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Influence of Soil Chemical Properties, Altitude and Slope on the Distribution and Growth of Conifer Species in Moist Temperate Areas of Himalayan and Hindukush Region of Pakistan

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ABSTRACT

PThis study attempts to investigate the possible role of edaphic and topographic variables on the distribution pattern of conifer tree species in the moist temperate area of western Himalayan and Hindukush region of Pakistan. Arboreal vegetation of 41 sites was analyzed using point-centered quarter method. Soil samples from 41 different sites were collected to determine the edaphic characteristics. Overall the soils of the study area were slightly acidic, salinity was observed in the range of 0.10-1.3 %, with a mean of 0.16 % ± 0.03. Total dissolved salts ranged between 16.8 to 377 mg / liter with a mean of 195.1± 30.11. Electrical conductivity of the forty one soil samples ranged between 0.0347 - 0.732 mmhos/cm with the mean value of 319 ±28.21 mmhos/cm. The amount of organic matter ranged from 2.62 to10.52 % while the mean value was 4.98 ± 0.24 %. Water holding capacity ranged between 32.50 to 65.40 % with a mean of 53.81±1.14. Minimum soil compaction was 90 PSI (pounds per square inch) while the maximum compaction was 250 PSI with a mean value of 166.7± 5.58 PSI. Weak or spurious correlations were observed between structural attributes of four conifer species with the physiographic factors. Density of Pinus wallichiana A.B. Jackson, Abies pindrow Royle and Picea Smithiana (Wall.) Boiss. while basal area of Pinus wallichiana, Cedrus deodara (Roxb.) G. Donf. and Picea smithiana did not show any significant correlation with the soil variables. Only soil conductivity was weakly correlated with basal area of Abies pindrow ($p < 0.1$). Density of Cedrus deodara showed positive significant but weak correlation ($p < 0.1$) with water holding capacity and a negative correlation ($p < 0.05$) with salinity. The structural features of the tree vegetation were usually uncorrelated with the edaphic features. However, any substantial edaphic relationships disclosed for the dominant tree species are discussed. It was concluded that most soil factors depict weak or no correlation among the tree distribution due to long history of anthropogenic disturbance.
KEYWORDS: Soil chemical properties; Altitude; Slope; Moist temperate area; Pakistan.

1 INTRODUCTION

This study examines the role of topographic and soil chemical properties on the vegetation distribution, composition and structure of moist temperate areas of Pakistan and exposed the regulation of vegetation composition and structure. One of the major objective of this study is to analyze the distribution of some soil chemical properties (water holding capacity, salinity, total dissolved salts, conductivity, organic matter, soil compaction and pH) that may affect the uptake and transport of nutrients, and topographic factors (elevation and slope) that may control the vegetation distribution pattern of the important tree species in the moist temperate area of western Himalayan and Hindukush region of Pakistan. Structural attributes (density and basal area) that depend on the availability of soil chemical properties are also considered here. Relationships were observed between the soil chemical properties and structural attributes to seek the pattern of abundance and distribution of dominant conifers.

Spatially heterogeneous resources affect numerous plant ecological processes, including the distribution of plant communities, the structuring of plant populations, establishment and recruitment of individuals (Kadmon 1993; Smith *et al.,* 1997). Forest soils influence the composition of forest stands and ground cover, rate of tree growth, vigour of natural reproduction and other silviculturally important factors (Bhatnagar, 1965). Physico-chemical characteristics of forest soils vary in space and time because of variation in topography, climate, weathering processes, vegetation cover, microbial activities and also

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several other biotic and abiotic factors (Paudel and Sah, 2003). Vegetation itself plays an important role in soil formation, by way of breaking the larger particles into finer particles, building up the soil structure, increasing soil depth, elevating the organic matter content and so on (Chapman and Reiss, 1992). The yearly contribution of surface vegetation to soil, in the form of needles, leaves, cones, pollen, branches and twigs, gradually decomposes and becomes a part of the soil (Singh and Bhatnagar, 1997). Plant tissues (above and below ground litter) are the main source of soil organic matter, which influences the physico-chemical characteristics of soil such as, texture, water holding capacity, pH and nutrient availability (Johnston, 1986). The nature of soil profile, pH and nutrient cycling between the soils and trees are the important dimensions to determine the site quality (Sheikh and Kumar, 2010). The vegetation influences the physico-chemical properties of the soil to a great extent by improving the soil structure, infiltration rate, water retaining capacity, hydraulic conductivity and aeration (Ilorkar and Totey, 2001; Kumar *et al.,* 2004). Soil chemical properties have controlling effect on vegetation distribution and composition (Sollins, 1998). Topographic feature such as elevation and slope play an overriding role in the distribution of vegetation (Sheikh and Kumar, 2010). Vegetation composition and distribution was strongly affected by soil chemical properties (Tareen *et al.,* 1987; Hussain and Badshah, 1998). Soil and conifer foliar nutrients concentration in the communities of moist temperate areas of Himalayan and Hindukush region of Pakistan was investigated by Siddiqui *et al.,* (2011). The need to evaluate the requirement of edaphic variables that control the distribution pattern of particular plant species is increasing day by day. In Pakistan researchers are trying to pay attention to evaluate the status of soil chemical properties of selected forests.

Besides these individual studies no extensive investigations were carried out to evaluate the effect of soil chemical properties on the distribution and composition of dominant conifer species in moist temperate areas of Pakistan. In Pakistan researchers have mostly focused on the edaphic variables of forest occurring in small sections of the moist temperate area which often masks the correlations owing to environmental stochastic variability in the concentrations of edaphic variables in various sites. However, no comprehensive study has yet been undertaken to cover a broad region such as the entire moist temperate region of Pakistan. Therefore, a detailed study of the vegetation-environment was conducted in moist temperate conifer forests. Multivariate techniques including Ward's cluster analysis (objective classification) is performed to extract the major groups of edaphic and topographic factors, based on these groups single factor ANOVA is computed. This study explores the status of topographic and soil chemical properties of moist temperate forests of Pakistan and their relationships with the structural attributes of dominant conifer species (*Pinus wallichiana*, *Abies pindrow, Cedrus deodara* and *Picea smithiana*) and the overall vegetation composition.

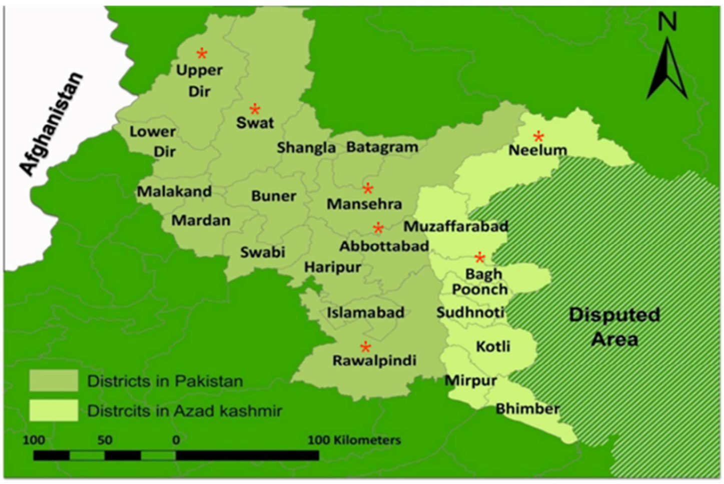

Fig.1 Study area map. * showing the district where forests were sampled Siddiqui *et al.,* (2011).

2.MATERIALS AND METHODS.

2.1. **Vegetation sampling.** Forty-one stands that were of adequate size, visually homogeneous and relatively free from recent anthropogenic disturbance were selected for detailed study of vegetation and environmental factors. The latitude, longitude, slope angle, aspect, altitude and soil compaction of each stand were recorded. The tree vegetation of 41 stands was sampled using point-centered quarter method (Cottam and Curtis, 1956) and various phytosociological attributes including relative and absolute density and basal area of tree species were computed following Meuller-Dombois and Ellenberg (1974); Kent and Kocker (1991) and Ahmed and Shaukat (2012).

Soil samples were collected at 5-30 cm depth from each stand. Five to six soil samples were randomly collected and pooled to obtain a composite soil sample for each site. During the collection of the soil, it was assured that no litter should be added with the soil. Soil samples were stored in labeled polythene bags and brought to the laboratory for analysis. In laboratory the soils were air dried, passed through a 2 mm (No. 10 mesh) sieve size and again stored in clean plastic bottles. Subsequently, these soils were used for different analyses.

2.2. **Preparation of the soil.** 0.4- 0.5g soil sample was digested with the mixture of 6ml $HClO_4$- HF (1:2) on hot plate at about 195 ºC until dried, cooled and acidified with HNO_3 (2ml) and then distilled water was added. It was warm enough to dissolve all salts and cooled again and the solution was made up to 100 ml with deionized distilled water.

2.3. **Edaphic variables of soil.** Salinity, pH and Conductivity were measured in the field with the portable instrument, Multiparameter [Model Sension TM 105, U.K]. Soil compaction was also measured in the field by portable Analog Soil Compaction gauge (USA). Maximum water holding capacity was determined, following the method of Keen (1931).

2.4. **Exchangeable Ca^{++}, Mg^{++} and K^{+} of soil.** Hitachi Z-8000 atomic absorption Spectrophotometer with Zeeman background correction and a data processor was used for elemental analysis. All the parameters were set according to the manufactures instructions using flame atomization. The dilution of standard and the test solutions were made such as to keep the concentration within the linear range of absorbance. Estimation was made of above mentioned elements against their respective standard solutions.

2.5. **Estimation of organic matter of soil.** Organic matter of soil was estimated by the loss-on-ignition method of Dean (1974) as follows: In a thoroughly clean crucible 30 g soil (sieved with a 2 mm sieve) was placed in an oven at 90ºC for 5 h to remove moisture. The soil was weighed and then kept in muffle furnace at 400ºC for 3 h. Subsequently, cooled to room temperature in a desiccator, the loss on ignition represented the organic matter content. This method was also compared with wet digestion method using potassium dichromate and closely similar results were obtained.

2.6. **Statistical Analysis.** Data were subjected to univariate or multivariate statistical analysis following Orloci and Kenkel (1985), Shaukat and Siddiqui (2005) and Zar (2008). Ward's cluster analysis (hierarchical agglomerative method) was chosen. Ward's cluster analysis was performed using the program-package PC-ORD (Grace and McCune, 2002; McCune and Mefford, 2005). ANOVA for each variable was performed with respect to clusters Correlation and regression analyses were performed (using SPSS-Package Ver. 12) to seek the relationship between structural attributes (density ha^{-1} and basal area m^2 ha^{-1}) with soil chemical properties (pH, salinity, conductivity, organic matter of soil, water holding capacity and slope angle) and topographic variables (elevation and slope).

3. OBJECTIVES OF THE STUDY

Sampling of vegetation was performed and the concurrent data on topographic and edaphic factors was gathered. The major objective of this investigation was to explore the present status of edaphic and topographic variables and correlate them with the vegetation distribution of dominant conifer species. Also we attempted to determine which environmental factors played overriding role in the distribution, composition and dominance of conifer species.

4. RESULTS AND DISCUSSION

Summary of sample sites locations, elevation, slope and minimum, maximum and mean values of soil chemical properties of 41 stands of moist temperate conifer forest are shown in Table 1 while the Figure 1 shows the locations where sampling was conducted. Minimum, maximum and mean values are presented in Table 2. Most of the forests were closed canopied (21 stands), sixteen forests occupied open canopy while only four forests were open canopied.

Some edaphic variables are not considered as nutrients but play a vital role in absorption and transportation of nutrients from the soil to aerial parts of plant. Soils of the study area showed considerable variability in each edaphic factor of different sampling sites because the environmental gradients of same geographical locations did not differ greatly. Overall the soil of the study area is slightly acidic. Minimum value of pH 5.2 was recorded from Malam Jabba 2 (stand 4) while the maximum value 6.98 was recorded from Changla Gali 1 (stand 22) and the mean value is 6.33 ± 0.08 (Table 1). Salinity was observed in the range of -0.10-1.3 in stands (38, 34) and 23 respectively, with a mean value of 0.16 ± 0.03. Total dissolved salts ranged from 16.8 to 377 mg / liter in stand 38 and 23 respectively with a mean value of 195.1± 30.11. Electrical conductivity of forty one soil samples ranged from 0.0347 - 0.732 mmhos/cm in stands 38 and 16 respectively with the mean value of 319±28.21. The amount of organic matter was ranged from 2.62 to10.52 % stands 13 (Patriata 2) and stand 1 (Kumrat valley) respectively while the mean value is 4.98 ± 0.24 %. Water holding capacity ranged from 32.50 to 65.40 % in stands 30 (Paye) and 1 (Kumrat valley) respectively while the mean value was 53.81±1.14. Minimum soil compaction 90 was estimated from Sri (stand 31) and maximum compaction of 250 PSI was observed from Neelam valley and Paye (stands 6, 30). The mean value was 166.7± 5.58.

Table 1 Summary of site characteristics, topographic and edaphic variables of studied moist temperate area of Himalayan and Hindukush region of Pakistan.

S. No.	Location and sites	Elevation	Slope	OM	pH	WHC	Salinity	Cond.	TDS	Soil Comp.	Ex. Ca^{++}	Ex. Mg^{++}	Ex. K^{+}
		(m)	(°)	(%)		(%)	(%)	(mmhos/cm)	mg/L	(PSI)	ppm	ppm	ppm
1-	**Dir Upper (district), Malakand Division**												
1	Kumrat	2400	5	10.5	5.8	65.4	0.34	215	115	165	484	269	38
2	Pana Kot	2200	40	9.9	6.64	62.5	0.1	230	122	150	468	264	35
2-	**Swat (district), Malakand Division**												
3	Malam Jabba 1	2600	34	5.5	5.4	49.7	0.1	237	119.4	175	458	254	33
4	Malam Jabba 2	2350	30	3.9	5.2	51.8	0.1	197.6	99.8	200	438	243	30
5	Miandam	2600	49	3.4	5.7	55.2	0.1	226	113.7	150	464	235	18
3-	**Neelam (district), Azad Kashmir**												
6	Keran	1960	30	7.2	6.85	48.1	0.1	204	102.9	250	368	188	20
4-	**Bagh (district), Azad Kashmir**												
7	Chikar	1930	28	5.0	6.39	45.4	0.13	120.1	60.5	150	395	186	22
8	Sudhan Gali 1	2450	22	3.8	6.02	50.2	0.23	220	111.1	200	435	232	23
9	Sudhan Gali 2	2500	32	4.3	5.65	56.5	0.2	395	201	130	452	233	24
10	Sudhan Gali 3	2420	38	5.1	6.51	54.4	0.1	276	140	110	386	245	18
5-	**Murree (district), Rawalpindi Division**												
11	Ghora Gali	2100	29	3.8	6.8	60.2	0.2	359	184.8	150	435	198	31
12	Patreata Top 1	2300	40	5.2	6.59	61.5	0.1	322	163.3	210	468	201	25
13	Patreata Top 2	2300	25	7.9	6.62	59.8	0.3	570	292	110	439	231	26
14	Nia, Near Patriata	2000	39	7.2	6.32	54.7	0.3	475	298	150	367	241	28
15	Kashmir Point	2500	39	5.2	6.9	51.2	0.3	688	354	150	345	230	29
6-	**Abbot Abad (district), Hazara Division**												
16	Ghora Dhaka 1	2500	36	4.3	6.7	56.6	0.4	732	377	130	435	267	15
17	Ghora Dhaka 2	2500	32	3.8	6.52	47.8	0.1	203	102.3	170	426	259	16
18	Ghora Dhaka 3	2800	40	6.7	6.31	57.3	0.2	391	199.3	180	456	264	25
19	Ghora Dhaka 4	2800	40	5.6	5.62	50.8	0.1	239	121	220	412	245	34
20	Ghora Dhaka 5	2600	37	8.4	6.77	58.7	0.1	242	122.2	170	421	222	29
21	Khaira Gali	2730	42	8.0	5.89	61.8	0.1	345	130	120	395	212	28
22	Changla Gali 1	2650	47	6.7	6.98	47.2	0.2	452	231	180	387	234	22
23	Changla Gali 2	2670	35	6.7	6.65	53.4	1.3	234	1250	150	426	187	24
24	Kuzah Gali 1	2560	5	3.4	6.15	48.5	0.34	348	176.3	210	465	195	23
25	Kuzah Gali 2	2560	28	4.4	6.18	52.7	0.2	534	271	210	423	215	32
26	Nathiagali, 1	2640	35	8.6	6.31	62.4	0.1	246	122.2	160	436	216	33
27	Nathiagali, 2	2630	33	3.8	6.8	63.5	0.3	714	364	190	468	242	34
28	Thandyani 1	2320	31	5.6	6.75	40.6	0.14	109	53.9	140	358	261	36
29	Thandyani 2	2300	38	5.1	5.3	46.5	0.1	260	129	140	345	234	16
7-	**Mansehra (district), Kaghan Valley**												
30	Paye	3100	38	3.8	5.23	32.5	0.1	317	160.7	250	435	197	16
31	Sri	2900	39	4.4	5.55	42.6	0.3	615	312	90	465	199	14
32	Shogran 1	2400	27	4.0	6.74	58.4	0.31	223	112	170	466	206	10
33	Shogran 2	2400	23	7.7	6.87	63.4	0.2	488	246	190	475	208	11
34	Shogran 3	2500	33	3.4	6.91	61.2	0.1	58.6	29	150	425	245	12
35	Paras,	1600	20	4.4	6.82	48.6	0.23	80	247	160	412	234	20
36	Khanian	2000	35	5.1	6.61	59.7	0.1	275	138	195	435	238	22
37	Shinu 1,	1900	39	6.7	6.75	54.3	0.3	611	313	180	366	221	16
38	Shinu 2,	1650	43	3.8	6.7	56.2	0.11	34.7	16.8	120	337	192	18
39	Naran, River Belt 1	2500	5	3.8	6.44	43.6	0.32	132	65.6	190	342	219	21
40	Naran, River Belt 2	2500	5	3.8	5.62	48.5	0.35	297	150	170	365	217	14
41	Lalazar (Naran)	3000	45	8.7	5.21	62.7	0.12	164.2	82.4	150	389	187	13

Key to abréviations:OM = Organic matter, WHC = Water holding capacity, Cond. = Conductivity, TDS = Total dissolved solids, PSI = pounds per square inch, Soil com. = Soil compaction and Ex. = Exchangeable.

4.1. **(1) Elevation.** Under studied conifer species were distributed from 1600m to 3100m elevation. *Pinuswallichiana* is widely distributed species in moist temperate area of Pakistan, out of 41 stands, *Pinus wallichiana* was recorded from 35 stands as a single dominant (pure stands), a dominant and a co-dominant or simply as an associated species. It is distributed from the elevation of 1600 m to 3100 m in the study area. *Abies pindrow, Picea smithiana* and *Taxus fuana* prefer to grow at high elevation. *A. pindrow* is second widely distributed species in moist temperate area. *Cedrusdeodara* was recorded from comparatively low elevation i.e. 1600m to 2730m. It is a diversified species found in different climatic regions. Beg (1975) placed this species under the dry temperate forests because it likes Mediterranean type of climate and avoids areas which receive high summer rainfall. But in the current study it was recorded from moist temperate area and showed relatively wide ecological amplitude.

Table 2 Minimum, maximum and mean values of some soil variables of 41 stands of study area.

S. No.	Variables	Minimum value	Maximum value	Mean value
1	Elevation	1600 m	3100 m	2422±51.526
2	Slope	5º	49º	32º±1.719
3	Organic matter (%)	2.6	10.5	5.52±0.31
4	pH	5.2	6.98	6.3±0.087
5	Water holding capacity (%)	32.5	65.4	53.8±1.15
6	Salinity (%)	-0.1	1.3	0.218±0.03
7	Conductivity (mmhos/cm)	0.0347	0.732	0.319±28.2
8	Total dissolved salts mg/L	16.8	377	167.7
9	Soil compaction (PSI)	90	250	167±5.578
10	Exchangeable Ca^{++} ppm	337	484	419±27.6
11	Exchangeable Mg^{++} ppm	186	269	234±18.5
12	Exchangeable K^{+} ppm	10	38	16.4±3.5

Key to abbreviations: Refer to Table 1.

4.2. **(2) Slope.** Slope angle of the study area lies between the 5º to 47º. Fourteen stands were located on northerly facing slope, seventeen stands were located southerly, six stands were located on westerly while only two stands occupied on east slope. *Pinus wallichiana* was recorded from ridge top to steep slope (39°). It usually prefers to grow on south and north facing exposures while at some locations it is recorded from west and east exposure also. *Abies pindrow* prefers to grow on south facing exposure and avoids east exposure because in only one stand it is found on east facing slope. *Picea smithiana* recorded from steep slopes (33° to 39°) but at one location it flourished at ridge top. No trees of *Picea smithiana* were recorded from east facing exposure. Ahmed and Naqvi (2005) reported *Picea smithiana* from Naltar valley (dry temperate area) and from Astor (sub-alpine region) while Wahab *et al*. (2008) recorded this species from Sheshan, Afghanistan which is also a dry temperate area which shows the adaptability and distribution range of *Picea smithiana* in different climatic zones. *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 *Picea smithiana* it also avoided east exposures.

4.3. **(3) Organic matter.** Organic matter from different mountainous areas of Pakistan dominated by conifers has been estimated by some workers. Malik *et al.*, (1973) recorded the organic matter incorporated in the first 12 inches layer of soil was 0.5 to 1.6 % from the Dir forest dominated by *Cedrus deodara* which rapidly decreases from B to C horizons. Qadir and Ahmed (1989) estimated the organic matter of soil that ranged from 1.6 to 2.29 (surface) and 1.99 to 2.18 (sub-surface) from Hazargangi National Park, Quetta. Hussain and Badshah (1998) recorded the soil organic matter from different altitudinal zonations i.e. 3.51% and 2.72 % at 2000 m, 2.24 and 2.58% at 2300 m, 4.4 & 2.58% at 2600 m and 5.6% at 3500 m elevation from north and south exposures respectively of Pirghar hills, south Waziristan, Pakistan (moist temperate area). Moreover, they demonstrated that the soil on northern slopes had generally higher organic matter content compared to southern slopes. Tareen and Qadir (2000) evaluated the organic matter of various plant communities of Harnai, Quetta, ranged between 0.57 to 9.57%. Malik *et al.*, (2007) recorded the organic matter of soil 3.3 to 6.7% in Pir Chinasi hills (moist temperate area), Azad Kashmir. The amount of organic matter was ranged from 2.62 to10.52 % stands 13 (Patriata 2) and stand 1 (Kumrat valley) respectively while the mean value is 4.98 ± 0.24 % which is also within the range of other studies in moist temperate area. The highest organic matter content was recorded from the Kumrat forest (10.52 %) where the top soil layer was rich in organic matter of which a high proportion occurred in the form of humus.

4.4.**(4) Soil pH.** The pH of the nutrient solution affects the availability of nutrients. The ideal pH of nutrient solution is from 6.0 to 6.5. Soil pH below 5.0 or above 7.0 may adversely affect plant growth by altering selected nutrient availability. The micro-elements are particularly affected with excessive uptake at low pH and removal from the solution through precipitation at higher pH (Jones, 1983). Overall the soil of the study area is slightly acidic. Minimum value of pH 5.2 was recorded from Malam Jabba 2 (stand 4) while the maximum value 6.98 was recorded from Changla Gali 1 (stand 22) and the mean value is 6.33 ± 0.08 (Table 3). Malik *et al.,* (1973) observed that the pH range of soil from Dir was 5.8 to 6.5, suggesting favorable environment for the growth of conifer vegetation. Qadir and Ahmed (1989) found that the pH of soil from Hazargangi National Park, Quetta, ranged from 7.56 to 8 which is slightly alkaline. Tareen and Qadir (1990) evaluated the pH from water courses of Quetta district which was 7.5 to 8.4. Ahmed *et al.,* (1991) estimated the pH from *Pinus gerardiana* forests of Baluchistan that was 7.1 to 7.8 i.e. close to neutral. Hussain and Badshah (1998) recorded the soil pH from different altitudinal zonations i.e. 6.7 & 7.5 at 2000 m, 7.7 and 7.5 at 2300 m, 7.2 & 7.1 at 2600 m and 6.9 at 3500 m elevation from north and south exposure respectively of Pirghar hills, south Waziristan, Pakistan (moist temperate area). They did not estimate the total N concentration from tissues of conifers. Tareen and Qadir (2000) evaluated the pH of various plant communities of Harnai, Quetta, the soil pH ranged from 6.7 to 7.5. Malik *et al.,* (2007) recorded the pH range i.e. 5.4 to 7.0 in Pir Chinasi hills (moist temperate area), Azad Kashmir. Sheikh and Kumar (2010) reported that the soil pH of oak forest was acidic and slightly acidic in the pine forest in Garhwal, Himalaya. The range of pH under study area was 5.2 to 6.98 that is slightly acidic and suitable for the normal (favorable) growth and survival of conifers as suggested by Jones (1983) and some other workers from Pakistan and India which are discussed above.

4.5.**(5) Water holding capacity (WHC).** The highest WHC (65.4 %) was recorded from Kumrat forest where organic matter content is also high while lowest WHC (32.5 %) also recorded from those forests where organic matter content was low i.e. stand 30. The total stand density of Kumrat forest is 400 while 218 total stand density was recorded from stand 30, where both the variables (organic matter and WHC) were at low levels. It seems that WHC and organic matter content are the controlling factor for vegetation density. Under study area WHC was closely similar to those studies conducted in different mountainous areas of Pakistan. Kayani *et al.,* (1984) observed the medium WHC from Wastelands of Quetta-Pishin district. Qadir and Ahmed (1989) analyzed 36.3 to 59.3 % WHC from the soil of Hazargangi National Park, Quetta. Tareen and Qadir (1990, 2000) evaluated the WHC ranged from 15.0 to 35.65% and 24.1 to 56.01 % respectively from Quetta district. Hussain and Badshah (1998) recorded the water holding capacity from different altitudinal zonations i.e. 12.9% & 14% at 2000m, 9.41 & 9.94% at 2300m, 23.1 & 24.9% at 2600m and 79.8% at 3500m elevation from north and south exposure respectively of Pirghar hills, South Waziristan, Pakistan. Since above mentioned studies were mostly conducted in dry temperate area, showed low WHC compared to present study. Sheikh and Kumar (2010) reported that the higher percentage of moisture and water holding capacity was in oak forest and lower in pine forest in Garhwal Himalaya forests.

4.6.**(6) Salinity.** Salinity (mainly soil sodium chloride) also affects the nutrient uptake. Saline water has high osmotic pressure which reduces the water uptake by the roots resulting in inhibition of plant growth. Yield reduction of 10-25% can be expected, depending on the species, variety and salinity of the soil water. Salinity also reduces availability of certain micronutrients, especially iron (Resh, 1983). Salinity was observed in the range of -0.10-1.3 in stands (38, 34) and 23 respectively, with a mean value of 0.16 ± 0.03 which is low. It could be due to high slope angle of mountains which presumably results in leaching of salts. It is evident that salinity is not a limiting factor for the growth of conifer trees in this study.

4.7. **(7) Electrical conductivity.** Most plants grow well in an electrical conductivity (EC) between 1.8 to 3.5 mmhos/cm. EC falls as the plants absorb nutrients from the solution. However, the EC does not measure which nutrients are being depleted, and with time selected elements may accumulate as they are not removed quickly by the plants (Ingratta *et al.,* 1985). Electrical conductivity plays an important role in absorption and transportation of nutrients. Electrical conductivity of forty one soil samples ranged from 0.0347 - 0.732 mmhos/cm in stands 38 and 16 respectively with the mean value of 319±28.21. Though the range of EC estimated from the study area is not within the range described by the Ingratta *et al.,* (1985) but it is closely similar with the EC observed by different workers who estimated this value from mountainous areas of Pakistan, it could be due to differences in geographical location. Qadir and Ahmed (1989) found the EC of the soil, ranged between 0 to 0.22 mmhos / cm from Hazargangi National Park, Quetta. Tareen and Qadir (1990, 2000) evaluated the electrical conductivity that ranged between 0.4 to 1.9

and 0.2 to 0.55 mmhos/cm in Quetta district. Malik *et al.,* (2007) recorded the range of electrical conductivity i.e. 0.02 to 1.48 Ds m^{-1} in Pir Chinasi hills, Azad Kashmir. Our results are within the range of other studies in Pakistan.

4.8. **(8) Total dissolved solids.** Total dissolved salt concentration, measured by electrical conductivity is used to monitor the status of the nutrient of soil (Ingratta *et al.,* 1985). The range of this parameter under study area was 16.8 to 377 mg / liter (0.00168 to 0.0377% respectively) in stand 38 and 23 respectively with a mean value of 195.1± 30.11which are comparable to the values of Hussain and Badshah (1998) who recorded the total dissolved salts concentration from different altitudinal zonations at 2000 (0.032%), 2300 m (0.064) & at 2600 m (0.112%), 3500 m (0.16%) elevation from north and south exposures respectively.

4.9. **(9) Soil compaction.** Soil compaction often increases total water storage, but decreases the amount of water available to plants (Jamison, 1953). Minimum soil compaction 90 PSI was estimated from Sri (stand 31) and maximum compaction of 250 was observed from Neelam valley and Paye (stands 6, 30). The mean value was 166.7± 5.58. The range of soil compaction estimated from the study area is suitable for seed germination, seedling survival and plant growth. Slightly compacted soil can speed up the rate of seed germination because it promotes good contact between the seed and soil interface. In addition, moderate compaction may reduce water loss from the soil due to evaporation. Excessive soil compaction impedes root growth and therefore limits the amount of soil explored by roots. This, in turn, can decrease the plant's ability to take up nutrients and water. No other work is available in Pakistan to compare our results. However, Bailey *et al.,* (1988) mentioned that excessive compaction may cause such undesirable effects as decreased infiltration of water, restriction of root growth, and increased runoff; these detrimental effects can increase erosion.

Without timely rains and well-placed fertilizers, yield reductions will occur. Soil compaction in wet years decreases soil aeration. This results in increased nitrogen and potassium deficiency. Reduced soil aeration affects root metabolism. Study area showed suitable compaction of soil and for conifers.

4.10.**(10, 11, 12) Exchangeable Ca^{++}, Mg^{++} and K^{+} of soil.** Maximum concentration of above mentioned three elements were recorded from stand 1; it could be due to high availability of organic matter in soil and high maximum water holding capacity. The minimum concentration of Ca^{++} was recorded from stand 38 (Shinu 2, Kaghan valley), Mg^{++} from stand 7 (Chikar, Azad Kashmir) and K^{+} from stand 32 (Shogran 1).

4.11.**ANOVA (single factor).** Using Ward's clustering strategy four groups of environmental variables are formulated. The individual environmental variable corresponding to the four groups were analyzed using univariate analysis of variance (ANOVA) (Table 3). Topographic variables (elevation and slope) did not show any significant difference among the four groups. Among the six edaphic variables i.e. water holding capacity, salinity and conductivity exhibited significant difference ($P < 0.001$) while organic matter of soil showed the significant difference at $P < 0.05$. Conductivity and pH did not show significant difference between the groups.

Table: 3 Analysis of variance of individual environmental variables (topographic and edaphic variables) for the four groups derived by Ward's cluster analysis based on environmental data of 41 stands of moist temperate areas of Pakistan.

ANOVA: Single Factor *F crit. 2.8588*

Source of Variation	F-value	P-value	Significance-level
Topographic Variables			
1- Elevation	52.65	1.99E-13	ns
2- Slope	2.662	0.0622	ns
Edaphic Variables			
3-Organic matter of soil	1.20337	0.322	P < 0.05
4- PH	3.2003	0.0344	ns
5- WHC	0.03394	0.992	P < 0.001
6- Salinity	0.684	0.567	P < 0.001
7- Conductivity	14.248	2.504E-06	ns
8- Total dissolved salts	11.421	0.00354	ns
9- Soil Compaction	0.21888	0.883	P < 0.001
10- Exchangeable Ca^{++} ppm	0.53215	0.9865	P < 0.001
11- Exchangeable Mg^{++} ppm	0.43652	0.86521	P < 0.05
12- Exchangeable K^{+} ppm	0.53284	0.7632	P < 0.01

Normal growth and development of plants depend upon the continuous supply of nutrients, moisture and certain other edaphic variables. Water holding capacity, organic matter of soil, salinity, conductivity, total dissolved salts, pH and soil compaction have marked relation with the growth. In this study we evaluated the extent of relationship between plant density and basal area of conifer species with the edaphic variables of soil. Such correlations were studied using Pearson's product moment correlation coefficient. The need to investigate the relationship between the edaphic variables with the structural attributes of vegetation is emphasized by many workers, like Sheriff *et al.,* (1986). Baslar *et al.,* (2002)observed a negative relationship in *Cistus creticus* between plant calcium with soil salinity and a positive relation between plant calcium and soil pH. In the current study, these two soil variables showed no correlation with the structural attributes except salinity with *Cedrus deodara* density.

Many soil characteristics are known to influence the uptake and transportation of soil nutrients, hence indirectly influence the growth and development of plants but in this study most edaphic variables did not show significant relationship with structural attributes of conifer species which seems to be due to difference in microclimatic conditions or perhaps the long history of anthropogenic disturbance associated with study sites. Ahmed *et al.,* (1990a,b) did not find significant correlations between the structural attributes of *Juniperus excelsa* with most of the soil characteristics in forests of Baluchistan, probably due to disturbance factor operating in the area that obscured statistical correlations.

However, in the present study, some weak correlations were observed. Only soil conductivity was positively correlated with basal area for *Abies pindrow*. Density of *Cedrus deodara* showed positive significant correlation with water holding capacity and a negative correlation with salinity, suggesting that these variables have some controlling influence over the distribution and abundance of the these species of moist temperate areas of Pakistan. Examples of such types of correlations from different climatic regions of Pakistan are presented here to seek the importance of relationship between the edaphic variables of soil with structural attributes.

4.12.**Correlation of other soil chemical properties with the density ha^{-1} and basal area of conifer species m^2 ha^{-1}.** Density of *Pinus wallichiana* exhibited significant correlation with organic matter of soil, exchangeable Ca^{++} and K^+ at $p<0.05$ while basal area showed significant correlation with water holding capacity ($p<0.05$), exchangeable K^+ ($p<0.05$) and exchangeable Ca^{++} ($p<0.01$). Density of *Abies pindrow* showed significant relationship with slope of the forest ($p<0.1$), WHC ($p<0.01$) and exchangeable Ca^{++} ($p<0.05$) while basal area also showed significant correlation with slope and exchangeable Ca^{++} ($p<0.05$), basal area of this species showed weak correlation ($p<0.1$) with conductivity. Ecologically widely distributed species *Cedrus deodara* exhibited maximum significant correlations. Its density correlated with elevation, salinity and exchangeable K^+ ($p<0.05$), WHC and exchangeable Ca^{++} ($p<0.1$ & $p<0.01$ respectively while its basal area significantly correlated with organic matter and exchangeable Ca^{++} ($p<0.05$). Threatened species of the moist temperate area *Picea smithiana* showed minimum number of significant correlation, its density and basal area correlated with slope at $p<0.02$ and $p<0.05$ respectively (Table 4).

Table 4 Correlation between soil chemical properties and topographic variables with the density and basal area of conifer species of study area.

S. No.	Nutrients	r value	Significance level	r value	Significance level
		Density ha^{-1} of a species		**Basal area of species m^2 ha^{-1}**	
Pinus wallichiana					
1	**Elevation**	-0.0101	ns	0.0435	ns
2	**Slope**	-0.0461	ns	0.1142	ns
3	**Organic matter**	0.3403	P < 0.05	0.0365	ns
4	**pH**	-0.1204	ns	0.0039	ns
5	**Water holding capacity**	0.1737	ns	0.3251	P < 0.05
6	**Salinity**	-0.1792	ns	-0.1589	ns
7	**Conductivity**	-0.0033	ns	0.0958	ns
8	**Total dissolved salts**	-0.1744	ns	-0.1525	ns
9	**Soil compaction**	-0.0250	ns	0.2022	ns
10	**Exchangeable Ca^{++}**	0.3924	P < 0.05	0.4384	P< 0.01
11	**Exchangeable Mg^{++}**	0.1971	ns	0.2846	ns
12	**Exchangeable K^+**	0.342	P<0.05	0.3318	P<0.05
Abies pindrow					
1	**Elevation**	0.1197	ns	0.1615	ns
2	**Slope**	0.3253	P < 0.1	0.3812	P < 0.05

3	**Organic matter**	-0.1519	ns	-0.1371	ns
4	**pH**	-0.1605	ns	-0.2359	ns
5	**Water holding capacity**	0.4325	P < 0.01	0.1234	ns
6	**Salinity**	0.2333	ns	0.0257	ns
7	**Conductivity**	0.2417	ns	0.3241	P < 0.1
8	**Total dissolved salts**	0.2077	ns	0.0012	ns
9	**Soil compaction**	-0.1289	ns	-0.2621	ns
10	**Exchangeable Ca^{++}**	0.3947	P<0.05	0.4185	P<0.05
11	**Exchangeable Mg^{++}**	0.3096	ns	0.2429	ns
12	**Exchangeable K^{+}**	0.2019	ns	0.1873	ns
Cedrus deodara					
1	**Elevation**	-0.4669	P < 0.05	-0.0242	ns
2	**Slope**	0.0859	ns	-0.1438	ns
3	**Organic matter**	-0.1775	ns	0.4284	P < 0.05
4	**pH**	0.2260	ns	0.1194	ns
5	**Water holding capacity**	0.4041	P < 0.1	0.1265	ns
6	**Salinity**	-0.4466	P < 0.05	-0.1071	ns
7	**Conductivity**	-0.3061	ns	0.0069	ns
8	**Total dissolved salts**	-0.2973	ns	0.0107	ns
9	**Soil compaction**	-0.0087	ns	0.1715	ns
10	**Exchangeable Ca^{++}**	0.4172	P<0.01	).3362	P<0.05
11	**Exchangeable Mg^{++}**	0.3149	ns	0.2201	ns
12	**Exchangeable K^{+}**	0.4282	P<0.05	0.3080	ns
Picea smithiana					
1	**Elevation**	-0.3489	ns	-0.2949	ns
2	**Slope**	-0.8260	P < 0.02	-0.751	P < 0.05
3	**Organic matter**	-0.3375	ns	-0.3402	ns
4	**pH**	0.2641	ns	0.2904	ns
5	**Water holding capacity**	-0.2322	ns	-0.2868	ns
6	**Salinity**	-0.3264	ns	-0.3169	ns
7	**Conductivity**	-0.3808	ns	-0.3716	ns
8	**Total dissolved salts**	-0.3829	ns	-0.3736	ns
9	**Soil compaction**	0.3312	ns	0.3879	ns
10	**Exchangeable Ca^{++}**	0.3871	ns	0.3207	ns
11	**Exchangeable Mg^{++}**	0.2558	ns	0.1792	ns
12	**Exchangeable K^{+}**	0.4188	ns	0.3750	ns

Structural attributes of selected conifers showed some significant correlations with soil chemical properties of corresponding stands as is also reported by Malik *et al.,* (2007) who stated that chemical contents of soil played a significant role in the growth and development of community. Similar phenomenon was observed by Hussain and Qadir (1970), they found significant association between soil characteristics and the distribution and abundance of angiospermic shrubs. In contrast to the above findings, poor relationships were observed between the structural attributes and soil chemical properties, it could be due to high degree of disturbance that was observed in many forests of the study area. Similar results were observed by Ahmed (1990b) who did not find any significant relationship with either juniper density or its basal area with soil variables, during the study of Rodhmallazi forest, Baluchistan.

Normal growth and development of plants depend upon the continuous supply of nutrients and other soil characteristics like topographic and edaphic variables. Water holding capacity, organic matter of soil, salinity, conductivity, total dissolved salts, pH and soil compaction have marked relation with the growth. This part of study also evaluated the extent of relationship between plant density and basal area of conifer species with the soil chemical properties, elevation and slope.

Many soil characteristics are known to affect the uptake and transportation of soil nutrients, hence indirectly influence the growth and development of plants but in this study soil characteristic did not show many significant relationship with structural attributes of conifer species which seems to be due to difference in microclimatic conditions or long history of anthropogenic disturbance associated with study sites. Ahmed *et al.,* (1990a); Ahmed *et al.,* (1990b) did not find significant correlations between the structural attributes of *Juniperus excelsa* with most of the soil characteristics in forests of Baluchistan, probably due to disturbance factor operating in the area that obscured statistical correlations.

However, in the present study, some correlations were observed, indicated that these variables have some controlling influence over the distribution and abundance of these species of moist temperate areas of Pakistan. Examples of such types of correlations from different climatic regions of Pakistan are presented here to seek the importance of relationship between other soil characteristics with structural attributes. Shaukat *et al.,* (1976) investigated plant communities of Gadap area southern Sind that were found to be correlated with organic matter, MWHC and exchangeable potassium. Ahmed (1986) noted that sodium, potassium and organic matter have some controlling influence over the vegetation of foothills of Himalaya while water holding capacity, pH, carbonate and phosphorus did not have any such influence. Kayani *et al.,* (1988) found significant correlation ($P < 0.05$) of *Cynodon dactylon* and *Desmostachya bipinnata* importance value with the electrical conductivity and negative correlation ($P < 0.05$) with *Panicum repens*. Ahmed *et al.,* (1990a) found significant correlation ($P < 0.01$) between electrical conductivity and *Juniper* density.

Therefore it is suggested that the poor relationship observed between structural attributes with soil nutrients and other soil characteristics could be attributed to high order of anthropogenic disturbance that presumably prevailed in the area over a long period.

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