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SPATIAL ANALYSIS OF VASCULAR FLORA OF AYUBIA NATIONAL PARK, KPK, PAKISTAN: A CLASSICAL EXAMPLE OF MOIST TEMPERATE HIMALAYA

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Abstract

The current study analyzed the diversity of vascular flora in relation to the prevailing environmental gradients of Ayubia National Park (ANP) of 33.2km^2 area. The phyto-environmental conditions of ANP were analyzed by multivariate techniques. The data analysis was based on indicator species concept and only presence data were used to classify and ordinate species distribution. The hierarchical clustering by an agglomerative method and ordination by Nonmetric multidimensional scaling (NMDS) identified major plant communities in the Park. The study revealed that some environmental factors have a determining role in defining and shaping the key vegetation classes and species richness in the area. NMDS-Ordination indicated elevation (Pr› 0.001) as highly significant environmental gradient followed by stream power index (Pr› 0.012) and slope length factor (Pr› 0.025) in plant species distribution. The study recommends important phytosociological parameters for species distribution that may facilitate conservation of biodiversity and developing future strategies for mountain ecosystems.

Key words: Ayubia National Park, Vascular flora, Multivariate analysis, Biodiversity conservation.

Introduction

The Himalayan region is the world's highest and geologically youngest mountainous province (Burchfiel & Royeden, 1985) with distinct biodiversity and is therefore important for ecologiests and biodiversity conservationists of the world (Mahagaonkar *et al*., 2017). Ecologists and biologists are interested to ascertain and determine the biological alteration among species diversity by different environmental factors in an ecosystem (Vetaas & Grytnes, 2002; Grytnes, 2003). Ascertaining and establishment of correlation between biological and physical elements of an ecosystem is very important branch of applied ecological study (Mofidi *et al*., 2013) particularly in mountainous regions, physical factors shows the greatest effect in limiting plant species and community types (Chawla *et al*., 2008; Sadia *et al*., 2017). Classification and categorization of forest's ecosystem into different assemblages and habitat categories is an imperative tool in natural resource conservation and management (Phillips *et al*., 2006).

Ayubia National Park (ANP), a classical example of moist temperate region of Pakistan, is a protected area spreads with 33km^2 cover. Approximately 50,000 inhabitants are residing around the Park in seven major villages (Afza *et al*., 2004). The park is a part of Lesser Himalaya extending from North to South at 34°1' to 34° 3.8 ′N and 73° 22.8′ to 73° 27.1' E; spreading between an elevation range of approximately ±1450 - 3,033m of Galliat region, District Abbottabad, Pakistan (Fig. 1). The floristic resemblance is with Saharo-Japanese phytogeographic region of the world (Mani 1974) with mean 1500 mm annual rainfall and 10°C temperature (Ahmad & Afza, 2014; Afza, 2016). The most of the precipitation is received in the form of snow (December to February) which characterised the vegetation as moist temperate and having variable degree of coniferous species including *Pinus wallichiana, Pinus roxburghii, Abies pindrow* and *Cedrus deodara. Taxus wallichiana* is also very common tree of the area. Geologically this zone is molded by precipitous and steep rocks (40 - 170 million years old) constituting shale, sand and limestone particles (Calkins *et al*., 1975; Latif 1976) with very shallow topsoil to sustain plant flora on steep slopes. The common broad leaves are *Acer caesium, Prunus padus, Aesculus Indica* and *Quercus* Species. The forests fluctuating from canopy to open lush grassy meadows with a high variety of ferns and perennial herbs; lichens on the trees trunks and an assortment of mosses. The bio-ecological habitats of the area by describing 5 major zones including (i) Coniferous Forests (49.2%) (ii) Shadow Coniferous Forests (32.2%), (iii) Coniferous Forest, Shrubs and Grasses (4.03%), (iv) Broadleaved Mix Forests (11.18%), (v) Pastures and Grasses (0.14%). The vegetation of the study area was first described by Champion *et al*., (1965) and Beg (1975) before the inception of the Park in 1984. After the establishment of the Park, the area was described by a number of ecologists like Hussain and Ilahi (1991); Saima *et al*., (2009) and Ahmad (2012), while the floristic composition of the area was analysed by using multivariant approaches only in selected compartments of the Park due to rugged terrains and steep slopes the whole area of the park was not covered till now with recently developed analytical tools. This study was designed therefore, to compute the richness of species in plant communities and place them in such an ecological and vegetation framework acceptable in

international terms, for identification of key environmental factors for distribution and classification of vegetation. The recent developments in multivariate statistical techniques have helped improve baseline knowledge of the ecological communities and are becoming increasingly popular in Pakistan for the same (Khan *et al.*, 2011; Afza *et al*., 2016). The use of computer-based statistical and multivariate analytical programs assists ecologists to find out proper configuration to analyse the outcomes of environmental gradients on entire sets of plant species (Phillips *et al*., 2006, Fatima *et al*., 2018). Statistical programs reduce the intricacy of data sets by clustering the vegetation types and correlating the results with abiotic (environmental) factors (McCune *et al*., 2004; Terbraak & Prentice, 2004, Zhang & Dong, 2010). Such multivariate tools have infrequently been applied in vegetation studies of Pakistan (Malik & Husain, 2008; Wazir *et al*., 2008; Saima *et al*., 2009; Shaheen *et al*., 2011; Khan *et al*., 2013, Afza, 2016).

Materials and Methods

Field data collection: In order to understand the broader ecological patterns in ANP, field data was collected in the study area during the spring and summer along different environmental gradients during year 2012 to 2014. A phytosociological approach (Rieley & Page, 1990; Malik & Hussain, 2006) was used to measure quantitative and qualitative attributes of vascular plants in quadrats. The vegetation pattern was studied in systematically laid plots at a grid spaced at 100 m altitudinal and at least 250m horizontal intervals to cover the whole extent of study area (33 km^2). The grid points were predetermined and located in field using handheld Global Positioning System (GPS) receiver. A circular plot of 18 x18 m^2 was used for trees, 4 x 4 m^2 for shrubby vegetation and 1 x 1 m^2 for the plots were chosen in a nested techniques for ground vegetation (Pfister *et al*., 1977). The overall data consisted of 160 nested data plots (0.1 hector/plot). The current study calculated frequency, cover density (absolute and relative) of all recorded vascular plant species using the formulae designed. The data collected within the plots included the occurrence record of plant species. The unidentified plants were duly labelled and collected for identification at herbarium of Hazara University Mansehra. The nomenclature follows Flora of Pakistan [Nasir & Ali (1971-89), Ali & Nasir (1989-1991) & Ali & Qaiser (1993-2017)].

Statistical analyses: The recoded data was analysed through classification and ordination tools of multivariate statistical ssoftware package (R-software3.1) (McCune *et al*., 2002).

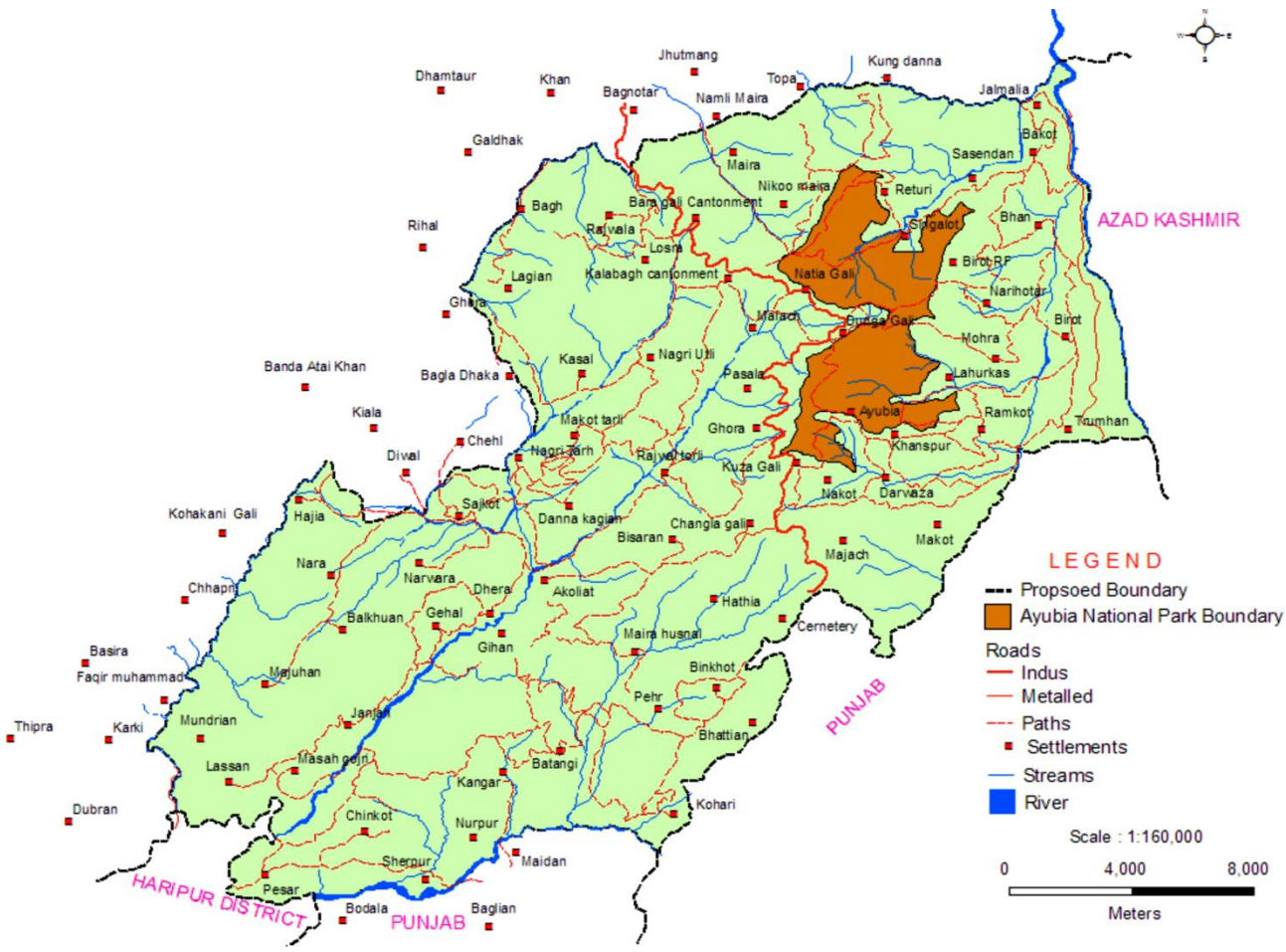

Fig. 1. Location map of Ayubia National Park.

Classification of vegetation plot data: Hierarchical clustering was performed by Bray-Curtis (1957) and Wards (1963) methods of classification, based on applied distance matrix. The broader communities were thus defined and presented as dendrogram. The communities were characterised based on the concepts of fidelity and constancy and the frequency of each of the species in respective community was also determined (Kent & Coker, 1992). Constancy was used in this analysis to name the vegetation communities (ecological zones). Species with constancy between 20% and 75% and degree of fidelity between 3 and 5 were considered '*characteristic species*' (Kent & Coker, 1992). Following quantitative attributes for each of the community were also determined:

Species diversity: Shanon-Weaver Index H' (Shannon & Weaver, 1948) was calculated as:

$$Diversity\ H' = -\sum p_i \ln p_i \quad \text{..... (Eq. 1)}$$

Species richness: Species richness means a count of the number of the plant species in a community.

Evenness or equitability: Shannon's-evenness index (E_1) to quantify the evenness component of species diversity as:

$$E_1 = H' / \ln s \quad \text{..... (Eq. 2)}$$

where H' = Shannon's diversity; ln = natural logarithm and s = the total number of species in a community

Ordination of vegetation plot data: To support the agglomerative hierarchal clustering and describe the influence of environmental gradients in vegetation pattern, Non-metric multidimensional scaling (NMDS) of vegan package (R-software), a PC- ORD Software was applied for ordination of sampling plots. Ordination of vegetation plot is used to assess the arrangement of species or samples along gradients and show their realistic relationship in a low-dimensional space (Legendre & Legendre, 2012). The default option for the analysis to eliminate species that is rarer than 5% (Gauch, 1982) was considered. The influence of environmental factors, extracted from a GIS database using corresponding locations on vegetation types was also assessed (Grandin, 2006).

Results

Classification and ordination: Sum of 250 plant species belonging to 79 plant families were recorded from 160 data plots (Table 1). The vegetation was dominated coniferous species (Phanerophytes) and together with hemi-cryptophytic and Therophytes indicated the generalized features of subalpine and moist temperate vegetation of the Park. The hierarchical Cluster Analysis (Bray-Curtis) broadly divided the plant community in to 3 assemblages. The outline of classification of vegetation data is presented as a dendrogram (Fig. 2) where the lower altitude (1467m) is dominated by subtropical followed by moist temperate vegetation and the higher altitude (3033m) is dominated by subalpine vegetation (Fig. 2). The Indicator Species Analysis (ISA) approach identified indicator species and the key variables for each plant community. The three plant communities delineated in ANP are:

i). *Pinus wallichiana – Viola canescens - Vibernum mullaha* community (PVV): The ecological community I is largely spreads at an altitudinal range of 1467m to 2693m covering 74 data plots confined to steep and rugged mountains of the Park. The lower elevation (1467m) comprised subtropical zone with indicator plant species like *Pinus roxburghii*, *Olea ferrogena* and *Zanthoxylum armatum* while vegetation at higher altitude is represented by *Abies pindrow*, *Pinus wallichiana*, Cedrus *deodara*, *Taxus baccata* and broad leaves *i.e. Acer caesium*, *Prunus padus*, *Juglans regia*, *Cornus macrophylla*, *Quercus dilatata*, *Quercus incana*, Q. *dilatata* and *Parrotiopsis jacquemontiana*. The herb layer was represented by *Viola canescens*, *Dioscorea deltoidea*, *Ainsliaea aptera*, *Nepeta connata*, *Geranium wallichianum*, *Bergenia* sp., *Dryopteris ramosa*, *Adiantum venustum*, *Gentiana kurroo*, *Swertia alata*, *S. paniculata*. The shrub layer of the community is represented by *Viburnum mullaha*, *Skimmia laureola*, *Lonicera quinquelocularis*, *Jasminum humile*, *Berberis kunawurensis*, *B. Parkeriana*, *Indigofera heterantha*, *Daphne papyracea* and *Cotoneaster bacillaris.* The dominant grass species of the community includes *Bromus hordeaceus* (prevailing grass), *B. pectinatus*, *Digitaria sanguinalis* and *Poa angustifolia*. This ecological zone faces high anthropogenic pressure in the form of fuel wood and fodder collection from the adjoining population.

ii). *Abies pindrow–Vibernum grandiflorum – Dryopteris ramosa* plant community (AVD): The plant community II covered an altitudinal range 1709m to 2685m and comprised 22 sampling plots. A sum of 199 plant species were recorded from this community dominated by coniferous vegetation *i.e. Abies pindrow*, *Pinus wallichiana*, *Cedrus deodara*, *and Picea smithiana*. *Taxus baccata* is also frequently recorded. The broad leaved layer is dominated by *Acer caesium*, followed by Q*uercus baloot*, *Rhamnus purpurea*, *Euonymus fimbriatus* and *Pyrus pashia.* The important grass species are *Apluda mutica*, *Bromus hordeaceus*, *B. catharicus*, *Stipa caragana*, *Phleum pratense* and *Poa pratensis*. While the herb layer is dominated by *Dryopteris ramosa* and followed by *Fragaria nubicola*, *Sinopodophyllum hexandrum*, *Adiantum venustum*, *Hedera nepalensis*, *Gentiana kurroo*, *Bupleurum hamiltonii* and *Asparagus filicinus*. The shrub layer is dominated by *Viburnum grandiflorum*, *Rubus pedunculosus*, and *Indigofera heterantha*, *V. mullaha*, *Lonicera quinquelocularis*, *Rosa macrophylla*, *Skimia laureola*, *Spiraea canescens* and *Jasminum humile*. This ecological community is playing a significant role by providing habitat to different wildlife species e.g. common leopard and pheasants.

Table 1. Synoptic table of communities resulting from Bray-Curtis classification showing the frequencies of individual species, number of sampling plots (Plant community I = PVV; Community II = AVD; Community III = PFI).

S.No.	Code	Botanical name	Frequency of occurrence of species		
			PVV	AVD	PFI
1.	Abel.tri	*Abelia triflora* R.Br. ex Wall.	0.05	0.05	0.00
2.	Abie.pin	*Abies pindrow* (Royle ex D. Don) Royle	0.72	0.86	0.68
3.	Acer.cae	*Acer caesium* Wall. ex Brandis	0.38	0.82	0.56
4.	Achi.mil	*Achillea millefolium* L.	0.01	0.14	0.12
5.	Acon.vio	*Aconitum violaceum* Jacquem. ex Stapf.	0.05	0.05	0.03
6.	Colu.lon	*Coluria longifolia* Maxim. Syn: *Geum elatum* var. *humile* (Royle) Hook.f.	0.24	0.36	0.21
7.	Anap.bus	*Anaphalis busua* (Buch.Ham.) DC.	0.01	0.00	0.21
8.	Acon.mol	*Aconogonon molle* (D. Don) H. Hara Syn: *Polygonum molle* D. Don, Prodr.	0.03	0.05	0.09
9.	Adia.ven	*Adiantum venustum* D. Don	0.69	0.45	0.12
10.	Aegi.cyli	*Aegilops cylindrical* Host.	0.11	0.27	0.12
11.	Aesc.ind	*Aesculus indica* (Wall. ex Cambess.) Hook.	0.35	0.05	0.38
12.	Ager.hou	*Ageratum albidum* (DC.) Hemsl.	0.04	0.18	0.00
13.	Agro.pil	*Agrostis pilosula* Trin.	0.08	0.05	0.12
14.	Agro.sto	*Agrostis stolonifera* L.	0.07	0.09	0.18
15.	Agro.vin	*Agrostis vinealis* Schreb.	0.08	0.09	0.09
16.	Aila.alt	*Ailanthus altissima* (Mill) Swingle	0.01	0.00	0.03
17.	Ains.apt	*Ainsliaea aptera* DC.	0.05	0.00	0.03
18.	Ajug.int	*Ajuga integrifolia* Buch.-Ham.	0.08	0.00	0.24
19.	Ajug.par	*Ajuga parviflora* Benth.	0.08	0.09	0.00
20.	Alnu.nit	*Alnus nitida* (Spach) Endl.	0.01	0.05	0.03
21.	Alce.ros	*Alcea rosea* L. Syn: *Althea rosa* L.	0.03	0.00	0.00
22.	Anap.bus	*Anaphalis busua* (Buch.-Ham.) DC.	0.04	0.00	0.06
23.	Andr.foli	*Androsace foliosa* Duby	0.08	0.14	0.09
24.	Andr.haz	*Androsace hazarica* R.R. Stewart ex Y.J. Nasir	0.08	0.05	0.06
25.	Andr.rot	*Androsace rotundifolia* Hardw.	0.19	0.14	0.09
26.	Anem.tet	*Anemone tetraflora*	0.05	0.05	0.06
27.	Anis.ind	*Anisomeles indica* (L.) Kuntze	0.07	0.00	0.00
28.	Ante.fil	*Antenoron filiforme* (Thunb.) Roberty & Vautier	0.03	0.05	0.00
29.	Aplu.mut	*Apluda mutica* L.	0.05	0.55	0.03
30.	Aqui.fra	*Aquilegia fragrans* Benth.	0.07	0.55	0.00
31.	Aqui.pub	*Aquilegia pubiflora* Wall. ex Royle	0.18	0.00	0.18
32.	Aren.ser	*Arenaria serpyllifolia* Bourg. ex Willk. & Lange	0.00	0.05	0.06
33.	Aris.jac	*Arisaema jacquemontii* Blume.	0.19	0.09	0.12
34.	Aris.uti	*Arisaema utile* Hook. f. ex Schott	0.05	0.05	0.06
35.	Arte.inc	*Artemisia incisa* Pamp.	0.14	0.09	0.12
36.	Arte.rox	*Artemisia roxburghiana* Wall. ex Besser	0.01	0.14	0.03
37.	Arum.jac	*Arum jacquemontii* Blume	0.08	0.05	0.06
38.	Aspa.fil	*Asparagus filicinus* Buch.-Ham. ex D. Don	0.14	0.14	0.09
39.	Aste.fal	*Aster falcifolius* Handel-Mazzetti	0.04	0.00	0.00
40.	Aple.mur	*Apluda muricata* L	0.13	0.18	0.09
41.	Atro.acu	*Atropa acuminate* Royle ex Lindl.	0.01	0.09	0.06
42.	Berb.kun	*Berberis kunawurensis* Royle	0.22	0.18	0.06
43.	Berb.par	*Berberis Parkeriana* C.K. Schneid.	0.03	0.00	0.06
44.	Berg.cil	*Bergenia ciliate* (Haw.) Sternb.	0.03	0.18	0.03
45.	Berg.str	*Bergenia stracheyii* (Hook. f. & Thomson) Engl.	0.03	0.00	0.12
46.	Betu.uti	*Betula utilis* D. Don	0.01	0.05	0.09
47.	Bide.chi	*Bidens pilosa* L.	0.08	0.00	0.00
48.	Both.bla	*Bothriochloa bladhii* (Retz.) S.T. Blake	0.07	0.05	0.15
49.	Brom.cat	*Bromus catharticus* Vahl	0.01	0.14	0.09
50.	Brom.hor	*Bromus hordeaceus* L.	0.54	0.27	0.41
51.	Brom.pec	*Bromus pectinatus* Thunb.	0.04	0.05	0.00
52.	Brom.por	*Bromus porphyranthos* Cope	0.15	0.00	0.15
53.	Bupl.ham	*Bupleurum hamiltonii* N.P. Balakr.	0.04	0.14	0.09
54.	Call.pim	*Callianthemum pimpinelloides* (D.Don ex Royle) Hook.f. & Thomson	0.08	0.05	0.06
55.	Calt.alb	*Caltha palustris* var. *alba* (Cambess.) Hook.f. & Thomson	0.03	0.00	0.03
56.	Cann.sat	*Cannabis sativa* L.	0.03	0.00	0.03
57.	Care.fil	*Carex filicina* Nees	0.16	0.05	0.06
58.	Care.wal	*Carex wallichiana* Spreng.	0.00	0.18	0.00
59.	Cedr.deo	*Cedrus deodara* (Roxb. ex D.Don) G.Don	0.16	0.41	0.24
60.	Celt.aus	*Celtis australis* subsp. *Caucasica* (Willd.) C.C. Towns.	0.03	0.09	0.00
61.	Cera.fon	*Cerastium fontanum* Baumg	0.03	0.00	0.03

Table 1. (Cont'd.).

S.No.	Code	Botanical name	Frequency of occurrence of species		
			PVV	AVD	PFI
62.	Chry.gry	*Chrysopogon gryllus* (L.) Trin.	0.09	0.05	0.09
63.	Cich.int	*Cichorium intybus* L.	0.05	0.00	0.06
64.	Clem.buc	*Clematis buchananiana* DC.	0.05	0.00	0.09
65.	Clem.cor	*Clematis catesbyana* Pursh	0.15	0.09	0.18
66.	Clem.gra	*Clematis graveolens* Lindl.	0.15	0.00	0.06
67.	Clem.mon	*Clematis montana* Buch.-Ham. ex DC.	0.03	0.05	0.00
68.	Clin.vul	*Clinopodium vulgare* L.	0.00	0.18	0.00
69.	Clin.hyd	*Clinopodium hydaspidis* (Fal ex Benth.) Kuntze	0.00	0.18	0.00
70.	Coni.mac	*Conium maculatum* L.	0.01	0.05	0.03
71.	Corn.mac	*Cornus macrophylla* Wall.	0.24	0.27	0.18
72.	Coto.bac	*Cotoneaster bacillaris* Wall. ex Lindl.	0.07	0.09	0.06
73.	Cruc.him	*Crucihimalaya himalaica* (Edgew.) Al-Shehbaz, O'Kane & R.A. Price	0.32	0.23	0.03
74.	Cymb.dis	*Cymbopogon distans* (Nees ex Steud.) W. Watson	0.01	0.00	0.03
75.	Cyno.lan	*Cynoglossum lanceolatum* Forssk.	0.15	0.18	0.06
76.	Cype.cyp	*Cyperus cyperoides* (L.) Kuntze	0.03	0.00	0.12
77.	Dact.glo	*Dactylis glomerata* L.	0.15	0.05	0.03
78.	Dact.hat	*Dactylorhiza hatagirea* (D. Don) Soó	0.00	0.05	0.09
79.	Daph.pap	*Daphne papyracea* Wall. ex G. Don	0.01	0.18	0.00
80.	Datu.str	*Datura stramonium* L.	0.01	0.00	0.00
81.	Delp.ves	*Delphinium vestitum* Wall. ex Royle	0.11	0.05	0.09
82.	Desm.ele	*Desmodium elegans* DC.	0.12	0.18	0.12
83.	Digi.san	*Digitaria sanguinalis* (L.) Scop.	0.11	0.00	0.15
84.	Dios.del	*Dioscorea deltoidea* Wall. ex Griseb.	0.05	0.09	0.06
85.	Dios.lot	*Diospyros lotus* L.	0.08	0.05	0.00
86.	Dips.ine	*Dipsacus inermis* Wall.	0.07	0.00	0.06
87.	Drab.ore	*Draba oreades* Schrenk	0.04	0.00	0.15
88.	Dryo.ste	*Dryopteris ramose* (C. Hope) C. Chr.	0.72	0.73	0.21
89.	Duch.ind	*Duchesnea indica* (Jacks.) Focke	0.03	0.05	0.03
90.	Echi.cor	*Echinops cornigerus* DC.	0.03	0.09	0.00
91.	Epip.hel	*Epipactis helleborine* (L.) Crantz	0.08	0.05	0.06
92.	Epip.per	*Epipactis persica* (Soó) Hausskn. ex Nannf.	0.03	0.05	0.00
93.	Erig.roy	*Erigeron roylei* DC.	0.01	0.00	0.03
94.	Euon.fim	*Euonymus fimbriatus* Wall.	0.00	0.09	0.00
95.	Euon.ham	*Euonymus hamiltonianus* Wall.	0.05	0.00	0.03
96.	Euph.hel	*Euphorbia helioscopia* L.	0.14	0.00	0.00
97.	Euph.wal	*Euphorbia wallichii* Hook. f.	0.16	0.14	0.18
98.	Ficu.pal	*Ficus palmata* Forssk.	0.01	0.00	0.00
99.	Frag.nub	*Fragaria nubicola* (Lindl. ex Hook.f.) Lacaita	0.78	0.64	0.59
100.	Frax.exc	*Fraxinus excelsior* L.	0.00	0.00	0.06
101.	Fuma.ind	*Fumaria indica* (Hausskn.) Pugsley	0.03	0.05	0.00
102.	Gali.ele	*Galium elegans* Wall. ex Roxb.	0.27	0.23	0.35
103.	Gali. Sub	*Galium subfalcatum* Nazim. & Ehrend.	0.08	0.00	0.09
104.	Gent.kur	*Gentiana kurroo* Royle	0.03	0.09	0.15
105.	Gera.luc	*Geranium lucidum* L.	0.04	0.05	0.06
106.	Gera.wal	*Geranium wallichianum* D. Don ex Sweet	0.42	0.23	0.12
107.	Gerb.gos	*Gerbera gossypina* (Royle) Beauverd	0.11	0.18	0.00
108.	Hede.nep	*Hedera nepalensis* K. Koch.	0.5	0.45	0.12
109.	Hera.can	*Heracleum candicans* Wall. ex DC.	0.04	0.00	0.12
110.	Hypr.per	*Hypricum perfuratum* L.	0.04	0.00	0.12
111.	Impa.bic	*Impatiens bicolor* Royle	0.32	0.18	0.06
112.	Indi.het	*Indigofera heterantha* Brandis	0.39	0.27	0.29
113.	Iris.hoo	*Iris hookerana* Foster	0.01	0.05	0.15
114.	Isod.coe	*Isodon coetsa* (Buch.-Ham. ex D. Don) Kudô	0.2	0.05	0.21
115.	Isod.rug	*Isodon rugosus* (Wall. ex Benth.) Codd	0.19	0.05	0.03
116.	Jasm.hum	*Jasminum humile* L.	0.11	0.09	0.09
117.	Jugl.reg	*Juglans regia* L.	0.2	0.05	0.12
118.	Leon.bra	*Leontopodium brachyactis* Gand.	0.14	0.09	0.32
119.	Leon.car	*Leonurus cardiac* L.	0.01	0.09	0.03
120.	Lepi.vir	*Lepidium virginicum* L.	0.11	0.14	0.24
121.	Lept.cor	*Leptopus cordifolius* Decne.	0.05	0.05	0.00
122.	Lesp.jun	*Lespedeza juncea* (L.f.) Pers	0.07	0.00	0.00
123.	Leuc.vul	*Leucanthemum vulgare* (Vaill.) Lam.	0.07	0.23	0.32
124.	Ligu.jac	*Ligularia jacquemontiana* (Decne.) M.A. Rau	0.12	0.09	0.00
125.	Loli.mul	*Lolium multiflorum* Lam.	0.09	0.05	0.18

Table 1. (Cont'd.).

S.No.	Code	Botanical name	Frequency of occurrence of species		
			PVV	AVD	PFI
126.	Loni.qua	*Lonicera quinquelocularis* Hard.	0.24	0.36	0.26
127.	Loni.web	*Lonicera webbiana* Wall. ex DC.	0.04	0.00	0.00
128.	Lotu.cor	*Lotus corniculatus* L.	0.00	0.00	0.03
129.	Lysi.che	*Lysimachia chenopodioides* Watt. ex Hook. f.	0.14	0.00	0.06
130.	Malv.neg	*Malva neglecta* Wallr.	0.07	0.05	0.03
131.	Malv.ver	*Malva verticillata* L.	0.00	0.05	0.03
132.	Marr.vul	*Marrubium vulgare* L.	0.05	0.00	0.03
133.	Matr.rec	*Matricaria chamomilla* L.	0.01	0.00	0.03
134.	Medi.lac	*Medicago laciniata* (L.) Mill.	0.04	0.05	0.06
135.	Ment.lon	*Mentha longifolia* (L.) L.	0.04	0.09	0.03
136.	Morc.esc	*Morchella esculanta* (L.) Pers.ex.Fr.	0.01	0.05	0.00
137.	Mori.per	*Morina persica* L.	0.04	0.05	0.12
138.	Moru.nig	*Morus nigra* L.	0.05	0.05	0.03
139.	Nepe.con	*Nepeta connate* Royle ex Benth.	0.01	0.05	0.03
140.	Nepe.ere	*Nepeta erecta* (Royle ex Benth.) Benth.	0.07	0.05	0.12
141.	Oeno.ros	*Oenothera rosea* L'Hér. ex Aiton	0.05	0.05	0.00
142.	Olea.fer	*Olea ferruginea* Wall. ex Aitch.	0.01	0.00	0.00
143.	Onos.his	*Onosma hispida* var. *kashmirica* (I.M. Johnst.) I.M. Johnst.	0.01	0.05	0.03
144.	Opli.und	*Oplismenus undulatifolius* (Ard.) Roem. & Schult.	0.03	0.00	0.00
145.	Orig.vul	*Origanum vulgare* L.	0.12	0.00	0.21
146.	Orth.sec	*Orthilia secunda* (L.) House	0.01	0.00	0.03
147.	Oxal.cor	*Oxalis corniculata* L.	0.11	0.23	0.00
148.	Paeo.emo	*Paeonia emodi* Royle	0.03	0.09	0.00
149.	Parn.lax	*Parnassia laxmannii* Pall. ex Schult.	0.03	0.09	0.03
150.	Parr.jac	*Parrotiopsis jacquemontiana* (Decne.) Rehder	0.05	0.05	0.03
151.	Pers.amp	*Persicaria amplexicaulis* (D.Don) Ronse Decr. Syn: *Bistorta amplexicaulis* (D.Don) Greene	0.45	0.27	0.56
152.	Phle.him	*Phleum himalaicum* Mez.	0.03	0.00	0.03
153.	Phle.pra	*Phleum pratense* L.	0.03	0.09	0.03
154.	Phlo.bra	*Phlomoides bracteosa* (Royle exBenth.) Kamelin & Makhm.	0.00	0.09	0.06
155.	Phra.aus	*Phragmites australis* (Cav.) Trin. ex Steud.	0.04	0.05	0.06
156.	Phyt.aci	*Phytolacca acinosa* Roxb.	0.05	0.05	0.03
157.	Pice.smi	*Picea smithiana* (Wall.) Boiss.	0.03	0.05	0.06
158.	Pinu.rox	*Pinus roxburghii* Sarg.	0.07	0.05	0.00
159.	Pinu.wal	*Pinus wallichiana* A.B. Jacks.	0.88	0.86	0.88
160.	Pipt.aeq	*Piptatherum aequiglume* (Duthie ex Hook. f.) Roshev.	0.16	0.05	0.06
161.	Plan.lan	*Plantago lanceolata* L.	0.12	0.05	0.24
162.	Plan.maj	*Plantago major* L.	0.08	0.05	0.06
163.	Pleu.sty	*Pleurospermum stylosum* C.B. Clarke	0.03	0.05	0.06
164.	Poa.pra	*Poa pratensis* L.	0.09	0.18	0.09
165.	Poa.pra.1	*Poa angustifolia* L. *Syn: Poa pratensis*	0.08	0.14	0.18
166.	Sino.hex	*Sinopodophyllum hexandrum* (Royle) T.S.Ying Syn: *Podophyllum hexandrum* Royle	0.16	0.64	0.12
167.	Poly.mul	*Polygonatum multiflorum* (L.) All.	0.18	0.09	0.09
168.	poly.ver	*Polygonatum verticillatum* (L.) All.	0.09	0.14	0.12
169.	popu.cil	*Populus ciliate* Wall. ex Royle	0.05	0.14	0.00
170.	Pote.nep	*Potentilla nepalensis* Hook.	0.01	0.00	0.24
171.	Prim.den	*Primula denticulata* Sm.	0.04	0.05	0.12
172.	Prun.vul	*Prunella vulgaris* L.	0.08	0.00	0.15
173.	Prun.pad	*Prunus padus* L.	0.27	0.36	0.29
174.	Pter.cau	*Pteridium caudatum* (L.) Maxon	0.05	0.00	0.15
175.	Pter.cre	*Pteris cretica* L.	0.01	0.09	0.03
176.	Pter.aca	*Pteris acanthoneura* Alston	0.36	0.05	0.03
177.	Puni.gra	*Punica granatum* L.	0.03	0.00	0.06
178.	Pyru.pas	*Pyrus pashia* Buch.-Ham. ex D.Don	0.1	0.05	0.00
179.	Quer.dil	*Quercus dilatata* Lindl. ex A.DC.	0.24	0.18	0.09
180.	Quer.bal	*Quercus baloot* Griff.	0.04	0.05	0.00
181.	Quer.inc	*Quercus incana* Bartram	0.11	0.09	0.15
182.	Ranu.mun	*Ranunculus munroanus* J.R. Drumm. ex Dunn	0.04	0.05	0.06
183.	Ranu.mur	*Ranunculus muricatus* L.	0.18	0.09	0.29
184.	Rhem.pur	*Rhamnus purpurea* Edgew.	0.19	0.68	0.03
185.	Rhem.aus	*Rheum australe* D.Don	0.01	0.00	0.00
186.	Rhus. Suc	*Rhus succedanea* L.	0.05	0.00	0.03
187.	Robi.pse	*Robinia pseudoacacia* L.	0.00	0.00	0.03

Table 1. (Cont'd.).

S.No.	Code	Botanical name	Frequency of occurrence of species		
			PVV	AVD	PFI
188.	Rosa.mos	*Rosa moschata* Herrm. Syn: *R. brunonii* Lindl	0.08	0.05	0.12
189.	Rosa.chi	*Rosa chinensis* Jacq.	0.03	0.00	0.15
190.	Rosa.mac	*Rosa macrophylla* Lindl.	0.05	0.18	0.06
191.	Rosa.mul	*Rosa multiflora* Thunb.	0.08	0.00	0.03
192.	Rosa.can	*Rosa canina* L.	0.05	0.09	0.09
193.	Rosa.web	Rosa webbiana Wall. ex Royle	0.07	0.18	0.12
194.	Rubi.him	*Rubia himalayensis* Klotzsch	0.07	0.09	0.03
195.	Rubu.vul	*Rubus vulgaris* Weihe & Nees	0.12	0.68	0.00
196.	Rubu.ped	*Rubus pedunculosus* D.Don	0.04	0.09	0.00
197.	Rume.ace	*Rumex acetosa* L.	0.08	0.14	0.09
198.	Rume.has	*Rumex hastatus* D. Don.	0.18	0.09	0.32
199.	Rume.nep	*Rumex nepalensis* Spreng.	0.05	0.00	0.15
200.	Sagi.tri	*Sagittaria trifolia* L.	0.03	0.00	0.06
201.	Sali.den	*Salix denticulate* Andersson	0.00	0.05	0.18
202.	Sali.alb	*Salix alba* L.	0.03	0.00	0.09
203.	Salv.nub	*Salvia nubicola* Wall. ex Sweet	0.01	0.00	0.00
204.	Samb.wig	*Sambucus adnata* Wall. Ex DC.	0.03	0.00	0.00
205.	Sarc.sal	*Sarcococca pruniformis* Lindl.	0.03	0.00	0.00
206.	Sass.het	*Saussurea costus* (Falc.) Lipsch.	0.01	0.00	0.03
207.	Saur.ven	*Sauromatum venosum* (Dryand. ex Aiton) Kunth	0.04	0.05	0.03
208.	Scro.cal	*Scrophularia calycina* Benth.	0.14	0.05	0.09
209.	Sedu.ewe	*Sedum ewersii* Ledeb.	0.04	0.05	0.03
210.	Seli.wal	*Selinum wallichianum* (DC.) Raizada & H.O. Saxena	0.03	0.36	0.06
211.	Sene.ana	*Senecio analogus* DC.	0.03	0.36	0.12
212.	Sene.nud	*Senecio nudicaulis* Buch.-Ham. ex D. Don	0.05	0.05	0.06
213.	Serr.pal	*Serratula pallida* DC.	0.00	0.05	0.12
214.	Seta.pum	*Setaria pumila* (Poir.) Roem. & Schult.	0.08	0.05	0.06
215.	Sisy.iri	*Sisymbrium irio* L.	0.01	0.05	0.12
216.	Skim.lau	*Skimmia laureola* Franch.	0.32	0.23	0.03
217.	Sola.sur	*Solanum surattense* Brum.f.	0.04	0.00	0.00
218.	Sola.vil	*Solanum villosum* Mill	0.03	0.00	0.03
219.	Soli.vir	*Solidago virgaurea* L.	0.00	0.14	0.03
220.	Sorb.tom	*Sorbaria tomentosa* (Lindl.) Rehder	0.2	0.45	0.03
221.	Sorb.cus	*Sorbus cuspidata* (Spach) Hedl.	0.03	0.09	0.00
222.	Spir.can	*Spiraea canescens* D.Don	0.18	0.05	0.03
223.	Stap.emo	*Staphylea emodi* L.	0.18	0.05	0.24
224.	Stip.car	*Stipa caragana* Trin.	0.08	0.23	0.06
225.	Stip.jac	*Stipa jacquemontii* Jaub. & Spach.	0.01	0.05	0.00
226.	Stro.urt	*Strobilanthes urticifolia* Wall. ex Kuntze	0.2	0.32	0.06
227.	Swer.ala	*Swertia alata* C.B. Clarke	0.12	0.00	0.03
228.	Swer.pan	*Swertia paniculata* Wall.	0.03	0.00	0.03
229.	Tara.cam	*Taraxacum* sp.	0.07	0.00	0.03
230.	Taxu.bac	*Taxus baccata* L.	0.31	0.73	0.5
231.	Thal.cul	*Thalictrum cultratum* Wall.	0.01	0.00	0.15
232.	Tori.jap	*Torilis japonica* (Houtt.) DC.	0.04	0.05	0.00
233.	Trif.rep	*Trifolium repens* L.	0.11	0.00	0.26
234.	Tril.gov	*Trillium govanianum* Wall. ex D.Don	0.03	0.00	0.06
235.	Tuss.far	*Tussilago farfara* L.	0.01	0.14	0.06
236.	Ulmu.wal	*Ulmus wallichiana* Planch.	0.08	0.00	0.12
237.	Urti.dio	*Urtica dioica* L.	0.3	0.45	0.29
238.	Vale.jat	*Valeriana jatamansi* Jones	0.38	0.45	0.29
239.	Verb.tha	*Verbascum thapsus* L.	0.14	0.18	0.03
240.	Verb.off	*Verbena officinalis* L.	0.001	0.00	0.00
241.	vero.lax	*Veronica laxa* Benth.	0.24	0.45	0.29
242.	Vibu.gra	*Viburnum grandiflorum* Wall. ex DC.	0.72	0.68	0.44
243.	Vibu.mul	*Viburnum mullaha* Buch.-Ham. ex D. Don	0.08	0.05	0.03
244.	Viol.can	*Viola canescens* Wall.	0.81	0.55	0.44
245.	Part.sem	*Parthenocissus semicordata* (Wall.)Planch.	0.04	0.05	0.00
246.	Wood.fru	*Woodfordia fruticosa* (L.) Kurz	0.04	00.00	0.03
247.	Wul.amh	*Wulfeniopsis amherstiana* (Benth.) D.Y. Hong	0.08	0.14	0.12
248.	Zant.arm	*Zanthoxylum armatum* DC.	0.01	0.00	0.03
249.	Zeux.str	*Zeuxine strateumatica* (L.) Schltr.	0.01	0.00	0.03
250.	Zizi.oxy	*Ziziphus oxyphylla* Edgew.	0.08	0.00	0.00

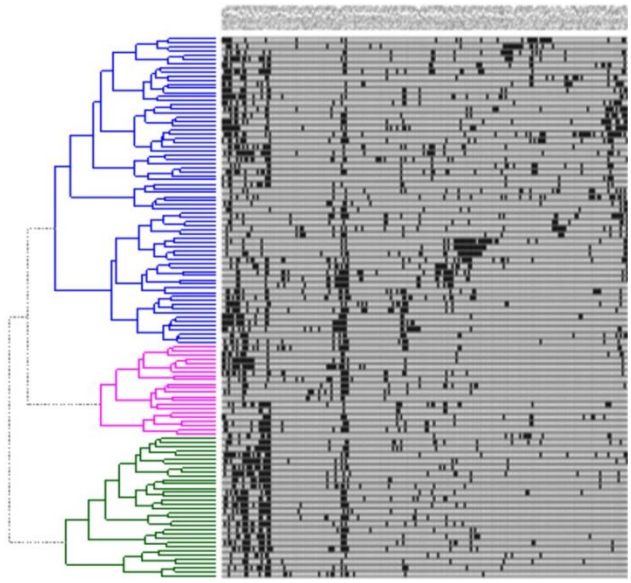

Fig. 2. A dendrogram of hierarchical clustering of vegetation of ANP using Bray/Curtis method of classification through PC-ORD.

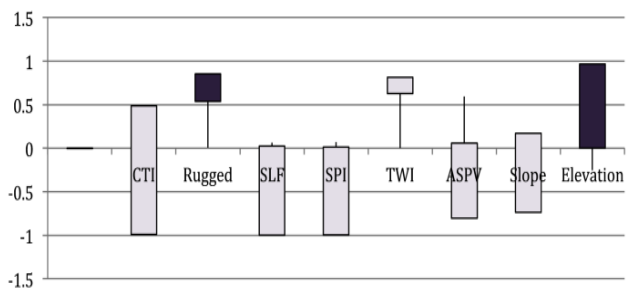

Fig. 3. NMDS ordination of Plant communities in Ayubia National Park.

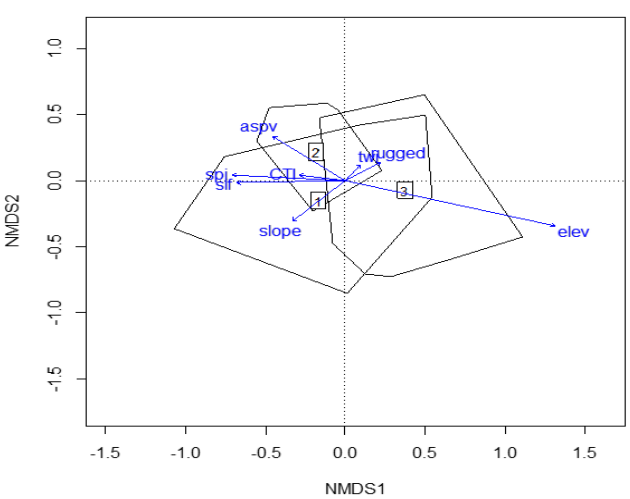

Fig. 4. Non- Parametric test for ecogeographical variables of ANP.

iii). *Pinus wallichiana – Fragaria nubicola –Indigofera heterantha* plant community (PFI): This plant community is representing the subalpine zone at higher elevation, spreads between1752m - 3033m altitudinal range. This community connsists of 34 sampling plots and 176 plant species. The dominant tree species is *Pinus wallichiana* and is followed by *Abies pindrow, Taxus baccata* and *Cedrus deodara* while *Picea smithiana* is infrequent species. The dominant broadleaved are *Acer caesium, Ulmus wallichiana* and *Prunus padus*. The two highest mountain tops of Ayubia National Parks are covered by this ecological community *i.e.* Miranjani and Mushkpuri top of subalpine zone. The community is occupied by lush grasses and herbs in the upper areas with bushes and stunted growth trees. At higher elevation broad leaved species like *Betula utilis* and *Salix denticulata* can be observed in association with *Euphorbia wallichii* and *Bromus hordeaceus.*The dominant tree species are *Pinus wallichiana*, *Abies pindrow, Taxus baccata, Cedrus deodara*, while *Picea smithiana* is less frequent. Among the broad leaved tree species *Acer caesium, Quercus incana*, Q. *dilatata, Prunus padus, Salix denticulate* are common. The dominant herbaceous flora is *Fragaria nubicola* followed by *Persicaria amplexicaulis, Viola canescens, Achillea millefolium, Euphorbia wallichii, Ranunculus muricatus, Leontopodium brachyactis, Rumex hastatus Galium elegans, Valeriana jatamansi* Jones, *Veronica laxa*, *Nepeta* sp., *Potentilla nepalensis, Staphylea emodi*, *Iris hookerana* and *Cotoneaster bacillaris.* This ecozone is severely disturbed by the contiguous communities in by free grazing. The dominant shrubs are *Indigofera heterantha, Vibernum grandiflorum, Lonicera quinquelocularis* and *Desmodium elegans*. Grasses are *Bromus hordeaceus, Agrostis stolonifera, Bothriochloa bladhii, B. porphyranthos* and *Digitaria sanguinalis*.

Environmental variables: In order to describe and determine the role of different environmental variables responsible (Fig. 3) for classification and spreading of plant species in the Park, a non-parametric analysis (Kruskal Wallis test) was done (Fig. 4). It showed that elevation is the key variable followed by SLF (slope length factor) and SPI (Stream power index).

The results revealed that the classified plant communities of ANP differed significantly from each other based on elevation and followed by TWI (Topographic wetness index) and Ruggedness (Fig. 3) while the rest of eco-variables shows insignificance in the classification of plant communities.

Discussion

Boundaries of an ecosystem are not fixed due vast micro and macro physical factors as prevailing drivers. The moist temperate vegetation of this region of Western Himalayan Province was classified as different on the basis different ecovariables (Chawla *et al*., 2008; Saqib *et al*., 2011; Mandal & Joshi, 2014) At the lowers altitudes, the vegetation has some characteristic species of moist temperate vegetation *Pinus wallichiana, Abies pindrow, Taxus baccata, Acer caesium, Aesculus indica, Prunus padus, Indigofera heterantha, Viburnum grandiflorum, Ranunculus muricatus Paeonia emodi* and *Bistorta amplexicaulis* and *Rheum australe* as reported from moist temperate Himalaya by Afza (2006). Community 1 reflects vegetation of temperate and subtropical plant species and exhibit rich diversity (236 species). Community III (199 sp) covered the subalpine under the effect of high altitude characterized by species like *Betula utilis, Salix denticulata, Iris hookeriana, Primula*

denticulata, *Potentilla nepalensis* and *Ranunculus sp.* While plant community II (177 spp.) covered the temperate vegetation type. This type of altitudinal gradient complex has been found in other studies around the globe where topographic variables also influence vegetation (Chawla *et al.*, 2008, Tımılehın *et al*., 2017). Species diversity was optimum at the middle altitudes as compared to the lower where direct anthropogenic activities are continuous and high altitudes where diversity reaches to its minimum but the high grazing pressure also cause this decrease. Such kind of species distributional phenomenon has also been observed in other mountainous ecosystems (Weaver, 1991, Fatima *et al*., 2018). The presence of a diverse flora in the identified ecological communities of ANP indicated that the study area supported an important habitat a variety of wildlife species like common Leopard and pheasants. The ecological communities identified during the current study were different from the other studies conducted in the study area by (Hussain & Ilahi, 1991; Ahmed *et al.*, 2006; Saima *et al.*, 2009 and Ahmad 2012) where the authors either discussed the general vegetation types of forested zones or select a specific compartment for study whereas the current study defined vegetation classes based on the species diversity, dominance and frequency of occurrence of plant species in a systematically laid out sampling plots in the entire area of the park, representing the major vegetation types. Hierarchical clustering classified the entire sampling plots into three ecological classes which provided an adequate classification to understand the broader ecological zones in ANP.

Elevation, SLF and SPI extracted from plot location data, were useful in further defining the floristic composition and distribution. Elevation was the major environmental factor that was very significant in determining the difference between the identified ecological communities. The importance of altitude as an environmental factor affecting plant species association and considered its close correlation with rainfall and temperature has been worked out by many researcher (Malik & Husain, 2006; Wazir *et al.*, 2008; Shaheen *et al*., 2011; Khan *et al*., 2011; Arshid *et al*., 2013; Saqib *et al*., 2011; Afza *et al*., 2016). However, detailed observations are required to look into the significance of edaphic, topographical and other environmental variables in defining the vegetation composition in the study area. Similar approaches using multivariate analyses were applied in mountain protected areas of Pakistan for vegetation classification and understanding the ecological communities in response to different environmental and topographic variables (Arshid *et al*., 2013). The variations in species richness, diversity and evenness among the different ecological types may be attributed to the difference in soil characteristics, topographic and environmental variables. As a result, the ecological communities II and III of the present study were more diverse than those of other ecological community types I which showed its presences at lower altitudes. This is also due to the reason that maximum number of sampling plots were laid out in these broader vegetation zones, which resulted in an increase in the species diversity.

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