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Species Composition, Production and Energetic Sustainability of Homegardens in the Highlands of Eastern Mizoram, India

Uttam K. Sahoo[1*] • Pebam Rocky[2] • Keny Vanlalhriatpuia[1] • Kalidas Upadhyaya[1]

[1] Department of Forestry, Mizoram University, Post Box-190, Aizawl-796009, India
[2] North-Eastern Space Application Centre, Shillong-793103, India

Corresponding author: * uttams64@gmail.com; uttamsahoo85@yahoo.com; uksahoo_2003@rediffmail.com

ABSTRACT

An in-depth study was undertaken in three villages taking 38 farms to analyze different components of homegardens and to critically analyze into various functional attributes so as to propose options for their improvement. We found homegarden sizes from 0.035 ha to 2 ha area (median = 1925 m^2). All together 199 plant species belonging to 67 families of which 80 were trees and 22 were shrubs were recorded from the homegardens. Mean number of species per garden was significantly higher in large gardens (53±10.8) as compared to small and medium (P<0.01). Shannon Weiner index for trees and shrubs was also higher in large gardens (H'=3.73, P<0.005). Mean number of species per garden and no of tree and shrubs species per garden significantly increases from small to large garden (P<0.01) where as there is no significant difference for herbs while mean number of species per 100 m^2 and trees and shrubs per 100 m^2 significantly decreases from small to large gardens (P<0.005). The energy input ranged from 125 MJ per m^2 in small to 31 MJ per 100 m^2 in large gardens. The energy efficiency was found to significantly (P<0.04) vary from 27 in small garden to 36 and 54 in medium and large gardens respectively. The monetary input significantly (P<0.02) varies from Rs. 928 per 100 m^2 in small to Rs. 228 per 100 m^2 in large gardens while there is no significant difference for the monetary output and the output-input ratio significantly (P<0.05) varies from 2.6 in small to 4.4 and 6.6 in medium and large gardens respectively. Mean net financial value of the homegardens ranged from Rs. 19,890 in small gardens to Rs. 1,31,476 in large gardens and the proceeds from the sale contributes 29.2% (small garden) to 52% (large gardens) of the total household income.

Keywords: energetic, financial value, homegarden, northeast India, plant composition, plant use

INTRODUCTION

Mizoram state, which lies in the northeastern corner of India, is well endowed with forests inhabited by different tribes. More than 0.4 million tribes live in the forested area which covers more than 80% of the total geographical area of the state. The forest products and agricultural yields meet the basic energy requirements of the tribal people and their domestic animals and the village ecosystems function mainly by recycling resources within the system. The traditional hill agro-ecosystems in India are mostly sustainable from an ecological point of view. In such ecosystem human labour is the main energy input (Ravelle 1976; Mitchell 1979; Nayak *et al.* 1993). Indigenous agroecosystems are highly site specific and differ from place to place, as they have evolved along divergent lines. In order to fulfill the food requirements, the farmers are struggling to compromise between small land holdings and better production. Since ecological sustainability of most of the earlier developed subsistence farming system is being increasingly questioned, new technologies that can be absorbed into the existing farming systems without increasing risk and also match with farmers' social objectives and economic resources are required in this region. In this regard, the locally practiced traditional agroforestry provides a promising alternative. Traditional homegardens are an important component of the indigenous village ecosystems which are based largely on indigenous knowledge and the species selection, where the farmers grow the plant species of the cultural patterns of the social and traditional significance.

Several studies have revealed that tropical homegardens are ecologically sustainable systems that not only generate important household savings on food, medicine and spice expenditures (Sanyal 1985; MacDicken 1990; Torquebiau 1992), but also provide subsistence agriculturalists with a supplementary income, dietary diversity and improve the nutritional quality of the families' diet (Immink *et al*. 1981; Niñez 1985b; Soemarwoto *et al*. 1985; Immink 1990; Nair 1997; Sahoo 2009, Akrofi *et al*. 2010). They offer productive opportunities (MacDicken 1990), and their food products provide badly needed energy, protein, minerals and vitamins to low-income peasant households (Niñez 1985b). Homegarden agroforestry also maintains high levels of productivity, stability and equitability (Zaman *et al*. 2010).

Although homegardens have been extensively described, there is a substantial lack of quantitative data about their benefits. No proper and widely applicable methodologies are available as yet to quantify these benefits, besides, the homegardens are most complex systems and therefore the methodologies applicable for single species system are not applicable for drawing suitable inferences. Personal preferences, socio-economic status and culture are few important determinants of the structure and function of homegarden (Christianty 1990).

Homegardens nevertheless have some tree output that can be used for long term production and sale for profit. Trees incorporated into agricultural systems have been found to yield greater payoffs than continuous agricultural monocropping (Leakey and Tomich 1999). Fruit cropping systems provide valuable market benefits and services, of which some have significant objectives (Withrow-Robinson *et al.* 1999). Many studies have reported a wide spectrum of goods and services from these homegardens, yet there is incomplete understanding about the value of these goods and services (Kumar *et al.* 2003). Studies on aspects such as income and employment generation from these system, their

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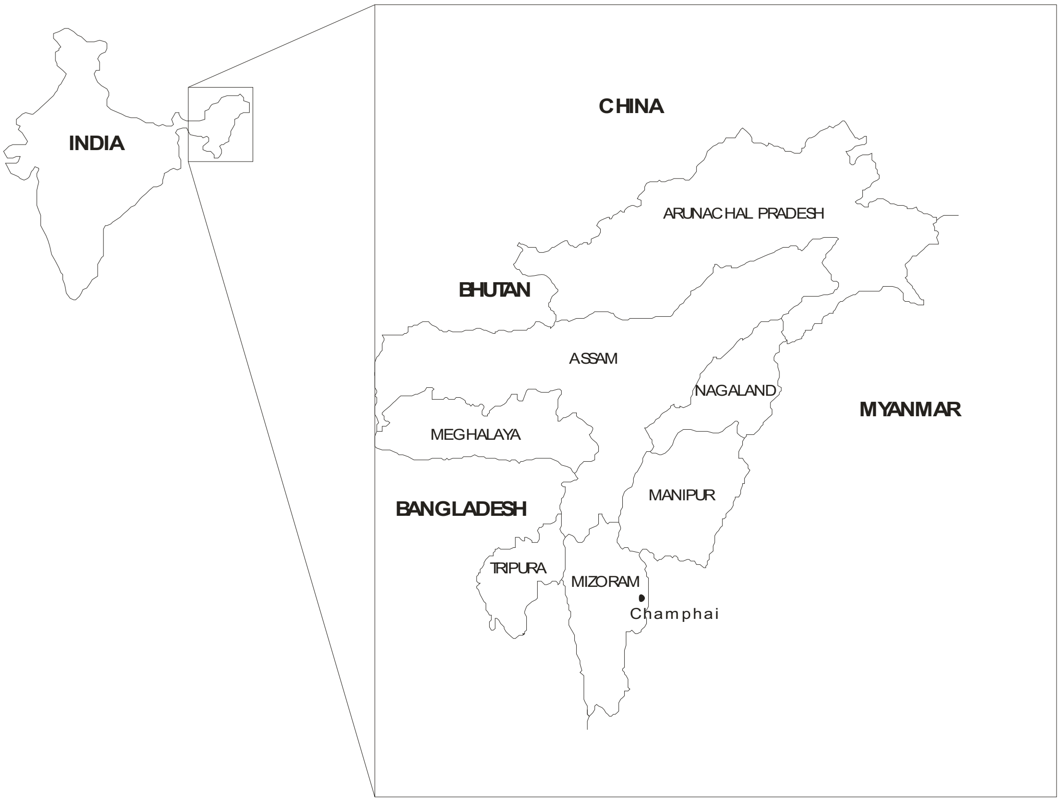

Fig. 1 Map of India showing the study site.

role in rural economy, profitability of certain crops, traditional knowledge, people's perception etc, particularly lacking.

Homegardens preserve much of the cultural history, as they are the site where useful plants species have been subjected to intense management regimes over extended periods. Throughout the years, farmers have cultivated and selected the plant species they desired and in this way homegarden are reservoirs of current and potential resources (Alvarez-Buylla *et al*. 1989) as well as a crucial site of selection and domestication of some plant species (Hawkes 1983).

The practice of indigenous agroforestry homegarden is an integral component in typical Mizo society (Sahoo *et al*. 2010). With the popularization of economically important trees and crops the traditional form of homegarden for subsistence is now gradually changing to a market oriented commercial agriculture which may not only be changing the home gardens structure and function, but also the intra-household dynamics of production, consumption and resource constraints that make home gardens part of a sustainable agricultural strategy. The present study quantifies and compares the economic and energetic role of tropical home gardens in households that practice agriculture as part of a diversified subsistence strategy and households for which agriculture is a business in the highlands of eastern Mizoram.

MATERIALS AND METHODS

The study area

Mizoram is a mountainous state inhabited by the *Mizo* communities who are predominantly Christians and few other ethnic communities. Champhai district is located in the northeastern corner of Mizoram state, India (**Fig. 1**) bordering Manipur state on the north and Myanmar in the east covering an area of 3185 sq km. in the biodiversity rich and ecologically fragile Indo-Myanmar pine belt. A subtropical monsoon climate characterize the region with cold winter and warm summer with a mean annual rainfall of 2438 mm and mean annual temperature of 21°C. Population density of the district is 35 person/km^2 and 51% of the population are below the poverty line (Anon. 2004). Agriculture (including shifting cultivation) is the main occupation of majority of the people. Christianity is the dominant religion in the study area. Among the Christians, Protestants of different sects form the majority while there are also Coptic orthodox Christians and Catholics. In addition to this, there are negligible Muslims, Hindus and few with traditional beliefs.

Three villages located on the hill slopes overlooking the Champhai valley landscape were chosen for the study. Wet paddy cultivation is practiced in the flat Champhai valley landscape (area about 10 sq. km.) with small intermittent isolated hillocks. The surrounding hill slopes are predominant with tree species belonging to Fagaceae and Pine (*Pinus kesiya*) plantations by the Forest Department. Zote (23° 29′ N and 93° 21′ E, 1365 m asl) is located on the north-eastern corner of the valley, Ruantlang (23° 26′ N and 93° 20′ E, 1376 m asl) on the south-eastern corner and Hmunhmeltha (23° 30′ N and 93° 19′ E, 1505 m asl) is on the north western hill range.

Data collection

Individual households having >0.01 ha gardens were considered as a unit of analysis and treated as a system. Thirty-eight households were randomly sampled, 12 each in Zote and Hmunhmeltha and 14 in Ruantlang. They were categorized according to the size of the homegarden area. For the convenience of comparing the gardens according to different management strategies they are categorized according to size. Gardens smaller the half the mean area are considered as small and those which are more than one and half times the mean area are considered as large and those in-between the two are categories as medium. Vegetation analysis of the homegardens was done in different seasons of the year. All species present in each sampled homegarden were identified and recorded by their botanical name, or by local name and later confirmed from published books. All individuals of trees and shrubs were counted and their height and GBH recorded except those shrubs on hedgerows following (Kabir and Webb 2008). No herbs or climbers were counted.

Observations of energy and economic input and output for all the homegarden activities and products were made over a one year period, only in 12 households, four in each of the three categories (small, medium and large) as only the 12 households were enthusi-

Table 1 Plant diversity in the different homegarden categories of Champhai, Mizoram.

	Small	Medium	Large	*F*-test
Total species encountered	153	118	162	-
Mean no. of species /garden	37 ± 6.8	44 ± 7.3	53 ± 10.8	P<0.0002
No of trees and shrubs /garden	26 ± 11.2	23 ± 5.4	37 ± 12.1	P<0.01
No. of herbs /garden	21 ± 4.8	21 ± 4.9	23 ± 6.1	NS
Mean species density (no of sp./100 m^2)	3.70 ± 1.7	1.40 ± 1.9	0.50 ± 0.6	P<0.0001
Mean tree density (tree sp./100 m^2)	1.13 ± 0.7	0.50 ± 0.2	0.19 ± 0.1	P<0.005
Shannon Weiner Index (trees and shrubs)	3.33 (0.08-2.84)	3.44 (1.76-3.16)	3.73 (1.83-3.58)	P<0.005

Values in parentheses are range ± SD

astic and ready to co-operate for the study. Each homegarden system is considered as a functional unit. The inputs were human labour, seeds and manure while the output was the crop productivity. Questionnaires were filled in and sample weighing was done in the fields. Questionnaire also includes a set of questions on the socio-economy, demography, sale of the garden products and management aspects of the garden. Cropping pattern in different seasons was noted.

Data analysis

Each species recorded in the homegarden was classified by family, habit based on morphology of the plant when it was full grown (tree, shrub, herb or climber) and plant use. Frequency – the fraction of homegarden containing the species (Cox 1990) – was calculated for all recorded species. Abundance – number of individuals per species – was calculated for trees and shrub species (except in hedgerows). The sum of the relative values of frequency and abundance for each species of trees and shrub was used for deriving the importance value. For trees and shrubs relative importance value was used to rank species per life form. For herbs and climbers, relative frequency was used to rank species per life form.

Shannon-Weiner index was used to determine the species richness, $H' = \Sigma^{s}_{i=1} p_i \ln p_i$ (Magurran 1988), where s is the numbers of species in the community p_i is the proportional abundance of species i (i.e., number of species i divided by total number in the community).

A process analysis was used to measure energy flow (Fluck 1992) adding human work contributions (Odum 1996). Internal and external inputs were measured in Mega Joules (MJ). These were estimated by extrapolating standard energy values (Mitchell 1979; Gopalan *et al*. 1982; Mittal and Dhavan 1989). The input of energy through seeds was calculated on the basis of total energy expended to produce that fraction of the crop yield. The economic yield per hectare in all cases was calculated on the basis of the entire plot. For calculating the output of energy the total economic yield of various crops was converted into mega joules of energy by multiplying with similar standard values. The energy efficiency of each system was calculated as the output/input ratio.

Input of household labour is a component that needs to be factored to an economic valuation. For the purpose of this study, opportunity cost of household labour is calculated as a function of time, $OC_{HL}=f$ ($t \times$ *labour rate*), where t is the time spent in the garden. The opportunity costs of land have been assigned values equivalent to the rate at which farmers were able to lease out all or parts of their lands. This rent was calculated to be an average of Rs. 9500 per hectare of the land per year. For monetary input/output analysis, labour charge was calculated on the basis of prevailing daily rates of Rs 70. The monetary returns in terms of crops, feed, milk, egg and organic manure were calculated based on prevailing market price for each commodity.

RESULTS

Homegarden area

The homegardens surveyed varied extensively in shape and size, however most of the gardens were commonly rectangular and occupied an area between 0.035 ha to 2.0 ha with a mean size of 0.43 ha. Of the 38 gardens studied 20 were small and 9 each were medium and large in size. The residential houses were located on the upper portion of the slope and the homegarden area extends towards the lower slope. Households with larger landholdings had garden areas on all sides of the slope.

Homegarden composition

Homegardens are typically populated by a wide variety of plants, varying from herbs to tall wide variety of plants, varying from small herbs to tall trees. A total of 199 plant species with a mean of 43 ± 9.9 were recorded from the 38 homegardens in the highlands of eastern Mizoram comprising of 80 trees, 22 shrubs, 79 herbs and 18 woody and non woody climbers representing 67 families. Trees and herbs predominated, accounting for 80% of all the identified species. The mean of 43 species of plants per homegarden was represented by 16 ± 3.1 trees, 4 ± 0.87 shrubs, 4 ± 0.95 woody and non-woody climbers and 19 ± 3.6 herbs.

Mean number of species per garden and no of tree and shrubs species per garden significantly increases from small to large garden (P<0.0002 and P<0.01) where as there is no significant difference for herbs while mean number of species per 100 m^2 and trees and shrubs per 100 m^2 significantly decreases from small to large gardens (P<0.0001 and P<0.005). Shannon Weiner index for trees and shrubs also significantly vary (P<0.005) with highest (H'=3.73) in large and least (H'=3.33) in small gardens (**Table 1**).

The species found and their corresponding parameters are listed in **Appendix 1 A-E**. The most frequently reported species were *Parkia timoriana*, *Psidium guajava*, *Mangifera indica*, among trees and. *Cucurbita maxima*, *Colocasia esculenta* and *Brassica juncea* dominated the herbs category. *P. timoriana* provides protein rich green pods and latter two species provide fruits that can be marketed locally. At the family level, Solanaceae, Poaceae, Papillionaceae and Euphorbiaceae demonstrated the highest floristic importance in homegardens. The composed species in the homegardens structurally resembled the adjacent forests having 3-4 storied vegetation structure. The uppermost canopy usually consists of protein rich leguminous tree *Parkia timoriana* which forms the principal crop of these homegardens in the highland of Mizoram. This topmost layer also includes species like *Artocarpus heterophyllus*, *Schima wallichii*, *Quercus serrata*, etc. which extends from 10-16 m. The most conspicuous characteristics of all homegardens irrespective of their size are their layered canopy arrangements and admixture of compatible species. The canopy layer from 3-10 m were constituted by other fruit trees like guava, papaya, banana, *Prunus*, *Citrus*, *Trevesia palmata*, etc. and the lowest canopy is occupied by *Clerodendrum colebrookianum*, woody climbers like *Acacia pennata* and *Eleagnus latifolia*, etc. up to 2-3 m (**Fig. 2**). Herbaceous vegetables, tubers and climbers constituted the ground layer.

Homegarden plant use

All species encountered in the homegarden were found very useful for several purposes. The households cited most species as useful for food (45%) followed by medicine (13%) fuelwood (12%) ornamental (9%) and timber (7%). Of the 199 recorded plants 132 have only one indicated use, while 58 had more than one attributed utility (Appendix-1 A-D).

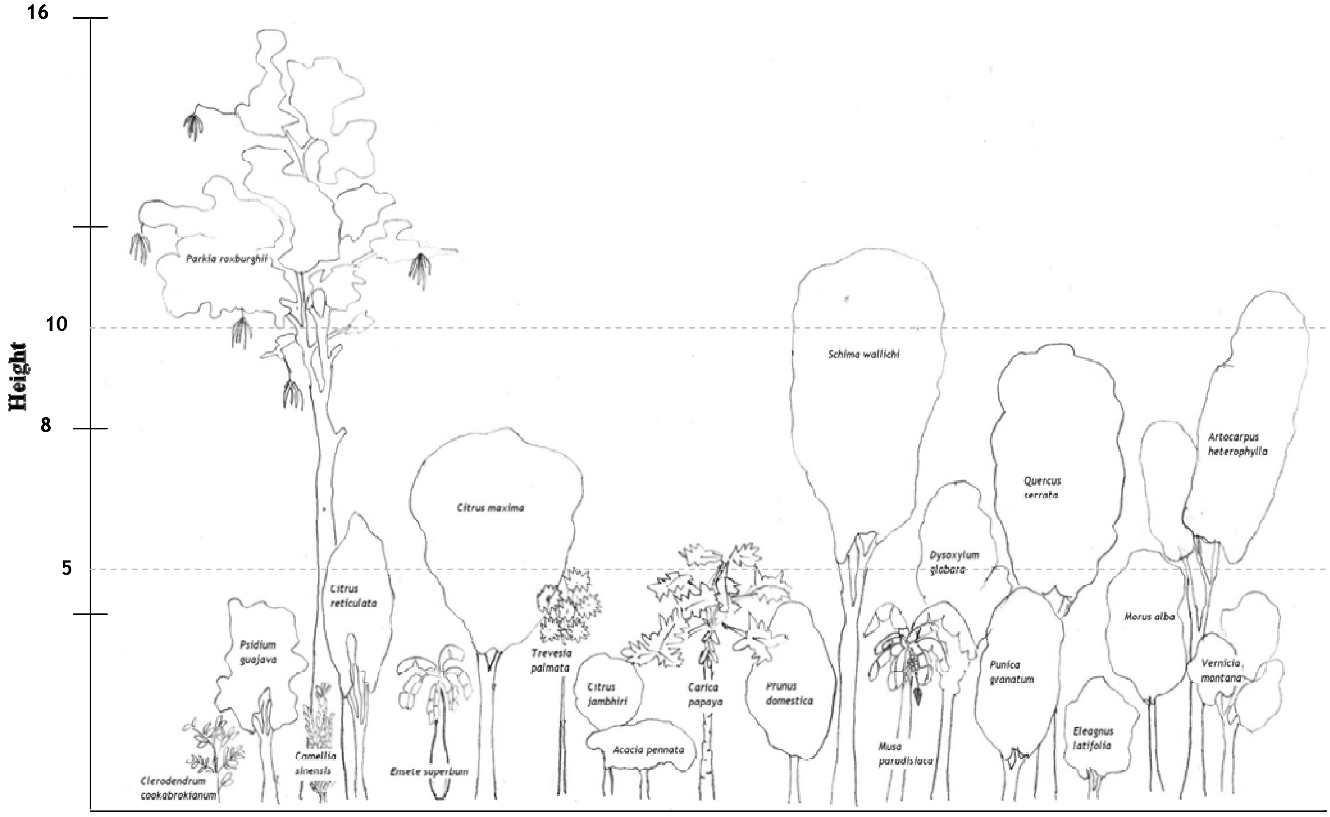

Fig. 2 Vertical profile of a typical homegarden in Champhai district, Mizoram, India. The profile is based on the IVI of plants occurring in the homegardens of the study site. Twenty plants with highest IVI were selected and are placed in the order from left to right. Plant heights are based on the modal height of the individuals recorded.

Table 2 Mean number of species for each use category in the different homegardens categories of Champhai, Mizoram.

Use	Small		Medium		Large	
Timber	2.85	(0-7)	3.89	(0-6)	9.3	(2-32)
Fruits	10.7	(4-15)	13.89	(7-20)	16	(13-21)
Vegetables	16.2	(10-24)	17.89	(10-23)	18	(12-23)
Spices and condiments	3.55	(0-7)	3.22	(2-5)	3.3	(0-7)
Stimulant	0.7	(0-3)	0.89	(0-2)	1	(0-2)
Ornamental	2.15	(0-7)	1.89	(0-5)	2.6	(1-7)
Miscellaneous	1.25	(0-3)	1.89	(0-6)	1.7	(0-3)

Values in parentheses are range.

Table 3 Energy output and input (MJ/100 m^2 $year^{-1}$) under different homegarden categories in Champhai, Mizoram.

Production measure	Small	Medium	Large	*F*-test
Input (total)	125 (81)	38 (61)	31 (61)	
Output				
Fruits	605 (50)	685 (68)	798 (89)	
Vegetables (leaves, pods, seeds, etc.)	3049 (110)	497 (115)	626 (97)	
Tubers & rhizomes	74 (81)	83 (46)	27 (40)	
Total	3728 (93)	1365 (50)	1452 (75)	
Output/input ratio	27 ± 5.3	36 ± 7.4	54 ± 7.8	P<0.04

Values in parentheses are CV% ± SEm

Amongst the different homegarden category large gardens have higher mean number of timber, fruit trees and vegetables as compared to small and medium (**Table 2**).

Homegarden energetic

The yield of homegarden products varied between the gardens, and was directly related to the species diversity. The total yield was higher; the yield per unit area was more in small gardens and decreased with increase in garden size (**Table 3**). The yield in terms of gross income per unit area similarly was higher in small gardens compared to medium and large ones because of the lower labour costs associated in the former than the later. It was observed that the major energy input to the homegardens were labour and in the small gardens labour inputs were only from household members whereas in the large gardens external hired labours were used for the energy requirements especially during the harvesting and sowing of crops. External labours were represented both by male and female workers with slightly higher participation from the female workers in the age group 22-35. One man-hour human labour was assigned 1.96 MJ energy and 1 woman-hour as 1.57 MJ and total energy input inclusive of seeds and manures/fertilizers worked out to be 125 MJ, 38 MJ and 31 MJ per 100 m^{-2} in small, medium and large gardens. Major output of the gardens was vegetables, rhizome, seeds, pods, and fruits etc which were usually for household consumption and sale of surplus after adequate savings of seeds for the following year. Total energy output was 3728 MJ, 1365 MJ and 1452 MJ in the small, medium and large homegarden respectively and the energy efficiency was found to significantly

Table 4 Monetary output and input (Rs/100 m^2) under different homegarden categories in Champhai, Mizoram.

	Small	Medium	Large	*F*-test
Input	928 (54)	315 (53)	228 (58)	P<0.02
Output	2597 (73)	1297 (31)	1375 (81)	NS
Output/input ratio	2.6 ± 0.9	4.4 ± 0.6	6.6 ± 1.5	P<0.05

Values in parentheses are CV% ± SEm

vary from 27 in small garden 54 in large garden (P<0.04).

Homegarden economics

Virtually all species in the homegarden have a multiple use. Higher number of species in the large homegardens obviously contributed to higher production resulting into availability of more products for sale after household consumption. Sale of surplus was much higher among the larger gardens which were with commercial motives and also among some of the medium size gardens with similar strategies while higher proportion of the products was consumed in the households in most of the smaller gardens. Major portion of the fruit species like *P. guajava*, *C. reticulata*, *Passiflora edulis*, rhizomes like *Zingiber officinalis* and pods of *P. timoriana* were sold out in the local market as the production are usually high and not all the products could be consumed within the household. The monetary input significantly vary from Rs. 928 per 100 m^2 in small to Rs. 228 per 100 m^2 in large gardens (P<0.02) while there is no significant difference for the monetary output and the output-input ratio significantly varies from 2.6 in small to 6.6 in large gardens (P<0.05) (**Table 4**).

The mean financial value of homegardens based on benefits and costs revealed higher net income in the large garden (**Table 5**) compared to the small and medium ones, however, since the intensity of production was greater in small gardens, the intensity of profit generation (mean profit/unit area) obviously was more in small garden. It was observed that a significant fraction of the profit was consumed by the farmers of small gardens in obtaining their daily requirements. Poorer households (small garden farmers) consumes proportionately less and sell more than the better off households (well developed gardens), therefore the profit generated was highest in small gardens and lowest in large gardens. The contribution of homegarden products to the total household income was higher from large garden (52%) while lower (29.0%) from the small garden (**Table 6**). This implies that the medium and large garden posses more liquid cash with which they may procure household products. However, the income generation from the garden irrespective of their size was subjected to market demand and quantum availability of a particular homegarden product. There was no fixed seasonality/time for harvest of homegarden products. Typically, the subsistence plants were harvested daily or according to the requirements. It was observed that when the products were used to supplement the dietary requirement as was the case with small gardens, they were sold for liquid cash. Although income generation was an important component of all homegardens for large gardens, it was given less importance by the smaller/poorer farmers who preferred more diversity and higher range of production and their contribution to livelihood of the households.

We could not evaluate the various non-market benefits of the homegarden. It was told that such benefits were important to the farmers. It was observed that the management of these gardens was done using mostly the traditional indigenous knowledge. The management of trees and shrubs were done according to the farmers' requirements. For example, the small tree *Clerodendrum colebrookianum* is pollarded at a height not above 1.5 m. Bamboos are usually grown on the lower slopes of the garden. Tea is not pruned unlike in the conventional tea gardens and is planted among *Citrus maxima* and *Artocarpus heterophyllus* for shading. Seasonal vegetable growing areas are more open and located adjacent or nearest to the residential house. Mangoes are grown among/under other trees whereas guavas are grown in closer spacing in open areas.

DISCUSSION

An analysis of the structural aspects of species composition

Table 5 Mean financial value of homegardens for 2007-2008 (in Rupees) based on the benefits and costs of 12 gardens surveyed in Champhai, Mizoram.

Category	Mean financial value (Rupees)	Mean financial value, including opportunity costs of land and household labour (Rupees)
Small (≤ 0.22 ha, n=4)	28,146	19,890
Medium (> 0.22 ha, ≤ 0.65 ha, n=4)	52,252	40,052
Large (> 0.65 ha, n=4)	1,58,161	1,31,476

Financial worth measured in Rupees (1.00 US$ ~ Rs. 46, October 2008)

Table 6 Contribution to total household income from sale of homegarden products.

Category	Mean annual proceeds from sale of products (Rupees)	Percentage to total household income
Small (≤ 0.22 ha, n=4)	13,012	29.2
Medium (> 0.22 ha, ≤ 0.65 ha, n=4)	33,750	32.5
Large (> 0.65 ha, n=4)	78,875	52.1

Table 7 Characteristics of the different homegarden types.

Category	Garden type		
	Small ≤ 0.22 ha	Medium > 0.22 ha, ≤ 0.65 ha	Large > 0.65 ha
Type	Hilly	Hilly	Hilly
Slope	80-95%	45-53%	38-42%
Crop composition			
Species richness	153	118	162
Diversity	3.33	3.44	3.73
Species density (± SD)	3.70 ± 1.7	1.40 ± 1.9	0.50 ± 0.6
Productivity	High	Less	Low
Management			
Indigenous traditional knowledge	High	Less	Low
Fertility level	High	High	High
Labour intensity	Low	Medium	High
Seasonality	Year round	Year round	Year round
Monetary input	Low	More	High
Sustainability	High	Medium	Low

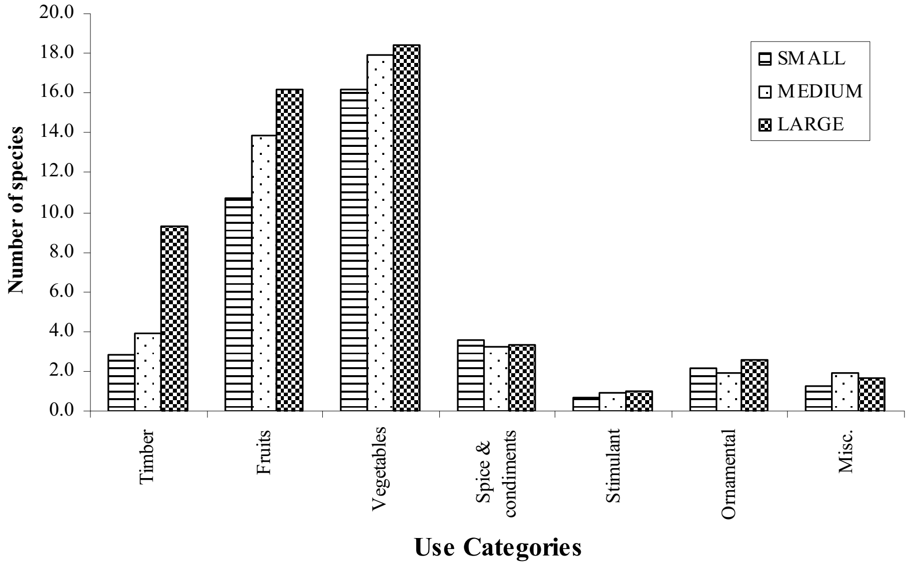

Fig. 3 Plant use category in the different homegarden types of Champhai, Mizoram.

of 38 selected homegardens of highlands of Champhai shows that the average size of the garden is only 0.43 ha, yet they are composed of a large variety of woody and herbaceous species, distinctly structured to form 3-4 vertical canopy strata. The distribution of the plants at different heights and architecture across the homegardens perfectly occupied the available space both horizontally and vertically. All the homegardens, in general, consisted of a herbaceous layer near the ground, a tree layer at the upper levels and an intermediate layer in-between (**Fig. 2**). The uppermost layer consisted of economic tree species like *Parkia timoriana*, *Artocarpus heterophyllus*, etc. extending from 10.0-16.0 m height. Sometimes in large garden another layer was also observed at about 8.0-10.0 m where the species like *Quercus serrata* dominated. The lowermost layer (about 1.0 m) in height always dominated by vegetables, spices and some medicinal herbs. The architectural analysis of the canopy revealed a relatively higher proportion of canopy distribution at the intermediate level (3.0-8.0 m height) containing about 31% of the total canopy volume. The lowermost or ground canopy contained about 11 to 15% of the canopies and the topmost layer occupies 7% of the canopy. The layered canopy configurations are quite conspicuous in all the gardens. The relatively higher proportion of the vegetables, roots, tubers in the small gardens compared to medium sized gardens revealed that these crops are important for family diet, meeting the increasing used of more volumes for feeding the family and domestic animals.

The species composition in all the homegardens irrespective of their size was fairly similar to each other which indicated that the farmers retain certain species in all the homegardens which they considered quite important to them, regardless of their economic value. As expected, the number of individual species per unit area of land increased with garden size but the density of the species was highest in small gardens (**Table 7**). A fairly similar number of trees species found in the different gardens were linked to gardeners' need and ability to manage the tree species. The small farmer wanted to have more tree diversity to attain maximum tree outputs while the large garden, on the other hand, utilized their land for many other commercial plants to allow maximum monetary benefits (**Fig. 3**). This is clearly evident from the mean number of species of different plant use category across the garden size (**Table 2**). However our results are somewhat lower compared to the Bangladesh homegardens (Kabir and Webb 2008) but in line with the reports from Kerala homegardens (Kumar 1994).

The presence of various use of plants (**Appendix 1A-E**) revealed that the homegardens are important source of timber, fuel wood, food, medicines particularly for poor households. The diverse food species grown in the homegardens obviously were linked to the seasonal dietary and nutritional requirements of the gardeners. Besides, the association of a diverse variety of species and clear stratification of the species in homegardens revealed that closeness to naturally biodiverse systems such as forest ecosystems.

The species diversity in the homegardens is always high. High diversity of the species always promote high soil fertility and retain soil humidity (Ninez 1985a; Rico-Gray *et al.* 1990; Gomez-Poppa *et al.* 1997; Nair 1997; Declerk and Negreros Castillo 2000; Nair 2001). According to Nair (1997) horizontal and vertical distribution of the species brings a dynamic equilibrium with respect to organic matter and plant nutrients on the garden floor because the root systems have little or no-overlapping at this layer. The root systems help in continuous addition of leaf litter and its constant removal though decomposition and the compatible admixture of the species in homegarden offer to enrich the top soil. However, at lower soil depth, the root competition will be high, which may be in proportion to the canopy volume (Nair 1977). Although we found species diversity to be quite similar in all gardens, the species density and species richness between the gardens were statistically significant (**Table 1**). Nevertheless, the species diversity indices of the homegarden in this present study are fairly comparable to those reported for natural forest ecosystem (Gajaseni and Gajaseni 1999) and Kerala homegardens (Kumar 1994). We encountered 3.7 species/100 m^2 in small homegarden, while the corresponding figures were 1.4 and 0.50 for medium and large gardens. These figures too are comparable with those reported for Kerala homegardens (Kumar *et al.* 1994).

The management of biological resources and economic production of homegarden was shared by both men and women. Through their different activities of management practices, men and women have developed different expertise and the knowledge about the local environment, plant and animal species and their products and uses. Nevertheless, this gender differentiated local knowledge system play a decisive role in the in-situ conservation, management and improvement of genetic resources for food in the homegardens. Therefore, the decision about what to conserve depends on the knowledge perception as to what is most useful to the gardener in ensuring food security and protecting soil, water, natural vegetation and biological diversity. The woman tended to be more actively involved than man in the household economy which typically involved the use of wider diversity of species for food and medicines while men involved in pruning and harvesting of the homegarden produce. Compared to the men, women had had better indigenous traditional knowledge about the crop selection, planting pattern, weeding and protective measures, and use of biodiversity than men, however they had limited participation in planning, implementation and decision-making of homegarden land and resources.

It was further observed that the small gardeners have benefited least from the modern high yield plant variety as up to 80-90% of the annual crops and vegetables they grow from the seeds and planting materials that they stored in previous year. On the other hand, the large gardeners had relatively better access to high yielding crop varieties. The small gardeners were not able to afford external inputs such as fertilizers, veterinary products, high quality seeds and fossil fuels for cooking and heating. They rely on maintaining a wide range of plants which are adapted to local environment and in that way, they are able to protect themselves against crop failure, provide continuous varied food supply. This means that the small gardeners play a crucial role in the preservation of management of local genetic resources and bio-diversity.

In large homegardens, however, the division of labour is not very clear; most of the work required is done through hired labour. However, women folks look after the livestock, raising of ornamental and medicinal plants. Unlike the adjacent Barak valley in Assam state where clear zone exist in homegardens for particular group of crops and linked to the proximity of the house (Das and Das 2005), no clear crop zone was observed in the present homegardens.

The flow of energy in the homegardens was between the associated plant and animal constituents with the gardeners. In the present study we restricted our inventory to only plant resources and therefore the energy flow may not complete without involving animals. However, the energy flow was strongly linked to the species composition, structure and function. The food plants, vegetables, tubers, rhizomes were the important homegarden outputs which directly contributed to the dietary and health requirement of the gardeners while the input to the system were brought from other parts of the system and got incorporated in the homegardens. For example, in large gardens procured animal feed and fertilizers, hired labour was used for homegarden production while the homegarden input was minimal for small and medium sized garden. The extent of production from homegarden also was dependent on biodiversity management, division of labour, integration of by-product from other agricultural systems, thus there was a visible energy exchange interaction between the household agriculture subsystems and other elements of households, more clearly in large homegardens while to a very minimal in small gardens. However, a deeper study is desired to depict the flow of energy between component systems. Nevertheless a system becomes more sustainable when there is smaller investment on non-renewable energy and external renewable energy requirements. The difference in energy efficiencies between various gardens have been observed by Shajaat Ali (2005) in Bangladesh, Pinton (1983) in Columbia and Peyre *et al*. (2006) in India. According to them, the efficiency diminished by increasing dependence on external inputs and greater use of non-renewable energy sources.

Monetary output: input reveals that large gardens are more efficient than the small and medium sized. Since the number of plant species use category was always higher in the large garden, obviously, garden produce were higher in the former than the latter. However, a large proportion of this monetary return in large gardens is used in buying input and labour for maintaining the garden and for long term production at a desired level, the reverse is the case with the small and medium gardens. The sustainability of the homegardens lie not only on the species composition, diversity, species richness and intrinsic structure of the homegardens but also on the disturbing forces that emanate from the surrounding biophysical and socio-economic environments. Although it is premature to conclude that the small gardens are more sustainable than medium and large sized homegardens within our limited study but there are enough indication supplying our arguments due to higher species density, low risk management, higher homegarden return per unit area in the former than the latter.

CONCLUSION

Our study revealed that homegardens in this part of India are rich in plant diversity and functionally dynamic to meet various ecological and economic needs of the farmers. Almost all the households in the rural areas have a homegarden small or big in size and depend on them for dietary requirements. Majority of the farmers sold their surplus products for income generation while the large gardens tended towards commercialization for higher economic benefits and as a choice for employment opportunity. Smaller gardens contribute maximum resiliency with the objective of household food security where the elder female members of the household take the major role of managing the garden whereas the large homegarden are managed by the male member of the family with use of external labour Smaller homegarden although with lesser monetary benefits were found to be more sustainable from ecological point of view as compared to large gardens.

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Appendix 1A List of trees in the homegardens of Champhai and their major use.

Botanical name	Local name	Family	% F	Parts used	Uses
Ailanthus integrifolia ssp *calycina*	Thing ar thau	Simarubaceae	2.6	st	t
Albizzia chinensis	Vang thing	Mimosaceae	7.9	st	t
Alnus nepalensis	Hriangpui	Betulaceae	7.9	st	t, fi
Antidesma bunius	Tuai tit	Euphorbiaceae	2.6	st	fi
Aphananthe cuspidata	Thei-she-rêt	Euphorbiaceae	2.6	st	fi, fd
Aralia foliosa var. *sikkimensis*	Chimchawk	Araliaceae	2.6	l	fo
Artocarpus heterophyllus	Lamkhuang	Moraceae	34.2	fr, s	fo, t
Artocarpus lakoocha	Thei tat	Moraceae	21.1	l, fr	fo, fd
Azadirachta indica	Nim-thing	Meliaceae	7.9	l, s	m, t
Bauhinia variegata	Vau be	Caesalpinaceae	18.4	st	t
Bombax insigne	Pang	Bombacaceae	2.6	st	t
Borassus flabellifer	Sial lu	Palmae	2.6	l, fr	th, fr, t
Callicarpa arborea	Hnah kiah	Verbenaceae	21.1	l, s	ferm, fi
Callistemon lanceolatus	Bottle brush	Myrtaceae	5.26	st	o, fi
Carallia branchiate	Thei-ria	Rhizophoraceae	18.4	fr, l	fo, fd
Carica papaya	Thingfanghma	Caricaceae	44.7	fr, l	fo
Caryota urens	Tum kaw palm	Palmae	5.3	b, s	fo, fb
Castanopsis tribuloides	Thing sia	Fagaceae	28.9	n, s	fo, fi
Citrus grandis	Sêr-tawk	Rutaceae	39.5	fr	fo
Clerodendrum colebrookianum	Phui-hnam	Verbenaceae	84.2	l	fo, m
Cupressus torulosa	Cedar	Cupressaceae	18.4	st	o, t
Cyphomandra betacea	Thing be râ	Solanaceae	28.9	fr	fo
Dysoxylum gobara	Thing thu pui	Meliaceae	47.4	l	fo
Emblica officinalis	Sun-hlû	Euphorbiaceae	28.9	fr	fo
Erythrina indica	Fartuah	Papilionaceae	5.3	st	fe, o
Eucalyptus sp.	Eucalyptus	Myrtaceae	5.3	st	t
Euphoria longan	Theifeihmung	Sapindaceae	2.6	fr	fo, m, t
Eurya cerasifolia	Si neh	Theaceae	15.8	l	fo, fi
Ficus benghalensis	Bung	Moraceae	7.9	a	fb
Ficus elastic	Thelret	Moraceae	10.5	-	o
Ficus prostata	Thei tit	Moraceae	2.6	fr	fo, fi
Ficus religiosa	Hmawng	Moraceae	2.6	st	fi
Ficus semicordata	Thei-pui	Moraceae	7.9	fr	fo, fi
Glochidion velutinum	Thingpawn chhia	Euphorbiaceae	2.6	st	fi
Gmelina arborea	Thlan vawng	Verbenaceae	2.6	st	t
Grevillea robusta	Silver oak	Proteceae	13.2	st	t, fi
Helica excelsa	Sialhmâ	Proteceae	2.6		fi
Heteropanax fragrans	Chhankhen	Araliaceae	2.6	l	fo
Jatropha curcas	Kang damdawi	Euphorbiaceae	2.6	s	m, fe
Leucaena leucocephala	Japan Zawngtah	Mimosaceae	39.5	l, p	fo, fd, fi
Lindera nacusua	Saper	Lauraceae	2.6	st	t
Lithocarpus dealbata	Fah	Fagaceae	7.9	st	fi
Litsea cubeba	Sêr-nam	Lauraceae	13.2	l, st	fo, fi
Lyonia ovalifolia	Tlangham	Ericaceae	2.6	st	fi
Mangifera indica	Thei hai	Anacardiaceae	73.7	fr, sh	fo, m
Michelia oblonga	Ngiau	Magnoliaceae	10.5	st	t
Morus alba	Thing-thei-hmu	Moraceae	36.8	fr, l	fo, fd
Morus macroura	Lung li	Moraceae	5.3	fr, l	fo, fd
Myrica esculenta	Keifang	Myricaceae	31.6	fr, b	fo, m
Oroxylum indicum	Archangkawm	Bignoniaceae	2.6	p, l	fo, m
Parkia timoriana	Zawngtah	Leguminoceae	86.8	p, l	fo
Persea americana	Butter thei	Lauraceae	7.9	fr	fo
Pinus kesiya	Fâr	Coniferae	15.8	st	t
Premna racemosa	Thingsailum	Verbenaceae	2.6	st	fi
Prunus cerasoides	Tlaizawng	Rosaceae	5.3	fr	fo
Prunus domestica	Thei te	Rosaceae	68.4	fr	fo
Prunus jenkinsii	Keipui	Rosaceae	2.6	fr	fo
Prunus persica	Thei te hmul	Rosaceae	42.1	fr, l	fo, m
Psidium guajava	Kawlthei	Myrtaceae	86.8	Fr, l	fo, m
Pyrus communis	Pear thei	Rosaceae	39.5	fr	fo
Pyrus pashia	Chalthei	Rosaceae	10.5	fr	fo
Quercus helferiana	Hlai	Fagaceae	2.6	st	fi
Quercus leucotrichophora	Then	Fagaceae	5.3	st	fi
Quercus polystachya	Thil	Fagaceae	10.5	st	fi, t
Quercus serrata	Sa-sua	Fagaceae	23.7	st	fi
Rhus semialata	khawmhma	Anacardiaceae	36.8	fr	fo, m
Rhus succedanea	Chhimhruk	Anacardiaceae	10.5		fi
Sapium baccatum	Thingvawkpui	Euphorbiaceae	2.6		fi, t
Saurauia punduana	Tiar	Saurauiaceae	2.6	fr	fo, fi
Schima wallichii	Khiang	Theaceae	39.5	st, l	t, fi
Spondias mangifera	Tawitawh	Anacardiaceae	5.3	fr	fo, fi
Syzigium cumini	Len hmui	Myrtaceae	2.6	fr	fo

Appendix 1A (Cont.)

Botanical name	Local name	Family	% F	Parts used	Uses
Syzigium grandis	Thei chhawl	Myrtaceae	2.6	fr	fo, fi
Tamarindus indica	Tengtere	Caesalpinaceae	7.9	p, l	fo
Toona ciliata	Tei	Meliaceae	7.9	st	t
Trema orientalis	Belphuar	Ulmaceae	2.6		fi, fb
Trevesia palmata	Kawh-te-bêl	Anacardiaceae	65.8	i	fo
Vaccinium sprengelii	Sir kâm	Vaccinaceae	2.6	l, fr	fo
Vernicia montana	Tung	Euphorbiaceae	26.3	fr	s
Wendlandia grandis	Batling	Rubiaceae	2.6	f	fo, fi

Parts used: p-pods, f-fruits, i-inflorescence, l-leaves, s-seeds, r-roots, n-nuts, st-stem, sh-shoots
Uses: m-medicinal, fo-food, fw- firewood, fi- fibre, fi-fb, t-timber, o-ornamental, s-soap making, b-broom, fc-fencing.

Appendix 1B List of shrubs found in the homegardens of Champhai and their main use.

Botanical name	Local name	Family	% F	Parts used	Uses
Albizzia myriophylla	Zang-zu	Mimosaceae	2.6		m
Camellia sinensis	Thingpuikung	Theaceae	52.6	l	fo
Citrus aurantifolia	Champara	Rutaceae	13.2	fr	fo
Citrus indica	Ser-pui	Rutaceae	2.6	fr	fo
Citrus jambhiri	Zamir	Rutaceae	55.3	fr	fo
Citrus limon	Sêr-fâng	Rutaceae	7.9	fr	fo
Citrus medica var. *acidus*	Limbu	Rutaceae	10.5	fr	fo
Citrus reticulata	Sêr-thlum	Rutaceae	44.7	fr	fo
Coffea arabica	Coffee thing	Rubiaceae	13.2	fr	fo
Crotolaria juncea	Tumthang	Papilionaceae	2.6	f, s	fo, fb
Debregeasia longifolia	Lengau	Urticaceae	2.6	l	fo, m, fd
Jasminum laurifolium	Hlo-khâ	Malvaceae	2.6	l	m, o
Luculia pinceana	Chawkhlei	Oleaceae	2.6	-	O
Manihot esculenta	Pâng-bal	Euphorbiaceae	10.5	r	fo
Punica granatum	Thei-buh-fai	Punicaceae	42.1	fr	fo
Ricinus communis	Mu-tih	Euphorbiaceae	2.6	l	m
Rubus acuminatus	Thei-hmu	Rosaceae	5.3	fr, l	fo
Sarcococca coriacea	Pawhrual	Euphorbiaceae	2.6	l	m
Solanum anguivera	Samtawk te	Solanaceae	36.8	fr	fo
Solanum torvum	Tawk pui	Solanaceae	5.3	fr	fo, m
Urena lobata	Sehnap	Solanaceae	2.6	l	m

Parts used: p-pods, f-fruits, i-inflorescence, l-leaves, s-seeds, r-roots, n-nuts, st-stem, sh-shoots
Uses: m-medicinal, fo-food, fw- firewood, fi- fibre, fi-fb, t-timber, o-ornamental, s-soap making, b-broom, fc-fencing.

Appendix 1C List of climbers found in the homegardens of Champhai and their main use.

Botanical name	Local name	Family	% F	Parts used	Uses
Acacia penneta	Khanghu	Mimosaceae	63.2	l	fo
Asparagus racemosus	Ar ke bawk	Liliaceae	44.7	r	m, o
Bougainvillea spectabilis	Sarawn	Nyctagineae	2.6	-	o
Cucurbita maxima	Mai-an	Cucurbitaceae	84.2	fr, l, s	fo, m
Derris thyrsiflora	Hul hu	Papilionaceae	2.6	l	fo, fi
Eleagnus latifolia	Sarzuk	Caesalpinaceae	52.6	fr, r	fo, m
Lablab purpureus	Bepui	Papilionaceae	18.4	p	fo
Luffa acutangula	Awmpawng	Cucurbitaceae	2.6	fr	fo
Mikania macrantha	Japan hlo	Compositeae	2.6	l	m, o
Passiflora edulis	Sapthei	Passifloraceae	57	fr, l, s	fo, m
Phaseolus vulgaris	Bean	Papilionaceae	31.6	p	fo
Piper sp.	Thing hmarcha suak	Piperaceae	2.6	fr	fo
Psophocarpus tetragonobulous	Bepuithlanei	Papilionaceae	15.8	p	fo
Sechium edule	Iskut	Cucurbitaceae	34.2	fr, r	fo
Smilax perfoliata	Kai ha	Liliaceae	2.6	r	m
Trichosanthes anguina	Berul	Cucurbitaceae	2.6	fr, s	fo
Vigna unguiculata	Behlawi	Papilionaceae	18.4	l, p	fo
Vitis vinifera	Grape	Ampelidaceae	26.3	fr	fo

Parts used: p-pods, f-fruits, i-inflorescence, l-leaves, s-seeds, r-roots, n-nuts, st-stem, sh-shoots
Uses: m-medicinal, fo-food, fw- firewood, fi- fibre, fi-fb, t-timber, o-ornamental, s-soap making, b-broom, fc-fencing.

Appendix 1D List of herbs found in the homegardens of Champhai and their main use.

Botanical name	Local name	Family	% F	Parts used	Uses
Abelmoschus esculentus	Bawrhsaibe	Malvaceae	15.8	f	fo
Allium cepa var cepa	Purun	Liliaceae	21.1		fo
Allium hookeri	Mizo purun	Liliaceae	52.6	r, sh	fo
Aloe vera	Aloe vera	Liliaceae	2.6	sh	m
Amomum dealbatum	Aidu	Zingiberaceae	68.4	r, sh	fo
Ananas comosus	Lakhuithei	Bromeliaceae	28.9	f	fo
Brassica juncea	Antam	Graminae	73.7	l	fo
Brassica oleracea var *capitata*	Zik hlum	Cruciferae	7.9		fo
Brassica oleracea var gongylodes	Bulbawk	Cruciferae	2.6	l	fo
Brassica oleracea var *italica*	Brokoli	Cruciferae	7.9	l	fo
Brassica oleracea var. *botrytis*	Par bawr	Cruciferae	2.6	l	fo
Brassica rapa	Antam, French	Cruciferae	18.4	l	fo
Brassica sp	Antam, thing	Cruciferae	21.1	l	fo
Cajanus cajan	Behliang	Cruciferae	57.9	p	fo
Canavalia ensiformis	Fang rah	Leguminoceae	7.9	p	fo
Canna orientalis	Kungpuimuthi	Papilionaceae	15.8		m, o
Capsicum annum	Hmarchate	Cannaceae	52.6	f	fo
Capsicum fructescens	Hmarcha pui	Solanaceae	7.9	f	fo
Cassia occidentalis	Rengan	Solanaceae	15.8	p	fo
Catharanthus roseus	Kumtluang	Apocynaceae	10.5	l	o, m
Centella asiatica	Lambak	Umbilifereae	2.6	l	fo, m
Chrysenthemum indicum	October par	Compositeae	5.3	-	o
Colocasia esculenta	Dawl	Araceae	81.6	l, r	fo, fd
Colocasia sp.	Dawl kerala	Araceae	63.2	l, r	fo, fd
Coriandrum sativum	Dhania	Umbilifereae	5.3	l	fo
Costus speciosus	Sumbul	Zingiberaceae	2.6	r, l	m
Cucurma caesia	Ailaidum	Zingiberaceae	7.9	r	fo
Curcuma longa	Aieng	Zingiberaceae	60.5	r	fo
Dahlia rosea	Dahlia	Asteraceae	10.5	-	o
Dendrobium chrysotoxum	Ban pui	Orchidaceae	5.3	-	o
Dichrocephala integrifolia	Vawk ek thung tual	Gramineae	2.6		m
Elsholtzia communis	Lengsher	Compositeae	34.2	i	fo
Ensete superbum	Saisu	Musaceae	57.9	st, l	fo, fd, p
Entada pursaetha	Kawi	Labiatae	2.6	p, l	fo, m
Eryngium foetidum	Bakhawr	Mimosaceae	36.8	l	fo
Euphorbia	Hling lukhum	Umbilifereae	2.6	-	o
Glycine max	Bekang	Papilionaceae	2.6	s	fo
Hibiscus sabdariffa	Anthur	Malvaceae	76.3	l, s	fo, fb
Hibiscus sabdariffa var. *sabdariffa*	Anthur, Kawl	Malvaceae	26.3	l, s	fo, fb
Impatiens balsamina	Nuaithang	Balsaminaceae	2.6	-	o
Imperata cylindrica	Di	Gramineae	5.3	l	th
Ipomea batatas	Kawl barsa	Convolvulaceae	76.3	r	fo
Lilium wallichianum	Weeding lily	Liliaceae	5.3	-	o
Lycopersicon esculentum	Sap bawk bawn	Solanaceae	15.8	f	fo
Mentha viridis	Pudina	Labiatae	5.3	l	m, fo
Momordica charantia	Chhankha	Cucurbitaceae	34.2	f	fo
Musa paradisiaca	Banhla	Musaceae	63.2	l, st	fo, p, fd
Musa paradisiaca var *sylvestris*	Chang el	Musaceae	7.9	l, st	fd, p
Nicotiana tobacum	Vai hlo	Solanaceae	15.8	l	m
Ocimum americanum	Run-hmui	Libiatae	7.9	l	fo, m
Oryza sativa	Buh	Oryzeae	2.6	s	fo
Phrynium capitatum	Hnathial	Marantacae	28.9	l	p
Pisum sativum	Channa	Papilionaceae	18.4	p	fo
Plactycerium wallichii	Awm vel	Polypodiaceae	2.6	-	o
Raphanus sativus	Bul-uih	Crucifeae	7.9	r	fo
Renanthera imschootiana	Sen hri	Orchidaceae	2.6	-	o
Rosa sp.	Rose	Rosaceae	18.4	-	o
Saccharum longisetosum	Luang	Gramineae	7.9	l	fd
Saccharum officinarum	Fu	Gramineae	36.8	s	fo
Sesamum orientale	Chhi-bung	Pedaliaceae	2.6	se	fo
Sida acuminata	Khingkhi	Malvaceae	10.5	sh	b
Solanum melongena var. *esculentum*	Bawkbawn	Solanaceae	23.7	f	fo
Solanum nigrum	Anhling	Solanaceae	13.2	f	fo, m
Solanum tuberosum	Alu	Solanaceae	5.3	f	fo
Solanum violaceum	Samtawk	Solanaceae	65.8	f	fo
Sorghum cernum	Chhaw-chhi	Gramineae	13.2	s	fo
Spilenthes acemella	Ankasa	Compositae	50.0	sh	fo
Spillenthes acmella var. *oleracea*	Ansapui	Compositae	15.8	sh	fo
Strobilanthes flaccidifolius	Tling	Acanthaceae	7.9	fr	fo
Tegetes patula	Derkhen	Compositae	18.4	-	o, m
Thysanolaena maxima	Broom grass	Gramineae	31.6	i	b
Trachyspermum roxburghianum	Pardi	Umbelliferae	2.6	s	Fo

Appendix 1D (Cont.)

Botanical name	Local name	Family	% F	Parts used	Uses
Triticum aestivum	Wheat	Graminae	2.6	s	fo
Vanda coerulea	Lawhlei	Orchidaceae	10.5	-	o
Zea mays	Vaimim	Gramineae	21.1	f	fo
Zingiber oficinale	Sawhthîng	Zingiberaceae	60.5	r, sh	fo
Euphorbia royleana	Chawng	Euphorbiaceae	7.9	s	m, o

Parts used: p-pods, f-fruits, i-inflorescence, l-leaves, s-seeds, r-roots, n-nuts, st-stem, sh-shoots
Uses: m-medicinal, fo-food, fw- firewood, fi- fibre, fi-fb, t-timber, o-ornamental, s-soap making, b-broom, fc-fencing.

Appendix 1E List of Bamboos found in the homegardens of Champhai and their main use.

Botanical name	Local name	Family	% F	Parts used	Uses
Bambusa arundinaceae	Rua	Graminae	44.7	s	fi, fe, fd
Melocanna baccifera	Mautak	Graminae	26.3	s, sh	fo, fi, fe, fd
Dendrocalamus longispathus	Rawnel	Graminae	21.1	s, sh	fo, fi, fe, fd

Parts used: p-pods, f-fruits, i-inflorescence, l-leaves, s-seeds, r-roots, n-nuts, st-stem, sh-shoots
Uses: m-medicinal, fo-food, fw- firewood, fi- fibre, fi-fb, t-timber, o-ornamental, s-soap making, b-broom, fc-fencing.