Pak. J. Bot., 40(2): 615-626, 2008.

MULTIVARIATE ANALYSIS OF VEGETATION OF CHAPURSAN VALLEY: AN ALPINE MEADOW IN PAKISTAN

SULTAN MEHMOOD WAZIR[1], ALTAF AHMAD DASTI[2], SHEHZADI SAIMA[2], JEHANDAR SHAH[3] AND FARRUKH HUSSAIN[4]

[1]*Department of Botany, University of Science & Technology, Bannu, Pakistan*
[2]*Institute of Pure and Applied Biology, Bahauddin Zakariya University, Multan, Pakistan*
[3]*University of Malakand, Chakdara, Pakistan*
[4]*Department of Botany, University of Peshawar, Pakistan*

Abstract

Climatically the Chapursan Valley (Gilgit) is classified as alpine region but floristically it may be characterized as a part of Eastern Irano-Turanian region. Presence/absence data were used to classify and ordinate for both sites and species. DCA axes 1 and 2 were used for data interpretation. The relationships between soil characters and DCA axes 1 and 2 were determined using Spearman Rank correlation. Cluster analysis identified 5 vegetation types viz., crassulescent steppes, chamaephytic steppes, erme, moist sub-alpine pastures and riverine pseudo-steppes. These vegetation types have been discussed in the context of topographic and edaphic heterogeneity.

Introduction

The vegetation in most parts of the Pakistan is greatly affected by the summer monsoon rains. The Himalayan ranges intercept the moisture laden rain clouds from the Arabian Sea and little rain gets across to the alpines. The vegetation in these alpines is mostly on the melting snow. During winter heavy snowfall support the greatest glaciers in the world outside the arctic. The low temperature is the main stressor that has a very strong impact on the natural vegetation and seasonal succession of plants. Knowledge of habitat associations for alpine pasture species is limited (Peer *et al*., 2006) but apparently the vegetation is controlled by two main factors: rainfall and redistribution of water that decrease with the altitude. Redistribution of rainfall water by run-off from some areas and concentration in other depends on relief, on rainfall intensity and on occurrence of surfaces with low infiltration rates rocks or crust-forming soils: (Yair & Shahak, 1982). In large areas of the alpine landscape, where rain fall is less than about 250-mm and the surface induces run off, there is a drastic ecological contrast between dry and poor habitats in most of the area, and very favorable habitats where water accumulates, which account for only a small proportion of the area.

In relatively flat areas, the factor most affecting the vegetation distribution is the minor difference of levels determining the movement of water both over and through the soil. In hilly parts altitude has a much greater effect on temperature than has latitude, the mean annual temperature decreasing with increase in elevation. The rate of decrease is much more rapid in summer than in winter. The altitudinal linked temperature gradient eventually caused in the altitudinal limits of species and vegetation types. At high altitude, the impact of snow pressure and strong winds on vegetation structure and species composition is expected (Marrs *et al.,* 1988; Heaney & Proctor, 1989; Tanner *et al.,* 1990, 1998, Vazquez & Givnish, 1998, Ahmed *et al*., 2006; Peer *et al.,* 2001, 2007).

The environment of Asian alpines varies widely. There is considerable year-to-year climatic variation, especially in rain and snowfall, while soil varies in depth, stoniness, pH and texture, often within a few meters (Rassam & Tully, 1986; Cooper *et al*., 1987; Peer *et al*., 2001, 2007). In such climates, soil heterogeneity is probably a more important cause of vegetation pattern than climatic variation (Fitter, 1982; Pagnotta *et al*., 1997) found correlation between species distribution and soil depth. Similarly, Sterling *et al*., (1984) measured correlation between species abundance and slope. The complex gradients in edaphic conditions or disturbances regimes that are associated with topography provide an opportunity to investigate the mechanism that maintains this structural and compositional variation. As yet no account appears to have been published of the phytoscociology of the alpine regions at the latitude of Chapursan valley (75º N). The aim of the present investigation was to give a general account of the major plant communities, with the ultimate intention of understanding the factors responsible for distribution of species and to complete the vegetation picture of Pakistan.

Materials and Methods

Study area: Chapursan Valley is located (74-76 °E 34-38 °N) at the northeast corner of Pakistan where the Hindu Kush, the Himalayas and Karakrum form a triangle of mountains and where Afghanistan, Pakistan, China and Russia come close together (Fig. 1). An abrupt relief, high snow-capped peaks and many glaciated valleys, characterizes the region. The mountains are lofty, with an average height of about 5000 meters. The valley is filled with glacial and glacio-fluvial deposits, terraced by Chapursan River. Nearly 15% of its area is covered by a great mass of glaciers. Most of the soil formed from the weathering of hard rocks is almost gravelly in nature. The extreme steepness of the land promoted the soil erosion in the valley.

Climate: The scarcity of meterological stations in alpine region makes it impossible to give a detailed account of the climate. Judging from the data gathered from the nearby stations, the temperature ranges from below zero (minimum) to 25ºC (Maximum). Maximum rainfall is received in the month of April. The erratic rainfalls and glaciers are the main sources of irrigation water for the upland fields. Heavy snow occurs throughout the winter season. The area experiences an extreme type of Eastern Irano-Turanian climate with very low and irregular rainfall.

Floristic inventory: After orientation survey of the area, a total of 51 sampling sites were marked keeping in view the maximum possible heterogeneity in vegetation. The vegetation data was collected during August and September 2002-2004. Each site included four habitats: river banks, mountain slopes, rocky outcrops and valleys. In each habitat, five 1000-meter square stands were delimited. In each stand, vegetation parameters were recorded by placing 10 randomly placed 5m quadrats. Complete lists of species with in each quadrat were prepared. Altitude of each stand was measured with altimeter. Plants were identified with Flora of Pakistan (Nasir & Ali, 1971-1995; Ali & Qaier, 1995-2005). Later on the voucher specimens were confirmed in various herbaria and scientific literature. Nomenclature of plants is that of Stewart (1972).

Fig. 1. Location of the study sites in Chapursan Valley, Pakistan.
The Cluster of black circles at the far end of the map indicates the study area

Vegetation analysis: Presence/absence data were used to classify and ordinate both sites and species by reciprocal averaging (RA) procedure of Hill & Gouch (1980). Since the presence of rare species can severely distort ordinations produced by RA (Hacker, 1983), such species were eliminated from the analysis. These were species occurring in only a single stand. Detrended Correspondence Analysis (DCA) was selected as an appropriate ordination method based on gradient length and preliminary correspondence analysis (Jongman *et al.*, 1995). The default options of the program DECORANA (Hill, 1979; Causton, 1988) were used for the analysis. DCA axes 1 and 2 were used to data interpretation.

Stands were clustered based on Monothetic Information Statistic procedure (Hill, 1979; Causton, 1988) incorporating Spearman rank order dissimilarity coefficient. Scatter of classification groups were plotted on overlays of the ordination axes to assess the compatibility of the two methods of data simplification (Dargie & Demerdash, 1991; Dasti & Agnew, 1994; Dasti & Malik, 1998). The relationships between soil characters and DCA axes 1 and 2 were determined using Spearman Rank correlation (Causton, 1988).

The % cover of each species in each quadrat was recorded according to the Braun-Blanquet Cover Scale. Importance value of each species was calculated following the method of Curtis & McIntosh (1951).

Soil analysis: In each quadrat, soil samples were collected from three points on the perimeter of each stand (at two adjacent corners and the middle of the opposite side). We extracted a 2 cm diameter core of the top soil (0-5 cm depth) and of the subsoil (10-15 Cm depth) at each point, bulked the samples from three collection points, and dried them at 70ºC. Topsoil samples were analyzed for available cations, phosphorus and organic mater. Subsoil samples were analyzed for soil texture. Soil texture, water holding capacity, soil moisture contents, pH, EC and organic carbon were determined using standard methods (Richards, 1954).

Results

Classification: Five plant associations were recognized on the basis of the cluster analysis. The botanical composition of each association is presented in Table 1. These associations were delineated based on specifying four hierarchical levels (Fig. 2). The tree layer was absent in the study area. The most noticeable feature indicated by this analysis was the separation of Crassulescent steppes (gravely dry association A) from aquatic and telmatic communities (B-E) at the first hierarchical level. The three samples of Riverine Pseudo-steppes belonging to association E were separated from the other samples at the second level by *Arnebia griffithii* and *Tamaricaria dioica.* Among the wet lands, moist sub-alpine pastures community (D) was separated from associations B and C at level three by *Geranium meeboldii, Primula denticulata* and *Saccharum spontaneum.* At the fourth level Chamaephytic steppe were separated from community C (Erme) by *Atriplex pamirica,* Further subdivisions at lower information gains were regarded as minor variants and were not considered. The vegetation communities are described briefly below in the context of major discriminating species.

Association-A

Crassulescent steppes: This association is characterized by the dominance of low shrubs or half-shrubs (0.2 to 0.5 m high) of CAM plants. Fleshy, halophilous shrubs belonging to Chenopodiaceae (*Haloxylon stocksii*) assume the leading role in the flora dominating the association. Among the component species, *Haloxylon stocksii* along with *Peganum harmala* occupy plains as well as plateau and sometimes hillsides. *Suaeda fruticosa* occupy lithosoles derived from sedimentary rocks. *Ephedra relegiana* is most common on stony pavements with shallow soils having no clear-cut profile. Among the associated species *Capparis spinosa* was found mainly on steep sloping side-lands and rocky out crops. It rapidly colonizes land-slips, which are a regular feature on the slates found in the study area. *Isolepis setace* and *Lepidium latifolium* occupy micro-relieves distributed along the permanent and seasonal water courses. *Lepidium latifolium* is often found around the water margins that remained moist round the year.

Association-B

Chamaephytic steppes: This association occupied the wetland sites of the valley highlands. Most of the component species such as *Nasturtium officinale, Astragalus macropterus, Bromus japonicus, Potentilla gelida, Berberis kunawurensis , Cichorium intybus* and *Medicago polymorpha* are commonly found on level to gently sloping wet meadows and pastures, as well as on damp to well drained grasslands, decreasing progressively at steep slopes. These species are often plentiful along water-courses and field margins. Among the bushes *Seriphidium brevifolium* and *Atriplex pamirica* are exceptionally tolerant of a wide range of site conditions and excellently equipped to colonize new land forming a very open cover, with fair amount.

Table 1. The vegetation of Chapursan valley; relative percentage dominance (Importance value to nearest integer) of species in the five associations segregated through the Normal Cluster Analysis.

Species	A	B	C	D	E
Aristida adscensionis L.	0	15	0	0	0
Arnebia griffithii Boiss.	0	0	0	0	15
Astragalus himalayanus Kl.	8	36	35	27	0
Astragalus macropterus D.C.	0	10	0	0	0
Atriplex pamirica Iljin	53	30	0	0	0
Berberis kunawurensis Royle	0	13	0	0	0
Bromus japonicus Thunb.	0	9	62	0	35
Campanula aristata Wall	0	0	3	11	0
Capparis spinosa L.	8	0	0	0	0
Chenopodium ambrosioides L.	11	18	0	0	0
Cichorium intybus L.	2	4	0	0	0
Cirsium arvense (L.) Scop.	0	2	17	63	52
Cnicus arvensis Hoffin	0	0	13	0	0
Cymbopogon L. Sp.	0	0	2	0	0
Cynodon dactylon Pers.	9	21	0	38	0
Cynoglossum lanceolatum Forssk.	10	0	0	0	0
Eleocharis mitracarpa Br.	0	0	24	0	0
Ephedra religiana Wall ex. Stapf	8	0	0	0	0
Eragrostis pilosa Beauv.	0	0	4	0	0
Geranium meeboldii Briq.	0	0	0	45	0
Haloxylon stocksii (Boiss) Benth. & Hook.	99	0	0	0	0
Hippophae rhamnoides L.	0	0	36	0	98
Hyocymus niger L.	6	0	0	0	0
Isolepis setacea (L.) R.Br	8	0	0	0	0
Lepidium latifolium L.	20	0	0	0	0
Limonium cabulicum (Boiss) O. Kuntze.	13	0	0	0	0
LoLium multiflorum Lamk	0	0	13	0	0
Medicago polymorpha L.	0	32	0	0	0
Melilotus indica (L.) All.	0	3	14	0	0
Myricaria dahurica (Willd) Ehrenb	0	3	0	0	0
Nasturtium officinale Br.	0	9	0	0	0
Onosma hispidium Wall ex. G. Don.	8	0	0	0	0
Peganum harmala L.	30	0	0	0	0
Plantago major L.	0	0	13	12	0
Potentilla gelida C.A. Mey.	0	50	43	33	0
Primula denticulata Sm.	0	0	0	17	0
Rheum emodi Wall	0	12	0	0	0
Rosa webbiana Wall ex Royle	0	0	2	0	0
Saccharum spontaneum L.	0	0	0	36	0
Salix acmophylla Boiss.	0	0	3	0	60
Seriphidium brevifolium (Wall ex DC) Ling and Y.R. Ling	0	33	10	0	0
Suaeda fruticosa (L.) Forssk.	7	0	0	0	19
Tamaricaria dioica Roxb.	0	0	1	0	21
Taraxicum officinale L.	0	0	2	18	0

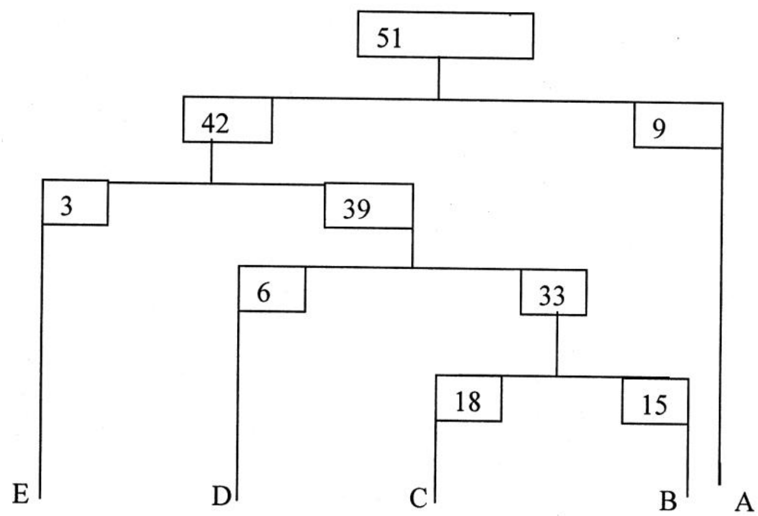

Fig. 2. The hierarchy of classification of 51 samples from the Chapursan Valley by the monothetic divisive technique. The number of samples (stands) in each association is given in boxes.

Association-C

Erme: Erme is a low growing community of forbs and grasses representing the post pastoral vegetation type resulting from over-grazing around villages and crop fields occupying the wet valley beds. The runoff produces wadies of considerable size, which are bordered by typical fertile silty soils located at the altitude ranges between 3350-3750 m. *Geranium meeboldii, Lolium multiflorum, Rosa webbiana, Eleocharus mitracarpa, Cnicus arvensis* and C*ymbopogon* are the characteristic species of these soils.

Association-D

Moist sub-alpine pastures: This association was distributed in between 3350 to 3400 meters or slightly higher at appropriate places. It represented an assemblage of spring flush of herbaceous flora. Avalanches sweep down the depressions and eliminate the perennials. Consequently these micro sites are later occupied by herbaceous pasture species including some genera of grasses.

Association-E

Riverine pseudo-steppes: This association represents riverine vegetation located at the boundary of terrestrial and aquatic habitats of the area. It is distributed along stony or gravelly stream or river beds and mountain swamps throughout the valley. The association overlaps the *Tamarix-Salix* type of formations extended up into the sub-alpine zone. The association is obviously dependent on continuous supply of water, which varies during the year from torrent largely submerging the vegetation to water table well below the surface. The association is characterized by having dense thickets of (usually 0.5 to 1 meter high) *Hippophae rhamnoides, Myricaria dahurica*. There is also varying proportion of shrubs of the adjoining climatic climax and *Salix acmophylla*.

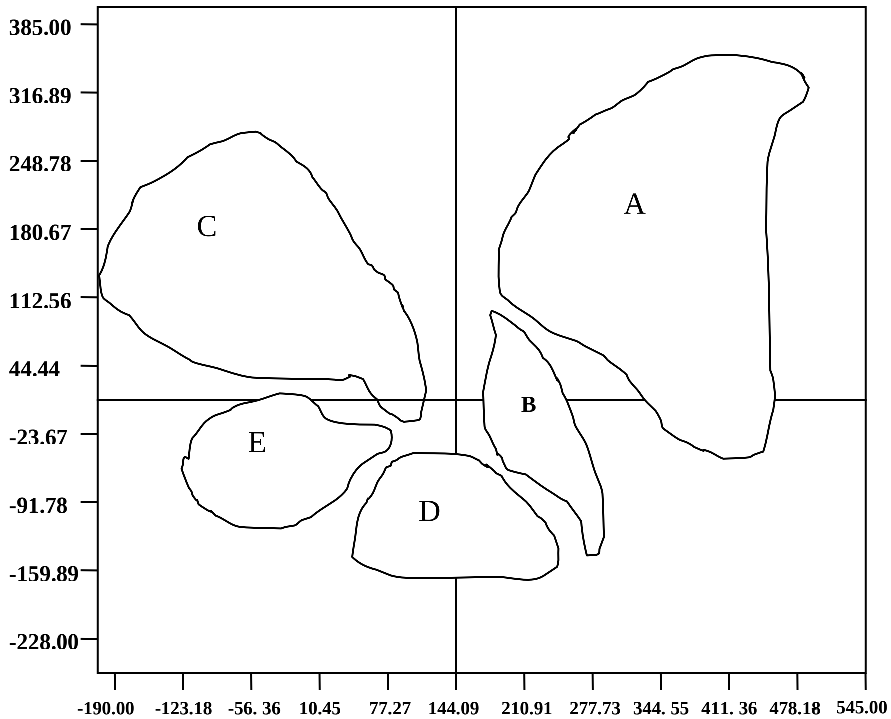

Fig. 3. DECORANA (axis 1 and 2) plot of the 51 samples from Chapursan valley. Points are not plotted individually. Instead zones are shown in which each of the five associations segregated through the cluster analysis as given in Figure 2 are found.

Gradient analysis: Stand ordination in the plane of first two axes is presented in Fig. 3. The first DCA axis of the normal data set had an Eigenvalue of 0.555 (15% of the variance explained). The Eigenvalue for the second axis was 0.472 (13% of variance explained). Further axes explained less than 12% of total variances and were thus ignored. Site ordination (Fig. 3) reveals a marked relationship between the first axis and the soil factors. There was highly significant correlation ($p<0.01$) between the sample scores along DCA axis 1 and the bare soil, soil nitrogen and calcium carbonates: *R* values exceeded 0.4. Regarding axis 2, *R* values of these edaphic factors were considerably low ($p<0.03$). Beside the soil characters, altitude showed a significant negative correlation ($p<0.05$) with DCA axis 1 (but not with axis 2). The organic mater availability in the sample plots showed a significant correlation with both the DCA axes (Table 2). In addition to these factors, ordination axes (1 and 2) appeared to be marked influenced from topography, redistribution of rainwater and soil depth. It is evident from Fig. 3 that sites of the river-beds (stands belonging to association E) are clearly grouped at one end (high score) and those of wet land complex (1-15 sites belonging to associations A-D) on the other end (low score) of DCA axis 1. However among the wet land complex, several sites are separated from the others suggesting a degree of floral diversity within this group. Site 15 is strongly separated from rest of the sites suggesting again the operation of site-specific factors. Sites of the enclosed basins (2-3 and 12) that collect the run-off water occupying the intermediate position along the axis 1 reflecting the fair conditions of water and soil availability for plants growth.

Table 2. Spearman's Rank Correlation Coefficients between DCA first and second axes scores, soil parameters and altitude for Chapursan valley.

Environmental variables	Axis 1	Axis 2
$CaCO_3$ (meq/l)	0.410*	-0.218
Organic matter (%)	-0.481*	0.457*
Nitrogen (ppm)	-0.488*	-0.174
Phosphorus (ppm)	-0.031	0.041
Potassium (ppm)	0.012	0.275
Ca and Mg (meq/l)	-0.048	-0.017
Sodium (meq/l)	-0.080	-0.096
pH	0.112	-0.293
Electrical conductivity (dsm^{-1})	-0.068	-0.036
Sand (%)	-0.609**	0.089
Silt (%)	-0.618**	0.161
Clay (%)	0.744***	-0.176
Moisture content (%)	0.425*	-0.115
Altitude (m)	-0.580**	0.092
Bare	0.624**	0.324
Stone	0.197	0.250

Significance is shown as: *** $p<0.001$, ** $p<0.01$, * $p<0.05$

Site ordination reveals that the separation of gravely dry sites (association A) as a distinct group at the resource poor end of the gradient is due to the relative abundance of *Atriplex pamirica* and *Haloxylon stocksii.* These species are virtually absent from wetland sites. The ordination position of *Astragalus himalayanus, Potentilla gelida* and *Campanula aristata* (association B) suggest that these are characteristic of moderately hydrophytic habitats. *Salix acmophylla*, *Hippophae rhamnoides* and *Cirsium arvense* show maximum frequency in riverbed sites (association E). These results clearly suggest that habitat strongly influence the special distribution of alpine species and is therefore likely to play a key role in structuring alpine vegetation communities.

Discussion

There are three classes of plants. First there are the plants of the deserts; secondly those of oases and thirdly there are plants that grow near melting snow or beside the streams. A number of Saharo-Sindian types have reached in this alpine valley *Peganum harmala, Capparis spinosa* and *Haloxylon recurvum* are a few examples.

The vegetation of the dry sites such as rocky slopes consisted of a limited number of low xerophytic shrubs, mostly deciduous and with small leaves but including evergreen *Juniperus excelsa* and *Ephedra gerardiana*. With the elimination of most trees and shrubs on relatively gentle slopes and flat grounds herbaceous pastures were developed especially on damper soils, with rich alpine flora including many wide-spread genera of grasses. Physiognomically the vegetation is open in dryer part of the area but along the river banks thickest of armed *Hippophae* and the microphyllous unarmed *Myricaria* along with *Salix* sp. is the common feature of the vegetation. This type of vegetation occurs throughout the study area and extends from low altitudes up to the sub-alpine zone. It was largely dependent on a continuous supply of water which varies during the year from a torrent largely submerging the vegetation to a water table well below the surface.

Table 3. Mean values and standard deviations (SD) for all soil variables for the five association identified by the Normal Cluster Analysis.

Factors		A	B	C	D	E	F-value
$CaCO_3$ (meq/l)	**Mean**	16.166	11.083	8.5	6.833	5.666	44.77^{***}
	S.D.	1.181	1.876	0.5	0.764	0.289	
Organic matter (%)	**Mean**	0.48	1.006	0.823	0.936	1.013	6.83^{**}
	S.D.	0.03	0.2139	0.0351	0.1457	0.1966	
Nitrogen (ppm)	**Mean**	0.025	0.043	0.031	0.053	0.065	136.75^{***}
	S.D.	0.001	0.0037	0.0021	0.0021	0.0023	
Phosphorus (ppm)	**Mean**	23.033	14.116	15.66	24.76	34.2	19.63^{***}
	S.D.	3.011	1.751	1.935	5.445	1.997	
Potassium (ppm)	**Mean**	371.66	243.33	219.66	259.33	174.66	11.33^{***}
	S.D.	51.03	12.5	23.29	51.08	34.43	
Ca and Mg (meq/l)	**Mean**	7.466	5.8	7	6.8	6.33	0.92
	S.D.	1.286	1.562	1	1.114	0.577	
Sodium (meq/l)	**Mean**	1.043	1.38	1.116	0.976	1.566	3.5^{*}
	S.D.	0.118	0.2	0.4124	0.006	0.21	
pH	**Mean**	7.77	7.83	7.96	8.1	7.766	1.62
	S.D.	0.321	0.0577	0.208	0.173	0.115	
Electrical conductivity (dsm^{-1})	**Mean**	0.213	0.21	0.24	0.18	0.253	8.32^{*}
	S.D.	0.035	0.00	0.01	0.01	0.005	
Sand (%)	**Mean**	68.46	66.46	75.13	74.86	74.8	1.47
	S.D.	1.155	11.01	5.03	2.73	4.58	
Silt (%)	**Mean**	21.66	30	12.66	15.33	10.66	19.14^{***}
	S.D.	2.88	5.29	1.15	1.15	3.05	
Clay (%)	**Mean**	10.86	9.53	9.53	9.8	12.86	3.68^{*}
	S.D.	1.155	1.155	1.155	1.709	1.155	
Moisture content (%)	**Mean**	0.216	0.55	1.403	0.976	0.993	20.06^{***}
	S.D.	0.029	0.086	0.0364	0.115	0.289	

Environmental factors affecting distribution of plants: The results indicate that landscape, the nature of the rock and the redistribution of rainfall water by run-off are the main sources of spatial variation in the study area. These geomorphologic factors determine the boundaries and the composition of the plant communities (Tuomisto, 2003). Apart from the fact that the landscape variables are indeed relevant for explaining the main vegetation types, the correspondence between the results of cluster analysis and DCA planes also permit a direct interpretation of scores of stand data in DCA plane in relation to soil variables (Kubota, 2004). The five associations produced by cluster analysis are plotted on first two axes as a scattered diagram (Fig. 3). The ordination axes may represent in some way the major substrate influenced which effect the stands in these data, and have been used the plant and soil characteristics of the association (Table 3) to discuss the overriding features of the environment.

Organic matter, bare soil, stone cover and altitude were significantly correlated with DCA axis 1 (Table 2). This correlation suggests that two factors seem to be operative: altitude and substrate. The importance of altitude as an environmental factor affecting plant species association is not surprising, considering its close correlation with rainfall and redistribution of rainfall distribution (Dasti & Malik, 1998; Danin *et al.,* 1975; Evenari *et al.,* 1982, Peer *et al*., 2001, 2007). The importance of percent soil stone cover and organic matter as an environmental factor, affecting plant species associations is not surprising but has close relationship with water absorption and its retention. The analysis and assessments of pattern and zonation along the first ordination axis suggest that the most important environmental gradients and boundaries across the landscape are associated with down slope movement of water. The variations in runoff patterns and soil texture might be responsible for the occurrence of such correlations. If this assumption is true then it is suggested that some combined effect is important in determining the distribution pattern of the plant species. This assumption is supported by the fact that all species show differential distributions in relation to edaphic factors over relatively short environmental gradients in such alpine shrub lands.

Plant assemblage: Topography predicts species composition of the study area. Many species changed in abundance along the ridge-valley catena, and there are impressive pairs of species in the genera *Hippophae* and *Haloxylon* that portioned the topographic niche very precisely. This ridge- valley difference is not surprising: catenas are fundamental in plant ecology in general and in the tropics in particular (Gartlan *et al*., 1986; Wever, 1991; Tuomisto & Ruokolainen, 1994; Tuomisto *et al*., 1995; Clark *et al*., 1999; Svenning 1999; Webb & Peart, 2000). The results (Table 1) suggested that abundance of some species (*Atriplex crassifolia, Haloxylon recurvum, Peganum hermala* and *Ephedra gerardiana*) decreased or became absent from ridge-top to valley. At the opposite, some species were much frequent in the valley and their frequency decreased as moved from valley sites to ridge top (*Chenopodium ambrosioides, Cynodon dactylon* and *Melilotus indica*). It seems reasonable to conclude that these species are specialists to topographic differences. However, some species are generalists (*Astragalus himalayanus, Circium arvense* and *Potentilla gelida*) with respect to catena, while the others are narrowly restricted to gullies or river beds. However, more observations or experiments would be required to establish topographic preferences of these species.

Conclusion

Summarizing the main findings it is concluded that both classification and ordination are able to delimit the plant association according to their environment. Because of the special nature of mountain landscapes with their variable disturbance and episodic resource base, the difficulty of describing vegetation boundaries may be a general one and it seems that plant ecologists must continue to attempt the difficult definition of hazy boundaries in these habitats.

References

Ahmed, M., T. Hussain, A.H. Sheikh, S.D. Hussain and M.F. Siddique. 2006. Phytosociology and structure of Himalayan forests from different climatic zones of Pakistan. *Pak. Jour. of Bot*., 38(2): 361-383.

Causton, D.R. 1988. Introduction to vegetation Analysis. *London Allen and Unwin*. 342pp.

Clark, D.B., M.W .Palmer and D.A. Clark. 1999. Edaphic factors and the landscape-scale distributions of tropical rain forest trees. *Ecology*, 80: 2662-2675.

Cooper, P.J.M., P.J. Gregory., D. Tully and H.C. Harris, 1987. Improving water use efficiency of annual crops in the rainfed farming systems of west Asia and North Africa. *Experimental Agriculture*, 23: 113-158.

Curtis, J.T. and R.R. McIntosh. 1951. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*, 31: 434-455.

Danin, A., G .Orshan and M. Zohary. 1975. The vegetation of the northern Negev and the Judaean desert of Israel. *Israel Journal of Botany*, 24: 118-172.

Dargie, T.C.D. and M.A. El-Demerdash. 1991. A quantitative study of vegetation-environmental relationship in two Egyptian Deserts, *Journal of Vegetation Science*, 2: 3-10.

Dasti, A.A. and D.Q. Agnew. 1994. The vegetation of Cholistan and Thal deserts, Pakistan. *Journal of Arid Environments*, 27: 193-208.

Dasti, A.A. and S.A. Malik. 1998. A transect of vegetation and soils on the Indus valley scarp slope, Pakistan. *Pakistan Journal Plant Sciences,* 4(2): 73-84.

Evenari, M., L. Shanan and N. Tadmore. 1982. The Negev: the challenge of a desert. *Harvard Univ. Press, Cambridge, M.A.*

Fitter, A.H. 1982. Influence of soil heterogeneity on the coexistence of grassland species. *Journal of Ecology*, 70: 139-148.

Gartlan, J.S., D.M. Newbery, D.W. Tomas and P.G. Waterman. 1986. The influence of topography and soil phosphorus on the vegetation Korup forest reserve Cameroun. *Vegetation*, 65: 131-148.

Hacker, R.B. 1983. Use of reciprocal averaging ordination for the study of range condition gradients. *Journal of Range Mangement*, 36: 25-30.

Heaney, A. and J. Proctor. 1989. Chemical elements in fitter at a range of altitude on Volcan barva, costa Rica: Nutrients in Tropical Forest and Sawanna Ecosystems. (Ed.): J. Proctor, pp. 255-271.*Blackwell Scientific publications, Oxford.*

Hill, M.O. 1979. DECORANA–FORTRAN program for detrended correspondence analysis and reciprocal averagining. *Ecology and systematic*, Cornell Univ. Ithaca, New York.

Hill, M.O. and H.G. Gouch. 1980. Detrended correspondence analysis: an improved ordination technique. *Vegetation*, 42, 47-58.

Jongman, R.H.G., C.J.F. Ter Braak and. D.F.R. van Tongeren. 1995. Data Analysis in Community and Landscape EcoLogy. *Cambridge University Press, Cambridge.*

Kubota, Y., H. Murata and K. Kikuzawa. 2004. Effects of topographic heterogeneity on tree species richness and stand dynamics in a subtropical forest in Okinawa Island, southern Japan. *Journal of Ecology*, 92: 230-240.

Marrs, R.H., J. Procter, A. Heaney and M.D. Mounford. 1988. Changes in soil nitrogen mineralization and nitrification along an altitudinal transect in tropical rain forest in Costa Rice. *Journal of Ecology*, 76: 466-482.

Nasir, E. and S.I. Ali. 1972-1995. *Flora of Pakistan*. Department of Botany, University of Karachi, Karachi, Pakistan

Pagnotta, M.A., R.W. Snaydonand and P.S. Cocks. 1997. The effects of environmental factors on components and attributes of a Mediterranean grassland. *Journal of Appled Ecology,* 34: 29-42.

Peer, A. Millinger, J.P. Ggruber and F. Hussain. 2001. Vegetation and altitudinal zonation in relation to the impact of grazing in steppe lands of hindukash range, Pakistan. *Phytocoenologia*, 31: 477-498.

Peer, T., J.P. Gruber, A. Millingard and F. Hussain. 2007. Phytosociology, structure and diversity of the steppes vegetation in the mountains of Northern Pakistan. *Phytocoenologia,* 37(1): 1-65.

Rassam, A. and D. Tully. 1986. Annual Report 1985. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

Richards, L.A. 1954. *Diagnosis and improvement of saline and alkali soils*. Agriculture handbook No. 60; U.S. Deptt. of Agriculture and JBH Publishing, Bombay. 230. pp.

Ali, S.I. and M. Qaiser. 1995-2005. *Flora of Pakistan*. Department of Botany University of Karachi, Karachi, Pakistan

Sterling, A., B. Peco, M.A. Casado, E.F. Galliano and F.D. Pineeda. 1984. Influence of microtopography on floristic variation in ecological succession in grassland. *Oikos,* 42: 334-342.

Stewart, R.R. 1972. *Flora of West Pakistan*. An annotated Catalogue to Vascular Plants of West Pakistan and Kashim. Fakhri Printing Press, Karachi. 1027 pp.

Svenning, J.C. 1999. Microhabitat specialization in a species rich palm community in Amazonia Ecuador. *Journal of Ecology*, 87: 55-65.

Tanner, E.V.J., P.M .Vitousek and E.Cuevas. 1998. Experimental investigation of nutrient limitation of forest growth on wet tropical mountains. *Ecology*, 79: 10-22.

Tanner, E.V.J., V. Kopos, S. Freskos, J.R .healey and A.M .Theobald. 1990. Nitrgen and phosphorus fertilization of Jamaican montane forest trees. *JournaL of Tropical Ecology*, 6: 231-238.

Tuomisto, H. and K. Ruokolainen. 1994. Distribution of Pterodophyta and Melastomataceae along an edaphic gradient in an Amazonian rainforest. *Journal of Vegetation Science,* 25-34.

Tuomisto, H., K. Ruokolainen, M. Agauilar and A. Sarmiento. 2003. Floristic patterns along a 43-km long transect in an Amazonian rain forest. *Journal of Ecology*, 91: 743-756.

Tuomisto,H, K. Ruokolainen, Z. Kalliola and Rodriguez. 1995. Dissecting Amazonian biodiversity.*Science,* 269: 63-66.

Vazquez, J.A.G. and T.J. Givnish. 1998. Altitudinal gradients in tropical forest composition, structure and diversity in the sierra de Manantlan, Jalisco, Mexico. *JournaL of Ecology*, 86: 999-1020.

Weaver, P.L. 1991. Environmental gradient affect forest composition in the Luquillo Mountain of Puerto Rico.*Interciencia,* 16: 142-151.

Webb, C.W. and D.R. Perart. 2000. Habitat associations of trees and seedlings in a Bornean rain forest. *Journal of Ecology*, 88: 464-478.

Yair, A. and M. Shadak. 1982. A case study of energy, waters and soil flow chain in an arid ecosystem. *Oecologia* (Berl.), 54: 389-397.

(Received for publication 27 July 2007)