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# Quantitative Assessment of Floristic Diversity in Large Cardamom based Traditional Agroforestry System Across Altitudinal Gradient in Darjeeling Himalaya, India

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***Abstract***: The present study was carried out in Darjeeling Himalayas region of West Bengal, India from January, 2019 to April, 2021. The study area was classified into three altitudinal class i.e., low, mid and high with eleven, nine and five holdings, respectively. The important value index (IVI) of the documented species at the studied systems varied from 0.15-17.11 irrespective of altitude classes. IVI estimated for large cardamom was 12.74 while, at low-, mid- and high-altitude class it was 9.41, 13.88 and 18.59 respectively. Overall, the most important species based on IVI was fern *Selaginella denticulata* followed by herb *Amomum subulatum*. The least important species based on IVI was a tree *Litsea glutinosa* (0.15). Based on the distribution of plant species in the system five species distribution models (SDM) were evaluated and the Preemption SDM give best fit to the data with highest Akaike Information Criterion (AIC) score.

***Keywords***: Large cardamom, Darjeeling Himalayas, Traditional, Altitude, Distribution model

Traditional agroforestry systems are unique and culturally sound land use systems which are still practiced globally by indigenous people since the time immemorial (Fischer et al 2014, Rendón-Sandoval et al 2020) including the Himalayas (Thakur et al 2017, Bhusara et al 2016). Eastern Himalayan region of India is a part of Indo Malayan Biodiversity Hotspot (Myers et al 2000) and thus home of the different types of traditional agroforestry systems (Sharma et al 2016a-c). Himalayan region of India is categorized by highly complex socio-ecological systems due to dominance of ethnic communities with rich cultural diversity directly associated with rich species diversity (Ramakrishnan 2007, Kumar et al 2012) which is seen as the foundation for safeguarding human security in these socio-ecologically fragile mountain systems. A number of workers studied the farming systems of Himalayan including agroforestry systems (Sharma et al 2007, 2016a-c, Kumar et al 2012, Pandey et al 2017) but the quantitative information on vegetation analysis, plant biomass and other aspect of traditional agroforestry systems are very limited and scanty (Maikhuri et al 2000, Kumar et al 2012). Traditional agroforestry systems have been influenced by many factors such as religious, social and economic since long time (Nath et al 2016, Pandey et al 2017) as well as these systems are also part of our tradition and culture (Kumar et al 2012). Indigenous agroforestry systems display a great complexity with regards to their component tree, shrub, climber and herb species (Thakur et al 2005, 2017). One such system is large cardamom (*Amomum subulatum* Roxb.) based traditional agroforestry in the north eastern Indian states including the Darjeeling Himalayas (Mehta et al 2015, Shrestha 2018, Vineeta et al 2021). Large cardamom, the oldest of spices is native to Sikkim and Darjeeling Himalaya including eastern hills of Nepal (Shrestha et al 2018). The distribution of large cardamom is very limited and mainly found in Eastern Himalayan region of India, Nepal and Bhutan (Mehta et al 2015). Large cardamom is a shade loving perennial cash crop traditionally inter-mixed as understorey of natural forest tree on marginal lands and slopes with high moisture in areas of high rainfall between 1500-3500 mm at an altitude of 600 and 2000 m above mean sea level (Gudade et al 2013, Yadav et al 2015). This complex traditional large cardamom based agroforestry systems of Darjeeling Himalayas are still not clearly understood in terms of their bio-physical and socio-cultural factors that determine its floristic composition, species diversity and distribution. Therefore, this study was carried out to generate precise and systematic quantitative data on the potential of large cardamom based traditional agroforestry in the Darjeeling Himalayas along the altitudinal gradient for its Vegetational analysis.

## MATERIAL AND METHODS

**Study site:** The present study was carried out in Kalimpong and Darjeeling districts, Darjeeling Himalayan region of West Bengal, India from January, 2019 to April, 2021 (Fig. 1).

The study site covering 3149 km$^2$ extends between 26° 27'

05"-27° 13' 10" N latitude and 87° 59' 30"-88° 53' E longitude with altitude of 132-3660 m. The region is humid and sub-tropical to sub-alpine with dry winter where normal temperature of coldest month is -3-18°C and warmest month is above 22°C (Saxena 2005). Soils of the region categorized as mountain and glacial soil, brown hill soil, forest soil, brown forest soil, tea soil, cinchona soil and Terai soil types (Kawosa 1988, Talwar 1988, De and Bera 1990) are acidic, yellow to red-brown in colour, silty loam to sandy loam textured and poor in calcium, magnesium, nitrogen, potassium, phosphate and organic matter (De and Bera 1990, Froehlich and Sarkar 2000). Tropical (below 800 m), subtropical (800-1600 m), temperate (1600-2400 m), cold-temperate (2400-3200 m) and sub-alpine (3200-4000 m) types of vegetation are found in the Darjeeling Himalayas (Bhujel 1996, Moktan and Das 2013, Cajee 2018). The forests in the region are mostly reserved and protected which were classified into five altitudinal zones by Basu (2000) as tropical moist deciduous (300-1000 m), tropical evergreen lower montane (1000-2000 m), tropical evergreen upper montane (2000-3000 m), temperate coniferous (3000-3500 m) and sub-alpine forest (> 3500 m).

Reconnaissance survey was conducted in the study area to explore the large cardamom based traditional agroforestry systems. The traditional large cardamom-based agroforestry farming in Darjeeling and Sikkim Himalayas were reported as the systems where large cardamom are cultivated under the canopy of reserved or protected forest leased out to the growers by the State Forest Department with no rights to cut the trees (Sharma et al 2009). Not many traditional large cardamom-based agroforestry systems/holdings were found in the study area. The size of the large cardamom holdings found were about 1-3 ha similar to the size reported from Sikkim (Sharma et al 2000, 2009). There was large cardamom under canopy cultivation in agricultural landscapes also which were not considered for the present study because these cultivations were adopted not more than a decade ago that too under the canopy of planted trees.

**Sampling design:** A total of 25 traditional large cardamom based agroforestry holdings found during the reconnaissance survey of the study area were distributed in the elevations between 700-2000 m, of which 17 were in Kalimpong district and only eight were in Darjeeling district. The geographical locations of the holdings were recorded with Garmin 72. Following the altitudinal chrono-sequence for distribution of vegetation in Darjeeling Himalayas by Das and Chanda (1987), Bhujel (1996), Moktan and Das (2013), Cajee (2018) and Sarkar (2020) the available traditional large cardamom holdings in the study area was also classified into three altitude class as low (700-1200 m asl), mid (1200-1700 m asl) and high (> 1700 m asl) with eleven, nine and five holdings, respectively. All the large cardamom holdings were analyzed for their phyto-sociological attributes adopting stratified random nested quadrate sampling method (Sarkar 2020, Tamang et al 2021). In these large cardamom holdings 1-4 quadrates were laid for vegetation analysis depending on its size. Holdings with size less than one hectare were laid with only quadrate in its centre and so on.

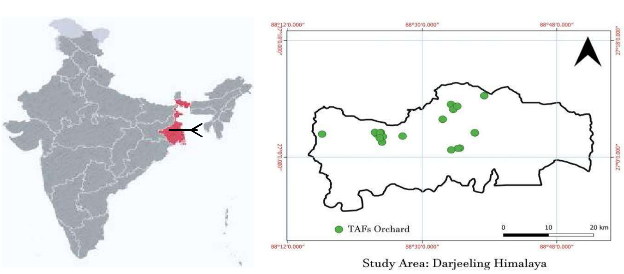


**Fig. 1.** Study area

**Phyto-sociological analysis:** In each large cardamom holding, 10 m × 10 m quadrates were laid down for trees within which two 5 m × 5 m sub-quadrates were laid at diagonal corners and five 1 m × 1 m sub-quadrates at four corners and center of the main quadrate. In each large cardamom holding the plant community was studied for their quantitative character. The trees, shrubs, herbs, climbers or any other vegetation was noted to keep an account of the floral composition of the plot.

**Life form:** Vegetation were stratified in to different layers according to its life forms like trees, shrubs, herbs, climbers, orchids and ferns (Johnson 1983) and every documented species were individually assigned a symbol like T, S, H, C, O and F, respectively.

**Frequency or occurrence/presence:** The degree of dispersion of an individual species in a community, i.e. chance of occurrence of species in each habitat is frequency (F) and expressed in per cent.

$$F = \frac{\text{No. of quadrates in which a species occurs}}{\text{Total no. of quadrates}} \times 100$$

Species documented from the large cardamom holdings were categorized as very less/rare (r), seldom present/less frequent (s), often present/frequent (o) and mostly or generally present/abundant (f) based on ≤10, 10-25, 25-75 and ≥ 75 % occurrence/presence, respectively of the total sampled homegardens.

**Relative frequency:** The frequency of a species relative to frequency of all other species in a community is relative frequency (RF).

$$RF = \frac{\text{No. of occurrence of a species}}{\text{No. of occurrence of all species}} \times 100$$

**Raunkiaer's law of frequency:** The frequency values are grouped in frequency classes to study the homogenous/heterogeneous nature of vegetation (Raunkiaer 1934). The law of frequency states that the numbers of species of a community in the five twenty per cent classes are A, B, C, D and E distributed as 0-20, 20-40, 40-60, 60-80 and 80-100 %, respectively.

**Density:** Abundance of a species in a unit area is expressed as density (D).

$$D = \frac{\text{Total no. of individuals of a species}}{\text{Total no. of quadrates}}$$

**Relative density:** Relative density (RD) is per cent representation of a species in term of number of individuals relative to all other species in a community.

$$RD = \frac{\text{No. of individuals of the species}}{\text{No. of individuals of all species}} \times 100$$

**Abundance:** Individuals of a species present in sampled area are expressed as abundance (A) of a species that also reflect commonality of the species in a studied habitat. Species abundance distribution (SAD) indicates most abundant and rare species in an ecosystem and was described through a number of models. Likelihood and Akaike Information Criterion (AIC) was used to fit the best SAD model out of the five models used i.e. Log-normal, Mandelbrot, Zipf, Null and Preemption models using abundance data of plant species documented from the 150 homegardens across an altitudinal gradient (Baldridge et al 2016).

$$A = \frac{\text{No. of individuals of the species in sampled quadrates}}{\text{No. of quadrates in which a species occurred}}$$

Log-normal model, a log-normal distribution is defined as a distribution whose variate conforms to the normal laws of probability. For SADs, the log-normal distribution characterizes a sample with relatively low abundance or very rare species (Matthews and Whittaker 2014). Preston (1948) introduced the log-normal SAD by demonstrating a good fit to a large number of data sets covering a number of different communities.

Log-normal (a^r) = exp [log (μ) + log (σ) Φ]

Zipf and Zipf-Mandelbrot model was originally developed for information systems, assessing the cost of information. In plant communities, the presence of a species can be seen as dependent on previous physical conditions and previous species presences.

Zipf (a^r) = Np^1rγ

Zipf-Mandelbrot a^r = (r + β)

Neutral-theory model was proposed by Hubbell (2001) and noted that the relative abundance of species within and the species diversity of a community can be explained through neutral drift of individual species abundances.

$$\text{Neutral - theory } \phi n = \theta + \frac{J!}{n!(J-n)!}\frac{r(y)}{r(J+y)!}\int_0^y \frac{r(n+y)}{r(1+y)}\frac{r(J-n+y-y)}{r(y-y)}\exp\left(\frac{y\theta}{dy}\right)$$

Niche-preemption model was proposed by (Motomura 1932) and assumes that the percentage of the total niche occupied by the first species is α, the second species occupied a percentage α of the reminder, (1 –a), and so on.

Niche-preemption (a^r) = (1 −a) −1

a^r is the expected abundance of species at rank r, *S* is the number of species, *N* is the number of individuals, Φ is a standard normal function, p^1 is the estimated proportion of the most abundant species, and α, σ, γ, β and *c* are the estimated parameters in each model. In neutral-theory model, where Γ(z) = ∫ t∞ z-1 0 e-t dt which is equal to (z-1)!, for integer z and γ = m(J-1) 1-m, θ is fundamental diversity number, *m* is migration rate.

**Relative abundance:** Abundance of a particular species relative to total number of individuals of all species in the sampled area is relative abundance (RA).

$$RA = \frac{\text{Abundance of a species}}{\text{Sum of the abundance of all species}} \times 100$$

**Basal area:** Total ground area occupied by a tree is its basal area (BA) which is estimated by measuring its diameter at breast height (1.37 m). BA of a tree species gives an idea on the proportion of its dominance in the community along with its relative size, volume and biomass. Basal area is calculated by the following formula (Chauhan et al 2009).

$BA = 0.7854 \times (DBH)^2$

**Importance value index:** Importance value index (IVI) reflects the sociological structure of a species in a community as it indicates its importance in the community. The summation of RF, RD and RA of a species is its IVI (Curtis 1959, Kershaw 1973).

## RESULTS AND DISCUSSION

**Vegetation analysis:** Overall plant species enlisted for the large cardamom based traditional agroforestry systems in the Darjeeling Himalayas was 130 species included 37 tree species 25 shrubs species, 46 herbs species, eight ferns species, 11 climbers species and three orchids species (Table 1, 2). Low- (700-1200 m asl), mid- (1200-1700 m asl) and high- (< 1700 m asl) altitude class was documented with 76 plant species, 60 species and 52 species. The overall range of plant species richness range recorded was 8-50 species with 16-50 species at low altitude class, 8-30 species

**Table 1.** Relative frequency and relative density of plant species in large cardamom based traditional agroforestry systems

| Plant species | RF | | | | RD | | | |
|---|---|---|---|---|---|---|---|---|
| | $O_a$ | L | M | H | $O_a$ | L | M | H |
| *Acalypha* accedens | 0.7 | - | 2.1 | - | 0.29 | - | 1 | - |
| *Acmella uliginosa* | 1 | 2.3 | - | - | 1.33 | 2.9 | - | - |
| *Adiantum capillus* | 1.3 | 2.9 | 4.5 | - | 2.29 | 4.9 | 7.5 | - |
| *Ageratina adenophora* | 4.2 | 5.4 | 2.9 | 3.1 | 2.7 | 4.3 | 1.1 | 1.29 |
| *Ageratum conyzoides* | 2.9 | 3.2 | 1.6 | 4.14 | 3.25 | 3.1 | 0.7 | 5.74 |
| *A. houstonianum* | 2.6 | 2 | 3.7 | 2.07 | 2.28 | 1.9 | 2 | 2.93 |
| *Albizia odoratissima* | 0.3 | 0.5 | - | - | 0.24 | 0.5 | - | - |
| *A. procera* | 0.3 | 0.6 | - | - | 0.15 | 0.3 | - | - |
| *Alnus nepalensis* | 0.5 | 0.3 | 0.4 | 0.72 | 0.67 | 0.2 | 1.2 | 0.94 |
| *Alsophila dregei* | 0.3 | 0.6 | - | - | 0.03 | 0.1 | - | - |
| *Amomum subulatum* | 7.8 | 5.7 | 8.2 | 10.3 | 4.77 | 3.4 | 5.7 | 5.5 |
| *Anaphalis triplinervis* | 1 | - | - | 4.14 | 1.86 | - | - | 6.67 |
| *Ardisiamacrocarpa* | 0.2 | - | - | 0.83 | 0.09 | - | - | 0.31 |
| *Artemesia vulgaris* | 1.6 | 2.3 | 1.6 | - | 0.89 | 1.6 | 0.5 | - |
| *Begonia palmata* | 1 | - | - | 4.14 | 0.44 | - | - | 1.6 |
| *B. tessaricarpa* | 0.9 | - | - | 3.62 | 0.38 | - | - | 1.37 |
| *Biden pilosa* | 1.6 | 3.4 | - | - | 2.43 | 5.2 | - | - |
| *Bischofia javanica* | 0.2 | - | 0.7 | - | 0.09 | - | 0.3 | - |
| *Boehmeria cylindrica* | 0.4 | 0.9 | - | - | 0.14 | 0.3 | - | - |
| *B. platyphylla* | 0.5 | 0.6 | 0.8 | 1.03 | 0.73 | 0.9 | 0.5 | 1.13 |
| *Brachiaria reptans* | 2.9 | 2.9 | 1.6 | 4.14 | 4.06 | 3.3 | 2.1 | 6.91 |
| *Brassaiopsis mitis* | 0.1 | - | 0.3 | - | 0.17 | - | 0.6 | - |
| *Brugmansia suaveolens* | 0.1 | 0.2 | - | - | 0.07 | 0.1 | - | - |
| *C. tetrandra* | 0.2 | 0.3 | - | - | 0.08 | 0.2 | - | - |
| *Carex sylvatica* | 0.9 | - | - | 3.62 | 1.48 | - | - | 5.31 |
| *Castanopsis indica* | 0.2 | 0.5 | - | - | 0.13 | 0.3 | - | - |
| *Cayratia geniculate* | 0.3 | 0.7 | - | - | 0.17 | 0.4 | - | - |
| *Centella asiatica* | 1.8 | - | 2.5 | 4.14 | 3.16 | - | 3.7 | 7.53 |
| *Citrus spp* | 0.2 | 0.3 | - | - | 0.1 | 0.2 | - | - |
| *Colebrookea oppositifolia* | 0.3 | - | 1 | - | 0.68 | - | 2.4 | - |
| *Commelina suffruticosa* | 0.4 | - | - | 1.55 | 0.18 | - | - | 0.66 |
| *Croton caudatus* | 0.2 | 0.3 | - | - | 0.39 | 0.8 | - | - |
| *Cryptomeria japonica* | 0.6 | 0.3 | 1 | 0.72 | 0.76 | 0.1 | 1.6 | 0.86 |
| *Cupressuscashmeriana* | 0.5 | 0.3 | 0.3 | 1.03 | 0.52 | 0.3 | 0.3 | 1.13 |
| *Dichroa febrifuga* | 0.7 | 0.6 | 2.1 | 1.55 | 0.27 | 0.2 | 2.7 | 0.59 |
| *Diplazium esculentum* | 2.6 | 0.6 | 2.1 | 6.72 | 4.3 | 1.3 | 2.8 | 10.4 |
| *Drymaria cordata* | 2.7 | 1.7 | 2.9 | 4.14 | 4.12 | 2.9 | 3.7 | 6.13 |
| *Drypetes lancifolia* | 0.2 | 0.3 | - | - | 0.2 | 0.4 | - | - |
| *Equisetum arvense* | 0.7 | 1.4 | - | - | 0.26 | 0.6 | - | - |
| *E. debile* | 1.8 | 2.3 | 2.5 | - | 1.48 | 1.7 | 2.4 | - |
| *Erythrina variegate* | 0.4 | 0.5 | 0.5 | - | 0.22 | 0.2 | 0.4 | - |
| *Euonymus attenuatus* | 0.2 | - | - | 0.31 | 0.17 | - | - | 0.62 |

**Cont...**

**Table 1.** Relative frequency and relative density of plant species in large cardamom based traditional agroforestry systems

| Plant species | RF | | | | RD | | | |
|---|---|---|---|---|---|---|---|---|
| | $O_a$ | L | M | H | $O_a$ | L | M | H |
| *Exbucklandia populnea* | 0.1 | - | 0.3 | - | 0.04 | - | 0.2 | - |
| *Ficus auriculata* | 0.4 | 0.8 | - | - | 0.41 | 0.9 | - | - |
| *F. lacor* | 0.3 | 0.6 | - | - | 0.25 | 0.5 | - | - |
| *F. semicordata* | 0.6 | 0.8 | 0.7 | - | 0.42 | 0.5 | 0.6 | - |
| *F.* spp. | 0.2 | | 0.6 | | 0.09 | | 0.3 | - |
| *Firmiana colorata* | 0.3 | 0.4 | 0.5 | - | 0.38 | 0.6 | 0.4 | - |
| *Floscopa scandens* | 0.9 | 2 | - | - | 1.3 | 2.8 | - | - |
| *Fragaria nubicola* | 2.2 | 1.3 | 2.5 | - | 1.97 | 2.8 | 2.4 | - |
| *Girardinia diversifolia* | 0.2 | - | - | 0.62 | 0.12 | - | - | 0.43 |
| *G. palmata* | 0.5 | 0.1 | 0.5 | 1.03 | 0.37 | 0.1 | 0.1 | 1.05 |
| *Goodyera oblongifolia* | 0.7 | 1.4 | - | | 0.35 | 0.7 | - | - |
| *Gynocardia odorata* | 0.1 | - | 0.4 | - | 0.1 | - | 0.3 | - |
| *Gynura cusimbua* | 0.2 | - | - | 1.55 | 0.16 | - | - | 0.59 |
| *Hydrocotyle javanica* | 0.5 | - | - | 2.07 | 0.85 | - | - | 3.04 |
| *Hydrocotyle nepalensis* | 0.5 | - | 1.6 | - | 0.27 | - | 0.9 | - |
| *Hypoestes phyllostachya* | 0.5 | 1.2 | - | - | 0.56 | 1.2 | - | - |
| *Juniperus indica* | 0.3 | 0.7 | - | - | 0.21 | 0.4 | - | - |
| *Justicia prostrata* | 1.3 | 0.9 | 2.9 | - | 0.2 | 0.1 | 0.5 | - |
| *Lantana camara* | 0.6 | 0.7 | 1 | - | 0.93 | 1 | 1.5 | - |
| *Laportea bulbifera* | 0.1 | - | - | 0.41 | 0.13 | - | - | 0.47 |
| *Lepidagathis incurva* | 1.6 | 1.4 | 2.5 | - | 1 | 1 | 1.8 | - |
| *Leucosceptrum canum* | 0.2 | - | 1 | - | 0.11 | - | 1.5 | - |
| *Lindenbergia grandiflora* | 1.2 | 1.2 | 2.1 | - | 0.81 | 0.8 | 1.6 | - |
| *Litsea glutinosa* | 0 | - | - | 0.1 | 0.01 | - | - | 0.04 |
| *L. monopetala* | 0.2 | 0.5 | - | - | 0.28 | 0.6 | - | - |
| *Lycopodium japonicum* | 2.2 | 2.3 | 3.7 | - | 2.18 | 2.1 | 4.1 | - |
| *Lygodium flexuosum* | 0.1 | - | - | 0.41 | 0.03 | - | - | 0.12 |
| *Macaranga denticulata* | 0.4 | 0.5 | 0.6 | - | 0.3 | 0.3 | 0.6 | - |
| *Machilus edulis* | 0.1 | - | - | 0.52 | 0.08 | - | - | 0.27 |
| *Magnolia doltsopa* | 0.1 | - | - | 0.21 | 0.03 | - | - | 0.12 |
| *M. grandiflora* | 0.1 | - | - | 0.31 | 0.03 | - | - | 0.12 |
| *M. lanuginosa* | 0.2 | - | - | 0.83 | 0.1 | - | - | 0.35 |
| *Mallotus tetracoccus* | 0.1 | - | 0.4 | - | 0.07 | - | 0.2 | - |
| *Matteuccia struthiopteris* | 2.2 | 2.3 | 3.7 | - | 1.12 | 1.2 | 1.9 | - |
| *Melastoma malabathricum* | 0.1 | - | - | 0.41 | 0.09 | - | - | 0.31 |
| *Mikania micrantha* | 0.4 | 0.9 | - | - | 0.12 | 0.3 | - | - |
| *Myrsine semiserrata* | 0.3 | - | 0.8 | - | 0.36 | - | 1.2 | - |
| *Nephrolepsis cordifolia* | 2.9 | 3.2 | 4.5 | - | 3.04 | 3.1 | 5.4 | - |
| *Oenanthe thomsonii* | 1 | - | 3.3 | - | 0.75 | - | 2.6 | - |
| *Oroxylum indicum* | 0.3 | 0.7 | - | - | 0.15 | 0.3 | - | - |
| *Ostodes paniculata* | 0.1 | 0.3 | - | - | 0.08 | 0.2 | - | - |
| *Oxalis corniculata* | 1.6 | 3.4 | - | - | 2.44 | 5.2 | - | - |
| *O. latifolia* | 0.7 | 1.4 | - | - | 0.5 | 1.1 | - | - |
| *O. martiana* | 1.4 | 3.2 | - | - | 2.21 | 4.7 | - | - |

**Cont...**

**Table 1.** Relative frequency and relative density of plant species in large cardamom based traditional agroforestry systems

| Plant species | RF | | | | RD | | | |
|---|---|---|---|---|---|---|---|---|
| | $O_a$ | L | M | H | $O_a$ | L | M | H |
| *Peliosanthes griffithii* | 0.5 | - | - | 3.1 | 0.27 | - | - | 0.47 |
| *Persicaria capitata* | 0.5 | 1.2 | - | - | 0.61 | 1.3 | - | - |
| *P. chinesis* | 0.2 | 0.5 | 0.7 | - | 0.61 | 1.3 | 1.1 | - |
| *Phaulopsis dorsiflora* | 0.7 | 1.4 | - | - | 0.49 | 1 | - | - |
| *Phlogacanthus thyrsiformis* | 0.5 | 0.6 | 0.8 | 1.03 | 0.47 | 0.6 | 0.7 | 0.98 |
| *Pilea cordifolia* | 0.5 | 1.2 | - | - | 0.38 | 0.8 | - | - |
| *P. involucrate* | 0.1 | - | - | 0.41 | 0.16 | - | - | 0.59 |
| *P. melastomoides* | 0.2 | - | - | 0.83 | 0.4 | - | - | 1.44 |
| *P. nummulariifolia* | 0.5 | - | 1.6 | - | 0.94 | - | 3.2 | - |
| *Pinus wallichiana* | 0.2 | - | - | 0.72 | 0.12 | - | - | 0.43 |
| *Piper attenuatum* | 0.2 | 0.5 | - | - | 0.18 | 0.4 | - | - |
| *P. boehmeriaefolium* | 0.7 | 0.7 | 0.7 | 0.83 | 0.67 | 0.5 | 0.8 | 0.86 |
| *P. peepuloides* | 0.3 | 0.6 | - | - | 0.29 | 0.6 | - | - |
| *Plantago asiatica* | 1.2 | - | 2.1 | 2.07 | 0.61 | - | 1.4 | 0.7 |
| *P. major* | 0.4 | - | - | 1.55 | 0.09 | - | - | 0.31 |
| *Plumbagoauriculata* | 0.5 | - | 1.6 | - | 0.44 | - | 1.5 | - |
| *Pogostemon andersonii* | 0.5 | - | 1.6 | - | 0.71 | - | 2.4 | - |
| *Polygonum rude* | 0.2 | - | 0.5 | - | 0.17 | - | 0.6 | - |
| *Pouzolzia zeylanica* | 0.8 | 1.7 | - | - | 0.76 | 1.6 | - | - |
| *Prunus cerasoides* | 0.1 | - | 0.3 | - | 0.08 | - | 0.3 | - |
| *Rhododendron griffithianum* | 0.2 | - | - | 0.72 | 0.08 | - | - | 0.27 |
| *Rubia cordifolia* | 0.1 | - | 0.3 | - | 0.07 | - | 0.2 | - |
| *Rubus diffusus* | 0.3 | - | 1 | - | 0.34 | - | 1.2 | - |
| *R. holosericeus* | 0.2 | - | - | 0.62 | 0.17 | - | - | 0.62 |
| *R. spp* | 0.2 | - | 0.5 | - | 0.04 | - | 0.2 | - |
| *Schima wallichii* | 0.7 | 0.7 | 0.6 | 0.83 | 0.81 | 1 | 0.7 | 0.59 |
| *Scutellarialateriflora* | 0.4 | - | - | 1.55 | 0.18 | - | - | 0.66 |
| *Selaginella denticulata* | 6.1 | 5.7 | 5.7 | 6.72 | 10.5 | 9.9 | 8.5 | 12.3 |
| *Senecio densiflorus* | 0.3 | - | - | 1.03 | 0.37 | - | - | 1.33 |
| *Smilax ovalifolia* | 0.3 | - | - | 1.24 | 0.13 | - | - | 0.47 |
| *Solena amplexicaulis* | 0.3 | 0.6 | - | - | 0.13 | 0.3 | - | - |
| *Spathoglottius plicata* | 0.9 | 0.9 | - | 2.07 | 0.52 | 0.5 | - | 0.98 |
| *Stephaniajaponica* | 0.4 | 0.9 | - | - | 0.51 | 1.1 | - | - |
| *Strobilanthes exserta* | 1.3 | 1.2 | 2.1 | - | 1.05 | 0.9 | 2.1 | - |
| *Synedrella nudiflora* | 0.7 | 1.4 | - | - | 0.2 | 0.4 | - | - |
| *Terminalia myriocarpa* | 0.5 | 0.6 | 0.4 | 0.31 | 0.41 | 0.5 | 0.4 | 0.27 |
| *Tetrastigma serrulatum* | 0.3 | - | - | 1.03 | 0.26 | - | - | 0.94 |
| *Thujaplicata* | 0.1 | - | - | 0.21 | 0.02 | - | - | 0.08 |
| *Thysanolaena latifolia* | 0.5 | 1.4 | - | - | 0.3 | 0.9 | - | - |
| *Toona ciliata* | 0.4 | 0.6 | 0.4 | - | 0.3 | 0.5 | 0.3 | - |
| *Vitex negundo* | 0.4 | 0.8 | - | - | 0.09 | 0.2 | - | - |
| *Vitis pedata* | 0.5 | 1.2 | - | - | 0.3 | 0.7 | - | - |
| *Zanthoxylum piperitum* | 0.2 | - | 0.5 | - | 0.08 | - | 0.3 | - |
| *Zephyranthes* carinata | 1.6 | - | 2.9 | 2.59 | 1.64 | - | 4.5 | 1.17 |

RF- Relative frequency; RD- Relative density; Oa- overall (700-1930 m asl); L- low (700-1200 m asl); M- mid (1200-1700 m asl); H- high (> 1700 m)

**Table 2.** Relative abundance and importance value index of plant species in large cardamom based traditional agroforestry systems

| Plant species | RA | | | | IVI | | | |
|---|---|---|---|---|---|---|---|---|
| | $O_a$ | L | M | H | $O_a$ | L | M | H |
| *Acalypha* accedens | 0.1 | - | 0 | - | 1.07 | - | 3.08 | - |
| *Acmella uliginosa* | 0.4 | 0.6 | - | - | 2.73 | 5.7 | - | - |
| *Adiantum capillus* | 0.5 | 0.8 | 0.1 | - | 4.08 | 8.53 | 12.1 | - |
| *Ageratina adenophora* | 0.2 | 0.4 | 0 | 0.8 | 7.04 | 10.1 | 4 | 5.21 |
| *Ageratum conyzoides* | 0.3 | 0.4 | 0 | 1.1 | 6.43 | 6.73 | 2.33 | 11 |
| *A. houstonianum* | 0.2 | 0.4 | 0 | 0.6 | 5.12 | 4.3 | 5.72 | 5.54 |
| *Albizia odoratissima* | 0.2 | 0.4 | - | - | 0.77 | 1.47 | - | - |
| *A. procera* | 0.2 | 0.2 | - | - | 0.59 | 1.19 | - | - |
| *Alnus nepalensis* | 0.4 | 0.3 | 0.2 | 0.2 | 1.54 | 0.7 | 1.71 | 1.85 |
| *Alsophila dregei* | 0 | 0.1 | - | - | 0.33 | 0.7 | - | - |
| *Amomum subulatum* | 0.2 | 0.3 | 0 | 2.8 | 12.7 | 9.41 | 13.9 | 18.6 |
| *Anaphalis triplinervis* | 0.5 | - | - | 1.1 | 3.39 | - | - | 11.9 |
| *Ardisiamacrocarpa* | 0.1 | - | - | 0.2 | 0.41 | - | - | 1.36 |
| *Artemesia vulgaris* | 0.2 | 0.3 | 0 | - | 2.61 | 4.23 | 2.1 | - |
| *Begonia palmata* | 0.1 | - | - | 1.1 | 1.6 | - | - | 6.84 |
| *B. tessaricarpa* | 0.1 | - | - | 1 | 1.41 | - | - | 5.95 |
| *Biden pilosa* | 0.4 | 0.7 | - | - | 4.42 | 9.31 | - | - |
| *Bischofia javanica* | 0.1 | - | 0 | - | 0.41 | - | 0.98 | - |
| *Boehmeria cylindrica* | 0.1 | 0.2 | - | - | 0.63 | 1.32 | - | - |
| *B. platyphylla* | 0.4 | 0.7 | 0 | 0.3 | 1.64 | 2.14 | 1.29 | 2.44 |
| *Brachiaria reptans* | 0.4 | 0.5 | 0.1 | 1.1 | 7.31 | 6.62 | 3.83 | 12.1 |
| *Brassaiopsis mitis* | 0.6 | - | 0.1 | - | 0.87 | - | 0.97 | - |
| *Brugmansia suaveolens* | 0.2 | 0.3 | - | - | 0.34 | 0.64 | - | - |
| *C. tetrandra* | 0.1 | 0.2 | - | - | 0.37 | 0.72 | - | - |
| *Carex sylvatica* | 0.5 | - | - | 1 | 2.84 | - | - | 9.89 |
| *Castanopsis indica* | 0.2 | 0.3 | - | - | 0.51 | 1.01 | - | - |
| *Cayratia geniculate* | 0.2 | 0.2 | - | - | 0.64 | 1.3 | - | - |
| *Centella asiatica* | 0.5 | - | 0.1 | 1.1 | 5.46 | - | 6.18 | 12.8 |
| *Citrus spp* | 0.2 | 0.3 | - | - | 0.43 | 0.82 | - | - |
| *Colebrookea oppositifolia* | 0.6 | - | 0.1 | - | 1.6 | - | 3.46 | - |
| *Commelina suffruticosa* | 0.1 | - | - | 0.4 | 0.71 | - | - | 2.63 |
| *Croton caudatus* | 0.7 | 1.1 | - | - | 1.24 | 2.27 | - | - |
| *Cryptomeria japonica* | 0.3 | 0.2 | 0.1 | 0.2 | 1.72 | 0.64 | 2.63 | 1.77 |
| *Cupressus cashmeriana* | 0.3 | 0.4 | 0.1 | 0.3 | 1.31 | 0.98 | 0.56 | 2.44 |
| *Dichroa febrifuga* | 0.1 | 0.2 | 0.1 | 0.4 | 1.04 | 0.99 | 4.8 | 2.55 |
| *Diplazium esculentum* | 0.5 | 1 | 0.1 | 1.8 | 7.36 | 2.8 | 4.95 | 18.9 |
| *Drymaria cordata* | 0.4 | 0.8 | 0.1 | 1.1 | 7.27 | 5.35 | 6.62 | 11.4 |
| *Drypetes lancifolia* | 0.4 | 0.5 | - | - | 0.7 | 1.3 | - | - |
| *Equisetum arvense* | 0.1 | 0.2 | - | - | 1.02 | 2.16 | - | - |
| *E. debile* | 0.2 | 0.3 | 0.1 | - | 3.52 | 4.29 | 4.89 | - |
| *Erythrina variegate* | 0.2 | 0.2 | 0 | - | 0.75 | 0.92 | 0.9 | - |
| *Euonymus attenuatus* | 0.3 | - | - | 0.1 | 0.64 | - | - | 1.02 |

**Cont...**

**Table 2.** Relative abundance and importance value index of plant species in large cardamom based traditional agroforestry systems

| Plant species | RA | | | | IVI | | | |
|---|---|---|---|---|---|---|---|---|
| | $O_a$ | L | M | H | $O_a$ | L | M | H |
| *Exbucklandia populnea* | 0.1 | - | 0 | - | 0.26 | - | 0.5 | - |
| *Ficus auriculata* | 0.3 | 0.5 | - | - | 1.09 | 2.18 | - | - |
| *F. lacor* | 0.3 | 0.4 | - | - | 0.78 | 1.52 | - | - |
| *F. semicordata* | 0.2 | 0.3 | 0.1 | - | 1.2 | 1.6 | 1.34 | - |
| *F.* spp. | 0.1 | - | 0 | - | 0.4 | - | 0.9 | - |
| *Firmiana colorata* | 0.3 | 0.6 | 0 | - | 1.03 | 1.58 | 0.94 | - |
| *Floscopa scandens* | 0.4 | 0.6 | - | - | 2.61 | 5.41 | - | - |
| *Fragaria nubicola* | 0.3 | 1 | 0.1 | - | 4.43 | 5 | 4.85 | - |
| *Girardinia diversifolia* | 0.2 | - | - | 0.2 | 0.49 | - | - | 1.21 |
| *G. palmata* | 0.2 | 0.4 | 0 | 0.3 | 1.06 | 0.57 | 0.61 | 2.36 |
| *Goodyera oblongifolia* | 0.2 | 0.2 | - | | 1.15 | 2.41 | - | - |
| *Gynocardia odorata* | 0.2 | - | 0 | - | 0.44 | - | 0.79 | - |
| *Gynura cusimbua* | 0.3 | - | - | 0.4 | 0.61 | - | - | 2.55 |
| *Hydrocotyle javanica* | 0.5 | - | - | 0.6 | 1.82 | - | - | 5.66 |
| *Hydrocotyle nepalensis* | 0.1 | - | 0 | - | 0.94 | - | 2.6 | - |
| *Hypoestes phyllostachya* | 0.3 | 0.5 | - | - | 1.39 | 2.82 | - | - |
| *Juniperus indica* | 0.2 | 0.3 | - | - | 0.7 | 1.42 | - | - |
| *Justicia prostrata* | 0 | 0.1 | 0 | - | 1.54 | 1 | 3.4 | - |
| *Lantana camara* | 0.4 | 0.7 | 0.1 | - | 1.97 | 2.41 | 2.59 | - |
| *Laportea bulbifera* | 0.4 | - | - | 0.1 | 0.58 | - | - | 0.99 |
| *Lepidagathis incurva* | 0.2 | 0.3 | 0 | - | 2.74 | 2.8 | 4.24 | - |
| *Leucosceptrum canum* | 0.2 | - | 0.1 | - | 0.46 | - | 2.59 | - |
| *Lindenbergia grandiflora* | 0.2 | 0.3 | 0 | - | 2.18 | 2.21 | 3.65 | - |
| *Litsea glutinosa* | 0.1 | - | - | 0 | 0.15 | - | - | 0.17 |
| *L. monopetala* | 0.4 | 0.6 | - | - | 0.87 | 1.65 | - | - |
| *Lycopodium japonicum* | 0.3 | 0.4 | 0.1 | - | 4.67 | 4.84 | 7.8 | - |
| *Lygodium flexuosum* | 0.1 | - | - | 0.1 | 0.22 | - | - | 0.64 |
| *Macaranga denticulata* | 0.2 | 0.3 | 0.1 | - | 0.92 | 1.08 | 1.18 | - |
| *Machilus edulis* | 0.2 | - | - | 0.1 | 0.37 | - | - | 0.93 |
| *Magnolia doltsopa* | 0.2 | - | - | 0.1 | 0.26 | - | - | 0.38 |
| *M. grandiflora* | 0.1 | - | - | 0.1 | 0.23 | - | - | 0.51 |
| *M. lanuginosa* | 0.1 | - | - | 0.2 | 0.44 | - | - | 1.4 |
| *Mallotus tetracoccus* | 0.1 | - | 0 | - | 0.33 | - | 0.66 | - |
| *Matteuccia struthiopteris* | 0.1 | 0.2 | 0 | - | 3.47 | 3.73 | 5.61 | - |
| *Melastoma malabathricum* | 0.2 | - | - | 0.1 | 0.42 | - | - | 0.84 |
| *Mikania micrantha* | 0.1 | 0.1 | - | - | 0.62 | 1.3 | - | - |
| *Myrsine semiserrata* | 0.4 | - | 0.1 | - | 1 | - | 2.13 | - |
| *Nephrolepsis cordifolia* | 0.3 | 0.4 | 0.1 | - | 6.19 | 6.7 | 10 | - |
| *Oenanthe thomsonii* | 0.2 | - | 0 | - | 1.99 | - | 5.89 | - |
| *Oroxylum indicum* | 0.2 | 0.2 | - | - | 0.59 | 1.26 | - | - |
| *Ostodes paniculata* | 0.2 | 0.3 | - | - | 0.37 | 0.7 | - | - |
| *Oxalis corniculata* | 0.4 | 0.7 | - | - | 4.44 | 9.34 | - | - |
| *O. latifolia* | 0.2 | 0.3 | - | - | 1.36 | 2.83 | - | - |
| *O. martiana* | 0.4 | 0.7 | - | - | 4.07 | 8.56 | - | - |

**Cont...**

**Table 2.** Relative abundance and importance value index of plant species in large cardamom based traditional agroforestry systems

| Plant species | RA | | | | IVI | | | |
|---|---|---|---|---|---|---|---|---|
| | $O_a$ | L | M | H | $O_a$ | L | M | H |
| *Peliosanthes griffithii* | 0.1 | - | - | 0.8 | 0.94 | - | - | 4.39 |
| *Persicaria capitata* | 0.3 | 0.5 | - | - | 1.45 | 2.95 | - | - |
| *P. chinesis* | 0.8 | 1.3 | 0.1 | - | 1.63 | 3.03 | 1.86 | - |
| *Phaulopsis dorsiflora* | 0.2 | 0.3 | - | - | 1.35 | 2.8 | - | - |
| *Phlogacanthus thyrsiformis* | 0.3 | 0.5 | 0 | 0.3 | 1.24 | 1.61 | 1.53 | 2.28 |
| *Pilea cordifolia* | 0.2 | 0.3 | - | - | 1.1 | 2.27 | - | - |
| *P. involucrate* | 0.4 | - | - | 0.1 | 0.7 | - | - | 1.11 |
| *P. melastomoides* | 0.5 | - | - | 0.2 | 1.15 | - | - | 2.49 |
| *P. nummulariifolia* | 0.5 | - | 0.1 | - | 1.97 | - | 4.98 | - |
| *Pinus wallichiana* | 0.2 | - | - | 0.2 | 0.48 | - | - | 1.35 |
| *Piper attenuatum* | 0.3 | 0.4 | - | - | 0.64 | 1.24 | - | - |
| *P. boehmeriaefolium* | 0.3 | 0.3 | 0.1 | 0.2 | 1.66 | 1.45 | 1.46 | 1.91 |
| *P. peepuloides* | 0.3 | 0.5 | - | - | 0.87 | 1.69 | - | - |
| *Plantago asiatica* | 0.1 | - | 0 | 0.6 | 1.92 | - | 3.5 | 3.32 |
| *P. major* | 0.1 | - | - | 0.4 | 0.54 | - | - | 2.28 |
| *Plumbagoauriculata* | 0.2 | - | 0.1 | - | 1.2 | - | 3.21 | - |
| *Pogostemon andersonii* | 0.4 | - | 0.1 | - | 1.6 | - | 4.14 | - |
| *Polygonum rude* | 0.3 | - | 0.1 | - | 0.64 | - | 1.15 | - |
| *Pouzolzia zeylanica* | 0.3 | 0.4 | - | - | 1.81 | 3.77 | - | - |
| *Prunus cerasoides* | 0.2 | - | 0 | - | 0.38 | - | 0.63 | - |
| *Rhododendron griffithianum* | 0.1 | - | - | 0.2 | 0.37 | - | - | 1.19 |
| *Rubia cordifolia* | 0.2 | - | 0 | - | 0.34 | - | 0.59 | - |
| *Rubus diffusus* | 0.3 | - | 0.1 | - | 0.95 | - | 2.2 | - |
| *R. holosericeus* | 0.3 | - | - | 0.2 | 0.64 | - | - | 1.41 |
| *R. spp* | 0.1 | - | 0 | - | 0.28 | - | 0.66 | - |
| *Schima wallichii* | 0.3 | 0.6 | 0.1 | 0.2 | 1.84 | 2.26 | 1.35 | 1.63 |
| *Scutellarialateriflora* | 0.1 | - | - | 0.4 | 0.71 | - | - | 2.63 |
| *Selaginella denticulata* | 0.5 | 0.8 | 0.1 | 1.8 | 17.1 | 16.4 | 14.3 | 20.8 |
| *Senecio densiflorus* | 0.4 | - | - | 0.3 | 1.02 | - | - | 2.64 |
| *Smilax ovalifolia* | 0.1 | - | - | 0.3 | 0.56 | - | - | 2.04 |
| *Solena amplexicaulis* | 0.1 | 0.2 | - | - | 0.53 | 1.07 | - | - |
| *Spathoglottius plicata* | 0.2 | 0.3 | - | 0.6 | 1.59 | 1.67 | - | 3.59 |
| *Stephaniajaponica* | 0.3 | 0.5 | - | - | 1.27 | 2.54 | - | - |
| *Strobilanthes exserta* | 0.2 | 0.3 | 0.1 | - | 2.58 | 2.37 | 4.22 | - |
| *Synedrella nudiflora* | 0.1 | 0.1 | - | - | 0.93 | 1.98 | - | - |
| *Terminalia myriocarpa* | 0.2 | 0.4 | 0.1 | 0.1 | 1.13 | 1.44 | 0.83 | 0.67 |
| *Tetrastigma serrulatum* | 0.3 | - | - | 0.3 | 0.8 | - | - | 2.25 |
| *Thujaplicata* | 0.1 | - | - | 0.1 | 0.19 | - | - | 0.34 |
| *Thysanolaena latifolia* | 0.2 | 0.3 | - | - | 0.99 | 2.65 | - | - |
| *Toona ciliata* | 0.2 | 0.4 | 0 | - | 0.91 | 1.44 | 0.7 | - |
| *Vitex negundo* | 0.1 | 0.1 | - | - | 0.52 | 1.09 | - | - |
| *Vitis pedata* | 0.2 | 0.3 | - | - | 0.99 | 2.05 | - | - |
| *Zanthoxylum piperitum* | 0.1 | - | 0 | - | 0.37 | - | 0.78 | - |
| *Zephyranthes* carinata | 0.3 | - | 0.1 | 0.7 | 3.49 | - | 7.46 | 4.44 |

RF- Relative frequency; RD- Relative density; Oa- overall (700-1930 m asl); L- low (700-1200 m asl); M- mid (1200-1700 m asl); H- high (> 1700 m) richness at mid-altitude class and 9-21 species at high altitude class. The frequency of species irrespective of altitude classes documented was 1.7-100.0. The most frequent species was *Amomum subulatum* and the least frequent species was *Litsea glutinosa* while *Amomum subulatum* and *Selaginella denticulata* (100.0 each) were the most frequent species at low-altitude. At mid-altitude, the most frequent species was *Amomum subulatum* (100.0) and the least frequent species was *Rubia cordifolia* (10.0). At high-altitude class *Amomum subulatum* was the most frequent species with frequency of 100.0 and the least frequent species class was *Litsea glutinosa* (5.0 each).The species documented with higher occupancy status i.e. frequency exhibited wider spatial distribution at multiple altitudinal levels were widely representing biodiversity across a broad landscape (Gbedomon et al 2017, Sarkar 2020). Overall, these systems across the altitudinal gradient with varying frequencies but multi-strata vegetation with herbs, shrubs and trees were contributing heterogeneity with temporal and spatial dynamism. Moreover, these Darjeeling Himalayan forest based below canopy large cardamom farming systems being close to natural forest ecosystems due to minimal disturbance can be considered as efficient and viable systems of biodiversity conservation intrinsically similar to its traditional homegardens (Sarkar 2020) and traditional homegardens elsewhere (Cruz-Garcia and Struik 2015, Gbedomon et al 2017). The species richness of 130 documented from these large cardamoms based traditional agroforestry farming systems of Darjeeling Himalayas can be sufficient enough to represent regional species richness (van der Wal and Bongers 2013) and thus are important to conserve regional plant diversity *in situ* (Galluzzi et al 2010, Sarkar 2020).

The overall density estimated for the documented species in Darjeeling Himalayan large cardamom based TAFs was in the range of 0.01-3.23 quadrate$^{-1}$. The densest species was *Selegnella denticulata* while, *Lygodium flexuosum* and *Alsophila dregei* were sparse. The plant density estimated for low-, mid- and high-altitude class was 0.03-4.26 (*Alsophila dregei-Selegnella denticulata*), 0.06-2.30 (*Rubia cordifolia- Selegnella enticulata*) and 0.03-3.16 (*Lygodium flexuosum-Selegnella denticulata*), respectively while, density of *Amomum subulatum* at these classes were 1.47, 1.50 and 1.41, respectively. Overall, abundance of species was in the range of 0.30-7.0. The least abundant species was *Alsophila dregei* and the most abundant species found was *Persicaria chinensis* while, for large cardamom the value was 1.47. The abundance for low-, mid- and high-altitude class was 0.27-7.0 (*Justicia prostrata-Persicaria chinensis*), 0.40-6.20 (*Justicia prostrata-Alnus nepalensis*) and 0.40-5.33 (*Peliosanthes griffithii-Euonymus attenuates).*

The important value index (IVI) of the documented species at the studied systems varied from 0.15-17.11 irrespective of altitude classes (Table 1, 2). IVI estimated for large cardamom was 12.74 while, at low-, mid- and high-altitude class it was 9.41, 13.88 and 18.59 respectively. Overall, the most important species based on IVI was a fern *Selaginella denticulata* followed by an herb *Amomum subulatum*. The least important species based on IVI was a tree *Litsea glutinosa* (0.15). The IVI of species estimated for low-altitude class was 0.57-16.39. The most important species based on IVI at this altitude was a fern *Selaginella denticulata* and the least important was a shrub *Girardinia palmata* (0.57). At mid-altitude class the IVI estimated was in the range of 0.50 (*Exbucklandia populnea*)-14.30 (*Selaginella denticulata*). The most important species based on IVI at this altitude found was a fern and the least important species was a tree (0.50). Similarly, IVI estimated for high-altitude class 0.17 (*Litsea glutinosa*)-20.84 (*Selaginella denticulata*). The plant assemblages in the large cardamom based traditional at low-, mid- and high-altitude class were more or less similarly distributed. Species with higher IVI signifies its ecological importance in the system. The species growing at a particular altitude in the Darjeeling Himalayas was primarily influenced by site factors and ecological conditions that they best adapted the natural selection and evolution . Similar vegetation analysis with comparable density, abundance, frequency and IVI of traditional agroforestry systems was reported in earlier studies also (Taran and Deb 2019, Sarkar 2020). Phyto-sociology of the plant communities varies with agroforestry systems, slope and land quality (Sharma et al 2010).

**Model:** The distribution of plant species in the large cardamom based traditional agroforestry systems was evaluated using Log-normal, Mandelbrot, Zipf, Null and Preemption species distribution models (SAM). The Preemption SDM give best fit to the data with highest Akaike Information Criterion (AIC) score (Fig. 2).Similarly, distribution of species using these species distribution models was also evaluated for the homegardens of Darjeeling Himalayas across the altitudinal gradient (Sarkar 2020). Among the models SAD was unable to distinguish the species with any degree of certainty due to limited information (Volkov et al 2005). Therefore, it was recommended that the models should be evaluated for their ability to simultaneously explain multiple macro-ecological data in order to obtain sufficient information on ecological processes (Xiao et al 2015).

The conservation status of the Darjeeling large cardamom based traditional agroforestry can be

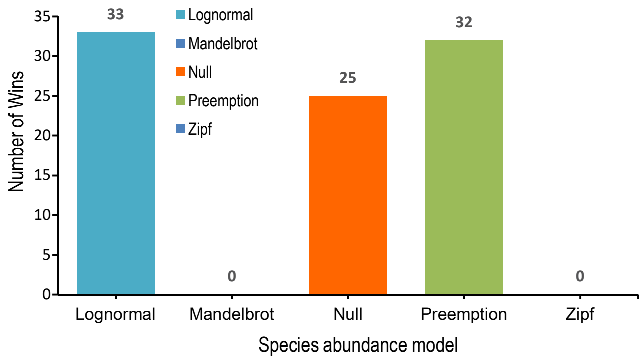


**Fig. 2.** Number of cases model provided best fit to plant species abundance data

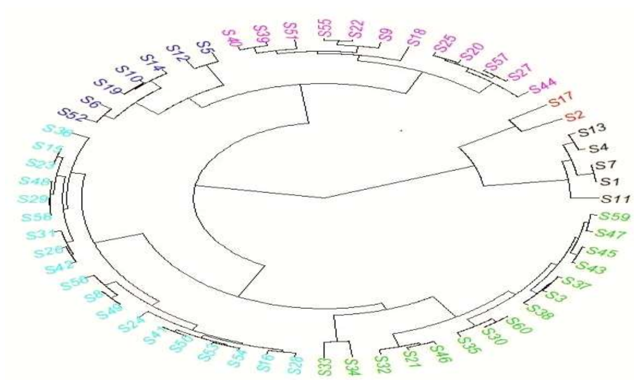

**Fig. 3.** Clustering based on plant species richness and population of the Darjeeling Himalayan large cardamom based traditional agroforestry systems

satisfactorily recognised only when its ecosystem services are fully realised in addition to factors affecting its spatial distribution, evolution and temporal resiliency understood and regularly monitored for any evolutionary changes there in (Agbogidi and Adolor 2013). These traditional large cardamom-based agroforestry systems of Darjeeling Himalayas are also diverse plant species with variable population size across the altitudinal gradient over reasonably wider landscape like many other traditional agroforestry systems (Abebe et al 2013, Gebrewahid and Meressa 2020) including its home gardens also (Sarkar 2020). Based on species richness and its plant population across the altitudinal gradient, large cardamom based traditional agroforestry farming systemswere grouped into six clusters illustrated with six different colors (Fig. 3). Similar cluster analysis of homegardens across the altitudinal gradient in Central (Vibhuti et al 2018) and Darjeeling (Sarkar 2020) Himalayas, India were also reported. These traditional agroforestry systems as are very close to natural ecosystems with potential to offer variety of ecosystem services from provisional to cultural services like NTFPs, biodiversity conservation, water regulation and purification, biomass production, carbon sequestration, nutrient cycling and socio-cultural service for the well-being of the society (Nath et al 2016, Vineeta et al 2021).

## CONCLUSION

The heterogeneity of the system can be attributed to richness of 130 plant species include 37 were tree species, 25 shrub species, 46 herb species; eight fern species, 11 climber species and three orchid species. Overall, the most important species based on IVI was a fern *Selaginella denticulata* followed by an herb *Amomum subulatum*. The least important species based on IVI was a tree *Litsea glutinosa* (0.15). The farming systems also varied on the basis of their species richness and plant population which were grouped into six clusters. Based on the distribution of plant species in the system five species distribution models (SDM) were evaluated and the Preemption SDM was provided best fit to the data with highest Akaike Information Criterion (AIC) score. This study recommends further in-depth analysis of structure and composition with respect to altitudinal location will generate more information on functional diversity, structure, composition and productivity.

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