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Elucidation of the details of structure, composition, underlying group structure and gradients in *Quercus baloot* dominated forests

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Abstract

Twenty-two relatively undisturbed *Quercus baloot* dominating stands were surveyed on different physiographic situations in district Dir upper Pakistan. The purpose of the study was to investigate the types and structure of plant communities and ecological status of *Q. baloot* using agglomerative cluster analysis and detrended correspondence analysis (DCA ordination). The distribution pattern and influential factors of the plant communities were also analysed by testing edaphic, topographic and soil variables of vegetation sampled by Point centered quarter method for trees. The shrubs and saplings were sampled by 5 × 5 m quadrats while herbs and seedlings were included in 1 × 1 m to assess the understorey vegetation. In the overstorey vegetation, beside the dominant *Q. baloot* 6 other tree species including *Olea ferruginea*, *Quercus dilitata*, *Juglans regia*, *Ficus palmata*, *Diospyros lotus* and *Robinia pseudoacacia* had a significant share of the tree stratum. Among the understorey vegetation frequent species were *Indigofera gerardiana*, *Artemisia maritima*, *Plantago lanceolata*, *Rumex dentatus*, *Micromeria biflora*, *Fragaria vesca*, *Geranium rotundifolium*, *Ajuga bracteosa*, *Daphne oleoides* and seedling of *Q. baloot* and *Q. dilitata*. The results of cluster analysis disclosed three major vegetation groups that were principally dominated by *Q. baloot* with varied co-dominants. The groups derived from classification method could be clearly demarcated in the ordination space suggesting continuity in vegetation. However, none of the environmental variables measured explained the distribution pattern of the vegetation in the site ordination. We concluded that past disturbances, particularly the anthropogenic disturbance are mainly responsible for governing the different community types. The structure and composition varied in different community types, thereby representing unique entities. Some recommendations are outlined for the protection and maintenance of each of the different forest communities through appropriate management and conservation techniques.

Keywords: Physiographic, communities, ecological status, influential factors, DCA-ordination.

INTRODUCTION

The distribution of plant communities and species composition are not only regulated by environmental conditions, but also by spatial and anthropogenic factors as well species competition etc (Cousin and Eriksson, 2002). The potential importance of spatial factors, biotic interactions and other stochastic factors must be considered for understanding the relationship between plant communities and environmental variables (Chuang-ye et al., 2009). Structure, composition and function are the three important attributes of forest ecosystems that change in response to climate, topography, soil and disturbances (human induced and natural) (Timilsina et al., 2009). These mentioned factors along with forest succession are also responsible for both local (within stand) and landscape level variation in forest attributes thereby the length of monsoon, total rainfall, seasonal flooding and soil conditions. Other factors such is grazing, clearing for cultivation, burning, selective cutting, logging and lopping have been considered as factors modifying vegetational composition and succession (Dinerstein, 1979). Physicochemical characteristics of forests soil vary in space and time due to various factors like topography climate, weathering processes,vegetation cover, microbial activities and several other biotic and abiotic factors (Bhatnagar, 1965); Paudel and Sah (2003). Vegetation plays an important role in soil formation by the yearly contribution of surface vegetation to soil (Singh and Bhatnagar, 1977; Champan and Reiss, 1992; Sheikh and Kumar, 2010) which exerts a strong feedback on the forest ecosystem (Poster et al, 1984) and resulting in the difference in plant community structure (Ruess and Innis, 1977). *Quercus* (oak) belonging to the family Fagaceae and as a main or admixed tree species 6 autochtonous species that is *Quercus baloot*, *Quercus incana*, *Quercus dilitata*, *Quercus semecarpifolia*, *Quercus glauca* and *Quercus robur* represented a significant share of growing stock in Pakistan (Nasir and Ali, 1972). However, among these species *Q. glauca* is the least common species in the moist temperate areas while *Q. robur* is not native to Pakistan and has been planted in various places in the hills. Whereas, *Q. baloot* and *Q. incana* are typically of dry temperate species while on the other hand *Q. semecarpifolia* and *Q. dilitata* are distributed in moist and also in moist parts of the dry temperate areas of Pakistan (Champion et al., 1965; Ahmed et al., 2006; Khan et al., 2010a, b).

The present study demonstrated about the *Q. baloot* dominated forest of district Dir Upper, which grow mostly in the lowland areas, and their hilly margins, where the percentage cover of forest is low and human population density is high (Alamgir, 2004). In such regions the ecological and the general beneficial function of forests are very important. Due to the anthropogenic impacts, which results from their vicinity to settlement *Quercus* forests are mostly altered forest communities.

In the study area and even in the whole province (Khyber Pukhtunkhwa) *Q. baloot* is considered the most valuable tree species. It is used in construction and carpentry work, and is the main source of fuel wood. *Q. baloot* leaves are valuable as fodder and their wood is used in agricultural implements (Khan et al, 2010 b). However, according to Alamgir (2004) the braches of this species are also used as fence around cultivated fields and a good source of tannin and charcoal. Most of Dir population including rural and urban communities which constitute about 80% of the whole district depend on *Q. baloot* forests for their daily needs. Local people collect fodder, firewood, poles, timber and wild vegetables (ferns, mushrooms, medicinal plants, etc.) from these forests. *Q. baloot* forests are also important for the landscape conservation in the study area because they occupy a larger percentage of area which are not conserved and provide a home to a variety of wildlife. Though the *Quercus* forests are under the control of Forest Department. However, the local inhabitants have been awarded the royalty, as a result the *Quercus* forests are subjected to extensive logging and used heavily for fodder, fuelwood and firewood, they are burnt frequently for charcoal extraction and exposed to livestock grazing.

Despite the widespread occurrence and its importance both economically and ecologically little information exists on the ecological aspects of *Q. baloot* forests, particularly their composition, structure and environmental relations. However, some ecological studies have been made by Beg (1984), Ahmed et al. (2006) and Khan et al. (2010a and b) but they do not provide details of the existing communities or phytosociological gradients, restricted and weak in sampling design. The present study attempts to unravel the details of structure, composition, underlying group structure and gradients in *Q. baloot* dominated forests of district Dir, Upper, Pakistan, with the aid of multivariate methods.

MATERIALS AND METHODS

Study area

The district Dir upper is located in northern part of the Khyber Pakhtunkhwa province (KPP) in the Hindukush range of Pakistan. Geographically the area is bounded by Swat in east, Bajur agency and Afghanistan in the west, district Dir lower in the south and Chitral in the north, spanning from 34° 10 N latitude and 72°20 E longitude. The study area is part of sub-tropical dry temperate areas. However, part of the district also lies in the moist temperate area of the country (Champion et al., 1965; Khan et al., 2010a).

It is one of the 24 district of KPP which spreads over an area of 3,699 km^2. The physiography of the area indicates that the terrain is rugged, gently to steep sloping and rises from 975 to 3100 m asl (Ali et al., 2008; Khan et al., 2010a). According to the district census report (1998) the total population of the area is 5,75858 and almost lies in the valley beside river Panjkora which rises high in the Hindukush at latitude 35° 45 and joins the Swat River at Sharbatayi near Chakdara at latitude 34° 40.

Climate

The climate of the area is broadly described as typically continental type (Wahab et al, 2008) and in a year quite distinctly represents four seasons that is winter, summer, spring, and autumn. Winters are relatively long and cold and severe usually in the months of December and January. The mean maximum and mean minimum temperature have been recorded as 8.8 and -7°C in winter. On the other hand, the mean maximum and minimum temperature in summer range between 34.4 to 11.5°C respectively. Generally summer season is moderate and June and July are the warmest months. The maximum average rainfall 269.6 mm has been recorded concentrated in the month of March, while winter season receives more rainfall as compared to other seasons. The mean relative humidity varies from 30 to 70%. According to the meteorological station in the area, it shows that the pattern of rainfall, relative humidity and temperature increase progressively from January to June and then gradually declines up to December.

Vegetation sampling

Sampling was conducted in *Q. baloot* dominated forests, ranging from an elevation between 1190 to 1928 m asl, in district Dir upper. Though all forests are disturbed to some extent**,** least disturbed stands which were at least 200 m away from roads were selected for quantitative sampling in order to avoid the effect of disturbance caused by traffic and grazing. The criteria for selection of stands were: (1) there should be no sign of recent major disturbance.(2) that the stand should contain trees of at least 40 cm dbh. (3) Stand should cover an area of five hectares or more. Point Centered Quarter Method (Cottam and Curtis 1956) was used for quantitative sampling of tree vegetations and twenty five points were taken at regular intervals of twenty meters in each stand**.** Understorey vegetation was examined in each stand using 5 × 5 m size quadrats for shrubs and 1 × 1 m for herbaceous species.

Seedlings were recorded in the smaller while saplings in the larger sized quadrats. Before collecting vegetation data information on the samples, slope, aspect, altitude, geographical coordinates (latitude and longitude), were recorded by using Sunto Clinometer, Altimeter. Aspect, Compass and GPS. The aspects were categorized into the usual eight aspect groups, that is N, NE, E, SE, S, SW, W and NW. Diameter of trees (DBH greater than or equal to 5 cm) and height of saplings (DBH less than or equal to 5 cm) were measured. Seedlings of individuals (of height less than 30 cm) were counted. Species were recorded by their vernacular names, assisted by local expert. The vernacular names were later translated into scientific names using species identification manuals and flora of Pakistan (Nasir and Ali, 1972).

Importance value (IV) and absolute values (stand density ha^{-1} and basal area $m^2 ha^{-1}$) were calculated according to the methods described by Mueller-Dombois and Ellenberg (1974)**.** Importance value (IV) of tree species was calculated as the sum of relative cover, relative density and relative frequency expressed as a percentage of the total (Curtis and McIntosh, 1950).

Soil sampling and data collection

Three soils samples from 0 to10, 10 to 20, and 20 to 30 cm depth at four different corners of the forest stands were collected using soil agar. These soil samples were bulked in plastic bags and were air dried, for 24 h in an oven, thoroughly mixed, crumbs broken and sieved through a 2 mm sieve in order to remove pebbles and gravels.

The soil samples were then subjected to chemical analysis in the laboratory of Plant Ecology and Dendrochronology Federal Urdu University Karachi. The measured soil factors included pH, water holding capacity (WHC), Salinity, conductivity, total dissolved salts (TDS), soil organic matter (SOM), calcium (Ca), magnesium (Mg), Sodium (Na), potassium (K) and total nitrogen (N). Soil pH was measured by a digital pH meter (PH5011) in a soil suspension in 1:5 soil water w/v . Soil organic matter was estimated using loss on ignition method. Total dissolved salts, salinity and conductivity were measured using multi-parameter meter (Model session, TM 105). Water holding capacity was determined in accordance with Keen (1931), while total nitrogen, Mg, K, Ca, and Na were determined using Atomic Absorption Spectrophotometer (AAS, Model PG 990). To improve the precision of the results, three replicates were analysed and average for each of the soil analysis are presented.

Vegetation classification and ordination

In order to expose similarity and dissimilarity between plant communities and to obtain an effective analysis of species and related environmental factors, both classification and ordination techniques were employed. Hierarchical agglomerative cluster analysis using minimum variance method (Orloci and Kenkel, 1985) was employed to unfold the group structure inherent among 22 stands. Cluster analysis (CA) was performed using the importance values of tree species, and the results were presented in a dendrogram. A matrix of environmental variables including topographic, edaphic and soil variables was also developed. Aspect and canopy were converted into an ordered scale so as to run in the software. The groups obtained were also subjected to univariate ANOVA based on soil variables to identified any significant variation between groups.

The interrelation between plant communities corresponding to their environmental variables were analysed by ordinating forest stands using detrended correspondence analysis (DCA) (Hill and Gauch, 1980). The DCA was carried out with the PC-ORD statistical package window version 5.10 (McCune and Mefford, 2005). DCA was first run with all forest stands to check for any outliers. However no outlier was detected. In order to elucidate the relationships between the vegetation and environmental variables the axes scores from DCA axis were plotted against the environmental variables in Excel spread sheet and Pearson correlations coefficients computed

RESULTS

The details of locations and characteristics features of each sampling site, dominant tree species are presented in Table 1, while Table 2 provides the summary of phyto-sociological sampling of 22 stands including relative frequency, relative density, relative basal area and importance values (IV) for all species. The results were summarized below.

Multivariate analysis

Cluster analysis (CA)

Hierarchical agglomerative, cluster analysis with Euclidean distance and Ward's strategy resulted in three groups with 75% of the information in the abundance of species retained or at 6.1E + 0.2 objective function levels (which is conceptually similar to within group variance) (Figure 1). The three groups derived from cluster analysis, as follows:

Group I – *Qercus baloot* (pure community type): This group comprises of a single species that is *Q. baloot*. Sampling site represents typical dry temperate condition. *Q. baloot* was the leading dominant species with 100% of importance value. The group members are distributed at an elevation between 1370 to 1670 m (mean1524 ± 52 m) and facing east to west between an average of 23° ± 2.6 of slope. Ground flora was composed of *Artemesia scoparia*, *Otostegia limbata, Astragalus* sp*, Mallotus philppensis, Fragaria vesca, Solanum nigram, Silene vulgaris, Ajuga bracteosa, Berberis lycium, Euphorbia prostrata, Malva neglecta* and *Ammi visnaga.* The abundant species under *Quercus baloot* canopy were *Rumex hastatus, Artemesia maritima* and a considerable number of dominant tree species seedlings which attained frequency ranging from 5.4 to 100%.

Group II – *Quercus baloot – Olea ferruginea* Community type: This group is distributed on an average 1503 m elevation with 22 to 30° (mean 26 ± 2.6) of moderate slope in moist, sites of dry temperate areas. However, the slope angle was comparatively higher than

Table 1. Ecological characteristics of each forest sampling site.

Forest stand	Location	Latitude N	Longitude E	Altitude (m)	Slope (°)	Aspect	Canopy
1	Sawny 1	35 º 17	72 º 51	1395	25 º	N	Moderate
2	Daramdala Upper	35 º 21	72 º 55	1420	34º	E	Moderate
3	Daboona Sheringle	35º 28	72 º 02	1435	35 º	E	Moderate
4	Patrick (Shekhano)	35 º 41	72 º 10	1720	25 º	N	Moderate
5	Chum Sheringle	35º 28	72º 03	1422	27 º	E	Moderate
6	Jetkoot	35 º 22	72 º 08	1425	22 º	E	Close
7	Hitch Kale	35 º 20	72 º 14	1440	32 º	E	Moderate
8	Sanana Bal Patrak	35 º 44	72 º 13	1728	24 º	S	Close
9	Mina Sheringle	35 º 27	72 º 05	1418	20 º	W	Open
10	Chinar Khwar	35 º 22	72 º 08	1410	26 º	W	Open
11	Sawny 2	35 º 12	72 º 38	1390	35 º	S	Open
12	Chukayiatan	35 º 10	72 º 54	1190	10 º	E	Close
13	Chinaran	35 º 25	72 º 05	1417	28 º	E	Moderate
14	Shaukanai Patrak	35 º 43	72 º 14	1730	19 º	N	Open
15	Shaoor	35 º 28	72 º 03	1928	30 º	W	Moderate
16	Soorbat	35 º20	72 º 04	1800	21 º	N	Moderate
17	Sharmai	35 º18	72 º 50	1420	17 º	S	Moderate
18	Sheringle	35 º26	72 º 03	1425	16 º	N	Moderate
19	Dun Ganshal	35 º09	72 º 11	1722	22 º	N	Moderate
20	Barawal Banda	35 º13	72 º 69	1716	27º	W	Close
21	Barawal Banda	35 º11	72 º 66	1725	18 º	N	Moderate
22	Usheri Dadra	35 º18	72 º 54	1820	15 º	**N**	Moderate

Table 2. Phytosociological attributes and absolute values of *Quercus* and associated tree species.

Forest stand	Species	Phytosociological attribute				Absolute value	
		[1]RF	[2]RD	[3]RBA	[4]IVI	[5]D.ha^{-1}	[6]BA.m^{2}.ha^{-1}
Stand 1	*Quercus baloot*	100	100	100.00	100	1145	16.07
Stand 2	*Quercus baloot*	100	100	100.00	100	1364	92.26
Stand 3	*Quercus baloot*	100	100	100.00	100	1198	62.55
Stand 4	*Quercus baloot*	100	100	100.00	100	1164	184.95
Stand 5	*Quercus baloot*	90	90	87.66	89	386.58	51.48
	Olea ferruginea	10	10	12.34	11	42.95	7.24
Stand 6	*Quercus baloot*	59	82	84.00	75	543.99	43.05
	Juglans regia	24	10	12.00	15.34	66.67	5.9
	Ficus carica	17	8	4.00	9.66	50.34	1.94
Stand 7	*Quercus baloot*	100	100	100.00	100	266.55	16.24
Stand 8	*Quercus baloot*	100	100	100.00	100	419.05	33.17
Stand 9	*Quercus baloot*	75	90	94.86	86.62	669	26.33
	Robinia pseudoacacia	10	5	2.54.00	5.86	37.19	2.2
	Olea ferruginea	15	5	2.59	7.53	37.19	2.1
Stand 10	*Quercus baloot*	69	88	92.49	83.16	698	85.77
	Juglans regia	9	4	1.00	4.66	32	2.1
	Olea ferruginea	22	8	6.51	12.18	63	5.78
Stand 11	*Quercus baloot*	100	100	100.00	100	1092	151.7

Table 2. Contd.

Stand 12	*Quercus baloot*	100	100	100	100	856.21	120.25
Stand 13	*Quercus baloot*	76	92	94.00	87.33	672	58
	Olea ferruginea	24	8	6.00	12.67	58.46	0.32
Stand 14	*Quercus baloot*	100	100	100.00	100	594.88	100.51
Stand 15	*Quercus baloot*	66	87	96.00	83	511	64
	Olea ferruginea	20	7	3.00	10	41	2.2
	Juglans regia	7	3	0.38	3.46	18	0.36
	Diosyros lotus	7	3	0.79	3.59	17	0.7
Stand 16	*Quercus baloot*	100	100	100	100	522.44	60.95
Stand 17	*Quercus baloot*	100	100	100.00	100	760.99	99.42
Stand 18	*Quercus baloot*	100	100	100.00	100	611.17	65.98
Stand 19	*Quercus baloot*	100	100	100.00	100	553.63	86.98
Stand 20	*Quercus baloot*	80	88	96.00	88	522	70.41
	Quercus dilitata	20	12	4.00	12	36	3.9
Stand 21	*Quercus baloot*	75	82	92.00	90	478	48.66
	Quercus dilitata	25	18	8.00	10	33	4.3
Stand 22	*Quercus baloot*	78	86	90.00	84.66	544	64.22
	Quercus dilitata	22	14	10.00	9.33	26	5.33

RF=relative frequency, RD=relative density, RB=relative basal area, IVI=Importance value index.

that of group 1. A total of six species were recorded from this group of which, *Quercus baloot* and O*lea ferruginea* were recorded as the dominant species. *Q. baloot* was the leading species with 84% importance value while *O. ferruginea* was the co-dominant species with 8.89% of Importance value (Table 3). Among the other associated tree species *Ficus palmata* was distributed with 3.91% of importance value while *Juglans regia*, *Robinia pseudoacacia* and *Diosyros lotus* exhibited 1.6, 0.97 and 0.59% importance value respectively.

Among the understorey vegetation *Indigofera gerardiana*, *Artemesia scorpia*, *Conyza aegyptica*, *Fragaria nubicola*, *Rumex dentetus, E. prostrata*, *Viola biflora, A. maritima*, *Convolvulus arvensis*, *Onosma hispida, B. lycium*, *Cynodon dactylon* and *Ziziphus nummularia* were frequent. Established Seedling of *Q. baloot* and *O. ferruginea* were also recorded on the forest floor.

Group III – *Quercus baloot* – *Quercus dilitata* community type: The main components in group III are *Quercus baloot* and *Q. dilitata*. The first species was the leading species with 89.44% while the associated species attains 10.46% of the importance value. Table 4 shows that the group members are distributed between 1716 to 1820 m elevation on 15 to 27° moderate west and north facing slopes. Like other groups, ground flora was poor due to overgrazing and disturbance. However, this group shares many species in common with the previous groups. *Polygonum* sp., *A. scoparia, Rumex hastatus, R. dentetus, B. lycium Ranunculus muricatus, Micromeria biflora, Tulipa setellata, Cymbopogon* sp., and *Viola biflora* were common species with frequency ranging between 20 to 70%. *Parratiopsis jacquemontiana., Viburnum grandiflorum, Cannabis sativa, Vicia sativa, Sisymbrium irio, Capsella bursa-pastoris* and *Daphne oleoides* were less frequent species with 5.9 to 40% frequency. Seedlings of tree species were recorded with 11.2 to 60% frequency.

Environmental characteristics of the groups

With respect to environmental variables the three groups showed some variability (Table 4). Group I is characterized by medium elevation, slope angle, high aspect rating while canopy was of moderate type. Among the edaphic variables this group was characterized by high pH, WHC, while, salinity and conductivity were of medium order with comparison to other groups. Group II is characterized by low elevation and high slope, aspect

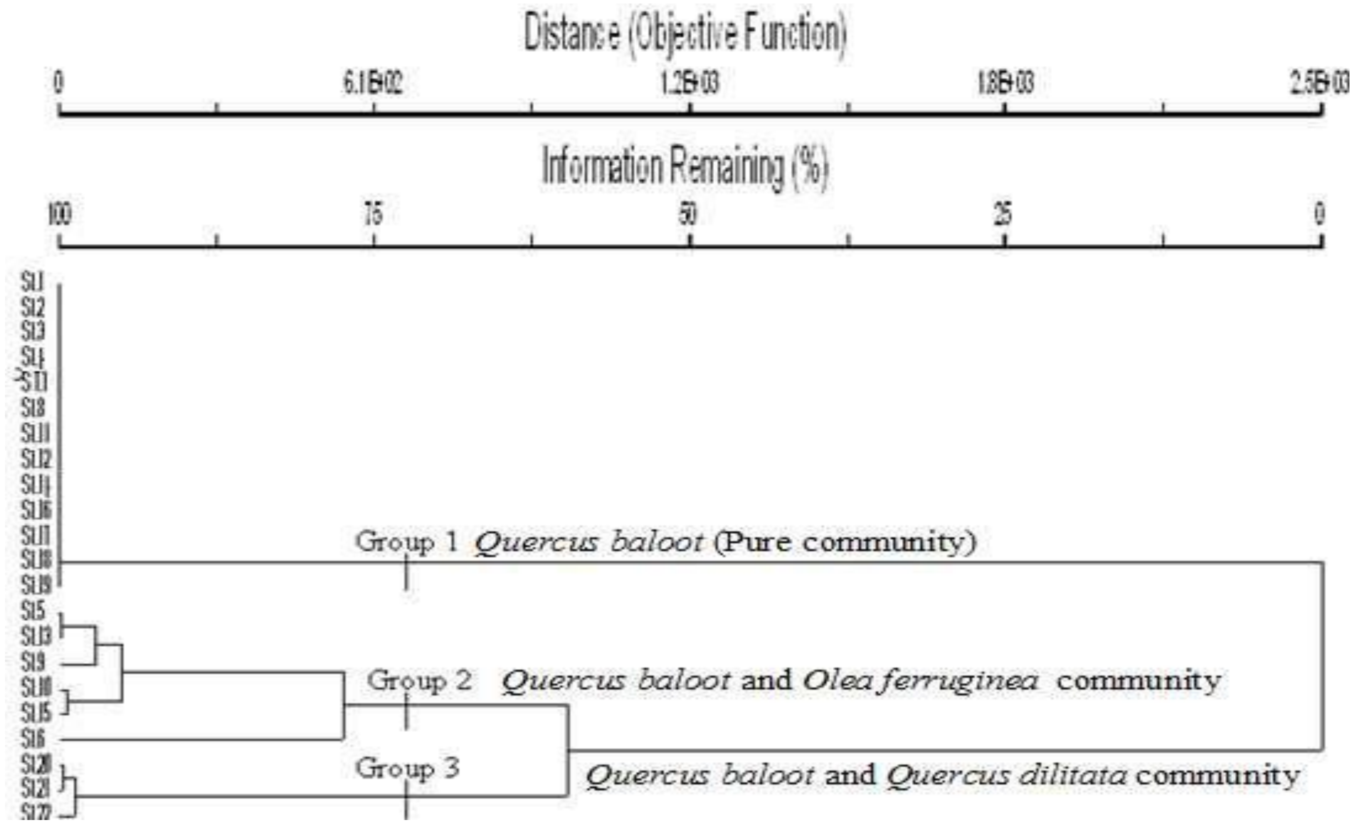

Figure 1. Cluster Analysis of tree species based on importance value (IVI).

rating, pH, OM, calcium, sodium Mg^{++}, potassium (K^{+}) and Nitrogen contents (Table 4). Group III is associated with high elevation, low slope angle, aspect, while canopy cover was of moderate type. Among the Edaphic variables this group is characterized by low pH while the values of organic matter, (OM), calcium (Ca^{++}), and potassium (K^{+}) values were highest among all groups.

Forest-environment relationship

DCA-Ordination

The Detrend correspondence analysis (DCA) of the tree data yielded a two-dimensional configuration (Figure 2). The community types distinguished in the classification analysis were clearly separated in the site ordination. Axis 1 and 2 separated the *Q. baloot* pure association from the *Q. baloot* – *Q. dilitata* and *Q. baloot* and *Olea ferruginea* association. Similar trend was repeated by axis 2 and 3 and 1 and 3 ordination configurations. It is obvious from Table 5 that the environmental variables including topographic, edaphic and soil variables superimposed on the 2-D ordination space did not suggest a strong relationship between any of the measured variables and forest composition. Pearson's correlation showed that non of axes was significantly correlated with environmental variables. One way ANOVA also test likewise indicated no statistically significant differences in the measured environmental variables among groups ($p>0.05$).

Correlation among environmental variables

The correlation among different environmental variables is given Table 6. The result shows that some of the environmental variables were found to be significantly correlated with each other. Among the 15 variables aspect was positively correlated with slope ($P < 0.05$), while potassium was significantly correlated with sodium on the same probability level. Soil pH is negatively correlated with sodium contents ($P < 0.01$). On the other hand water holding capacity (WHC) and salinity shows significant correlation with nitrogen (N) content, calcium (Ca), and soil pH, respectively.

Conductivity exhibited strong positive correlation ($P < 0.001$), while weak correlation with soil pH. Total dissolved salt (TDS), shows strong correlation with salinity and conductivity respectively. However, calcium and soil pH were also positively correlated with total dissolved salt (Table 6).

Table 3. The three groups derived from Ward's cluster analysis of 22 stands and their average tree species composition (average importance value for each group).

Column 1	Name	Mean±SE	Mean±SE2	Mean±SE3
1	*Quercus baloot*	100±00	84±2.0	89.44±1.66
2	*Olea ferruginea*	×	8.89±1.92	×
3	*Quercus dilitata*	×	×	10.46±0.80
4	*Ficus palmata*	×	3.91±2.4	×
5	*Juglans regia*	×	1.61±00	×
6	*Robinia pseudoacacia*	×	0.97±00	×
7	*Diosyros lotus*	×	0.59±00	×

Table 4. The three groups derived from Ward's cluster analysis using tree vegetation data of 22 stands of *Quercus baloot* dominated stands along with the mean values and standard error of their topographic, edaphic and soil nutrient characteristics (Mean ± SE).

S.No	Characteristics	Mean±SE		
		Group 1	Group 2	Group 3
	Topographic variables			
1	Elevation	1524±52	1503±84	1753±33
2	Slope	23±2.6	26±2.62	20±3.6
3	Aspect	2.6±0.36	2.5±0.56	1.3±0.33
4	Canopy	2±0.13	1.6±0.65	2.3±0.33
	Edaphic variables			
1	pH	6.2±0.13	6.1±0.19	6.7±0.12
2	WHC	54±1.72	48.8±2.2	43.6±42.3
3	Salinity	0.14±0.02	0.18±0.04	0.13±0.03
4	Conductivity	303±44	393±80	346±60
5	TDS	159±24	200±41	161±35
	Soil nutrient characteristics			
1	Organic matter	5.3±0.52	6.5±0.65	7.8±0.73
2	Calcium	0.41±0.08	0.45±0.06	0.51±0.17
3	Magnesium	0.51±0.04	0.45±0.03	0.48±0.07
4	Sodium	0.73±0.12	0.67±0.14	0.52±0.10
5	Potassium	1.67±0.18	1.43±0.18	2.05±0.20
6	Nitrogen	0.56±0.19	0.62±0.25	0.46±0.03

WHC = Water holding capacity, TDS, Total dissolved salt.

DISCUSSION

Multivariate analyses

Classification of forest vegetation by cluster analysis

The vegetation of the study area is fairly diverse and typical of much dry temperate area of the country (Champion et al., 1965; Khan et al., 2010a). These forest vegetation types based on importance values of tree species were classified using cluster analysis; a quantitative method of analysis used for objective categorization (Okono, 1996). In general, multivariate analysis was exceedingly useful in exposing the underlying group structure in data structure. The clustering strategy employed namely the agglomerative clustering technique developed by Ward (1963) was applied to 22 forest stands and was proved to be useful in classifying the stands into three main vegetation groups. Each community type is characterized by a dominant, diagnostic species as well as by associated species which had high constancy or relative abundance in the group.

Results from the cluster analysis indicated that three

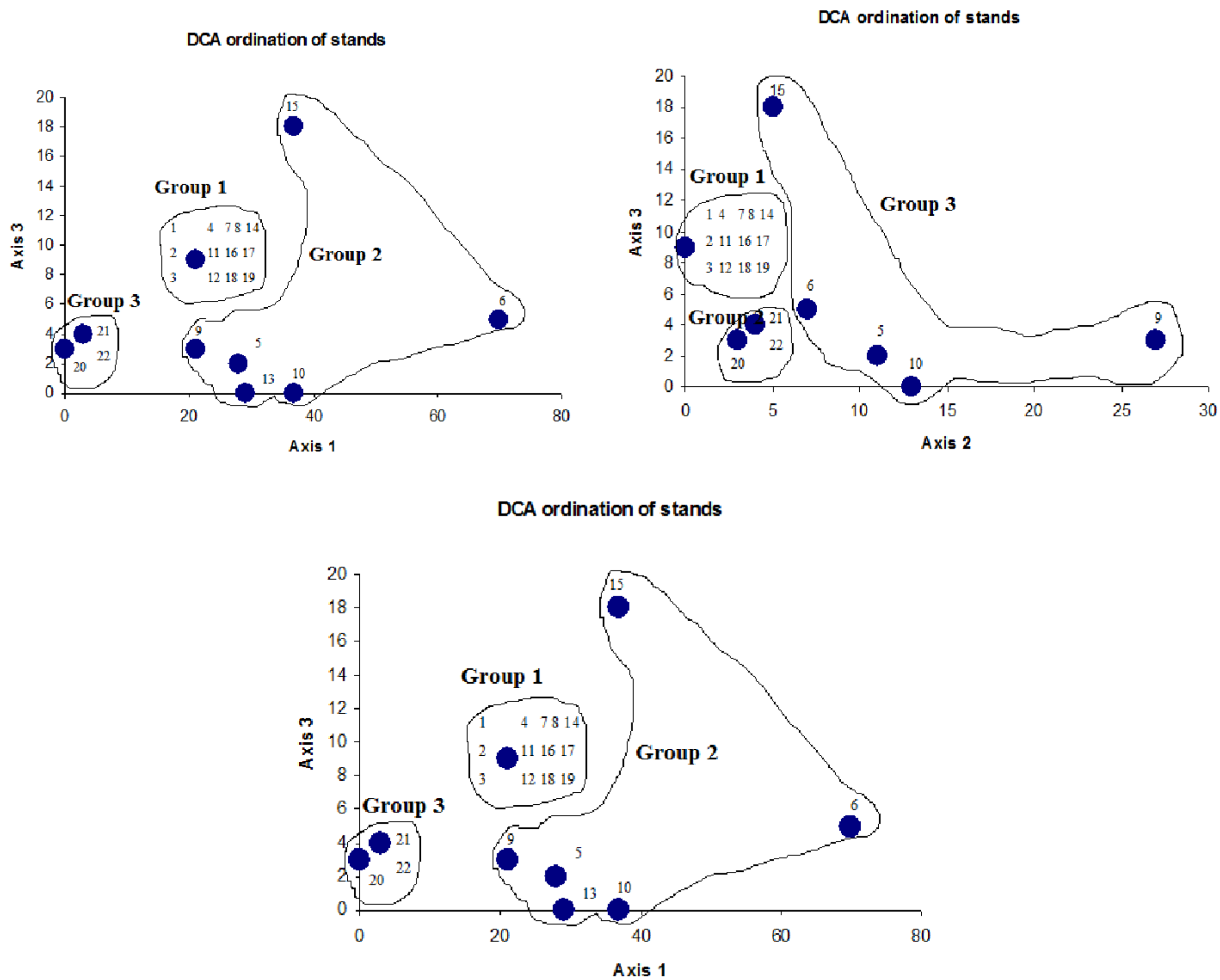

Figure 2. DCA ordination (axes 1, 2 and 3) of the 22 stands surveyed. The groups derived from Ward's cluster analysis are superimpose d on the ordination space.

different associations of *Q. baloot* forest occur in district Dir Upper Pakistan. Among these groups *Q. baloot* and *Q. dilitata* were clearly separated , and two different associations were identified in the former. The *Quercus* forest in the district mostly occurs in pure form. It was also observed that some exotic species were found in an association with *Q. baloot* with low importance value. Table 3 showed that *R. pseudoacacia* and *D. lotus* are the two species which are planted or introduced perhaps by the forest department in the past. It is also worthwhile to mention that *J. regia* and *F. palmata* are fruit yielding species they have been reported with fairly high importance value (IV) in comparison to the formerly mentioned species. The local community encourages the plantation of these two species in terms of obtaining greater yield and boosts the economy. However, *J. regia* was severely exploited by the local community in the past for their wood, because the wood of this species is considered to be best among all angiospermic tree species for making furniture.

Relationship between vegetational gradients and environmental variables

DCA- Ordination was applied to expose the major pattern in vegetation composition across the terrain examined. Besides, the results of DCA ordination strongly supported the results of cluster analysis as the groups disclosed could readily be superimposed on the two-dimensional

Table 5. Correlation coefficients of environmental variables with the three axes of DCA ordination.

Column 1	Column 2	Column 3	Column 4	Column 5
Environmental variable		**Axis 1**	**Axis 2**	**Axis 3**
Elevation	Topographic variables	0.277	-0.188	0.288
Slope		0.146	-0.020	0.104
Aspect		0.392	0.100	-0.115
Canopy		0.067	-0.343	0.095
Soil pH	Edaphic variables	-0.295	-0.157	0.062
Water holding capacity		-0.256	0.062	-0.161
Salinity		0.031	0.143	0.144
Conductivity		-0.018	0.169	0.170
Total dissolve salt		0.014	0.139	0.203
Organic matter	Soil variables	0.116	-0.246	0.208
Calcium		-0.329	-0.195	-0.014
Magnesium		-0.052	-0.109	-0.024
Sodium		0.289	-0.122	0.098
Potassium		-0.148	-0.100	-0.128
Nitrogen		-0.323	-0.273	0.055

**p<0.01; *p<0.05.

Table 6. Cross correlation among different topographic, edaphic and soil variables

	Ele	Sl	As	Can	OM (%)	Ca (%)	Mg (%)	Na (%)	K (%)	N (%)	pH	WHC (%)	Sal (%)	Cond. (mS/cm)	TDS (g/L)
Ele	1														
Sl	0.007	1													
As	0.038	0.38*	1												
Can	0.199	-0.18	0.29	1											
OM	0.102	-0.22	0.29	0.06	1										
Ca	0.206	-0.295	0.297	-0.13	0.15	1									
Mg	0.233	-0.206	0.297	-0.19	-0.37	0.16	1								
Na	0.049	0.235	0.297	0.179	0.46	-0.1	-0.25	1							
K	0.51**	-0.325	0.297	0.219	0.47	-0	0.15	0.374*	1						
Na	0.37	0.051	0.297	0.094	-0.04	0.31	0.325	0.25	0.1	1					
pH	0.28	-0.18	0.297	-0.03	-0.1	0.24	0.305	-0.62**	-0.2	0.117	1				
WHC	-0.02	-0.025	0.297	-0.099	0.05	-0	0.036	0.23	0.1	0.417*	0.08	1			
Sal	-0.15	-0.12	0.297	-0.32	-0.07	0.356*	0.1	-0.25	-0.2	-0.13	0.37*	0.16	1		
Con	-0.12	-0.16	0.297	-0.24	-0.11	0.29	0.08	-0.3	-0.2	-0.12	0.50*	0.17	0.95***	1	
TDS	-0.15	-0.14	0.29	-0.28	-0.04	0.375*	0.071	-0.29	-0.3	-0.12	0.47*	0.14	0.97***	0.98***	1

Ele=elevation, Sl=Slope, Asp=Aspect, Can=Canopy, OM=organic matter, Ca=Calcium, Mg=Magnesium Na=Sodium, K=Potassium, WHC=Water holding capacity, Sal=Salinity, Con=Conductivity, TDS=total dissolve salts.

DCA ordination configurations. It has been pointed out by Greig-Smith (1983) that the two basic techniques viz. classification (clustering) and ordination are complementary to each other though fundamentally applied for different purposes. In the present investigations the DCA ordination of tree (stand ordination) depicts a vegetation continuum. However, the environmental variables (topographic, edaphic and soil variables) measured in the present study did not explain the distribution of stands in ordination space as they gave non-significant correlations with the ordination axes.. Thus, the question arises as to what factors are responsible for the differences in species composition among sites? A similar situation has been recorded by

Timilsina et al. (2009) in Sal forest of Nepal. Hubbell and Foster (1986); Bares et al. (1998) and Clark et al. (1999) have suggested that the distribution of forest communities is determined together by soil moisture, soil nutrients, rainfall, past disturbances, mass effects and chance factor. However, Miehe et al. (2009) described that besides the role of other factors, responsible for change in vegetation human impact on regional vegetation pattern cannot be neglected. District Dir upper is a zone of heavy snowfall in winter season and of the rainfall in comparison to district Dir lower. The snowfall begins from December and continues up to March, while the peaks of the mountains remain covered almost throughout the year. During summer season the snow starts to melt and coming down to the river Panjkora passing through the rich *Q.* zone in the entire study area. Most of the forest stands are located in lower elevations on shaded places along the river. Consequently the snow and water from melting snow increase the water table which greatly influences soil moisture regime that, may have an important bearing on the distribution of vegetation. In addition the forests of the district have been exposed to different intensities of anthropogenic disturbances, especially fuel wood collection and selective logging in the past. The present logging history revealed that *Q. baloot* was once a homogenous forest which, was severely exploited by the local community for selective logging, burning, overgrazing, indiscriminate cutting of firewood and timbers. It is worthwhile to mentioned that in most of the stands, the largest *Q. baloot* trees were harvested, resulting in a change in the proportion of the species. So it was concluded that the soil moisture due to heavy snow and rainfall and past anthropogenic disturbances are together responsible for the distribution of different community types.

Conclusion

The application of classification technique (Cluster analysis) resulted in 3 main groups or community types, and was proved to be useful in disclosing the underlying group structure in the vegetation. Besides the DCA ordination technique strongly supported the results of cluster analysis (CA) as the resulting groups could be superimposed quite neatly on the two dimensional (2-D) ordination configurations. Nevertheless, the environmental variables (topographic, edaphic and soil variables) measured in the present study did not explain the distribution of stands in ordination space.

It is conjectured that soil moisture regime owing to an amalgam of heavy snowfall and, rainfall as well as past anthropogenic disturbances could be overriding factors in controlling the vegetational composition. Understanding the relationships between environmental variables and distribution of vegetation in the study area would help greatly in the management of *Quercus* forests of Pakistan.

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