Chapter 6
General Discussion

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GENERAL DISCUSSION

6.1. Community Analysis

Plant community defines the association of species growing together in a particular habitat. It is an important component to understand the behavior of the species and to determine its gene pool. Community analysis is an important basis for vegetation study and to understand its function (Warger & Morrel, 1978). The plant sociology of the rich flora of Darjiling hills have been analysed and thereby a quantitative data have been derived. The variation in the edaphic, climatic, altitudinal and different biotic components and their inter-relationships with composition of the species at various altitudinal levels have enriched the flora of this part of the Eastern Himalaya to maintain and sustain the different types of vegetation. The five types of altitudinal vegetation provide a healthy data on the present phytosociological status of the rich floral community in this region.

6.1.1. Tropical Zone

In the tropical zone of Darjiling hills, the phytosociological study within the forest in three different seasons revealed a total of 261 species of trees, shrubs/climbers and herb/ground covers distributed among 203 genera under 76 families. Of these, 74 are tree species under 64 genera and 36 families, whereas 73 and 114 are shrub and herb species with 52 and 87 genera, under 29 and 37 families respectively. The dominant family recorded from this zone combining all the three layers was Poaceae (18 spp), Leguminosae (14 spp), Compositae (13 spp), Malvaceae (11 spp), Acanthaceae and Vitaceae (10 spp), Lamiaceae and Phyllanthaceae (8 spp), Apocynaceae, Commelinaceae and Lauraceae (7 spp), Rubiaceae (6 spp), Convolvulaceae and Urticaceae (5 spp). Ten species of pteridophytes under 7 genera and 3 families was also recorded from this zone (Fig. 6.1).

The family Orchidaceae was also represented by 7 species under 5 genera. There were atleast 27 families distributed each with two or more species while the remaining 37 families were represented by only a single species.

Trees are the indicators of changes and forms functional and structural basis in tropical vegetation (Khan *et al.,* 1997). The total number of individuals for the tree stands was 721 with total density of 2436.62 individuals ha^{-1} and total basal area of 343.223 m^2 ha^{-1} (Table 6.1). The forest in this zone was found to be heterogeneous with healthy diversity of species and *Shorea robusta, Tetrameles nudiflora* and *Tectona grandis* dominating the zone with *Schima wallichii, Duabanga grandiflora, Gmelina arborea, Bombax ceiba, Lagerstroemia parviflora,* and *Chukrasia tabularis* forming co-dominant layer. These species also showed high density in the forest with most of the species distributed randomly or contiguously. The density was similar to that of the tropical forests of other regions in India (Jaykumar & Nair, 2013). The sapling density of the canopy was also observed to be diverse with many of the species expressing healthy growth in saplings especially during the post-monsoon period. The total density for the saplings was estimated at 1286.5 sapling count/ha. The maximum frequency of the tree was observed in the class 40 – 60 % and minimum in the above classes. This depicts the heterogenous distribution of the tree layer that may be due to the couplings of abiotic and biotic process.

In the shrub layer, the maximum diversity and dominance was expressed by *Mikania micrantha, Ichnocarpus frutescens, Tetrastigma serrulatum, Stephania japonica* with co-dominant shrubs/climbers like *Sauropus compressus, Coffea benghalensis, Stephania glabra* and *Dioscorea bulbifera.* In the herb layer, the maximum dominance was shown by a grass species *Oplismenus compositus* followed by *Phaulopsis imbricata, Spermococe alata* with co-dominant species such as *Achyranthes bidentata, Urena lobata, Chloranthus elatior, Globba racemosa* and *Synedrella nodiflora.* These species also showed high density inside the forest and they remained in association with the canopy cover with contiguous nature of distribution. The diversity of the species during the post-monsoon was high especially for the herb layer while the shrub layer expressed almost similar count in the species number both during pre-monsoon and winter. However, the concentration of dominance was highest for the shrubs as well as herbs during the winter as compared to other seasons.

The Shannon-Wiener diversity of index (SWI) for the vegetation in this zone was 6.07. The herb layer was found to be more diverse than the tree and shrubs with index of 5.427. The determined diversity values for tree and shrub layer was 4.195 and 4.999 respectively. The diversity was greater than the earlier record for the foot hill forests by Rai and Das, (2005). Similarly, the Menhinick's index (MI) of species richness for the vegetation was observed to be 5.70, with 2.756 for tree layer, 2.964 for shrubs and highest for herb layer with richness of 4.035. The Pielou's evenness (PI) for the vegetation was observed to be 0.976 with shrubs expressing highest evenness of 0.980 and the lowest evenness of 0.973 by herb layer (Fig. 6.2). Similarly, the concentration of dominance was calculated at 0.002 for the vegetation, 0.017 for tree layer, 0.007 and 0.004 for shrub and herb layers respectively.

The tropical vegetation shows good species diversity, richness and evenness with low concentration of dominance. The herb layer was more heterogeneous with high species diversity and richness than the other two layers. Trees however showed low richness compared to other two layers but higher concentration of dominance, probably due to maximum dominance of *Shorea robusta.*

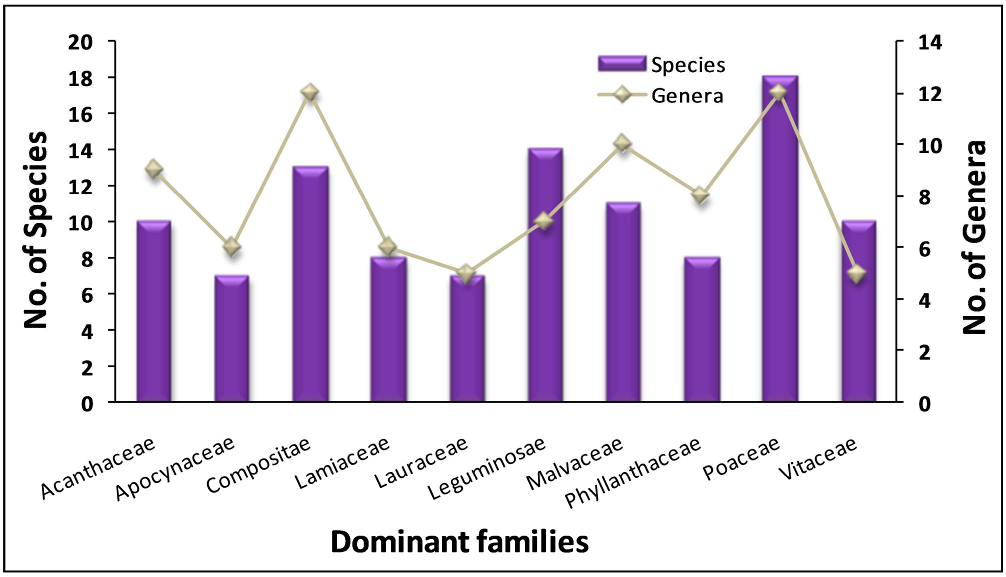

Fig. 6.1. Distribution of taxa under dominant family in tropical zone

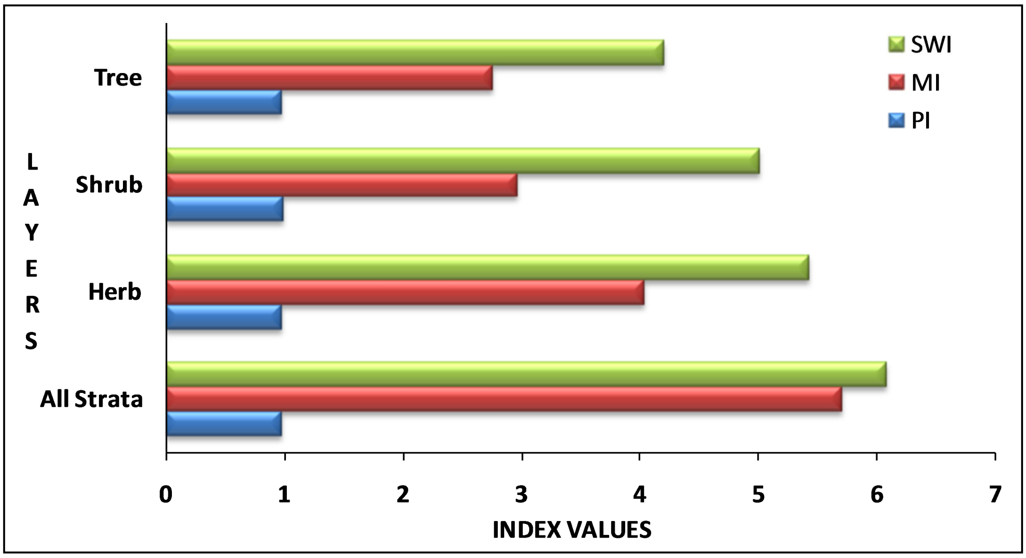

Fig. 6.2. Diversity indices in tropical zone

6.1.2. Sub-tropical Zone

The forest diversity in the Himalayan sub-tropical region have been studied by many phytosociologist in the past (Gairola *et al.,* 2008; Kunwar & Sharma, 2004). The sub-tropical zone of Darjiling hills that cover the altitudinal range between 500 – 1200 m amsl possess mixture of some species from tropical and sub-temperate also. The community analysis in this zone during three different seasons revealed a total of 260 species of trees, shrubs/climbers and herb/ground covers distributed among 204 genera under 81 families. Tree contained 48 genera and 61 species under 32 families. This was similar to that recorded by Sharma and Kant (2014), for the sub-tropical forest of Siwaliks of Jammu. The shrub layers had 87 species with 63 genera under 29 families, the herb layer had higher number of 112 species belonging to 93 genera under 41 families. Maximum number of species in all the layers combined was recorded under the family Acanthaceae, Compositae and Leguminosae (14 spp), followed by Lamiaceae (13 spp), Urticaceae (10 spp), Poaceae and Vitaceae (10 spp), Lauraceae (9 spp), Malvaceae (8 spp), Menispermaceae and Rubiaceae (7 spp) (Fig.6.3).

Two species of gymnosperms were also observed in this zone while eight species of pteridophytes belonging to 6 genera under 4 families was also seen distributed. 31 families had distribution of two or more species while the remaining 39 families remained with a single species. The total number of individuals for the tree stands was 790 with total density of 2078.07 individuals ha^{-1}and total basal area of 295.63 m^2 ha^{-1} (Table 6.1). The dominant canopy layer in this zone was formed by *Schima wallichii*, *Terminalia myriocarpa* and *Ailanthus integrifolia* with the distribution of some other important woody species such as *Bombax ceiba, Sterculia villosa, Ostodes paniculata*, *Duabanga grandiflora*, *Litsea monopetala* and *Macaranga denticulata* that remained with contiguous nature of distribution. The frequency distribution was maximum in the class 0 – 20 % followed by similar frequency distribution like that of the Raunkiaer expressing almost homogenous nature of vegetation. The sapling density of tree species was moderate in the forest with total density of 437.8 sapling count/ha. The growth of the saplings seems to be good due to moist humid climate that may cause regeneration of seedlings into saplings.

The shrubs/climbers that remained in association with the woody species was mostly *Stephania japonica, Thunbergia fragrans, Cyclea bicristata Phlogacanthus thyrsiflorus* and *Maesa chisia* with species such as *Natsiatum herpeticum, Mimosa himalayana, Boehmeria glomerulifera, Tetrastigma serrulatum* and *Pericampylus glaucus* occupying co-dominant layer. In the herb layer, the maximum diversity was shown by *Nephrolepis cordifolia*, *Lepidagathis incurva, Gonostegia hirta* and a grass species *Oplismenus burmanii* with co-dominant species such as *Dicliptera bupleuroides, Hypoestes phyllostachya, Peristrophe speciosa, Polygonum runcinatum* and *Globba racemosa.* These species exhibited high diversity with more than thousand individual counts especially during the post-monsoon season that remained in contiguous association with the shrubs and canopy. The number of shrub species recorded during post-monsoon was equal to number the tree species, while the distribution during winter was moderate. The climatic condition of the zone supports species both from tropical and temperate. Behera and Roy (2005), highlighted similar observation from the district in Arunachal Pradesh.

The Shannon-Wiener index for the sub-tropical vegetation was 5.972. The herb layer expressed least dominance of 0.005 but it had highest diversity of 5.224 whereas that of tree and shrub layer was 3.978 and 5.032 respectively. The Menhinick's index of species richness for the vegetation was observed to be 5.347, with 2.162 for tree layer, 3.305 for shrubs. These values were higher than the study on sub-tropical forest made by Sharma and Kant (2014). The herb layer showed highest richness of 3.616. The total evenness for the vegetation was observed to be 0.987 with herb layer expressing highest evenness of 0.990 and the lowest evenness of 0.967 for tree layer (Fig. 6.4). The concentration of dominance was calculated at 0.002 for the vegetation, with 0.020 for tree layer and 0.007 for shrub layer.

The sub-tropical vegetation showed similar species diversity like the tropical in terms of number of species and genera but the distribution of families was higher in this zone. The herb layer expressed high diversity and richness but the concentration of dominance was low than the above two layers. Although tree layer showed low richness, the concentration of dominance was high.

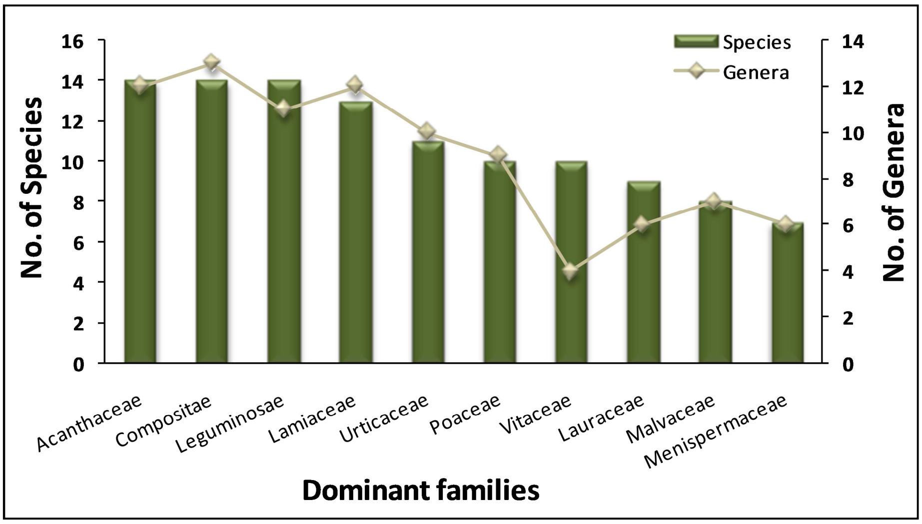

Fig. 6.3. Distribution of taxa under dominant family in sub-tropical zone

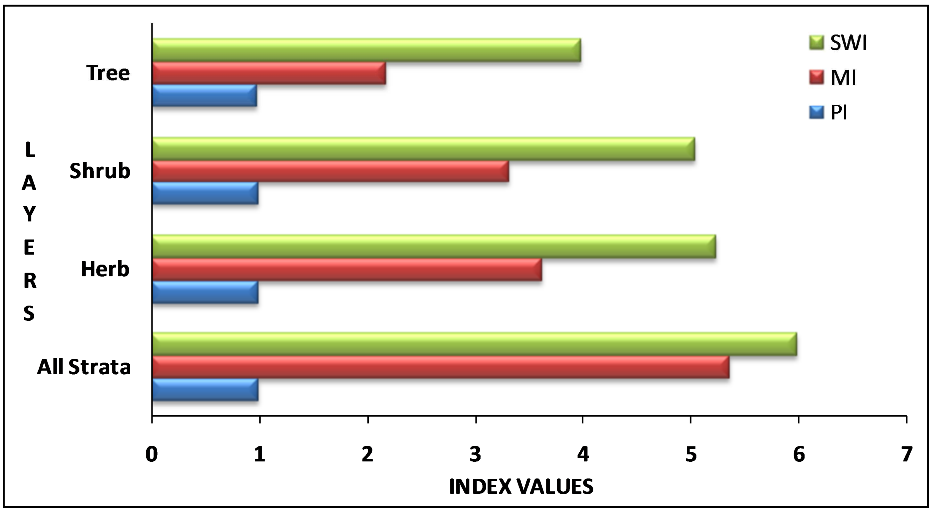

Fig. 6.4. Diversity indices in sub-tropical zone

6.1.3. Sub-temperate Zone

This zone that lies within the altitudinal range of 1200 – 1850 m amsl shows mixture of species both from sub-tropical and temperate region. Phytosociological analysis conducted during three different seasons showed altogether 272 species belonging to 213 genera under 97 families from this zone. Of these, 52 species under 42 genera and 30 families were observed for tree layer, 72 species under 61 genera and 40 families was seen in shrub layer and 148 species belonging to 110 genera under 48 families was recorded for herb layer from this zone in total. The maximum species diversity was observed for the family Urticaceae (15 spp), Compositae and Lamiaceae (12spp), Poaceae (10 spp), Commelinaceae and Gesneriaceae (9 spp), Lauraceae, Rosaceae and Rubiaceae (7 spp), Acanthaceae and Cyperaceae (6 spp) (Fig. 6.5).

Fifteen species of Pteridophytes under 6 families was also observed with 4 species of orchids under 4 genera. There were atleast 41 families distributed each with two or more species while the remaining 45 families were represented by only a single species. The total number of individuals for 52 species of tree stands was 624 with an estimated total density of 1630.65 individuals ha^{-1} and total basal area of 194.84 m^2 ha^{-1} (Table 6.1). The diversity of species in this zone seems to be higher than that of the tropical and sub-tropical, although the altitudinal range is narrow. Species such as *Cryptomeria japonica, Lithocarpus pachyphyllus, Quercus glauca, Schima wallichii* formed dominant layer in the canopy cover associated by other co-dominant species like *Eriobotrya petiolata, Magnolia cathcartii, Exbucklandia populnea, Acer campbellii* and *Eriobotrya dubia.* These species were randomly and contiguously associated with the other layers. The frequency distribution of the tree species showed maximum in class 0 – 20 % followed by the class 20 – 40 % and none in the other classes exhibiting heterogeneous distribution pattern of vegetation. The sapling density in this zone was recorded as 552.9 sapling count/ha.

Coming to the shrub/climbers, the dominating cover was formed by Rosacean species *Rubus acuminatus* and *Rubus buergeri* along with *Dichroa febrifuga, Astilbe rivularis, Hedyotis scandens, Rubus ellipticus, Ficus sarmentosa* and species of *Hypericum.* In the herb layer, the maximum diversity and dominance was expressed by *Isodon lophanthoides, Melissa axillaris, Craniotome furcata, Lecanthus peduncularis* and even pteridophytic species *Selaginella* *monospora* with co-dominantly associated species *Elatostema sessile, Sarcopyramis napalensis, Strobilanthes divaricatus, Isodon coetsa, Torenia cordifolia, Drymaria cordata* and *Sanicula elata.* These species exhibited healthy association with the higher layers with high richness and contagious distribution. The distribution was quite moderate for the tree and shrub layer, but the number of species for the herb was healthy both during pre and post-monsoon.

The Shannon-Wiener index of diversity for the vegetation in sub-temperate zone was 6.03. The determined diversity values for tree and shrub layer was 3.887 and 4.960 respectively, whereas for the herb layer it was highest with 5.417. The richness index of species for the vegetation was calculated to be 6.142, with 2.082 for tree layer, 3.434 for shrubs and highest for herb layer with index values of4.669. The total estimated evenness for the vegetation was observed to be 0.990 which was equal to that of the herb layer. The evenness for shrubs was 0.988 and that for the tree layer was 0.983 (Fig. 6.6). Similarly, the concentration of dominance was calculated at 0.002 for the vegetation, 0.021 for tree layer, 0.007 for shrub layer and 0.004 for herb layer in the sub-temperate zone.

Although the altitudinal range for the zone was narrow, yet the diversity of the species compared to the sub-tropical zone seems to be greater and the number of species was also higher than the tropical and sub-tropical vegetation. The herb layer was observed to be more diversified with double the species than that of the tree or the shrub with low concentration of dominance.

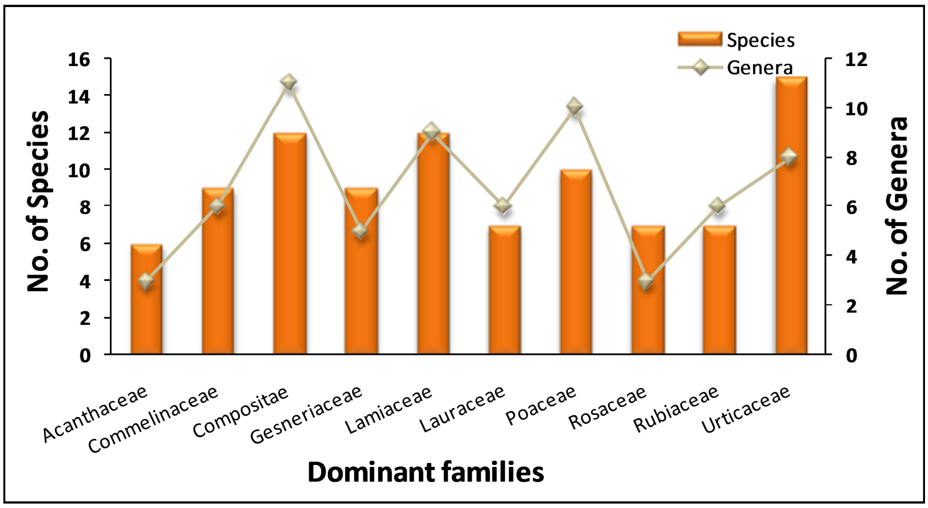

Fig. 6.5. Distribution of taxa under dominant family in sub-temperate zone

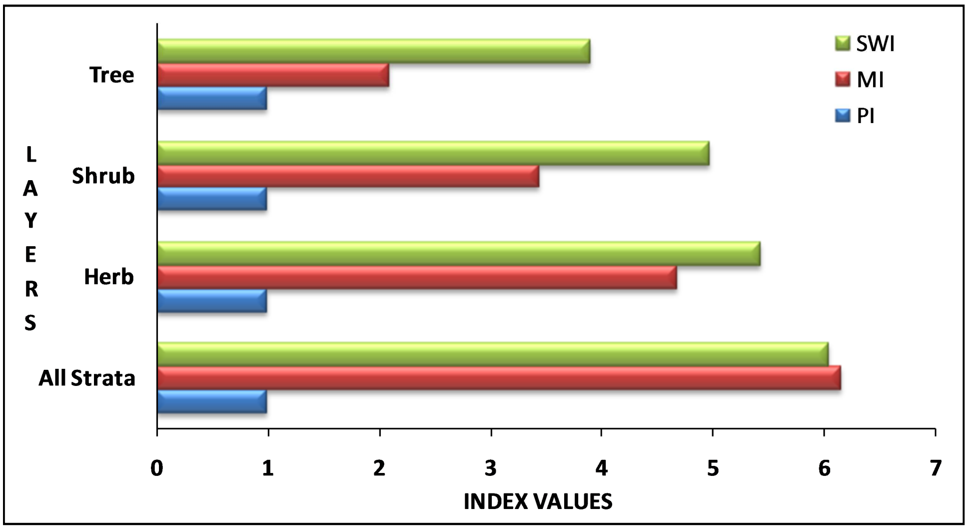

Fig. 6.6. Diversity indices in sub-temperate zone

6.1.4. Temperate Zone

The community analysis in the temperate zone that covers wide altitudinal range between 1850 – 3200 m amsl exhibited an enormous number of species including many that have been observed in sub-temperate and sub-alpine zones also. The total number of species recorded form this zone during three seasons was 440 that belonged to 271 genera under 99 families. This data seems higher than that recorded by Dar and Sundarapandian (2016), from temperate forest type of Western Himalaya. The woody layer contained 51 genera and 91 species under 27 families, whereas 134 species belonging to 80 genera under 49 families was recorded for the shrub layer. Highest number of 215 species under 140 genera and 57 families was observed for the herb layer. Maximum number of species in all the layers combined was recorded for the family Rosaceae (23 spp), Compositae (20 spp), Ericaceae (19 spp), Urticaceae (15 spp), Gentianaceae (12 spp), Fagaceae and Lamiaceae (11 spp), Cyperaceae, Lauraceae and Rubiaceae (10 spp), Araceae, Araliaceae, Caprifoliaceae and Gesneriaceae (9 spp), Orchidaceae, Polypodiaceae and Ranunculaceae (8 spp) (Fig. 6.7).

Nine species of ferns under 5 genera were also observed in this zone. 48 families had distribution of two to seven species while the remaining 34 families had a single species distribution. The total number of individuals for the tree stands was 969 with total density of 2896.83 individuals ha^{-1} and total basal area of

300.64m^2 ha^{-1} (Table 6.1). This area is the ecotone for both the middle and high altitude vegetation. The dominant canopy layer in this zone was formed by Fagacean species *Lithocarpus pachyphyllus, Lithocarpus fenestratus, Quercus lamellosa* with *Rhododendron arboreum, Cryptomeria japonica, Magnolia campbellii* along with some other associated species such as *Engelhardtia spicata, Alnus nepalensis, Machilus edulis, Symplocos glomerata, Symplocos lucida, Magnolia doltsopa, Abies densa* and *Exbucklandia populnea* that remained in contiguous nature of distribution in the temperate zone. Due to the favourable climatic condition at this altitude, the frequency and abundance of the saplings inside the forests was also high and so was the density with total density of 955.6 sapling count/ha. The frequency percentage distribution for the tree layer was highest for 0 – 20 % followed by 20 – 40 % expressing heterogeneous nature of the vegetation.

The diversity in the shrub layer showed dominant species as *Astilbe rivularis, Gaultheria nummularioides, Yushania maling, Vaccinium retusum, Daphne bholua, Viburnum mullaha, Clematis buchananiana* and *Crawfurdia speciosa.* These species remained in close association with the canopy cover especially with the *Rhododendrons.* Species such as *Yushania maling* was found to be dispersed widely inside the forests in this zone. The other associated shrubs/climbers that remained in association with the woody species was *Senecio scandens, Vaccinium vacciniaceum, Rubus splendidissimus, Streptolirion volubile* along with species such as *Dichroa febrifuga, Rosa sericea, Agapetes serpens* and *Mahonia napaulensis.*

In the ground cover layer, the maximum dominance was expressed by *Fragaria nubicola, Galium elegans, Hypoestes triflora, Ainsliaea latifolia, Ageratina adenophora, Hydrocotyle himalaica, Strobilanthes wallichii, Torenia cordifolia* with co-dominant species such as *Sanicula elata, Melissa axillaris, Strobilanthes capitata, Viola pilosa, Hemiphragma heterophyllum, Loxostigma griffithii* and *Rubus calycinus.* High number of individual count was observed for the herb layer both during pre and post-monsoon. The species exhibited close association with the canopy and the shrub layer within the moist vegetation with high diversity and contiguous nature of distribution. The diversity of herb layer during post-monsoon was almost double than that of tree or shrub count.

The vegetation of the temperate zone showed Shannon-Wiener index of diversity as 6.616. The herb layer expressed least dominance of 0.002 but it had highest diversity of 6.032 whereas that for tree and shrub layer was 4.398 and 5.537 respectively. These values were higher than the values estimated for Himalayas (Kunwar & Sharma, 2004; Shaheen *et al.*, 2012). The Menhinick's index of species richness for the vegetation was calculated at 9.353, with 2.923 for tree layer, 5.406 for shrubs and highest for herb layer with richness of 7.073. The Pielou's evenness for the vegetation was observed to be 0.989, for tree layer it was 0.975, for shrubs and herb layer it was 0.987 and 0.991 respectively (Fig. 6.8). The concentration of dominance for the vegetation was low than the determined values for different layers with 0.013 for tree layer and 0.004 for shrub layer.

Changes in species diversity and composition along altitudinal gradient have been studied by several workers (Lomolino, 2001; Fetene *et al.*, 2006). The temperate vegetation showed highest diversity of species than the other vegetation zones of Darjiling hills with some species distribution having wide ecological amplitude. Altitude, aspect, slope have played a key role in the diversity of vegetation in this zone of Darjiling Himalaya with amalgamation of species both from the sub-temperate and sub-alpine region.

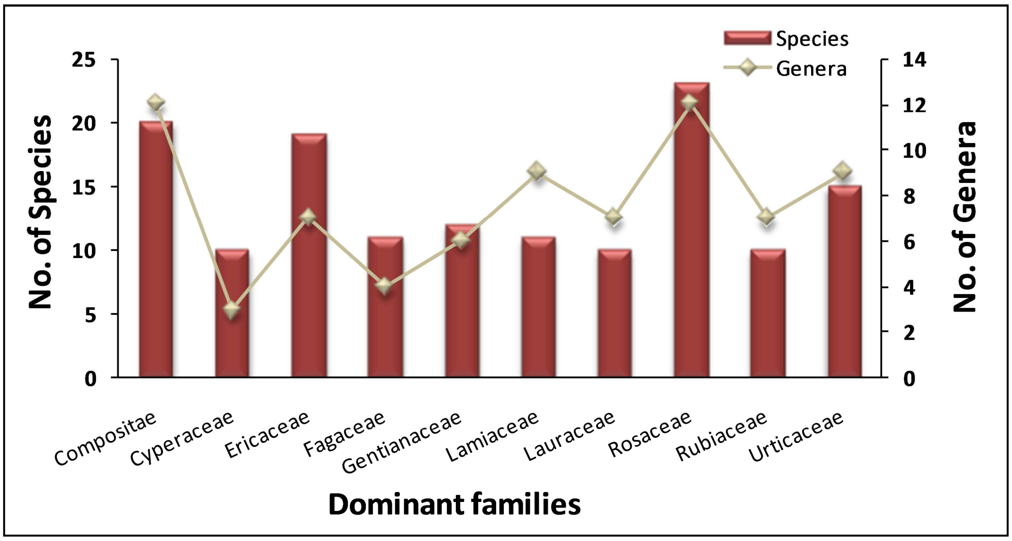

Fig. 6.7. Distribution of taxa under dominant family in temperate zone

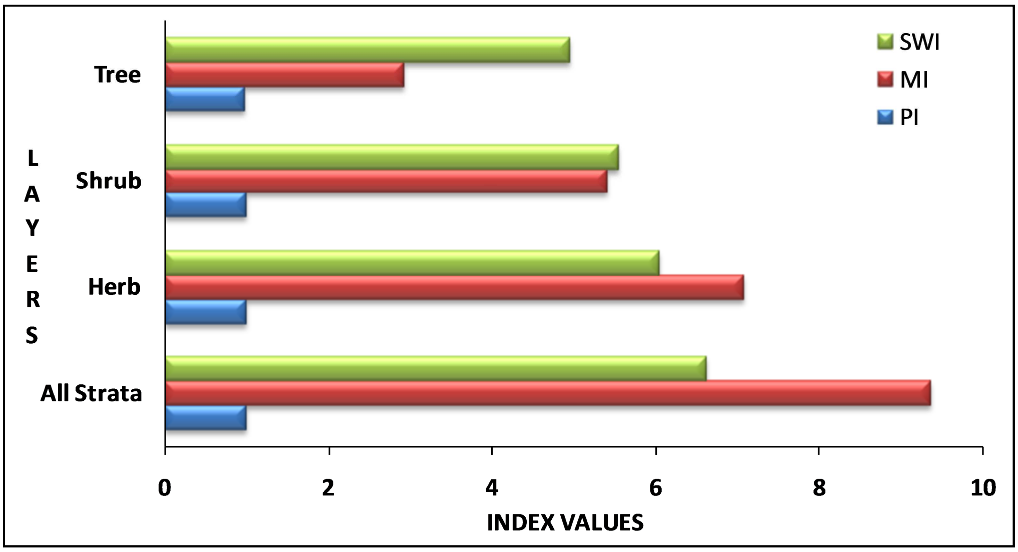

Fig. 6.8. Diversity indices in temperate zone

6.1.5. Sub-alpine Zone

The Himalayan sub-alpine vegetation reflects an ecotone between temperate forest and alpine grasslands with their own specialized floral elements (Gairola *et al.,* 2008). The community study in the high altitude sub-alpine zone of Darjiling hills that lies within the altitudinal range of 3200 – 3660 m amsl has been investigated only for two seasons. The total number of species recorded from this altitudinal vegetation was 109 belonging to 80 genera under 44 families. 23 species of trees, under 14 genera and 9 families, 28 species of shrubs/climbers under 23 genera and 16 families and 58 species of herb/ground covers belonging to 43 genera under 24 families have been observed to be distributed in this zone.

The dominant family recorded from this zone combining all the three layers was Ericaceae (16 spp), Rosaceae (11 spp), Compositae (10 spp), Ranunculaceae, Primulaceae and Poaceae (4 spp), Apiaceae, Araceae, Lamiaceae, Saxifragaceae and Violaceae (3 spp) (Fig. 6.9). There were atleast 11 families distributed each with two species while the remaining 22 families were represented by only a single species. The total number of individuals for the tree stand from this zone was 226 with total density of 890.5 individuals ha^{-1}and total basal area of 85.476 m^{2} ha^{-1} (Table 6.1). The zone that occupies a narrow altitudinal range was observed to be mostly dominated by the conifer *Abies densa* in association with *Rhododendron* *barbatum, Rhododendron arboreum, Rhododendron falconeri, Rhododendron hodgsonii, Quercus lineata* and *Magnolia campbellii.* These species were randomly distributed and were in close association with the dominating *Abies densa* along with some other co-dominant species like *Rhododendron arboreum* var. *cinnamomeum, Pieris formosa* and *Rhododendron grande.* The frequency distribution was moderately closer to the percentage of Raunkiaer class exhibiting somewhat homogeneous nature of distribution. The density of the scattered sapling was also moderate even in that short altitudinal stretch with estimated total of 364.1 saplings count/ha.

In the shrub layer the dominating species was *Cotoneaster microphyllus, Gaultheria nummularioides, Arundinaria sp.* and *Rosa sericea* with *Rhododendron lepidotum* and *Yushania maling.* The other co-dominant shrub from this zone includes *Senecio scandens*, *Daphne bholua* var. *glacialis* and *Vaccinium retusum.* These species were healthily amalgamated with the canopies showing contiguous distribution pattern. The herb layer exhibited dominant species as *Primula denticulata, Persicaria campanulata, Anaphalis busua, Meconopsis paniculata, Bistorta emodi* which were scattered in the forest floor along with some grass species. The ground covers also expressed contiguous associationwith the shrubs and under shrubs. Some of the other co-dominant species include *Potentilla sundaica, Saxifraga gageana, Saxifraga parnassifolia, Elsholtzia strobilifera, Gentiana capitata, Prunella vulgaris, Fragaria daltoniana, Viola wallichiana* and *Tiarella polyphylla.* High abundance of these species was also observed at some slopes during the study.

The Shannon-Wiener diversity of index (SWI) for the vegetation in this zone was 4.963. The herb layer was found to be more diverse than the tree and shrubs with index of 4.36. The determined diversity values for tree and shrub layer was 2.922 and 3.870 respectively. Similarly, the Menhinick’s index of species richness (MI) for the vegetation was observed to be 4.318, with 1.530 for tree layer, 2.744 for shrubs and 3.019 for herb layer. The Pielou’s evenness (PI) for the vegetation was observed to be 0.982 with herb layer expressing highest evenness of 0.992 and the lowest evenness of 0.932 by woody layer (Fig. 6.10). Similarly, the concentration of dominance was calculated at 0.007 for the vegetation, 0.068 for tree layer, 0.022 and 0.013 for shrub and herb layers respectively.

The diversity of life decreases with increasing altitude and only few species remains at highest zones (Pavon *et al.*, 2000). This can be understood from the decrease in species diversity and richness in the present study also (Fig. 6.11). Even though the area above 3200 m occupies only about 25 – 35 sq km, yet the population of the species was observed to be reasonably diverse, with moderate richness and dominance. The herb layer was more diversified than the other two layers but with low concentration of dominance.

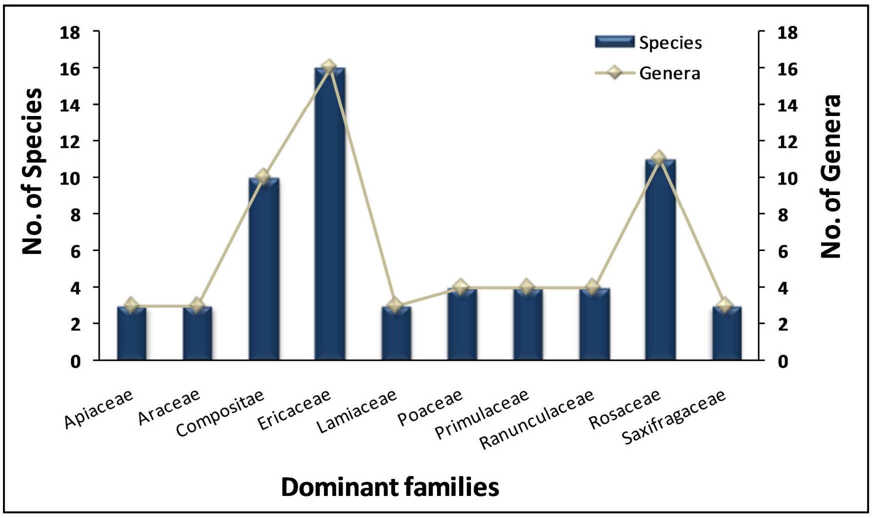

Fig. 6.9. Distribution of taxa under dominant family in sub-alpine zone

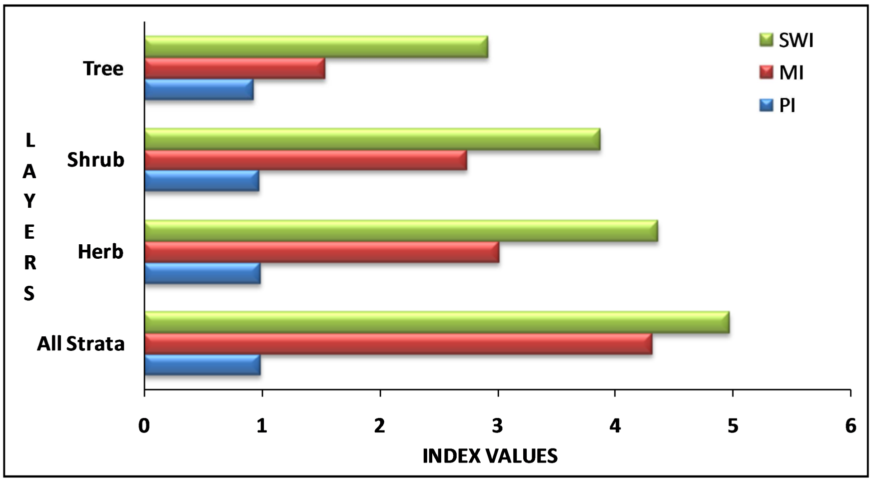

Fig. 6.10. Diversity indices in sub-alpine zone

Table 6.1. Vegetation parameters for tree phases in different vegetation types

Vegetation types (Altitude range)	Phases of trees	Density ind/ha	Basal Area (m^2/ha)	Shannon index (*H'*)	Menhinick index (*D*)	Simpson index (*CD*)	Pielou index (*J*)
Tropical	Mature	2436.62	343.22	4.195	2.756	0.017	0.975
(0 – 500)	Saplings	1286.51	8.62	2.704	0.667	0.07	0.902
Sub-tropical	Mature	2078.07	295.63	3.978	2.162	0.020	0.967
(500 – 1200)	Saplings	437.88	3.79	2.679	0.930	0.085	0.894
Sub-temperate	Mature	1630.65	194.84	3.887	2.082	0.021	0.983
(1200 – 1850)	Saplings	552.95	2.28	2.749	1.065	0.068	0.970
Temperate	Mature	2896.83	300.64	4.398	2.923	0.013	0.975
(1850 – 3200)	Saplings	955.60	3.24	3.193	1.368	0.043	0.980
Sub-alpine	Mature	890.50	85.47	2.922	1.530	0.068	0.932
(above 3200)	Saplings	364.13	0.69	2.276	1.166	0.113	0.942

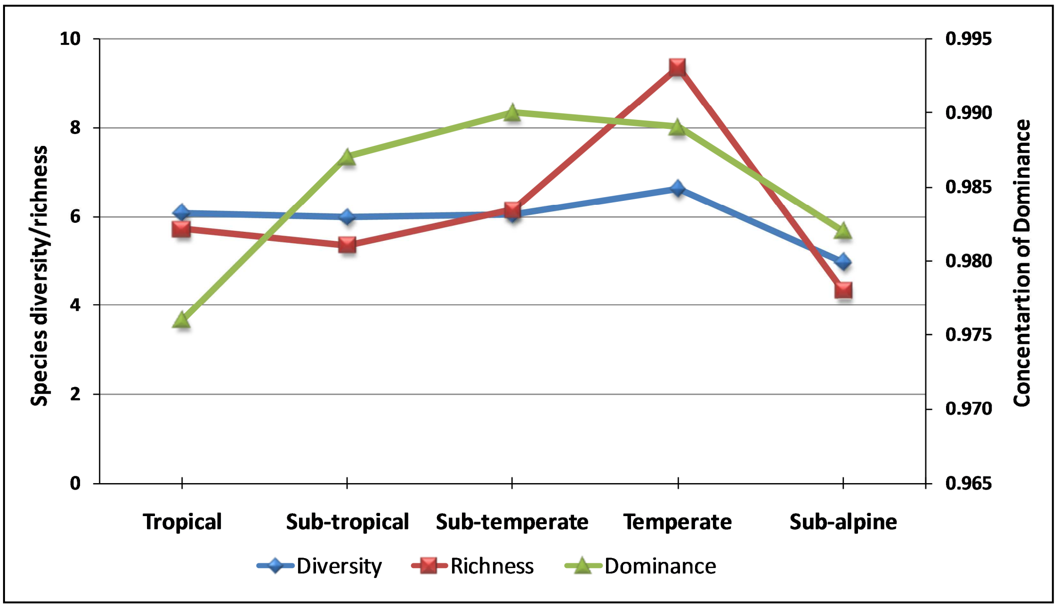

Fig. 6.11. Diversity index values along the altitude

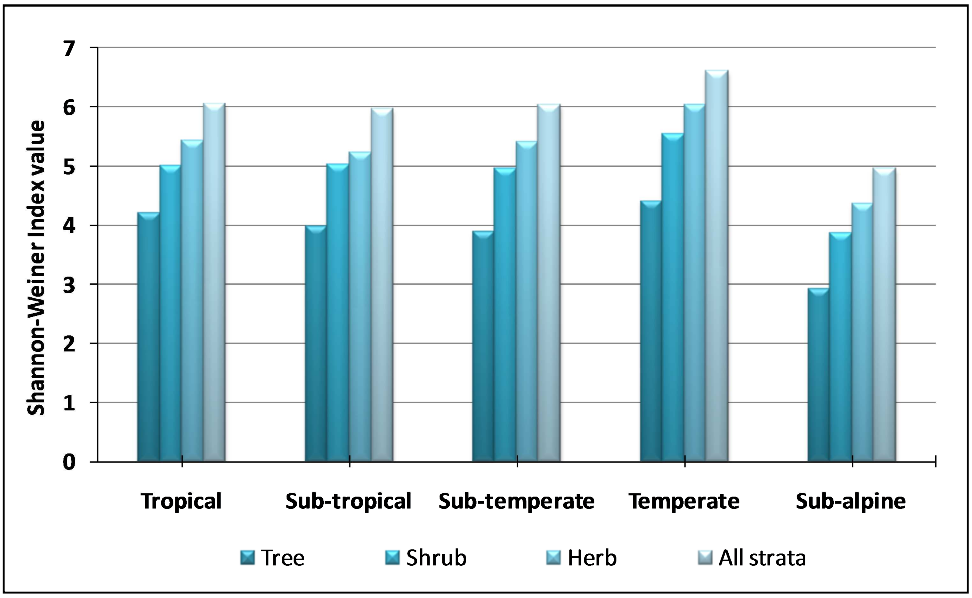

Fig. 6.12. Shannon-Weiner Index of species diversity in different vegetation types

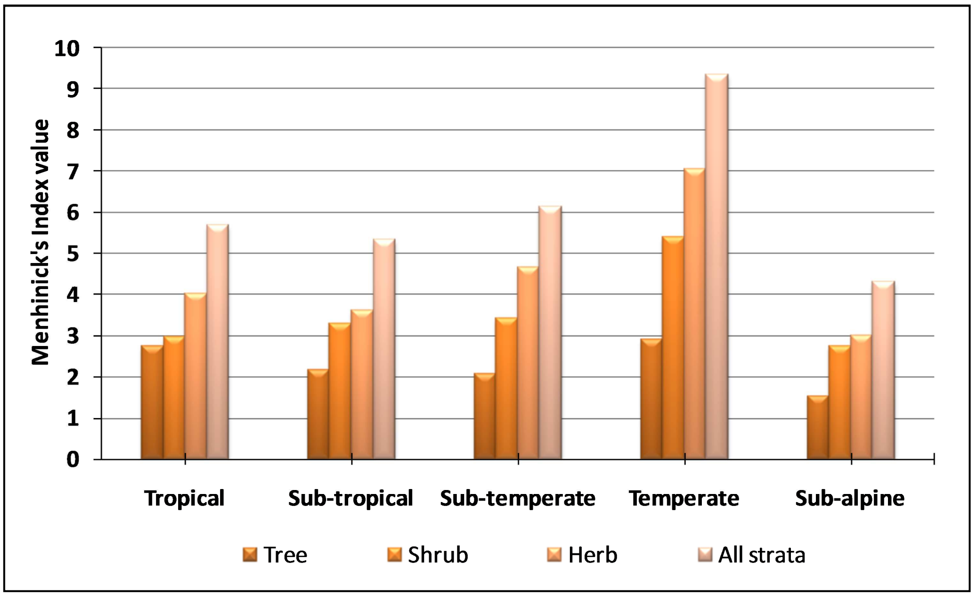

Fig. 6.13. Menhinick's Index of species richness in different vegetation types

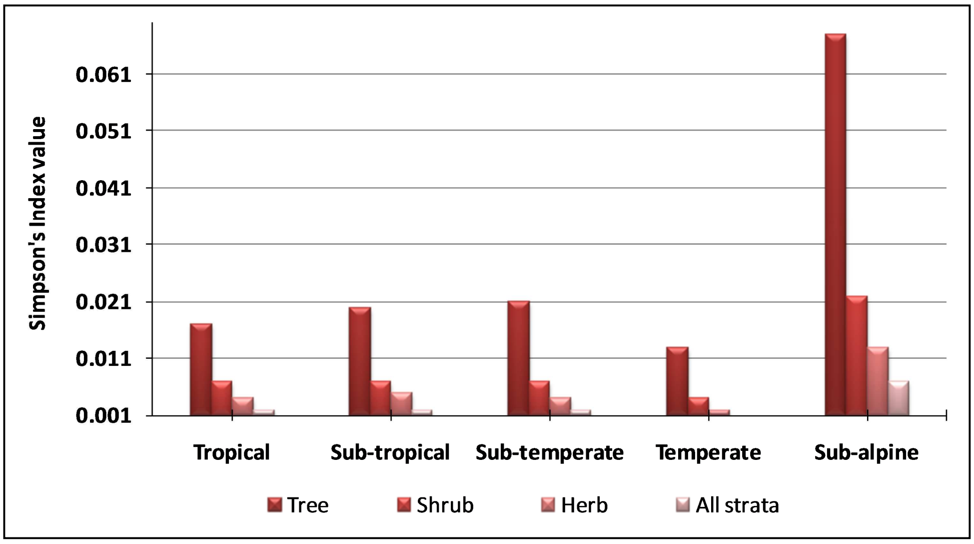

Fig. 6.14. Simpson's Index of concentration of dominance in different vegetation types

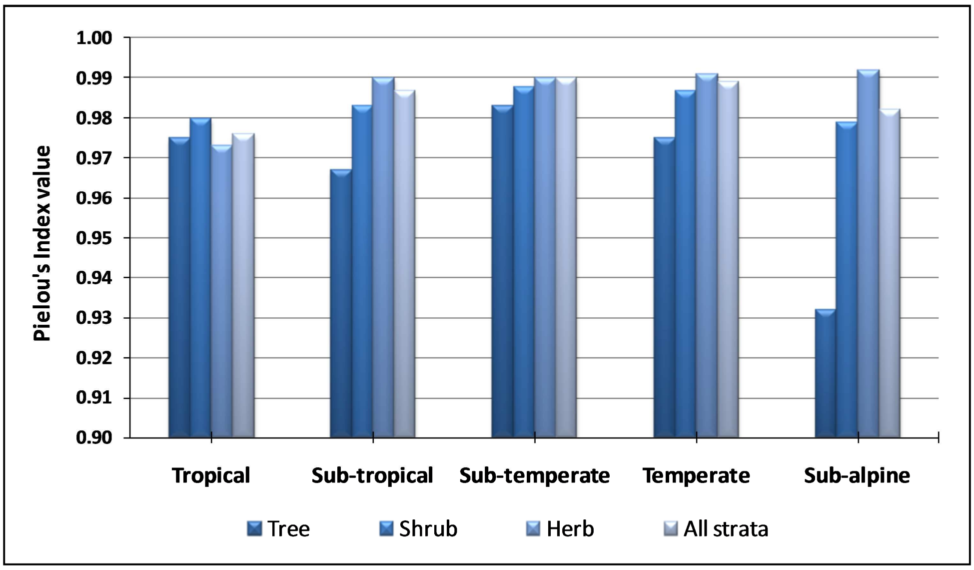

Fig. 6.15. Pielou's Index of species evenness in different vegetation types

6.2. GIRTH CLASS DISTRIBUTION

The girth class measurement of an individual in a forest is an important parameter to understand the interaction of the vegetation with the ecosystem components which in turn determines the health of the forest. Individual with wider basal area depicts the nature of mature forest while small basal area with large number of individual reflects the regenerating vegetation. Girth class provides the necessary regeneration potential in the forest and thereby ecosystem stability (Maiwada, 2014). In the present study, the measured girth class of the tree individual at different vegetation types has been classified into five girth class as (i) 15 – 30 cm (ii) 30 – 45 cm (iii) 45 – 60 cm (iv) 60 – 75 cm and (v) >75 cm.

The distribution of the girth class at different zones has been provided in Figure 6.16. A total number of 3336 individuals have been recorded during the quadrat sampling from all the five vegetational zones. The number of individuals of trees species ranged from 27 to 263. Highest number of 193 stands under girth class <30 cm has been observed from the temperate zone that accounted for 27.14 % in this class. This was followed by 190 individuals from tropical zone making distribution percentage for this girth class at 26.12 %. This reflects the developing nature of the forest both at lower and upper hill.

It has been observed that the maximum number of 945 stands fell under the girth class above 75 cm accounting for 30 % of the individual distribution, followed by 711 individual with girth class between 15 – 30 cm that constituted for 26 % of the total canopy stands (Fig. 6.17). The lowest number of 412 individuals was observed between the girth classes of 60 – 75 cm constituting about 10 % of the total. This may also predict the poor health of the forest.

Towards the higher zone, the temperate vegetation constituted maximum number of 969 individuals that accounted for 29 % of the total number of tree stands from the study. This was followed by sub-tropical zone with 796 stands occupying 23 % and 721 individuals at tropical region that accounted for 21 %.

However, the short stretch of the sub-alpine zone contained 226 individuals occupying 6.7 % of the total stand count but the major portion of the individuals was above 75 cm of girth that reflect the healthiness of the vegetation. The low number of stem counts at lower girth class tallies with the data as recorded by Rai (2006). Many of the individuals had measured girth class above 100 cm, particularly in the tropical *Tectona* forests, sub-temperate to temperate *Cryptomeria* vegetation and high altitude conifer vegetation.

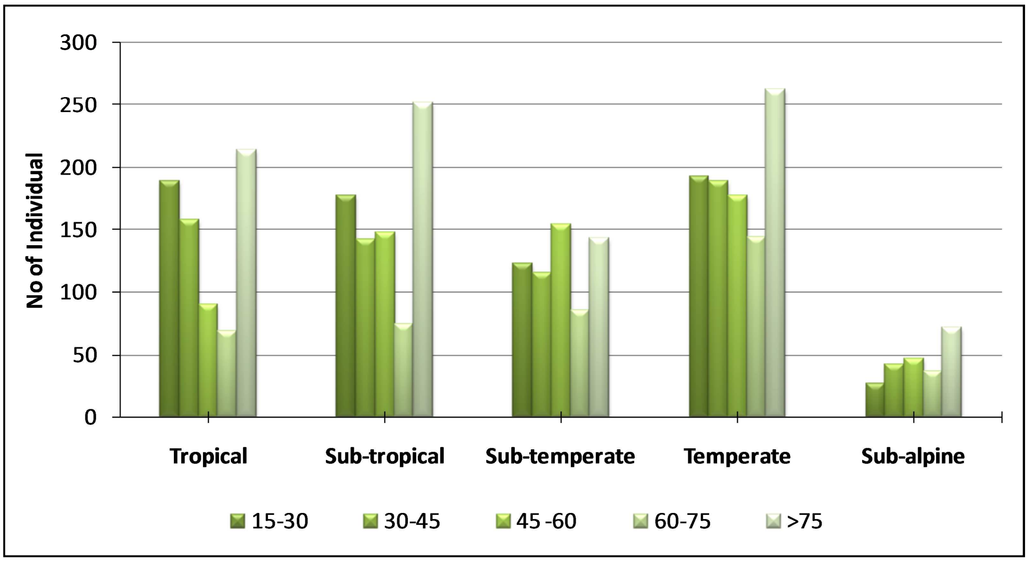

Fig. 6.16. Number of individuals in different girth class

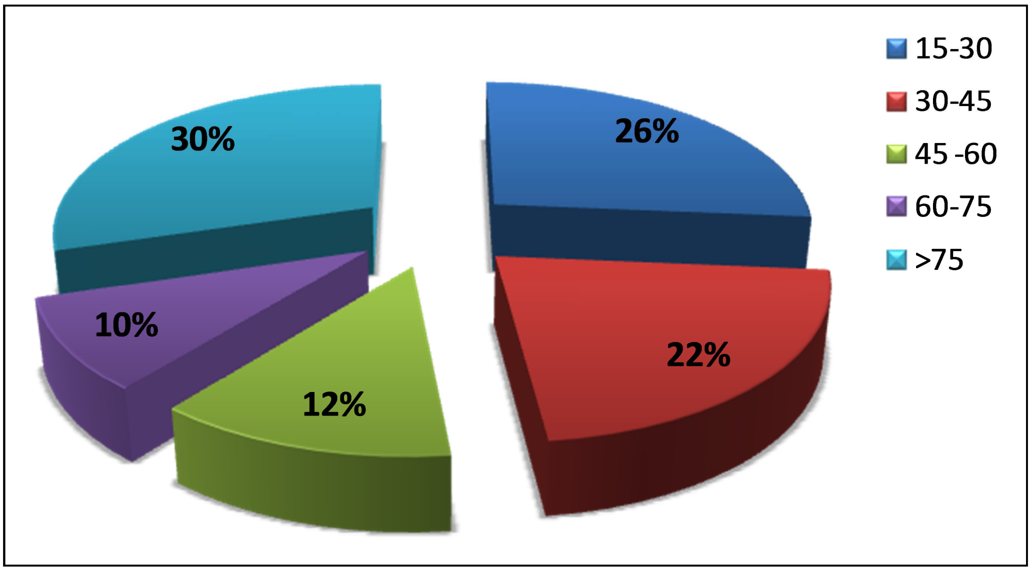

Fig. 6.17. Percentage of individuals in different girth class

6.3. SIMILARITY INDEX

The Sorenson's similarity index was estimated to understand the phytosociological affinities and similarities within each layer of the vegetation at different zones. Analysis showed that in the tree layer, about 45 % similarity was observed between the species distributed at sub-tropical and sub-temperate zone. The tropical and the sub-tropical zone also expressed about 20% similarities in the distribution of trees. However, about 19 % and 15 % similarities was observed between temperate zone with that of the sub-temperate and the sub-alpine zone respectively (Table 6.2).

Very few species were also found to be migrated sparsely from tropical to sub-temperate and also from sub-tropical to temperate. In the shrub layer, the similarity of 25 % was observed between tropical and the sub-tropical zone and around 23 % between the temperate and sub-temperate. Also, some of the shrub species observed in the temperate zone were scattered sparsely in the sub-alpine altitude thereby expressing percentage similarity of around 14 %. A certain percentage of species observed in the sub-tropical zone were also seen to be dispersed along sub-temperate to temperate vegetation (Table 6.3).

The vegetation in the herb layer also expressed 20 % and 11 % distribution similarity between tropical with that of sub-tropical and sub-temperate. The similarity percentage between sub-tropical and sub-temperate was also observed to be around 12 %. The herb layer in the temperate vegetation expressed similarity index of 18 % and 13 % with the vegetation of sub-temperate and sub-alpine altitude. A very few species that were observed in the tropical and sub-tropical zone also seem to be showing low similarity index with that of the temperate zone (Table 6.4).

Thus, the migration of the species from the tropical through sub-temperate to temperate zone has been observed in the study and the speciation of many of the species has been occurring especially in the herb layer. However, an enormous difference in the altitude, slope, aspect, edaphic factors, climatic conditions and also the anthropogenic stress between the lower hill forest and the higher region has brought about considerable differences in the diversity and composition of the species at different zones that can be understood from low percentage of similarity between different vegetation zones.

Table 6.2. Similarity index of tree layer in different vegetation zones

Vegetation Zones	Tropical	Sub-tropical	Sub-temperate	Temperate	Sub-alpine
Tropical	1.000				
Sub-tropical	0.220	1.000			
Sub-temperate	0.070	0.460	1.000		
Temperate	0.006	0.052	0.195	1.000	
Sub-alpine	0.000	0.000	0.020	0.150	1.000

Table 6.3. Similarity index of shrub layer in different vegetation zones

Vegetation Zones	Tropical	Sub-tropical	Sub-temperate	Temperate	Sub-alpine
Tropical	1.000				
Sub-tropical	0.250	1.000			
Sub-temperate	0.060	0.080	1.000		
Temperate	0.029	0.030	0.230	1.000	
Sub-alpine	0.000	0.000	0.009	0.140	1.000

Table 6.4. Similarity index of herb layer in different vegetation zones

Vegetation Zones	Tropical	Sub-tropical	Sub-temperate	Temperate	Sub-alpine
Tropical	1.000				
Sub-tropical	0.200	1.000			
Sub-temperate	0.110	0.120	1.000		
Temperate	0.030	0.070	0.184	1.000	
Sub-alpine	0.000	0.000	0.004	0.130	1.000

6.4. SPATIAL DISTRIBUTION PATTERN

The connection between the biotic and abiotic components of an ecosystem can be understood by the factors controlling the spatial distribution pattern of the species (Hubbell, *et al.,* 1999). Spatial distribution pattern and species richness are being analysed to understand and identify hotspots (Parviainen, *et al.,* 2009). Dispersal of the species is an important parameter for analyzing the different ecological attributes that play role in its nature of distribution.

The A/F ratio estimates from different vegetation types can be assessed to understand the spatial pattern of distribution in different layers in the habitat. Analysis of the distribution behavior indicates contiguous nature of distribution of species in the tropical zone with certain percentage of species showing random distribution and low number of species has been observed to be regular. It does not fit with the view that the regular pattern of dispersion in tropical forest maintains high diversity (Connell, 1978). 51 % of trees and 52 % of shrubs were randomly distributed in this zone. However, herb layer at all the seasons was contiguous and was in good association with the shrubs and canopy. The combined total number of species dispersed during three seasons at various altitudinal zones have been presented in the Table 6.5.

The sub-tropical zone also expressed contiguous nature in all the layers with around 23 % of species distributed randomly during the pre-monsoon. Sub-temperate zone reflected about 42 % of the woody species randomly distributed while the shrubs and the herb layer were contiguous. The temperate vegetation exhibited only about 1 % of random dispersal and the rest as contiguous. However, in the sub-alpine vegetation, 4 % of the tree layer expressed regular, distribution and about 75 % of the species exhibited random nature of distribution while about 30 % of the species showed contiguous dispersal. Similar pattern was observed by Sharma *et al.,* (2009) at high altitude forest of Garhwal Himalaya. The other strata were contiguously distributed at this altitude.

Species like *Schima wallichii* was regularly distributed at lower altitude while it was observed to be random as the altitude increased. Similarly, tree like *Lithocarpus pachyphyllus* with wide ecological amplitude expressed contiguous nature at medium altitude while it was randomly distributed with other dominant species towards higher zone. Species such as *Rhododendron arboreum* and *Lyonia ovalifolia* was seen to be dispersed contiguously at temperate zones with rich diversity but towards the sub-alpine belt the species was found to be random in association with the conifers. The change in the nature of distribution highlights the species interaction with the changing environment and the habitat (Sagar, *et al.*, 2003). Some species of *Quercus* was observed to be showing random pattern at low altitude which however changed to contiguous as the altitude increased. As per Odum (1971), regular distribution exists whenever there is competition between the individuals, random distribution occurs in uniform environments whereas contiguous distribution is common in nature. The contiguous aggregation of the species in a habitat may be due to lack of sufficient seed dispersal and it has been observed that the spatial distribution in the present study also reflects such a scenario (Fig. 6.18).

Table 6.5. Distribution percentage in different vegetation zones

Vegetation zones	Nature of Distribution		
	Regular (%)	Random (%)	Contiguous (%)
Tropical	4	20	76
Sub-tropical	–	7	93
Sub-temperate	–	5	95
Temperate	–	0.5	94.5
Sub-alpine	1	9	90

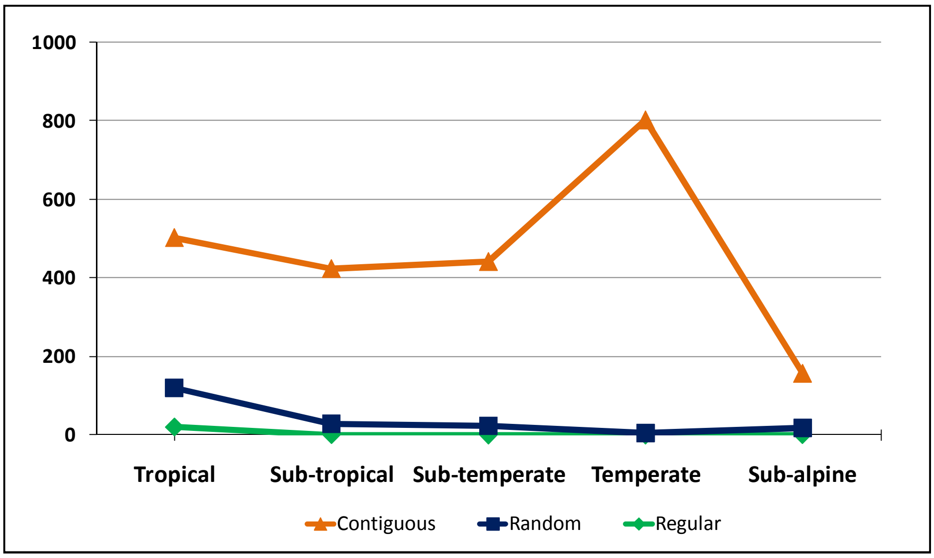

Fig. 6.18. Spatial distribution pattern in different vegetation types

6.5. ANALYISIS OF THE FLORA

The Darjiling hill is an integral part of the Eastern Himalaya that lies in the form of a spur in the vast stretch of the Himalaya hotspot. This region harbors rich floristic elements and has been able to attract large number of tourist, naturalist, conservationist, botanist from all corners of the world since time immemorial.

The present study from different zones of Darjiling hills has revealed quite a healthy flora with good association between the species at various altitudinal levels. From tropical through temperate to sub-alpine the distribution of the flora is fairly good with migration and amalgamation of many species at different zones. The hill represents all the habit groups of plants from herbs, shrubs, under shrubs, trees, climbers, epiphytes and pteridophytes due to varied topography, edaphic factors and environmental conditions that enriched the vegetation and diversifies it like the other floristically rich regions of the Eastern Himalaya.

The present phytosociological investigation of the hilly area of Darjiling hill revealed a rich flora with a total number of 911 species and varieties, 509 genera and 145 families. Out of this, 7 species of gymnosperms under 7 genera belonging to 2 families and 66 species of pteridophytes belonging to 41 genera under 20 families have been accounted. The total number of angiosperms recorded was 838 species under 461 genera and 123 families out of which the dicotyledons represented 690 species under 380 genera and 103 families while the monocots were 148 species belonging to 81 genera under 20 families (Table 6.6).

The dicotyledons seem to be over dominating the vegetation inside the forest with monocot to dicot ratio for the flora of about 1:4.5. The diversity, distribution and dominance of the floral elements at different ecotones have been observed. The dense forest at different altitude harbors rich vegetation with large number of trees, shrubs and the ground covers. However, forest at some locations seems to be poor in the ground cover flora.

It is observed that *Compositae* seems to be the largest family with 43 species and 32 genera (Fig 6.19). Other dominant families accounted during the study include *Poaceae* (36 spp, 22 genera), *Lamiaceae* (35 spp, 23 genera), *Urticaceae* (30 spp, 11 genera), *Rosaceae* (27 spp, 11 genera), *Leguminosae* (25 spp, 17 genera), *Acanthaceae* (23 spp, 12 genera), *Ericaceae* (23 species, 7 genera), *Rubiaceae* (22 spp, 14 genera) etc. Amongst the monocot group the largest family was *Poaceae* (36 spp, 22 genera), *Cyperaceae* (19 spp, 5 genera), *Orchidaceae* (16 spp, 13 genera), *Araceae* (15 spp, 5 genera), *Commelinaceae* (14 spp, 8 genera) etc.

The Pteridophytic species mostly dominated by the family *Polyodiaceae* (15 spp, 10 genera) and *Pteridaceae* (9 spp, 4 genera). The dominant family *Compositae* includes mostly undershrubs and the herb species whereas families like *Fagaceae, Combretaceae* and *Lauraceae* includes tree species with large girth size. Towards the lower altitude the dominating families were *Poaceae, Leguminosae, Compositae*, *Malvaceae, Acanthaceae* and *Vitaceae* whereas towards the higher zone, the species were mostly represented by the dominant families like *Rosaceae, Ericaceae, Ranunculaceae* and *Primulaceae.* However, the major families that were observed at middle vegetation zones were *Acanthaceae*, *Compositae, Leguminosae, Urticaceae*, *Lamiaceae*, *Commelinaceae*, *Gesneriaceae* and *Lauraceae.* Species under the family *Compositae* was found to be distributed at all vegetation zones.

Many species have been found to be of economically important as food, ornamental and ethno-medicinal use by the inhabitants at some places residing close to the forests area at different altitudinal zones. Similarly, many tree species were found to be of great timber yielding, some of which include *Magnolia doltsopa, Toona ciliata, Terminalia alata, Terminalia myriocarpa, Tectona grandis, Shorea robusta*, *Alnus nepalensis* etc. The vegetation at different altitudinal zones of Darjiling hill harbors a healthy number of plants from all groups with many species as endemic, whereas many were assessed as rare, threatened or endangered. On the other hand a number of exotic flora were also observed during the course of study with species migrated, adapted and naturalized from countries like North America, South America, Central America, China, Japan, Mexico, Central Asia, Europe, West Indies and also the African continent. Major taxa from the flora of Darjiling hill region were found to be of Himalayan origin with many of the species having South-East Asian and Sino-Himalayan origin.

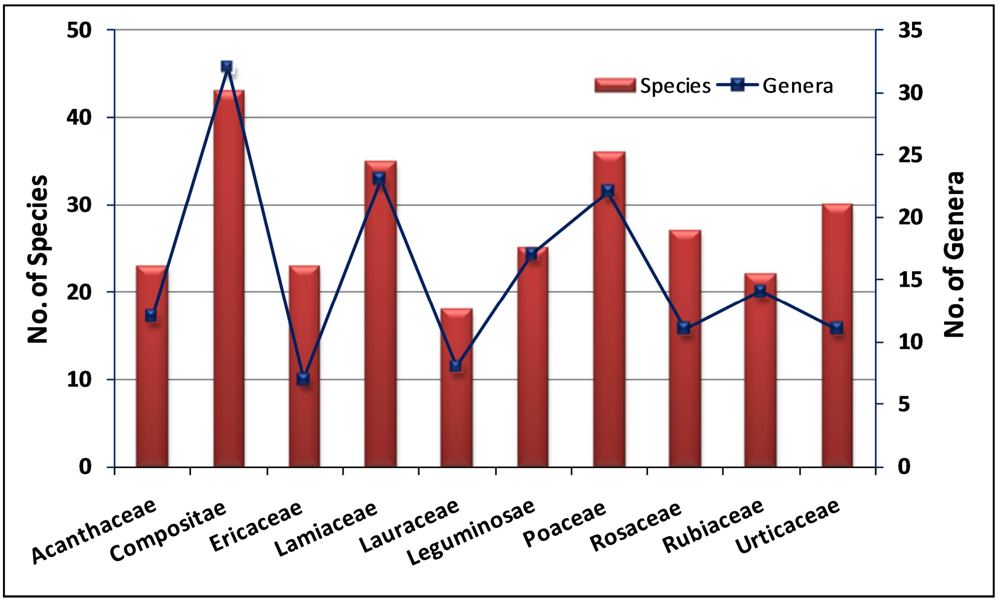

Fig. 6.19. Dominant families with highest species number

6.6. NUMERICAL DISTRIBUTION OF THE TAXA

The present phytosociological study from the Darjiling part of the Eastern Himalaya accounted for 123 families of angiosperms out of which 103 families are dicotyledons while the remaining 20 families are monocotyledons. 690 species under 380 genera were recorded from 103 dicot families and 148 species belonging to 81 genera were recorded under 20 monocot families. The gymnosperms accounted for 7 species under 7 genera and 2 families whereas a total of 66 species under 41 genera belonging to 20 families were recorded for the fern species (Table 6.6).

Table 6.6. Numerical distribution of taxa from Darjiling hills

Taxa	*Species*	*Genera*	*Families*
Dicotyledons	690	380	103
Monocotyledons	148	81	20
Gymnosperms	7	7	2
Pteridophytes	66	41	20
Total	**911**	**509**	**145**

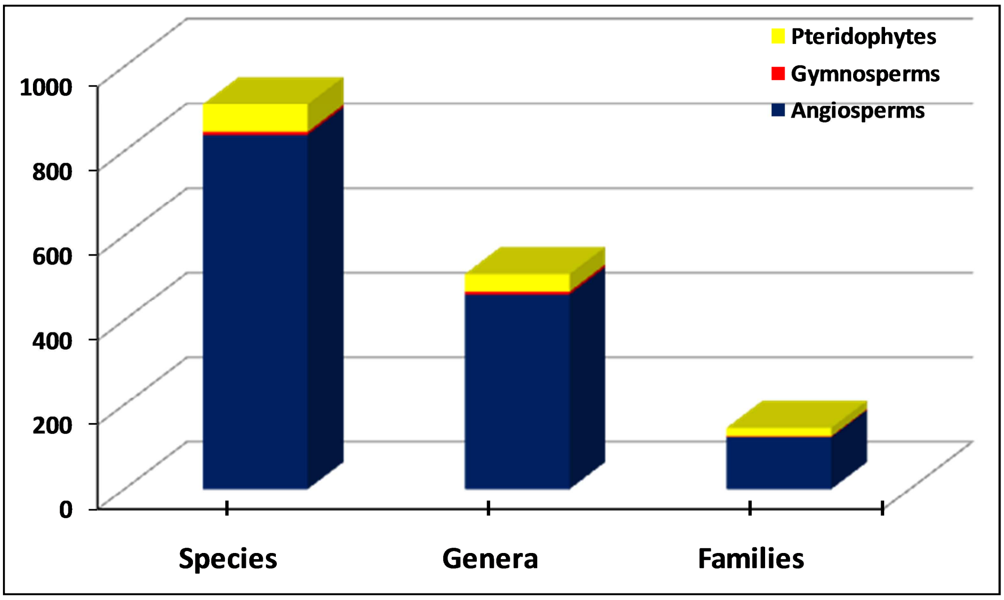

Fig. 6.20. Number of taxa distributed in Darjiling hills

6.7. HABIT GROUPS

The vegetation analysis of the Darjiling hills exhibited a great diversity of plants from different habit types. The diversity, richness and the composition of the forest at various altitudinal levels have been conserved quite naturally and the habitat for different life form appears to be healthy, except at certain places where the disturbances by anthropogenic activities are high and have made the forest fragmented. The species richness and evenness at different vegetational zones have also been figured out to be in good condition.

The maximum habit type was observed for herb/ground covers with 48 % of the total number of species accounted. The shrub/climber represented 29 % of the habit types while 23 % of life form was occupied by the tree layer combining all the strata. The herbaceous species is almost equal to the combined total of shrubs and trees. Orchids, epiphytes and ferns are also included under the ground covers. The diversity of the herbaceous flora is rich in the tropical, sub-temperate to temperate zone while the shrubs/climbers were observed to be rich in sub-tropical and temperate regions. However, trees expressed good number of species at tropical and temperate zone and also towards the sub-alpine habitat.

Many species of shrubs like *Hedyotis scandens, Tetrastigma serrulatum* exhibit wide ecological amplitude while some species like *Rubus buergeri*, *Hypericum sp.*, *Dichroa febrifuga* have been found to be dominant towards the middle zone but towards the upper stretch of altitude, the diversity decreased. The climbers that were included in the shrub layer were also diverse with different categories such as epiphytic climbers, twinner, herbaceous climber, lianas etc. The abundance and density of the shrubs/climber were fairly good at all vegetational zones. Many of the common climbers include species of *Stephania*, *Clematis*, *Tripterospermum*, *Tetrastigma*, *Holbeollia* etc.

Coming to the tree layer, the species varies from *Shorea robusta* in lower hill forest to Fagacean species in the middle zone and *Abies densa* at higher altitudes. Many of the species like *Schima wallichii*, *Actinodaphne sikkimensis* were found to be dispersed (though with low frequency) till the sub-temperate zones. The tree species have formed the climax vegetation right from the tropical zone upto high altitude sub-alpine forest. It has been observed clearly, as the altitudinal range change, the diversity and composition of the tree species also changed and thereby the vegetation.

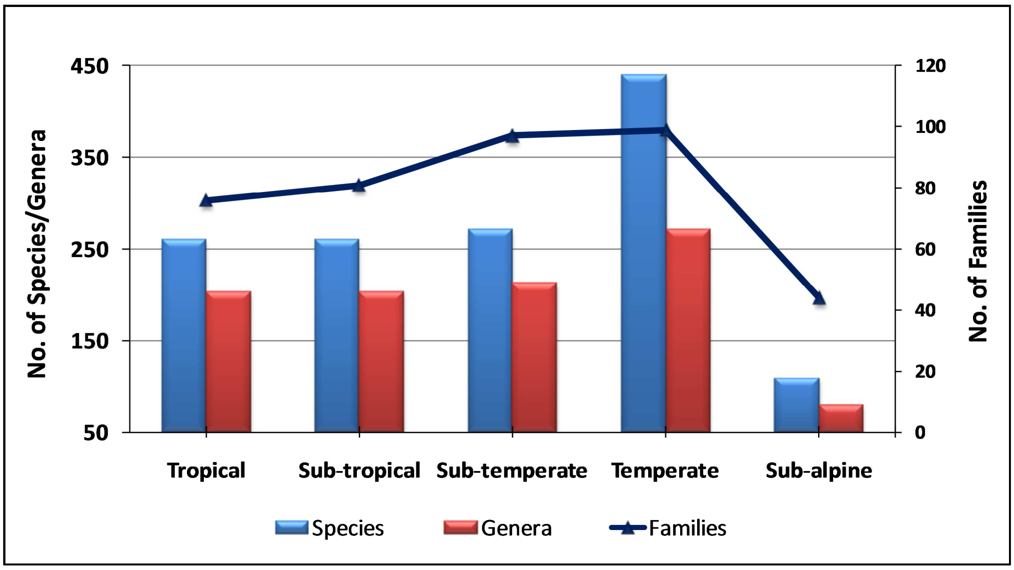

Fig. 6.21. Distribution of taxa in different vegetation types

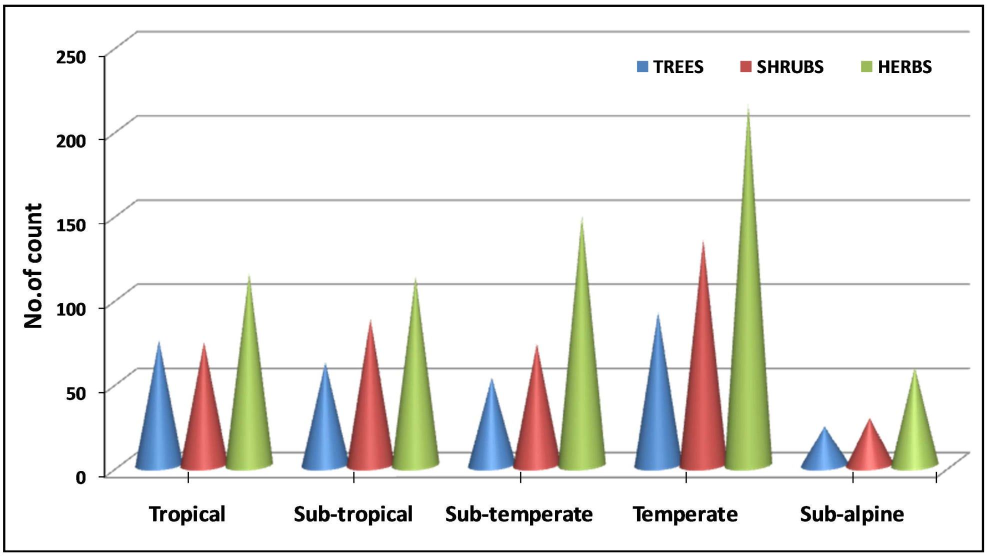

Fig. 6.22. Distribution of habit group in different vegetation types

6.8. ENDEMISM AND RET FLORAL ELEMENTS

In the Eastern Himalaya, the process of speciation has been long occurring and it is still continuing. It is evident from the frequent record of new species from this zone. The extent of distribution of endemic floral elements in Darjiling part of the Himalaya indicates high percentage of endemism. The originality of the flora is reflected in the percentage of endemicity to a region (Rai, 2006). The flora of the Darjiling hills possesses 479 species that constitute about 21 % of the flora as endemic (Bhujel & Das, 2002; Das, 1995, 2004). In the present study a certain number of species were found to be endemic and these species were distributed particularly towards the upper hill zones. The lower vegetational zones were not rich in the distribution of endemic species. However, some species that were distributed at middle hills were also recorded to be indigenous.

Species that were found to be endemic to Darjiling hills region were *Thunbergia lutea, Acer hookeri, Carpinus viminea, Daphniphyllum himalense, Rhododendron griffithianum, Aristolochia nakaoi, Clematis napaulensis, Daphne bholua, Leycesteria stipulata, Schisandra grandiflora, Streptolirion volubile* and *Polygonatum verticillatum.* Some species that are endemic to the western part of Eastern Himalaya have also been observed in the present study, some of which include *Carex crassipes, Symplocos dryophila, Rubia charifolia, Heracleum wallichii, Didymocarpus albicalyx* and *Porana grandiflora.*

The species endemic to Eastern Himalaya are also found to be dispersed at various altitudinal zone of Darjiling hills, the recorded ones are *Begonia gemmipara, Acer hookeri, Boehmeria glomerulifera, Maesa macrophylla, Mahonia napaulensis, Agapetes hookeri, Ajuga macrosperma, Callicarpa vestita, Clematis acuminata, Enkianthus deflexus, Brassaiopsis mitis, Neanotis gracilis, Ophiorrhiza succirubra, Persea gamblei, Pouzolzia sanguinea*, *Primula denticulata, Daphne bholua* var. *glacialis*, *Rhododendron barbatum, Rhododendron dalhousiae, Rhododendron falconeri, Eriobotrya dubia, Fragaria daltoniana, Gynocardia odorata, Rubus paniculatus, Rubus splendidissimis, Sorbus foliolosa, Thunbergia lutea, Celastrus paniculatus, Ceropegia longifolia, Holboellia angustifolia, Polygonum microcephalum, Vaccinium retusum, Wenlandia wallichii* and *Zanthoxylum oxyphyllum.* Some of the endemic monocots include *Carex decora, Arisaema griffithii*, *Peliosanthes griffithii*, *Yushania maling, Amorphophallus nepalensis, Dioscorea prazeri*, *Globba clarkei* and *Hedychium ellipticum.*

Many of the plant species that were earlier collected or recorded by many workers have been found to be missing. The changes or absence of boundaries between neighboring state or country in the past makes it hard to determine the habitat for such species. Therefore, many species have become extinct or their availability is very rare. Some of the RET species that were recorded from the present study include *Acer hookeri, Acer sikkimense, Acer oblongum, Aristolochia nakaoi, Anemone rupicola, Codonopsis affinis, Schisandra grandiflora, Berberis aristata, Berberis asiatica, Holboellia latifolia, Smilax elegans, Vaccinium vacciniaceum*, *Bistorta emodi, Euonymus frigidus, Euonymus tingens, Fritillaria cirrhosa, Helwingia himalaica, Lobelia montana, Mahonia napaulensis, Maianthemum oleraceum, Paris polyphylla, Polygonatum verticillatum, Primula ianthina, Saxifraga parnassifolia, Saxifra gageana, Valeriana jatamansi* and *Trollius pumilus.*

The endemic or RET species are confined to a limited area for survival, and many of such species have been found to grow in a specific habitat or restricted hill slope. They seem to be highly endangered and have high risk of extinction and therefore needs an effective conservation measures.

6.9. EXOTIC FLORAL ELEMENTS

The Himalayas have always been intruded by the exotic floral elements (Khuroo, *et al.,* 2012). These floral elements are also one of the important component of Eastern Himalaya and particularly the Darjiling part where the migration and acclimatization of the exotics have been occurring for the past many centuries. Many of these species have been introduced desirably for food and fiber, ornamental flowers, edible fruits and also for medicinal purposes. The migration of the exotic species from one sub-continent to the other is a continuous process and is catalyzed by various physiographical and environmental factors. The natural migration of many species in this region is affected through three lines, *viz.* migration of South East Asiatic plants from the low altitude hill ranges of North East India, entry of the European floristic elements through different parallel mountain systems and the migration of tropical and subtropical elements of Deccan and Peninsular India through the vast plains of central India (Rai, 2001). Other factors contributing are the transfer of human settlements, introduction of food grains carried by the migrating people, edible and ornamental species etc.

These exotic floral elements may be categorized as migrated or introduced intentionally or unintentionally which thereby forms an integral part of the vegetation of this zone. In Darjiling part of the Eastern Himalaya, the Britishers were the main reasons for introducing the exotics especially after the establishment of the tea gardens at various locations of the hill. Many notes on the distribution of exotics of the Eastern Himalaya have been made by earlier workers like Biswas (1940), Hara (1966-1971), Ohashi (1975), Mathew (1981), Bhujel & Das (2002). Biswas (1940) stated that over 40 % of species in and around Darjiling are exotics. Das (2002), have recorded 114 exotic species from Darjiling hills that were either naturalized or semi-naturalized out of which 86 % were dicotyledonous while 14 % were monocotyledonous.

Darjiling, due to its varied topography and climatic variation have been an excellent house for the acclimatization of exotics. The present study noted many species that are of American origin, followed by Asian, European and African. Some examples of these elements that have its origin in the American sub-continent includes *Adenostemma lavenia, Ageratum conyzoides, Ageratum houstonianum, Ageratina adenophora, Bidens pilosa, Brugmansia suaveolens,* *Calceolaria tripartita, Crassocephalum crepidioides, Drymaria villosa, Galinsoga parviflora, Hyptis suaveolens, Lantana camara, Mikania micrantha, Mimosa pudica, Nicandra physalodes, Oxalis corymbosa, Physalis peruviana, Rubus ellipticus, Senna tora, Solanum torvum, Tithonia diversifolia, Triumfetta rhomboidea, Urena lobata, Youngia japonica, Zephyranthes carinata.* The species from the Asian sub-continent are *Anaphalis contorta, Cissus javana, Clerodendrum japonicum, Elephantopus scaber, Fagopyrum acutatum, Persicaria chinensis, Stephania japonica, Cryptomeria japonica, Synedrella nodiflora, Tiarella polyphylla*. The European exotics include *Fragaria nubicola, Oxalis corniculata, Sonchus asper, Stellaria media, Trifolium repens* while *Emelia sonchifolia* and *Hypoestes phyllostachya* was noted to be an African species.

The distribution and naturalization of these exotics were wide along the altitude of Darjiling hills and many species like *Fragaria nubicola, Mikania micrantha, Persicaria chinensis, Cryptomeria japonica, Oxalis corniculata* have established themselves as one of the dominating species in the vegetation. Species like *Ageratina adenophora, Persicaria chinensis, Ageratum conyzoides* and *Lantana camara* have been found to be dispersed at various altitudinal zones with wide ecological amplitude. The invasive growth of these species have tremendous negative role for the local resident flora thus hampering the microclimate at certain zones. The population of the exotic species in this region has been a threat at large to the local floristic environment that may cause loss of genetic diversity and species extinction.

6.10. THREATS TO THE FLORA

The vegetation of Darjiling, although maintains a healthy diversity and species richness, have always been threatened by many interferences. Towards the lower belt, major threats seem to be illegal trade in timber and excessive collection of NTFPs and forest floor humus. Although the *Shorea robusta* forest express a healthy dominance, the disturbances by the illegal traders of timber grows continuous as wood has always been an important material for construction of beautiful houses and furniture. Such is the case with *Tectona grandis,* species of *Terminalia, Gmelina arborea* etc. One of the reasons for such a trade is the increase in the unemployment among the youths that compels them to follow this risky shortcut route.

Towards the middle zone, the threat that has been observed are the rapid expansion of the surrounding villages near the vicinity of the forests. Inhabitants of these settlements will surely depend on the forests nearby. The woody species that are being used by the people for various purposes were *Schima wallichii,* species of *Magnolia* and *Quercus.* The felling of the trees and clearing of the forest for Tea plantation have also become a major cause for deforestation. Towards the higher zones, one of the major threats that have been occurring naturally is the rapid expansion of bamboo species *Yushania maling.* Even the forest department is worried by its growth which flourishes every year especially in the Senchal part of the hills.

Towards the higher temperate and sub-alpine zones, the problem on the deforestation arises when the people erects cattle sheds made up of species of *Rhododendrons* and bamboo culms. The inhabitants are also dependent on the locally grown vegetables and fruits as the mode of transportation in those areas are not easily accessible. Therefore, the expansion of the crop field is also making the forest patchy. Cattle grazing are also a major threat at higher altitudes as the forest floor of these regions is abundant in many species growing together. The high altitude shares its boundary with the other countries, and the setup of the defense unit and frequent transportation of military heavy vehicles has also become a matter of concern. Not only that, digging of bunkers and disposing plastic litters by the military personal is also a threat to the natural vegetation.

The area being a place of tourist interest is intruded by the seasonal visitors twice in a year during peak seasons, and the natural habitat of the forest gets disturbed not only for the plant species but also the faunal species like the endangered Red Panda. Due to its beautiful flowers the visitors cut twig of *Rhododendrons* and that also leads to the reduction in the growth of the species. Another threat to the ecology is the trash disposal by the trekkers along the route that is polluting different remote locations. The increasing human movement through the forest has caused an enormous amount of trodding and trampling which thereby causes soil erosion. Even the strong winds, high rainfall and active cattle grazing are also the main causes of soil erosion.

One of the threats that have been observed in the forest is the medicinal plant collectors. Recent rise in the belief of human being towards herbal medicines has posed a great threat to the medicinal herbs from this region as it harbors species with potential medicinal values. Also the orchid collectors who are engaged in the collection of orchids for sale to the local nursery are a cause of concern. Besides these, some of the major development projects like the Hydel power projects has been a major cause of threat to the flora.

Due to these activities at various levels, the vegetation of Darjiling is continuously under threat and thus natural streams and springs have dried up, frequency of landslides have increased in recent years, unusual fluctuation in rainfall behavior, increase in summer temperature and it can also be felt that a place which used to snow almost every winter haven't been snowing densely for the past half a decade.

6.11. PROPOSED METHOD OF CONSERVATION

After the Convention on Biological Diversity at Rio de Janeiro in 1992, major countries of the world has been working jointly towards the conservation of Biodiversity. The IUCN till date has demarcated 35 regions around the world as Biodiversity hotspot areas. Four among those lie on the Indian sub-continent and the Eastern Himalaya is one of the significant part of the Himalaya hotspot. However, these hotspots are under immense threats due to active anthropogenic influences globally. Government has taken some major steps to conserve the biodiversity by commissioning many areas of rich flora and fauna as Protected Areas (PAs) such as Wildlife Sanctuary, National Park and Biosphere Reserves, but these areas are only a negligible portion of the total land of the nation. The management and strategies for the maintenance of these protected areas should be strict for achieving goal towards proper conservation practices.

Although, there are five *in-situ* conserved areas in Darjiling, the fragmentation of the forest at various levels has been occurring continuously. Therefore, few proposals have been made, which if considered seriously by the policy makers and development planners would help to enrich the vegetation of this part of Eastern Himalaya and maintain a healthy ecosystem.

- Firstly, the administration should be strictly vigilant at the illegal cutting and commercial exploitation of forest timber. Clearing of many plant species and felling of trees for the construction of roads in different corners of the hills should be immediately reviewed and alternatives need to be explored.

- Human settlements in the vicinity and forest fringes should be strictly checked and the existing settlements may be shifted.
- All the visitors, researchers, trekkers should be prior counseled and the rules should be promptly exercised by all.
- The Ministry of Environment, Forest & Climate change has recently asked the visitors at Corbett's National park to take away the garbage with them instead of disposing in the forest. Similar rules should be applied in this part of the Himalaya also as the high altitude have frequent visitors.
- Population studies, distribution pattern, reproductive mechanisms, phenology, ecological community behavior and role in ecosystem and biodiversity of lower group of plants like Bryophytes, Mosses, Fungi etc. should also be checked and documented in detail for planning and formulating conservation strategies.
- Establishing more *ex-situ* conservation sites at different ecological zones for multiplication and reintroduction of RET species.
- Active cattle grazing in core forests should be banned.
- The plant collectors, hunters, poachers should be restricted with the strict enforcement of existing rules and regulations.
- Collections of wild edibles, orchids, medicinal plants, ornamental plants etc. from their natural habitat should be stopped.
- Some of the important medicinal species that needs proper conservation measures include *Swertia chirayita, Heracleum wallichii, Aconitum lethale, Valeriana hardwickii, Valeriana jatamansi, Rubia manjith, Clematis buchananiana* etc. These species should be studied at the micro habitat level.
- Detail study on the diversity and distribution of the invasive floral elements should be carried out and proper management strategies for controlling its effect should be formulated immediately.
- Eco-friendly procedures should be implemented for every tourism activity including trekking and explorations with strict guidelines.
- The degradation of the vegetation also narrows down the habitat for avi-fauna. Establishing vertical and parallel corridor within the protected areas would definitely connect the fragmented patches within the forest and also expand the habitat for the floral and faunal species and their migration.

- The invasive growth and expansion of *Yushania maling* should be separately analysed and studied by the expert at genetic and ecological level.
- Soils experts and geologists should build up an appropriate strategy to check natural soil erosion and landslides.
- The dominant species in its natural state are to be conserved and the less dominant species are to be introduced by the forest department during plantation programs.
- For plantations, use of exotic species need to be avoided and local tree species should accompany plants of lower tier also.
- It is also observed during the present study that although the forest looks dense form outside due to large canopy, the shrubs, under shrubs and herb layers are in a state of vulnerable condition. Many of the common species that were recorded by earlier workers have lost their population distribution and this brings about a great concern for Biodiversity conservation in this part of the Eastern Himalaya.

CONCLUSION

The present dissertation work characterizes the phytosociological attributes of the vegetation in different zones along the altitudinal gradient in Darjiling part of Eastern Himalaya. Due to its varied topographic, geographic, physiographic, edaphic and climatic factors, the different vegetation zones along the altitude reflect a great diversity and species composition during different seasons.

The species distribution pattern in Darjiling hills indicates a rich phytodiversity with heterogeneity of species with little change in altitude and habitat. This can be understood from the number of species recorded during the work that reveals a rich flora with a total number of 911 species and varieties belonging to 509 genera under 145 families. These species count are from inside the forest and does not incorporate species from fringe areas or road sides.

The phytosociological status and community analysis of the vegetation during different seasons in different ecological zones reflected a healthy distribution of species along the altitude with diversity as high as 5.236 during post-monsoon and as low as 2.908 during pre-monsoon. Analyses of diversity indices indicate temperate forest to be more diverse with high richness and low dominance. It may be due to the transitional nature of the forest harboring species both from the higher and the middle zones. This is followed by tropical and sub-temperate forest with significantly high diversity and richness values. The other zones expressed moderate values though showing a reasonably good diversity. Similarly the total richness for the species at different zones ranged between 4.318 in the sub-alpine forest to 9.353 in the diverse temperate forest. As per Rahbek (1997), the species richness decreases with altitude.

The association and closeness of the species in various type of habitat was also reflected through the evenness that ranged from 0.976 to 0.990. The concentration of dominance of the species is inversely related to the diversity which is in accordance with Odum, (1971) and it also indicates increased stability of the vegetation (McNaughton, 1967). The maximum values of dominance were 0.007 towards sub-alpine zone and a minimum value of 0.001 for the temperate vegetation.

The pH of the soil at different zone ranged from 4.69 to 6.61 with lowest in the sub-tropical forest and maximum for the temperate. The organic carbon and nitrogen both was estimated highest for the tropical zone. However, it was observed that the sub-alpine soil had lowest value of nitrogen present and so was the content of phosphorus.

The dominating species recorded include *Shorea robusta* in lower hill forest to *Lithocarpus* in mid zones and *Abies densa* in the forest of highest zones. Similarly in the shrub layer, species like *Mikania* seems to be dominating lower zones while in the middle forests species such as *Stephania japonica, Rubus acuminatus* and *Rubus buergeri* and towards the higher belt *Cotoneaster microphyllus, Gaultheria nummularioides* and *Yushania maling* were populated. The ground covers that were dominant along the altitude include species such as *Oplismenus compositus, Lepidagathis incurva* and *Nephrolepis cordifolia* towards lower hill forest to *Isodon lophanthoides, Melissa axillaris* at middle zone to *Fragaria nubicola, Galium elegans* and *Primulas* at high alpine vegetation. In the lower hill forest the populations of trees were more than the higher hills but in the higher vegetation, the herb occupies major percentage of species.

The growth of the forest vegetation can also be understood from the regenerating tree saplings that expressed healthy density in some quadrats. The high percentage of low girth class revealed that the vegetation is in developing state while the maximum percentage of girth class above 75 cm depicted an established climax forest towards higher zones. The amalgamation of the species were also observed at various zones and the similarity index estimated between the vegetation was moderate with some species having wide ecological amplitude and distributed both at low and high forest habitats.

Many of the species were found to be endemic to the region whereas some species were categorized under RET. The distribution of the invasive elements was also speculated and it was also observed that some of the species have posed a serious threat to the native flora. The hills also house many plant species of medicinal values that were dispersed at various sites under study.

However, several categories of threats have been observed at certain level and a number of conservation measures have been proposed. Nevertheless, the favorable climatic condition that prevails in Darjiling Himalaya has always been a boon for the vegetation to develop and flourish making the habitat rich in this botanical paradise of the world. Although, several earlier workers have explored the Darjiling part of the Himalaya, the present dissertation is the first of its kind that highlights the plant sociology and community analysis and thereby characterizes the vegetation of Darjiling hills in different seasons at various altitudinal zones.