Plant Diversity in the Indigenous Home Gardens in the Eastern Himalayan Region of Mizoram, Northeast India

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The eastern Himalayan region of Northeast India is well known for its traditional home gardens, which are considered to play important roles in the maintenance of livelihoods of indigenous communities and conservation of biological diversity. This study determines the plant diversity in home gardens and their importance in conservation of plant genetic resources (PGR) through utilization. We studied 90 home gardens in detail located in six villages. Different aspects of the home gardens and plant species were observed directly and through discussion with the farmers. A total of 333 plant species (133 trees, 92 shrubs, and 108 herbs) belonging to 128 plant families with an average of 78 species per home garden were recorded. The size of home gardens ranged between 0.10 and 0.60 ha and showed significant ($P<0.001$) positive correlation between the garden size and plant species diversity. The species diversity index for trees, shrubs, and herbs was 4.76, 4.39, and 4.58, respectively. The species similarity within each life form was high with 50% for trees, 38% for shrubs, and 49% for herbs. Plant species in the home gardens could be grouped into 11 major use categories with the majority of plants in the medicinal or multiple use category. These home gardens are reservoirs of PGR and play a vital role in sustaining the livelihood of local inhabitants. They are also functioning as domestication and conservation centers of many crop relatives.

Key Words: Diversity, home garden, indigenous, Northeast India, plant, people, ethnobotany.

Introduction

Home gardens are considered one of the oldest subsistence farming systems practiced by rural communities in many parts of the world, consisting of multi–layer systems of trees, shrubs, and herbs around homesteads (Idohoua et al. 2014; Kabir and Webb 2009; Kumar and Nair 2004; Salako et al. 2014). Home gardens are generally multifunctional and play key roles in providing goods and ecosystem services and numerous benefits for sustaining the livelihood of local inhabitants (Calvet–Mir et al. 2012; Clarke et al. 2014; Galluzzi et al. 2010; Reyes–Garcia et al. 2012). Home gardens are important as a means of maintaining PGR (plant genetic resources) (Agelet et al. 2000; Sunwar et al. 2006), as potential hotspots of agricultural biodiversity (Galluzzi et al. 2010; Kumar and Nair 2004; Taylor and Lovell 2014), as natural resources for alleviating poverty (Reyes–Garcia et al. 2012; Salako et al. 2014), and can help in reducing hunger and malnutrition in the impending world food crisis, climate change, and a large number of socio–economic benefits (Cruz–Garcia and Struik 2015; Galhena et al. 2013). In addition, they represent a viable solution for biodiversity conservation as *ex–situ* and *in–situ* conservation areas for rare and threatened species (Kabir and Webb 2009; Roy et al. 2013). Abundant wild crop relatives in those gardens may be an important resource for domestication of modern agricultural crops and can also play a significant role in plant breeding and further

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improvement (Cruz–Garcia and Struik 2015; Galluzzi et al. 2010; Hammer et al. 1999).

The home gardens in the eastern Himalayan region of Northeast India (NEI) are known for important role in the domestication of many plants and crops. Home gardening in NEI is believed to have evolved with the local practice of jhum agriculture, the slashing and burning of the forest, which results in the loss of topsoil and nutrients, leading to habitat degradation. Farmers of the region have recognized the adverse impacts of jhum agriculture and consequently developed a preference for home gardening over jhum for the maintenance of crop diversity, household food security, nutrition, and subsistence income. Such systems in NEI resemble the agroforestry systems practiced in many parts of the world (Sahoo 2007), and serve as an important source of various resources for local inhabitants. Since most of the landscapes in the region are steep slopes and such land use is a suitable approach to minimize soil erosion and easily adaptable for ecological rehabilitation and agricultural productivity (Sahoo 2007). Along with the indigenous and local varieties of crops, farmers of the region cultivate large numbers of improved varieties of annual/biennial crops. This complex farming system is dynamic and includes various life forms of plants such as herbs, shrubs, and trees.

Despite their biological richness and importance, the species composition in these systems remains poorly understood in the mountainous, limited cropland areas. Thus, the objective of this study is to determine plant diversity in the indigenous home gardens in order to understand their importance in food production, livelihood, and conservation of local plant diversity. These home gardens are indigenous in the view that they evolved from locally available resources in relation to the culture of pastoral tribal people of the region. Thus, home gardening became the prevailing farming system for the region within the steep topography. Quantitative characterization of these gardens may contribute to better understanding the structure and function and may prescribe sustainable land–use systems in the region. Because people tend to keep genetic resources in their vicinity mainly for food and medicinal uses (Achigan–Dako et al. 2011; Horn et al. 2012), we assumed that home garden species would be mostly used for providing plants for food and medicinal uses as well as other purposes. Indigenous tribal farmers residing in these villages generally lack access to industrial and other major income–generating facilities as well as urban food markets as compared to the other areas in India. Therefore, the majority of the villagers may be expected to select garden species for monetary support for the family through selling extra crop yields. These gardens are often enriched by wild germplasm from nearby forests and hence it can also be hypothesized that species found in home gardens are representative of the native forest species.

Methods

Study Site

Mizoram or "land of the hill people" is located within the Indo–Burma biodiversity hotspot at the far end of the Himalayan mountain range. Roughly 91% of the area is under forest cover. It lies between 92°15' and 93°26'E longitude and 21°58' and 24°35'N latitude, with an altitudinal range of 2,100 – 2,157 m msl. The climate of the area is moist tropical to sub–tropical. The temperature ranges between 20°and 30°C and between 7°and 18°C during summer and winter, respectively, and it receives an annual rainfall of 2,000 – 3,200 mm. We studied 90 indigenous home gardens located in six villages in Mizoram, NEI. Three villages (Selesih, Sairan, and Thingsulthliah) are in Aizawl district, while the other three villages (Serchhip, Keitum, and Chaitlang) are in Serchhip district (Fig. 1). These home gardens are mostly rainwater fed. Water harvesting technology in the villages is almost non–existent due to steep slopes coupled with poor water–holding capacity of the soil. Almost all gardeners use traditional tools and practice manual weeding and pest control. Soil fertility is maintained through natural means using organic manures produced at home and through composting leftover crops. In general, adult family members contribute equal labor to the overall maintenance and management of gardens; men select cash crops, trees, and fruit species and obtain and sow seed materials, while women mainly grow and manage vegetables, spices, medicinal plants, and harvest and market subsistence crops. In general, flatland or settled valley cultivation practices are very limited and most of the agricultural practices are performed in the sloppy upland areas. The majority of the villagers practice home gardening for livelihood in those slopes without intensive and mechanized agricultural practices. Home gardens are still widespread and historically have been an integral

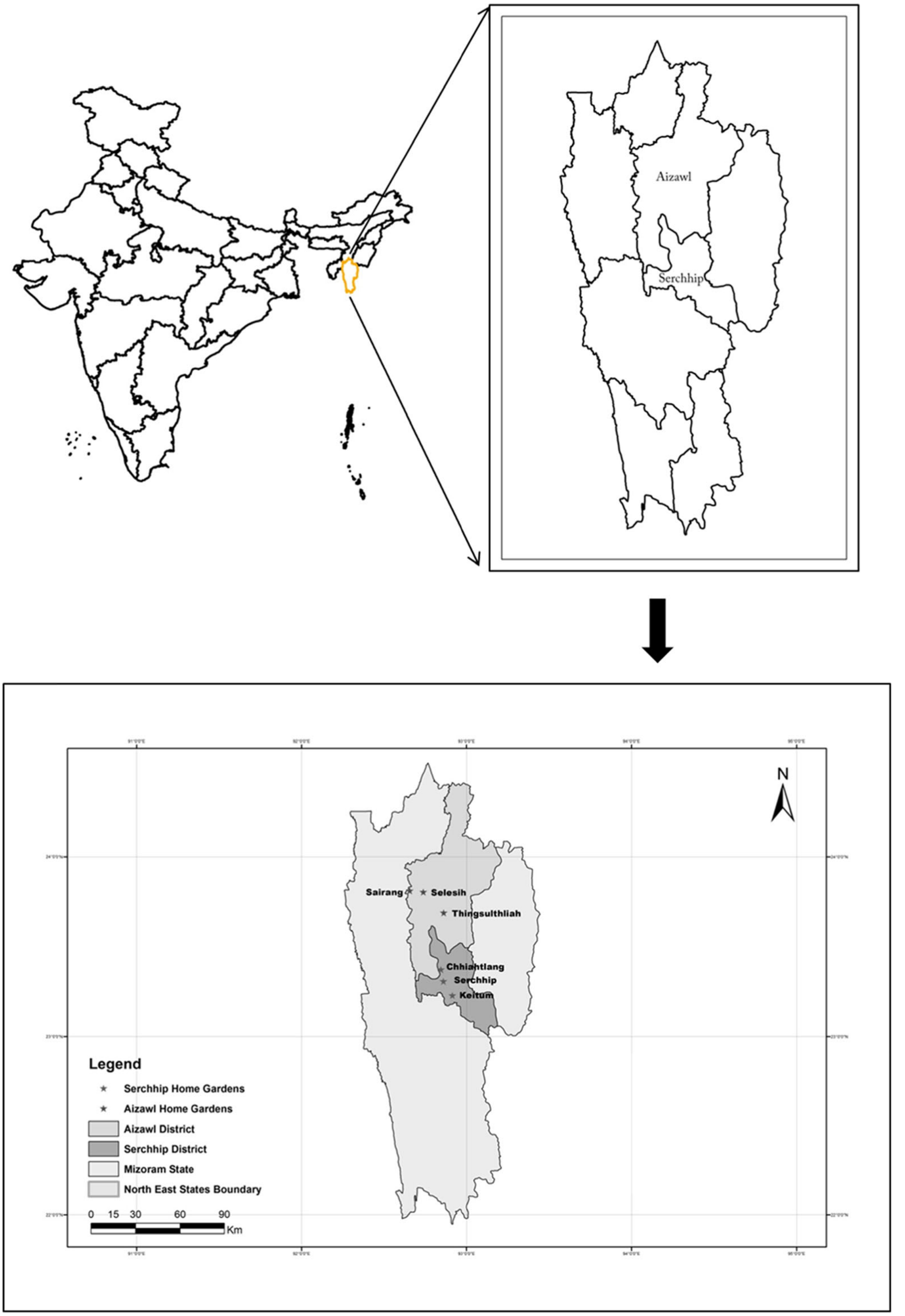

Fig. 1. Map showing the villages where home gardens are located in Aizawl and Serchhip district, Mizoram, NEI.

part of the subsistence agricultural systems of those villages along with sporadic shifting cultivation. Data describing the physical location and a few sociological characteristics of the study areas are given in Table 1. A wide variation in home garden sizes was observed. The mean area ranged between 2,211 – 4,297 m^2 and in general, home gardens located in Serchhip are relatively smaller ($P<0.001$; $t(44)=5.085$) than the home gardens in Aizawl (Table 1).

Data Collection and Analysis

The sampling strategy was based on the selection of villages and home gardens. As those villages do not have home garden censuses, we used purposive sampling strategies to ensure that we captured variability in the type and size of home gardens selected for the study. After proper identification of the potential garden for the study, we requested voluntary participation of the elderly and active members from each household to provide basic knowledge about different aspects of their home gardens. Field surveys were conducted from March to October in 2008. In each village, a minimum of 35 households (ca. 23% of the overall existing home gardens) were selected and interviewed. After interviewing with the gardeners of all the villages, 15 gardens in each village were finally selected (a total of 90 gardens) for detailed study with a confidence interval of 35%. The gardens having less area (<0.05 ha) were not included in the current samplings. Garden owners provided information of the social customs surrounding gardening practices. Information on plant species composition was collected by quadrats, and the use of each species was identified through direct observation and discussion with the farmers. We measured the area of total plant cover in each garden after excluding the dwelling area. Data collection was conducted in each home garden during the peak sowing and growing (April–June) and harvesting (June–September) seasons of the year. In each garden, species composition was enumerated by randomly placing five 10 m x 10 m quadrats for trees. Within each of these quadrats, another 5 m x 5 m quadrat for shrubs, and a 1 m x 1 m quadrat for herbs were established. Species richness was calculated as the number of species encountered in all quadrats grouped by habit forms. The local names of all plants were recorded, and each was identified to species level in consultation with the herbarium at the Mizoram University and taxonomists at regional herbaria of the Botanical Survey of India, Shillong. Plants with multiple uses were classified by main use, into categories including fencing, food, fuel–wood, fruits, medicinal, ornamental, roofs, timber, trade, and spice. Plant species with several uses other than the above–mentioned categories were included in

Table 1. Survey results describing physical and sociological characteristics of the villages (study sites) in Aizawl and Serchhip districts of Mizoram. Population information from Census of India (2011).

	Aizawl District			Serchhip District		
	Sairang	Selesih	Thingsulthlia	Serchhip	Keitum	Chhiahtlang
Population	5,034[a]	4,779[a]	3,402[a]	3,865[a]	2,022[a]	4,142[a]
No. of households	1,051[a]	873[a]	724[a]	613[a]	412[a]	308[a]
No. of households having home garden	112[a]	89[a]	64[a]	78[a]	46[a]	52[a]
No. of adult males	2,829[a]	2,409[a]	1,663[a]	1,947[a]	1,007[a]	2,137[a]
No. of adult females	2,205[a]	2,370[a]	1,739[a]	1,918[a]	1,015[a]	2,005[a]
Average garden size (m^2)	4,297[a]	3,887[a]	2,874[a]	3,159[a]	2,556[a]	2,211[a]
Range of the garden size (m^2)	1,421-6,027 (±330)	1,047-5,462 (±295)	1,064-4,321 (±223)	1,127-4,867 (±240)	1,245-3,891 (±207)	1,098-3,245 (±179)
Distance from market (km)	19[a]	12[a]	47[a]	4[a]	16[a]	10[a]
Mean altitude (m)	225[a]	1,163[a]	780[a]	1,013[a]	991[a]	695[a]

± Standard error values (N=15); Values with similar alphabets in a row as superscripts are significantly different at $P< 0.05$ level across each village.

the "other" category, which includes a variety of uses including shade, timber, fiber, and soil fertility.

The plants in each quadrat were counted, and a t–test was performed to identify the significant differences in the mean values of species richness. The diversity and abundance of plants in home gardens between villages were examined using ANOVA (SPSS 16.0) at two scales: garden and village. Garden level plant diversity and abundance were compared within the home garden in each village and overall villages. The data collected in the quadrats were used to determine the frequency, density, and dominance, following Phillips (1959). Species diversity was calculated using the Shannon–Weaver (1963) index of diversity: $H = -\sum \{(n_i / N) \ln(n_i / N)\}$, where n_i = importance value index (IVI) of a species and N = total IVI of the community. The importance value index (IVI) of each species was computed according to Curtis and Macintosh (1951) by adding relative frequency, density, and abundance values described in Salako et al. (2014). The dominance index (Simpson 1949) of the community was calculated as: $C = \sum \{(n_i/N)^2\}$, where n_i and N are the same as for Shannon–Weaver's index. Pielou's (1969) evenness index was calculated as: $e = H / \log(S)$, where H = the Shannon–Weaver index of diversity, and S = total number of species. Sorensen's similarity index (Sorensen 1948) was calculated as, $[2C / (A + B)] \times 100]$, where A and B are the total species content in stand A and B respectively, while C is the number of species common to both stands. Differences in mean numbers of species, overall species richness, and different community diversity parameters at the village levels were tested by non–parametric methods using Kruskal–Wallis and Mann–Whitney tests in SPSS 16.0. Multiple linear regression analyses were performed to find the factors determining plant species richness, diversity, and dominance indices in SPSS 16.0. In these analyses, dependent variables were species richness (total number of species in each garden), Shannon–Weaver indices of diversity, dominance indices of different species at garden levels, and the number of species under different use categories. The independent variables include garden size, distance of the garden from the local market, and the mean elevation of the garden.

Regarding income, the data obtained from the farmers on annual production basis were converted into USD during the sampling year (2008). Since the financial output of these gardens needs long–term studies, these results can be considered as a first step in understanding the financial value of these home gardens. Data about the approximate annual production for a limited number of plants (25 species only) from six gardens (each village, one garden) were calculated based on the farmer's information. Further, the income from these products was calculated by multiplying the selling portion of the products as per local market price.

Results

Species Richness and Diversity

A total of 128 plant families were recorded in the present study (Appendix 1—Electronic Supplementary Material–ESM). The most common plant families (Fig. 2) were Fabacece, Rutaceae, Zingiberaceae, Solanaceae, Asteraceae, Euphorbiaceae, and Cucurbitaceae, which contained 25, 18, 14, 13, 11, 11, and 10 species respectively. The highest numbers of food plants were from Fabaceae; the Rutaceae contributed the maximum number of fruits and medicinal plants. The most abundant tree species included *Areca cathechu* L., *Artocarpus heterophyllus* Lam., *Mangifera indica* L., *Parkia timoriana* (DC.) Merr., and several *Citrus* species. The dominant shrubs species were *Amaranthus viridis* L., *Cajanus cajan* (L.) Millsp., *Calamus erectus* Roxb., *Capsicum annuum* L., *Carica papaya* L., *Clerodendrum colebrookianum* Walp., *Hibiscus macrophyllus* Roxb. ex Hormen, *Murraya koenigii* (L.) Spreng, and a large number of *Musa* and *Solanum* species. The dominant herbaceous species were *Ageratum conyzoides* L., with some *Allium, Brassica,* and *Cucurbita* species (Appendix 1—ESM).

The number of plant species in each home garden ranged from 36 to 167, with an average of 78 species, suggesting a high intra–garden variation in overall species composition and richness. The species accumulation curve based on 90 gardens sampled in the area did not reach an asymptote, indicating that home gardens in the region may contain more number of species (Fig. 3). The lack of an asymptote further indicates that multiple species share dominance in the overall structural community of the home gardens (Fig. 3). The majority (85%) of the species were represented in a broad range of frequency (5% to 40%) classes and only a few (15%) in high frequency classes (41% to 75%) (Fig. 4), indicating the

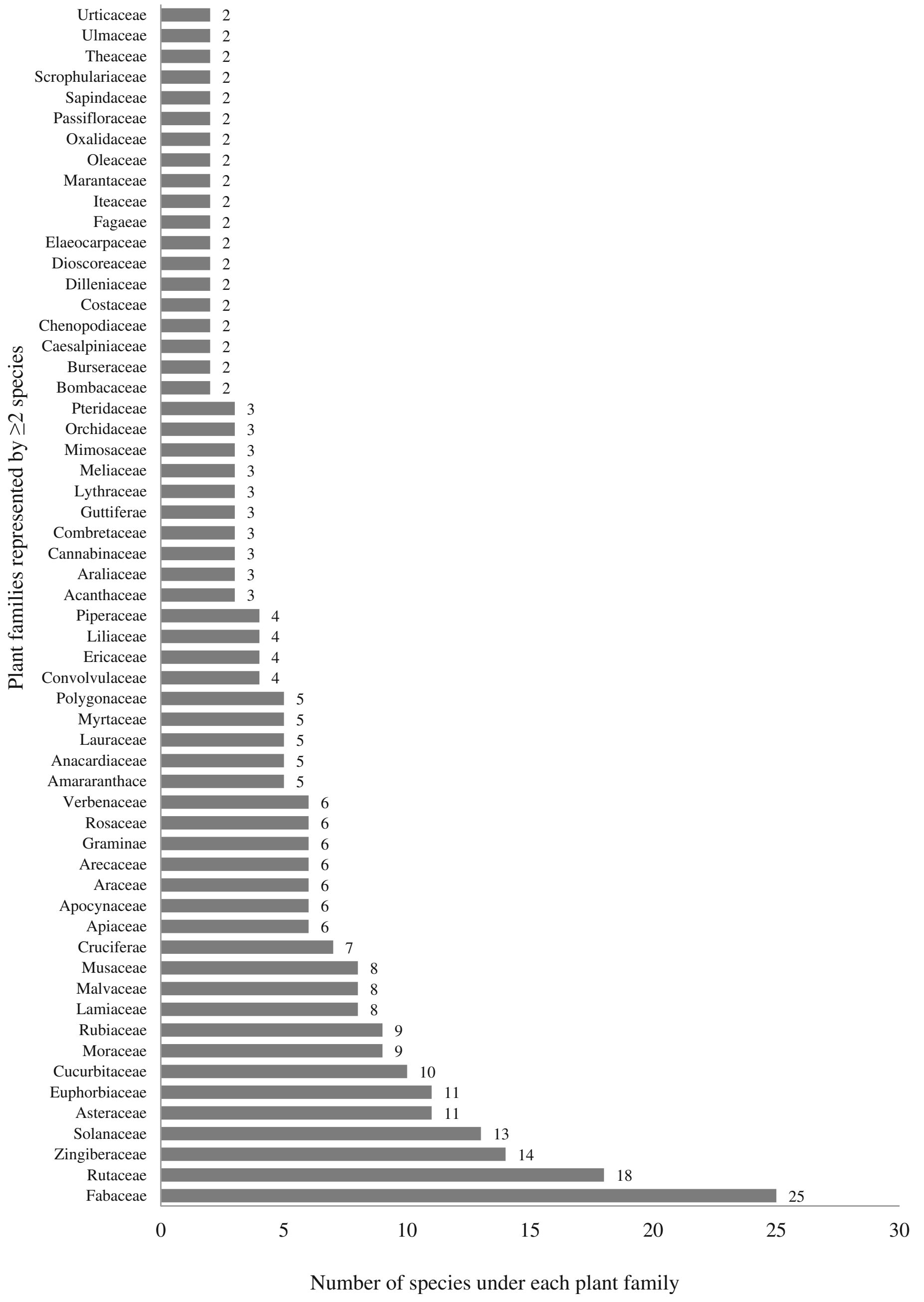

Fig. 2. Species–rich plant families (≥2) in the home gardens in Mizoram.

occurrence of a large number of species in those gardens and that they have a normal distribution pattern. A total of 333 plant species were found, with trees being most abundant (133 species, 40%), followed by 108 (32%) herbs, and 92 (28%) shrubs. Overall, 96 genera of trees in 52 families were identified, including 59 genera of shrubs in 36 families and 59 genera of herbaceous plants belonging to 52 families (Table 2). Species richness varied significantly (Mean=1124.55, SD=1292.65;

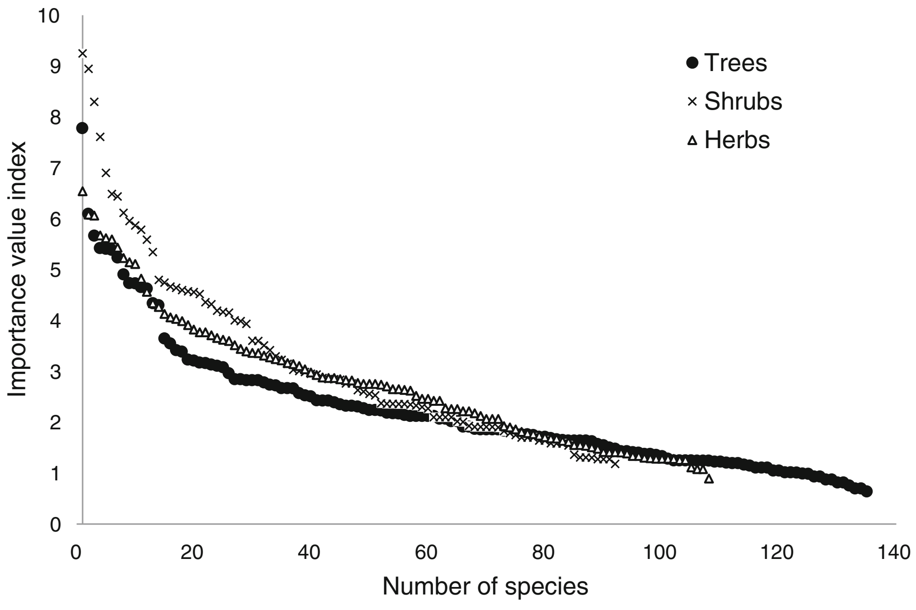

Fig. 3. Importance value distribution curve of tree, shrubs, and herbs species in the six home–gardens in Mizoram.

t[44]=5.83, P=0.001) among villages with the highest number of species in Sairang, followed by Serchhip, and the lowest in Thingsulthliah (Table 2).

Species diversity indices for trees, shrubs, and herbs varied significantly (Mean=4.11, SD=0.288; t[17]=60.41, P=0.001) within gardens. Overall, the tree species diversity was higher (F=6.84, P=0.01; ANOVA) than for herbs and shrubs. The evenness index for trees, shrubs, and herbs also showed a trend similar to the diversity index values and varied slightly within gardens (P<0.05). The evenness

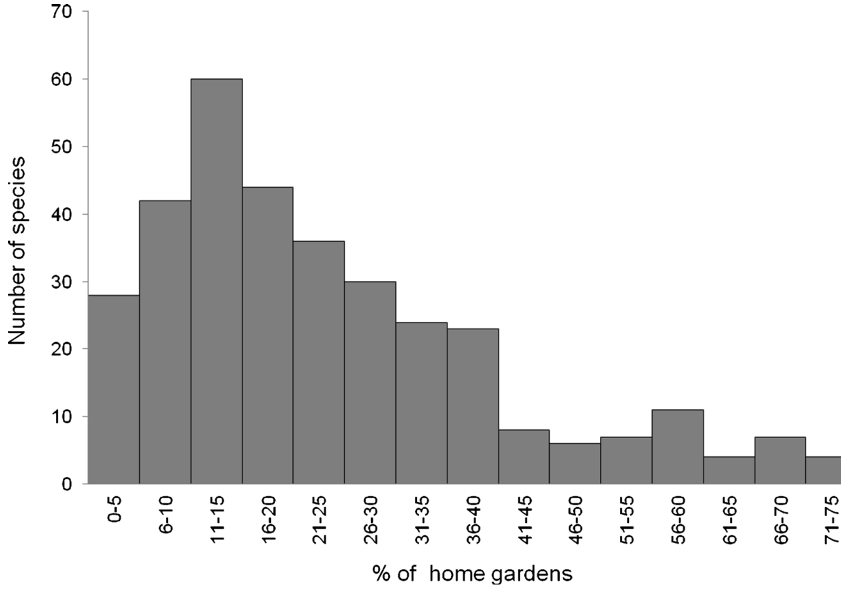

Fig. 4. Frequency distribution of species richness.

TABLE 2. SPECIES RICHNESS AND COMMUNITY INDICES OF HOME GARDENS LOCATED IN SIX DIFFERENT VILLAGES IN MIZORAM, NORTHEAST INDIA.*,**

Parameters	Sairang	Selesih	Thingsulthliah	Serchhip	Keitum	Chhiahtlang	Overall
Total number of species							
Trees	110[a]	94[a]	93[a]	97[a]	96[a]	99[a]	133
Shrubs	63[a]	52[a]	40[a]	61[a]	67[a]	58[a]	92
Herbs	88[a]	61[a]	35[a]	74[a]	55[a]	66[a]	108
Number of genera							
Trees	83[a]	66[a]	64[a]	74[a]	75[a]	63[a]	96
Shrubs	44[a]	36[a]	29[a]	43[a]	45[a]	40[a]	59
Herbs	69[a]	45[a]	26[a]	57[a]	49[a]	51[a]	59
Number of families							
Trees	42[a]	42[a]	39[a]	42[a]	45[a]	41[a]	52
Shrubs	26[a]	25[a]	21[a]	28[a]	29[a]	26[a]	36
Herbs	33[a]	27[a]	19[a]	31[a]	26[a]	28[a]	40
Diversity index							
Trees	4.05[a]	4.44[ab]	4.42[a]	4.45[a]	4.43[ab]	4.44[ab]	4.76
Shrubs	4.06[ab]	3.87[a]	3.61[a]	4.11[a]	4.00[ab]	3.94[a]	4.39
Herbs	4.40[a]	4.04[a]	3.48[a]	4.23[a]	3.94[a]	4.15[a]	4.58
Dominance index							
Trees	0.164[a]	0.237[ab]	0.240[a]	0.237[ab]	0.239[ab]	0.239[ab]	0.200
Shrubs	0.287[ab]	0.316[a]	0.355[a]	0.280[ab]	0.296[a]	0.305[a]	0.246
Herbs	0.241[a]	0.290[a]	0.373[a]	0.264[a]	0.304[a]	0.274[a]	0.220
Evenness index							
Trees	0.863[a]	0.978[ab]	0.975[ab]	0.972[ab]	0.971[ab]	0.966[a]	0.971
Shrubs	0.980[a]	0.978[ab]	0.978[ab]	0.968[a]	0.952[a]	0.971[ab]	0.970
Herbs	0.983[ab]	0.982[ab]	0.979[a]	0.982[ab]	0.984[ab]	0.990[a]	0.978

*Values with similar alphabets in a row as superscripts are significantly different at P< 0.05 level across each village. **Shannon-Weaver diversity= $H' = -\sum \{(n_i/N) \log_e (n_i/N)\}$; Dominance index= $C=\sum \{(n_i/N)^2\}$; Pielou's evenness index= e= H'/logs.

values were higher in the small gardens in Selesih and lower in the large gardens in Sairang (Table 2). The overall tree, shrub, and herb species richness (number of species, genera, and families) and the different community parameters (diversity and dominance indices) were slightly higher in larger home gardens and have significant differences (P<0.05) among the gardens in different villages (Tables 2 and 3). Although this indicates their distinctiveness in species composition and diversity among the different villages, insignificant differences in evenness values among the majority of the gardens reveal similar species preferences among the farmers (Table 2). Multiple regression analysis between the distances of the garden from the local markets showed a significant positive relationship with the overall species richness but insignificant with diversity and uses of the species (Table 3). The relationship between the altitudinal differences of the villages and overall species richness were highly significant; however, diversity and uses of the species were merely significant (Table 3). In general, the gardens located in the mid–elevation range have greater number of species as compared to

TABLE 3. RESULTS OF MULTIPLE REGRESSION ANALYSIS BETWEEN GARDEN SIZE, DISTANCE OF THE GARDENS FROM THE MARKETS, AND ELEVATION WITH DIFFERENT DIVERSITY FACTORS AND USES OF SPECIES AMONG THE DIFFERENT HOME GARDENS IN MIZORAM. FOR EACH VARIABLE THE ADJUSTED R^2 AND SIGNIFICANCE VALUES ARE PROVIDED.

Dependent Parameters	Species Richness	Shannon-Weaver Diversity	Dominance Index	Uses of Species
Degree of freedom	98	98	98	98
Garden size (m^2)	0.668**	-0.004*	-0.002*	0.742**
Distance from market (km)	0.277**	0.018 [ns]	0.012[ns]	0.014 [ns]
Elevation (m)	0.142**	0.002 [ns]	0.011 [ns]	0.003 [ns]

**P(t)<0.001, *P(t)<0.05, ns-not significant (N=90).

the gardens located in the higher elevation range. The similarity indices of trees, shrubs, and herbs were high (91%) between gardens in Selesih and Sairang followed by Thingsulthliah and Sairang (88%). The lowest similarity values (68%) were observed among the gardens of Serchhip and Selesih. The tree species similarity indices showed significant variation (Mean=70.76, SD=6.33; t[14]=43.23, P=0.001) among gardens with highest similarity (87%) between gardens in Selesih and Sairang and the lowest in Keitum and Chhiahtlang (51%) (Fig. 5). In general, 66 trees (50%), 35 shrubs (38%) and 53 herb (49%) species were common to all gardens.

Stratification and Functional Diversity

All home gardens were composed of a mixture of herb, shrub, and tree species forming multiple layers of different species with three to four distinct vertical stratifications. The uppermost canopy consisted of trees and therefore represent a perennial layer. Species commonly found in this layer included *Alstonia scholaris* (L.) R.Br., *A. cathechu*, *Bombax ceiba* L., *Borassus flabellifer* L., *Canarium bengalense* Roxb., *Castanopsis indica* (Roxb.) D.C., *Grevillea robusta* A. Cunn. ex R.Br., *Mesua ferrea* L., *P. timoriana*, *Quercus griffithii* Hook & Th., *Sterculia villosa* Roxb., and *Tectona grandis* L. This layer followed by individuals of *Aegle marmelos* (L.) Correa, *A. heterophyllus*, *Dillenia indica* L., *Elaeocarpus floribundus* Blume., *Lagerstroemia speciosa* (L.) Pers., *M. indica*, *Oroxylum indicum* (L.) Kurz, *Psidium guajava* L., *Schima wallichii* (D.C.) Korth., and *Tamarindus indica* L. Annual and perennial plants are found immediately below this layer. The most common and important species are *Acacia nilotica L.*, *Albizia procera* (Roxb.) Benth, *Averrhoa carambola* L., *Bauhinia variegata* L., *Citrus aurantifolia* (Christm.) Swingle,

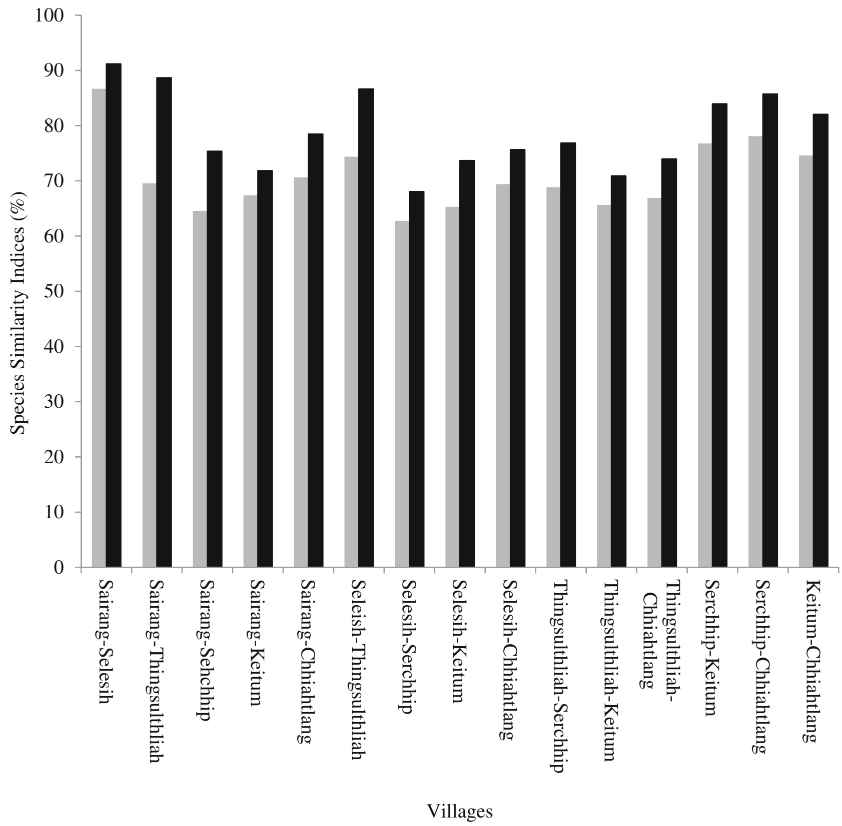

Fig. 5. Species composition similarity index based on Sorensen's similarity index ([2C/{A+B}] x 100) of the overall species (▭) and tree species (■) within the six villages in Mizoram.

C. grandis L., *C. macroptera* Montr., *C. reticulata* Blanco, *C. medica* L., *C. rugulosa* Tanaka, *Persea americana* Mill., *Phyllanthus acidus* (L.) Skeels., *Ziziphus jujube* Mill. The third story consisted of a variety of shrub species including a large number of perennial medicinal and crop plants including *A. viridis*, *C. cajan*, *C. colebrookianum*, *Chenopodium album* L., *Ocimum sanctum* L., *Hibiscus sabdariffa* L., *Manihot esculenta* Crantz., *Solanum khasianum* Clarke, *S. melongena* L., and also climbing crops like *Sechium edule* (Jacq.) Sw., *Piper betle* L., *Glycine max* (L.) Merr., *Momordica charantia* L., *Dolichos tetragonolobus* L., *Vitis vinifera* L., and a variety of *Musa* species. The lowest ground story consisted of species that were 20 cm or less in height, such as *Ageratum conyzoides* L., *Allium cepa* L., *A. hookeri* Thwaites, a few species and varieties of *Brassica*, *Colocasia* and *Cucurbita*, *Curcuma longa* L., *Ipomoea batatas* (L.) Lam., and *Zingiber officinale* Roscoe.

Plant species were broadly categorized into 11 use groups (Fig. 6). The species in different use categories were well represented in each surveyed garden. Medicinally important plants were best represented (33%) followed by food plants (16%), fruits species (10%), ornamentals (6%), timber (5%) and fuel wood (2%), trade and spice plants (2%), and 1% each of roofing and fencing category. A large proportion of plants (22%) had multiple uses (Fig. 6). Different tree species were associated with various socio–economic and ecological roles in the site. For example, a large number of timber species (5%), such as *Artocarpus chama* Buch–Ham., *Chukrasia velutina* M. (Roem.), *Cinnamomum tamala* (Buch.–Ham.) T. Nees. & Eberm., *M. indica, M. ferrea*, *Michelia champaca* L., *S. villosa*, and *S. wallichii* are used for the construction of houses and furniture in addition to their fruit products. Many of these species also serve multiple functions, such as *Trema orientalis* (L.) Blume, *Calamus acanthospathus* Griff., *Lantana camara* L., *Erythrina arborescens* Roxb., and *A. nilotica,* which were planted as living fences between home gardens to protect crops from wild animals and also to increase soil fertility. As per gardeners' knowledge and information sharing during the survey, a few evergreen and perennial tree species viz., *A. scholaris*, *Azadirachta indica* A. Juss., *P. timoriana*, *S. wallichii*, and *S. villosa* also have a number of ecological values besides their timber and fuel wood supply. Those ecological services include shade under canopy trees, as well as shrubs and herbs

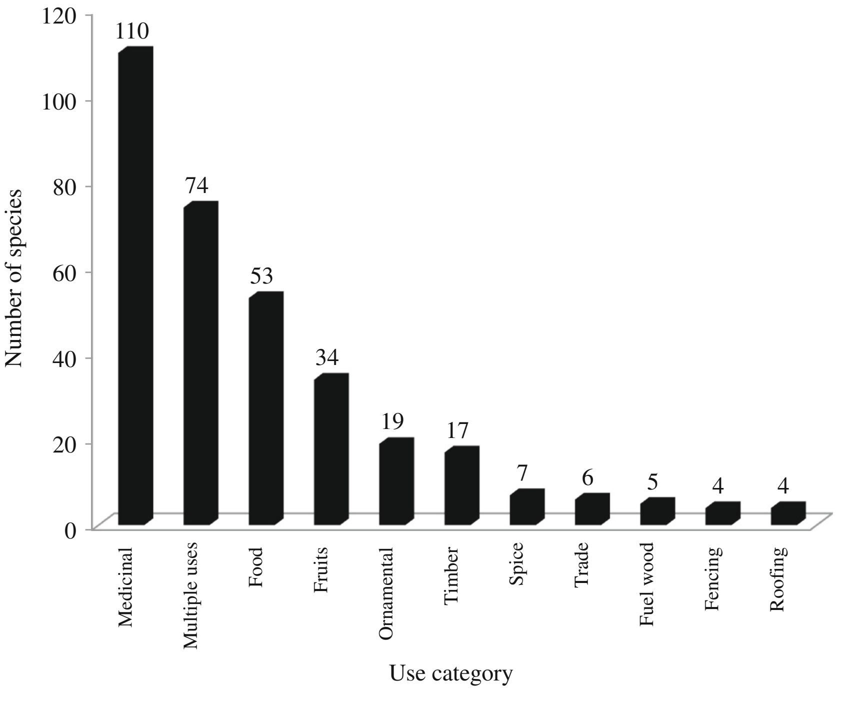

Fig. 6. Use category of species.

providing improved soil fertility through leaf litter decomposition. According to farmer perspectives, many annual crops show better yield when they are in association with a few tree species like *Albizia myriophylla* Benth., *Cassia nodosa* Roxb., *Erythrina indica* Lam., and *Duabanga grandiflora* (D.C.) Walp. This may be due to better nitrogen fixing abilities of those plants. *P. timoriana*, is found to be common in almost all of the home gardens because of its wide economic and ecological roles in these systems. This species also provides good economic return every year through the sale of its long, tender pods as a delicious vegetable throughout the region. Furthermore, this plant is occasionally harvested for timber, is used for making furniture, and fulfills other domestic needs. Varieties of *Cucurbita* species are used for their tender shoots, flowers, and fruits. Taro and yam–like roots representing a few *Colocassia* and *Dioscorea* species are used for leaf, petiole, corm, and rhizomes, and several *Musa* species are harvested as fruits and vegetables. In general, home gardens are sources of various bio–products for the overall and basic need of families in the hilly region.

Home gardening in Mizoram represents an integrated production system for subsistence food production and family income. A few plant products from home gardens were sold regularly (Table 4) because most are exclusively used for household consumption. Sales were confined almost exclusively to the local market because transport to the district capital market and other areas is costly due to the poor road communication system in the region. According to a conservative estimate, a household can earn annually about USD 3,000, thus representing a major contribution to the family's income. Table 4 presents the average annual yield (after consumption) and monetary values of a few important plants grown in these home gardens. The commonly sold vegetables include

TABLE 4. MEAN ANNUAL YIELD AND INCOME FOR A FEW SELECTED PLANTS FOUND IN THE HOME GARDENS IN MIZORAM

Species	Local Unit of Measurement	Average Yield /Garden	Financial Income (USD)	% Consumed	% Sold
*Ananas comosus (*L.) Merrill	Unit	282±23	56	40	60
Areca cathechu L.	Unit	6550±610	66	35	65
Artocarpus heterophyllus Roxb.	Unit	412±21	82	30	70
Averrhoa carambola L.	Unit	2572±211	103	40	60
Brassica juncea L.	Bundle	592±54	118	50	50
Capsicum annum L.	Kg	34±6	34	40	60
Carica papaya L.	Unit	577±52	231	30	70
Citrus aurantifolia (Ch.) Swingle	Unit	3350±112	134	30	70
Citrus grandis L.	Unit	1850±173	370	30	70
Citrus limon (L.) Burm	Unit	3000±139	90	40	60
Citrus macroptera Montr.	Unit	2867±198	287	40	60
Citrus medica L.	Unit	800±55	80	50	50
Citrus reticulata Blanco	Unit	2438±70	195	30	70
Clerodendrum colebrokianum Walp.	Bundle	282±17	56	40	60
Colocasia affinis L.	Bundle	470±44	94	50	50
Cucurbita maxima Duchesne	Unit	302±31	60	50	50
Mangifera indica L.	Kg	189±15	189	40	60
Musa acuminata Colla.	Unit	3675±210	110	40	60
Musa paradisiaca L.	Unit	2267±150	91	50	50
Parkia timoriana (DC) Merr.	Unit	683±22	137	50	50
Passiflora edulis Sims.	Unit	1518±23	61	40	60
Persea americana Mill.	Unit	393±15	78	40	60
Psidium guajava L.	Unit	1224±219	73	40	60
Sechium edule (Jacq.) Sw.	Kg	1035±69	104	40	60
Zingiber officinale Roscoe	Kg	288±20	144	30	70

± Standard Error (N=6).

spinach, pumpkin, cucumber, squash, taro, and okra, and fruits like mango, orange, banana, pineapple, papaya, and jack fruit. The majority of farmers sell more than 60% of their produce for income generation, whereas the rest are used for family consumption. Besides, those many other vegetables, fruits, flowers, bulbs/corms, and medicinal plants also provide useful economic returns that need further and extensive study for proper quantification.

Discussion

The mountainous region of Mizoram in the Indo–Burma biodiversity hotspot is home to many indigenous communities where individuals have unique life styles and are accustomed to living on steep slopes using locally available natural resources. Increased population and urbanization in many parts of India has led to a reduction in forest cover. However, the mountain areas of Mizoram have not experienced extensive deforestation except for shifting cultivation. Home gardens are the primary agricultural land use system, as well as a source of year–round food and other daily necessities. The ownership of these gardens passes from one generation to the next and is maintained as permanent family gardens, sustaining productivity for many generations without major changes in the composition of plant communities. In addition, the maintenance of large numbers of species in home gardens provides indirect benefits and ecological services. Similar services from home gardens throughout the world have been reported (Calvet–Mir et al. 2012; Clarke et al. 2014; Das and Das 2015; Fernandes and Nair 1986; Gautam et al. 2008; Idohoua et al. 2014; Mendez et al. 2001; Sunwar et al. 2006).

The size of home gardens in Mizoram ranged between 0.10 and 0.60 ha, which is similar to global average home garden sizes of 0.10 – 0.50 ha (Das and Das 2005; Fernandes and Nair 1986; Kumar et al. 1994). Plant diversity and home garden productivity is largely a function of garden size; large home gardens provide sufficient products for home consumption as well as significant financial gains through sale (Table 4). Our study has shown a significant positive correlation ($R=0.820$, $P<0.001$) between garden size and total species diversity. Farmers constrained with land shortage concentrate on fewer species with high usage and allocate more land area for food crops as evident by the significant ($R=0.650$, $P<0.001$) positive correlation between garden size and plants used for food. This pattern of increasing tree species richness with increasing land holding is also reported in other home gardens (Das and Das 2015; Kumar et al. 1994; Mendez et al. 2001; Zhang and Jim 2014).

Representation of over 300 species in diverse plant families and genera with an average of 78 species per garden highlights their species richness (Table 2). The species composition of these home gardens is similar to general floristic profile reported from other tropical home gardens. Fernandes and Nair (1986) reported that tropical home gardens harbor diversity equivalent to tropical forests. Many other studies (Eyzaguirree and Linares 2004; Gautam et al. 2008; Poot–Pool et al. 2015; Shastri et al. 2002) also highlighted the importance of home gardens for the maintenance and conservation of plant genetic diversity. Several taxa such as *Allium*, *Annona, Brassica*, *Calamus*, *Citrus*, *Dioscorea*, *Carica*, *Capsicum*, *Curcuma*, *Mangifera, Psidium,* and *Spondias* have been reported in several tropical home gardens in many regions of the world (Das and Das 2015; Das and Das 2005; Kabir and Webb 2009; Shastri et al. 2002; Sunwar et al. 2006). In general, the plant richness estimated in this study is relatively higher than the other reported home gardens of India including Assam in NEI (Das and Das 2005), Karnataka (Shastri et al. 2002), and Kerala (Kumar et al. 1994). Several home garden species surveys have been reported in other areas of the world, with 278 species reported in China (Clarke et al. 2014), 281 in Mexico (Larios et al. 2013), 200 species in Thailand (Makaraphirom 1989), and 62 species in Bangladesh (Roy et al. 2013). High species richness and diverse plant composition provide a wide range of choices of plant material to meet diverse farmer needs. The species diversity index for trees, shrubs, and herbs in the present study was 4.76, 4.39, and 4.58, respectively (Table 2). The species diversity index values are higher than the corresponding values of home gardens in various parts of the world: 0.50 – 3.30 in Hong Kong (Zhang and Jim 2014); 1.007 – 3.153 in Tehuacán Valley, Mexico (Larios et al. 2013); 1.9 – 2.7 in Thailand (Gajaseni and Gajaseni 1999); 2.30 – 3.39 in Bangladesh (Roy et al. 2013); 2.43 – 3.84 in Mexico (Gliessman 1990a); 3.21 in Karnataka, India (Shastri et al. 2002); and 3.55 in Costa Rica (Gliessman 1990b). The species diversity index of home gardens in Mizoram are similar to the values (4.03 – 4.42) reported from home gardens in western Nepal (Sunwar et al. 2006). The high diversity values found in those gardens highlights their richness and are related to several factors, such as varied geography, favorable microclimates, high rainfall, long history, introduction of species from the nearby forest, as well as exchange and sharing of resources by the communities. Multiple nutritional demands and year–round needs of various products also increased the diversity in those home gardens. Further, the higher diversity indices indicates the stability of those systems as these home gardens are the result of varied selection of species by the farmer for their various needs. Dietary changes and needs also might have resulted in increased diversity of species, including exotic and improved varieties of plants. In the current study a large number of species (142 species; Appendix 1—ESM) was found to be wild, indicating dependence on local and regional species. Similar findings were also reported by Poot–Pool et al. (2015). Dominance index values ranged between 0.164 and 0.373 among the gardens, and tree species have lower values then herbs and shrubs (Table 2). Overall low dominance indices explain the heterogeneity and richness in species composition with greater dominance of trees followed by herbs and shrubs respectively. The greater evenness values of 0.970 – 0.978 among different plant categories and gardens indicate that a greater percentage (ca. 97%) of the species is uniformly distributed in different gardens in the area. In general, high evenness and low dominance values in the gardens confirm that those gardens are not occupied by a limited number of species; rather, they are occupied by an abundant number of species. Greater species similarities among the gardens of different villages result from the fact that tribal communities in all the villages are from same ethnic groups. And they have similar management and conservation strategies. In general, the household requirements for food, spices, and other uses are similar among the farmers residing in the different villages. Some variation may be due to individual family species preference, size of home garden, altitude, and soil fertility status.

In regard to vertical structure, different species composition and perennial habits of a large number of plants make these gardens resemble tropical forests with multi–layered vegetation structure. Smith et al. (2005) and Das and Das (2005) stated that different stratifications and dynamic architecture make home gardens a sustainable and resilient ecosystem. Vertical stratification in vegetation makes such systems more productive by capturing light sources and the uptake of soil nutrients by different root systems. On the other hand, many shade–loving crop plants receive an optimal environment for their growth and yield. Different climbing crops such as grapes, squash, betel vine, and pumpkin receive physical support from other plants and act as host for a number of epiphytes, such as orchids. The indigenous tribal communities of the region have developed and learned similar management strategies through generations. Furthermore, similar practices may have evolved through direct observations and cultural experiences through living in association with natural forests for many generations.

The year–round and regular services provided by different plant products are due to combinations of a large variety of crops of different habits viz., annual, biennial, and perennial. The presence of crops with different functions and habits fulfills the nutritional and financial needs of the farmer. Home garden plants are used for food and fruit production as well as medicinal needs. These results are also consistent with findings from other studies that highlighted the importance of home gardens in producing healthy food and economic support to the gardener (Calvet–Mir et al. 2012; Das and Das 2015; Reyes–Garcia et al. 2012; Poot–Pool et al. 2015). The perennial nature of these home gardens and the combination of herbaceous vegetables, shrubs, and trees form mixed and balanced production systems. This might play an important role in ecological sustainability and stability through effective management strategies by the owner of home gardens. Gardeners also reported that they continue to grow many landraces over hybrid and modern varieties of crops for specific traditional dishes, tastes, and flavors. Thus, indigenous wild crop varieties are also maintained regularly in every garden (e.g., *A. viridis*, *A. spinosus*, *C. esculenta*, *C. mannii*, *C. gigantea*, *D. tetragonolobus*, *H. macrophyllus*, *M. esculanta*, *Solanum anguivi* Lam., *S. khasianum*, *Polygonum convolvulus* L., *P. orientale*, etc.) along with domesticated and improved varieties of crops (e.g., *A. cepa*, *A. sativum*, *Abelmoschus esculentus* (L.) Moench., *Brassica oleracea* var. *capitata* L., *B.rapa* L., *C. papaya*, *Coriandrum sativum* L., *Daucus carota* L., *Phaseolus* *vulgaris* L., *Raphanus sativus* L., *Solanum melongena* L., *Vigna mungo* (L.) Hepper, etc.).

The high inter–specific diversity observed in many species of different plant families viz., Araceae (6 *Colocasia* species), Musaceae (8 *Musa* species), Polygonaceae (5 *Polygonum* species), Rutaceae (14 *Citrus* species), Solanaceae (10 *Solanum* species), and Zingiberaceae (8 *Curcuma* species) could be attributable to the introduction of crop plants from wild sources, preference of the farmers, and selection for desired traits. This also suggests that these gardens maintain wild crop relatives and could serve as an important center of plant domestication. Hammer et al. (1999) pointed out that genetic exchange through natural crosses among wild and domestic crops is a common phenomenon in home gardens. Human–regulated backyard and kitchen gardens may also play an important role in domestication and further utilization of wild crop relatives through hybridization (Hughes et al. 2007). These hybrid landraces will have higher capacity to overcome environmental challenges than highly exploited commercial crops (Jackson et al. 2007; Negri 2005). Other workers also reported maintenance of landraces and a wide range of genetic diversity to be a highly valued ecosystem service provided by home gardens from different regions of the world (Calvet–Mir et al. 2012; Eyzaguirre and Linares 2004). The importance of intra–specific diversity is highly recognized in various ecological and biological phenomena like adaptation, survival, and breeding (Feuillet et al. 2008; Nunney and Campbell 1993).

Although a very limited number of species recorded from home gardens are commercialized in the region (e.g., *A. cathechu*, *Citrus macroptera*, *C. reticulata*, *C. sinensis*, *M. indica*, *C. papaya*, *Musa paradisiaca*, and *M. acuminata*), there are many species grown in those gardens that have potential market value. Besides, many other species endemic to the region are also commonly found in those gardens (e.g., *Artocarpus chama* Buch–Ham., *Artocarpus lakoocha* Roxb., *Canarium bengalense* Roxb., *Citrus indica* L., *Cinnamomum tamala* [Buch.–Ham.] T.Nees. & Eberm, *Citrus macroptera* Montr., *Clerodendrum colebrookianum* Walp., *Michelia champaca* L., *Oroxylum indicum* [L.] Kurz, *Solanum khasianum* Clarke, *Curcuma amada* Roxb., and *Zingiber zerumbet* [L.] Roscoe ex. Sm.). As per IUCN endangered and threatened categories, species like *Bombax insigne* Wall., *Borassus flabellifer* L., *Centella asiatica* (L.) Urban., *Citrus macroptera*, *Citrus rugulosa* Tanaka, *Garcinia cowa* Roxb., *Hedychium spicatum* Sm., *Livistona chinensis* L., *Mangifera sylvatica* Roxb., and *Rauvolfia serpentina* (L.) Benth. Ex. Kurz. were also found in the local home gardens. This indicates that home gardens harbor many regionally endemic, endangered, and threatened species.

Conclusion

Home gardens harbor high biodiversity composed of annual, biennial, and perennial plants with structural similarity to tropical forests. Home gardening in the hilly region of Mizoram is an important agricultural system for fruits, vegetables, and medicine. The diversity and incorporation of native and introduced species, and cultural practices make the home gardens in the region a sustainable and economically viable subsistence agricultural system. Home gardens in the region are effective reservoirs of diverse PGR. They serve as an important means of conservation of native plants through use and reducing pressure on wild resources. The presence of inter–specific diversity in a variety of plant species revealed their existence of wild relatives near domesticated sites.

Future Work

Abundant plant species diversity in the home garden can play an important role in the management and conservation of regional agro–biodiversity. Detailed studies about the socio–economy are significant as these gardens are fulfilling the subsistence need of the farmers through generations. Favorable warm and humid climates encourage farmers to grow and maintain large number of fruits species and varieties of different taste and flavor; e.g., *Citrus*, in their native distributional range. The development of improved cultivation processes and improvement in fruit quality and yield may help in enhancing rural livelihood. Various aspects of crop plant genetics and ecology remain unexplored. Comparative diversity analyses among the wild and domesticated species at population level will help farmer in better utilization of resources and conservation.

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