Dynamics and Characterization of Herbaceous Vegetation in Three Forest Communities in a Subtropical Dry Deciduous Forest in Jammu, Jammu and Kashmir

Neeraj Sharma

Institute of Mountain Environment, University of Jammu, Jammu

Abstract: ***The investigations on the herbaceous vegetation in terms of its composition and diversity were conducted in three different forest communities in a sub-tropical forest of Jammu Siwaliks. These included Northern dry mixed deciduous forests (5B/C2), Himalayan subtropical scrub (9/C1/DSI) and Himalayan subtropical Pine forest (9/C1a) in an altitudinal range of 300 m asl to 990 m asl. The community analysis was performed using stratified random sampling involving 0.01 % of the total area for each community. 750 quadrats of 1 m^2 each were laid for various phytosociological parameters and diversity indices to reveal the community structure, species richness, diversity and evenness for the terrestrial herbs in different forest types. A total of 266 species belonging to 201 genera and 64 families were recorded from the forest. The vegetation analysis revealed the dominance of Cynodon dactylon Pers (SIV = 12.75, 4.25%), Ageratum conyzoides L. (18.03, 6.01%) and Cynodon dactylon Pers. (23.07, 7.69%) as herbaceous elements in northern dry mixed deciduous forests, Himalayan subtropical scrub and Himalayan subtropical Pine forest respectively. The northern dry mixed deciduous forest occupying 27.3 % of the study area revealed maximum herb species richness and diversity as indicated by the higher values obtained for Shannon-Wienner's index, Margalef's index and Simpson's index of dominance.***

Keywords: Subtropical vegetation, community analysis, stratified random sampling, vegetation analysis, herbaceous elements

1. Introduction

The herbaceous layer significantly contributes to the diversity of forests. The forest understory is heterogeneous and dynamic habitat with bulk of species contributing to ecosystem functioning and sustenance. It is indeed a high stress environment where the vital resources that influence the growth of vegetation especially the sunlight, water and nutrients are the major limiting factors. Still few favourable factors influence the luxuriant growth of under storey which defines the structure and dynamics of future communities. Since understorey defines the future species composition and structure of the canopy, its thorough understanding is crucial to forest management. Despite a growing awareness that the herbaceous layer serves a special role in maintaining the structure and function of forests, this stratum remains an underappreciated aspect of forest ecosystems (Gilliam, 2006). The ecology of the herbaceous layer has been the focus of numerous studies (Gilliam & Roberts, 2003; Roberts, 2004; Whigham, 2004 and Gilliam *et al.*, 2006). Herbaceous layer in the forests determines the spatio-temporal distribution and dynamics of woody seedlings through regeneration (Maguire & Forman, 1983) and regulates the recruitment of woody plants directly and indirectly. It offers better protection to soil (Gilliam, 1988) and influences nutrient cycling and energy flow in the ground stratum (Scheller & Mlandenoff, 2002 and Das *et al.*, 2008). Grasses are beneficial in binding soil particles thus reducing soil erosion and water loss and finally maintaining the soil structure (Sagar *et al.*, 2008) besides providing shelter for microbial communities (Singh *et al.*, 2006).

There have been some important contributions on vegetation analysis, phytosociology and community structure in certain Himalayan forest types (Kunwar & Sharma, 2004; Gairola *et al.*, 2008; Kharakwal, 2009; Todoria *et al.*, 2010 and Tynsong & Tiwari, 2011). The forest diversity patterns and governing environmental as well as anthropogenic variables in the Himalayan sub-tropical region have been studied in the past by phyto-sociologists (Rao *et al.*, 1990; Sharma & Kumar, 1992; Varghese & Menon, 1998; Sharma, 2003; Ilorkar & Khatri, 2003; Jhangir, 2004; Kunwar & Sharma, 2004; Negi & Nautyial, 2005; Ahmed *et al.*, 2006; Naithani *et al.*, 2006; Raghubanshi & Tripathi, 2009; Krishnamurthy *et al.*, 2010; Tripathi *et al.*, 2010; Ekka and Behera, 2011; Joshi, 2012; Sahu *et al.*, 2012; Gairola and Soni, 2013; Sinha & Sinha, 2013; Shaheen *et al.*, 2011; Gupta & Kumar, 2014; Sharma & Kant, 2014 a & b and Shukla & Chakarvarty, 2014). Since understanding the composition, distribution, and diversity of herbaceous vegetation is basic to the know the dynamics of the forest ecosystem, the present study was conducted with the broader objective to provide the baseline information on composition, structure and diversity of herbaceous layer in different forest communities of a dry tropical forest in north western Himalayas.

2. Materials and Methods

2.1 Vegetation sampling and data analysis

A reconnaissance survey was undertaken to define vegetation type and community association and traverses along roads, drainage, hills and ridges were made and three forest types were identified on the basis of forest classification by Champion and Seth (1968). A total of seven hundred fifty sample points were laid separately for northern dry mixed deciduous (370), Himalayan sub-tropical scrub (280) and Himalayan sub-tropical pine forest (100) respectively for quantitative sampling. Stratified random sampling with a sample intensity of 0.01 per cent of the total area was adopted for covering the ground flora in all forest types. The analysis was carried out by laying the quadrats of 1 m^2 each and a single summary statistic or importance value was calculated by summing the relative values for species following Ganesh *et al*. (1996). The equation used is Species Importance Value (SIV%) = Relative Frequency + Relative Density + Relative Dominance.

2.2 Species richness and diversity

Total species richness was simply taken as a count of number of species present in the respective forest type. Species richness (number of species per unit area) was calculated as Margalef's Index (1958) using formula Da = S-1/ln (N) and Menhinik's index of richness (Whittaker, 1977) was calculated as Richness Db= S/√N, where, S = number of species and N = Total number of individuals (of all species in case of Menhinik's index). The diversity (H′) was determined by using Shannon-Weiner (1963) information index as H′= - ∑ni/n log2 ni/n; where ni was the SIV value of a species and n was the sum total SIV values of all species in that forest type. Simpson's diversity index (1949) was calculated as Ds = 1-Cd, Where Cd = Simpson's concentration of dominance = $(\sum ni/n)^2$. Indices used to calculate species evenness 'r' included Peilou's Index (1975) as E_1 = H′/ln (s) and Sheldon's Index (1969) E_2 = eH′/s, where H′ is Shannon-Wiener's Index and 's' is the number of species.

2.3 Study Area

The present study area extends northwards of Pathankote-Jammu national highway covering the southern areas of Kathua, Samba and Jammu districts respectively with an approximate geographical coverage of 3350 sq km with predominance of typical sub-tropical vegetation ranging from 300 m asl to 990 m asl (Fig.1) Beset with small dry hillocks, gorges and ravines, the major part of this zone is under forests and offers but limited facility to agriculture. The soils are shallow and infested with gravel and stones. The Jammu Siwaliks has a markedly periodic climate, characterized by dry and increasingly hot season from March to June, a warm humid monsoon season from July to September and a dry and cold weather from October to December. The normal annual rainfall of Jammu is 1113 mm, 72% of it is received during monsoon months with an average number of rainy days per year being 54. June is recorded as hottest month with average maximum of 47^0C while January being the coldest month (6.8^0C). The foggy winters and scorching summers bear a marked climatic perturbation

3. Results

3.1 Vegetation structure and composition

The forests of *Kandi* Siwaliks were divided into three types in accordance with the classification made in revised survey of forest types of India by Champion and Seth (1968).

3.1.1 Northern dry mixed deciduous forest (5B/C2)

Occupying an area of 804.46 km^2 accounting to 27.3% of total geographical area, this forest type is restricted to Jammu foothills of low to moderate elevations (Fig.1). The herbaceous layer is structurally and numerically most prominent during monsoon season. Most commonly found species include *Anagalis arvensis* L., *Fumaria indica* Pugsley, *Oxalis corniculata* L., *Stellaria media* Vill., *Gnaphalium purpureum* L., *Eclipta prostrata* L., *Youngia japonica* DC, *Salvia plebia* R. Br., *Malvastrum coromendellianum* Garcke, *Erigeron bonariensis* L., *Bidens biternata* Merr. and Sherff., *Achyranthes aspera* L., *Sonchus oleraceus* L., *Euphorbia hirta*, *Geranium rotundifolium* L., *Carex fedia* Nees., *Cynodon dactylon* Pers. etc.

Most of understorey is dominated by scattered or gregarious chunks of weed flora. The commonly found species include *Argemone mexicana* L., *Cassia occidentalis* L., *Solanum nigrum* L., *Xanthium strumarium* L., *Euphorbia heliscopia* L., *Datura innoxia* Mill., *Chenopodium murale* L., *Malva parviflora* L. etc. The most notorious among the herbaceous weeds in this forest are *Parthenium hysterophorus* and *Cannabis sativa* L.

3.1.2 Himalayan subtropical scrub (9/C1/DSI)

296.80 km^2, amounting to 10.1% of the total geographic area under study, recorded the dominance of scrubby vegetation. Restricted to dry hillocks and gentle slopes of low elevation, the fairly dense vegetation cover comprised an admixture of shrubs and rather small sized deciduous trees, mostly of thorny type. The perennial grasses are represented chiefly by *Apluda mutica* L., *Chrysopogon fulvur* Choiv., *Cymbopogon stracheyi* Raizada, *Heteropogon contortus* P. Beauv., *Dicanthium annulatum* Stapf. and *Saccharum benghalense* Retz., the latter occurring in tall dense clumps in riparian localities.

Among the herbaceous layer, *Ageratum conyzoides* L., *Barleria cristata* L, *Boerhavia diffusa* L., *Carthamus oxycantha* M, *Rumex hastatus* D. Don. *Sonchus oleraceus* L., *Swertia angustifolia* Buch.-Ham., *Tribulus terrestris* L,. *Verbascum thapsus* L,. *Viola cinerea* Boiss,. *Heteropogon contortus* Beauv., *Gomphrena celosioides* Mart, *Gagea pseudoreticulata* Vved. and *Commelina benghalensis* L. are the common elements.

3.1.3 Himalayan subtropical pine forest (9/C1a)

This forest type occupied an area of 99.85 km^2, thus forming 3.4% of the total area under study. It comprised of 25-30 m high pure crop of *Pinus roxburghii* in all the higher ridges and on the steeper rocky slopes at an altitude of 900 m asl, with broad-leaved species and shrubs towards moderate and lower elevations (Fig.1). The herbaceous flora included *Rumex hestatus* Don, *Cymbopogon stracheyi* Raizada & Jain., *Allium rubellum* M. Bieb., *Antirrhinum orontium* L., *Arenaria serpyllifolia* L., *Atylosa crassa* Prain.., *Borreria stricta* K., Schum. *Capsella bursa-pastoris* Medik., *Carthamus oxycantha* M. Bieb., *Commelina benghalensis* L., *Fumaria indica* Pugsley, *Gentiana aprica* Dcne, *Lindenbergia indica* Vatke and *Reinwaratia indica* Dummort.

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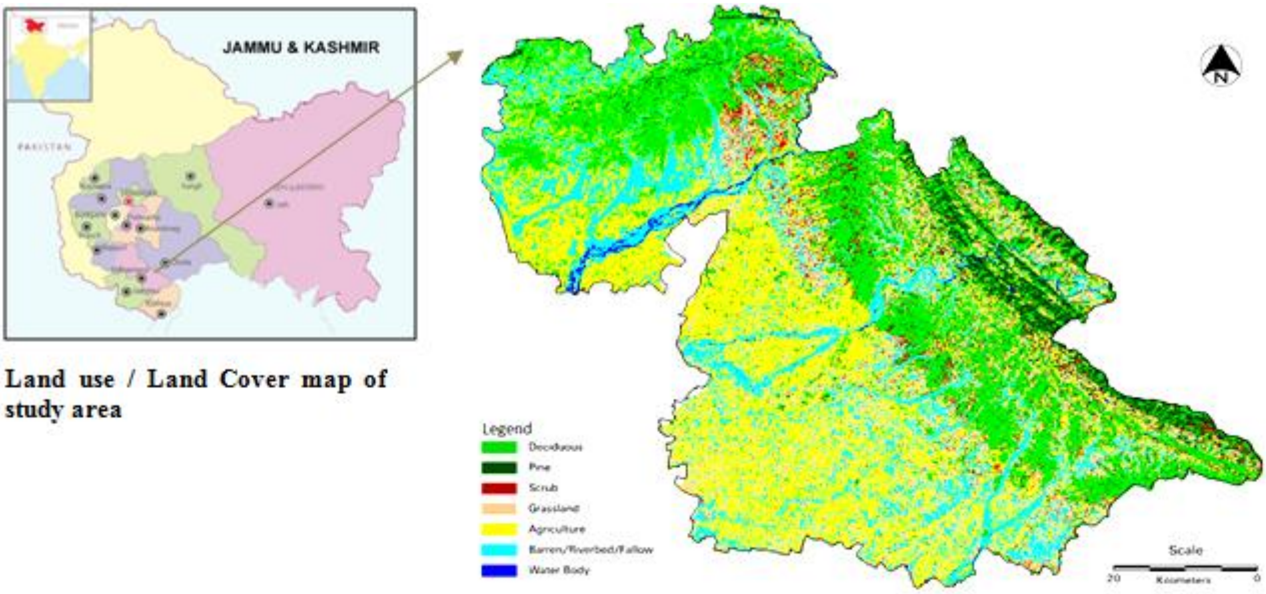

Figure 1: Land use / Land Cover map of the study area

3.2 Floristic structure species richness and diversity

A total of 266 species belonging to 201 genera and 64 families have been recorded in the ground stratum of different forest communities. Most of the herbs are annuals and biennials restricted to forest floors or open blanks within and along the forest fringes. Among the angiosperm families, Fabaceae topped the list with 21 genera and 35 species followed by Asteraceae (24/28), Poaceae (19/21), and Lamiaceae (10/15) respectively. As many as 25 families showed monotypic representation in the area as represented by a single genus and single species.

The community analysis was performed using stratified random sampling involving 0.01 % of the total area for each community wherein 750 quadrats of 1 m^2 each were laid for various phytosociological parameters. Maximum species richness *i.e* 135 was recorded for subtropical dry deciduous forest followed by 62 in Himalayan subtropical scrub and 59 in Himalayan subtropical Pine forest respectively (Table-1). Further, the species diversity was also found maximum in subtropical dry deciduous forest with highest values recorded for Margalef's Index (34.89), Menhinick's Index (1.62), Simpson's Index (0.97) and Shannon-Wiener's Index (3.66 followed by Himalayan subtropical scrub [Margalef's Index (17.68), Menhinick's Index (1.16), Simpson's Index (0.97) and Shannon-Wiener's Index (3.55)] and Himalayan subtropical Pine forest [Margalef's Index (18.01), Menhinick's Index (1.43), Simpson's Index (0.96) and Shannon-Wiener's Index (3.40)] respectively (Table -1).

Table 1: Community Characteristics of herbaceous layer in different forest ecosystems

Parameter	*Forest Types*		
	Subtropical dry deciduous forest	*Himalayan subtropical scrub*	*Himalayan subtropical Pine forest*
Species richness	135	62	59
Total number of individuals	6936	2865	1689
Margalef's Index (Da)	34.89	17.68	18.01
Menhinick's Index (Db)	1.62	1.16	1.43
Simpson's Index (Ds)	0.97	0.97	0.96
Shannon-Wiener's Index (H′)	3.66	3.55	3.40
Pielou's Index (E_1)	0.75	0.86	0.83
Sheldon's Index (E_2)	0.28	0.56	0.50

The Peilou's evenness Index varied from 0.75 to 0.86 with maximum values recorded as 0.86 for Himalayan subtropical scrub followed by Himalayan subtropical pine forest (0.83) and subtropical dry deciduous forest (0.75) respectively. The Sheldon's evenness index ranged from 0.28 to 0.56 with highest value (0.56) noticed in Himalayan subtropical scrub followed by Himalayan subtropical Pine forest (0.50) and subtropical dry deciduous forest (0.28) respectively.

3.3 Vegetation Analysis

Vegetation analysis revealed that highest Species Importance Value (Value, percentage) amongst the herbs in different forest communities. In northern dry mixed deciduous forest, *Cynodon dactylon* Pers. is found the most dominant species (IVI = 12.75, 4.25%) with relative frequency of 7.00%, relative density of 5.70% and relative dominance of 0.05%, respectively. The most frequently occurring species is again *Cynodon dactylon* Pers. with frequency value of 48.60%. *Dicanthium annulatum* Stapf. possessed highest density *i.e.* 107.29, whereas *Torenia cordifolia* Roxb. was most abundant herb of the region with a value of 16.50. While in Himalayan sub-tropical scrub, among the herbaceous layer *Ageratum conyzoides* L. was observed most dominant with IVI value of 18.03 (6.01%) in which relative frequency contributes to 6.49% followed by relative density of 7.66% and relative dominance of 3.88%. *Ageratum conyzoides* L. was found highly frequent with frequency value of 25.71% and highest density i.e. 78.93 among its associates. *Heteropogon contortus* Beauv. had the highest abundance value of 7.06. The herbaceous layer in Himalayan Subtropical Pine Forest was dominated by *Cynodon dactylon* Pers. with highest IVI value of 23.07 (7.69%) of which the major share is contributed by relative density value of 10.82% followed by relative frequency of 12.17% and relative abundance of 0.08%, respectively. *Cynodon dactylon* Pers. also possessed the highest frequency and density values of 88% and 185, respectively, whereas *Arenaria serpyllifolia* L. was found abundant among its associates with abundance value of 4.66 (Table - 2).

4. Discussion

Though a number of studies have been undertaken on composition, structure and diversity of vegetation in different regions of the state, hardly a few studies pertaining to herbaceous stratum are available. As a result our understanding of various aspects of herbaceous species distribution is far from adequate in this part of Himalayas. The edaphic conditions, topography, weather and seasonal pattern coupled with unregulated man-made disturbances have greatly influenced the pattern and distribution of ground layer in Kandi Siwaliks. Several factors as lower altitude, habitat heterogeneity, resource availability, disturbance levels, moderate fragmentation together with stochastic factors like random climatic variability, fluctuations to resources and dispersal limitation may influence the vegetation composition (Connell, 1989; Whitmore, 1998; Dalling *et al*., 2002; Fajardo & Alaback, 2005 and Shaheen *et al*., 2011).

The recorded diversity values (H′) of 3.40 to 3.66 lie more or less within the reported range of 0.83 to 4.0 for Himalayas (Singh *et al*., 1981 & 1984 and Gupta & Kumar, 2014). Present study revealed the changing patterns of herbaceous vegetation composition, diversity and structure in different forest communities. Northern dry mixed deciduous forests occupying 27.3% of the study area exhibited maximum species richness and diversity. Similar trends were obtained in middle and higher elevations in a sub-tropical forest in Arunachal Pradesh by Rana & Gairola (2010).

Maximum species richness of 135 was found in Northern dry deciduous forest. Similar trends were also noted in case of diversity values to the tune of H′ = 3.66 for Subtropical dry deciduous forest, 3.55 for Himalayan subtropical scrub and 3.40 in case of Himalayan subtropical Pine forest. The values of the present study are in consonance to the values reported for different subtropical forest types by many workers viz., Singh *et al.* (1984 & 1985), Jha and Singh (1990), Parthasarthy *et al*.(1992), Visalakshi, (1995), Pandey and Shukla (1999), Gautam *et al*. (2008), Sagar *et al*. (2008), Krishnamurthy *et al*. (2010), Rana and Gairola (2010), Tynsong & Tiwari (2011), Sagar *et al*. (2012), Gairola and Soni (2013), Gunaga *et al*. (2013) and Mandal & Joshi (2014). The concentration of dominance (Simpson's index) in the present study sites were within the reported range (0.10-1) for tropical dry forests by other workers (Negi *et al*., 2002; Kukreti & Negi, 2004; Gautam *et al*., 2008; Gupta & Kumar, 2014 and Mandal & Joshi, 2014).

Table 2: Species Importance Value Index of herb species in different forest communities

S. No.	Species	*Northern dry mixed deciduous forest*			*Himalayan subtropical dry scrub*			*Himalayan subtropical Pine forest*		
		Density (Trees Ha^{-1})	*Basal Area (m^2)*	*SIV (%)*	*Density (Trees Ha^{-1})*	*Basal Area (m^2)*	*SIV (%)*	*Density (Trees Ha^{-1})*	*Basal Area (m^2)*	*SIV (%)*
1.	*Cynodon dactylon* Pers.	105.13	0.00028	12.75	-	-	-	185.00	0.0002	23.07
2.	*Oxalis corniculata* L.	104.05	0.0005	10.55	-	-	-	109.00	0.0005	10.99
3.	*Crotalaria prostrata* Rottl.	19.72	0.00039	10.27	9.64	0.0005	2.11	-	-	-
4.	*Dichanthium annulatum* Stapf.	107.29	0.0013	10.09	37.14	0.0017	6.44	-	-	-
5.	*Poa annua* L.	93.24	0.0040	9.34	30.00	0.0031	6.04	-	-	-
6.	*Malvastrum coromandelianum* Garcke	56.48	0.0028	7.25	29.64	0.0031	6.90	49.00	0.0031	7.00
7.	*Parthenium hysterophorus* L.	52.70	0.0017	6.81	-	-	-	-	-	-
8.	*Ageratum conyzoides* L.	35.40	0.0073	6.50	78.92	0.0097	18.03	93.00	0.0081	12.41
9.	*Anagallis arvensis* L.	49.45	0.0011	6.39	31.78	0.0021	7.16	43.00	0.0011	4.60
10.	*Tridax procumbens* L.	52.16	0.00064	6.18	-	-	-	63.00	0.0009	8.05
11.	*Cyperus rotundus* L.	79.72	0.00028	6.04	38.92	0.00019	9.88	-	-	-
12.	*Amaranthus viridis* L.	29.45	0.0049	4.89	-	-	-	-	-	-
13.	*Apluda mutica* L.	24.59	0.007	4.68	-	-	-	-	-	-
14.	*Ipomea carnea* Jack.	20.27	0.012	4.47	23.57	0.010	8.35	23.00	0.013	7.78
15.	*Cardiospermum halicacabum*	22.4	0.0121	4.45	-	-	-	32.00	0.0128	9.61
16.	*Saussurea heteromalla* Hand-Maz.	25.13	0.0054	4.22	-	-	-	63.00	0.0004	7.02
17.	*Aspidopterys wallichi* Hook.	10.0	0.014	4.18	10.35	0.010	6.62	-	-	-
18.	*Solanum erianthum* Don.	0.81	0.0191	4.08	-	-	-	-	-	-
19.	*Verbascum thapsus* L.	8.64	0.014	3.87	7.50	0.0097	5.68	-	-	-
20.	*Gomphrena celosioides* Mart.	13.51	0.011	3.74	60.35	0.0021	12.55	31.00	0.011	7.31
21.	*Heteropogon contortus* Beauv.	29.45	0.0021	3.69	46.07	0.0013	6.61	-	-	-
22.	*Sida alba* L.	22.43	0.0062	3.57	3.92	0.007	3.53	-	-	-
23.	*Commelina benghalensis* L.	27.83	0.00028	3.54	23.92	0.0005	4.59	73.00	0.0002	10.02
24.	*Cannabis sativa* L.	42.97	0.0023	3.53	-	-	-	-	-	-
25.	*Rosa brunonii* Lindl.	2.43	0.0153	3.42	-	-	-	-	-	-
26.	*Euphorbia hirta* L.	22.43	0.0025	3.35	10.00	0.0036	3.04	-	-	-
27.	*Cryptolepis buchanani* Roem & Sch.	8.91	0.010	3.24	2.14	0.0121	5.17	-	-	-
28.	*Boerhavia diffusa* L.	24.05	0.0013	3.23	15.35	0.0017	4.60	-	-	-
29.	*Solanum surrattense* Burm.f	9.45	0.009	3.19	-	-	-	10.00	0.010	5.27
30.	*Triumfetta rhomboidea* Jacq.	13.78	0.0054	3.14	5.00	0.0062	3.59	-	-	-
31.	*Carthamus oxycantha* M.Bieb.	6.21	0.0128	3.10	44.28	0.012	12.87	21.00	0.0731	7.70

32.	*Caesalpinia decapetala* Alston.	0.81	0.014	3.02	2.00	0.017	7.18	-	-	-
33.	*Datura innoxia* Mill.	1.35	0.013	2.84	14.64	0.0012	3.61	-	-	-
34.	*Mazus japonicus* Ktze.	17.02	0.00078	2.64	30.35	0.0005	5.39	71.00	0.0002	7.41
35.	*Celastrus paniculata* Willd.	9.45	0.0066	2.61	-	-	-	11.00	0.0061	4.04
36.	*Abrus precatorius* L.	6.21	0.0081	2.51	20.71	0.0035	5.30	-	-	-
37.	*Desmodium gangeticum* DC	11.62	0.0066	2.50	-	-	-	-	-	-
38.	*Desmodium heterocarpon* DC	20.27	0.0040	2.50	22.14	0.0049	5.27	-	-	-
39.	*Gloriosa superba* L.	3.51	0.0097	2.47	-	-	-	7.00	0.0121	5.65
40.	*Reinwardtia indica* Dummort.	11.62	0.0021	2.45	16.07	0.0038	4.61	41.00	0.0058	13.13
41.	*Cassia tora* L.	14.3	0.0021	2.40	22.70	0.0023	4.54	-	-	-
42.	*Pueraria tuberosa* DC.	2.43	0.010	2.39	-	-	-	-	-	-
43.	*Xanthium strumarium* L.	12.70	0.0066	2.39	25.35	0.0086	9.77	21.00	0.0097	6.48
44.	*Sphenoclea zeylanica* Gaertn.	27.83	0.00028	2.37	-	-	-	-	-	-
45.	*Campanula benthamii* Wall.	21.35	0.0013	2.31	-	-	-	35.00	0.0009	5.30
46.	*Malva parviflora* L.	17.02	0.0013	2.31	16.78	0.0013	3.85	39.99	0.00013	4.86
47.	*Duchesnea indica* Focke.	21.35	0.00019	2.30	8.21	0.00039	1.38	-	-	-
48.	*Clematis gouriana*	3.51	0.008	2.27	-	-	-	-	-	-
49.	*Aerua sanguinolenta* Bl.	8.37	0.0071	2.24	-	-	-	-	-	-
50.	*Inula cappa* DC.	2.16	0.0097	2.23	22.50	0.012	9.32	31.00	0.0097	7.07
51.	*Vitis latifolia* Roxb.	8.91	0.0058	2.22	-	-	-	11.00	0.009	4.65
52.	*Vitis trifolia* L.	11.62	0.0036	2.18	-	-	-	-	-	-
53.	*Allium rubellum* M. Bieb.	3.51	0.0081	2.14	-	-	-	5.00	0.0073	3.62
54.	*Dioscorea belophylla* Voigt.	8.64	0.0040	2.14	2.50	0.0023	1.60	-	-	-
55.	*Taraxacum officinale* Webber.	14.31	0.00012	2.03	3.92	0.0007	1.10	29.00	0.0001	3.52
56.	*Eclipta prostrata* L.	19.72	0.0005	2.01	-	-	-	14.00	0.0006	9.00
57.	*Desmodium velutinum*	2.43	0.0086	1.98	-	-	-	-	-	-
58.	*Trichodesma indicum* R. Br.	11.62	0.0005	1.85	-	-	-	-	-	-
59.	*Cissampelos pareira* L.	10.54	0.0036	1.77	3.93	0.0021	1.76	9.00	0.0038	2.86
60.	*Diplocyclus palmatus* Jeff.	9.45	0.0025	1.75	-	-	-	-	-	-
61.	*Swertia angustifolia* Buch.-Ham.	15.94	0.00039	1.75	1.78	0.00039	0.59	-	-	-
62.	*Tinospora cordifolia* Hk.f &T	4.05	0.0058	1.75	1.78	0.0066	3.16	-	-	-
63.	*Blainvellea acmella* Philip.	4.05	0.0066	1.69	1.78	0.007	3.24	-	-	-
64.	*Arabidopsis thaliana* Heyne.	14.32	0.0005	1.68	-	-	-	39.00	0.0005	4.27
65.	*Sisymbrium irio* L.	15.13	0.00039	1.67	-	-	-	-	-	-
66.	*Dicliptera bupleuroides* Nees.	3.51	0.0058	1.66	-	-	-	47.00	0.0066	8.57
67.	*Amaranthus tricolor* L.	2.97	0.0066	1.64	-	-	-	-	-	-
68.	*Alysicarpus procumbens* Schind.	8.91	0.0038	1.61	-	-	-	-	-	-
69.	*Martynia annua* L.	4.86	0.0058	1.57	-	-	-	11.00	0.092	4.87
70.	*Emilia sonchifolia* DC.	11.62	0.00039	1.52	-	-	-	-	-	-
71.	*Bidens bipinnata* L.	6.21	0.00376	1.49	-	-	-	-	-	-
72.	*Ipomea nil* Roth.	14.05	0.0015	1.49	-	-	-	-	-	-
73.	*Cucumis melo* L.	0.81	0.0066	1.48	2.50	0.0058	2.73	-	-	-
74.	*Helinus lanceolatus* Brandis	0.54	0.0066	1.46	-	-	-	-	-	-
75.	*Borreria stricta* Schum.	8.37	0.0015	1.45	-	-	-	13.00	0.0013	2.52
76.	*Ipomea muricata* Jacq.	8.91	0.0028	1.40	-	-	-	-	-	-
77.	*Eremostachys superba* Royle	6.21	0.0040	1.35	-	-	-	-	-	-
78.	*Pergularia extensa* N.E. Br.	10.00	0.0013	1.31	-	-	-	-	-	-
79.	*Euphorbia prostrata* Ait.	7.29	0.0021	1.24	31.78	0.0040	7.92	-	-	-
80.	*Cynoglossum lanceolatum* Forssk.	11.62	0.0005	1.23	-	-	-	-	-	-
81.	*Barleria cristata* L.	4.59	0.0038	1.22	4.64	0.007	3.88	19.00	0.0032	3.91
82.	*Sonchus oleraceus* L.	5.13	0.0040	1.21	1.78	0.0049	2.30	-	-	-
83.	*Corchorus aestuans* L.	3.24	0.0040	1.19	-	-	-	-	-	-
84.	*Rungia pectinata* Nees.	8.91	0.00028	1.19	-	-	-	-	-	-
85.	*Momordica charantia* L.	6.21	0.0025	1.18	-	-	-	-	-	-
86.	*Fumaria indica* Pugsley	11.89	0.00012	1.16	-	-	-	41.00	0.0002	5.23
87.	*Tylophora hirsuta* Wt. & Arn.	4.05	0.0040	1.15	-	-	-	-	-	-
88.	*Trichosanthes cucumerina* L.	8.91	0.0012	1.14	-	-	-	7.00	0.0002	1.17
89.	*Micromeria biflora* Bth.	11.62	0.00012	1.11	-	-	-	21.00	0.0001	2.22
90.	*Cassia occidentalis* L.	4.05	0.0038	1.10	10.71	0.0058	4.52	8.00	0.0027	1.95
91.	*Coccinia grandis* Voigt.	3.51	0.0031	1.10	8.57	0.0049	3.96	13.00	0.0028	2.29
92.	*Geranium rotundi folium* L.	11.62	0.00028	1.10	22.14	0.0005	4.95	35.00	0.0002	4.19
93.	*Clematis graveolens* Lindl.	3.24	0.0031	1.08	-	-		19.00	0.0031	3.45
94.	*Mucuna pruriens* DC	2.43	0.0040	1.07	-	-		-	-	-
95.	*Sonchus asper Garsault*	3.51	0.0031	1.02	5.00	0.0040	2.62	9.00	0.0049	2.89
96.	*Vigna vexillata Arich.*	6.21	0.0013	1.02	-	-	-	-	-	-
97.	*Evolvulus alsinoides*	4.05	0.0023	0.98	-	-	-	29.00	0.0052	5.15
98.	*Ocimum americanum L.*	3.24	0.0036	0.98	-	-	-	-	-	-

99.	*Convolvulus arvensis L.*	8.91	0.0011	0.97	-	-	-	23.00	0.0004	1.92
100.	*Alysicarpus rugosus DC.*	4.05	0.0031	0.96	-	-	-	12.00	0.0033	2.71
101.	*Lindenbergia indica Vatke*	8.91	0.0013	0.94	-	-	-	14.00	0.0015	2.55
102.	*Sacchrum benghalense Retz.*	4.59	0.0021	0.94	-	-	-	-	-	-
103.	*Viola cinerea Boiss.*	6.75	0.00028	0.91	-	-	-	-	-	-
104.	*Costus speciosus Smith*	1.35	0.0036	0.88	-	-	-	-	-	-
105.	*Withania somnifera Dunal.*	2.97	0.0028	0.85	-	-	-	-	-	-
106.	*Incarvillea emodii Chatt.*	1.62	0.0031	0.83	-	-	-	-	-	-
107.	*Ruellia prostrata Poir.*	4.59	0.0013	0.78	-	-	-	-	-	-
108.	*Antirrhinum orontium L.*	5.13	0.0013	0.73	-	-	-	13.00	0.0014	1.59
109.	*Indigofera trifoliata L.*	3.51	0.0013	0.73	-	-	-	-	-	-
110.	*Gagea pseudoreticulata Vved.*	6.21	0.00019	0.70	13.92	0.000012	2.65	19.00	0.0003	2.75
111.	*Torenia cordifolia Roxb.*	8.91	0.0007	0.69	-	-	-	-	-	-
112.	*Urginea indica Kunth.*	6.21	0.00028	0.69	-	-	-	-	-	-
113.	*Blepharis maderaspatensis Heyne.*	5.13	0.0011	0.68	-	-	-	-	-	-
114.	*Gentiana aprica Dcne.*	6.21	0.00007	0.68	-	-	-	10.00	0.0001	1.03
115.	*Centella asiatica Urban.*	6.21	0.00028	0.65	5.00	0.0007	1.03	-	-	-
116.	*Capsella bursa-pastoris Medik.*	1.35	0.0021	0.61	-	-	-	19.00	0.0023	3.41
117.	*Crotalaria albida Heyne*	6.21	0.000078	0.61	-	-	-	-	-	-
118.	*Shuteria densiflora Bth.*	4.86	0.00039	0.61	-	-	-	-	-	-
119.	*Dregea volubilis Bth.*	3.51	0.00039	0.58	-	-	-	7.00	0.0004	1.11
120.	*Luffa acutangula Roxb.*	1.89	0.0017	0.56	-	-	-	-	-	-
121.	*Cyperus niveus Retz.*	9.45	0.00012	0.55	-	-	-	-	-	-
122.	*Solanum nigrum L.*	3.78	0.0012	0.55	-	-	-	-	-	-
123.	*Tulipa stellata Hk.f.*	3.51	0.00019	0.49	-	-	-	-	-	-
124.	*Ipomea hispida Roem & Schult*	2.43	0.0012	0.48	-	-	-	-	-	-
125.	*Portulaca grandiflora Hk.*	5.13	0.00028	0.43	-	-	-	-	-	-
126.	*Androsace umbellata Merr.*	2.97	0.0007	0.41	-	-	-	-	-	-
127.	*Salvia plebia R.Br.*	3.51	0.00051	0.40	2.50	0.00019	0.58	-	-	-
128.	*Stellaria media Vill.*	3.51	0.00019	0.33	-	-	-	-	-	-
129.	*Phyllanthus simplex Retz.*	3.78	0.00005	0.32	8.92	0.00019	2.19	-	-	-
130.	*Senecio nudicaulis Buch.-Ham.*	2.7	0.00028	0.32	-	-	-	15.00	0.0023	2.89
131.	*Sclerocarpus africanus Jacq.*	2.50	0.0005	0.30	-	-	-	17.00	0.0082	5.37
132.	*Viola canascens Wall.*	2.16	0.0005	0.28	-	-	-	18.00	0.0005	1.94
133.	*Lotus corniculatus L.*	1.35	0.00039	0.26	-	-	-	-	-	-
134.	*Galium aparine L.*	1.35	0.00019	0.21	-	-	-	-	-	-
135.	*Crotalaria hirsuta Willd.*	0.81	0.00019	0.14	-	-	-	-	-	-

The Peilou's evenness Index varied from 0.67 to 0.84 whereas, the Sheldon's evenness index ranged from 0.29 to 0.62. Similar results have been obtained in the studies conducted in other parts of Himalayas (Behera *et al.*, 2002; Feroz *et al.*, 2008; Tynsong & Tiwari, 2011 and Gupta & Kumar, 2014). In several studies it has been observed that the species diversity in highest in the herb layer among all forest strata and it bears a marked influence on the establishment of higher strata. Slobodkin and Sanders (1969) opined that species richness of any community is a function of severity, variability and predictability of the environment in which it develops. Therefore, diversity tends to increase as the environment becomes more favourable and more predictable (Putman, 1994). The study therefore, concludes that northern dry mixed deciduous forests revealed maximum herb species richness and diversity which is attributed to congenial environmental factors, moderate disturbance and edge effect along the forest fringes.

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References

[1] M. Ahmed, T. Husain, A.H. Sheikh, S.S Hussain and M. Siddiqui, "Phytosociology and structure of Himalayan forests from different climatic zones of Pakistan". Pak. J. Bot., **38 (2),** pp 361-383, 2006

[2] M.D. Behera, S.P.S. Kushwaha, P.S. Roy, S Srivastava, T.P. Singh and R.C. Dubey, "Comparing structure and composition of coniferous forests in Subansiri district, Arunachal Pradesh", Current Science, **82 (1)**, pp 70-75, 2002.

[3] H.G Champion, and S.K. Seth, "A Revised Survey of the forest types of India", Govt. of India Press, Delhi, 1968

[4] J.H. Connell, "Some processes affecting the species composition in forest gaps, Ecology, **70**, pp 560-562, 1989.

[5] J.W. Dalling, H.C. Muller-Landau, S.J. Wright and S.P. Hubbell, "Role of dispersal in the recruitment limitation of neo-tropical pioneer species", J. Ecol., **90**, pp 714-727, 2002.

[6] D.K. Das, O.P. Chaturvedi, M.P. Mandal and R. Kumar, "Effect of tree plantation on biomass and primary

productivity of herbaceous vegetation in eastern India". Tropical Ecology, **49**, pp 95-101, 2008.

[7] N.J. Ekka, and N. Behera, "Species composition and diversity of vegetation developing on an age series of coal mine spoil in an open cast coal field in Orissa, India", Tropical Ecology, **52 (3)**, pp 337-343, 2011.

[8] A. Fajardo and P. Alaback, "Effects of natural and human disturbances on the dynamics and spatial structure of *Nathofagus glauca* in south central Chile", Journal of Biogeography, **32**, pp 1811-1825, 2005.

[9] S.M. Feroz., K. Yoshimura and A. Hagihara, "Architectural stratification and woody species diversity of a subtropical forest frown in a limestone habitat in Okinawa Island, Japan", World academy of Science, Engineering and Technology, **2**, pp 11-20, 2008.

[10] S. Gairola, R.S. Rawal and N.P. Todaria, "Forest vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India", African Journal of Plant Science, **2 (6)**, pp 042-048, 2008.

[11] S. Gairola, and P. Soni, "A study on herbaceous layer in an age series of restored mined land using cluster analysis". Proceedings of the International Academy of Ecology and Environmental Sciences, **3 (2)**, pp 133-142, 2013.

[12] T.R. Ganesh, M. Ganesan, S. Devy, P. Davidar & K.Bawa, "Assessment of plant biodiversity at a mid-elevation evergreen forest of Kalakad-Mandanthurai Tiger Reserve, Western Ghats, India", Current Science, **71**, pp 379-392, 1996.

[13] M.K. Gautam, A.K. Tripathi and S.K. Kamboj, "TWINSPAN classification of moist *Shorea robusta* Gaertn. f. (Sal) forests with respect to regeneration", Annals of Forestry **16**, pp 713-717, 2008.

[14] F.S. Gilliam, A.W. Hockenberry and M.B Adams, "Effects of atmospheric nitrogen deposition on the herbaceous layer of a central Appalachian hardwood forest", Journal of the Torrey Botanical Society **133**, pp 240–254, 2006.

[15] F.S. Gilliam and M.R. Roberts, "The Herbaceous Layer in Forests of Eastern North America", New York, Oxford University Press, 2003

[16] F.S Gilliam, "Response of the herbaceous layer of forest ecosystems to excess nitrogen deposition", Journal of Ecology **94**, pp 1176–1191, 2006.

[17] F.S. Gilliam, "Interaction of fire with nutrients in herbaceous layer of a nutrients poor Coastal Plain forest", *Bull. Torrey Bot. Club*, **115**, pp 265-271, 1988.

[18] S. Gunaga, N. Rajeshwari and R. Vasudeva, "Tree diversity and disturbance of Kaan forests: relics of a community protected climax vegetation in the central Western Ghats", Tropical Ecology, **54 (1)**, pp 117-131, 2013.

[19] S.R. Gupta and R. Kumar, "Vegetation composition and plant biodiversity in forest ecosystems of Siwaliks in northern Haryana", Indian Journal of Fundamental and Applied Life Sciences, **4 (2)** pp 76-88, 2014.

[20] V.M. Ilorkar and P.K. Khatri, "Phytosociological study of Navegaon national Park, Maharashtra", Ind. For., **129 (3)**, pp 377-387, 2003.

[21] C.S. Jha and J.S. Singh, "Composition and dynamics of dry tropical forest in relation to soil texture", Journal of Vegetation Science, **1**, pp 609-614, 1990.

[22] M. Jhangir,"Phytodiversity characterisation using remote sensing and GIS of district Kathua, Jammu and Kashmir", Ph.D thesis, University of Jammu (J&K), Jammu, India, 2004

[23] H.G. Joshi, "Vegetation structure, floristic composition and soil nutrient status in three sites of tropical dry deciduous forest of West Bengal, India", *I*ndian Journal of Fundamental and Applied Life Sciences, **2 (2)**, pp 355-364, 2012.

[24] G.Kharkwal, "Qualitative analysis of tree species in evergreen forests of Kumaun Himalaya, Uttarakhand, India", African Journal of Plant Science, **3 (3)**, pp 049-052, 2009

[25] Y.L. Krishnamurthy, H.M. Prakasha, A. Nanda, M. Krishnappa, H.S. Dattaraja and H.S. Suresh, "Vegetation structure and floristic composition of a tropical dry deciduous forest in Bhadra Wildlife Sanctuary, Karnataka, India", Tropical Ecology, **51 (2)**, pp 235-246, 2010.

[26] P. Kukreti and J.D.S Negi, "Tree mortality and vegetational changes in a natural Sal forest of Barkot range, Dehra Dun Forest Division", Annals of Forestry, **12**, pp 47-55, 2004.

[27] R.M. Kunwar and S.P. Sharma, "Quantitative analysis of tree species in two community forests of Dolpa district, mid-west Nepal", Him J Sci., **2 (3)**, pp 23-28, 2004.

[28] D.A. Maguire and R.T.T. Forman, "Herb cover effects on tree seedling patterns in a mature Hemloch-Hardwood Forest", Ecology **64**, pp 1367–1380, 1983.

[29] G. Mandal and S.P. Joshi, "Analysis of vegetation dynamics and phytodiversity from three dry deciduous forests of Doon Valley, Western Himalaya, India", 2014.

[30] D.R. Margalef, "Information theory in ecology", Genetics and systematic, **3**, pp 36-71, 1958.

[31] H.B. Naithani, R.C. Pal and R.K. Srivastava, "Vegetation analysis of the Trimula hills, Andhra Pradesh", Indian Forester, **132 (9)**, pp 1110-1130, 2006.

[32] J.D.S. Negi, D. Shah, P. Kukreti, M. Negi, H.S. Basera, S.K. Kamboj and P.S. Chauhan, "An ecological assessment of Sal mortality in Uttaranchal", Annals of Forestry **10 (2)**, pp 193-203, 2002.

[33] S.C. Negi and S. Nautyial, "Phytosociological studies of a traditional reserve forests Thal-ke-Dhar, Pithoragarh, Central Himalayas, India", Indian Forester,**131 (4)**, pp 519-532, 2005.

[34] S.K. Pandey and R.P. Shukla, "Plant diversity and community patterns along the disturbance gradient in plantation forests of Sal (*Shorea robusta* Gaertn. f)", Current Science **77**, pp 814-818, 1999.

[35] N. Parthasarthy, V. Kinhal and P.L. Kumar, "Plant species diversity and human impact in the tropical wet evergreen forests of southern Western Ghats". In: Indo-French Workshop on Tropical Forest Ecosystem: Natural functioning and anthropogenic impact. Pondicherry: French Institute, pp. 165-176, 1992.

[36] E.C. Pielou, "Ecological diversity, John Wiley and Sons, New York, 1975.

[37] R.J. Putman, "Community Ecology. Chapman & Hall, London, 1994.
[38] A.S. Raghubanshi and A. Tripathi, " Effect of disturbance, habitat fragmentation, and alien invasive plants on floral diversity in dry tropical forests of Vindhyan Highlands: a review", Tropical Ecology, **50 (1)**, pp 57-69, 2009
[39] P.K. Ralhan, A. K. Saxena, and J. S. Singh, "Analysis of forest vegetation at and around Nainital in Kumaun Himalaya", Proc. Indian National Sciences Academy, **348**, pp 121-137, 1982.
[40] C.S. Rana and S. Gairola, "Forest community structure and composition along an elevational gradient of Parshuram Kund area in Lohit District of Arunachal Pradesh, India", Nature and Science, **8 (2)**, pp 27-35, 2010.
[41] P. Rao, S.K. Barik, H.N. Pandey and R.S. Tripathi, "Community composition and tree population structure in sub-tropical broadleaved forest along a disturbance gradient", Vegetatio, **88**, pp 151-162, 1990.
[42] M.R. Roberts, "Response of the herbaceous layer to disturbance in North American forests", Canadian Journal of Botany **82**, pp 1273–1283, 2004.
[43] R. Sagar, A.S. Raghubanshi and J.S. Singh, "Comparison of community composition and species diversity of understorey and overstorey tree species in a dry tropical forest of northern India", J Environ Manag, **88**, pp 1037–1046, 2008.
[44] R. Sagar, A. Pandey and J.S. Singh, "Composition, species diversity, and biomass of the herbaceous community in dry tropical forest of northern India in relation to soil moisture and light intensity", Environmentalist **32**, pp 485-493, 2012.
[45] R. Sagar, A. Singh and J.S. Singh, "Differential effect of woody plant canopies on species composition and diversity of ground vegetation : a case study", Tropical Ecology, **49 (2)**, pp 189-197, 2008.
[46] S.C. Sahu, N.K. Dhal and R.C. Mohanty, "Tree species diversity, distribution and population structure in tropical dry deciduous forest of Malygiri hill ranges, Eastern India", Tropical Ecology, **53 (2)**, pp 163-168, 2012.
[47] R.M. Scheller and D.J Mladenoff. "Understory species pattern in old growth and managed northern hardwood forests", Ecological Applications, **12**, pp 1329-1343, 2002.
[48] H, Shaheen, R.A. Qureshi and Z.A. Shinwari, "Structural diversity, vegetation dynamics and anthropogenic impact on lesser Himalayan sub-tropical forests of Bagh district, Kashmir", Pak.J.Bota., **43 (4)**, pp 1861-1866, 2011.
[49] C.E. Shanon and W. Weaver, "The mathematical theory of communication", University of Illinois Press, Urbana, USA, 1963.
[50] C.M. Sharma and A. Kumar, "Community structure of some natural forest stands in Lansdowne Forest range of Garhwal Himalayas", J. Trop. For. Sci., **5**, pp 8-12, 1992.
[51] N. Sharma, "Biodiversity characterization at landscape level in Jammu district of J & K (Western Himalayas) using remote sensing and GIS, Ph.D Thesis, University of Jammu, (J & K), India", 2003.
[52] N. Sharma and S. Kant, "Vegetation structure, floristic composition and species diversity of woody plant communities in sub-tropical *Kandi* Siwaliks of Jammu, J & K, India", International Journal of Basic and Applied Sciences, **3 (4)**, pp 382-391, 2014 a.
[53] N. Sharma and S. Kant, "Landscape dynamics in a sub-tropical deciduous forest in north-western Himalayas, Jammu and Kashmir, India, International Journal of Current Research, **6 (12)**, pp 10956 – 10963, 2014 b.
[54] A. L. Sheldon, "Equitability indices: Dependence on the species count", Ecology, **50**, pp 466-467, 1969.
[55] G. Shukla and S. Chakarvarty, "Cause, pattern and consequence of under storey herbaceous vegetation at a foothill forest in Indian eastern Himalaya", Indian Forester, **140 (4)**, pp 354-262, 2014.
[56] E.H. Simpson, " Measurement of diversity", Nature, 163-168, 1949
[57] J.S. Singh, S.P. Singh and S.R. Gupta, "Ecology environment and resource conservation, Anamaya Publishers, New Delhi, 2006.
[58] J.S. Singh, S.P. Singh and A.K. Saxena, "The forest vegetation of Silent Valley, India". In: Chadwick AC, Literary Society, editors. Tropical rain forest: the Leeds Symposium. Leeds, U.K.: Central Museum, pp. 25-52, 1984
[59] J.S. Singh., S.P. Singh, A.K. Saxena and Y.S. Rawat, "The forest vegetation of Silent Valley in India, In: Tropical Rain Forest: The Leeds Symposium (eds. Chadwick AC and Sutton SL), Leeds Philosophical and Literary Society, Leeds, U.K, 25-52, 1985.
[60] J.S. Singh, S.P. Singh, A.K. Saxena, and Y.S. Rawat, "Report on the Silent Valley Study", Ecology Resaerch Cycle, Kumaon University, Nainital p 86, 1981.
[61] J.S. Singh, S.P. Singh, A.K. Saxena and Y.S Rawat, "The forest vegetation of Silent Valley, India". In : Tropical Rain Forest (Chadwick, A.C and Sutton, S.L Eds). The Leeds Symposium. Leeds philosophical and Literary Society, Leeds, England, pp 25-52, 1981
[62] M.K. Sinha and D. Sinha, "Composition of forest vegetation of Koria district, Chhattisgarh (India)", Global Journal of Biology, agriculture and health sciences, **2 (4)**, pp 160-168, 2013.
[63] L.B. Slobodkin. and H.L Sanders, "On the contribution of environmental predictability to species diversity", Brookhaven Symposium on Biology; **22**, pp 82–95, 1969.
[64] N.P. Todaria,. P. Pokhriyal, P. Uniyal and D.S. Chauhan, "Regeneration status of tree species in forest of Phakot and Pathri Rao watersheds in Garhwal Himalaya", Current Science, **98 (2)**, pp 171-175, 2010.
[65] O.P. Tripathi, K. Upadhaya, R.S. Tripathi and H.N Pandey, "Diversity, dominance and population structure of tree species along fragment- size gradient of a sub-tropical humid forest of northeast India", Research Journal of Environmental and Earth sciences **2 (2)**, pp 97-105, 2010.
[66] H, Tynsong and B.K. Tiwari, "Diversity and population characteristics of woody species in natural forests and arecanut agroforests of south Meghalaya, Northeast India", Tropical Ecology **52 (3)**, pp 243-252, 2011.
[67] A.O.Varghese and A.R.R. Menon, "Vegetation characteristics of southern secondary moist mixed

deciduous forests of Agasthyamalai region of Kerala", Indian Journal of Forester, **21 (4)**, pp 337-344, 1998.

[68] N. Visalakshi, "Vegetation analysis of two tropical dry evergreen forests in Southern India", Tropical Ecology **36**, pp 117-127, 1995.

[69] D.F. Whigham, "Ecology of woodland herbs in temperate deciduous forests", Annual Review of Ecology and Systematics, **35**, pp 583–621, 2004.

[70] T.C. Whitmore, "An introduction to tropical forests", Clarendron Press, Oxford and University Illinois Press, Urbana, 2nd edition, 117 p., 1998.

[71] R.H. Whittaker, "Evolution of species diversity in land plant communities", Evolutionary Biology, 10, 1-67,. 1977.