# Effects of homegarden size on floristic composition and diversity along an altitudinal gradient in Central Himalaya, India

**Vibhuti, Kiran Bargali and S. S. Bargali***

Department of Botany, Dev Singh Bisht Campus, Kumaun University, Nainital 263 001, India

**In the present study, data were collected from 36 homegardens at four altitudes, viz. very low (up to 350 m), low (350–700 m), mid (700–1500 m) and high (above 2000 m). Homegardens were categorized into three sizes: large (>0.007 ha), medium (0.004–0.006 ha) and small (<0.003 ha). A total of 111 plant species belonging to 55 families were recorded. Asteraceae, Fabaceae and Cucurbitaceae (seven species each) formed the most diverse family, and 34 families were mono-specific. Species richness was maximum (22) in medium homegarden at mid altitude and minimum (11) in small homegardens at high altitude. Herb density was maximum (84 individuals $m^2$) at very low altitude and diversity was maximum (2.38) at mid altitude in large homegardens. Tree density was maximum (1200 individuals $ha^{-1}$) at mid altitude and diversity was maximum (2.42) at very low altitude in large homegardens. Total tree basal area was maximum (66.61 $m^2$ $ha^{-1}$) in small homegardens at very low altitude. Principal component analysis showed that the first component accounted for 54.53% most reliable and high loadings of tree (0.959) and herb density (0.922) with positive effect. The second component (74.93%) showed high factor loading of concentration of dominance for herbs (0.729) with positive effect.**

**Keywords:** Altitudinal gradient, floristic composition, homegarden size, species diversity.

HOMEGARDEN agroforestry is a land-use practice involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably livestock within the compound of individual houses, the whole crop–tree–animal unit being intensively managed by family labour[1]. Crop diversity in homegardens attributed to a broad range of known factors and ecological conditions, economic context and demands, taste, knowledge, ethnicity, culture and special experiments of homegarden owners[2,3]. Most of the homegardens particularly in rural areas are maintained for subsistence production and income generation[4]. Because of high plant diversity, a wide spectrum of multiple-use plant products can be generated with relatively low labour, cash and other inputs. They also fulfil many social, cultural and ecological needs. The species composition of homegardens varies according to climatic and edaphic factors of the place and socio-economic condition of the farmers[5]. Traditional homegardens have been shown to be ecologically sustainable agroecosystems[6–8]. Their benefits include maintenance of soil fertility and soil structure as well as nutrient cycling[9].

Homegardens are traditional farming systems which may have evolved over time from the practices of hunters/gathers and continued in the ancient civilization agroecosystems that existed throughout the world[10]. These are usually small-scale supplementary food production systems designed for local inhabitants[11]. These systems ensure food security, play a significant role in the regional and national economics, and also contribute to environmental resilience. In addition, homegardens provide habitat for wild animals, especially birds[12]. The homegardens vary in size influencing the species diversity and composition. It is expected that with variation in size, density and compositional pattern, the soil condition also varies and requires different management practices for improving the overall sustainability of these important land-use systems. However, only few studies have been undertaken on these systems in the Central Himalayan region of India and these systems have received little scientific attention[13,14]. The present study was conducted with the following two objectives: (1) How is homegarden plant diversity affected by altitudinal variation? (2) How is the size of a homegarden affected by the plant diversity?

## Material and methods

### *Study area*

The present study was conducted in Kumaun Himalaya which forms the northwestern part of the Central Himalaya at 28°44′–30°49′N lat and 78°45′–85°5′E long. The study sites were selected between 350 and 2000 m amsl (at 29°19′–29°28′N and 79°22′–79°38′E) in Nainital district, Central Himalaya (Figure 1). For phytosociological studies, 36 homegardens were selected in 12 villages at

*For correspondence. (e-mail: surendrakiran@rediffmail.com)

4 altitudinal ranges, viz. very low (up to 350 m) low (350–700 m), mid (700–1500 m) and high (above 2000 m). Homegardens were then divided into small (<0.003 ha), medium (0.004–0.006 ha) and large (>0.007 ha) size to assess the relation between the size and distribution of plant diversity. The homegarden size was found to be related to the socio-economic conditions of the families that maintained them. The poorer farmers with less land holdings had smaller homegardens and farmers having large land holdings had larger homegardens.

After the selection of study sites, a survey was conducted and information on existing homegardens collected through personal interviews of households using semi-structure questionnaires and direct observations[15,16]. The farmers were encouraged to give their views and perceptions on the homegardens with respect to ecological perspectives.

### *Climate*

The study area falls in the subtropical to temperate climate. The maximum temperature is around 40.2°C and minimum temperature –5.4°C. The average annual rainfall in the district is 1407 mm.

### *Vegetation analysis*

For collection of vegetational data, the random quadrat method was used covering a minimum of 30% area in each homegarden, following Saikia *et al.*[17]. Trees and saplings were sampled in ten quadrats of 10 × 10 m size. Within each of these quadrats, two 2 × 2 m quadrats were laid for shrubs and ten 1 × 1 m quadrats for herbs (including crops), following Bargali *et al.*[18,19], and Singh *et al.*[20]. Plant species were noted with the help of the homegarden owners and identified on the basis of vernacular names, floras and consulting available herbaria of the region. Circumference at breast height (cbh, at 1.37 m from the ground) of individual trees and saplings was measured in each quadrat. Density, frequency, abundance, basal area and importance value index (IVI) were calculated following Cottam and Curtis[21]. Species richness (number of species per unit area)[22], Shannon–Wiener index[23] and Simpson's dominance index[24] as a measure of alpha diversity were calculated for each homegarden.

Index of similarity (IS) between communities was calculated according to Muller–Dombois and Ellenberg[25] using species richness in different forests as

$$\mathrm{IS} = \frac{2C}{A+B} \times 100,$$

where $C$ is the common species in comparison sites, $A$ the total number of species in site A and $B$ in site B.

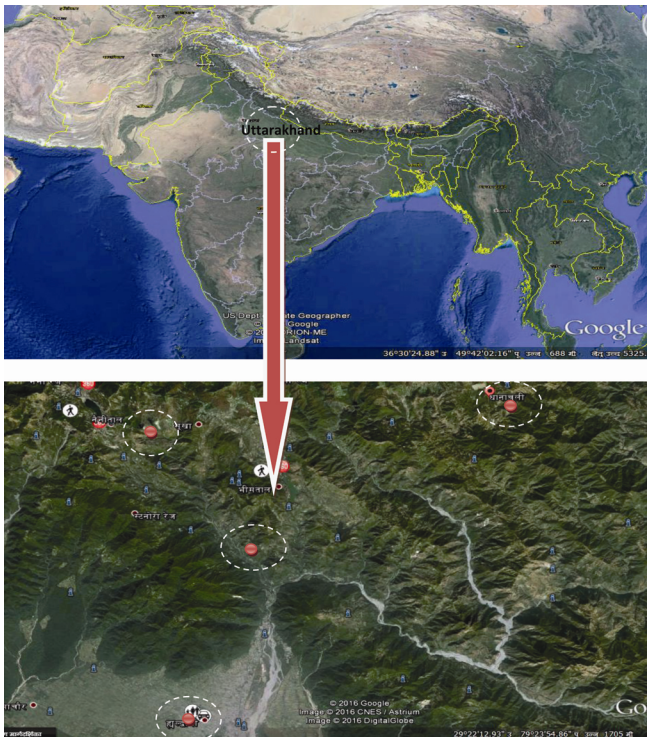


**Figure 1.** Map showing location of study sites.

## Results

### *Floristic composition*

Across the sites, a total of 111 plant species belonging to 55 families were recorded. Among these, 5 were shrubs, 23 fruit trees, 18 multipurpose trees, 30 cultivated crops and 35 were wild herbs. Based on species diversity, Asteraceae, Cucurbitaceae, Fabaceae and Poaceae (7 species in each) were the most diverse family followed by Moraceae (6 species in each) and 34 were mono-specific. Cluster analysis is a way of grouping cases of the data and in the present study, seven clusters were formed on the basis of families and number of species across the altitudinal gradient (Figure 2). Maximum number of plant species (22) was observed in medium-sized homegardens at mid altitude and minimum number of plant species (11) was observed in small-sized homegardens at high altitude. Along the altitudinal gradient, maximum number of species was observed at mid altitude compared to high, low and very low altitudes. Table 1 shows plant species richness in the homegardens according to landholding size and altitude.

### *Effect of altitudinal variation on plant diversity*

For each homegarden size class, maximum number of herb species was recorded in mid altitude and minimum number was recorded in high altitude (Table 1). At low

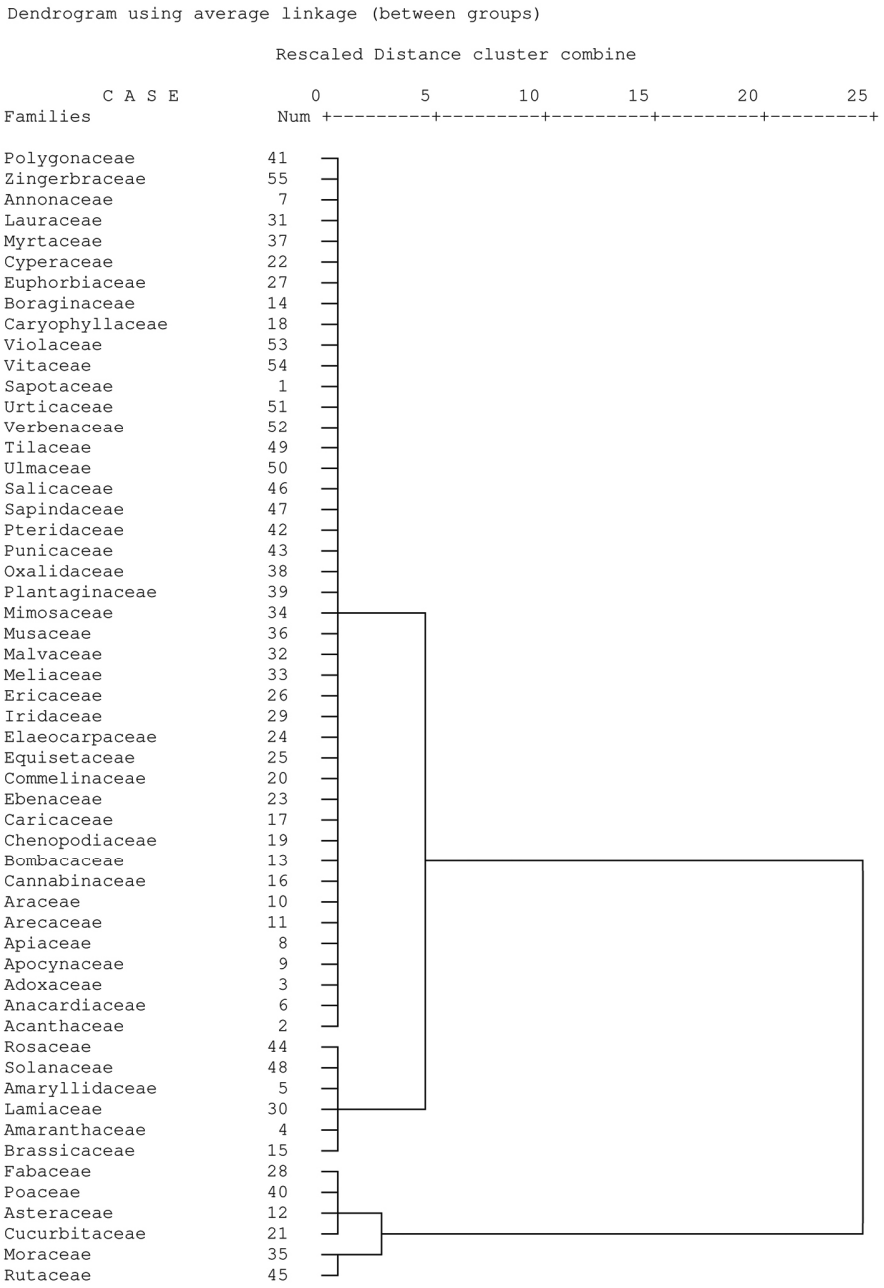


**Figure 2.** Dendrogram showing cluster analysis (based on families and number of species across the sites).

altitude, *Allium cepa* (100%) was the most frequent species followed by *Abelmoschus esculentus* (83.33%), whereas *Glycine max*, *Allium sativum* and *Zingiber officinale* (33.33%) were the least frequent species. At mid altitude, *A. sativum* and *Capsicum annum* (100%) showed maximum frequency, whereas *Z. officinale* (33.37%) showed minimum frequency. At high altitude, *A. cepa* (100%) showed maximum frequency compared to other species. At very low altitude, *A. cepa* (100%) showed maximum frequency, whereas *Colocasia esculenta* (33.33%) showed minimum frequency in all homegardens (Figure 3).

The number of tree species was also higher in the mid altitude than low and high altitude homegardens (Table 1). *Mangifera indica* (100%) was the most frequent species followed by *Cinnamomum tamala* (66.66%), whereas *Litchi chinensis* (33.33%) was least frequent in all homegardens at low altitude. *M. indica* (100%) and *Diospyros kaki* (100%) showed maximum frequency, whereas *Ficus auriculata*, *Citrus limon*, *Punica granatum* and *Psidium guajava* (33.37%) showed minimum frequency in all homegardens across the mid altitude. At high altitude, *Prunus armeniaca* and *Prunus domestica* (100%) showed maximum frequency whereas *Prunus*

**Table 1.** Plant species richness in homegardens across altitudinal gradient and size

| Homegarden (HG) size | Parameters | Altitudinal range | | | |
|---|---|---|---|---|---|
| | | High | Mid | Low | Very low |
| SHGs | Herb species | 10 | 13 | 13 | 13 |
| | Tree species | 1 | 1 | 3 | 4 |
| | Family | 9 | 13 | 13 | 13 |
| | Total area of HGs (ha) | 0.002 | 0.001 | 0.003 | 0.003 |
| MHGs | Herb species | 14 | 22 | 16 | 15 |
| | Tree species | 2 | 7 | 3 | 5 |
| | Family | 10 | 21 | 14 | 16 |
| | Total area of HGs (ha) | 0.004 | 0.005 | 0.005 | 0.006 |
| LHGs | Herb species | 14 | 20 | 18 | 15 |
| | Tree species | 2 | 6 | 4 | 6 |
| | Family | 11 | 19 | 16 | 15 |
| | Total area of HGs (ha) | 0.007 | 0.01 | 0.008 | 0.008 |

SHGs, Small homegardens; MHGs, medium homegardens and LHGs, Large homegardens.

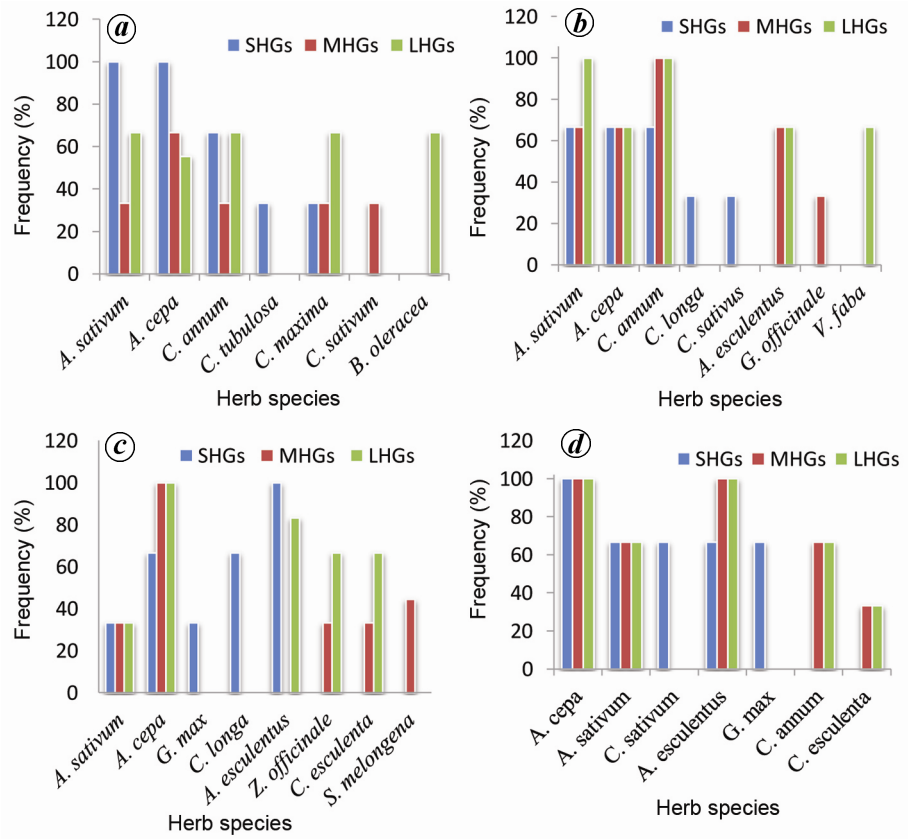


**Figure 3.** Frequency of herb species as affected by size and altitude of homegardens: ***a***, high; ***b***, mid; ***c***. low and ***d***, very low altitude.

*persica* (50%) showed minimum frequency. At very low altitude, *M. indica* and *L. chinensis* (100%) showed maximum frequency followed by *Polyathia longifolia* (66.66%), whereas *F. auriculata* and *Morus alba* (33.33%) showed minimum frequency in all homegardens (Figure 4).

### *Effect of homegarden size on plant diversity*

Herb density was maximum in large-sized homegardens (84 ± 26.32 individuals $m^2$) at very low altitude compared to other altitudinal ranges. On the basis of holding size, density increased with increasing homegarden size

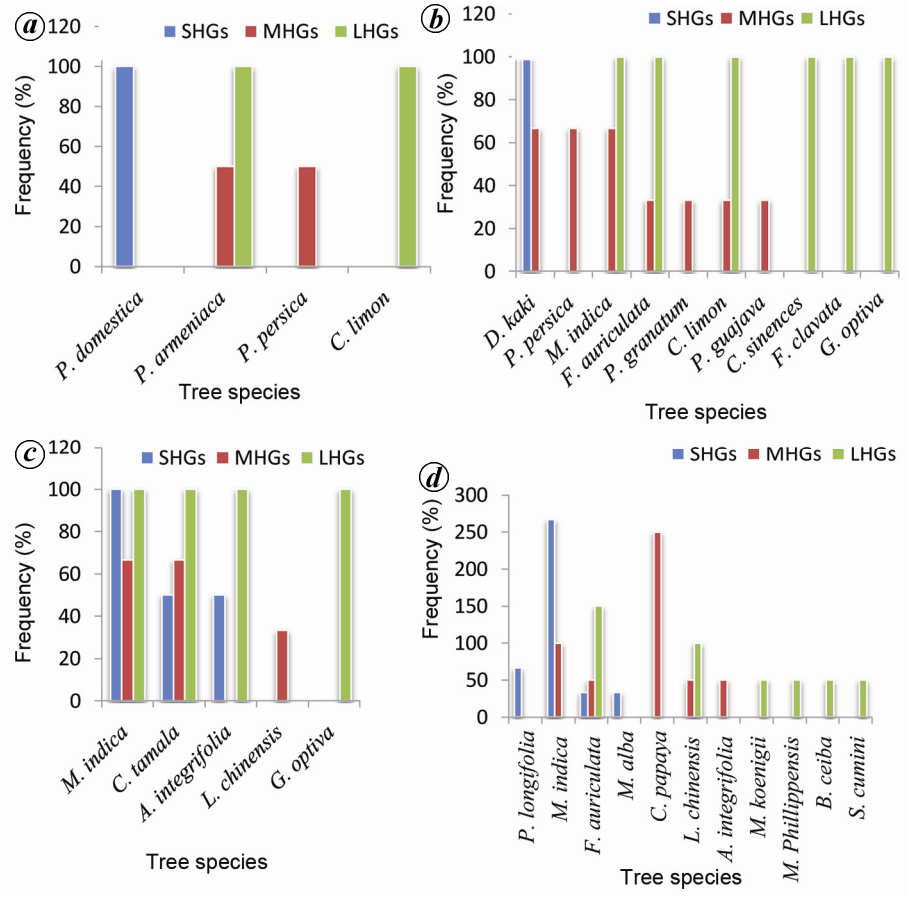


**Figure 4.** Frequency of tree species as affected by size and altitude of homegardens: ***a***, high; b. mid; ***c***, low and ***d***, very low altitude.

**Table 2.** Density, diversity and concentration of dominance (Cd) of herb layer in different homegardens as affected by size and altitudinal range

| Homegarden sizes | Parameters | High altitude | Mid altitude | Low altitude | Very low altitude |
|---|---|---|---|---|---|
| SHGs | Density (individuals $m^{-2}$) | 19.52 ± 8.82 | 41.61 ± 21.55 | 43.81 ± 25.30 | 78.74 ± 44.28 |
| | Diversity ($H'$) | 1.41 ± 0.53 | 1.66 ± 0.67 | 1.62 ± 0.61 | 1.37 ± 0.63 |
| | Cd | 0.19 ± 0.09 | 0.25 ± 0.16 | 0.28 ± 0.07 | 0.36 ± 0.08 |
| MHGs | Density (individuals $m^{-2}$) | 28.94 ± 14.52 | 84.01 ± 40.44 | 49.54 ± 24.18 | 71.47 ± 26.89 |
| | Diversity ($H'$) | 1.99 ± 0.32 | 2.09 ± 0.86 | 1.19 ± 0.45 | 2.04 ± 0.26 |
| | Cd | 0.29 ± 0.05 | 0.25 ± 0.01 | 0.27 ± 0.06 | 0.29 ± 0.05 |
| LHGs | Density (individuals $m^{-2}$) | 42.46 ± 12.44 | 80.16 ± 18.63 | 50.32 ± 24.12 | 84 ± 26.32 |
| | Diversity ($H'$) | 0.91 ± 0.56 | 2.38 ± 0.49 | 1.87 ± 0.69 | 1.97 ± 0.53 |
| | Cd | 0.24 ± 0.05 | 0.24 ± 0.06 | 0.26 ± 0.21 | 0.31 ± 0.08 |

(small homegardens (SHGs) < medium homegardens (MHGs) < large homegardens (LHGs)) in all the altitudinal ranges (high, low and very low altitude), except mid altitude, in which maximum density was observed in medium-sized (84.01 ± 40.44 ind. $m^2$) homegardens (SHGs < LHGs < MHGs). The diversity of herbs was maximum in large-sized homegardens (2.38 ± 0.49) at mid altitude compared to other altitudinal ranges. The species diversity increased with increasing homegarden size (SHGs < MHGs < LHGs) in mid altitude and low altitude compared to high altitude and very low altitude (MHGs > LHGs > SHGs). Concentration of dominance of herbs was maximum in small-sized homegardens at mid altitude and low altitude compared to other altitudinal ranges (Table 2).

Tree density was maximum in large-sized homegardens (1200 ind. $ha^{-1}$) at mid altitude compared to other altitudinal ranges. The density increased with increasing size of homegardens (SHGs < MHGs < LHGs) in all the altitudes (high, mid and low altitude), except very low altitude, in

**Table 3.** Diversity and concentration of dominance of tree layer in different homegardens as affected by size and altitude

| Homegarden sizes | Parameters | High altitude | Mid altitude | Low altitude | Very low altitude |
|---|---|---|---|---|---|
| SHGs | Density (ind. $ha^{-1}$) | 200 | 200 | 200 | 399.8 |
| | Total basal area ($m^2$ $ha^{-1}$) | 2.48 | 5.26 | 13.67 | 66.61 |
| | Diversity ($H'$) | – | – | 1.50 | 1.41 |
| | Cd | 1 | 1 | 0.38 | 0.49 |
| MHGs | Density (ind. $ha^{-1}$) | 150 | 466.64 | 599.99 | 500 |
| | Total basal area ($m^2$ $ha^{-1}$) | 1.88 | 12.91 | 14.43 | 204.73 |
| | Diversity ($H'$) | 0.92 | 2.61 | 1.41 | 1.96 |
| | Cd | 0.56 | 0.18 | 0.41 | 0.32 |
| LHGs | Density (ind. $ha^{-1}$) | 600 | 1200 | 1000 | 450 |
| | Total Basal area ($m^2$ $ha^{-1}$) | 4.8 | 40.68 | 33.45 | 31.97 |
| | Diversity ($H'$) | 1 | 2.40 | 1.69 | 2.42 |
| | Cd | 0.5 | 0.21 | 0.36 | 0.21 |

**Table 4.** Similarity index between homegardens as affected by altitudes

| Altitudes | High altitude | Mid altitude | Low altitude | Very low altitude |
|---|---|---|---|---|
| High altitude | 100 | | | |
| Mid altitude | 37.5 | 100 | | |
| Low altitude | 22 | 11.9 | 100 | |
| Very low altitude | 23.76 | 18.89 | 26.08 | 100 |

**Table 5.** Similarity index between homegardens as affected by size

| HG size | SHGs | MHGs | LHGs |
|---|---|---|---|
| SHGs | 100 | | |
| MHGs | 47.71 | 100 | |
| LHGs | 45.97 | 41.97 | 100 |

which maximum density (SHGs < LHGs < MHGs) was observed in medium-sized homegardens. Total basal area was maximum (204.73 $m^2$ $ha^{-1}$) in medium-sized homegardens at very low altitude. The diversity of trees was maximum in large-sized homegardens (2.42) at very low altitude compared to other altitudinal ranges. Species diversity increases with increased homegarden size (SHGs < MHGs < LHGs) in all the altitudinal ranges. Concentration dominance of trees decreased with increasing homegarden size at all the altitudinal ranges (Table 3). Similarity indices showed a high degree of similarity among different homegarden categories (Tables 4 and 5).

## Discussion

Traditional homegardens of the study site possessed a multilayered vegetation structure which could provide advantages in controlling soil erosion. The surveyed homegardens were highly variable in size, plant species composition, richness and species diversity. In the present study, 111 (41 trees, five shrubs and 65 herbs) plant species belonging to 55 families were recorded, which is comparatively lower than that reported from homegardens in Bangladesh where 419 species belonging to 109 families were reported by Kabir and Webb[26]. In India, Tynsong and Tiwari[27] reported 197 plants species (70 trees and 41 shrubs) belonging to 77 families from 150 homegardens and Saikia *et al.*[17] reported 294 plant species (142 trees and 56 shrubs) belonging to 92 families from 80 homegardens of Upper Assam. In the homegardens of Kerala, Kumar *et al.*[28] reported 127 trees and shrubs. The higher number of species reported in these studies may be due to their large sample size and larger geographical extent of the samples[29], and suggests that the total number of species recorded in the present study may increase if we increase the sample size. The species composition in all the homegardens within the altitudinal zone was fairly similar to each other. *M. indica* was the only tree species that was present in all altitudinal ranges (except high altitude) as well as all size class; however, frequency of occurrence differed for each homegarden (Figure 5). Similarly, three herb species (*A. cepa*, *A. sativum* and *C. annum*) were common in the studied homegardens with different frequencies (Figure 6).

The number of herbs and trees was minimum in high-altitude homegardens. Sahoo *et al.*[30] also reported that the number of herb and tree species decreased with increasing altitudinal range. At mid altitude, maximum number of species was observed in medium-sized homegardens, whereas at other altitudinal ranges maximum number of species was recorded in large-sized homegardens. These results suggest that owners maintain a diverse group of plants to fulfil their regular needs, and with more available land they grow more plant species for different uses.

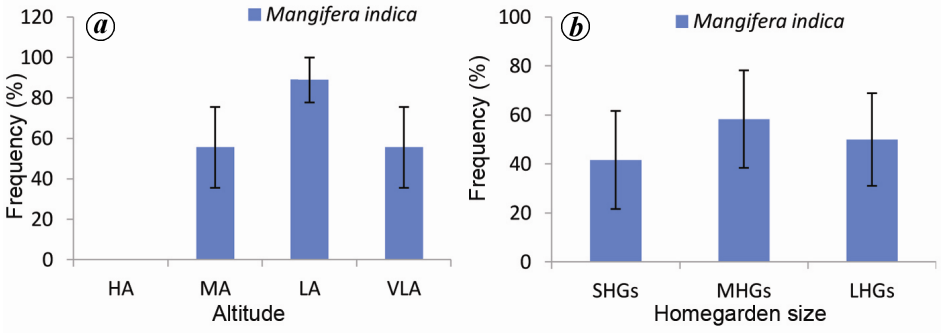


**Figure 5.** Frequency of common tree species as affected by (***a***) altitude and (***b***) size of homegarden.

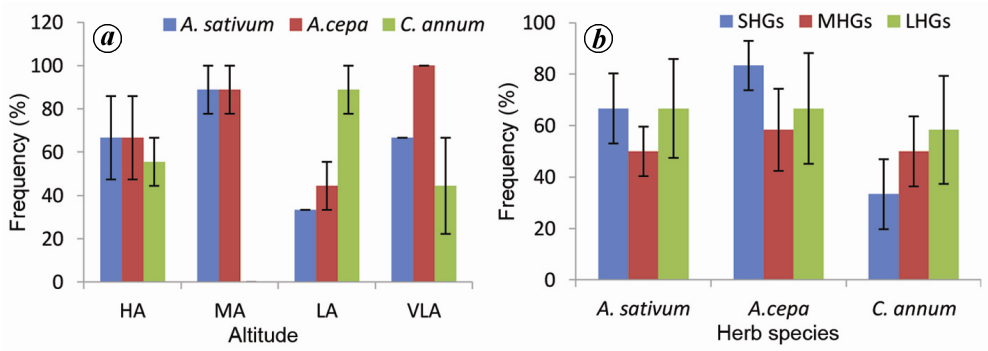


**Figure 6.** Frequency of common herb species as affected by (***a***) altitude and (***b***) size of homegarden.

The high floristic diversity is a reflection of the potential of homegardens to serve as repositories of genetic diversity. Das and Das[31] also reported increase in species number with increasing homegarden size. At mid altitude ($R^2 = 0.57$), the number of plant species was insignificantly correlated to homegarden size, whereas at other altitudinal ranges species richness showed significant relationship with homegarden size (Figure 7). Senanayake *et al.*[32] explained that the inter-household differences in species richness are influenced by homegarden size, which is maintained by the members of the households. Species distribution in the homegardens is determined by environmental factors and dietary habits as well as the socio-economic and market demands[1]. Studies of homegardens in Mexico[33] and Indonesia[34] indicated that the number of species or individuals is not related to homegarden sizes.

*A. cepa* (100%) was the most frequent species followed *by A. esculentus* (83.33%), whereas *Glycine max*, *A. sativum* and *Z. officinale* (33.33%) were the least frequent in all homegardens across the altitudinal ranges. Herb density was maximum in large-sized homegardens (84 ± 26.32 ind. $m^2$) at very low altitude compared to other altitudinal ranges. Concentration of dominance for herbs was maximum in small-sized homegardens at mid and low altitude compared to other altitudinal ranges. According to Abdoellah *et al.*[34], high diversity and low concentration of dominance in different homegarden categories may be due to variations in anthropogenic pressure in different homegardens. The average number of species per homegarden did not differ significantly among the homegarden categories, but density and frequency of species increased with decreasing homegarden size.

*M. indica* (100%) was the most frequent tree species followed by *C. tamala* (66.66%) and *L. chinensis* (33.33%) was the least frequent in all homegardens across the altitudinal ranges. Tree density was maximum in large-sized homegardens (1200 ind. $ha^{-1}$) at mid altitude compared to other altitudinal ranges. Density increased with increasing homegarden size (SHGs < MHGs < LHGs) in all the altitude (high, mid and low), except very low altitude, where maximum density (SHGs < LHGs < MHGs) was observed in medium-sized homegardens. Total basal area was maximum (66.61 $m^2$ $ha^{-1}$) in small-sized homegarden at very low altitude. The diversity of trees was maximum in large-sized homegarden (2.42) at very low altitude compared to other altitudinal ranges. Species diversity increased with increasing homegarden size (SHGs < MHGs < LHGs) in all the altitudinal ranges. Concentration of dominance for tree layer decreased with increasing homegarden size at all the altitudes. Kabir and Webb[26] also found a strong relationship between homegarden size and species richness in the homegardens of Bangladesh. Ecological and socio-economic factors, including geographic location, climate, water availability, homegardens size, agricultural

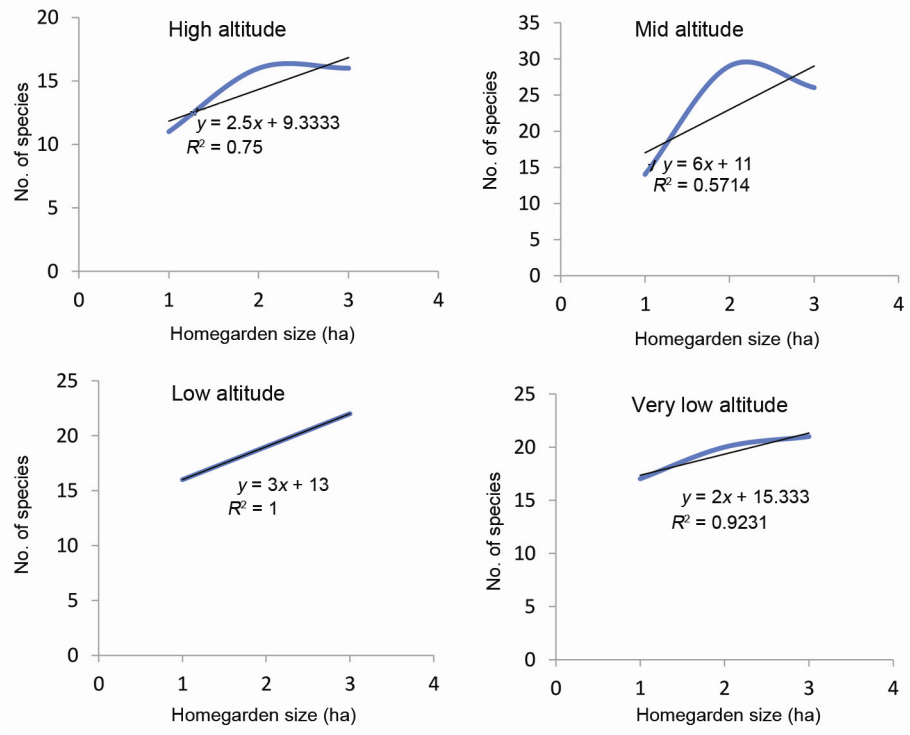


**Figure 7.** Regression analysis between species richness, altitude and homegardens size.

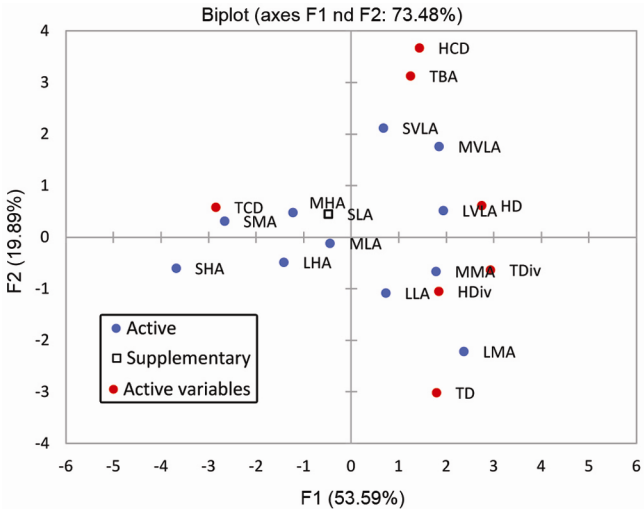


**Figure 8.** Principal component analysis between some variable components (HD, HDiv, HCD, TD, TBA, TDiv, TCD) and their sites.

**Table 6.** Factor loading values of F1 and F2 from components

| Variable components | F1 | F2 |
|---|---|---|
| HD | 0.922 | 0.141 |
| HDiv | 0.687 | –0.291 |
| HCD | 0.518 | 0.729 |
| TD | 0.554 | –0.620 |
| TBA | 0.399 | 0.618 |
| TDiv | 0.959 | –0.122 |
| TCD | –0.917 | 0.103 |

HD, Herb density; HDiv, Herb diversity; HCD, Herb concentration dominance; TD, Tree density; TBA, Total basal area; TDiv, Tree diversity and TCD, Tree concentration dominance.

policy, market needs, food culture and household preferences influence the diversity and utilization of products of traditional homegardens[35,36].

Principal component analysis (PCA) reveals the relationship between some variable components (HD, herb density; HDiv, herb diversity; HCD, concentration dominance of herb; TD, tree density; TBA, total basal area; TDiv, tree diversity; TCD, concentration dominance of tree) and their sites (SHA, MHA, LHA: small, medium and large homegardens at high altitude, SMA, MMA, LMA: small, medium and large homegardens at mid altitude, SLA, MLA, LLA: small, medium and large homegardens at low altitude, SVLA, MVLA, LVLA: small, medium and large homegardens at very low altitude; Figure 8). Table 6 shows the loading value of the first two principal components (F1 and F2). These loadings explain the contribution of each variable in principal components. The first component accounted for 54.53% most reliable (pc1) and showed high loadings of tree density (0.959) and herb density (0.922) with positive effect. The second component (pc2; 74.93%) was associated with concentration of dominance of herbs (0.729) with positive effect (Table 7). The bold numbers in Table 8 indicate the variables load on that component (loadings >0.8). The Pearson correlation shows

**Table 7.** Eigenvalue of all components

| | F1 | F2 | F3 | F4 | F5 | F6 | F7 |
|---|---|---|---|---|---|---|---|
| Eigenvalue | 3.751 | 1.392 | 0.757 | 0.616 | 0.281 | 0.200 | 0.003 |
| Variability (%) | 53.585 | 19.892 | 10.819 | 8.796 | 4.016 | 2.852 | 0.040 |
| Cumulative (%) | 53.585 | 73.477 | 84.296 | 93.092 | 97.108 | 99.960 | 100 |

**Table 8.** Correlation matrix (Pearson (*n*)) of different variables

| Variables | HD | HDiv | HCD | TD | TBA | TDiv | TCD |
|---|---|---|---|---|---|---|---|
| HD | 1 | 0.467 | 0.517 | 0.420 | 0.354 | 0.866 | –0.781 |
| HDiv | | 1 | 0.060 | 0.295 | 0.190 | 0.567 | –0.451 |
| HCD | | | 1 | –0.110 | 0.416 | 0.347 | –0.384 |
| TD | | | | 1 | –0.003 | 0.578 | –0.606 |
| TBA | | | | | 1 | 0.272 | –0.259 |
| TDiv | | | | | | 1 | –0.973 |
| TCD | | | | | | | 1 |

HD, Herb density; HDiv, Herb diversity; HCD, Herb concentration dominance; TD, Tree density; TBA, Total basal area; TDiv, Tree diversity and TCD, Tree concentration dominance.

positive and significant (always lower than $P < 0.05$) correlation between variables (Table 8).

pc1 = Tree diversity (0.959) + herb density (0.922)

+ concentration dominance of tree (–0.917)

+ herb diversity (0.687).

In pc1, highest loading was observed with tree diversity followed by herb diversity, a closely related indicator. The components contributing to maximum variance always accounted for pc1 and hence, more quality indicators were selected from this component. In this case four quality indicators with highest loading were selected for PCA.

pc2 = Concentration dominance of herb (0.729)

+ tree density (–0.620) + total basal area (0.618).

In pc2, the highest loading was observed with concentration of dominance of herb, followed by tree density, a closely related indicator.

The traditional cultivation system of homestead homegardens in the study area was moderate in all the altitudes (low altitude, mid altitude and very low altitude) compared to high altitude, in which the least species diversity was recorded due to the absence of improved management practices and high-quality variety.

## Conclusion

This study suggests that large-sized homegardens are more efficient than the small- and medium-sized homegardens in all the altitudinal ranges, except in mid altitude, where maximum species richness is observed in medium-sized homegardens compared to small- and large-sized homegardens. *A. cepa*, *A. esculentus*, *A. sativum*, *Z. officinale*, *F. auriculata*, *M. indica*, *P. armeniaca* and *P. domestica* are the most frequent species. Frequency and density of herbs are maximum in the mid altitude homegardens and they are ecologically, socially and economically diversified. These homegardens could be considered as potential units for maintaining species diversity and conserving plant genetic resources, and would become important for food security.

*Disclosure:* The authors declare no conflict of interest.


1. Fernandes, E. C.M. and Nair, P. K. R., An evaluation of the structure and function of tropical homegardens. *Agrofor. Syst*., 1986, **21**, 279–310.
2. Zaldivar, M. E., Rocha, O. J., Castro, E. and Barrantes, R., Species diversity of edible plants grown in homegardens of Chibchan Amerindians from Costa Rica. *Human Ecol*., 2002. **30**(3), 30.
3. Khoshbakht, K., Hammer, K. and Amini, S., Interdisciplinary analysis of homegardens in Savadkouh/Iran: plant uses and socio-economic aspects. *Food Agric. Environ*., 2006, **4**, 277–282.
4. Kumar, B. M. and Nair, P. K. R., The enigma of tropical homegardens. *Agrofor. Syst*., 2004, **61**,135–152.
5. Mendez, V. E., Lok, R. and Somarriba, E., Interdisciplinary analysis of homegardens in Nicaragua: microzonation, plant use and socioeconomic importance. *Agrofor. Syst*., 2001, **51**, 85–96.
6. Torquebiau, E., Are tropical agroforestry homegardens sustainable? *Agric. Ecosyst. Environ*., 1992, **41**, 189–207.
7. Jose, D. and Shanmugaratnam, N., Traditional homegardens of Kerala: a sustainable human ecosystem. *Agofor. Syst*., 1993, **24**, 203–213.
8. Kehlenbeck, K. and Maass, B. L., Crop diversity and classification of homegardens in Central Sulawesi, Indonesia. *Agrofor. Syst*., 2004, **63**, 53–62.

9. Schroth, G., Lehmann, J., Rodrigues, M. R. L., Barros, E. and Macêdo, J. L. V., Plant–soil interactions in multistrata agroforestry in the humidtropics. *Agrofor. Syst*., 2001, **53**, 85–102.
10. Soemarwoto, O., Home gardens: a traditional agroforestry system with a promising future. In *Agroforestry: A Decade of Development* (eds Steppler, H. A. and Nair, P. K. R.), World Agroforestry Centre, Nairobi, Kenya, 1987.
11. Hoogerbrugge, I. D. and Fresco, L. O., Homegarden systems: agricultural characteristics and challenges. International Institute for Environment and Development, Gatekeeper series no. 39, London, 1993, p. 23.
12. Steinberg, M. K., Neotropical kitchen gardens as a potential research landscape for conservation biologists. *Conserv. Biol*., 1998, **12**(5), 1150–1152.
13. Bargali, K., Comparative participation of rural women in agroforestry home gardens in Kumaun Himalaya, Uttarakhand, India. *Asian J. Agric. Extens. Econ. Sociol*., 2015, **6**(1), 16–22.
14. Bargali, K., Traditional homegardens as a sustainable ecosystem for maintenance of biodiversity: a case study from Kumaun Himalaya, India. *J. Biodivers*., 2016, **7**(2), 88–100.
15. Bargali, S. S., Singh, S. P., Shrivastava, S. K. and Kolhe, S. S., Forestry plantations on rice bonds: farmers' perceptions and technology adoption. *Int. Rice Res. Notes*, 2007, **32**, 40–41.
16. Parihaar, R. S., Bargali, K. and Bargali, S. S., Diversity and uses of ethno-medicinal plants associated with traditional agroforestry systems in Kumaun Himalaya. *Indian J. Agric. Sci*., 2014, **84**(12), 1470–1476.
17. Saikia, P., Choudhury, B. I. and Khan, M. L., Floristic composition and plant utilization pattern in homegardens of Upper Assam, India. *Trop. Ecol*., 2012, **53**(1), 105–118.
18. Bargali, S. S., Singh, S. P. and Pandia, K. S., Effects of *Acacia nilotica* on gram crop in a traditional agroforestry system of Chhattisgarh plains. *Int. J. Ecol. Environ. Sci*., 2004, **30**, 363–368.
19. Bargali, S. S., Bargali, K., Singh, L., Ghosh, L. and Lakhera, M. L., *Acacia nilotica* based traditional agroforestry system: effect on paddy crop and management. *Curr. Sci*., 2009, **96**(4), 581–587.
20. Singh, L., Ghosh, L., Bargali, S. S. and Saxena, R. R., Influence of naturally occurring trees on field bunds and their impact on yield parameters of paddy crop. *Range Manage. Agrofor.*, 2008, **29**(2), 134–137.
21. Cottom, G. and Curtis, J. T., The use of distance measures in phytosociological sampling. *Ecology*, 1956, **35**, 451–460.
22. Marglef, D. R., Information theory in ecology. *Int. J. General Syst. Book*, 1958, **3**, 36–71.
23. Shannon, C. E. and Weiner, W., *The Mathematical Theory of Communities*, University of Illinois Press, Urbana, USA, 1963.
24. Simpson, E. H., Measurement of diversity. *Nature*, 1949, **163**, 688–692.
25. Mueller-Dombois, D. and Ellenburg, H., *Aims and Methods of Vegetation Ecology*, John Wiley, Ellenberg, New York, London, 1974.
26. Kabir, M. E. and Webb, E. L., Can homegardens conserve biodiversity in Bangladesh? *Biotropica*, 2008, **40**, 95–103.
27. Tynsong, H. and Tiwari, B. K., Plant diversity in the homegardens and their significance in the livelihoods of War Khasi community of Meghalaya, North East India. *J. Biodivers*., 2010, **1**, 1–11.
28. Kumar, B. M., George, S. J. and Chinnamani, S., Diversity structure and standing stock of wood in the homegardens of Kerala in peninsular India. *Agrofor. Syst*., 1994, **25**, 243–262.
29. Sahoo, U. K., Rocky, P., Vanlalhriatpia, K. and Upadhyaya, K., Species composition, production and energetic sustainability of homegardens in the highlands of Eastern Mizoram, India. In *Forest Restoration. Tree and Forestry Science and Biotechnology* (*Species Issue I*) (ed. Xi, W.), Global Science Books, Ikenobe, Japan, 2012, pp. 81–92.
30. Sahoo, U. K. and Rocky, P., Species composition and plant diversity as influenced by altitude and size of homegardens in Mizoram, North-East India. *Ecol. Environ. Sci*., 2015, **41**, 3–4.
31. Das, T. and Das, A. K., Inventorying plant biodiversity in homegardens: a case study in Barak Valley, Assam, North East India. *Curr. Sci*., 2005, **89**,155–163.
32. Senanayake, R. L., Sangakkara, U. R., Pushpakumara, D. K. N. G. and Stamp, P., Vegetation composition and ecological benefits of home gardens in the Meegahakiula Region of Sri Lanka. *Trop. Agric. Res*., 2009, **21**(1), 1–9.
33. Rico-Gray, V., Garcia-Franco, J. G., Alexandra, C., Armando, P. and Paulino, S., Species composition, similarity and structure of Mayan homegardens in Tixpeual and Nicaragua: micro-zonation, plant use and socioeconomic importance. *Agrofor. Syst*., 1990, **51**, 85–96.
34. Abdoellah, O. S., Hadikusumah, H. Y., Takeuchi, K., Okubo, S. and Parikesit, Commercialization of homegardens in an Indonesian village: vegetation composition and functional changes. *Agrofor. Syst*., 2006, **68**, 1–13.
35. Gajaseni, N. and Gajaseni, J., Ecological rationalities of the traditional home-garden system in the Chao Phraya Basin, Thailand. *Agrofor. Syst*., 1999, **46**, 3–23.
36. Trinh, L. N., Watson, J. W., Hue, N. N., De, N. N., Minh, N. N., Chu, P., Sthapit, B. R. and Eyzaguirre, P. B., Agrobiodiversity conservation and development in Vietnamese home gardens. *Agric. Ecosyst. Environ*., 2003, **97**, 317–344.


ACKNOWLEDGEMENTS. We thank Head, Department of Botany, Kumaun University, Nainital for providing the necessary facilities. We also thank UGC, New Delhi for financial support through major project.

Received 28 December 2017; revised accepted 21 March 2018

doi: 10.18520/cs/v114/i12/2494-2503