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VEGETATION-ENVIRONMENT RELATIONSHIP OF CONIFER DOMINATING FORESTS OF MOIST TEMPERATE BELT OF HIMALAYAN AND HINDUKUSH REGIONS OF PAKISTAN

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Abstract

The present investigation focuses on quantitative description of moist temperate conifer forest vegetation. Forty-one stands of conifer dominating forests, throughout their natural range, were sampled by point-centered quarter method while associated understorey vegetation was sampled by circular plots (1.5 m radius) and relevant quantitative attributes calculated and described. In addition to vegetational sampling, topographic observations were also taken and described in relation to vegetation description and distribution. Out of the twelve tree species, five conifer species were common in moist temperate area of Pakistan, including *Pinus wallichiana* A.B. Jackson (average importance value = 46%), *Abies pindrow* Royle (43%), *Cedrus deodara* (Roxb.) G. Don. (49.6%), *Picea smithiana* (Wall.) Boiss. (25.2%) and *Taxus fuana* Nan Li & R.R. Mill. (6%). Among angiospermic trees, *Juglans regia* L. attained 9.25 % average importance value. Common understorey species were: *Pteris cretica* L., *Rosa brunoni* Lindl, *Berberis lyceum* Royal I.C., *Hedera nepalensis* K. Koch, *Rubus biflorus* Ham. ex Sm., *Thymus serpyllum* L., *Rosa webbiana* Wall. ex Royle, *Rubus ellipticus* Smith and seedlings of some tree species. Thirteen forest community types were recognized on the basis of dominance (importance value) and described in relation to associated topographic and climatic characteristics. The community types examined, in particular, correlated well with the biotemperature and precipitation.

Introduction

Even though the modern techniques of vegetation analysis are common these days, a number of vegetation classification schools or groups of ecologists are still employing the simple criteria of dominance and similarity in floristic composition. The major reason is that such simple classification or typification of communities often provides quick and efficient results than the elaborated and mathematically elegant procedures.

European workers, who first used the term phytosociology, have long been interested in detailed structure, precise description, and system of classification of plant communities (Oosting, 1956). Depending upon the vegetation, their structure, composition, distribution and association between species in various regions of the world, different systems of vegetation analysis and classification evolved (Shimwell, 1971; Muller-Dombois & Ellenberg, 1974). However, most of the commonly used systems of vegetation classification suffer a great deal from subjectivity and in many instances applicable to particular vegetation types.

In Pakistan, the earlier ecological studies were generally observational but with the passage of time quantitative principles were introduced and the vegetation description evolved to quantitative studies. The earlier studies, that were descriptive, generally appeared in 1950's. No attempts were made to recognize community types and to correlate them with the relevant environmental factors. The present study focuses on the species composition, distribution pattern and dominance concentration of the forests sampled. Different workers have investigated the phytosociology of moist temperate locations in some parts of Pakistan, but no comprehensive study covering the entire distributional limits of moist temperate region exists. Furthermore, the sampling design of such studies is weak, sampling frame incomplete and sampling intensity low. Moreover, the relationships between vegetation and the perceived environmental gradients remained obscure. This study attempts to cover a substantially greater part of the moist temperate areas of Himalayan and Hindukush region of Pakistan and carries out a quantitative phytosociological investigation to unravel the various community types on the basis of floristic composition and to find the relationship with the associated environmental factors and gradients, particularly with the biotemperature and precipitation. In this study particular emphasis has been laid on bioclimate as the study area is vast with wide variation in precipitation and biotemperature. Consequently, vegetation is expected to show marked correlation with the bioclimatic factors as suggested by Rivas-Martínez *et al*., (1999).

Material and Methods

Forty one stands were sampled in conifer dominating forests by Point Centered Quarter Method (Cottam & Curtis, 1956), throughout their natural limits in moist temperate area in western Himalayan and Hindukush region of Pakistan**.** Though some forests are disturbed but mature and least disturbed forests were selected for quantitative sampling. The criteria for the site selection were: i) No signs of grazing by domestic animals, ii) no cutting (chopped stems and branches), Undisturbed soil, iii) no winds throw of trees, and iv) no foot tracks (trampling).

The criteria for the selection of stands were: 1) The stands were at least five hectare or more in area and dominated by conifer trees. 2) Visual homogeneity of physiography and vegetation. 3) Relatively free from recent major anthropogenic disturbance. Depending on the topography of the site at least twenty points were taken at 20 m intervals along the sampling direction. According to Cottam *et al.,* (1953) at least twenty PCQ points are required for accurate calculation of individual species density. Nonetheless, in some cases due to high slope angle *i.e.*, more than 45^{o} this technique was slightly modified and shorter distance between the points were taken.

A species list with a frequency table for understorey plants (<10 cm dbh) was made using a circular plot (1.5 m diameter) at each PCQ point. In some cases this included tall shrubs and small trees. Lower plants were also included in circular plot. Conifer "seedlings" (<10cm dbh) were enumerated in each plot and the number ha^{-1} for every stand was calculated. Phytosociological attributes (relative frequency, density and basal area)**,** and absolute values (stand density ha^{-1} and basal area m^2ha^{-1})**,** were calculated according to the method described by Mueller-Dombois & Ellenberg (1974).

The concept of importance value as a synthetic quantitative attribute was given by Curtis & McIntosh (1951). Brown & Curtis (1952) asserted that importance value gives more information about the species than any other single attribute alone and reflects the realistic ecological importance of a species in a community. Importance value (Brown & Curtis, 1952) was used to rank each species and the tree species with the highest importance value in the stand was considered the dominant species. With this dominance based method K=13 communities were recognized. Using K-mean method of non-hierarchical cluster analysis (Jancey, 1966), for K=13 clusters, minimum within group sum of squares was obtained, thereby the validity of the 13 communities was confirmed by the multivariate method. The plant communities were designated on the basis of first two dominant species**.**

Estimation of environmental variables: GPS was used to record elevation, position of stands**,** Latitude, Longitude, while degree of slope was recorded from clinometer, aspect estimated by compass and canopy of trees was also recorded by observing the forest richness.

Identification of species: Most of the identification of tree and understorey species was done in the field during the study but some plant specimens were brought to the laboratory and identified with the help of the Flora of Pakistan (Nasir & Ali, 1970-1989; Ali & Qaiser, 1993-2008).

Climatic estimation: Climatic data of different stations in the northern areas of Pakistan for 33 years (1976 to 2008) were obtained from Meteorological Department, Karachi. Data were formatted to mean monthly, maximum and minimum temperature and monthly and yearly precipitation. For each study area biotemperature was computed in accordance with Holdridge (1947). Among different parameters of climatic variables only biotemperature and precipitation are used to correlate with the corresponding community types.

Results

Quantitative description of communities: The main locations, close to the sampling sites showed in Fig. 1 while the locations of sampling sites in relation to their ecological characteristics are presented in Table 1. Summary of phytosociological analysis of 41 stands, their main locations, sampling sites and absolute values of species are presented in Table 2 while mean importance value, absolute density ha^{-1}, basal area m^2ha^{-1} and dominant position of conifer and angiospermic tree species are presented in Table 3. Species are ranked on the basis of importance value.

Among conifers *Pinus wallichiana*, *Cedrus deodara* and *Abies pindrow* were the most widely distributed species while *Picea smithiana* and *Taxus fuana* were recorded from only a few stands. Angiospermic species like *Juglans regia*, *Quercus incana* Roxb., *Quercus ilex* auct., non Linn., *Albizia chinensis* (Osbeck) Merrill, *Pyrus pashia* Hamilton ex D. Don, *Populus pamirica* L. and *Populus alba* L. were also associated with conifer trees in some stands of the study area forming mixed forests.

Summary of undersotrey species presence in number of stands and range of relative frequency is given in Table 4. In the circular plots of the study area, overall 87 undersotrey species were recorded. Grasses and lower plants were also included in the sampling. Complete list of species recorded in circular plot investigation is presented. Presence of undersotrey species in maximum number of stands is also presented in Table 4 to evaluate the abundance and future trend of the forests.

On the basis of importance value and the floristic composition of stands following 13 communities (Table 5) including five monospecific forests were recognized. Communities were named on the basis of first two dominant species. Two taxonomically identical dominant species with different rank in different stands were regarded as belonging to the same community type:

1. *Pinus wallichiana* (monospecific)
2. *Cedrus deodara* (monospecific)
3. *Abies pindrow* (monospecific)
4. *Pinus wallichiana-Picea smithiana* community
5. *P. wallichiana-Albizia chinensis* community
6. *P. wallichiana-Pyrus pashia* community
7. *Cedrus deodara-P. wallichiana community*
8. *Cedrus deodara-Picea smithiana* community
9. *Cedrus deodara-Abies pindrow* community
10. *Cedrus deodara-Juglans regia* community
11. *Abies pindrow-P. wallichiana* community
12. *Abies pindrow-Picea smithiana* community
13. *Abies pindrow-Taxus fuana* community

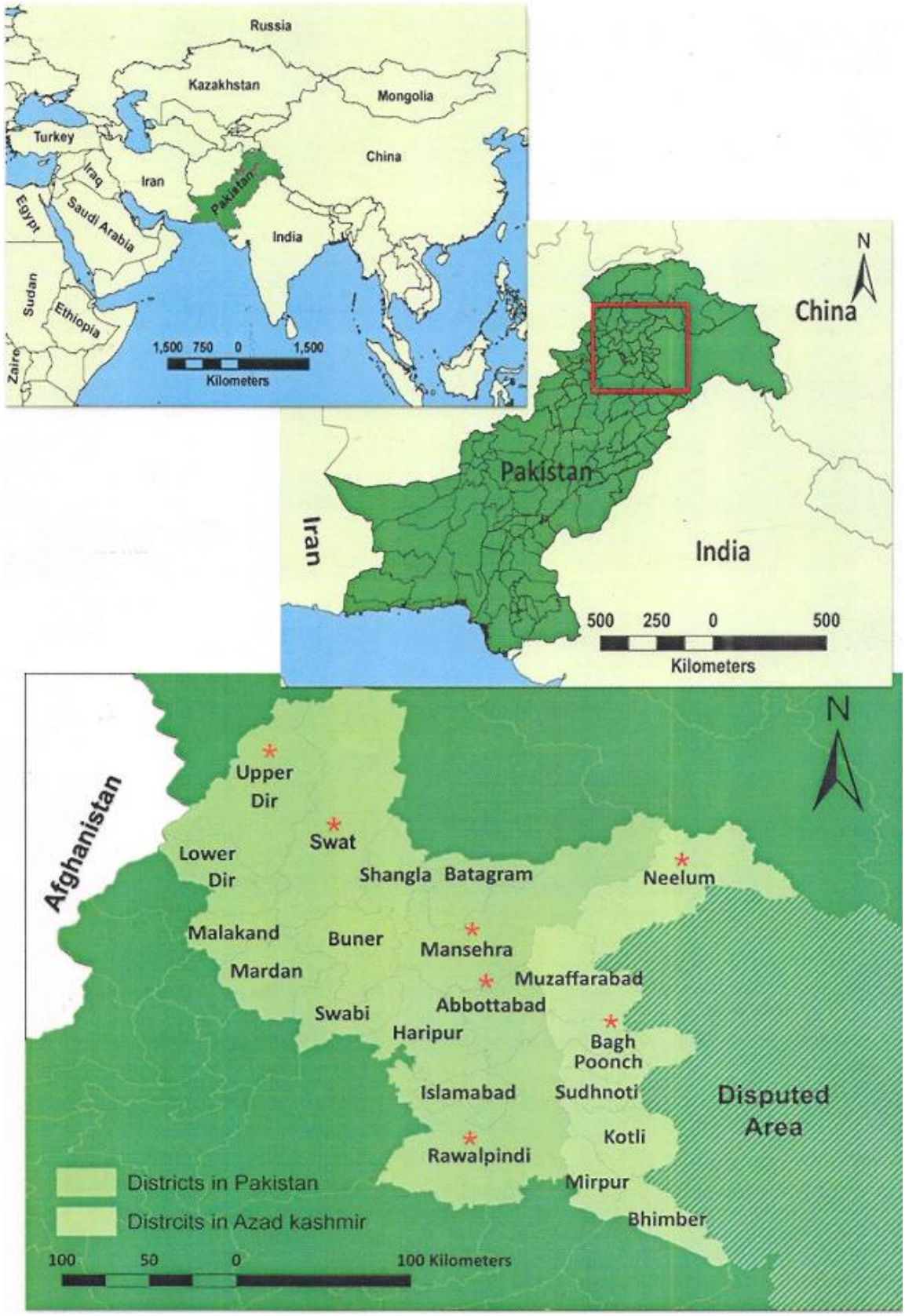

Fig. 1. Study Area Map; * showing the main locations (district) where moist temperate forests were studied. Details of the sites and stands are given in Table 1.

Table 1. Distribution of conifer species in moist temperate Himalayan region of Pakistan. Site characteristics of the sampling area.

Stand No.	Location and sites	Elevation (m)	Slope (º)	Aspect	Canopy	Communities
1. Malakand division						
	(a) Dir Upper					
1.	Kumrat	2400	R. Top	R. Top	Closed	*Pw/Cd*
2.	Pana Kot	2200	40	W	Closed	*Pw/Cd*
	(b) Swat					
3.	Malam Jabba 1	2600	34	W	Moderate	*Ap/Ps*
4.	Malam Jabba 2	2350	30	N W	Open	*Pw/Ap*
5.	Miandam	2600	49	N	Moderate	*Ap/Pw*
2. Azad Kashmir						
6.	Keran, District Neelam	1960	30	N E	Open	*Cd/Pw*
7.	Chikar, District Baagh	1930	28	N W	Moderate	*Pw*
8.	Sudhan Gali 1,	2450	22	E	Moderate	*Ap/Pw*
9.	Sudhan Gali 2	2500	32	N	Partly closed	*Ap/Pw*
10.	Sudhan Gali 3	2420	38	West	Moderate	*Pw/Ap*
3. Muree, Rawalpindi division						
11.	Ghora Gali	2100	29	N	Moderate	*Pw/Pp*
12.	Patreata Top 1	2300	40	S E	Closed	*Cd/Pw*
13.	Patreata Top 2	2300	25	S W	Moderate	*Pw*
14.	Nia, Near Patriata	2000	39	S	Moderate	*Pw/Ac*
15.	Kashmir Point	2500	39	S	Closed	*Ap/Pw*
4. Abbot Abad, Hazara division						
16.	Ghora Dhaka 1	2500	36	N E	Closed	*Ap/Tw*
17.	Ghora Dhaka 2	2500	32	S E	Closed	*Ap/Pw*
18.	Ghora Dhaka 3	2800	40	S W	Moderate	*Pw/Ap*
19.	Ghora Dhaka 4	2800	40	W	Closed	*Ap/Pw*
20.	Ghora Dhaka 5	2600	37	S W	Closed	*Ap/Pw*
21.	Khaira Gali	2730	42	S E	Closed	*Cd/Pw*
22.	Changla Gali 1	2650	47	W	Open	*Ap/Pw*
23.	Changla Gali 2	2670	35	S	Closed	*Pw/Ap*
24.	Kuzah Gali 1	2560	R. Top	R. Top	Moderate	*Cd/Ap*
25.	Kuzah Gali 2	2560	28	S E	Closed	*Ap/Pw*
26.	Nathia Gali, Lalazar 1	2640	35	S	Moderate	*Pw/Ap*
27.	Nathia Gali, Lalazar 2	2630	33	N W	Open	*Ap/Pw*
28.	Thandyani 1	2320	31	S	Moderate	*Pw/Cd*
29.	Thandyani 2	2300	38	S	Moderate	*Cd/Pw*
5. Kaghan Valley, district Mansehra						
30.	Paye	3100	38	S	Closed	*Pw/Ps*
31.	Sri	2900	39	N	Closed	*Ps/Ap*
32.	Shogran 1	2400	27	S W	Closed	*Pw/Ap*
33.	Shogran 2	2400	23	S	Closed	*Cd/Pw*
34.	Shogran 3	2500	33	S	Closed	*Cd/Ps*
35.	Paras, Malkandi Pine Park	1600	20	N E	Closed	*Cd/Jr*
36.	Khanian	2000	35	E	Closed	*Cd/Pw*
37.	Shinu 1, Near Jurait Park	1900	39	N W	Moderate	*Cd/Pw*
38.	Shinu 2, Near Jurait Park	1650	43	W	Closed	*Cd*
39.	Naran, River Belt 1	2500	R. Top	N W	Moderate	*Pw/Ps*
40.	Naran, River Belt 2	2500	R. Top	N W	Moderate	*Cd*
41.	Lalazar (Naran)	3000	45	N W	Closed	*Ap*

Key to abbreviations: R. Top = Ridge top, E = East, W = West, N = North, S = South, *Pw = Pinus wallichiana*, *Ap = Abies pindrow*, *Cd = Cedrus deodara*, *Ps = Picea smithiana*, *Tw = Taxus fuana*, *Ac = Albizia chinensis* and *Jr = Juglans regia*.
Note: Authority of species is shown in Table 4.

Table 2. Phytosociological Attributes and absolute values of tree species in forty one stands of moist temperate areas of Himalayan range of Pakistan.

Main location, sites and stand no.	Species name	Phytosociological attributes				Absolute values	
		Relative frequency	Relative basal area	relative density	IV	D ha^{-1}	BA m^2 ha^{-1}
1. Dir upper (district), Malakand division							
1. Kumrat	*Pinus wallichiana*	71	43	61	58	245	41
	Cedrus deodara	16	40	28	28	110	4
	Populus pamirica	12	10	10	11	40	9
	Abies pindrow	1	7	1	3	5	11
2. Panahkot	*Pinus wallichiana*	57	61	60	59	340	59
	Cedrus deodara	43	39	40	41	228	37
2. Swat (district), Malakand division							
3. Malam Jabba 1	*Abies pindrow*	83	91	95	90	288	64
	Picea smithiana	17	9	5	10	15	6
4. Malam Jabba 2	*Pinus wallichiana*	91	99	97	96	93	22
	Abies pindrow	9	1	3	4	2	1
5. Miandam	*Abies pindrow*	56	84	55	65	239	108
	Pinus wallichiana	44	16	45	35	196	20
3. Nellam (district), Azad Kashmir							
6. Keran	*Cedrus deodara*	60	61	60	60	52	25
	Pinus wallichiana	40	39	40	40	35	16
4. Bagh (district), Azad Kashmir							
7. Chikar	*Pinus wallichiana*	100	100	100	100	135	69
8. Suddhan Gali	*Abies pindrow*	41	49	42	44	70	26
	Pinus wallichiana	38	37	45	40	74	20
	Cedrus deodara	21	14	13	16	21	8
9. Suddhan Gali 2	*Abies pindrow*	63	93	83	79	110	67
	Pinus wallichiana	31	4	15	17	20	3
	Cedrus deodara	6	3	3	4	3	2
10. Suddhan Gali 3	*Pinus wallichiana*	83	70	95	83	117	8
	Abies pindrow	17	30	5	17	6	3
5. Murree (district), Rawalpindi division							
11. Ghora Gali	*Pinus wallichiana*	85	94	87	89	227	9
	Pyrus pashia	5	2	7	5	19	0.26
	Taxus fuana	5	2	3	3	7	0.07
	Quercus incana	5	2	3	3	7	0.1
12. Patriata Top 1	*Cedrus deodara*	83	91	83	78	362	55
	Pinus wallichiana	17	9	17	22	73	28
13. Patriata Top 2	*Pinus wallichiana*	100	100	100	100	429	78
14. Patriata Top 3	*Pinus wallichiana*	88	97	87	91	72	21
	Albizia chinensis	12	3	13	9	10	1
15. Kashmir Point	*Abies pindrow*	60	49	60	56	142	25
	Pinus wallichiana	27	25	27	26	65	13
	Juglans regia	8	21	8	13	18	11
	Cedrus deodara	5	5	5	5	12	5
6. Abbot Abad (district), Hazara division							
16. Ghora Dhaka 1	*Abies pindrow*	89	89	89	89	293	142
	Taxus fuana	5	9	5	7	16	14
	Pinus wallichiana	3	1	3	2	8	1
	Cedrus deodara	3	1	3	2	8	1
17. Ghora Dhaka 2	*Abies pindrow*	60	51	60	57	289	43
	Pinus wallichiana	35	47	35	39	168	39
	Taxus fuana	5	2	5	4	24	1.34
18. Ghora Dhaka 3	*Pinus wallichiana*	87	86	87	87	137	23
	Abies pindrow	13	14	13	13	20	4
19. Ghora Dhaka 4	*Abies pindrow*	60	60	60	60	160	36
	Pinus wallichiana	35	35	35	35	94	22
	Taxus fuana	5	5	5	5	13	3
20. Ghora Dhaka 5	*Abies pindrow*	62	42	62	55	112	12
	Pinus wallichiana	17	16	17	17	31	4
	Cedrus deodara	13	18	13	15	22	5
	Juglans regia	8	24	8	13	13	7

Table 2. (Cont'd.).

Main location, sites and stand no.	Species name	Phytosociological attributes				Absolute values	
		Relative frequency	Relative basal area	relative density	IV	D ha^{-1}	BA m^2 ha^{-1}
21. Khera Gali	*Cedrus deodara*	42	67	63	57	379	100
	Pinus wallichiana	33	31	26	30	159	37
	Abies pindrow	25	2	11	13	68	4
22. Changla Gali 1	*Abies pindrow*	57	78	57	64	60	31
	Pinus wallichiana	25	10	25	20	26	4
	Taxus fuana	15	11	15	14	16	26
	Juglans regia	3	1	3	2	3	1
23. Changla Gali 2	*Pinus wallichiana*	50	72	50	57	173	23
	Abies pindrow	46	27	46	40	158	8
	Taxus fuana	4	1	4	3	14	1
24. Kuzah Gali 1	*Cedrus deodara*	70	87	70	76	233	159
	Abies pindrow	25	12	25	21	83	15
	Pinus wallichiana	5	1	5	3	17	1
25. Kuzah Gali 2	*Abies pindrow*	60	51	60	57	200	43
	Pinus wallichiana	25	28	25	26	83	23
	Cedrus deodara	15	21	15	17	50	18
26. Nathia Gali 1	*Pinus wallichiana*	64	47	64	55	116	25
	Abies pindrow	36	53	36	45	66	29
27. Nathia Gali 2	*Abies pindrow*	95	96	95	91	128	60
	Pinus wallichiana	5	4	5	9	7	3
28. Thandyani 1	*Pinus wallichiana*	80	83	80	81	143	34
	Cedrus deodara	20	17	20	19	36	7
29. Thandyani 2	*Cedrus deodara*	50	74	70	65	120	15
	Pinus wallichiana	50	26	30	35	52	5
7. Mansehra (district), Kaghan valley							
30. Paye, Shogran	*Pinus wallichiana*	57	60	57	58	125	55
	Picea smithiana	28	30	28	29	60	28
	Abies pindrow	15	10	15	13	33	9
31. Sri, Shogran	*Picea smithiana*	67	70	67	68	279	102
	Abies pindrow	33	30	33	32	138	44
32. Shogran 1	*Pinus wallichiana*	62	72	62	65	149	75
	Abies pindrow	38	28	38	35	89	30
33. Shogran 2	*Cedrus deodara*	70	92	86	82	274	60
	Pinus wallichiana	20	2	7	10	23	2
	Abies pindrow	10	6	7	8	23	4
34. Shogran 3	*Cedrus deodara*	84	95	94	91	392	56
	Picea smithiana	8	4	3	5	10	3
	Abies pindrow	8	1	3	4	10	1
35. Paras	*Cedrus deodara*	55	96	80	76	176	54
	Juglans regia	18	1	8	9	19	1
	Pinus wallichiana	9	1	4	5	9	0.18
	Quercus ilex	9	1	4	5	9	1
	Quercus incana	9	1	4	5	9	0.1
36. Khanian	*Cedrus deodara*	75	91	83	83	282	43
	Pinus wallichiana	25	9	17	17	56	4
37. Shinu 1	*Cedrus deodara*	53	75	72	67	208	72
	Pinus wallichiana	47	25	28	33	79	24
38. Shinu 2	*Cedrus deodara*	100	100	100	100	410	36
39. Naran valley 1	*Pinus wallichiana*	65	77	65	69	102	79
	Picea smithiana	13	16	13	14	20	6
	Cedrus deodara	13	3	13	10	20	1
	Populus alba	6	3	6	5	10	1
	Abies pindrow	3	1	3	2	5	0.04
40. Naran valley 2	*Cedrus deodara*	100	100	100	100	284	50
41. Lalazar, Naran	*Abies pindrow*	100	100	100	100	189	109

Key to abbreviations: D ha^{-1} = Density ha^{-1}, BA m^2 ha^{-1} = Basal area m^2 ha^{-1} and IV = Importance value

Note: Authority of species is shown in Table 4

1. Monospecific *Pinus wallichiana* forest: At two different locations *i.e*., Chikar forest, Azad Kashmir (stand 7) and Patriata, Murree (stand 13) *Pinus wallichiana* is recorded as the sole dominating species. These sampling stands were located at the elevation of 1930 m and 2230 m with 25^o to 28^o moderate slopes respectively. The biotemperature of this community is low (14 to 15^o C) with high annual precipitation (185 to 215 cm). In these monospecific stands *Pinus wallichiana* density ranged from 135 to 429 ha^{-1} with 69 to 78 m^2ha^{-1} basal area. Seven non-Conifer understorey species with seedlings of *Pinus wallichiana* and *Cedrus deodara* were recorded from these two stands. Presence of *Cedrus deodara* seedlings indicated that trees of this species have been eliminated from this site. Poor floristic similarities exist among these two stands. *Berberis lyceum* and *Pinus wallichiana* seedlings were common in both stands. *Berberis lyceum* occupied 20 and 80% of the plot sampled with 13 and 27% relative frequency in both stands respectively and *Pinus wallichiana* seedlings attained 50 and 80% of the plot sampled with 30 and 27% relative frequency in these two locations. However**,** *Ribes alpestre, Jasminium grandiflorum* and *Hedera nepalensis* recorded from Chikar forest and *Echinops niveus, Cedrus deodara* seedlings and *Cotoneaster microphylla* were recorded from circular plot investigation at Patriata forest.

2. Monospecific *Cedrus deodara* forest: At Naran II (stand 40) and Shinu (stand 38) Kaghan valley deodar is recorded as a single dominating species. These stands were located at the elevation of 1650 m and 2500 m with flat ridge top to 43^o steep slopes. The biotemperature of these forests was 15.5 to 16.5^oC with an annual precipitation of 160 to 185 cm. In these monospecific stands deodar density ranged from 284 to 410 ha^{-1} with 36 to 50 m^2 ha^{-1} basal area. This species is considered as that of dry temperate area. Its presence in moist temperate area indicate a wide ecological amplitude of this species. Five non-tree species**,** including seedling of deodar and *Abies pindrow* were associated on the forest floor, under the pure stands of *Cedrus deodara*, however poor floristic similarities exist among two stands. *Abies pindrow* seedlings indicated logging of this species in recent past from this area. Nevertheless**,** following species are associated as understorey plants *i.e*., *Ficus palmata* (seedlings) and *Cymbopogon jawarancusa* occupied 20% each of the plots sampled with 50% each of the relative frequency in circular plot of stand 38. Whereas, in stand 40 again two non tree species *Asplenium viride* and *Aristida adscensonis* and seedlings of *Cedrus deodara* and *Abies pindrow* occupied 12.5% each of the total plot sampled with 25% each relative frequency. Sparse and depauperate vegetation was recorded underneath *Cedrus deodara* in both stands mainly due to anthropogenic disturbance.

3. Monospecific *Abies pindrow* forest: Closed canopy pure stand of *Abies pindrow* was found at only one location at Lalazar, (Naran, Kaghan valley, stand 41) at the elevation of 3000m on north west facing aspect, with 45^o slope angle. The biotemperature of this location is 13.5^oC with an annual precipitation of 190 cm. Among the communities studied this forest prevails in the coldest area with highest annual precipitation. This stand showed a density of 189 trees ha^{-1} with 109 m^2ha^{-1} basal area. The area is extensively disturbed due to human interference, resulting in only two understorey plants *i.e*., *Echinops niveus* (20% of the total plot sampled) and *Aristida adscensonis* (50% of the plot sampled) with 29 and 71% relative frequency were found in this stand. No seedlings and saplings of *Abies pindrow* were recorded which presumably indicates little or no regeneration in this forest.

Table 3. Summary of Phytosociological sampling of 41 stands of moist temperate area of Pakistan. Mean importance value, absolute density ha^{-1}, basal area m^2ha^{-1} and dominant position of conifer and angiospermic tree species are presented. Species are ranked on the basis of importance value.

S.No.	Name of species	Presence in # of stands	Mean importance value	Mean density ha^{-1}	Mean basal area m^2ha^{-1}	Dominant		
						1st	2nd	3rd
1.	*Pinus wallichiana*	35	46 ± 5.2	108.6 ± 15.8	25.4 ± 4	15	17	3
2.	*Abies pindrow*	27	42.9 ± 5.9	108.8 ± 18	34.41 ± 7.1	13	8	4
3.	*Cedrus deodara*	22	49.6 ± 7.3	156.9 ± 28.8	37 ± 8.3	12	3	5
4.	*Taxus fuana*	6	6 ± 1.7	15 ± 2	7.6 ± 4.2	-	1	5
5.	*Picea smithiana*	5	25 ± 11	77 ± 51	29 ± 19	1	4	-
6.	*Juglans regia*	4	8 ± 3.2	11.7 ± 4.7	3 ± 2	-	1	1
7.	*Quercus incana*	2	4 ± 1	8 ± 1	0.1 ± 0.0	-	-	-
8.	*Quercus ilex*	1	5	9	1	-	-	-
9.	*Populus pamirica*	1	11	40	9	-	-	1
10.	*Albizia chinensis*	1	9	10	1	-	1	-
11.	*Populus alba*	1	5	10	1	-	-	-
12.	*Pyrus pashia*	1	5	19	0.26	-	1	-

Note: Species 1-5 are Conifer while 6-12 belong to Angiosperm

Authority of species: *Populus pamirica* Komarov and for other species referes to Table 4

Table 4. Summary of circular plot (understorey species) from forty one stands of study areas. Species are listed in decreasing order of presence in stands and range of relative frequency in stands.

S. No.	Name of species	NSSP	RF in stands (range)
1.	*Pinus wallichiana* A.B. Jackson (seedlings)	27	4.0-30
2.	*Pteris cretica* L. mant	22	4.0-25
3.	*Acer caesium* Wall. ex brandis	19	5.0-32
4.	*Abies pindrow* Royle (seedlings)	17	4.1-58
5.	*Cedrus deodara* (Roxb.) G. Don. (seedlings)	15	2.0-32
6.	*Rosa brunonii* Lindl	10	7.0-22
7.	*Berberis lycium* Royal I.C.	9	6.0-26.7
8.	*Hedera nepalensis* K. Koch	9	5.0-25
9.	*Rubus biflorus* Ham ex Sm.	9	4.0-17
10.	*Thymus serphyllum*. L.	9	3.0-25
11.	*Rosa webbiana* Wall ex Royle	8	4.0-22
12.	*Rubus ellipticus* Smith	8	6.0-21
13.	*Adiantum venustum* D.Don	6	3.0-18
14.	*Echinophs niveus* Wall ex D.C.	6	7.0-29
15	*Adiantum capillus veneris* L.	5	9.0-18
16.	*Aristida adscensionis* L.	5	5.0-71
17.	*Cymbopogon jawarancusa* (Jones) Schult	5	7.0-50
18.	*Duchesnea indica* (Andr)	5	4.0-13
19.	*Dicanthium annulatum* (Forssk**)**	4	8.0-16
20.	*Indigofera hebepatela* Ali	4	6.0-8
21.	*Picea smithiana* (Wall.) Boiss (seedlings)	4	5.0-12
22.	*Podophylum emodi* Wall	4	10.0-21
23.	*Quercus incana* Roxb (seedlings)	4	3.0-12
24.	*Andropogon lancifolius* (Toin) Hochst	3	8.0-25
25.	*Athyrium filix foemina* (L.)	3	6.0-13
26.	*Cotoneaster microphylla* Wall ex Lindl	3	6.7-26
27.	*Gloriosa superba* L.	3	4.0-10
28.	*Plantago asciatica* L.	3	5.0-9.8
29.	*Ranunculus muricatus* L.	3	5.0-8
30.	*Sinapis arvensis* L.	3	9.0-11
31.	*Taxus fuana* Nan Li & R.R. Mill (seedlings)	3	4.0-7.3
32.	*Argemone mexicana* L	2	14.6-17.0
33.	*Aristida cyanantha* Nus ex. Stand	2	15-18
34.	*Asplenium viride* Huds.,	2	8.0-25
35.	*Aster molliusculus* (D C) C.B. Clarke	2	1.0-7
36.	*Chrysopogon echinulatus* Nees ex Steud	2	11.0-27
37.	*Erianthus griffithii* (Munro) HK.f	2	10.0-20
38.	*Juglans regia* L. (seedlings)	2	1.0-3
39.	*Pteridium aquilinum* (L)	2	7.0-22
40.	*Punica granatum* L.	2	11.0-22
41.	*Pyrus pashia* Ham ex D. Don (seedlings)	2	8.0-13
42.	*Quercus ilex* Griff., Itin. (seedlings)	2	7.0-14
43.	*Rosa macrophylla* Lindl	2	8.0-11

Table 4. (Cont'd.).

S. No.	Name of species	NSSP	RF in stands (range)
44.	*Rubus macilentus* Camb.,	2	11.0-25
45.	*Rubus ulmifolius* Schott.	2	14.1-14
46.	*Agaricus campestris* L. Ex. Fr.	1	4
47.	*Andropogon tristis* Nees ex Hack	1	23
48.	*Anemone falconeri* T.T	1	7
49.	*Asplenium adiantum nigrum*. L	1	8
50.	*Asplenium trichomanes* L.	1	12
51.	*Athyrium atkinsonii* L.	1	9
52.	*Berberis kunawurensis* Royle	1	6
53.	*Bothriochloa bladhii* (Retz)	1	4
54.	*Brassica campestris* L.	1	17
55.	*Brassica nigra* (L.) Koch.	1	7
56.	*Campanula tenuissima* Dunn	1	9
57.	*Carissa opaca* Stapf ex Haines	1	5
58.	*Chrysopogon aucheri* (Boiss) Stapf.	1	11
59.	*Companula latifolia* L.	1	8
60.	*Delphinium uncinatum* H&T	1	11
61.	*Dryopteris barbegera* (Moore) O.Kze	1	7
62.	*Ephedra gerardiana* Wall ex Stapf	1	12
63.	*Euphorbia hispida* Boissier	1	11
64.	*Geranium wallichianum* D. Don	1	7
65.	*Hypericum dyeri* Rehder	1	20
66.	*Indigofera gerardiana* Wall. Ex Baker	1	20
67.	*Jasminum grandiflorum* L.	1	19
68.	*Lycopodium selago* L.	1	11
69.	*Morus alba* L.	1	13
70.	*Selaginella jacquemontii* Spring	1	4
71.	*Ficus palmata* Forssk (seedlings)	1	50
72.	*Pleopeltis clathrata* (clarke) Bedd	1	7
73.	*Polygala abyssinica* R. Br. Ex Fresen	1	15
74.	*Polygala erioptera* DC	1	18
75.	*Bistorta amplexicaule* (D.Don) Greene	1	10
76.	*Polygonum caespitosum* Blume	1	13
77.	*Polygyla sibrica* L.	1	7
78.	*Polyporus abietinus* Fr.	1	7
79.	*Quercus dilatata* Lindl. ex Royle (seedlings)	1	7
80.	*Ribes alpestre* Dcne. ex Jacq.,	1	13
81.	*Rubus antennifer* Hk. F	1	14
82.	*Rubus niveus* Hk. F	1	9
83.	*Selaginella sanguinlenta* (L.)	1	15
84.	*Sonchus asper* L.	1	5
85.	*Carum carvi* (Gracile) Wolff	1	7
86.	*Tetrapogon villosus* Huds / Desf	1	8
87.	*Urtica dioica* L.	1	6

Key to abbreviations: NSSP = Number of stands in which species was present and RF = Relative frequency (range) in stands

Table 5. Communities, stand numbers and topographic attributes of communities are listed below.

S. No.	Community	Stand No.	Elevation (m) range	Slope (o)	Aspect
1.	*Pinus wallichiana* (Pure)	7,13	1930-2230	25-28	NW-SW
2.	*Cedrus deodara* (Pure)	38,40	2500-2650	0-43	W-NW
3.	*Abies pindrow* (Pure)	41	3,000	45	NW
4.	*Pinus wallichiana/Picea smithiana*	30,39	2500-3100	Plain-38	S, NW
5.	*Pinus wallichiana/Albizia chinensis*	14	2,000	39	S
6.	*Pinus wallichiana/Pyrus pashia*	11	2,100	29	N
7.	*Cedrus deodara/Pinus wallichiana*	6,12,21,29,33,36,37	1900-2730	23-42	NE,SE,S,E,NW
	Pinus wallichiana/Cedrus deodara	1,2,28	2200--2400	Plain-40	R. top, W, S.
8.	*Cedrus deodara/Picea smithiana*	34	2500	33	S
9.	*Cedrus deodara/Abies pindrow*	24	2560	Plain	R. top
10.	*Cedrus deodara/Juglans regia*	35	1,600	20	NE
11.	*Abies pindrow/Pinus wallichiana*	5,8,9,15,17,19,20,22,25,27	2450-2650	22-49	N,E,SE,W,S,NW
	Pinus wallichiana/Abies pindrow	4,10,18,23,26,32,	2350-2800	27-40	NW,W,SW,S
12.	*Abies pindrow/Picea smithiana*	3	2600	34	W
	Picea smithiana/Abies pindrow	31	2900	36	N
13.	*Abies pindrow/Taxus fuana*	16	2500	28	NE

Note: Authorities of scientific names of plants are mentioned in Table 4
For main location and sites of stands refer to Table 1

4. *Pinus wallichiana-Picea smithiana* community: This community was recorded at two different locations *i.e*., Paye, Shogran (stand 30) and Naran 1 (stand 39), situated at Kaghan valley. Both the stands were occurred on South and North-West facing exposures with gentle (5^o) to extremely steep slopes (38^o) on 2500 to 3100 m elevation respectively. The biotemperature associated with these forests is 16 to 17.5^{o}C. The annual precipitation has been estimated as 170 to 184 cm. In these communities dominant species *Pinus wallichiana* attained 58 to 69% importance value**,** 120 to 125 trees ha^{-1} density with 55 to 79 m^2 ha^{-1} basal area while co-dominant species *Picea smithiana* occupied 14 to 29% importance value**,** 20 to 60 trees ha^{-1} density with 6 to 28 m^2 ha^{-1} basal area. *Cedrus deodara* and *Populus alba* are found as third and fourth dominant species in stand 39 (Naran I) with 10% and 5% importance value each, 20 and 10 trees ha^{-1} density respectively and each having 1 m^2 ha^{-1} basal area. At Paye (stand 30) *Abies pindrow* was designated as associated species, it attained 13% importance value, 33 trees ha^{-1} density and 9 m^2 ha^{-1} basal area while at Naran I it showed 2% importance value, 5 trees ha^{-1} density and extremely low basal area (0.04 m^2 ha^{-1}).

As far as understorey species are concerned, many plant species (mostly angiosperms, some gymnosperms and Pteridophytes) were distributed in forest floor of Paye, Shogran *i.e*., *Rosa webbiana*, (80% of the plot sampled with 20% relative frequency), *Rubus biflorus*, (60% of the plot sampling with 16% relative frequency), *Sinapis arvensis*, *Pinus wallichiana* (seedlings) and *Thymus serpyllum* (40% of the plot sampling with 11% relative frequency each), *Acer caesium* (30% of the plot with 8% relative frequency), *Sonchus asper*, *Picea smithiana* (seedlings) and *Pteris cretica* (20% of the plots with 5% relative frequency each), while *Ephedra gerardiana* (a gymnosperm) (38% of the plot with 12% relative frequency), *Asplenium trichomenses*, *Tetrapogon villosus* and *Asplenium viride* (25% each of the plot) were recorded in stand 39. Seedlings and saplings of Conifer species were also recorded in circular plots *i.e*., *Pinus wallichiana* (40 and 60% of plots), *Picea smithiana* (20 and 40% of plots), *Abies pindrow* (30 and 40% of plots), while seedling of *Cedrus deodara* were recorded only from Naran I (stand 39).

5. *Pinus wallichiana-Albizia chinensis* community: This is moderate canopy community in which *Pinus wallichiana* is dominant. Occasionally *Albizia chinensis* is associated with the *Pinus wallichiana* with low abundance. This community was recorded at Patriata 3 (stand 14) sampling area lies on South facing exposure, 39^o slope on 2200m elevation. The biotemperature of this community is 15.5^o C with an annual precipitation of 185 cm. *Pinus wallichiana* showed 91% importance value with 72 individuals ha^{-1} and 21 m^{2}ha^{-1} basal area**,** while co-dominant broad leaved angiospermic species *Albizia chinensis* have 10 individual ha^{-1} with a low value of basal area *i.e*., 1 m^{2}ha^{-1}. *Pinus wallichiana* seedlings and saplings were present in this stand. It occupies 67% of the total plot sampled with 26% relative frequency of the total circular plot. Other understorey species *i.e*., *Cotoneaster microphylla* attained 67% of the plot sample with 26% relative frequency. Some other understorey species including *Rosa webbiana* (17% in plot and 7% relative frequency), *Berberis lyceum* (17% in plots and 7% relative frequency), *Pyrus pashia* (33% in plots and 13% relative frequency) and *Rosa brunoni* (50% in plots with 21% relative frequency) occurred in this community.

6. *Pinus wallichiana-Pyrus pashia* community: This community supported by the Ghora gali (Murree, stand 11) sampling area, lies on North facing, 29^o moderate

slope at 2100 m elevation. The biotemperature of this area is 16.5°C with an annual precipitation of 178 cm. *Pinus wallichiana* showed 89% importance value with 227 individuals ha^{-1} and 9 m^2ha^{-1} basal area**,** while a co-dominant broad leaved species *Pyrus pashia* was present with 5% importance value and 19 individual ha^{-1} density and a very low, 0.26 m^2ha^{-1} of basal area. *Taxus fuana* and *Quercus incana* also showed their presence in this stand with 3% importance value each. Both species have 7 trees ha^{-1} each density and very low basal area *i.e*., 0.07 and 0.1 m^2ha^{-1}. No seedlings or saplings of *Pinus wallichiana* was recorded from this location but seedlings of *Taxus fuana* were present which indicates possible replacement of *Pinus wallichiana* with *Taxus fuana* in this forest in the future.

Ground flora consists of the following species: *Rosa brunonii* occurring in 80% of the plots with relative frequency of 19.5%, *Cotoneaster microphylla* occupied 70% of the plots with relative frequency of 17%, *Argemone mexicana* attained 60% of the plots with 15% relative frequency, *Rubus biflorus* and *Pteris cretica* show 50% each of the plots sampled and 12.2% each relative frequency, *Plantago asciatica* occurring 40% of the plots with 10% relative frequency, and *Indigofera hebepetala* occupy 30% of the plots with 7.3% relative frequency.

7. *Cedrus deodara-Pinus wallichiana* community: This is the second most common community in the surveyed area, recorded at 10 different locations from 1900 m to 2730 m elevation on moderate ridge top to very steep (45°) slopes. The biotemperature varies from 15.5-17.5°C while annual precipitation ranges from 160 to 180 cm. At many places the canopy was closed and most common aspect was south facing exposure. On the basis of importance value, at some locations, this community may be designated as *Pinus wallichiana – Cedrus* community such as stands 1, 2 and 28. In these stands importance value of *Pinus wallichiana* was higher than that of *Cedrus deodara* (58 to 81%), density 143 to 340 trees ha^{-1} with 34 to 59 m^2 ha^{-1} basal area. In stand 1, Kumrat a broad leaved species *Populus pamirica was* designated as a third dominant and a few trees of *Abies pindrow* were also recorded.

Stands in which deodar (*C. deodara*) appeared as the first leading dominant (stands 6, 12, 21, 29, 33, 36 and 37) its importance value ranged from 57 to 83% (density 52 to 362 ha^{-1} and basal area 15 to 100 m^2 ha^{-1}) while in stands where *Pinus wallichiana* is the leading dominant the importance value of *C. deodara* ranged between 19 to 41% with density 36 to 228 trees ha^{-1} and 4 to 37 m^2 ha^{-1} basal area. Considering all stands, density of *C. deodara* ranged from 52 to 362 trees ha^{-1} and basal area were 4 to 100 m^2 ha^{-1}.

Abies pindrow present as third dominant species in Stand 21 Khaira Gali and stand 33 Shogran 2 occupying 8% importance values each, 19 to 33 trees ha^{-1} density and 1-4 m^2 ha^{-1} basal area respectively. Due to low importance value it occupied fourth position at Kumart (stand 1) with the density of 5 trees ha^{-1} and 11 m^2ha^{-1} basal area.

Seedlings and saplings of *Cedrus deodara* and *Pinus wallichiana* were recorded in 5 stands as first and second dominant species in the understorey (circular plot) respectively while *Abies pindrow* was found in 3 stands indicating survival potential of this species in these stands**.** Like other communities, ground flora of this community also exhibited varied floristic composition. Some understorey dominant plants were *Acer caesium, Pteris cretica, Thymus cerpyllum* (found in five stands) whereas *Cymbopogon jawarancusa, Rosa brunoni, Berberis lycium* were found in four stands. *Pteris cretica* and *Berberis lycium* each occupied 40% of the plot with 17 % each relative frequency in stand 12 (Patriata 1). *Rosa webbiana, Erianthus griffithii, Hedera nepalensis, Indigofera hebepetala, Pteridium equalinum, Rubus ellipticus, Duchesnea indica* were recorded in two stands out of 10 stands.

Following species attained 20% frequency such as *Adiantum venustum, Bothriochloa bladhii, Brassica nigra, Dicanthium annulatum, Plantago asciatica, Polyporus abietinus, Rubus antennifer,* and *Rubus biflorus* etc. Forty eight understorey species were found in ten stands of this community, species with low frequency (10% of the plot) were *Agaricus compestris, Aristida adscensionis, Asplenium filix, Aster molliusculus, Carissa opaca, Juglans regia, Quercus dilitata* (seedlings), and *Quercus ilex* (seedlings).

8. *Cedrus deodara–Picea smithiana* community: This community was distributed from Shogran, Kaghan valley in Stand 34 on South facing steep slope (33º) on 2500 m elevation. The biotemperature of this forest is 18.2°C while the annual precipitation is 175 cm. *Picea smithiana* had 5% of the total importance value with 10 trees ha^{-1} and low basal area *i.e*., 3 m^2 ha^{-1}. At this location *Abies pindrow* was also associated with similar quantity but lower basal area**.** In this forest type Deodar was dominant with 91% of total importance value, density of 392 ha^{-1} and a basal area of 56 m^2 ha^{-1}. Ground flora (circular plot) was composed of six species including deodar seedlings. In this stand common understorey species were: *Acer caesium and Pteris cretica* occupied 60, 40% of the plots with 32 and 21% relative frequency. *Rubus ellipticus,* and *Aristida adscenionis* attained 30% each of the plot with 16% relative frequency each while seedlings of *Cedrus deodara* and *Hedera nepalensis* occupied 20 and 10% of the plot with 10 and 5% relative frequency respectively.

9. *Cedrus deodara–Abies pindrow* community: This community was recorded at Kuzah Gali (stand 24) on moderate ridge top slope at 2560m elevation with moderate canopy**.** The biotemperature of Kuzah Gali is 14.5°C while the annual precipitation recorded from this area is 180 cm. Importance value of *Cedrus deodara* was 76%. In this forest type a high density (233 trees ha^{-1}) and highest basal area (159m^2ha^{-1}) were recorded from *Cedrus deodara*. This community was co-dominated by *Abies pindrow* and *Pinus wallichiana* was also associated in this forest with low importance value. These two species had importance values of 21 and 3% with 83 and 17 trees ha^{-1} density and basal area 15 and 1 m^2ha^{-1}.Circular plot

sampling showed seedlings/saplings of the three dominant conifer species (*Abies pindrow*, *Pinus wallichiana* and *Cedrus deodara*) occupied 40, 20 and 20% of the plot sampled with 15, 8 an 8% relative frequency. Some other species like *Acer caesium*, *Pteris cretica* and *Andropogon lancifolius* which occupied 80, 60 and 40% of the plots respectively with 31, 23 and 15% relative frequency.

10. *Cedrus deodara-Juglans regia* community: This community was located on lowest elevation in study area (1600m) on north- east facing exposure with gentle slope 20º at Paras, Kaghan valley (stand 35). The biotemperature of Paras is 17.5°C while the annual precipitation is 170 cm. Co-dominant angiospermic tree species occupied only 9% of the total importance value with 19 trees ha^{-1} density and very low basal area (1 m^2ha^{-1}). Dominant Conifer species *Cedrus deodara* occupied 76% importance value with 96% of the relative basal area forming closed canopy. It showed high density of 176 trees ha^{-1} with 54 m^2ha^{-1} basal area. *Pinus wallichiana, Quercus ilex* and *Quercus incana* were the associates of this forest type; each of these species occurred with 9 trees ha^{-1} density. Understorey was represented by *Rosa webbiana* and *Rosa brunonii* which were present in 50% each of the total plots sampled and 44% relative frequency of the total circular plots. *Rubus ulmifolius, Hedera nepalensis*, seedlings of *Quercus ilex* and C*edrus deodara* (33% each of the plot sampling) were also recorded from forest floor.

11. *Abies pindrow-Pinus wallichiana* community: This type of community is the most widely distributed type in the sampling area, recorded at 16 different locations from 2350 m to 2800m elevation on moderate (22°) to very steep (49°) slopes. The biotemperature ranges from 14.5 to 17.5°C while the annual precipitation varies from 165 to 180 cm. At many places the canopy was closed (in 8 stands), or moderate (in 5 stands) and least frequently open (in 3 stands)**.** In stands 5, 8, 9, 15, 17, 19, 20, 22, 25 and 27 *Abies pindrow* appeared as first dominant. In these stands an importance value of *Abies pindrow* was higher than that of *Pinus wallichiana* which ranged from 44% to 91% with density 60 to 289 trees ha^{-1} and basal area 12 to 108 m^2ha^{-1}.

Stands in which *Pinus wallichiana* appeared as a first leading dominant the importance value of *Abies pindrow* ranged from 4% to 45% while density 2 to 158 trees ha^{-1} and basal area 1 to 30 m^2ha^{-1}. On the basis of greater importance value, at some locations, this community may be designated as *Pinus wallichiana- Abies pindrow* community (stands. 4, 10, 18, 23, 26 and 32), its importance value ranged from 55% to 96% with 93 to 173 trees ha^{-1} density and 8 to 75 m^2 ha^{-1} basal area. Stands in which *Abies pindrow* appeared as a first leading dominant the importance value of *Pinus wallichiana* ranged from 9% to 40% while density 7 to 196 trees ha^{-1} and basal area 3 to 39 m^2ha^{-1}.

Along with *P. wallichiana* and *Abies pindrow*, some other conifer species (*Cedrus deodara* and *Taxus fuana*) and broad leaf species (*Juglans regia*) were found as third or fourth dominant species in some stands, such as in stand 8, 9 and 20 *Cedrus deodara* was found as third dominant species while in stand 15 it occupies the fourth position. In these stands the importance values of *Cedrus deodara* ranged from 4% to 16% with the density of 3 to 22 trees ha^{-1} and basal area is 2 to 8 m^2ha^{-1}.

Taxus fuana occupies on third position with respect to importance value in stands 17, 19, 22 and 23 (Ghora Dhaka II and IV, Changla gali I & II). It has 3 to 14% importance value with the density of 13 to 24 trees ha^{-1} and 1 to 26 m^2 ha^{-1} basal area. In three stands a broad leaved angiospermic species *Juglans regia* was associated as a third dominant (stand 15 Kashmir point), fourth dominant (stand 20 Ghora Dhaka 5 and stand 22 Changla Gali I). It occupied 13, 13 and 3% importance value respectively while the density 3-18 trees ha^{-1} and 1-11 m^2 ha^{-1} basal area.

It is the most common vegetation type of the study area, hence, 46 understorey species were recorded under the canopy cover of this community. Some dominant species were *Pteris cretica* (found in 11 stands), *Acer caesium* (in 10 stands), *Rubus biflorus, Hedera nepalensis, Delphenium uncinatum, Adiantum capillus veneris* (in 4 stands each) occupied in 58% of the plots sampled with 14% average relative frequency. Species found in three stands were *Adiantum venustam, Echinops niveus, Gloriosa superba, Podophylum emodi, Quercus incana, Rosa brunonii, Rosa webbiana, Rubus ellipticus* and *Thymus serphyllum. Andropogon lancifolius, Aristida cyanantha, Asplenium filix, Chrysopogon echinulatus, Duchesnea indica, Ranunculus muricatus,* and *Rubus macilentus* appeared in two stands.

Andropogon tristis, Anemone falconeri, Aster molliusculus, Athylium atkinsonii, Berberis lycium , Berberis kunawurensis, Brassica compestris, Campanula tenuissima, Chrysopogon aucheri, Geranium wallichianum, Hypericum dyeri, Indigofera hebepatela, Juglans regia (seedlings), *Picea smithiana*(seedlings), *Plantago asiatica, Polygala abyssinica, Polygala erioptera, Bistorta amplexicaule, Polygyla sibrica, Punica granatum, Pyrus pashia, Rosa macrophylla, Sinapis arvensis* and *Urtica dioica* occurred in only one stand.

Seedlings and saplings of *Pinus wallichiana* were found in 15 stands, *Abies pindrow* in 8 stands, *Cedrus deodara* in 4, *Taxus fuana* in 2 and *Picea smithiana* in 1 stand out of 16 stands, exhibited the future trend of species in these forests.

Average frequencies of the seedlings or other dominant understorey species recorded from circular plot sampling are described. Seedlings of *Abies pindrow* attained 28% of the plot sampling, *Pinus wallichiana* 59%, *Cedrus deodara* 6% and *Acer caesium* attained 39%. Other species like *Pteris cretica* 28%, *Adiantum capillus veneris* 14%, *Hedera nepalensis* 7.5%, *Rubus biflorus* 4% and *Rubus ellipticus* attained 11% average frequency in this community (comprises on 16 stands). Average frequency obtained by the frequency of species in all occurring stands / total no. of stands of this community *i.e*., 16.

12. *Abies pindrow–Picea smithiana* community: This community was found on two different locations of study area with overlapping conditions. Malam Jabba (stand 3) sampling site was located on West facing steep slope (34º) at 2600m elevation shows *Abies–Picea* community whereas Sri, Shogran (stand 31), North facing steep slope (36º) on 2900m elevation shows *Picea-Abies* community. The biotemperature associated with this community varies between 14.3 to 14.8°C while the annual precipitation ranges between 180 to 187 cm. Importance value of *Abies pindrow* in Malam Jabba is 90% whereas in Sri, it is 32%. The density of 288 trees ha^{-1} was recorded from Malam Jabba and 138 trees ha^{-1} from Sri. Basal area of 64 and 44 m^2 ha^{-1} recorded respectively. *Picea smithiana* showed 15 and 279 trees ha-1 density with 6 & 102 m^2ha^{-1} basal area in both stands respectively.

Seedlings and saplings of both Conifer species were recorded only at Sri, occupied 33 % of the plots sampled with 8% each relative frequency. Among other species only *Pteris cretica* and *Adiantum venustum* were found in both stands. *Pteris cretica* attained 40 and 100% of the plot sampled with 15 and 25% relative frequency in both the stands respectively while *Adiantum venustum* occupied 30, 50% of the plot sampled with 11 and 13% relative frequency. The circular plot of Malam Jabba included *Rubus biflorus, Berberis lyceum* (attained 40% each of the plot sampled with 15% each relative frequency), *Rosa macrophylla, Lycopodium selago, Euphorbia hispida,* and *Duchesnea indica,* occupied 30% each of the plots sampled with 11% each of the relative frequency. The understorey investigation by circular plot of Sri included *Quercus incana* (seedlings occupied 17% of the plots with a relative frequency of 4%), *Rubus ellipticus, Ranunculus muricatus* (attained 33% each of the plots with a relative frequency of 8% each), *Acer caesium* (seedlings) and *Polygonum caespitosum* (occupied 50% of the plots with a relative frequency of 13% each).

13. *Abies pindrow–Taxus fuana* community: This community was found only at Ghora Dhaka 1 (stand 16) sampling site, located on North-East facing moderately steep slope (28º) on 2500m elevation. The biotemperature of this community is 15.0°C while the annual precipitation is approximately 173 cm. *Abies pindrow* showed high (89%) importance value with a density of 293 stem ha^{-1}. *Taxus fuana* occurred with only 7 percent importance value with 16 stem density ha^{-1} as a co-dominant species. *Pinus wallichiana* and *Cedrus deodara* occur in this stand with low importance values *i.e*., 2% only with the density 8 trees ha^{-1} and 1 m^2 ha^{-1} basal area each.

Seedlings and Saplings of *Abies pindrow* and *Pinus wallichiana* occupied 70 and 30% of the plots with 58, 25% relative frequency in the understorey. *Rubus biflorus* is the only non-tree species attained 20% of plots with 17% relative frequency. No seedlings and saplings of *Taxus fuana* occurred in circular plots which showed poor regeneration of this species.

Discussion and Conclusions

Quantitative vegetation description of conifer dominating moist temperate forest of Pakistan is presented in this article. The investigation focused on quantitative vegetation data of 41 stands, 12 tree species and 87 understorey species, that was organized and classified (using K-mean method) into 13 forest communities and evaluating the relationships between the communities and the environment, essentially the topographic bioclimatic conditions prevailing in the area. According to Brown & Curtis (1952) importance value of trees exhibits the relative ecological importance of each species in a stand. Those species which attained high importance values were considered as dominants. Out of 41 stands, 5 stands were monospecific *i.e*., 2 pure stands of *Pinus wallichiana*, 2 stands of *Cedrus deodara*, while 1 stand of *Abies pindrow* were recorded. Except for these 3 monospecific forest types, 10 other community types could also be recognized easily. *Picea smithiana* and *Taxus fuana* are generally associated with other species, low in abundance due to severe disturbance; therefore, they are recorded from a few locations *i.e*., 5 and 6 stands respectively and were not found as monospecific stands.

Pinus wallichiana, occurring at 35 sites, was recorded as a leading or co-dominant showing a widespread occurrence across the range of altitude 1600 to 3100 m asl. It usually prefers to grow on south and north facing exposures while at some locations it is recorded from west and east exposures also. Thus, it can be regarded as a species with wide ecological amplitude (or niche width) particularly with respect to altitude. *Abies pindrow, Picea smithiana* and *Taxus fuana* were found to prefer high elevation and dominated the vegetation between 2500 to 3100 m altitudes. *A. pindrow* is second widely distributed species in moist temperate area, attaining the position of a leading dominant in 13 different stands, while it remained as a co-dominant in 8 stands. *Abies pindrow* was mostly found in association with *Pinus wallichiana* (16 stands) but showed poor association with *Cedrus deodara, P. smithiana* and *T. fuana*. At one location it formed a monospecific forest. In earlier studies no such monospecific stand of *A. pindrow* was recorded from high elevation (3000m). In the present study it was found to prevail from ridge top to steep slope (39°) while it preferred to grow on south facing exposures and mostly avoided eastern aspect. Its associations were seen from 2500-2900m elevation. *Cedrus deodara* thrives at different altitudes and was recorded from 22 different locations of the study area from comparatively low elevation, 1600 m up to 2730 m asl. It constituted a dominant position in 12 forests, co-dominant in 3 forests while it was placed at third position in 5 stands. It was seen as a dominant species mainly in Kaghan valley (dominant in 7 forests) from the elevation of 1600m to 2500m, indicating that it forms communities at medium elevation. *Picea smithiana* exhibited rather restricted distribution in moist temperate area occurring at high elevation (2500-3000m). However, Wahab *et al*., (2008) recorded this species from Sheshan, Afghanistan which is a dry temperate area while Ahmed & Naqvi (2005) reported *Picea smithiana* from Naltar valley (dry temperate area) and from Astor (sub-alpine region) which shows the adaptability and distribution range of *Picea smithiana* in different climatic zones. It forms communities with three conifer species of the study area except *Taxus fuana*. In the present study, it was recorded from steep slopes (33° to 39°) but at one location it flourished at ridge top. *Taxus fuana* is a moist temperate

species but widely exploited and disturbed by the local inhabitants, so it also exhibited rather restricted distribution in the study area and was recorded from six stands on steep slopes (29° to 47°). Like *P. smithiana*, it seems to avoid east exposures. In all stands of the study area *Taxus fuana* did not occupy dominant or co-dominant position but at one location it attained third rank albeit with low importance value. None of the Angiosperm (broad-leaved) tree species attained the position of leading dominant though at some places they occurred as second or third dominant species. Therefore, it is apparent that in the vegetation under study there exists an underlying altitudinal gradient; species seem to prefer different altitudes, though there exists some overlap between their altitudinal ranges. Some of the community types recognized here have been previously reported by earlier workers (Chaghtai *et al.*, 1989).

The main community types recognized, are discussed in the succeeding text. *Pinus wallichiana* was recorded from 35 stands as one of the first three dominants. Ahmed *et al.,* (2006) observed pure stands of *Pinus wallichiana* at Nalter (Gilgit) on South facing slopes at 2770 m elevation and Takht-e-Sulaiman (Baluchistan) at 3100 m elevation. They recorded *Pinus wallichiana-Quercus incana* community from moist temperate mixed forests *i.e*., Lower Topa, Jhika Gali and Murree hills at the elevations of 1970 m to 2250 m. *Pinus wallichiana* occurred as dominant with 72% importance value with 63% density and 88% basal area while associated species *Quercus incana* attained 16% importance value. In the understorey, two species (*Berberis lyceum* and *Hedera nepalensis*) that were conspicuous in such communities were also recorded with high frequency in the present studies. Chaudhri (1960) stated that *Pinus wallichiana* is a pioneer species distributed on all aspects with wide altitudinal limits. Naqvi (1976) considered it as a connecting species that links up other conifer species in the area. According to Hussain & Illahi (1991) the adaptability and colonizing ability of this species is phenomenal; they recognized *Pinus wallichiana* community as mixed temperate forest. Beg (1975) recognized *Pinus wallichiana* as dry zone Blue-Pine forests. According to Champion *et al.,* (1965) this species requires more moisture than the other species of dry temperate zone. The distribution of *Pinus wallichiana* in different climatic zones reported by earlier researchers reflected its wide ecological amplitude.

Pinus wallichiana formed a community with *Picea smithiana* at two different localities of the study area. Ahmed *et al.,* (2006) also recorded *Picea smithiana-Pinus wallichiana* community at Astore. With regard to the understorey vegetation of this community type (current study), the species diversity was found to be generally high in the constituting stands of the community. The major species were: *Rosa webbiana, Rubus biflorus,* and *Thymus serpyllum* which occurred with high frequency. Seedlings or saplings of the conifer species were often present with moderate abundance showing that the stands have regenerative potential and the mortality of old trees is compensated by the recruitment of new individuals.

An association of *Pinus wallichiana* and a broadleaf species *Albizia chinensis* was recorded which has not been reported by earlier workers. The major understorey species associated with this community type were *Rosa webbiana, Berberis lyceum, Pyrus pashia* and *Rosa brunoni* that are mostly representative of relatively undisturbed conditions.

Pyrus pashia was associated with *Pinus wallichiana* at Ghora Gali on 2100 m elevation. *Taxus fuana* and *Quercus incana* also showed their presence in this stand with comparatively low importance value. Ahmed *et al.,* (2006) recorded *Pinus roxburghii-Pinus wallichiana* community from this general area at low elevation (1570 m). This may be an ecotonal zone of subtropical and moist temperate forests.

Pinus wallichiana –Cedrus deodara community type is fairly common in the study area and was recorded from 10 different stands although the sequence of dominance changed. Generally, this community type was recorded from moderate to high elevation (1900 m to 2730 m). Seedlings and saplings of both the tree species *Cedrus deodara* and *Pinus wallichiana* were recorded in 50% of the stands depicting a fair regeneration of tree species. *Abies pindrow* was found in three stands indicating. The common understorey plants under this association were *Acer caesium, Pteris cretica, Thymus cerpyllum, Cymbopogon jawarancusa, Rosa brunoni, Berberis lyceum, Pteris cretica.* Sometimes *Rosa webbiana, Erianthus griffithii, Hedera nepalensis, Indigofera hebepetala, Pteridium equalinum, Rubus ellipticus, Duchesnea indica* were also recorded. Notably, seedlings of *Quercus dilitata,* and *Quercus ilex* were seen to flourish.

Another, widely distributed community of the present study is *Abies pindrow- Pinus wallichiana,* was recorded from 16 stands of different localities on moderate elevation (2350-2800m). Both the species seem to prevail with closely similar importance values but *Abies pindrow* is the leading dominant in 10 stands while *Pinus wallichiana* in 6 stands of the sampled sites. Some other conifer species (*Cedrus deodara* and *Taxus fuana*) and broad leaf species (*Juglans regia*) were found as third or fourth dominant species in some of the stands. This community type prefers cool and moist sites even in dry zones (Hussain & Illahi, 1991). Ahmed & Naqvi (2005) observed *P. wallichiana-Abies pindrow* community at the lower elevation of Naltar valley, Gilgit (dry temperate area). Ahmed *et al.,* (2006) recorded this association type from Dunga Gali, Murree hills, Ayubia and Miandam. Co-dominant species *P. wallichiana* attained 23% importance value. Understorey showed that ground flora was dense and comprised of 15 species. Ahmed *et al.,* (2006) recorded this community (combination-type) with varying importance value from dry temperate mixed forests around Rama (Astore) and Nashterbool (Takht-e-Sulaiman, Baluchistan.The dominant species attained 329 trees ha^{-1} density while 34 m^2 ha^{-1} basal area. Associated species occupied 36 trees ha^{-1} density and 5 m^2 ha^{-1} basal area. The present as well as previous studies together disclose wide distribution pattern for both the species in different ecological zones. Understorey vegetation of this forest type (*Abies pindrow- Pinus wallichiana*) also exhibited varied floristic composition. Forty six understorey species were found associated with the tree stratum. Some dominant species were *Pteris cretica, Acer caesium, Rubus biflorus, Hedera nepalensis, Delphenium uncinatum, Adiantum capillus veneris.* Understorey vegetation associated with this community type showed typical plants of cool and moist temperate conditions.

A symbol of national tree of Pakistan *Cedrus deodara* is is a widely distributed conifer in Himalayan and Hindukush region of Pakistan, Kashmir, India, Nepal and Myanmar. *Cedrus deodara* was recorded from 22 different locations of study area (moist temperate) but Beg (1975) placed this species under the dry temperate forests because it seems to prefer Mediterranean type of climate and avoids areas which receive high summer rainfall. Wahab *et al.,* (2008) also recorded this species from dry temperate zone while Ahmed *et al.,* (2006) observed this species at Astore (sub-alpine area) thereby it showed wide ecological amplitude. Champion *et al.,* (1965) stated that *Cedrus deodara* extends gradually into the dry inner valley of the Himalaya and ultimately shifts to an entirely different dry deodar forest though they described it under the moist temperate forest.

In the present study, at two different locations deodar was recorded as a single dominating species but it also was found associated with other conifer or angiosperm species. Mostly it occurred together with *Pinus wallichiana*. Meager and sparse vegetation was recorded underneath *Cedrus deodara* in both the stands which can readily be attributed to anthropogenic interference. Wahab *et al.,* (2008) recorded pure stands of *Cedrus deodara* at Surgulo Sar, Afghanistan. Nevertheless**,** following species are associated under the canopy cover of pure stands of *Cedrus deodara*, i.e., *Ficus palmata* (seedlings) and *Cymbopogon jwarancusa* a perennial grass. Ahmed *et al.,* (2010) recorded the pure stands of *Cedrus deodara* from twelve different locations of northern part of Pakistan from 1650 m to 2770 m elevation.Poor similarities were observed among the ground vegetation of different stands.

A combination of *Cedrus deodara* with *Picea smithiana* was recorded from only one stand. It was found to prevail at a moderate elevation of 2500 m. Ahmed *et al.,* (2010) recorded this community from three locations viz., Ziarat (Chitral), Shogran and Kaghan valley from 2500 m to 2534 m elevation on steep slopes. Ziarat is a dry temperate area while Kaghan valley is moist temperate area indicated the resistance of both the species in different climatic region. Ground flora was composed of six species including *C. deodara* seedlings, suggesting that the stand has a good regenerative potential and that *C. deodara* will prevail as dominant species in the future community.

Cedrus deodara-Abies pindrow community was recorded from one stand at an elevation of 2560 m. *C. deodara* in this community had not only high density but also high basal area. Seedlings of tree species including *C. deodara, A. pindrow, and Acer caesium* were common. In the undergrowth *Pteris cretica* and *Andropogon lancifolius* occurred with high frequency.

Cedrus deodara also exhibited association with *Juglans regia* occurring with low abundance at Paras, Kaghan valley at lower elevation. They were also associated with *Pinus wallichiana, Quercus ilex* and *Quercus incana*, which contributed low quantitative attributes. Among circular plots species *Rosa webbiana* and *Rosa brunonii* attained high frequency while *Rubus ulmifolius, Hedera nepalensis* had low frequencies. Seedlings of *Quercus ilex* and *C. deodara* also occurred with low abundance and showed the future trend of this forest. No seedlings of *Juglans regia* were recorded from this forest, indicating elimination of this species in future. This specific combination of species has not been recorded by other workers with the exception of Ahmed *et al.,* (2010) who recorded *Juglans regia-Cedrus deodara* community at Malkandi.

Abies pindrow is the second widely distributed species, found together with *Pinus wallichiana, Cedrus deodara, Picea smithiana* and *Taxus fuana* but only at one location it forms a monospecific forest. In earlier studies no such monospecific stand of *A. pindrow* were recorded. Closed canopy pure stand of *Abies pindrow* was found at only one location at high elevation. The highly disturbed area indicated by absence of *Abies pindrow* seedlings and saplings and only two understorey species. Due to severe disturbance the future of the forest is not secure and it appears that it could be converted into a barren land.

Picea smithiana co-dominated with *Abies pindrow* at two different locations of study area with overlapping environmental conditions at the high elevation of 2600 to 2900 m on steep slope angle. At Malam Jabba the community changed to *Abies–Picea* whereas at Sri it shows *Picea-Abies* community due to change in dominance. Seedlings and saplings of both Conifer species were recorded only at Sri. Among the understorey species only *Pteris cretica* and *Adiantum venustum* were found in both stands and showed varied floristic composition.

In present study *Taxus fuana* associated with *Abies pindrow* at a moderate elevation of 2500 m. *Taxus fuana* is one of the coniferous trees most subjected to disturbance in the moist temperate area. People use its branches to make welcome gates and for decoration. The processes that could lead to this unique association are hard to predict with accuracy. *Pinus wallichiana* and *Cedrus deodara* occurred in this stand with very low abundance. Seedlings and saplings of *Abies pindrow* and *Pinus wallichiana* were observed in many circular plots of this stand while no seedlings and saplings of *Taxus fuana* were recorded which showed poor or no regeneration of this species or *Pinus wallichiana* could replace this species in future. *Rubus biflorus* is the only understorey species that was recorded from this stand, attributed to high degree of anthropogenic disturbance.

Understorey species composition differs with the canopy composition. Overstorey species can directly facilitate understorey species through altering precipitation distribution under their canopy, soil bulk density, soil moisture, soil oxygen, soil surface temperature, available sun light and leaf litter accumulation, soil nutrient concentrations and seed bank density (Warnock *et al.,* 2007). Understorey species composition prevailing under the tree canopy varied from stand to stand, site to site, and with changing altitude. Floristic composition of the understorey vegetation varied even under communities with similar tree composition. In many stands of the sampled forests, ground flora (understorey species) showed poor floristic composition, possibly due to differences in local environmental factors, microclimatic conditions or owing to high degree of disturbance. Boza, 1993 indicated that factors like intensive deforestation and unlimited expansion of urban area have considerably reduced the extent of plant communities' world wide. Plant communities are also losing their species richness at high rate due to clear cutting (Johnson *et al.,* 1993) and extensive exploitation of grasslands for raring animal herds (Peet *et al.,* 1983).

The most common understorey species found in the vegetation were *Pteris cretica* (in 22 stands), *Acer caesium* (19 stands), *Rosa brunoni* (10 stands), *Berberis lyceum*, *Hedera nepalensis*, *Rubus biflorus*, *Thymus serpyllum* (each in 9 stands each), *Rosa webbiana*, and *Rubus ellipticus* (found in 8 stands). The rare species encountered were *Agaricus compestris*, *Bothriochloa bladhii*, *Carissa opaca*, *Sonchus asper* and *Urtica dioica*. Out of 87 understorey species, 40 species occurred only once with poor abundance that could be attributed to high degree of disturbance. Seedlings of *Pinus wallichiana* were recorded from 27 stands, *Abies pindrow* from 17, *Cedrus deodara* from 15 while *Picea smithiana* from 4 and *Taxus fuana* from 3 stands. The low number of seedlings of two conifer species could be due to deteriorating environmental conditions such as aridity, soil salinity, soil erosion and acid rain as indicated by Hussain (2003).

Among the environmental factors regulating vegetation composition, bioclimatic factors, particularly biotemperature (Holdridge, 1947) and the annual precipitation seem to have overriding control in patterning vegetation. Among the dominant conifer species, *Pinus wallichiana* seems to prevail in a wide range of biotemperatures (14 to 18ºC) and annual precipitation of 160 to 185 cm). When occurring in monospecific stands it is associated with lower biotemperature (nearly 14ºC) while towards higher limit of its range of biotemperature (17.5ºC) when found in association with *Cedrus deodara*. Of all the conifers found in the area *Abies pindrow* seems to flourish in the coldest biotemperature range (13.5 to 17.5ºC) and it appears to form dominant vegetation in areas with greater precipitation (maximum being 190 cm). *Cedrus deodara* forests were distributed within a biotempaerature range of 15.5 to 18.2ºC. It occurs in monosspecific stands at relatively lower biotemperature but when forming assemblages with other species (*A. pndrow*, *P. wallichiana*, *Juglans regia* and *Picea smithiana*) it is associated with greater biotemperature (17 to 18ºC). The range o associated precipitation is towards higher side but lesser than that of *Abies pindrow* and *Pinus wallichiana*. *Picea smithiana* seems to require lower biotemperature for its abundance and forms associations with *Abies pindrow* and *Pinus wallichiana*. *Juglans regia*, an angiosperm species, formed a community with *Cedrus deodara* that was associated with a biotemeperature of 17.5ºC. Though the biotemperature and precipitation requirements seem to be close but there are subtle differences in the ranges of both these factors for the various dominating species in the area surveyed.

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