Pak. J. Bot., 52(5): 1727-1736, 2020. DOI: http://dx.doi.org/10.30848/PJB2020-5(43)

ECOLOGICAL EVALUATION OF EXISTING PLANT RESOURCES OF MANRAI HILLS, SWAT, PAKISTAN USING MULTIVARIATE ANALYSIS

MUHAMMAD ILYAS[1, 2*], RAHMATULLAH QURESHI[2*], ZIAUL-HAQ[3], IZHAR UL HAQ[4], MUBASHRAH MUNIR[5], MEHMOODA MUNAZIR[6] AND MUHAMMAD MAQSSOD[2]

[1]*Department of Biology, Islamabad Model College for Boys, G-10/4, Islamabad, Pakistan*
[2]*Department of Botany, PirMehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan*
[3]*Department of Botany Government Post Graduate Jahanzeb College, Swat, Pakistan*
[4]*Department of Plant Pathology, University of Agriculture, Peshawar, Pakistan*
[5]*Department of Biology, Uniersity of Animal &Veterianry Sciences, Patoki Campus, Lahore*
[6]*Department of Botany, Government College, Women University 51040 Sialkot, Punjab, Pakistan*
**Corresponding author's email: rahmatullahq@yahoo.com*

Abstract

Like other montane temperate forests in Pakistan, vegetation of Manrai hills, Swat is declining at an alarming rate due to anthropogenic pressure, although they represent abode of plant biodiversity and need special care and attention. Keeping this motive in mind, the area was studied to evaluate the existing vegetation during 2012-2016. Species and environmental data from 50 quadrats by using stratified random sampling viz., 1x1m^2, 2x2m^2 and 10x10m^2 for herbs, shrubs and trees, respectively were placed in TURBOVEG (v. 2.101) software and transferred to JUICE (v. 7.0.102) software for establishing reliable clusters. From the sampled area, a total of 270 species of vascular plants were recorded. Three communities viz., 1) *Quercus-Sarcococca-Pinus*, 2) *Iris-Poa-Arenaria* and 3) *Abies-Picea-Viburnum* were determined through standard default parameters of modified TWINSPAN. All communities showed distinct strata with clear demarcation of tree, shrub and herb layers. On an average, tree, shrub and herb layers were occurred at 13.52±7.62m, 0.90±0.39m, 35.0± 7cm, respectively. Average Species richness (21.38±5.29), Shannon-Wiener (2.56±0.32), Simpson (0.88±0.05) and evenness (0.85±0.06) indices were comparatively higher in comparison to other studies from Pakistan. Canonical Correspondence Analysis (CCA) run through PC-ORD (v.6) indicated that topographic, edaphic and anthropogenic factors as the main determinants of community types. Lopping, deforestation and overgrazing are serious ecological threats to the vegetation of the area. Practical and workable measures for conservation of this valuable bio-resource are suggested considering our findings.

Key words: Manrai hills, Multivariate analysis, Diversity indices, Canonical Correspondence Analysis, Moist temperate forests, Plant biodiversity.

Introduction

Montane forests occur between the sub-montane and the subalpine zones. Montane temperate forests are typically of temperate coniferous or broadleaved or mixed forest types that are well known habitats of a rich biota (Price, 1986). InPakistan, Montane temperate forests are dominated by conifers in association with broad-leaved species (Champion *et al*., 1965; Hussain & Ilahi, 1991). Temperate forests are under severe anthropogenic pressure throughout the world (Ahmad *et al*., 2008; 2012; Singh *et al*., 2008; Ilyas *et al*., 2012; Shaheen*et al*., 2011; 2015; Abbas *et al.,* 2020). Major anthropogenic threats accountable for the overall degradation of these forests include deforestation, overgrazing, denudation and clearing of forested land for terrace cultivation (Hussain *et al*., 1997; Ahmad *et al*., 2008; 2011; Ilyas *et al*., 2012: Abbas *et al.,* 2020). High altitude forests of the Hindukush-Himalaya are the most vulnerable ecosystems to climate change that may pose a severemenace to mountain forests (Cavaliere, 2009; Glatzel, 2009; Shaheen *et al*., 2015). In the temperate forests, deforestation is a pre-eminentreason for biotic extinctions. According to estimates if deforestation continues at the present pace, almost a quarter of the endemic species of these forests could be vanished out (Pandit *et al*., 2007; Schickoff, 1993).

Biodiversity is the product of intricate interaction between many species and of the many intrinsic factors that constitute the environment in which a species live. The technique of multivariate analysis uses interrelation between variables to reassemble the components of study according to their cumulative properties, and to classify species or ecosystems in distinct groups each comprising entities with similar characteristics. The main objective is to correlate the apparent biological variation to the corresponding environmental factors (Thuiller *et al*., 2006; Li *et al.,* 2020). As a complex property of natural systems, biodiversity is hard to quantify as manifested by the variety of indices suggested for this purpose. One purpose of these diversity indices is to sketch general attributes of communities that allow us to compare different regions. These indices are iconic for environmental monitoring and conservation, although there is no agreement about which indices are more appropriate and informative than others (Morris *et al.*, 2014). For thorough understanding the biodiversity of an area, units of population ecology must be identified. A community is an operational unit of species in spatial and temporal terms (Ali *et al*., 2015).

In community ecology, the common type of data set consists of the abundance of taxa measured in standard sampling units like quadrats, stands, transects etc. For a reliable classification and underlying factors that are responsible for determining plant community types, the use of computer software is a common practice (Ahmad, 2009). Two-way Indicator Species Analysis (TWINSPAN) is a computer-based classification technique, which give a valid clustering of vegetation units while Canonical Correspondence Analysis (CCA) clearly shows the relationship between the pattern of communities and corresponding environmental gradients.

In Pakistan, multivariate analysis of vegetation is in infancy, but rigorous studies have been conducted by workers throughout the country. In Kirthar National Park, Enright *et al.*, (2005) classified the vegetation and ascertained the vegetation-environment relationship. Wayside vegetation of Havelian city was assessed by Ahmad *et al.*, (2009). The effect of environmental factors on vegetation pattern in Ayub National Park was worked out by Jabeen & Ahmad (2009); while Khan *et al.*, (2011) investigated diversity of species and communities along environmental variables in Naranvalley. Khan *et al.,* (2020) phytogeographically classified the vegetation of Jambil valley, Swat, using multivariate approach. Research on montane temperate forests using multivariate techniques include Siddiqui *et al.*, (2010), Ahmad *et al.*, (2011), Ilyas *et al.*, (2015; 2018), Ali *et al.*, (2015),Shaheen *et al.*, (2015), Rahman *et al.*, (2016) and Rehman *et al.*, (2017).

Manrai hill are relics of the montane temperate forestare located in district Swat, Pakistan. Since this hilly range depicts remnant vegetation type, therefore requires to be well documented. Theaim of our study was to classify the existing vegetation, quantify the diversity of vascular flora and find the relationships of vegetation with natural environmental and anthropogenic factors.

Materials and Methods

Study area: Manrai hills constitute the north-western corner of District Swat that lies 30 Km away from Mingora/Saidu Sharif. Geographic coordinates of Manrai hills are 72.20°E longitude and 34.98° N latitude. Manraihills send some off shoots towards the south which demarcate Arnovay valley from the Nekpikheil valleys of tehsil Kabal. The altitude of the hills varies between 1676 to 3012 meters. The hills are surrounded by Peuchar valley in East, district Dir in North-West and Nikpikheil valley in South. In geological terms, the hills originated recently and contain Hornblenditic and Schistose rock types (Zeb, 1970). The opened rocks in the area have zones of felsic type's showingfoliation which is parallel with the country rock (Dipietro *et al.*, 1993). The climate of the area is montane temperate type with four seasons where winters are harsher and longer, while summers are milder and shorter.

Species and environmental data sampling: Using stratified random sampling, data from 50 quadrats of 1 x 1 m^2 (Herb layer), 2 x 2 m^2 (Shrub layer) and 10 x 10 m^2 Tree layer) was recorded during 2012-16. Quadrat size and number was determined according to minimal area curve method (Hussain, 1989) as shown in Fig. 1. Cover-abundance scale of Braun-Blanquette as modified by Barkman *et al.*, (1964) was used for data recording in each quadrat. The height of herb and shrub layers was directly estimated by a measuring tape. The height of tree layer was calculated according to Brower *et al.*, (1998). A composite mix of soil sample weighing one kilogram was taken up to an average depth of 15 centimetres from each quadrat. The physical parameters like texture and moisture content was ascertained according to Koehler *et al.*, (1984), while chemical parameters were calculated according to Hussain (1989). Handheld Garmin GPSMAP® Global Positioning System (GPS) was used to record geographic features including coordinates, altitude, slope gradient and exposure of each quadrat. Deforestation level was determined based on trump/tree ratio while grazing pressure level was assigned on the basis of visual appearance of trampling degree and grazers faecal units into three levels (Rauzi& Smith, 1973).

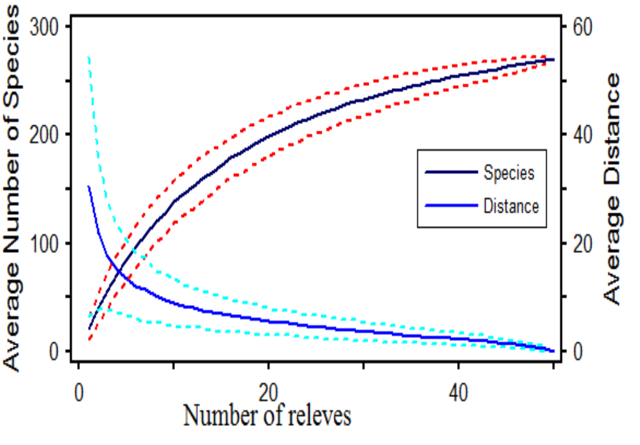

Fig. 1. Species area curve.

Data processing: Data from all quadrats was incorporated in the database software TURBOVEG (V. 2.101) after Hennekens & Schaminee (2001) and arranged it into standard XML files which were exported to JUICE (V. 7.0.99) (Tichý, 2002). In the JUICE program, modified Two-Way Indicator Species Analysis (TWINSPAN) (Roleček *et al.*, 2009) was selected as classification tool, to generaterepresentational species-quadrat associations. Parameters set for producing clusters were three pseudospecies cut levels at 0, 5 and 25 and Whittaker's beta-diversity. Fidelity was calculated using phi-coefficient taking presence/absence data. For highlighting diagnostic, constant and dominant species of each plant community in the synoptic table, threshold levels of fidelity, frequency and cover percentage were set at 40-60, 40-60 and 10-100 respectively ($p\leq0.05$). Plant communities in the area were named after three species having highest values of fidelity and constancy. Rarefaction curves based on 95% confidence interval were produced according to Colwell *et al.*, (2004) in R-Package Vegan (Oksanen *et al.*, 2010). Diversity indices were calculated according to Shannon-Weiner (1949) and Simpson (1949), evenness indices were calculated according to Pielou (1966) and Smith & Wilson (1996) whereas dissimilarity indices were measured according to Jaccord and Sorensen (Hussain, 1989). Ordination analysis was executed by Canonical Correspondence Analysis (CCA) in the software PC-ORD (V. 6) (Mc Cune & Mefford, 1999) to perceive the correlation between species, quadrats and environmental factors.

Results

Plant communities: Within the 50 quadrats, a total of 270 species of vascular plants were recorded. Characteristic diagnostic and constant species of each community along with the concerned environmental factors are shown in Table 1. Based on set parameters**,** three plant communities were recognized in Manrai hills (Fig. 2) as follows:

Table 1. Synoptic table with species and environmental data. Dominant species of each community are shown in bold and highlighted.

Number	**1**	**2**	**3**
Abbreviated community names	QSP	IPA	APV
Nuber of releves (quadrats)	16	8	26
Number of species	169	62	176
Geographic position			
Longitude ○ E	72.19-72.24	72.18-72.20	72.18-72.23
Latitude ○ N	34.96-34.99	34.97-34.99	34.84-34.99
Topographic features			
Altitude (Meters)	1676-2373	2646-3012	2236-2967
Aspect (Degree)	201.2 ± 105.4	126.6±106.7	167.7 ± 70.6
Slope (Degree)	25.3 ± 8.7	13.7±15.9	38.1 ± 6.1
Physiognomic features			
Total cover %	69.06 ± 6.7	70.62 ± 12.6	70.57 ± 8.5
Tree layer cover	31.56 ± 14.8	5.62 ± 14.9	42.31 ± 12.2
Shrub layer cover	30.31 ± 7.6	3.12 ± 4.3	23.08 ± 9.3
Herb layer cover	45.31 ± 5.1	65.42 ± 15.1	48.27 ± 3.9
Mosses cover	2.56 ± 1.2	1.0 ± 0.9	3.23 ± 0.3
Lichens cover	2.31 ± 1.3	2.62 ± 1.2	2.96 ± 1.3
Bare rock cover	8.12 ± 6.8	8.75 ± 6.0	11.54 ± 4.9
Average height highest trees (Meters)	12.06 ± 5.0	1.87 ± 5.0	18.00 ± 4.8
Average height lowest trees (Meters)	6.50 ± 2.6	1.12 ± 3.0	9.58 ± 3.3
Average height highest shrubs (Meters)	1.11 ± 0.25	0.26 ± 0.35	0.97 ± 0.23
Average height lowest shrubs (Meters)	0.37 ± 0.1	0.14 ± 0.2	0.43 ± 0.1
Average height highest herbs (cms)	39.37 ± 8.1	32.50 ± 5.6	33.08 ± 5.0
Average height lowest herbs (cms)	5.0 ± 0	4.4 ± 0.7	4.8 ± 0.6
Edaphic features			
Clay %	7.34 ± 3.3	8.15±1.9	6.10 ± 2.2
Silt %	43.87 ± 7.2	47.07 ± 6.8	40.7 ± 9.5
Sand %	48.29 ± 7.1	47.77 ± 5.5	52.32 ± 9.3
Textural class	Loam	Loam	Sandy loam
Moisture %	36.19 ± 2.4	33.62 ± 2.7	35.04 ± 3.3
pH	5.65 ± 0.5	5.96 ± 0.4	6.11 ± 0.5
$CaCO^3$ %	7.09 ± 1.4	7.84 ± 0.5	7.32 ± 1.5
Organic matter %	2.64 ± 1.3	2.44 ± 1.1	2.34 ± 1.3
Nitrogen %	0.13 ± 0.06	0.12 ± 0.05	0.12 ± 0.06
Phosphorus (mg/kg)	3.24 ± 2.3	4.28 ± 2.6	3.18 ± 2.1
Potassium (mg/kg)	157.5 ± 64.4	170.5 ± 93.7	147.5 ± 81.1
Biotic factors			
Grazing level	High	Moderate	Low
Deforestation level	High	Low	Moderate
Diagnostic species of communities (Fidelity ^{Frequency})			
Quercus dilatata	**72.5^{62}**	-	-
Sarcococca saligna	**68.8^{62}**	-	$-^{4}$
Pinus wallichiana	**47.6^{81}**	-	19.7^{62}
Diospyros lotus	58.4^{44}	-	-
Spiraea bella	54.0^{44}	-	$-^{4}$
Euonymus hamiltonianus	53.5^{38}	-	-
Chrysopogon gryllus s. echinulatus	53.5^{38}	-	-

Table 1. (Cont'd.).

Number	**1**	**2**	**3**
Juglans regia	48.2^{31}	-	-
Impatiens bicolor	48.2^{31}	-	-
Rottboellia exaltata	48.2^{31}	-	-
Achyranthes bidentata	48.2^{31}	-	-
Berberis lycium	46.2^{44}	-	$-^{12}$
Jasminum officinale	42.6^{25}	-	-
Campanula pallida	42.6^{25}	-	-
Desmodium elegans	42.6^{25}	-	-
Equisetum arvense	42.6^{25}	-	-
istacia chinensis s. Integerrima	42.6^{25}	-	-
Quercus incana	42.6^{25}	-	-
Iris hookeriana	-	$\mathbf{81.6^{75}}$	-
Poa alpina	-	$\mathbf{72.0^{75}}$	$-^{12}$
Arenaria serpyllifolia	-	$\mathbf{68.8^{62}}$	$-^{4}$
Gentianodes argentea	-	65.3^{62}	$-^{8}$
Ranunculus laetus	-	63.2^{50}	-
Sibbaldia procumbens	-	59.1^{50}	$-^{4}$
Achillea millefolium	-	59.1^{50}	$-^{4}$
Plantago lagopus	-	58.9^{62}	$-^{15}$
Cerastium dahuricum	-	55.2^{50}	$-^{8}$
Cirsium falconeri	-	55.2^{50}	$-^{8}$
Medicago lupulina	-	53.5^{38}	-
Taraxacum officinale	-	53.5^{38}	-
Trifolium repens	-	53.5^{38}	-
Senecio chrysanthemoides	-	51.6^{50}	$-^{12}$
Aster alpinus	-	42.6^{25}	-
Arabidopsis thaliana	-	42.6^{25}	-
Poa pratensis s. angustifolia	$-^{6}$	41.9^{38}	$-^{4}$
Arisaema jacquemontii	$-^{6}$	40.7^{75}	16.1^{58}
Abies pindrow	-	$-^{12}$	$\mathbf{72.8^{77}}$
Picea smithiana	-	$-^{12}$	$\mathbf{69.8^{73}}$
Viburnum grandiflorum	-	$-^{12}$	$\mathbf{63.6^{65}}$
Carex psychrophila	-	-	51.1^{35}
Nepeta erecta	-	-	44.4^{27}
Taxus wallichiana	-	-	44.4^{27}
Rosa webbiana	-	$-^{12}$	44.0^{42}
Podophyllum emodi	-	-	40.8^{23}
Trillium govanianum	-	-	40.8^{23}
Epipactis veratrifolia	-	-	40.8^{23}
Inula species	-	-	37.0^{19}
Quercus semecarpifolia	-	$-^{12}$	32.9^{31}
Dactylorhiza hatagirea	-	-	32.9^{15}
Primula denticulata	-	-	32.9^{15}
Bergenia ciliata	-	-	32.9^{15}
Impatiens pallida	-	-	32.9^{15}
Polygonatum verticillatum	-	-	32.9^{15}
Corydalis diphylla	-	-	32.9^{15}
Skimmia laureola	-	-	32.9^{15}

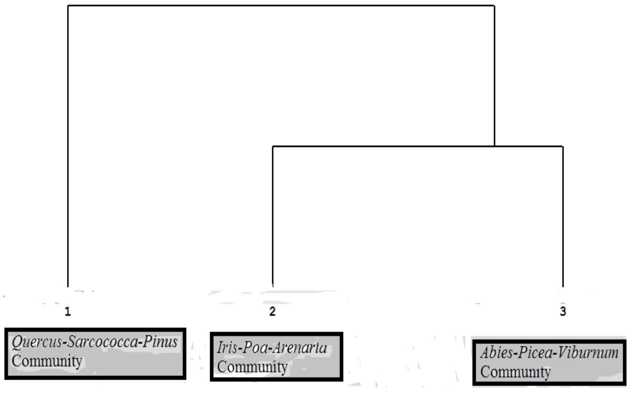

Fig. 2. Simplified cluster dendrogram of the tree communities.

Quercus-Sarcococca-Pinus **community (QSP):** This community is located at lower altitudes between 1676-2373 meteres on loam soil. Based on 16 releves the community cotained 169 species. In this community diagnostic species with highest fidelity values were , *Quercus dilatata* (72) *Sarcococca saligna* (68.8) and *Diospyros lotus* (58.4). *Spiraea bella* (54.0), *Euonymus hamiltonianus, Chrysopogon gryllus* subsp. *echinulatus* (53.5 each) *Achyranthes bidentata, Juglans regia, Impatiens bicolor, Rottboellia exaltata* (48.2 each) *Pinus wallichiana* (47.65) *Berberis lycium* (46.2), *Jasminum officinale, Campanula pallida, Quercus incana. Pistacia chinensis subsp. Integerrima, Desmodium elegans* and *Equisetum arvense* (42.6 each) were the other diagnostic species. Constant species with highest frequencies were *Pinus wallichiana* (81), *Quercus dilatata* (62) and *Sarcococca saligna* (62). Dominant species with highest cover values were *Pinus wallichiana* (69), *Pteridium aquilinum* (12) *Berberis lycium, Indigofera heterantha v. gerardiana, Impatiens bicolor, Pennisetum flaccidum and Rumex hastatus* (6 each). The dominance of Pinus wallichiana is due to its overall highest relative cover. Total cover was 69.06±6.7%, of which tree layer was 31.56±14.8%, shrub layer 30.31±7.6%, herb layer 45.31±5.1%, mosse 2.56±1.2%, lichens 2.31±1.3% and bare rocks 8.12±6.8%. Average highest tree layer was 12.06±5.0 m., lowest tree layer was 6.5±2.6m., highest shrub layer was 1.11±0.25m., lowest shrub layer was 0.37±0.1 m., highest herb layer was 39.37±8.1 cms and lowest herb layer was 5.0±0 cms (Table 1). Species richness in this community was 22.69, Shannon-Weiner diversity was 2.72, Simpson diversity was 0.91, Pielou evenness was 0.88; while Smith and Welson evenness was 0.65 (Table 2). The soils were slighly acidic (pH 5.65±0.5) that contained 36.19±2.4% moisture, 7.09±1.4% Calcium carbonate, 2.64±1.3% organic matter, 0.13±0.06% nitrogen, 3.24±2.3 $mgKg^{-1}$ phosphorus and 157.5±64.4 $mgKg^{-1}$ potassium. The community faceseverebiotic pressure in the form of overgrazing and deforestation.

Iris-Poa-Arenaria **community (IPA):** This is a sub-alpine ecotone type of meadow. The community is located at higher altitudes between 2646-3012 m and is dominated by herbs. Total species recorded from 8 releves were 62. Diagnostic species of this community were *Iris hookeriana* (81.6), *Poa alpina* (72.0), *Arenaria serpyllifolia* (68.8), *Gentianodes argentea* (65.3), *Ranunculus laetus* (63.2), *Achillea millefolium, Sibbaldia procumbens* (59.1 each) *Plantago lagopus* (58.9), *Cerastium dahuricum, Cirsium falconeri* (55.2 each), *Medicago lupulina, Taraxacum officinale, Trifolium repens* (53.5 each), *Senecio chrysanthemoides* (51.6), *Arabidopsis thaliana, Aster alpinus* (42.6 each), *Poa pratensis* subsp. *angustifolia* (41.9*)* and *Arisaema jacquemontii* (40.7). Constant species were *Iris hookeriana, Poa alpina, Arisaema jacquemontii* (75 each), *Arenaria serpyllifolia, Gentianodes argentea* and *Plantago lagopus* (62 each). Dominant species were *Senecio chrysanthemoides* (25), *Quercus semecarpifolia, Iris hookeriana* and *Rumex nepalensis* (12 each). Total cover percentage was 70.62±12.6, tree layer was 5.62±14.9, shrub layer was 3.12±4.3, herb layer was 65.42±15.1, moss layer was 1.0±0.9, lichens were 2.62±1.2 and bare rock layer was 8.75±6.0 %. Trees were sporadic that have an average height of 1.87±5.0 m at upper layer and 1.12±3.0 m at lower layer. Highest shrub layer was 0.26±0.35 m, lowest shrub layer was 0.14±0.2m, highest herb layer was 32.5±5.6 cms, and lowest herb layer was 4.4±0.7 cms high (Table 1). Species richness in this community was 16.63, Shannon diversity was 2.40, Simpson diversity was 0.86, pielou evenness was 0.86; while Smith evenness was 0.69 (Table 2). In this community, the soil was loamy with slightly acidic pH (5.96) and 33.62±2.7% moisture. The soil contained 7.84±0.5%, Calcium carbonate, 2.44±1.1% organic matter, 0.12±0.05% nitrogen, 4.28±2.6 $mgKg^{-1}$ phosphorus and 170.5±93.7 $mgKg^{-1}$ potassium (Table 1). The community is under moderate grazing and low deforestation prssures (Table 1; Figs. 4 and 5).

Abies-Picea-Viburnum **community (APV):** It is a typical community type of montane temperate zone. The community is situated at altitudina rang of 2236-2967m. Overall, 176 species of vascular plants were recorded from 26 releves. The diagnostic species of this community were *Abies pindrow* (72.8), *Picea smithiana* (69.8), *Viburnum grandiflorum* (63.6), *Carex psychrophila* (51.1)*, Taxus wallichiana, Nepeta erecta* (44.4 each), *Rosa webbiana* (44.0), *Epipactis veratrifolia, Podophyllum emodi* and *Trillium govanianum* (40.8 each). Constant species were *A. pindrow* (77), *P. smithiana* (73), *V. grandiflorum* (65), *P. wallichiana* (62) and *Arisaema jacquemontii* (58). Dominant species were *P. smithiana* (42), *P. wallichiana* (35), *Quercus semecarpifolia* (31), *V. grandiflorum* (27), *A. pindrow* (15) and *Pteridium aquilinum* (12). Vegetation cover was thicker with overall coverage of 70.57±8.5% of which major portion was contributed by tree layer (42.3 1±12.3%). Shrub layer, herb layer, moss layer and lichen layer were 23.08±9.3%, 48.27±3.9%, 3.23±0.3%, 2.96±1.3%, respectively; while bare rocks occupied 11.54±4.9% area. In this stratified community, the highest tree layer occured at 18.0±4.8 m, lowest tree layer at 9.58±3.3 m, the highest shrub layer at 0.97±0.23 m, the lowest shrub layer at 0.43±0.1 m, highest herb layer at 33.08±5.0 cm and lowest herb layer at 4.8±0.6 cm. Diversity indices were moderate. Species richness was 22.04. Shannon diversity was 2.56, Simpson diversity was 0.87, Pielou evenness was 0.82, while Smith evenness was 0.58 (Table 2). The soils were mostly sandy loam with comaratively higher pH (6.11±0.5) and moisture content (35.04±3.3%). $CaCO^3$ content was 7.32±1.5 %, organic matter 2.34±1.3%, nitrogen 0.12±0.06%, phosphorus 3.18±2.1 $mgKg^{-1}$ and potassium 147.5±81.1 $mgKg^{-1}$ (Table 1). This community is under low grazing and moderate deforestation pressure due to comaratively hard accessibility.

Table 2. Diversity indices of plant communities from Manrai hills, Swat.

Communities	Number of releves	Number of species	Dissimilarity indices		Diversity indices			Evenness indices	
			Jaccord	Sorensen	Species Richness	Shannon-Weiner	Simpson	Pielou	Smith and Wilson
QSP	16	169	0.898	0.820	22.69	2.72	0.91	0.88	0.65
IPA	8	62	0.807	0.684	16.63	2.40	0.86	0.86	0.69
APV	26	176	0.878	0.787	22.04	2.51	0.87	0.82	0.58
Over all	50	270	0.929	0.873	21.38	2.56	0.88	0.85	0.62

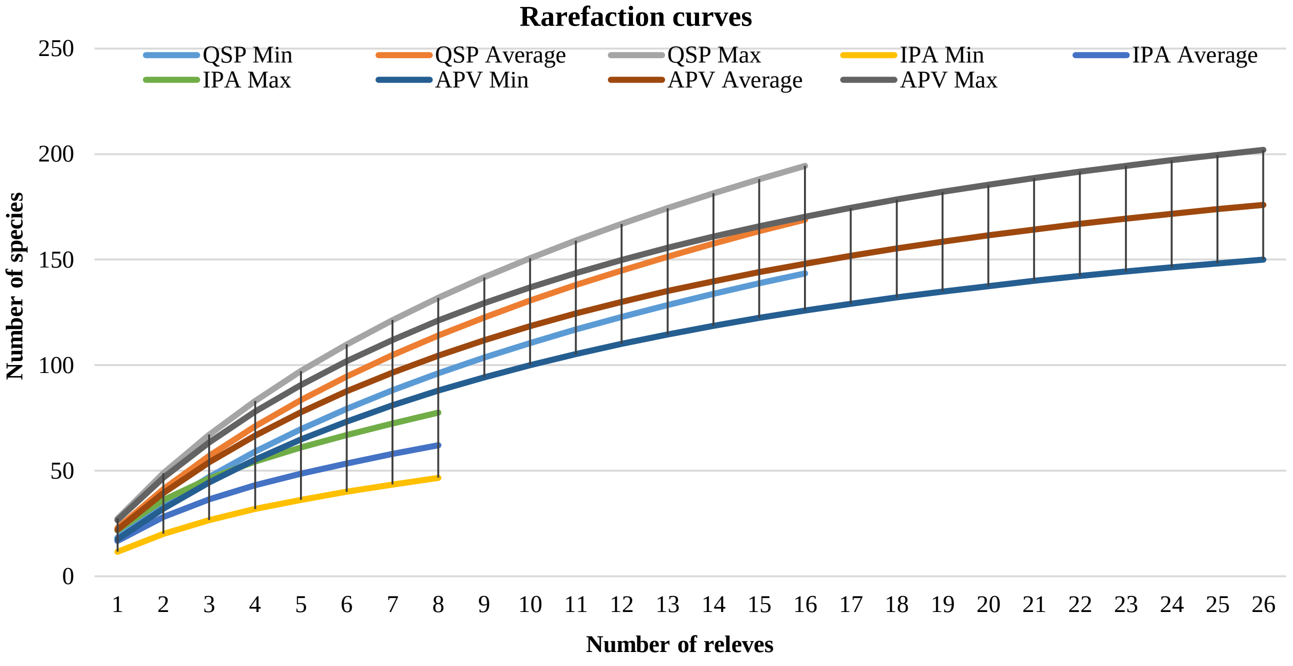

Fig. 3. Rarefaction curves for estimated number of species at 95% confidence interval.

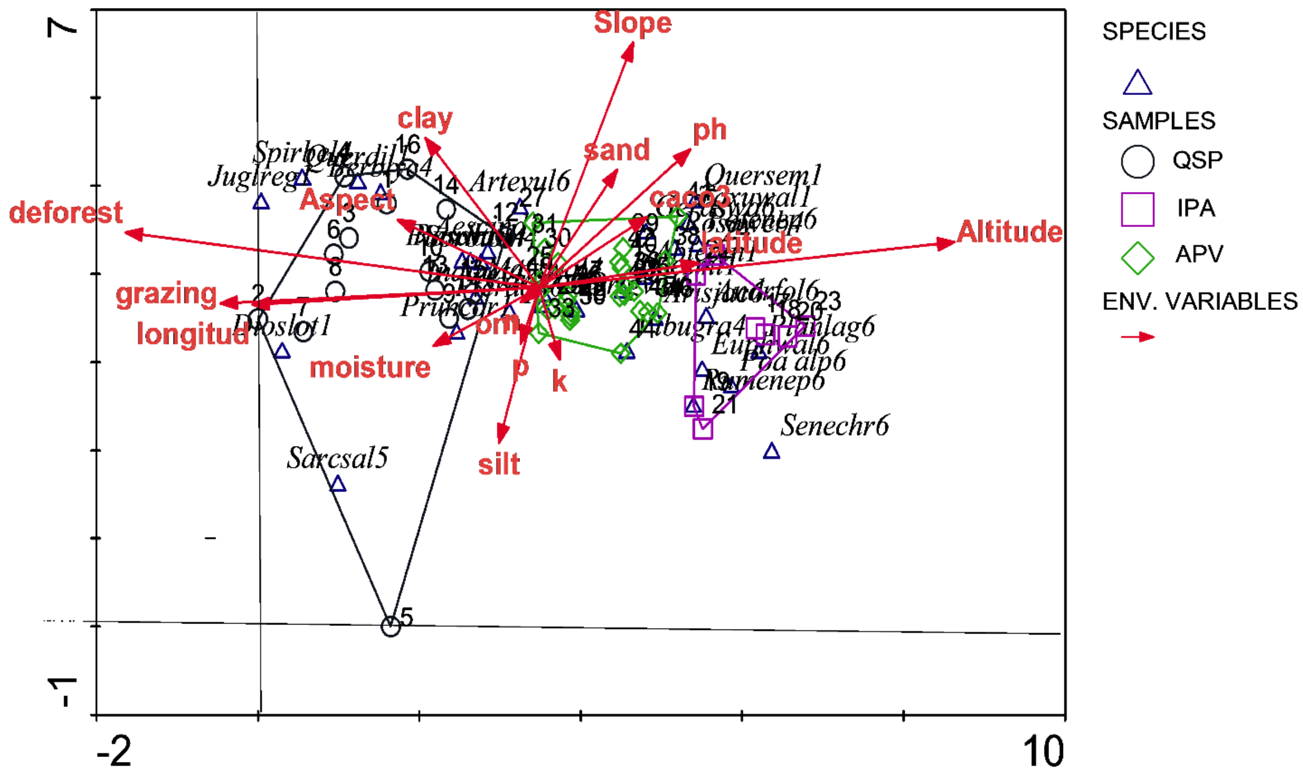

Fig 4. CCA joint triplot of species, samples and environmental variables.

Table 3. Estimated number of species at 95% confidence interval.

Communities	QSP			IPA			APV		
Number of releves	Min	Average	Max	Min	Average	Max	Min	Average	Max
1	18.172	22.688	27.203	11.562	16.625	21.688	17.497	22.038	26.58
2	33.648	41.225	48.802	20.1	28.071	36.041	32.001	39.375	46.75
3	47.096	57.086	67.075	26.576	36.393	46.209	44.378	53.924	63.471
4	58.991	70.998	83.005	31.816	43.036	54.256	55.18	66.542	77.904
5	69.65	83.398	97.146	36.168	48.536	60.904	64.745	77.673	90.602
6	79.29	94.572	109.853	40.001	53.429	66.856	73.292	87.592	101.892
7	88.076	104.729	121.382	43.437	57.875	72.313	80.979	96.491	112.002
8	96.134	114.031	131.929	46.567	62	77.433	87.927	104.516	121.106
9	103.565	122.606	141.646				94.234	111.788	129.343
10	110.453	130.555	150.656				99.979	118.403	136.827
11	116.866	137.963	159.06				105.231	124.443	143.654
12	122.86	144.901	166.941				110.047	129.975	149.903
13	128.485	151.427	174.368				114.474	135.058	155.642
14	133.781	157.592	181.402				118.555	139.742	160.929
15	138.783	163.438	188.092				122.326	144.068	165.811
16	143.52	169	194.48				125.817	148.074	170.332
17							129.055	151.791	174.528
18							132.064	155.248	178.431
19							134.865	158.468	182.071
20							137.477	161.474	185.472
21							139.916	164.287	188.657
22							142.197	166.922	191.647
23							144.334	169.397	194.46
24							146.339	171.726	197.113
25							148.223	173.923	199.623
26							149.998	176	202.002

Table 4. Canonical correspondence analysis (Summery).

Axes	1	2	3
Eigenvalue	0.731	0.398	0.304
Lengths of gradient	6.784	5.189	3.143
Species-environment correlations	0.966	0.717	0.659
Pearson Correlation, Spp-Envt	0.978	0.944	0.927
Kendall (Rank) Corr., Spp-Envt	0.878	0.765	0.690
Cumulative percentage variance			
of species data	7.3	11.3	14.4
of species-environment relation	15.8	19.6	0.0
Sum of all eigen values		9.964	
Sum of all canonical eigenvalues		4.298	

Estimated number of species at 95 % confidence intervals: The estimated number of species at 95% confidence intervals in successive releves in the three plant communities are shown in Table 3, and shown as rarefaction curves in Fig. 3. For successive releve, the estimated minimum and maximum number of estimated species is highest for *Quercus-Sarcococca-Pinus* community and lowest for *Abies-Picea-Viburnum* community.

Ordination: Canonical Correspondence Analysis (CCA) scores indicated the gradient length along axis 1 as 6.783. Altitude was a powerful factor that positively affected on *Iris-Poa-Arenaria* community and negatively affected on *Quercus-Sarcococca-Pinus* community along axis 1 (Figs. 4 and 6). Deforestation and grazing levels were stronger negative factors along axis 1. Along axis 2, slope degree and soil pH were effective factors. Organic matter content, nitrogen content and aspect had negligible influence on the distribution of vegetation. Majority of species and samples were gathered around the centre of ordination axis (Table 4; Fig. 4).

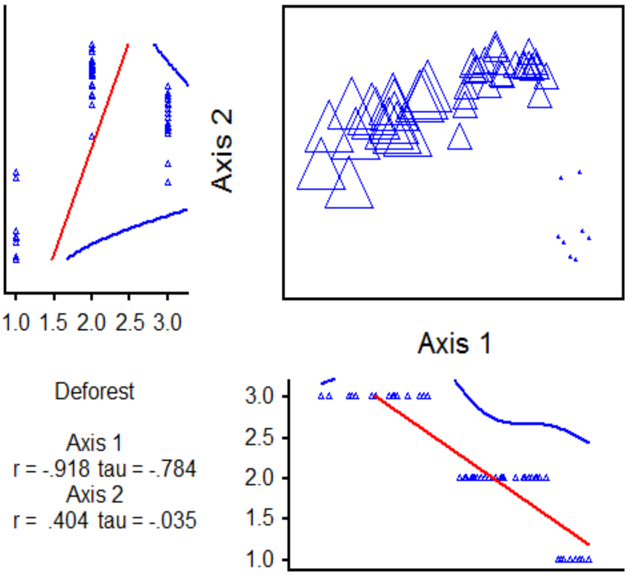

Fig. 5. CCA plot along axis 1 and 2 showing the effect of deforestation.

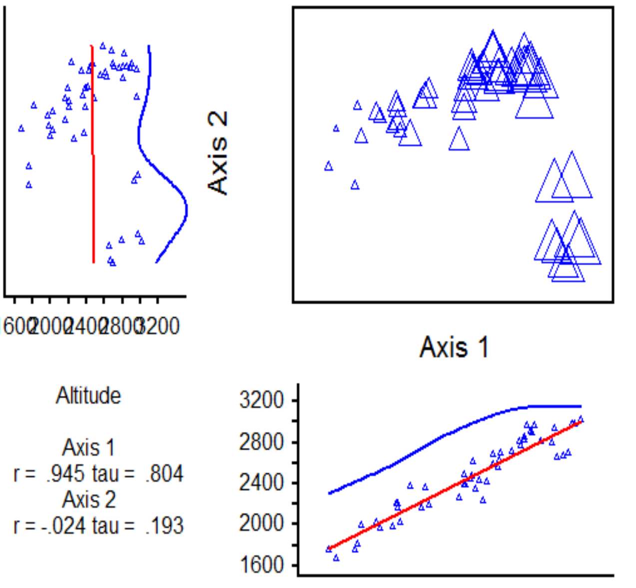

Fig. 6. CCA plot showing the effect of altitude on the distribution of samples.

Discussion

Due to rapid pace of environmental changes faced by the earth today has resulted in unprecedented conditions (Millar *et al.*, 2007) and posed serious threats to all global ecosystems including temperate forests (Ahmad *et al.*, 2012; Ilyas *et al.*, 2012; Shaheen *et al.*, 2015). Montane temperate forests are suitable habitats for rich diversity of plant resources (Price, 1986). Wild edible plants, timber/fuel wood species and medicinal plants are valuable resources if utilized in sustainble manner. In Manrai hills, relics of this vegetation type is left over but is facing tremendous anthropogenic pressure along withthe novel stresses such as pollution, habitat degradation, landuse changes, invasive species, pathogens and climate change regime. Vegetated areas are more vulnerable to climate change (Cramer *et al.*, 2001) and need more care before they are badly affected. In Manrai hills, 270 species of vascular plants were encountered that assorted into three community types with different diagnostic species. Differences in dominant species were due to changes in edaphic, anthropogenic and other environmental factors (Ahmad *et al.*, 2016; Khan *et al.*, 2016; Ilyas *et al.*, 2018; Li *et al.,* 2020; Abbas *et al.,* 2020). *Abies-Picea-Viburnum* is a typical community of temperate forest zone in Pakistan (Hussain & Ilahi, 1991; Ilyas *et al.*, 2015). *Iris-Poa-Arenaria* community is representing an ecotone form of typical sub-alpine pastures. *Poaalpinia*has been reported as a leading dominant species in various plant communities of alpine pastures (Shaheen *et al.*, 2011). Species diversity indices are moderate and comparable to reports from other areas (Shaheen *et al.*, 2011: Ilyas *et al.*, 2018). The communities exhibited a high degree of species evenness which indicated that individual species show uniform distribution. Inter-specific competition decreases when there are fewer species in a community that ultimately results in a high degree of species evenness (Shaheen *et al.*, 2011).

As reflected in Table 4 and Fig. 4, a high species environment correlation and high cumulative percentage of variance was exhibited along axis 1 of the ordination scale that indicated that the measured environmental variables used in CCA explained greater portion of the gradient. Altitude, and steepness of slope were the most influential topographic while soil pH, $CaCO^3$ concentration and texture were the edaphic factors that positively affected the distribution of vegetation. Along an altitudinal gradient, many other factors including ecological, biological and historical featuresinfluence species distribution (Ilyas *et al.*, 2015; 2018; Dad, 2016; Khan *et al.*, 2016; Ali *et al.*, 2017). In present study, plant species with different altitudinal preferences were perfectly associated along this gradient. Topography expressed by steeper slope seemed to be the reason for the distribution of *Abies-Picea-Viburnum* and *Iris-Poa-Arenaria* communities. Grazing and deforestation pressures have a negative influence as seen in Fig. 4. Studies from other areas have similar results (Shaheen *et al.*, 2011).

It is evident that Manrai hills have the potential for biodiversity conservation including all its components like ecosystem diversity, species diversity and genetic diversity. The area is also a sustainable abode of important profitable natural resources. Anthropogenic and other biotic pressures have posed a serious threat to the invaluable bio-resources of Manrai hills. If the level of stress as noted presently, continues in the area, the valuable bio resources of Manrai hills may be vanished and lost rapidlyas is seen in other areas of Swat like Girbanr hills (Hussain *et al.*, 1997), Qalagai hills (Ilyas *et al.*, 2012; 2013) and Hindukush range of Swat (Ali *et al.*, 2018). Proper care both by government agencies and nongovernmental organizations is essential for protection, conservation, management, development, sustainable use and improvement of the area. Any attempt started for the improvement of the area must involve the cooperation and input of local inhabitants as they have a broadcapacity to identify, classify, name and comprehend nature that guide them to perceive the ecology, reproductive behaviour and uses of organism in their ecosystem (Hu, 2002; Ilyas *et al*., 2013). It is high time to control the degradation and disruption processes that are degenerating the community structure and declining of plant biodiversity of the area. Regional conservation strategies need to be adopted and implemented in true letter and spirit to protect the existing plant resources and broaden the bio-resource base of the area.

Conclusion

This study was conducted to determine the existing vegetation cover of Manrai hills, Swat. This hilly range was occupied by 270 vascular plants with a dominance of three communities such as *Quercus-Sarcococca-Pinus*, *Iris-Poa-Arenaria* and *Abies-Picea-Viburnum* established by multivariate analysis. Besides, these communities revealed unique strata with obvious differentiation of tree, shrub and herb layers. Moreover, the diversity indices from these hills were comparatively higher compared to other studies from Pakistan. CCA showed that topographic, edaphic and anthropogenic factors were found responsible in determining these community types. Personal investigation revealed that lopping, deforestation and overgrazing are seriously threatened the vegetation of the area. It is recommended that serious conservation measures are required to save this valuable bio-resource base for the sustainable development.

References

Abbas, Z., S.M. Khan, J. Alam, Z. Abideen and Z. Ullah, 2020. Plant communities and anthropo-natural threats in the Shigar valley, (Central Karakorum) Baltistan-Pakistan. *Pak. J. Bot*, 52(3): 987-994.

Ahmad, I., M. Hussain, M.S.A. Ahmad and M. Hameed. 2008. Spatio-temporal effects on association of plant species in Soone valley of Pakistan. *Pak. J. Bot.,* 40(5): 1865-1876.

Ahmad, I., M.S.A. Ahmad, M. Hussain and M.Y. Ashraf. 2011. Spatiotemporal variations in soil characteristics and nutrient availability in open scrub type semi-arid rangelands of typical sub-mountainous Himalayan tract. *Pak. J. Bot.*, 43(1): 565-571.

Ahmad, K.S., M. Hameed, F. Ahmad and B. Sadia. 2016. Edaphic factors as major determinants of plant distribution of temperate Himalayan grasses. *Pak. J. Bot*., 48(2): 567-573.

Ahmad, S.S. 2009. Ordination and classification of herbaceous vegetation in Margalla Hills National Park Islamabad Pakistan. *Biol. Div. Cons.*, 2(2): 38-44.

Ahmad, S.S., S. Fazal, E.E. Valeem and I. Zafar. 2009. Evaluation of ecological aspects of road side vegetation around Havalian city using multivariate techniques. *Pak. J. Bot.*, 41(1): 53-60.

Ahmad, S.S., Q.U.A. Abbasi, R. Jabeen and M.A. Shah. 2012. Decline of conifer forest cover in Pakistan. *Pak. J. Bot.,* 44(2): 511-514.

Ali, A., L. Badshah and F. Hussain. 2018. Vegetation structure and threats to montane temperate ecosystems in Hindukush range, Swat, Pakistan. *Appl. Ecol. Env. Res.,* 16(4): 4789-4811.

Ali, F., N. Khan, K. Ali and I. Khan. 2017. Influence of environmental variables on the distribution of woody species in Muslim graveyards of Malakand division, Hindukushrange mountains of Pakistan. *Pak. J. Bot.,* 49(6): 2357-2366.

Ali, K., N. Khan, I.U. Rahman, H. Ahmad and S. Jury. 2015. Multivariate analysis and vegetation mapping of a biodiversity hotspot in the Hindu Kush Mountains. *Int. J. Adv. Res.,* 3(6): 990-1006.

Barkman, J.J., H. Doing and S. Segal. 1964. Kritischebemerkungen und vorschlägezurquantitativen Vegetationsanalyse. *Acta Bot. Neerl*., 13(3): 394-419.

Brower, J.E., J.H. Zar and C. von Ende. 1998. *Field and laboratory methods for general ecology.* 51pp.

Cavaliere, C. 2009. The effect of climate change on medicinal and aromatic plants. *Herbal Gram.,* 81: 44-57.

Colwell, R.K., C.X. Mao and J. Chang. 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. *Ecology*, 85(10): 2717-2727.

Cramer, W., A. Bondeau, F.I. Woodward, I.C. Prentice, R.A. Betts, V. Brovkin, P.M. Cox, V. Fisher, J.A. Foley, A.D. Friend and C. Kucharik. 2001. Global response of terrestrial ecosystem structure and function to CO2 and climate change: results from six dynamic global vegetation models. *Global Change Biol.*, 7(4): 357-373.

Dad, J.M. 2016. Distribution, species diversity and composition of plant communities in relation to various affecting factors in an alpine grassland at Bandipora, Kashmir. *Pak. J. Bot.,* 48(2): 551-560.

Dipietro, J.A., K.R. Pogue, R.D. Lawrence, M.S. Baig, A. Hussain and I. Ahmad. 1993. Stratigraphy south of the Main Mantle Thrust, Lower Swat, Pakistan. *Geological Society, London, Special Publications,* 74: 207-220.

Enright, N.J., B.P. Miller and R. Akhter. 2005. Desert vegetation and vegetation-environment relationships in Kirthar National Park, Sindh, Pakistan. *J. Arid Environ.*, 61(3): 397-418.

Glatzel, G. 2009. Mountain forests in a changing World, an Epilogue. *Mount. Res. Dev.,* 29: 188-190.

Hennekens, S.M. and J.H.J. Schaminée. 2001. TURBOVEG, a comprehensive data base management system for vegetation data. *J. Veg. Sci.,* 12: 589-591.

Hu, H., 2002. Ethnoecological knowledge and biodiversity conservation: Application of applied ethnobotany in western China. In: *Proc. Workshop on Curriculum Development in App. Ethnobotany,* (Eds.): Shinwari, Z.K., A. Hamilton and A.A. Khan. WWF, Pakistan, 40-48.

Hussain, F. and I. Ilahi. 1991. Ecology and vegetation of Lesser Himalayas Pakistan. *Bot. Dept. Uni., Peshawar,* 187pp.

Hussain, F., M. Ilyas and S. Takatsuki. 1997. Plant communities of Girbanr hills, Swat district, North-Western Pakistan. *Ecol. Rev.,* 23(4): 247-260.

Hussain, F. 1989. *Field and Laboratory manual of plant ecology.* N.A.H.E., University Grants commission, Islamabad, 422pp.

Ilyas, M., R. Qureshi, Z.K. Shinwari, M. Arshad, S.N. Mirza and Z. Haq. 2013. Some ethnoecological aspects of the plants of Qalagai hills, Kabal valley, swat, Pakistan. *Int. J. Agric. Biol.*, 15(5): 801-810.

Ilyas, M., Z.K. Shinwari and R. Qureshi. 2012. Vegetation composition and threats to the montane temperate forest ecosystem of Qalagai hills, Swat, Khyber Pakhtunkhwa, Pakistan. *Pak. J. Bot*., 44: 113-122.

Ilyas, M., R. Qureshi, N. Akhtar, M. Munir and Z. Haq. 2015. Vegetation analysis of Kabal valley, district Swat, Pakistan using multivariate approach. *Pak. J. Bot.*, 47: 77-86.

Ilyas, M., R. Qureshi, N. Akhtar, Z. Haq and A.M. Khan. 2018. Floristic diversity and vegetation structure of the remnant subtropical broad leaved forests from Kabal valley, Swat, Pakistan. *Pak. J. Bot.*, 50(1): 217-230.

Jabeen, T. and S.S. Ahmad. 2009. Multivariate analysis of environmental and vegetation data of Ayub National Park Rawalpindi. *Soil & Environment*, 28(2): 106-112.

Khan, A., M. Ahmed, M.F. Siddiqui, J. Iqbal and M. Wahab. 2016. Phytosociological analysis of pine forest at Indus Kohistan, KPK, Pakistan. *Pak. J. Bot.,* 48(2): 575-580.

Khan, S.A., S.M. Khan, Z. Ullah, Z. Ahmad, N. Alam, S.N. Shah, R. Khan and M. Zada. 2020. Phytogeographic classification using multivariate approach; a case study from the Jambil Valley Swat, Pakistan. *Pak. J. Bot*., 52(1): 279-290.

Khan, S.M., D.M. Harper, S. Page and H. Ahmad. 2011. Species and community diversity of vascular flora along environmental gradient in Naran Valley: a multivariate approach through Indicator Species Analysis. *Pak. J. Bot*., 43: 2337-2346.

Koehler, F.E., C.D. Moudre and B.L. McNeal. 1984. Laboratory manual for soil fertility. Washington State University, Pulman, pp. 456-461.

Li, W., J. Yang, H. Li and C. Zhang. 2020. Effects of environmental factors on species diversity among the plant communities in the mount Lao nature reserve, Shandong province of China. *Pak. J. Bot*., 52(4): 1205-1213.

McCune, B. and M.J. Mefford. 1999. PC-ORD: multivariate analysis of ecological data; Version 4 for Windows; [User's Guide]. MjM software design.

Millar, C.I., N.L. Stephenson and S.L. Stephens. 2007. Climate change and forests of the future: managing in the face of uncertainty. *Ecol. Appl*., 17(8): 2145-2151.

Morris, E.K., T. Caruso, F. Buscot, M. Fischer, C. Hancock, T.S. Maier, T. Meiners, C. Müller, E. Obermaier, D. Prati and S.A. Socher. 2014. Choosing and using diversity indices: insights for ecological applications from the German Biodiversity Exploratories. *Ecol. Evo*., 4(18): 3514-3524.

Oksanen, J., F.G. Blanchet, R. Kindt, P. Legendre, R.B. O'hara, G.L. Simpson, P. Solymos, M.H.H. Stevens and H. Wagner. 2010. Vegan: Community Ecology Package. R package version 1.17-2. R Development Core Team. R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing.

Pandit, M.K., S.S. Navjot, P.K. Lian, B. Arun and W.B. Barry. 2007. Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalaya. *Biodiv. Conser*., 16: 153-163.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *J. Theor. Biol*., 13: 131-144.

Price, L.W. 1986. Mountains and man: a study of process and environment. University of California Press.

Rahman, A.U., S.M. Khan, S. Khan, A. Hussain, I.U. Rahman, Z. Iqbal and F. Ijaz. 2016. Ecological assessment of plant communities and associated edaphic and topographic variables in the Peochar Valley of the Hindu Kush mountains. *Mount. Res. Dev*., 36(3): 332-341.

Rahman, I.U., N. Khan and K. Ali. 2017. Classification and ordination of understory vegetation using multivariate techniques in the Pinuswallichiana forests of Swat Valley, northern Pakistan. *The Science of Nature*, 104(3-4): p.24.

Rauzi, F. and F.M. Smith. 1973. Infiltration rates: three soils with three grazing levels in north-eastern Colorado. *J. Range Manage*., 26(2): 126-129.

Roleček, J., L. Tichý, D. Zelený and M. Chytrý. 2009. ModifiedTWINSPAN classification in which the hierarchy respectscluster heterogeneity. *J. Veg. Sci*., 20(4): 596-602.

Schickoff, U. 1993. Man's impact on vegetation and landscape in the Kaghan valley, Pakistan. *Pak. J. For*., 128-148.

Shaheen, H., S.M. Khan, D.M. Harper, Z. Ullah and R.A. Qureshi. 2011. Species diversity, community structure, and distribution patterns in western Himalayan alpine pastures of Kashmir, Pakistan. *Mount. Res. Dev*., 31(2): 153-159.

Shaheen, H., R. Sarwar, S.S. Firdous, M.E.I. Dar, Z. Ullahand S.M. Khan. 2015. Distribution and structure of conifers with special emphasis on Taxusbaccata in moist temperate forests of Kashmir Himalayas. *Pak. J. Bot*., 47: 71-76.

Shannon, C.E. and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press: Urbana, IL. USA.

Siddiqui, M.F., M. Ahmed, S.S. Shaukat and N. Khan. 2010. Advanced multivariate techniques to investigate vegetation-environmental complex of pine forests of moist temperate areas of Pakistan. *Pak. J. Bot*., 42: 267-293.

Simpson, E.H. 1949. Measurement of diversity. *Nature*, 163: 688.

Singh, K.N., Gopichand, A. Kumar, B. Lal and N.P. Todaria. 2008. Species diversity and population status of threatened plants in different landscape elements of the Rohtang Pass, Western Himalaya. *J. Mount. Sci*., 5(1): 73-83.

Smith, B. and J.B. Wilson. 1996. A consumer's guide to evenness indices. *Oikos*, 76(1): 70-82.

Thuiller, W., D.M. Richardson, M. Rouget, Ş. Procheş and J.R. Wilson. 2006. Interactions between environment, species traits, and human uses describe patterns of plant invasions. *Ecology*, 87(7): 1755-1769.

Tichý, L. 2002. JUICE, software for vegetation classification. *J. Veg. Sci*., 13: 451-453.

Zeb, A. 1970. The geology of the Shah DeriKabal area, Swat. *J. Himalayan Earth Sci*., 5: 96-111.

(Received for publication 15 February 2019)