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VEGETATION ANALYSIS OF KABAL VALLEY, DISTRICT SWAT, PAKISTAN USING MULTIVARIATE APPROACH

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Abstract

Natural vegetation of Kabal valley district Swat, Pakistan was analyzed during 2009-2013. The stratified random sampling design was used to collect vegetation data of 314 relevés and stored in the TURBOVEG database software. The same was analyzed through modified Two Way Indicator Species Analysis (TWINSPAN) using the host program JUICE and correlated with edaphic, topographic and environmental variables using Detrenched Correspondence Analysis (D.C.A). Based on the topographic and edaphic factors, nine different plant communities viz. 1) Nasturtium-Paspalum-Veronica Wetland, 2) Abies-Picea-Viburnum Coniferous Forest, 3) Pinus-Quercus-Berberis Mixed Forest, 4) Pinus-Indigofera Blue Pine Forest, 5) Celtis-Olea-Cynodon Sacred Groves Broad Leaved Forest, 6) Diosperos-Pinus-Quercus Mid Hill Degraded Forest, 7) Dodonaea-Isidon-Berberis in Xeromorphic Scrub, 8) Pinus-Quercus-Galium in Protected Chir Pine Forest and 9) Isodon-Berberis-Indigofera in Montane scrub were established. The conservation measure of this ecosystem is the need of hours through active participation of the local communities.

Key Words: Kabal valley, Relevé, Multivariate analysis, Plant communities, Turboveg, Twinspan, DCA

Introduction

Vegetation is a unit which possesses characteristics in physiognomy and structure sufficiently large enough to permit its differentiation from other such units (Hussain & Ilahi, 1991). The vegetation, climate and soil are related to each other. The variation in any one of these components may cause a change in the associated other component. The existence and establishment of a community reflects the plant type and habitat condition under which they develop (Malik, 1986). As a scientific discipline phytosociology deals with plant communities, their classification, their composition and development due to the interrelationships between the constituent species and their relation to the physical environment (Allaby, 2004). It has provided effective methods for vegetation analysis that have been applied in vegetation mapping, ecosystem services evaluation and biodiversity conservation (Rieley & Page, 1990; Ewald, 2003; Biondi, 2011; Khan *et al.,* 2013). Habitat variation, time and biotic interactions determine the distribution of individuals of the same and different plant species in a community (Khan *et al.*, 2013). The health of any ecosystems is dependent on plant biodiversity (Ruiz *et al.*, 2008) and thus the vegetation classification is a prerequisite for ecosystem management and biodiversity conservation.

The vegetation of Swat and adjoining areas is a mosaic of different community types and has been studied sporadically (Beg & Khan, 1984; Hussain *et al.,* 1992; Hussain *et al*., 1995; Peer *et al*., 2007; Ahmad *et al*., 2009; Sher & Al-Yameni, 2010; Ahmad *et al*., 2010; Rashid *et al.,* 2011; Khan, 2012; Ilyas *et al*., 2012; Khan *et al*., 2011, 2012, 2013; Ahmad *et al*., 2014; Haq *et al*., 2015). There is a dire need to study, document and map the vegetation of diverse areas of Pakistan, according to international standards, to provide a baseline for effective plant conservation strategies and sustainable development. The Kabal Valley Swat is one of such important areas; therefore it was selected for the present study.

Materials and Methods

Study area: Kabal valley is part of tehsil Kabal located in the North West of District Swat at a distance of about 15 Km from Saidu Sharif, Khyber Pakhtunkhwa, Pakistan. The area lies between 34°43′ to 35° North latitude and 72°07′ to 72°21′ East longitude in Swat district. The average elevation of the area varies from 833 to 3012 meters from the mean sea level. The valley is U-shaped and opens on the southern side towards the river Swat, while from three sides, i.e., east, north and west it is surrounded by an arc shaped series of hills having different elevations and aspects. The series of hills are offshoots of the Hindu Kush mountain range (Ahmed & Sirajuddin, 1996). Geologically the hills are of recent origin and forms part of the southern stretch of Kohistan Island arc which is delineated on the South from the northern tip of the Indian plate marginal mass by a Himalayan mega shear called the Main Mantle Thrust, the southern suture (Tahirkheli, 1982). The area mainly contains the rocks of Hornblenditic and Schistose groups (Zeb, 1970). The rocks exposed in the area are characterized by felsic zones which are more or less parallel with the general foliation in the country rock and extend discontinuously (Moosvi *et al.*, 1974; Dipietro *et al.,* 1993). The low lying areas of the valley are very fertile with alluvial soils (Hussain & Ilahi, 1991) supporting a variety of crops, vegetables and fruit orchards. Climatically the area falls in the temperate zone with four clearly defined seasons. Winters are harsh and long, while summers are mild and short. Total area of Tehsil Kabal is

40026 hectares, of which 20722 hectares are cultivated and 19304 hectares uncultivated. The human population is approximately 0.4 million (Anon., 1999).

Vegetation survey: The study area was surveyed once in a month starting from September, 2010 till August, 2013. Stratified random sampling was used for field data collection. Species minimal area/number curve rule (Hussain, 1989) was used to determine the plot (*relevé*) size and number for each site. A quadrat that encloses the minimal area is called a *relevé*. A total of 314 *relevés* were studied. In each *relevé*, cover-abundance values were recorded according to the modified method of Braun-Blanquet (Barkman *et al.,* 1964). The soil sample was collected from at least three randomly selected areas in each *relevé* up to a depth of 15cm and thoroughly mixed to make a composite mixture. About one kilogram from the mix was packed in ploythene bags and labeled. The physical and chemical analyses of soils were conducted in the soil testing laboratory, Agricultural research station, Minogra, Swat. The texture was determined by the hydrometer method as described by Koehler *et al.,* (1984). The pH was determined in 1:5 soil water suspension using the pH meter (Mclean, 1982). Lime was determined by acid neutralization method (Black, 1965). The soil organic matter was determined by using standardized solution of $FeSO_4$ and $K_2Cr_2O_7$ as given by Nelson & Sommer, (1982). AB-DTPA or Mehlic No.3 extractable P and K was determined in samples on the basis of pH of soil samples. Furthermore, geographic coordinates, altitude, exposure, and slope gradient were recorded for each *relevé* using Global Positioning System (GPS).

Data storage and analysis: Data from 314 relevés was stored in the database software TURBOVEG (V. 2.101) (Hennekens & Schaminee, 2001) and exported as standard XML files to JUICE (V. 7.0.99) ((Tichý, 2002). The same was classified and sorted using modified Two Way Indicator Species Analysis (TWINSPAN) as designed by Roleček *et al.,* (2009) in host program JUICE to create realistic species-*relevé* associations. Five pseudospecies cut levels (0, 2, 5, 10 and 20) and Whittaker's beta-diversity was set as TWINSPAN parameters for producing clusters. Threshold levels of fidelity, frequency and cover were set as 30-60, 30-60 and 10-50 respectively to highlight diagnostic, constant and dominant species of each association in the synoptic table at $p \leq 0.05$. The associations were named after two or three species having highest fidelity/constancy values and the main habitat type of the location. Ordination analysis was performed by Detrended Correspondence Analysis (DCA) in CANOCO (V. 4.5) for windows (ter Braak and Smilauer, 2002) to observe the relationship between species, *relevés* and environmental variables.

Results

Associations: Based on the modified TWINSPAN classification, five pseudospecies cut levels (0, 2, 5, 10 and 20) and Whittaker's beta diversity as classification parameters, the following nine associations were separated at 13.753% dissimilarity (Fig. 1). Short synoptic table of associations showing fidelity values of important species which are significant at $p \leq 0.05$ after the Fischer test and percentage frequencies are shown in Table 2.

1. Nasturtium-Paspalum-Veronica (NPV) wetland association: This association is based on 18 *relevés* that contained 107 species confined to wetland habitats near the River Swat and Deolai Khwarh stream and spread over an altitudinal range of 836-1783m. The soil type of this association was silt loam with a major proportion of silt (58.9±2.39) having slightly alkaline nature (pH=7.92±0.2). There was the highest soil moisture content in this association (43.2±3.2%) with the lowest amount of potassium (52.6±17.9ppm). The diagnostic species with fidelity values were *Nasturtium officinale* (80.8), *Paspalum paspalodes* (70.5), *Veronica anagallis-aquatica* (69.7), *Cyperus difformis* (56.9), *Populus nigra* (56.6), *Persicaria hydropiper* (56.6), *Salix babylonica* (51.6), *Marsilea polycarpa* (51.6), *Salix tetrasperma* (46.1), *Kyllinga nemoralis* (46.1), *Typha latifolia* (39.8) and *Potamogeton nodosus* (39.8).

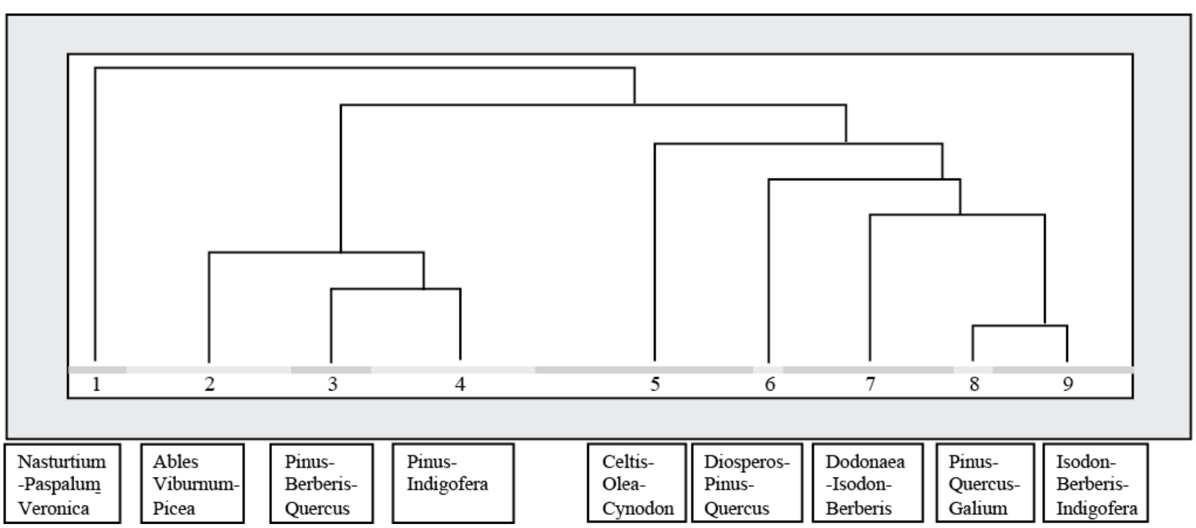

Fig. 1. Cluster dendrogram of nine association of Kabal valley, Swat.

Table 1. Summary of detrended correspondence analysis

Axes	1	2	3	4
Eigenvalues	0.872	0.439	0.391	0.31
Length of gradient	10.67	5.274	5.31	3.92
Species-environmental correlations	0.94	0.64	0.498	0.46
Cumulative percentage variance:				
Of species data	2.8	4.2	5.4	6.4
Of species-environmental relations	19.8	24.8	0	0

2. Abies-Picea-Viburnum (APV) coniferous forest association: This association was represented by 48 *relevés*. A total of 189 species were recorded in this association. This association is situated in the higher altitudinal range between 2197-3012m. Latitudinally too this association occupied northern parts of the higher mountains between 34.89°-35°N. The slope angle varied between 0-45°. The soils in this association were of sandy loam textue with 52.0±8.8% sand, 42.5±9.1% silt and 5.11±1.8% clay. With reference to pH, the soils of this association were slightly acidic with 6.03±0.46 pH value. The moisture content was 34.2±3.1. The soils contained 8.17±1.26% $CaCO_3$, 2.6±1.4% organic matter, 0.13±0.07% Nitrogen, 3.6±3.5ppm Phosphorus and 164.3±104ppm Potassium (Table 3).

The diagnostic species in this association with their respective fidelity values were *Abies pindrow* (60.7), *Picea smithiana* (53.6), *Viburnum grandiflorum* (53.3), *Gentianodes argentea* (58.1), *Poa alpina* (56.4), *Arisaema jacquemontii* (55.9), *Senecio chrysanthemoides* (52.7), *Plantago lagopus* (52.4), *Euphorbia wallichii* (50.4), *Achillea millefolium* (42.7), *Androsace foliosa* (42.7), *Quercus semecarpifolia* (40.4), *Rosa webbiana* (40.0) and *Taxus wallichiana* (35.6).

3. Pinus-Quercus-Berberis (PQB) mixed forest association: Based on 24 *relevés,* this association was found at an elevation range of 1676-2373, almost at the mid hills. It occupied a latitudinal range between 34.84-34.98°N and a longitudinal range between 72.15-72.30°E. The slopes were mostly gentle and varied between 0-35°. The soils in this association were mostly loam type, having 46.3±8.5% sand, 45.88±8.1% silt and 7.85±3.05% clay (Table 3). Soil moisture was 36±3.3% and pH was slightly acidic (5.61±0.51). The soils contained 7.3±1.53% $CaCO_3$, 2.23±0.94% organic matter, 0.11±0.05% nitrogen, 2.92±1.1ppm phosphorus and 152±67.5ppm potassium. The association is an assemblage of 187 species and was named after the leading diagnostic, constant and dominant species such as *Pinus wallichian, Quercus incana* and *Berberis lycium* (Table 2). Diagnostic species were *Pinus wallichiana* (36.2), *Quercus incana* (37.0), *Spiraea bella* (46.7), *Sarcococca saligna* (39.6), *Impatiens bicolor* (35.7), *Rottboellia exaltata* (34.6), *Achyranthes bidentata* (34.4), *Galinsoga parviflora* (34.4), *Juglans regia* (33.4), *Quercus dilatata* (32.2), *Jasminum officinale* (30.1), *Wikstroemia canescens* (30.1) and *Cirsium arvense* (31.0).

4. Pinus-Indigofera (PI) blue pine forest association: This association was formed based on the species and environmental data from 54 *relevés*. This community was located at higher elevations between 1893-2608m, forming a belt of vegetation type below the Abies-Picea-Viburnum association. It occupied an area between 34.80-34.99°N latitude and 72.13-72.29°E longitude. Slope angles were steeper and varied between 15-45°. The soils in this association were sandy loam type with 51.5±8.5% sand, 42.4±9.3% silt and 6.0±3.1% clay. The mean moisture content of the soil was 35.4±2.6%. The soils were mostly with slight acidic with pH between 5.2-7 (6.05±0.44). The soils contained 7.1±1.5% $CaCO_3$, 2.9±1.5% organic matter, 0.14±0.08% nitrogen, 3.16±1.9ppm phosphorus and 154±58.5ppm potassium (Table 3).

Diagnostic species of this association were *Pinus wallichiana* (66.0), *Indigofera heterantha* var. *gerardiana* (40.8), *Adiantum venustum* (44.5), *Prunus cornuta* (43.3), *Pteridium aquilinum* (39.6), *Cedrus deodara* (39.3), *Valeriana jatamansi* (36.5), *Rosa brunonii* (36.5), *Maytenus wallichiana* (32.9), *Fragaria nubicola* (32.3), *Galium asperuloides* (32.3), *Aesculus indica* (30.5), *Paeonia emodi* (30.5) and *Onychium contiguum* (30.2).

5. Celtis-Olea-Cynodon (COC) sacred groves broad leaved forest association: This association represents the remnant natural vegetation of the low lying, so called plain areas between an altitudinal range of 833-1510m mostly confined to Muslim graveyards, some drier stream sides and protected areas. Almost every village has one or more graveyards. The local people give the sanctity and honor to shrines and graveyards and avoid using the plants in these sacred areas for their immediate needs of fuel, timber, fodder and medicinal plants, therefore the natural vegetation has been left almost safe. The vegetation is stratified with clear tree, shrub and herb layers. The soils in this association are loam type and almost neutral in majority of sampling points with pH ranging between 6.1-8 (7.2±0.4). The soils contained 32.2±4.63% moisture, 7.4±4.6% $CaCO_3$, 2.1±0.9% organic matter and 0.11±0.05% nitrogen. Phosphorus and potassium content of the soils were highest in this association which were 14.8±11.3ppm and 330.7±173.4ppm respectively (Table 3). Comprising of 58 relevé, this association contained the highest number of species i.e. 288. The association was named after the three species having highest fidelity, frequency and cover values (Table 2). Diagnostic species were *Celtis eriocarpa* (68.3), *Olea ferruginea* (53.4), *Cynodon dactylon* (64.9), *Bosea amherstiana* (51.8), *Vitex negundo* (65.5), *Achyranthes aspera* (54.5), *Dicliptera bupleuroides* (51.2), *Justicia adhatoda* (46.4), *Oxalis corniculata* (45.9), *Malvastrum coromendelianum* (45.4), *Artemisia scoparia* (45.0), *Alliaria petiolata* (43.7), *Cyperus rotundus* (43.7), *Narcissus tazetta* (43.7), *Pelargonium zonale* (41.9), *Setaria viridis* (41.9), *Melia azedarach* (41.2), *Daphne mucronata* (38.9), *Cannabis sativa* (37.4), *Celtis caucasica* (35.6), *Ceterach dalhousiae* (35.6), *Celtis tetrandra* (31.2), *Maytenus royleanus* (33.5) and *Amaranthus viridis* (33.5).

Table 2. Part of the synoptic table with percentage frequency and fidelity index (phi coefficient at p≤0.05) shown as superscript of diagnostic species in the nine associations of Kabal valley, Swat, Pakistan. [Frequency and fidelity of diagnostic species in an association are shown in bold and highlighted].

Species	Group No.	1	2	3	4	5	6	7	8	9
	Assosiation	NPV*	APV	PQB	PI	COC	DPQ	DIB	PQG	IBI
	No. of *relevés*	18	48	24	54	58	9	50	11	42
Nasturtium officinale		**67**$^{80.8}$	-	-	-	-	-	-	-	-
Paspalum paspalodes		**61**$^{70.5}$	-	-	-	3^{-}	-	-	-	-
Veronica anagallis-aquatica		**50**$^{69.7}$	-	-	-	-	-	-	-	-
Cyperus difformis		**39**$^{56.9}$	-	-	-	2^{-}	-	-	-	-
Populus nigra		**33**$^{56.6}$	-	-	-	-	-	-	-	-
Persicaria hydropiper		**33**$^{56.6}$	-	-	-	-	-	-	-	-
Abies pindrow		-	**60**$^{60.7}$	-	20^{-}	-	-	-	-	-
Arisaema jacquemontii		-	**50**$^{55.9}$	-	15^{-}	-	-	-	-	-
Picea smithiana		-	**50**$^{53.6}$	-	$19^{11.3}$	-	-	-	-	-
Poa alpina		-	**46**$^{56.4}$	-	7^{-}	-	-	-	-	2^{-}
Rumex nepalensis		-	**46**$^{46.8}$	-	$22^{16.0}$	2^{-}	-	-	-	-
Plantago lagopus		-	**38**$^{52.4}$	-	6^{-}	-	-	-	-	-
Gentianodes argentea		-	**38**$^{58.1}$	-	-	-	-	-	-	-
Euphorbia wallichii		-	**33**$^{50.4}$	-	4^{-}	-	-	-	-	-
Cirsium falconeri		-	**33**$^{52.4}$	-	2^{-}	-	-	-	-	-
Senecio chrysanthemoides		-	**31**$^{52.7}$	-	-	-	-	-	-	-
Sarcococca saligna		6^{-}	-	**50**$^{39.6}$	$19^{13.9}$	2^{-}	22	-	-	10
Spiraea bella		-	2	**33**$^{46.7}$	2	-	11	-	-	-
Adiantum venustum		-	12^{-}	4^{-}	**35**$^{44.5}$	-	-	-	-	-
Pteridium aquilinum		-	$17^{13.7}$	-	**31**$^{39.6}$	-	-	-	-	-
Rosa brunonii		-	6^{-}	12^{-}	**30**$^{36.5}$	-	11	-	9	2
Cynodon dactylon		-	4^{-}	4^{-}	2^{-}	**71**$^{64.9}$	11	20^{-}	-	2
Celtis eriocarpa		-	-	-	-	**52**$^{68.3}$	-	-	-	-
Vitex negundo		-	-	-	-	**50**$^{65.5}$	-	2^{-}	-	-
Oxalis corniculata		-	2^{-}	-	2^{-}	**38**$^{45.9}$	22	4^{-}	-	5
Dicliptera bupleuroides		-	-	4^{-}	-	**38**$^{51.2}$	-	2^{-}	9	2
Achyranthes aspera		-	-	-	-	**36**$^{54.5}$	-	-	-	2
Maytenus royleanus		-	-	-	-	**36**$^{33.5}$	-	$24^{14.7}$	9	14
Daphne mucronata		-	-	4^{-}	-	**36**$^{38.9}$	-	14^{-}	18	7
Artemisia scoparia		-	-	-	-	**33**$^{45.0}$	-	10^{-}	-	-
Bosea amherstiana		-	-	$-^{-}$	-	**31**$^{51.8}$	-	-	-	-
Diospyros lotus		-	-	$25^{21.9}$	4	-	**100**$^{65.9}$	-	$27^{16.3}$	-

Table 2. (Cont'd)

Species	Group No.	1	2	3	4	5	6	7	8	9
	Assosiation	NPV*	APV	PQB	PI	COC	DPQ	DIB	PQG	IBI
	No. of *relevés*	18	48	24	54	58	9	50	11	42
Rumex hastatus		-	-	-	-	12^{-}	**$56^{25.8}$**	14^{-}	18^{-}	$26^{20.8}$
Andrachne cordifolia		-	-	12^{-}	2	-	**$56^{46.4}$**	-	18^{-}	2^{-}
Ficus palmata		-	-	8^{-}	-	$28^{30.2}$	**$44^{20.9}$**	2^{-}	18^{-}	10^{-}
Jasminum officinale		-	-	$25^{30.1}$	2	-	**$33^{25.2}$**	-	9^{-}	5^{-}
Girardinia palmata		-	-	-	-	-	**$33^{49.1}$**	-	-	2^{-}
Pilea umbrosa		6	10	12^{-}	4	2^{-}	**$33^{23.0}$**	-	-	-
Ficus sarmentosa		-	-	4^{-}	-	-	**$33^{43.6}$**	-	9^{-}	-
Zanthoxylum armatum		-	-	-	-	5^{-}	**$33^{26.4}$**	2^{-}	-	$12^{16.6}$
Dodonaea viscosa		-	-	-	-	12^{-}	-	**$72^{66.7}$**	27^{-}	10^{-}
Periploca aphylla		-	-	-	-	3^{-}	-	**$44^{59.6}$**	-	-
Otostegia limbata		-	-	-	-	9^{-}	-	**$40^{48.7}$**	-	5^{-}
Aristida adscensionis		-	-	-	-	3^{-}	-	**$38^{52.8}$**	-	2^{-}
Galium aparine		-	2^{-}	-	-	$21^{26.7}$	-	4^{-}	**$55^{36.5}$**	-
Viola canescens		-	-	8	9	5^{-}	-	-	**$45^{35.0}$**	2^{-}
Taraxacum officinale		-	$19^{12.6}$	4	4	$17^{11.8}$	11	6^{-}	**$36^{16.9}$**	2^{-}
Myrsine africana		-	-	-	9	2^{-}	-	2^{-}	**$36^{26.1}$**	$14^{15.4}$
Diagnostic species of two or more associations										
Viburnum grandiflorum		-	**$60^{53.3}$**	-	**$35^{25.2}$**	-	-	-	-	-
Quercus incana		-	-	**$50^{37.0}$**	-	2^{-}	22^{-}	-	**$73^{38.7}$**	$24^{17.0}$
Olea ferruginea		-	-	-	-	**$69^{53.4}$**	**33^{-}**	26^{-}	18^{-}	29^{-}
Rubus fruticosus		22	-	4^{-}	-	$17^{13.9}$	**$33^{14.7}$**	6^{-}	**$45^{24.4}$**	5^{-}
Sageretia thea		-	-	17^{-}	-	7^{-}	-	4^{-}	**$36^{18.9}$**	**$31^{31.3}$**
Pinus wallichiana		-	35^{-}	**$88^{36.2}$**	**$96^{66.0}$**	-	-	-	9^{-}	7^{-}
Quercus dilatata		-	-	**$50^{32.2}$**	**$31^{25.6}$**	-	$56^{22.1}$	2^{-}	9^{-}	10^{-}
Indigofera heterantha var. gerardiana		-	29^{-}	**42^{-}**	**$72^{40.8}$**	3^{-}	22^{-}	8^{-}	18^{-}	$57^{22.3}$
Isodon rugosus		-	-	**33^{-}**	19^{-}	5^{-}	11^{-}	**$58^{29.5}$**	18^{-}	**$81^{46.7}$**
Origanum vulgare		-	12^{-}	8^{-}	**$30^{18.2}$**	5^{-}	11^{-}	4^{-}	**36^{-}**	**$33^{19.7}$**
Cotoneaster racemiflorus		-	-	-	2^{-}	**$36^{29.7}$**	**33^{-}**	8^{-}	**$45^{16.9}$**	$26^{13.3}$
Pinus roxburghii		-	-	29^{-}	-	12^{-}	**$56^{17.2}$**	**$30^{14.3}$**	**$91^{36.8}$**	26^{-}
Berberis lycium		-	10^{-}	**$58^{18.4}$**	**30^{-}**	-	**33^{-}**	**$44^{14.1}$**	**36^{-}**	**$67^{32.3}$**

*Key for associations: 1.NPV (Nasturtium-Paspalum-Veronica) 2.APV (Abies-Picea-Viburnum) 3.PQB (Pinus-Quercus-Berberis) 4.PI (Pinus-Indigofera) 5.COC (Celtis-Olea-Cynodon) 6.DPQ (Diosperos-Pinus-Quercus) 7.DIB (Dodonaea-Isodon-Berberis) 8. PQG (Pinus-Quercus-Galium) 9.IBI (Isodon-Berberis-Indigofera)

Table 3. Mean values of environmental variables for the nine plant associations of Kabal valley, Swat, Pakistan.

Parameters	ASSOCIATIONS								
	1. NPV	2. APV	3. PQB	4. PI	5. COC	6. DPQ	7. DIB	8. PQG	9. IBI
Altitude (m)	1079.17±271.7	2657.96±200.0	1956.25±153.8	2281.43±165.6	1063.26±167.9	1671.44±71.4	1274.36±172.8	1514.09±186.9	1634.71±270.0
Slope (deg.)	0.00	28.98±17.17	26.04±7.94	32.87±7.37	4.33±6.87	15.00±10.61	20.24±5.25	21.36±4.52	24.76±7.32
Longitude	72.2683±0.05	72.1881±0.03	72.2145±0.04	72.1895±0.04	72.2642±0.04	72.1752±0.02	72.2542±0.04	72.2341±0.04	72.2302±0.05
Latitude	34.8320±0.06	34.9628±0.04	34.9359±0.04	34.9219±0.05	34.8322±0.05	34.8972±0.04	34.8356±0.04	34.8606±0.04	34.8706±0.04
Clay	3.19±1.04	5.11±1.80	7.85±3.05	6.00±3.09	11.81±4.39	4.20±1.57	8.42±5.43	7.11±5.14	9.08±5.79
Silt	58.90±2.39	42.50±9.13	45.88±8.10	42.40±9.25	44.73±9.84	50.89±6.87	14.90±9.08	26.20±11.25	19.70±10.88
Sand	37.91±2.57	52.00±8.81	46.27±8.51	51.45±8.48	42.93±11.91	44.91±7.10	76.72±11.28	66.69±9.08	70.98±10.98
Moisture	43.17±3.20	34.19±3.07	35.96±3.30	35.39±2.62	32.22±4.63	32.78±1.09	20.68±3.05	23.82±2.75	23.07±4.31
pH	7.92±0.17	6.03±0.46	5.61±0.51	6.05±0.44	7.18±0.41	5.51±0.21	7.27±0.21	7.05±0.20	6.79±0.43
$CaCO_3$	4.33±1.86	8.17±1.26	7.26±1.53	7.12±1.46	7.41±4.61	6.03±0.67	6.03±1.55	7.20±2.39	6.95±1.89
Org. Mat.	2.36±1.01	2.59±1.39	2.23±0.94	2.88±1.52	2.13±0.91	4.24±0.85	1.93±0.82	2.14±0.65	2.37±0.69
N	0.12±0.05	0.13±0.07	0.11±0.05	0.14±0.08	0.11±0.05	0.22±0.05	0.14±0.15	0.11±0.03	0.12±0.03
P	4.58±2.75	3.57±3.50	2.92±1.12	3.16±1.87	14.85±11.33	4.27±2.94	2.90±1.49	2.68±1.07	3.68±2.86
K	52.56±17.90	164.29±104.05	151.88±67.49	154.00±58.54	330.72±173.40	224.11±26.13	112.88±17.47	81.45±26.96	122.76±47.32

6. Diosperos-Pinus-Quercus (DPQ) mid hill degraded forest association: This association is based on 9 *relevés* located in a narrow belt in the valley, between 34.87-34.97°N latitudes and 72.15-72.21°E longitude and distributed in mid hill elevations between 1564-1780m. The slopes were gentle with inclination ranging between 0-30°. The soils were silt loam containing 32.8±1.09% moisture. The pH of the soils was of slightly acidic nature ranging between 5.3-6 (5.5±0.21). $CaCO_3$ content was 6.03±0.67%, organic matter was 4.24±0.85%, nitrogen was 0.22±0.05%, phosphorus was 4.3±2.9ppm and potassium was 224±26.1ppm (Table 3). The diagnostic species were *Diospyros lotus* (65.9), *Girardinia palmata* (49.1), *Fallopia dumetorum* (46.6), *Andrachne cordifolia* (46.4), *Ficus sarmentosa* (43.6), *Rhus punjabensis* (32.9), *Ophiopogon intermedius* (32.9) and *Pteris cretica* (32.1). Furthermore, *Girardinia palmata, Fallopia dumetorum, Rhus punjabensis* and *Ophiopogon intermedius* are only found in this association.

7. Dodonaea-Isodon-Berberis (DIB) xeromorphic scrub association: This association was found in the drier foothills between altitudinal ranges of 862-1874m and was based on 50 *relevés.* Most of the *relevés* in this association had south, south-eastern or south western aspects. There were gentle slopes with angles ranging from 10-30. The association occupied mid-southern zone of the valley between 34.73-34.88°N latitudes and 72.15-72.33°E longitudes. The soils in this association were sandy loam in nature with a relatively higher percentage of sand (76.7±11.3%) than the rest of the associations. The silt and clay percentages were 14.9±9.1 and 8.4±5.4 respectively. Soils were slightly alkaline, with a pH 7.27±0.21 and driest with 20.7±3.0% moisture. Soils contained 6.0±1.6% $CaCO_3$, 1.9±0.8% organic matter, 0.14±.15% nitrogen, 2.9±1.5ppm phosphorus and 112.8±17.5ppm potassium. Amount of organic matter and nitrogen were lowest in this association (Table 3). Leading species in this association were *Dodonaea viscosa, Isodon rugosus* and *Berberis lycium* (Table 2). Diagnostic species of the association were *Dodonaea viscosa* (66.7), *Periploca aphylla* (59.6), *Aristida adscensionis* (52.8), *Otostegia limbata* (48.7), *Trichodesma indicum* (39.0), *Teucrium stocksianum* (34.5) and *Chrysopogon serrulatus* (30.1). Since, this association is located in drier and sandy soil with south facing slope having xeric conditions; most of the species were xerophytic nature that includes *Dodonaea viscosa, Berberis lycium, Acacia modesta, Periploca aphylla, Otostegia limbata, Teucrium stocksianum, Trichodesma indicum* and *Aristida adscensionis* (Table 2). The association was dominated by shrubs with sporadic trees.

8. Pinus-Quercus-Galium (PQG) protected Chir pine forest association: This association is representing the remnant sub-tropical Chir-pine forest type and is based on 11 *relevés.* This was confined to limited sites in the area and was protected from excessive human intervention by the owner landlords of the area. It occupied mid-hill elevations between 1223-1876 and a segment of the area between 34.80-34.92° N latitude and 72.18-72.28° E longitude. The slope inclination varied between 15-30°. The soils in this association were of sandy loam type

having almost neutral pH (7.05±0.2) and a low fraction (23.8±2.8%) of moisture. $CaCO_3$ content was 7.2±2.39%, organic matter was 2.14±0.6%, nitrogen was 0.11±0.03%, phosphorus was 2.7±1.1 and potassium was 81.4±27.0 (Table 3). The leading species having highest fidelity, frequency and cover were *Pinus roxburghii, Quercus incana* and *Galium aparine.* The diagnostic species of this association were *Pinus roxburghii* (36.8), *Quercus incana* (38.7), *Galium aparine* (36.5), *Reinwardtia indica* (33.7), *Valerianella szovitsiana* (33.7) and *Viola canescens* (35.0).

9. Isodon-Berberis-Indigofera (IBI) montane scrub association: This association was found at slightly higher elevations in the hilly areas between 1227-2210m. It occupied a wider latitudinal and longitudinal range within the valley. The *relevés* representing this association were located between 34.80-34.92°N latitudes and 72.16-72.33°E longitudes. The 42 *relevés* of this association were located on steeper slopes that reached up to 40°. The soils of this association were sandy loam having almost neutral pH (i.e. 6.8±0.43) with dried conditions (23.1±4.3% moisture). Based on soil chemical composition, there was 6.9±1.9% $CaCO_3$, 2.4±0.7% organic matter, 0.12±0.03% nitrogen, 3.7±2.9ppm phosphorus and 122.8±47.3ppm potassium (Table 3). The association was named after *Isodon rugosus, Berberis lycium* and *Indigofera heterantha* var. *gerardiana* based on the highest fidelity, frequency and coverage (Table 2). The diagnostic species of this association were *Isodon rugosus* (46.7), *Berberis lycium* (32.3), *Cymbopogon martini* (43.5), *Polygala abyssinica* (35.2) and *Sageretia thea* (31.3). The dominant plant group in this association is shrubby nature. Though in physiognomy, this association resembles Dodonaea-Isodon-Berberis association, but differ from the latter in species composition.

Ordination (Detrended Correspondence Analysis): As shown in Table 1, the length of gradient along DCA axis-1 is longer with altitude, slope and latitude as the strongest factors along it. Along axis-2, moisture, pH and sand content are more important. Nasturtium-Paspalum-Veronica and Abies-Picea-Viburnum associations are located far away on the ordination plot showing maximum dissimilarity between them. Dodonaea-Isodon-Berberis and Isodon-Berberis-Indigofera associations are located very closely because of maximum similarity between them. The DCA triplot of diagnostic species, samples and environmental variables (Fig. 2) show that Nasturtium-Paspalum-Veronica association is strongly and positively correlated to pH gradient, longitude and moisture content along axis-2. The percentage content of clay also has a positive correlation with this association. Along axis-2, sand content of the soil was the strongest factor showing positive correlation with Abies-Picea-Viburnum association, Dodonaea-Isodon-Berberis association and Isodon-Berberis-Indigofera association, while the same was negatively correlated with Pinus-Quercus-Berberis and Diosperos-Pinus-Quercus associations. Nitrogen content and potassium are almost uniform throughout the study area and have a negligible effect on the distribution pattern of vegetation in the area.

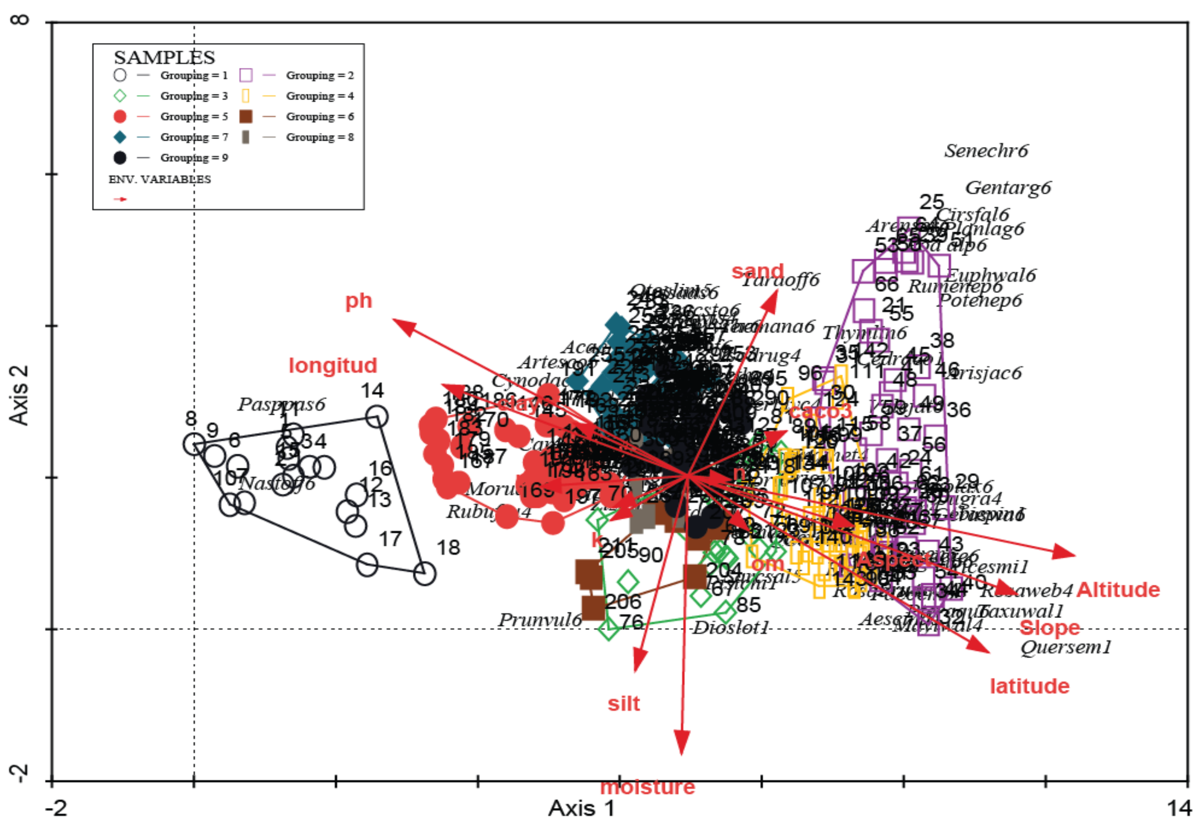

Fig. 2. DCA joint triplot of *releves*, species and environmental variables.

Discussion

The existence and establishment of a plant association reflects the plant type and habitat condition under which they develop (Malik, 1986). The climate and vegetation of the Kabal valley as a whole is of sub-tropical and temperate type (Champion *et al.*, 1965; Beg, 1975; Hussain et al., 1995) but due to the marked differences in physiographic, edaphic and local climatic conditions in different slopes at different elevations, they support different plant formations (Ahmad, 1986). Our present work delineated nine associations with different floristic elements and micro-environmental conditions. The spatial distribution and floristic composition of plant associations in the area seem to be determined by a complex of environmental factors including climate, topography, soil and biotic influence. These factors undergo changes of different degrees due to interactions among themselves and result in micro-gradients (Hanson and Churchill, 1965) that result in the formation of numerous habitats and vegetation groups. It is therefore imperative to correlate the vegetation composition and structure of the area with environmental variables for a proper understanding of the mechanism of plant distribution in an area (Eriksson & Bergstrom, 2005).

The climate determines the large scale patterns in physiognomy and potential species distribution, but other factors such as soil characteristics are important as well because they influence plant distribution on smaller scale i.e. more local scale (Bakkenes *et al.*, 2002). Climate can be described by numerous climate variables. These variables should at least reflect summer and winter temperature and a measure of the available moisture, which are regarded as the main controlling factors for plant distribution (Leeman & Cramer, 1991). The climate of Kabal valley is characterized by extremes of temperature and moderate rainfall, with more rain received in spring and monsoon seasons which is responsible for the establishment of stratified forests in the area. Topography is one of the main factors that play important role in structural characteristics of vegetation. Different altitudes, aspects and slopes harbour different associations. North facing slopes are moist than South facing slopes and thus harbor thick vegetation with high species diversity than south facing slopes. The same results were obtained by Hussain *et al*., (1995), Hussain *et al*., (1997), Carmel & Kadmon (1999), Khan *et al.*, (2011) and Haq *et al.,* (2015). When precipitation is received; slope, smoothness of slope, position of slope, vegetation and soil interact to control the amount of runoff and water infiltration, which in turn affect plant growth and survival. Slope, aspect and steepness also affect solar radiation received and thus the temperature at and near the ground surface (Sukopp & Werner, 1983) and the amount and type of soil accumulated (Monsen *et al.*, 2004). Consequently, the topography affects the vegetation indirectly by modifying other factors of the environment. The drier, more steep and the south facing slopes in the hilly areas contain heliophytes like *Pinus roxburghii, Cedrus deodara, Micromera biflora, Dodonaea viscosa, Periploca aphyla,* etc.; while the moist, less steep, northern slope had sciophytes like *Pteridium aquilinum, Viburnum grandiflorum, Prunus cornuta, Arisaema jacquimontii,* etc. Altitudinally, *Pinus roxburghii, Ficus palmata, Rumex hastatus* and *Olea ferruginea* occupied lower elevations; while, *Pinus wallichiana, Pteridium aquilinum, Fragaria nubicola, Viburnum grandiflorum* etc. occurred on higher elevation. Some species like *Berberis lycium, Indigofera heterantha* var. *gerardiana, Tarraxicum officinale*, etc. occupied the area form bottom to top mainly due to their broad ecological amplitude. Species like *Bergenia ciliata, Campanula tennuissima* and *Wulfenia amhestiana* were confined to steep slopes, while *Plantago lagopus, Medicago lupulina, Salvia moocroftiana* and *Erodium cicutarium* preferred flat and gentle slopes.

Soil is an important factor that play key role in plant selection through evolutionary change (Barbour *et al.*, 1980). There is close relationship between the vegetation of a particular area and its soil (Ali *et al.*, 2004). The physical properties of soil are related to depth, texture, permeability to water and water holding capacity. Soil depth play important role in establishment of plant communities (Khan *et al.,* 2012). Chemical characteristics exert physiological stresses on plants through their effects on plant water relations, nutrient availability and uptake and toxicity effect and due to execs of certain chemical elements. Optimum pH for nutrient availability is between 5 and 7.5 with the greatest availability at about 6.5 (Monsen *et al.*, 2004). The soils of Kabal valley were coarse textured with the highest percentage of sand followed by silt and least clay contents. The pH of soil varied from 4.9 to 8.3 (6.64±0.78). The soil type of association of wetlands was slightly alkaline, with the highest pH (7.92±0.2) and thus supported a vegetation type that was totally different from other associations. Dominant plant species in this association were *Nasturtium officinale*, *Paspalum paspaloides, Veronica anagallis-aquatica*, *Populus ciliata* and *Salix tetrasperma* which possess adaptations to slightly alkaline soils. The rest of communities were established on slightly acidic soils. Slight differences in the available nutrients are positively correlated with variations in community structure (Noor & Khatoon, 2013).

Man is one of the major ecological agents controlling the balance in an ecosystem by various direct and indirect ways (Hussain & Ilahi, 1991). People of Kabal valley are dependent on the vegetation to meet their direct and indirect needs. Deforestation has multiple causes with the particular mix of causes varying from place to place (Helmut & Lambin, 2001, Shaheen *et al*., 2011). The main reasons for deforestation in Kabal valley are fuel wood extraction, timber wood extraction, occasional fires and clearing of forest for terrace cultivation. Deforestation is the forerunner of many associated and subsequent ecological problems which ultimately merges with the socioeconomic problems (Hussain, 1981; Khan *et al*., 2012). Overgrazing is another biotic factor in the area. The problem is more severe in the lower hill elevations than the higher ones. It is generally accepted that in ecosystems, grazing inhibits the development and growth of woody vegetation and that intensive grazing may reverse the course of succession in such systems

(Seligman & Perevolotsky, 1994). Overgrazing indirectly accelerate soil erosion by reducing plant cover and regeneration (Hussain & Ilahi, 1991). Marked differences prevail in the overgrazed and non grazed areas (Hussain *et al.*, 1997; Sher *et al.,* 2010). The major social problems responsible for the enormous anthropogenic pressures on the vegetation in Kabal valley are the prevailing poverty, lack of awareness, poor education and seasonal utilization, which combine to increase the competition for and overexploitation of the natural vegetation resources (Khan *et al*., 2012). In spite of the fact that the people of the area are dependent on the plant bioresources of the area, remnant vegetation have been left safe in the Muslim graveyards, depicting rich plant biodiversity and thick vegetation cover, since the people give respect and sanctity to shrines (Chughtai *et al.,* 1983; Hussain *et al.,* 1993; Ahmad *et al.,* 2009). There is a co-evolutionary relationship between biological and cultural diversity (Pei *et al.,* 2010). Recent studies have revealed that traditional beliefs related to religion are powerful forces promoting environmental preservation, including conservation of biodiversity (Pei, 2013). Traditional knowledge should be given due importance in a long term strategy to conserve the natural vegetation of the area.

Conclusion

The results clearly depicts that there is huge anthropogenic pressure on the vegetation of this mountainous region that may be due to increased human and livestock population, poverty, lack of awareness, poor education and seasonal utilization that resulted into overexploitation and degradation of the natural vegetation. The conservation measure of this ecosystem is the need of hours through active participation of the local communities.

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