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Floristic composition and plant utilization pattern in homegardens of Upper Assam, India

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Abstract: Homegardens of Upper Assam, northeastern India are diverse and species-rich. We conducted vegetation survey of 80 homegardens in 17 villages of Golaghat and Jorhat districts of Upper Assam. Structure, diversity and plant uses were analyzed. Altogether, 294 plant species representing 217 genera and 92 families were encountered. Of these, 260 species were economically important and were categorized into seven use categories. The remaining 34 species were weeds and grasses. *Aquilaria malaccensis* Lam., an endangered and red listed species of India, was the most dominant tree (1,414 trees ha^{-1}). This species contributes significantly to the economy of the region. Principal Component Analysis (PCA) using frequency data showed two groups for each of the tree, shrub and herb layers. The high floristic diversity and presence of many rare/endangered species in the homegardens reflect the ways how owners utilize and conserve plant diversity. However, genetic diversity of such rare species of forest origin could be affected in managed ecosystems due to limited gene flow, inbreeding and selection pressure. Therefore, studies on genetic diversity of rare/endangered species in homegardens are required so that potential of homegardens for their conservation can be assessed.

Resumen: Los huertos familiares del Alto Assam, en el noreste de la India, son diversos y ricos en especies. Realizamos muestreos de la vegetación en 80 huertos familiares en 17 poblados de los Distritos Golaghat y Jorhat. Se analizaron la estructura, la diversidad y los usos de las plantas. En total, se encontraron 294 especies de plantas que representan 217 géneros y 92 familias. Entre ellas, 260 especies tienen importancia económica y éstas fueron clasificadas en siete categorías de uso. Las 34 especies restantes fueron malezas y pastos. *Aquilaria malaccensis* Lam., una especie amenazada e incluida en la Lista Roja de la India, fue el árbol más dominante (1,414 árboles ha^{-1}). Esta especie contribuye significativamente a la economía de la región. Un Análisis de Componentes Principales basado en datos de frecuencia mostró dos grupos para cada uno de los estratos arbóreo, arbustivo y herbáceo. La diversidad florística alta y la presencia de muchas especies raras o en peligro en los huertos familiares reflejan las maneras en que los propietarios usan y conservan la diversidad vegetal. Sin embargo, la diversidad genética de esas especies raras de origen forestal podría estar afectada en ecosistemas manejados debido a un flujo genético limitado, a la endogamia y a presiones selectivas. Por lo tanto, es necesario hacer estudios sobre la diversidad genética de las especies raras o amenazadas en los huertos familiares que permitan evaluar su potencial para la conservación de dichas especies.

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Resumo: Os quintais do Alto Assam, nordeste da Índia, são diversificados e ricos em espécies. Realizou-seum levantamento da vegetação de 80 quintais em 17 aldeias nos distritos de Golaghate Jorhat do Alto Assam. A estrutura, diversidade e uso das plantas foram analisadas. Ao todo, registaram-se 294 espécies de plantas representando 217 géneros e 92 famílias. Destas, 260 espécies são economicamente importantes e foram classificados em sete categorias de uso. As restantes 34 espécies eram plantas daninhas e ervas gramíneas. A *Aquilaria malaccensis* Lam., uma espécie ameaçada e na lista vermelha da Índia, era a árvore predominante (1.414 árvores ha^{-1}). Essa espécie contribui significativamente para a economia da região. A análise por Componentes Principais (PCA), utilizando dados de frequência, evidenciou dois grupos para cada um dos estratos arbóreo, arbustivo e herbáceo. A elevada diversidade florística ea presença de muitas espécies raras/ameaçadas de extinção nos quintais reflectem as formas como os proprietários utilizam e conservam a diversidade de plantas. No entanto, a diversidade genética dessasespécies raras de origem florestal pode ser afectada nos ecossistemas manejados, devido ao fluxo genético limitado, à endogamia e à pressão de selecção. Portanto, os estudos sobre a diversidade genética de espécies raras/ameaçadas nos quintais são necessários para que o potencial da sua conservação possa ser avaliado.

Key words: Cash crop, homegarden macrostructure, Shannon-Wiener Diversity Index, stratification.

Introduction

Homegardens are species-rich agroforestry systems maintained on the basis of choice, needs and importance of plants. It is a traditional land use practice around a homestead where several plant species are maintained by members of the household and their products are intended primarily for household consumption (Shrestha *et al.* 2001). Homegarden is generally accepted to be an economically efficient, ecologically sound and biologically sustainable agroforestry system (Fernandez & Nair 1986). Homegardens have attracted considerable attention of researchers during the past three decades mainly due to two reasons: (i) they contain characteristics which make them interesting models for research and design of sustainable agroecosystems. Some of these characteristics include efficient nutrient cycling, high biodiversity, low use of external inputs and soil conservation potential (Jose & Shanmugaratnam 1993; Torquebiau 1992), and (ii) they provide a diverse and stable supply of socioeconomic products and benefits to the families that maintain them (Christanty 1990). Compared to other agricultural or horticultural ecosystems, homegardens are very species rich and well suited for *ex situ* conservation of many rare/endangered species, besides fruit and timber trees. Homegarden structure also varies from place to place according to the local physical environment, ecological characteristics, socioeconomic and cultural factors (Abdoellah 1990; Kumar & Nair 2004). Several studies have been undertaken to investigate homegardens in different regions of the world including India. Homegardens in the northeastern Brazil contributed to the sustainable use of natural resources by reducing pressure on the native vegetation (Albuquerque *et al.* 2005). Besides species composition, annual income from the homegarden biodiversity was also found to correlate with household size in the offshore island of Bangladesh (Alam & Masum 2005). Trees constitute a major component in village ecosystems as evident from a study by Shastri *et al.* (2002) in Karnataka. Homegardens also serve as sink of carbon, thereby, playing an ecological role in the current global climate change scenario (Saha *et al.* 2009). Northeast India, having rich ethnic and cultural diversity, gave rise to diverse homegarden structures where important plant species are maintained to fulfill various needs. A study of different ethnic groups in Brahmaputra Valley, Assam, India indicated that production from homegardens maintained by immigrant people was over four times higher and their economic returns were greater than those maintained by the native people (Shrivastava & Heinen 2005). Ramakrishnan *et al.* (1996) stressed that socioeconomic and sociocultural issues, and traditional knowledge of the

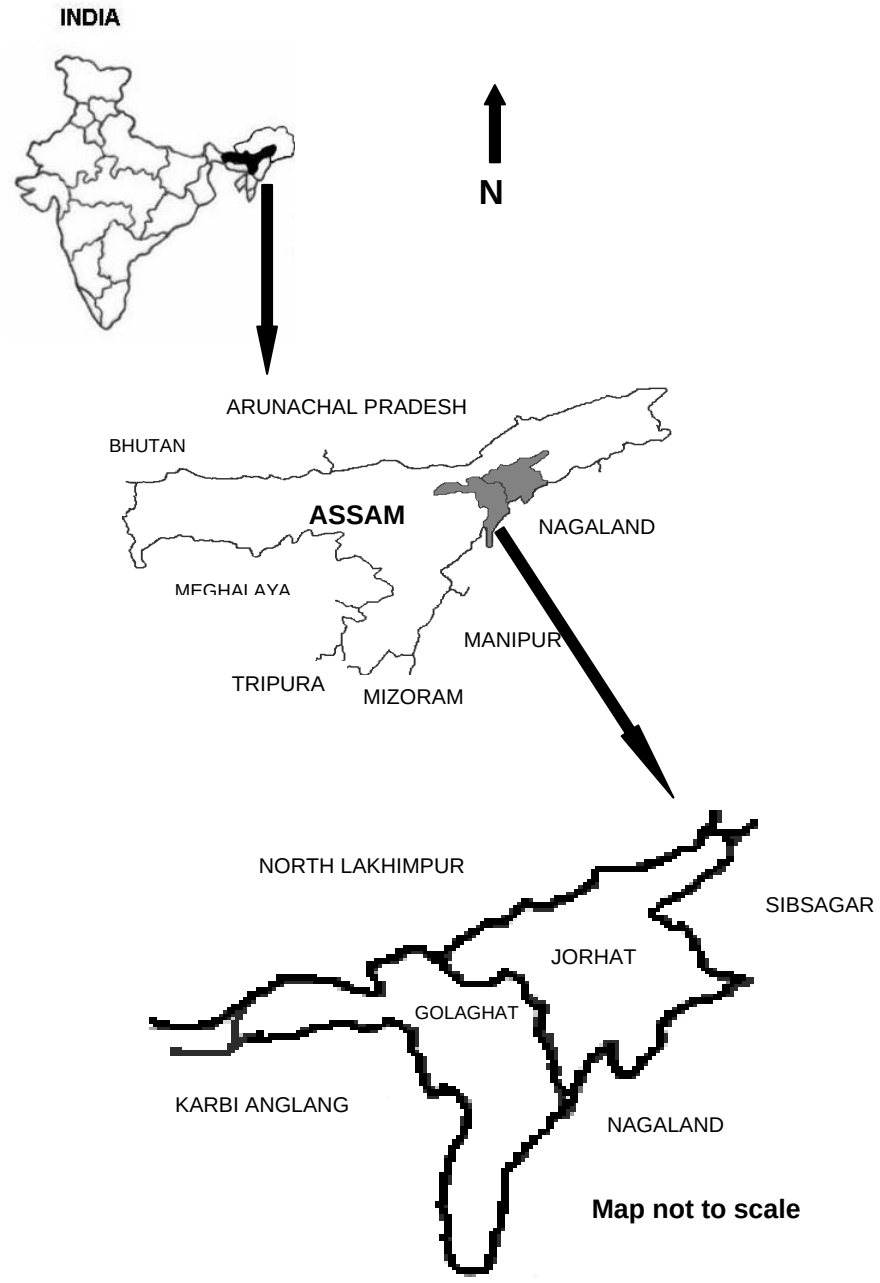

Fig. 1. Map of the study site (Golaghat and Jorhat districts) of Upper Assam, northeastern India.

local communities aided in the sustainability of agroecosystems. Ramakrishnan (2001) also suggested adopting the northeastern Indian experience linked with natural resource management initiatives as a basis for traditional societies. Another study on village homesteads in Barak Valley (Das & Das 2005) showed rich biodiversity, livelihood dependency as well as conservation of rare and endangered species. Bamboos are also very common in homegardens as well as in bamboo groves, and seven species of bamboos were reported in Barak Valley (Nath & Das 2008). Borthakur *et al*. (1998) stressed the role of homegardens, a traditional Indian experience, in the management and conservation of biodiversity in Assam.

Although considered ecologically and economically important, there is a lack of information on the traditional homegardens of Upper Assam. Therefore, we studied the homegarden structure, species diversity and utilization pattern in Upper Assam and tried to establish how threatened and

economically important species are conserved in traditional homegardens. There is a vital need for greater diversification of techniques of management and utilization of homegarden species, which warrants further research commitment.

Materials and methods

Study area

This study was conducted in homegardens of Golaghat and Jorhat districts of Upper Assam, northeastern India (25° 48' to 27° 10' N and 93° 17' to 94° 36' E) covering *ca.* 6,400 sq. km area (Fig. 1). The area is surrounded by Sibsagar and Dibrugarh districts to the east, Karbi Anglong and Nagaon districts to the west, Lakhimpur and Sonitpur districts to the north and the bordering state of Nagaland to the south. The climate is typical 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 1,300 and 2,244 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 traditional homegardens of different sizes. The common indigenous communities of this area are Kuch, Kalita, Brahmin, Keot, Ahom, Sut, Missing, Chutia, Kachari, Bodo and teagarden workers. The population is comprised of predominantly Hindus followed by Muslims and Christians. The economy is mainly agriculture-based comprising rice, tea and sugarcane as the major crops. Agarwood also contributes significantly to the economy of the region.

Analysis of homegarden structure, species diversity and utilization pattern

Eighty homegardens from 10 villages of Golaghat district and 7 villages of Jorhat district of Upper Assam, northeastern India were studied during 2007-2009. Homegardens were then divided into small (< 1,338 m^2), medium (1,338 - 1,632 m^2) and large (> 1,632 m^2) size categories to asses any relation between the size and distribution of different plant species. Vegetation was studied using quadrat method covering a minimum of 30 % area in each homegarden. Random quadrats of 10 x 10 m size were laid for trees and within each of these quadrats, one 5 x 5 m quadrat for shrubs and two 1 x 1 m quadrats for herbs were laid in each homegarden. Diameter at breast height (1.3 m above ground) and height of all the individual trees were recorded during the study. Plant species were identified on the basis of vernacular names, published field inventories, floras and consulting available herbaria of the region. Herbarium specimens were collected and deposited in the Department of Forestry, North Eastern Regional Institute of Science and Technology, Arunachal Pradesh, India.

Information regarding utilization pattern of homegarden plants was collected by interactive questionnaires focusing on: (i) selection of homegarden plants, (ii) utilization pattern of available plant species, and (iii) traditional management practices for conservation of rare and endangered species. Economically important plants were then classified into seven different use categories such as fruit, fuelwood, miscellaneous, medicinal, ornamental, timber and vegetable. Plants which yield oil, sugar, non alcoholic beverages, masticators, building materials, spices and/or are of religious importance were included under miscellaneous category.

Data analysis

Quantitative analysis of vegetation was done following Misra (1968). Importance Value Index (IVI) was computed by summing up relative density, relative frequency and relative basal area. Species richness was defined as the total number of species present in the homegardens. The Shannon-Wiener Diversity Index (Shannon & Weaver 1963) was calculated from the abundance values using the formula given by Magurran (1988). Concentration of Dominance was assessed by Simpson's Index (Simpson 1949). Sørensen Similarity Index (Sørenson 1948) was calculated on the basis of the ratio of number of common species to total species of pairs of stands.

Principal Component Analysis (PCA) was carried out separately for tree, shrub and herb strata, using frequency data, following Albuquerque *et al.* (2005). Software program STATISTICA-9.0 version was used for this purpose. Statistical analysis (standard error and t-test) was performed following Zar (1974). Software packages (MS Excel and ORIGIN) were used for such analysis.

Results

Homegarden structure

The size of individual homegardens in the 17 studied villages of Golaghat and Jorhat districts ranged from 535.12 to 3344.50 m^2 [mean 1,603.02 ±

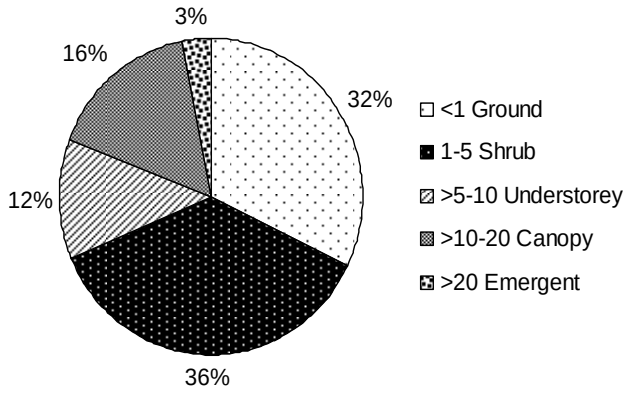

Fig. 2. Percentage of species in different strata of the homegardens of Upper Assam.

79.36 (SE) m²]. The total area of the studied homegardens was 0.13 km². Out of 80 studied home gardens, 30 were found as large (2637.91 ± 82.68 m²), 28 as medium (1405.65 ± 22.63 m²) and 22 as small (811.19 ± 47.24 m²). Though, no specific planting pattern was observed, it was found that smaller plants were preferred in the front yard, while the boundaries and backyard of homegardens consisted of taller, upper storey timber trees and the bamboos.

Stratification of plant species was common in homegardens, which makes them typical agroforestry systems that are somewhat similar to forests. Based on average height of the plant species, our study showed five different strata. These were emergent (> 20 m), canopy (> 10 - 20 m), understorey (> 5 - 10 m), shrub (1 - 5 m, including saplings of the tree species) and ground (< 1 m, including seedlings of both tree and shrub species) strata. Timber trees like *Talauma rabaniana* Hk.ef. & Th., *Cinnamomum glanduliferum* (Wall.) Meisn., *Anthocephalus chinensis* (Lam.) Rich. ex Walp. and bamboos were dominant in the emergent stratum. Canopy stratum was dominated again by timber as well as fruit plants like *Chukrasia tabularis* Juss., *Terminalia myriocarpa* Van Heurck & Muell.-Arg., *Artocarpus heterophyllus*, *Mangifera indica*, etc. The understorey stratum, having 12 % of the total flora, was dominated by *Aquilaria malaccensis* along with other fruit and ornamental plants. The shrub layer consisted of many shrub species and saplings of higher strata. Lastly, the ground stratum consisted of seedlings of both tree and shrub species and, mainly, weeds and grasses such as *Axonopus* sp., *Panicum* sp., *Cyperus rotundus* and *Cynodon dactylon*.

However, the percentage of occurrence of different plant species in different strata was not uniform. Maximum percentage (36 %) of species was found in the shrub stratum which includes the saplings of trees, followed by ground stratum (32 %) which includes seedlings of higher strata and the lowest percentage (3 %) was found in the emergent stratum (Fig. 2).

PCA, based on frequency data, clearly structured the homegardens into specific groups. PCA dealing with trees showed two distinct groups of homegardens (Fig. 3A). *Terminalia chebula* Retz. was the most common species in the homegardens of group I, while cash crops like *A. malaccensis* and *Areca catechu* were common in the homegardens of group II. Shrubs and herbs were also clustered into two groups each (Figs. 3B & C). In the case of shrubs, ornamental species like *Ixora javanica*, *Bougainvillea spectabilis* Wild. etc. were most common in the homegardens of group I and *Camellia sinensis*, *Adhatoda vasica* Nees., etc. were common in the homegardens of group II. On the other hand, in the case of herbs, *Coriandrum sativum L.*, *Raphanus sativus* L. etc. were common in the group I homegardens while, species like *Axonopus* sp., *Centella asiatica* (L.) Urban, etc. were common in the group II homegardens.

Species diversity and floristic composition

A total of 294 plant species belonging to 217 genera and representing 92 families was encountered from the 80 homegardens consisting of 142 (48 %) trees, 56 (19 %) shrubs and 96 (33 %) herbs, excluding cultivars of *Musa* and *Citrus* spp. (Appendix Table 1). Although, the number of tree species documented from both the districts was higher than those of herbs and shrubs, differences were not statistically significant among the above three lifeforms. Overall, the family Euphorbiaceae had the highest number of species (14) followed by Moraceae and Poaceae (12 each). While Moraceae (12 spp.) was the most dominant tree family, Cucurbitaceae (9) was the most dominant family of herbs, and Malvaceae and Solanaceae (7) the most dominant families of shrubs. District wise data showed that Moraceae and Rutaceae (10 spp., each) for trees, Cucurbitaceae and Poaceae (6, each) for herbs and Solanaceae (7) for shrubs were the most dominant plant families in Golaghat. Moraceae, Rutaceae and Euphorbiaceae (7 spp. each) for trees, Cucurbitaceae (9) for herbs and Malvaceae (5) for shrubs were the most dominant plant families in Jorhat.

Agarwood (*Aquilaria malaccensis*), areca nut

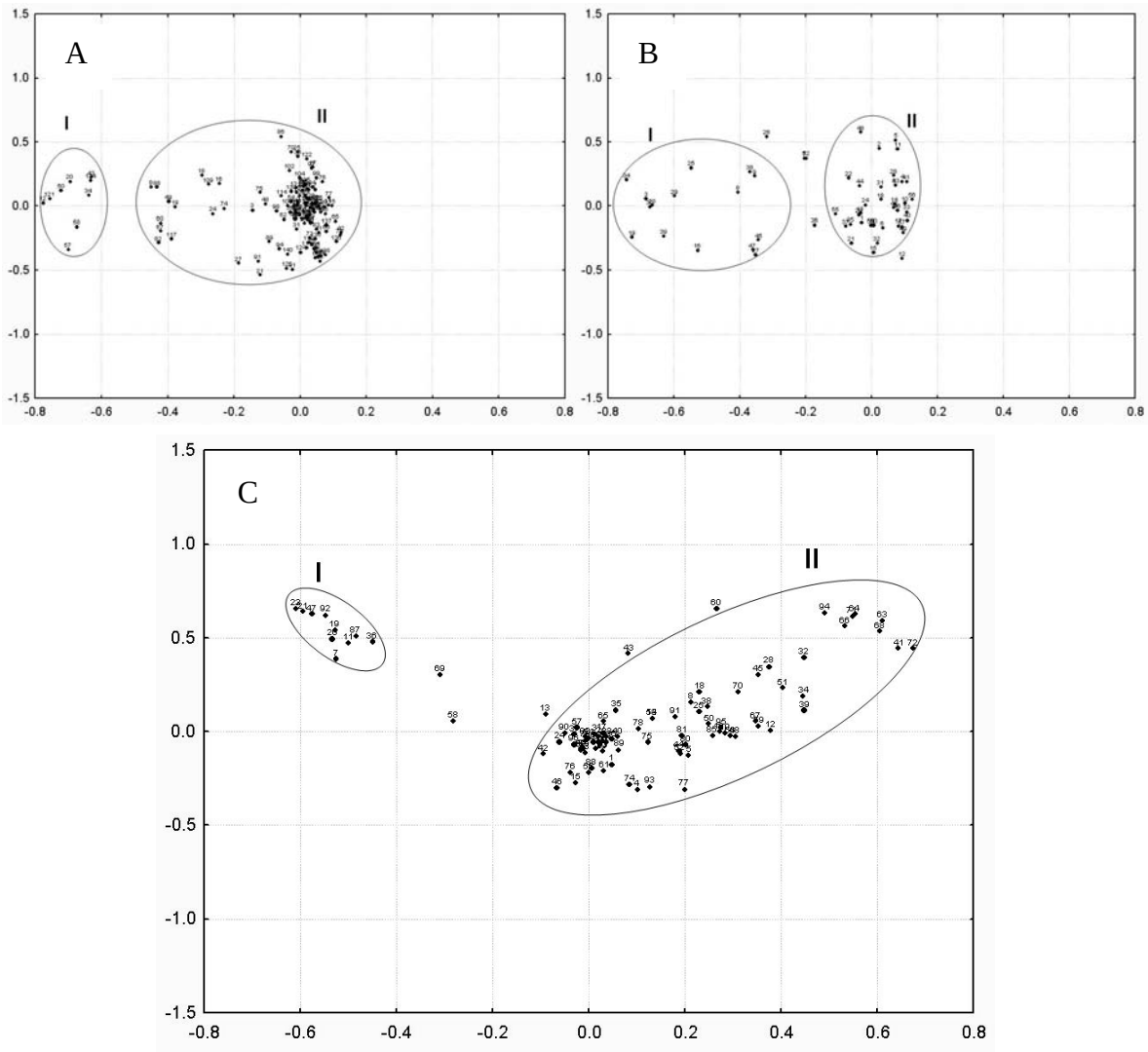

Fig. 3. Structure of homegardens on the basis of principal component analysis (PCA) using frequency data. (A) trees (B) shrubs and (C) herbs. (Different homegarden groups are designated by the numbers I & II).

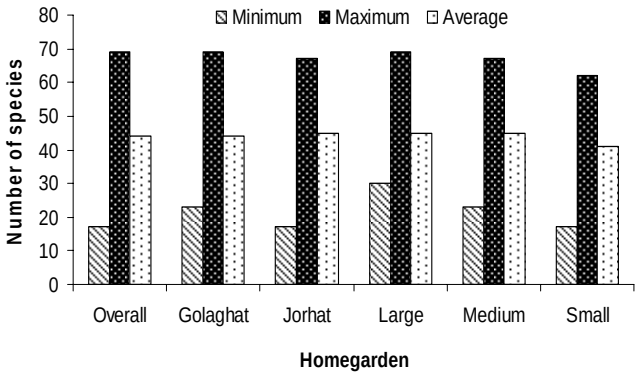

Fig. 4. Minimum, maximum and average species richness of different homegarden types of Upper Assam.

(*Areca catechu*), mango (*Mangifera indica*), tea (*Camelia sinensis*) and jackfruit (*Artocarpus heterophyllus*) were more frequent species than others. Majority of the high density species were cash crops and fruit plants, and were more or less the same in all categories of homegardens. *A. malaccensis* contributed 37 % of the total tree density and was the most common tree species in the homegardens of the region (Table 1). However, a high variability in density of plant species was noticed in different homegarden categories. Tree density was highest in the small- (4,574 individuals ha^{-1}) followed by medium- (4,046 individuals ha^{-1}) and large-sized (3,448 individuals ha^{-1}) homegardens. Similarly, frequency of species occurrence increased with decreasing homegarden size. On

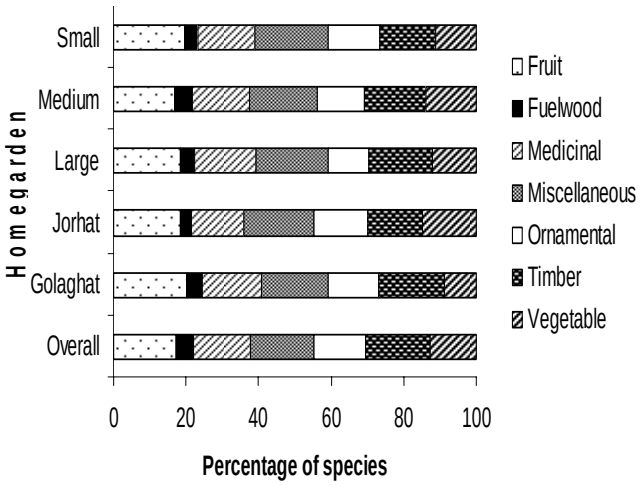

Fig. 5. Percentage of species in different use categories in different homegarden types of Upper Assam.

the other hand, basal area of the tree species was highest in medium- (3.51 m^2 ha^{-1}) followed by large- (3.22 m^2 ha^{-1}) and small-sized (1.78 m^2 ha^{-1}) homegardens. Medium-sized homegardens, were also more species rich (236 spp.) than large-sized (total 232 spp.) and small-sized (total 210 spp.) ones. Number of species per homegarden was variable (17 to 69 with a mean of 44 ± 1.09) but, the difference was not significant in different homegarden categories (Fig. 4).

Concentration of dominance (Simpson's Index) and diversity of tree species (Shannon-Wiener Diversity Index) in all size categories were almost the same (Table 2). Sørensen's Similarity Indices showed a high degree of similarity among different homegarden categories (Table 3). Most importantly, the number of non-native plants (107) was lower than their native counterparts (186).

Plant uses

The majority of homegarden species were useful for different purposes. Plants of miscellaneous and timber categories were the most frequent component (18 % of total economically important species) followed by fruit, medicinal, ornamental, vegetable and fuelwood categories in these homegardens. Occurrence percentage of different plant species in each use category varied among different homegarden categories but the variation was not significant (Fig. 5). Miscellaneous category was the most common (20 % of total economically important species) component in the homegardens of Jorhat district followed by fruit and timber categories, whereas, the fruit category (21 % of total economically important species), followed by miscellaneous and timber categories, was the most common component in the homegardens of Golaghat district.

Fuelwood plants like *Macaranga peltata* (Roxb.) Mueller., *Mallotus philippinensis* Muell. Arg. and *Ficus hispida* L. contributed the least to the homegardens of the region. Overall, the most frequently occurring economically important species were cash crops followed by fruit plants. *Aquilaria malaccensis* was the most frequent tree in all the size-categories of the homegardens as well as in both districts. A few important timber trees viz. beechwood (*Gmelina arborea* Roxb.), teak (*Tectona grandis* L.), magnolia (*Magnolia sphenocarpa* Roxb.), black dammar (*Canarium strictum* Roxb.) and champak (*Michelia champaca* L.) contributed significantly to the homegarden vegetation of the region. Fruit plants of common occurrence were *Artocarpus heterophyllus*, *Ananas comosus* (L.) Merr., *Cocos nucifera*, *Litchi chinensis* Sonn., *Mangifera indica,* etc.

Medicinal plants (15 - 17 % of the total economically important species) having different curative properties were abundant in all categories of homegardens. Most important ones were *Azadirachta indica* Juss., *Oroxylum indicum* (L.) Kurz., *Acorus calamus* L., *Houttuynia cordata* Thunb. and *Terminalia chebula*. Plants like *Carica papaya*, *Moringa oleifera* Lam. and *Musa paradisiaca* L. were cultivated as vegetable plants in the majority of the homegardens. Percentage of native and non-native plants in the entire use categories varied greatly. Percentage of native plants was higher in fuelwood, timber, miscellaneous, fruit and medicinal categories, whereas, the proportion of non-native plants was highest in the ornamental followed by weeds and grasses and vegetable categories. Weeds and grasses, contributing 11-14 % of the total flora, have potential medicinal properties as well. Most importantly, a few rare species such as *Acorus calamus*, *Aquilaria malaccensis*, *Costus speciosus* (Koen. ex Retz.) Smith, *Clerodendrum colebrookianum* Wall. and *Livistona jenkinsiana* Griff. were also encountered in the studied homegardens.

Discussion

In the present study, the size range of homegardens was 535.12 to 3,344.50 m^2 (mean 1,603.02 ±79.36 m^2) of which more than one third were in the range of 1,070.24 m^2 to 1,337.80 m^2. Our

Table 1. Homegarden category (size range), total area and tree density ha^{-1} of the sampled homegardens (HGs) of Upper Assam, northeast India.

Farm size category (m^2)		Small (< 1,338)	Medium (1,338 - 1,632)	Large (> 1,632)
No. of HGs		22	28	30
Total area of HGs (m^2)		17,846	39,358	71,037
Tree density ha^{-1}				
Aquilaria malaccensis				
	Min	600	260	400
	Max	6,600	3,075	7,913
	Mean	1,496 ± 276	1,492 ± 130	1,341 ± 248
Areca catechu				
	Min	160	57	83
	Max	1,433	1,400	1,117
	Mean	649 ± 71	690 ± 76	488 ± 48
Other tree species				
	Min	225	325	350
	Max	9,933	7,380	9,967
	Mean	2,787 ± 586	2,040 ± 351	1,613 ± 389

Table 2. Community characteristics of homegarden (HG) categories of Upper Assam, northeast India.

Parameters	Overall	Golaghat	Jorhat	Large HGs	Medium HGs	Small HGs
Number of families	92	89	81	82	82	77
Number of genera	217	196	188	183	186	171
Number of species	294	248	235	232	236	210
Tree density (ha^{-1})	3,843	4,004	3,572	3,448	4,046	4,574
Basal area of trees (m^2 ha^{-1})	3.73	3.41	2.76	3.22	3.51	1.78
Tree diversity (Shannon's H´)	3.53	3.29	3.25	3.09	3.27	3.20
Concentration of dominance of trees	0.05	0.05	0.05	0.06	0.06	0.05

Table 3. Sørensen's Similarity Index (%) for different homegarden (HG) categories of Upper Assam, northeast India.

	Golaghat	Jorhat	Large HGs	Medium HGs	Small HGs
Golaghat	00.00				
Jorhat	78.28	00.00			
Large HGs	88.43	80.51	00.00		
Medium HGs	84.25	87.63	79.92	00.00	
Small HGs	84.35	83.93	77.93	79.73	00.00

observed homegarden size range for the districts of Upper Assam is within the global inventory range of other tropical homegardens (Fernandez & Nair 1986). Studies of homegardens in Mexico (Rico-Gray *et al*. 1991) and Indonesia (Abdoellah *et al*. 2006) indicated that the number of species or individuals is not related to homegarden size.

High diversity and low concentration of dominance in different homegarden categories may be due to variations in anthropogenic pressure in different homegardens. The average number of species per garden did not differ significantly among the homegarden categories, but, density and frequency of species increased with decreasing homegarden size. This suggests that owners maintain a diverse group of plants to fulfill their regular needs regardless of the homegarden size. This is, however, contrary to the findings by Kabir

& Webb (2009) who reported strong relationship between homegarden size with species richness in Bangladesh homegardens. With increase in holding size, more variations in species composition were also reported by Das & Das (2005) in Barak valley, Assam. Higher density, frequency and abundance of cash crops like agarwood, tea and areca nut than the other plants in the majority of homegardens indicate a common structuring of the homegardens in Upper Assam districts of northeastern India. This also clearly signifies the importance of homegarden species in economic sustainability of the region.

The wide range of species of different heights and life forms found in traditional homegardens add to their ecological efficiency in terms of use of physical and chemical resources such as water, sunlight and nutrients (Blanckaert *et al*. 2004; Wiersum 1982). Multilayered canopy configuration of the homegardens with lower plant density and species richness in the upper strata was also observed in Bangladesh homegardens (Millat-e-Mustafa *et al.* 1996) and the neighboring forests in physiognomic terms (Barrera 1980). However, such strata vary in numbers in different areas and may range from three to six (Fernandez & Nair 1986; Das & Das 2005; Millat-e-Mustafa *et al.* 1996). Homegardens in the Upper Assam region, consisting of five distinct strata with lower tree density and species richness in the upper most stratum, may serve as efficient ecological systems because the light energy in such a system can be distributed efficiently among different strata, thereby harmonizing the rate of photosynthesis as well as productivity among the strata.

On the basis of PCA using frequency data, we observed distinct groupings of homegardens. In the case of tree species, species like *A. malaccensis* and *A. catechu* were the most common species in the larger group (group II) of the homegardens, had the highest density and frequency and were more or less evenly distributed throughout the homegardens of the region. This may be due to high market value of the species and low input and maintenance costs. On the other hand, the homegardens in the smaller group (group I) were composed of less frequent species like *T. chebula*. Similarly, in the case of shrub and herb strata, the larger group of homegardens had the most frequent species and the smaller group had the less frequent species.

Albuquerque *et al.* (2005) also showed similar structuring based on relative abundance and dominance data in homegardens of northeastern Brazil. They found five groups of homegardens using abundance data and three groups using dominance data. Using multivariate methods with presence or absence data, Millat-e-Mustafa *et al.* (1996) established the existence of different floristic patterns in the homegardens of Bangladesh. Similarly, Caballero (1992) found homegarden groups based on floristic variations observed in the Maya region of the Yucatan Peninsula.

Species distribution in the homegardens is determined by environmental factors and dietary habits as well as the socio-economic and market demands (Fernandez & Nair 1986). Species diversity of the tropical homegardens is generally believed to be very high (Babu *et al.* 1982; Michon *et al.* 1983). Our findings of 294 plant species (142 trees, 56 shrubs and 96 herbs) of different utilities indicate the biological richness of homegardens in the Upper Assam region of India. Though this value is lower than the reported 301 trees and shrubs from the Mayan homegardens of Yucatan, Mexico (Rico-Gray *et al*. 1991), it is substantially higher than 168 species from Santa Rosa in the Peruvian Amazon (Padoch & de Jong 1991) or 127 woody species from homegardens of Kerela, India (Kumar *et al.* 1994).

Similar to our findings, Kabir & Webb (2008) also reported predominance of trees and herbs in homegardens of southwestern Bangladesh. The high floristic diversity is, perhaps, a reflection of the potential of homegardens to serve as repositories of genetic diversity as well. In the present study, species richness varied greatly and ranged from 17 to 69 plant species per homegarden with a mean value of 44 ± 1.09; whereas Trinh *et al.* (2003) reported 12 to 103 species per homegarden in Vietnam.

We recorded the maximum density (37 % of the total tree density ha^{-1}) of agarwood (*Aquilaria malaccensis*) in the homegardens showing a trend towards monoculture. Jose (1992) reported that introduction of rubber (*Hevea brasiliensis*) into the homegardens resulted in a reduction of species diversity in the homegardens of Kerela. Although, species diversity was high, the high similarity index between different categories indicates that homegarden floristic composition is characteristically similar in the region. Apart from edaphic, cultural, socio economic factors, needs and interest may play a vital role in regulating such floristic compositions of homegardens in the region.

Ecological and socioeconomic factors, including geographic location, climate, water availability,

garden size and history, agricultural policy, market needs, food culture and household preferences influence the species diversity and utilization of the products of traditional homegardens (Gajaseni & Gajaseni 1999; Trinh *et al.* 2003). Although, the proportions of species used for different purposes vary, in general, traditional homegardens contribute substantially towards meeting the basic subsistence needs of their owners for products and services such as food including vegetables and fruits, medicines, forage, shade and ornamentals (Albuquerque *et al.* 2005). Our results indicate a considerable array of plant species in the homegardens of Upper Assam characterized by a high density of plants having miscellaneous utilization followed by timber, fruit and medicinal plants. Presently, many traditional homegardens show a shift from subsistence-oriented agriculture to market economy (Peyre *et al.* 2006). An abrupt shift of choice from traditional homegarden plants to cash crops is also noticed in the present study and is evident by the high frequency and density of cash crops like *A. malaccensis* and *Camelia sinensis*. Owners' choice for increased earning rather than the supply of seasonal crop or fruit plants may be the main reason for such change in the area. In contrast to the present report, the dominance of only fruit trees in homegardens of Thailand (Gajaseni & Gajaseni 1999), food and fruit producing species in Bangladesh (Millat-e-Mustafa *et al.* 1996) or medicinal plants in Cuba (Hammer *et al.* 1989) is also evident. Although the fuelwood category plants are less abundant, other woody species are also utilized as fuelwood, thereby, minimizing the harvesting pressure in the nearby forests. Most importantly, conservation of rare species such as *Acorus calamus, Aquilaria malaccensis*, *Costus speciosus, Clerodendrum colebrookianum* and *Livistona jenkinsiana* signify homegardens as a storehouse of rare plant genetic resources.

Conclusions

The present study revealed that homegardens of Upper Assam are the depositories of diverse plant resources of both ecological and economic significance. The high frequency and density of agarwood and tea indicates a shift of choice towards cash crops and, thereby, homegardens may be considered as a vital source of income in the coming days. Common occurrence of few rare species like *A. malaccensis* signifies homegardens as a storehouse of genetic resources. However, genetic diversity of such rare species of forest origin may be affected in managed ecosystems due to limited gene flow, inbreeding and selection pressure. Further studies may be conducted to understand the genetic diversity of rare/ endangered species in the homegardens and to assess the the potential of homegardens for their conservation.

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References

Abdoellah, O. S. 1990. Homegardens in Java and their future development. pp. 69-79. *In*: K. Landauer & M. Brazil (eds.) *Tropical Homegardens*. United Nations University Press, Tokyo, Japan.

Abdoellah, O. S., H. Y. Hadikusumah, K. Takeuchi, S. Okubo & Parikesit. 2006. Commercialization of homegardens in an Indonesian village: vegetation composition and functional changes. *Agroforestry Systems* **68**: 1-13.

Alam, M. S. & K. M. Masum. 2005. Status of homestead biodiversity in the offshore Island of Bangladesh. *Research Journal of Agriculture and Biological Sciences* **1**: 246-253.

Albuquerque, U. P., L. H. C. Andradeb & J. Caballeroc. 2005. Structure and floristics of homegardens in Northeastern Brazil. *Journal of Arid Environments* **62**: 491-506.

Babu, K. S., D. Jose & C. Gokulapalan. 1982. Species diversity in a Kerala homegarden. *Agroforestry Today* **4**: 15.

Barrera, A. 1980. Sobre la unidad de habitacio´ n tradicional campesina y el manejo de recursos bio´ ticos en el area Maya Yucatense. *Biotica* **5**: 115-129.

Blanckaert, I., R. L. Swennen, P. M. Flores, R. I. Lopez & R. L. Saade. 2004. Floristic composition, plant uses and management practices in homegardens of San Rafael Coxcatlan, valley of Tehuacan-Cuicatlan, Mexico. *Journal of Arid Environments* **57**: 39-62.

Borthakur, S. K., T. R. Sarma, K. K. Nath & P. Deka. 1998. The house gardens of Assam: a traditional

Indian experience of management and conservation of biodiversity- I. *Ethnobotany* **10**: 32-37.

Caballero, J. 1992. Maya homegardens: past, present & future. *Etnoecolo´gica* **1**: 35-54.

Census of India. 2001. *Census Report*. Ministry of Home Affairs, Govt. of India.

Christanty, L. 1990. Homegardens in tropical Asia, with special reference to Indonesia. pp. 9-20. *In*: K. Landauer & M. Brazil (eds.) *Tropical Home Gardens*. United Nations University Press, Tokyo, Japan.

Das, T. & A. K. Das. 2005. Inventorying plant biodiversity in homegardens: A case study in Barak Valley, Assam, North East India. *Current Science* **89**: 155-163.

Fernandez, E. C. M. & P. K. R. Nair. 1986. An evaluation of the structure and functions of tropical homegardens. *Agroforestry Systems* **21**: 279-310.

Gajaseni, J. & N. Gajaseni. 1999. Ecological rationalities of the traditional homegarden system in the Chao Phraya Basin, Thailand. *Agroforestry Systems* **46**: 3-23.

Hammer, K., H. Knupfer & M. Esquivel. 1989. An inventory of Cuban cultivated medicinal plants. *Newsletter of Medicinal and Aromatic Plants* **1**: 64-75.

Jose, D. 1992. Structure and productivity of the homegardens of Kerala: A case study. pp. 17-19. *In*: C. G. R. Nair (ed.) *Proceeding of Fourth Kerala Science Congress*. Science, Technology and Environment Department, Government of Kerala, Thiruvananthapuram, India.

Jose, D. & N. Shanmugaratnam. 1993. Traditional homegardens of Kerala: A sustainable human ecosystem. *Agroforestry Systems* **24**: 203-213.

Kabir, M. E. & E. L. Webb. 2008. Can homegardens conserve biodiversity in Bangladesh? *Biotropica* **40**: 95-103.

Kabir, M. E. & E. L. Webb. 2009. Household and homegarden characteristics in southwestern Bangladesh. *Agroforestry Systems* **75**: 129-145.

Kumar, B. M. & P. K. R. Nair. 2004. The enigma of tropical homegardens. *Agroforestry Systems* **61**: 135-152.

Kumar, B. M., S. J. George & S. Chinnamani. 1994. Diversity, structure and standing stock of wood in the homegardens of Kerala in Peninsular India. *Agroforestry Systems* **25**: 243-262.

Magurran, A. F. 1988. *Ecological Diversity and its Measurement*. Princeton University Press, Princeton, New Jersey.

Michon, G., J. Bompard, P. Hecketsweiler & C. Ducatillion. 1983. Tropical forest architectural analysis applied to agroforestry in the humid tropics, the example of traditional village agro-forestry in West Java. *Agroforestry Systems* **1**: 117-129.

Millat-e-Mustafa, M. D., J. B. Hall & Z. Teklehaimanot. 1996. Structure and floristics of Bangladesh homegardens. *Agroforestry Systems* **33**: 263-280.

Misra, R. 1968. *Ecology Workbook*. Oxford & IBH Publishing Company, Calcutta, India.

Nath, A. J. & A. K. Das. 2008. Bamboo resources in the homegardens of Assam: A case study from Barak Valley. *Journal of Tropical Agriculture* **46**: 46-49.

Padoch, C. & W. de Jong. 1991. The house gardens of Santa Rosa: Diversity and variability in an amazonian agricultural systems. *Economic Botany* **45**: 66-175.

Peyre, A., A. Guidal, K. F. Wiersum & F. Bongers. 2006. Dynamics of homegarden structure and function in Kerala, India. *Agroforestry Systems* **66**: 101.

Ramakrishnan, P. S., A. K. Das & K. G. Saxena. 1996. *Conserving Biodiversity for Sustainable Development*. Indian National Science Academy, New Delhi, India.

Ramakrishnan, P. S. 2001. *Ecology and Sustainable Development*. National Book Trust, New Delhi, India.

Rico-Gray, V., A. Chemas & S. Mandujano. 1991. Uses of tropical deciduous forest species by the Yucatecan Maya. *Agroforestry Systems* **14**: 149-161.

Saha, S. K., P. K. R. Nair, V. D. Nair & B. M. Kumar. 2009. Soil carbon stock in relation to plant diversity of homegardens in Kerala, India. *Agroforestry Systems* **76**: 53-65.

Shannon, C. E. & W. Weaver. 1963. *The Mathematical Theory of Communities*. University of Illinois Press, Urbana, Illinois.

Shastri, C. M., D. M. Bhat, B. C. Nagaraja, K. S. Murali & N. H. Ravindranath. 2002. Tree species diversity in a village ecosystem in Uttara Kannada district in Western Ghats, Karnataka. *Current Science* **82**: 1080-1084.

Shrestha, P., R. Gautam, R. B. Rana & B. Sthapit. 2001. Home gardens in Nepal: status and scope for research and development. pp. 105-124. *In*: J. W. Watson & P. B. Eyzaguirre (eds.) *Homegardens and in situ Conservation of Plant Genetic Resources in Farming Systems*. Proceedings of the Second International Home Gardens Workshop, Witzen-hausen, Federal Republic of Germany.

Shrivastava, R. J. & J. T. Heinen. 2005. Migration and home gardens in the Brahmaputra valley, Assam, India. *Journal of Ecological Anthropology* **9**: 20-34.

Simpson, E. M. 1949. Measurement of diversity. *Nature* **163**: 688.

Sørenson, T. 1948. A method of establishing groups of equal amplitude on similarity of species content. *Biologiske Skrifter K. Danske Videnskbernes Selskab* **5**: 1-34.

Torquebiau, E. 1992. Are tropical agroforestry home-

gardens sustainable? *Agriculture, Ecosystems and Environment* **41**: 189-207.

Trinh, L. N., J. W. Watson, N. N. Hue, N. N. De, N. V. Minh, P. Chu, B. R. Sthapit & P. B. Eyzaguirre. 2003. Agrobiodiversity conservation and development in Vietnamese homegardens. *Agriculture, Ecosystems and Environment* **97**: 317-344.

Wiersum, K. F. 1982. Tree gardening and Taungya on Java: examples of agroforestry techniques in the humid tropics. *Agroforestry Systems* **1**: 53-70.

Zar, J. H. 1974. *Biostatistical Analysis*. Englewood Cliffs, N J, Prentice-Hall.

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Appendix Table 1. List of the 10 most important trees (> 10 cm GBH) with Density (D) and Importance Value Index (IVI) and 10 shrubs and herbs with Density (D) and Frequency (F) in different homegarden types of Upper Assam, northeast India. Complete data for all species are available from the Corresponding author on request.

Species	Family	Golaghat		Jorhat		Large HGs		Medium HGs		Small HGs	
		D (ha^{-1})	F	D (ha^{-1})	F	D (ha^{-1})	F	D (ha^{-1})	F	D (ha^{-1})	F
Tree											
Aquilaria malaccensis Lam.	Thymelaeaceae	1522.6	53.7	1231.7	51	1378.3	57.6	1466.2	51.2	1422.2	45.3
Areca catechu L.	Arecaceae	524.8	24.6	568.3	28.6	483.7	27.3	620.6	26.9	564.2	22.1
Artocarpus heterophyllus Lam.	Moraceae	26.6	4.96	40.2	7.13	21.3	5.19	28.7	5.56	65.4	7.89
Bambusa balcooa Roxb.	Poaceae	130.7	3.49	56.1	1.98	139.8	4.28	78.7	2.28	42	1.26
Bambusa tulda Roxb.	Poaceae	1086.5	28.6	793.9	23.8	809.1	24.7	1008.1	26.2	1382.7	32.5
Carica papaya L.	Caricaceae	18.6	2.72	42.7	4.69	27.6	3.63	23.5	3.26	34.6	3.29
Cocos nucifera L.	Arecaceae	21.9	5.09	16.5	3.78	19.5	5.08	24.3	4.31	13.6	5.84
Mangifera indica L.	Anacardiaceae	62.8	8.49	57.9	8.25	47.1	8.22	66.2	8.61	90.1	8.88
Musa balbisiana Colla.	Musaceae	105.8	6.36	96.3	6.72	99.1	6.8	101.5	6.15	112.4	6.65
Musa calosperma F. Muell.	Musaceae	39.1	2.52	110.4	6.89	50.2	3.83	69.1	4.39	102.5	4.29
Shrub											
Camellia sinensis (L.) Kuntze.	Theaceae	1285	17.52	3385	37.20	2219	26.24	2256	28.68	1358	14.81
Capsicum annum L.	Solanaceae	29	1.82	80	7.93	42	3.17	50	5.88	64	3.70
Capsicum annum L. var. *longum*	Solanaceae	57	4.38	49	3.66	20	2.26	103	6.62	64	4.94
Chromolaena odorata (L.) King & Robins.	Asteraceae	485	12.77	34	1.22	273	6.79	515	13.24	99	4.94
Clerodendrum viscosum Vent.	Verbenaceae	870	23.72	261	7.93	521	12.22	718	22.06	844	25.93
Hibiscus rosa chinensis L.	Malvaceae	39	4.38	41	2.44	4	1.81	59	5.15	94	6.17
Ixora javanica (Blume) DC.	Rubiaceae	36	3.65	12	2.44	24	2.26	32	3.68	30	4.94
Melastoma normale Don.	Melastomaceae	55	3.28	63	4.88	45	3.17	88	5.88	44	2.47
Solanum melongena L.	Solanaceae	26	2.19	98	7.93	45	4.07	76	5.88	35	2.47
Tabernaemontana divaricata Don.	Apocynaceae	73	6.93	10	1.22	20	3.17	91	8.09	59	3.70

Contd...

Appendix Table 1. Continued.

Species	Family	Golaghat		Jorhat		Large HGs		Medium HGs		Small HGs	
		D (ha^{-1})	IVI	D (ha^{-1})	IVI	D (ha^{-1})	IVI	D (ha^{-1})	IVI	D (ha^{-1})	IVI
Herb											
Achyranthes aspera L.	Amaranthaceae	22938	26.64	14665	17.07	19095	21.27	23419	28.31	15864	19.14
Ageratum conyzoides L.	Asteraceae	23759	39.05	25549	33.84	20520	29.41	30625	47.43	24691	40.74
Axonopus sp.	Poaceae	53996	32.30	69543	33.54	54299	30.54	70515	37.50	56914	30.86
Borreria articularis (L. f.) F. N. Will.	Rubiaceae	21642	23.72	22652	25.91	20181	21.95	23603	26.47	24383	28.40
Colocasia esculentum (L.) Schott.	Araceae	11679	16.06	9817	18.90	11923	17.87	8971	13.60	11790	20.99
Cynodon dactylon (L.) Pers.	Poaceae	10839	12.04	29512	13.41	21041	14.71	16397	12.13	11481	7.41
Cyperus rotundus L.	Cyperaceae	17737	20.62	20884	25.00	17466	21.72	23015	26.84	15988	16.05
Oplismenus sp.	Poaceae	27080	18.98	62927	36.59	37262	22.85	31360	22.79	64691	37.65
Panicum sp.	Poaceae	45493	41.79	52561	45.12	40656	37.56	46324	43.75	71605	56.79
Spilanthes paniculata Wall. ex DC.	Asteraceae	9526	11.31	13476	19.21	7398	9.28	14706	18.75	14630	20.37