Schulte & Marshall 1983).

Variation in the seedling survival rate among the eight selected homegardens is mainly because of the various degrees of disturbances in various homegardens. Better survival during rainy seasons may be because of favorable growing conditions and increased availability of soil moisture and nutrient due to rapid decomposition of leaf litter (Khumbongmayum 2004). On the other hand, lowest seedling growth and survival during winter season (November to January) in all the selected homegardens may be due to adverse effects of limited rainfall and unfavorable temperatures during this season. Similar findings were also reported by several workers (Khan et al. 1986; Tripathi & Khan 1990; Kumar et al. 1994; Khumbongmayum et al. 2005; Saikia & Khan 2012). Ability to initiate new seedlings, their survival and growth are the three major components of successful regeneration of tree species (Good & Good 1972).

Conclusions

Homegardens of upper Assam are very rich in plant diversity, and density of Agarwood was very high in all the studied homegardens. Besides, its economic potential, it is also on the verge of extinction and needs proper conservation and management for further existence. Natural regeneration is essential for conservation and maintenance of biodiversity and Agarwood showed good regeneration and population status in the studied homegardens of upper Assam. Therefore, homegardens can be considered as a tool for on farm conservation of Agarwood. On the other hand, Agarwood has great economic prospects in the homegardens of upper Assam. Owners are getting good amount of subsidiary income without any extra care and effort. Based on the present information, it may be concluded that Agarwood may be introduced in homegardens of other parts of north east India as a potential economic crop for the upliftment of rural economy which alternatively protects the species from the danger of extinction.

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Note

1. Conversion rate: US$1.00 = ₹ 50.00

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