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ORIGINAL ARTICLE

Plant species and communities assessment in interaction with edaphic and topographic factors; an ecological study of the mount Eelum District Swat, Pakistan



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Plant communities;
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Abstract The current analyses of vegetation were aimed to study the different effects of environmental variables and plant species and communities interaction to these variables, identified threats to local vegetation and suggestion for remedial measures in the Mount Eelum, Swat, Pakistan. For assessment of environmental variability quantitative ecological techniques were used through quadrats having sizes of 2×2 , 5×5 and 10×10 m² for herbs, shrubs and trees respectively. Result of the present study revealed 124 plant species in the study area. Canonical Correspondence Analysis (CCA) was used to analyze the ecological gradient of vegetation. The environmental data and species abundance were used in CANOCO software version 4.5. The presence absence data of plant species were elaborated with Cluster and Two Way Cluster Analysis techniques using PC-ORD version 5 to show different species composition that resulted in five plant communities. Findings indicate that elevation, aspect and soil texture are the strongest variables that have significant effect on

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species composition and distribution of various communities shown with *P* value 0.0500. It is recommended to protect and use sensibly whole of the Flora normally and rare species particularly in the region.

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1. Introduction

The study of plant communities is the best way to learn about habit, habitat, niche and vegetation structure (Khan et al., 2016a; Malik, 1986) as well as various interaction among the plants in an ecosystem. Forest ecosystems in the world have a history of fragmentation due to activities of human advancement (Chabrerie et al., 2013). The deforestation mask the greenery, created ecological disturbance, drastic change in soil chemistry, physical weathering and denudation of rocks which leading to floods and changed almost the natural structure of vegetation. The important zone of ecological study is to determine the interaction between different biotic and abiotic components of an ecosystem (Rahman et al., 2016; Tavili and Jafari, 2009). Abiotic variations are well known characteristics both in space and time which effect plant communities and population. The plant communities highlight changes in response to various factors not only related to its zone of origin but also to its ecology (Afzal et al., 2000). The most simply interpretable sign of biological variation is species richness which highlight by different environmental characters (Khan et al., 2016b; Shrestha and Vetaas, 2009). Researchers study several factors (abiotic and biotic) basically which interact in community structure formation. These factors contribute to comprehend distribution, composition and diversity of plant species and communities (Brown, 1984). Variations in plant species composition along altitude and latitude is well establishment phenomenon (Kitayama, 1992; Lieberman et al., 1985; Shaheen et al., 2012) and one of the ultimate effect in restricting plant species and communities types in mountainous regions (Khan et al., 2011a). Furthermore soil is an environmental factor that also determines plant growth which is influenced by organisms, climate, topography, time and parent material (Hoveizeh, 1997). Climate is affected by topography such as slope, elevation and aspect, in addition to affect of evapotranspiration and temperature that as a whole result rich vegetation in the northern aspects as compared to southern ones (Ordoñez et al., 2009). Furthermore, the quantitative analysis has a strong back ground and a lot of different field scientist have contributed to use it (Shaheen and Shinwari, 2012). Quantitative measure updates the feature of vegetation because of its obvious effects on all types of associated life to vegetation communities. Ecologists use multivariate approach for seeking and summarizing ecological set of plants data regarding with environmental variables. The statistical study of these data help in finding actual position of plant species in the field (Curtis and McIntosh, 1950). The multivariate statistical analytical programs assists the ecologists to analyse the effects of environmental variables on whole numbers of species and to know structure in the data set (Anderson et al., 2006). Canonical Correspondence Analysis (CCA) shows the relationship amongst the species as linear combinations of environmental variables graphically (Green, 1979). So this

technique interrelates with different types of reciprocal averaging with multiple regression techniques together (Ter Braak, 1986, 1987). Canonical Correspondence Analysis (CCA) is a type of direct gradient analyses which show the difference among vegetation patterns under the influence of environmental variables (Al-Qarawi, 2011).

The purpose of present study is to attain realistic prototypical form of vegetation and its interaction due to location of Eelum hills – a rich floristic zone, its distant peaks inaccessibility and harsh terrain evaluation. It has been planned to evaluate vegetation variability in relation to environmental factors through advanced analytical analyses (CCA, PC-ORD). It is specially intended to quantify the vegetation of the region with various edaphic and physiographic factors to get knowledge about microclimate of each and every plant species. Particularly, present research work carried to find out the indicator species of diverse communities through multivariate analyses and the anthropogenic activities as threat to local flora.

2. Materials and methods

The Swat has always remained self-sufficient in its natural and agricultural resources (DiPietro et al., 1999). The mount Eelum located on southern watershed of the Murghuzar Valley in famous mountain range with altitude of 9273 feet (Altimeter data). It belts a natural boundary between district Swat and Buner. Agriculture is common practice in the outskirts of Mount Eelum, with typical crops of maize (1069 ton), wheat (3.5 metric ton), rice (2.5 ton), onion and Trifolium, while in fruits, the area is dominated by plum, persimmon and pears. The present study was carried out to find the Indicator species, plant communities, species composition, distribution and abundance with a special relation or interaction to edaphic factors and various threats to flora in the Eelum hills Swat, Pakistan. The quantitative ecological techniques (Quadrat methods) were carried out for assessment of plant species and environmental variability. The various transects were placed from lower to higher elevations at regular interval of 100 m. Quadrates having sizes of $2 \times 2 \text{ m}^2$ for herbs, $5 \times 5 \text{ m}^2$ for shrubs and $10 \times 10 \text{ m}^2$ for trees were placed randomly at systematically established stations. For all quadrates phytosociological attributes i.e., density, frequency, cover, relative density, relative frequency, relative cover and importance values (IVs) were recorded. The plant specimens were collected, tagged, and identified using flora of Pakistan and other related literature and then deposited in the Herbarium of Hazara University Mansehra, Pakistan (HUH).

2.1. Environmental data

The Altimeter was used to find elevation of each station, transect as well as geographical coordinates i.e. latitude and

longitude. Aspect variation at each quadrat was observed from sun rise and set using compass and different geographical techniques.

2.2. Soil collection and analyses

The soil sampling tubes were used to collect the soil samples up to a depth of 30 cm from each station. The samples were air dried, grinded for composite sample, sieved through 2 mm screen to remove the stone pieces and large root particles. The soil analyses and physiochemical properties were assessed in the soil science laboratory of Agriculture Research Institute Tarnab, Peshawar. Soil texture, lime concentration, organic matter concentration, phosphorous, potassium, sulfate concentration and pH were measured. Soil textures were determined by hydrometer (Koehler et al., 1984), pH was determined by pH meter (Khan et al., 2012), for lime determination acid neutralization method was used (Thomas, 1982) and standardized solution of FeSO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$ were used for the determination of soil organic matters (Nelson et al., 1996). AB-DTPA extractable P and K was determined in samples through method described by (Soltanpour, 1991) and soil texture was determined by hydrometer method (Koehler et al., 1984), sulfate was determined using the procedure of (Belyea and Lancaster, 1999).

2.3. Data analyses

The obtained data of five Transects and 124 quadrates arranged in MS Excel for further analyses through Cluster analysis and Two Way Cluster analysis based on presence and absence value of plant species. The species data was arranged in row and quadrates in column as per requirement of PC-ORD version 5 software (Lepš and Šmilauer, 2003). CANOCO software version 4.5 was used to find the influence of different environmental variables on species compositions and community formation.

3. Results

A field research conducted in different seasons based on different criteria, advance parameters and a statistical approaches is explained theoretically and diagrammatically as under.

3.1. Species composition with special reference to altitudinal range of Eelum hills

A total of 124 plant species, belonging to 52 families distributed over 25 Transects (372 quadrats) were collected from Eelum hills, including 86 (70%) herbs, 22 (17%) shrubs and 16 (13%) are trees. The topmost leading families were Asteraceae having 20 species followed by Lamiaceae having 13 Species and Poaceae with 10 species individually (Table 1).

3.2. Abundant and less abundant species of the area

The abundance of plant species was assessed through Importance Values Index (IVI) that is explained in the following sub headings.

3.3. Tree layer

In tree layer *Pinus wallichiana*, *Quercus incana*, *Quercus baloot*, *Cedrus deodara*, *Ficus palmata* and *Pyrus pashia* were observed mostly in tree layer of Eelum hills that show highest IVI. The rare species includes *Pistacia integerrima*, *Acer pentapomicum* and *Prunus cornuta* having minimum IVI in the region (Fig. 1).

3.4. Shrub layer

In shrubby layer the most abundant species with high IVI are *Desmodium elegans*, *Zizyphus oxyphylla*, *Berberis lycium*, *Sarcococca saligna*, *Datura stramonium* and *Hedera nepalensis*. Whereas *Clematis orientalis*, *Indigofera heterantha*, *Justicea adhatoda*, *Viburnum grandiflorum* and *Buddleja crispa* was recorded as rare plant species in region (Fig. 2).

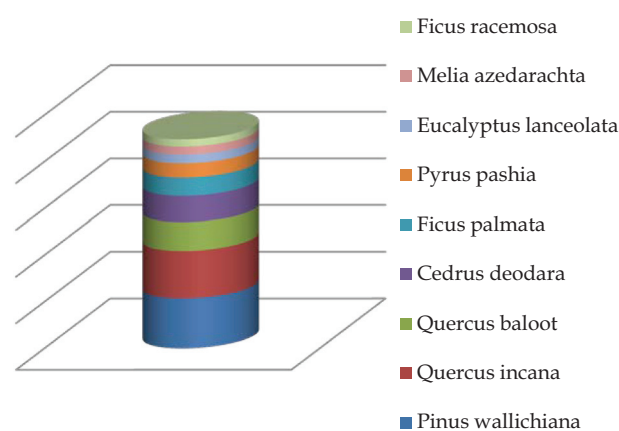


Figure 1 The top 10 abundant tree species with high important value index of the Eelum hills.

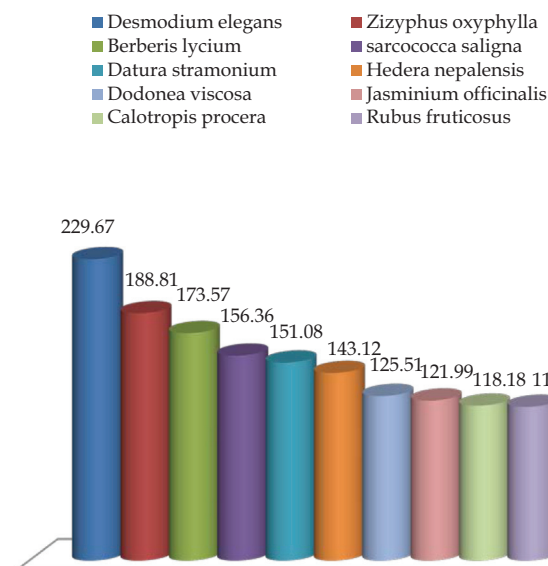


Figure 2 The top 10 most abundant shrubs with high important value index in the region.

3.5. Herb layer

The *Sorghum helepense*, *Solanum xanthocarpum*, *Stachys parviflora*, *Hypericum perforatum*, *Heliotropium strigosum*, *Sedum hispanicum*, *Stellaria media*, *Spirea nipponica*, *Origanum vulgare* and *Imperta cylindrical* are the abundant herb species with highest IVI. The rare herb species recorded with low IVI are *Conyza canadensis*, *Cleoma viscosa*, *Chrysopogon gryllus*, *Calamintha umbrosa* and *Xanthium strumarium* (Fig. 3).

3.6. Plants communities and habitat types

Plant species by origins restricted to specific habitat and be reached in that particular habitat due to the presence of optimum environmental factors. The five different plant communities were determined by using Cluster and Two Way Cluster Analyses through PCORD version 5.

3.7. Result of Cluster analysis

PCORD version 5 clustered five transects (elevation classes) into 5 communities/groups through Cluster Analyses (Fig. 4).

3.8. Two Way Cluster Analyses

The Two Way Cluster Analyses of 5 transect including 124 quadrates resulted 5 various plant communities. In diagram the black boxes show presence whereas the white one show absence of a plant species in the region (Fig. 5).

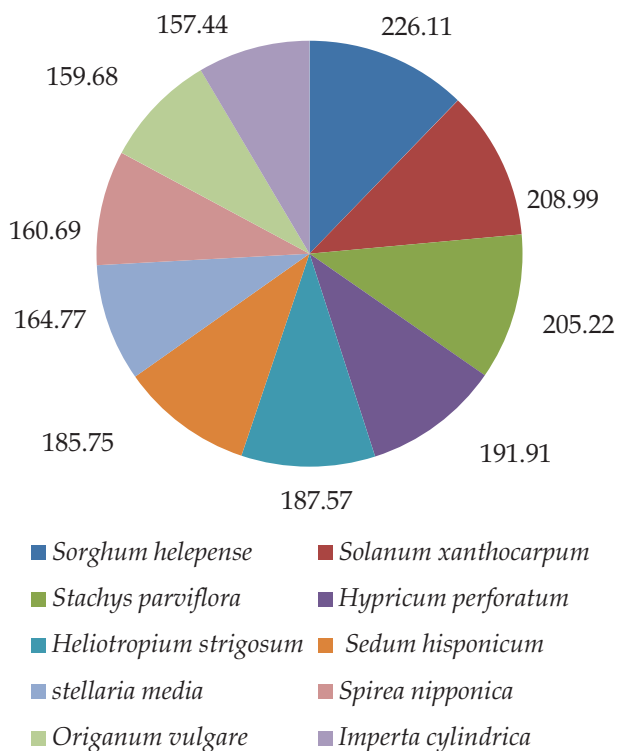


Figure 3 The top ten most dominant herbs with highest IVI of Eelum hill during different seasons.

Indicator species of each plant community were identified through indicator species analyses (ISA). Among all the environmental variables the elevation, organic matter, sand, phosphorous and nitrogen played significant role in the establishment of plant communities of this region. Along with the environmental gradients the five plant communities are described as below

1. *Pinus-Calotropis-Colchicum* community

This community arisen on 35 different stations through Sorenson measures on the Northern aspect at 1500 m to 3900 m elevation at sea level. The *P. wallichiana* A.B. Jackson, *Calotropis procera* (Willd.) R. Brown and *Colchicum luteum* Baker are the characteristics plant species of trees, shrubs and herbs layer respectively. The other dominated tree species included *Q. baloot* and *F. palmata*. While at the same time the rare tree species that were recorded are *Andrachne cardifolia*, *Anaphalis triplinervis* and *C. deodara*. Although the abundant shrubs layer is dominated by *Berberis lycium* and *S. saligna* whereas the rare species documented are *I. heterantha*, *Justicia adhatoda* and *B. crispa* in the region. The herbaceous layer is characterized by *Cyperus glomeratus*, *Polypogon fugax*, *S. xanthocarpum*, *S. parviflora*, *Solidago Canadensis*, *Vicia sativa* however *C. umbrosa* is the rare herbaceous species of the first community.

This community is dominated by *P. wallichiana*, *C. procera* and *C. luteum* have an important value index (IVI) of 27.76, 76.37 and 65.09 respectively. The dominated edaphic factors show great environmental influences in species composition, abundance and its distribution pattern of community.

2. *Pyrus-Berberis-Hypreicum* Community

The community revealed on 28 different stations on the North-Eastern aspect from 1300 to 3900 m. The topmost indicator species of this community are *P. pashia* Buch-ham ex D. Don, *B. lycium* Royle and *H. perforatum* Linn. Other indicator of tree layer is dominated by *C. deodara* and *Q. baloot* whereas *F. palmata* *Litsea deccanensis* and *A. pentapomicum* are rare tree species of community. The *Ziziphus oxyphylla* and *S. saligna* are the dominant while on the other hand *C. procera*, *V. grandiflorum* and *Periploca aphylla* are the rare shrubby species. The herbaceous layer is characterized by *H. strigosum*, *S. helepense*, *Lactuca serriola* and *Scrophularia sachbiosifolia* whereas rare species included in this layer are *Tribulus terrestris*, *X. strumarium*, *Verbascum thapsus* and *Heracleum spirea* in the region.

The described indicators *P. pashia* having 11.37, *B. lyceum* with 50.03 and *Hypricum perforatum* with 71.07 IVI were used for naming the community. The applied statistical analyses of Canonical Correspondence Analyses (CCA) show the impact of various environmental variables i.e., elevation and aspects are the main significant variables in the distribution and composition of this plant community.

3. *Quercus-Desmodium-Heliotropium* Community

Based on Cluster Analysis the 3rd community is established at 9 different stations after Sorenson measures. It can be located on the Northern aspect from 1400 to 3700 m at sea level. The topmost characteristics species are *Q. incana* Roxb,

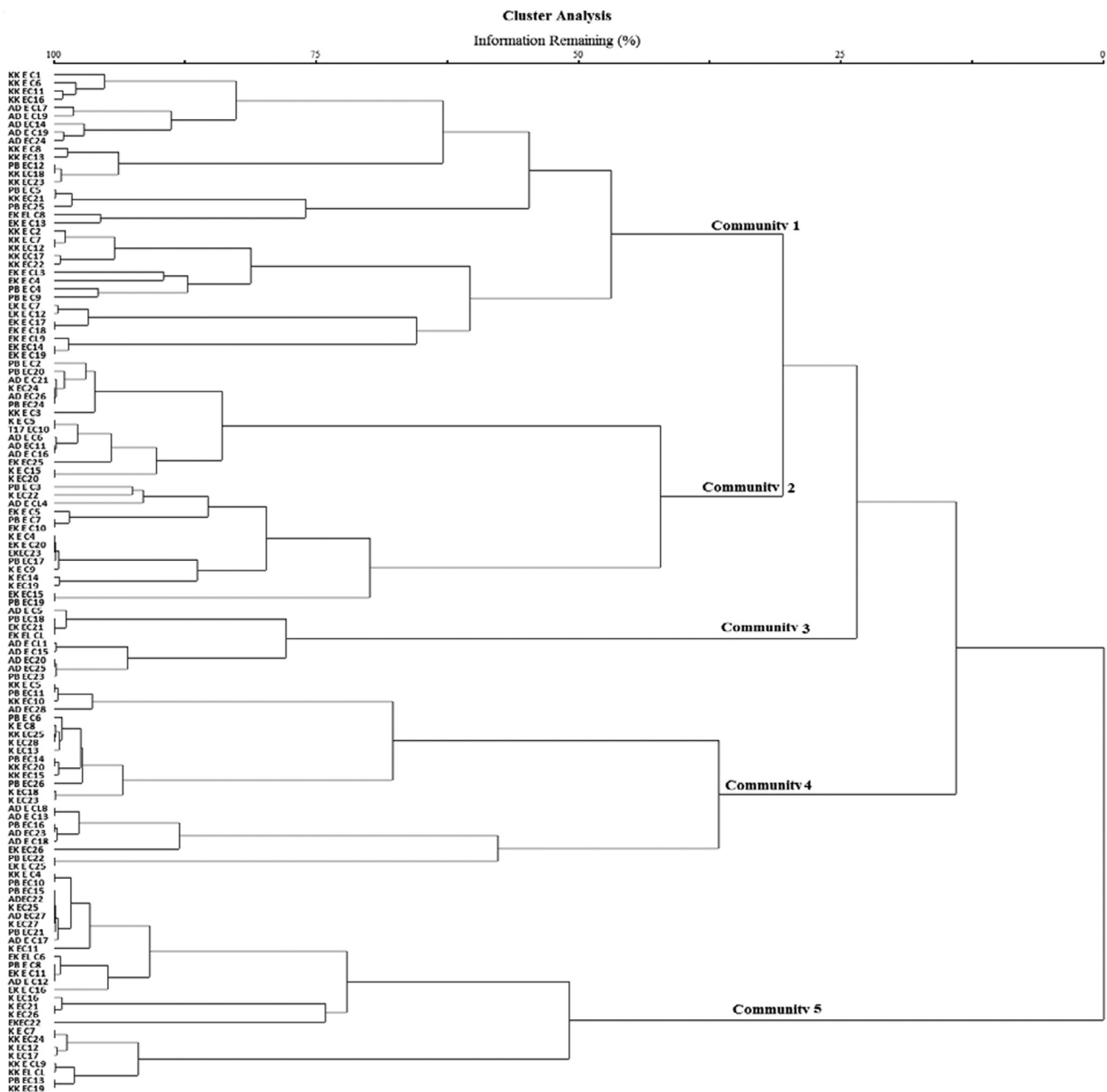


Figure 4 The Cluster dendrogram of 124 different station based on Sorensen measure showing 5 plant communities/habitat types. The grouping of station designated as communities 1, 2, 3, 4 and 5.

D. elegans DC and *H. strigosum* Willd one from each tree, shrub and herb layer respectively. The important value index (IVI) of *Q. incana* is 4.43, *D. elegans* 36.10 and *H. strigosum* with 28.88 were recorded in the region. The other dominated trees are *P. wallichiana* and *Adhatoda vasica*. Whereas the rare tree species recorded are *Q. baloot*, *A. triplinervis* and *C. deodara* with minimum importance values. The dominant shrubs of the community are *D. elegans*, *Ziziphus oxyphylla* and *Rubus fruticosus*. While *V. grandiflorum*, *C. orientalis* and *Justicia adhatoda* are the rare shrub species in community. The other characteristics herbaceous species after *H. strigosum* includes *Amaranthus viridis*, *Ajuga bracteosa*, *H. perforatum* and *L. serriola*. While at the same time *C. viscosa*, *Conyza*

bonariensis, *H. perforatum*, *L. serriola*, *Nepeta laevigata* and *Sedum hispanicum* are the rare herbaceous species with minimum importance values of the region.

This community is also strongly influenced by Elevation and Aspects among the measured environmental variables.

4. *Cedrus – Dodonea – Sorghum* Community

This community comprise of 23 stations at North-southern aspect at altitudinal range of 1200–3600 m. The characteristic species include *C. deodara* (Roxb. Ex Lamb.) G.Don followed by *Q. baloot* and *Q. incana* are the dominated tree species. The rare tree species included *Eucalyptus lanceolata* and

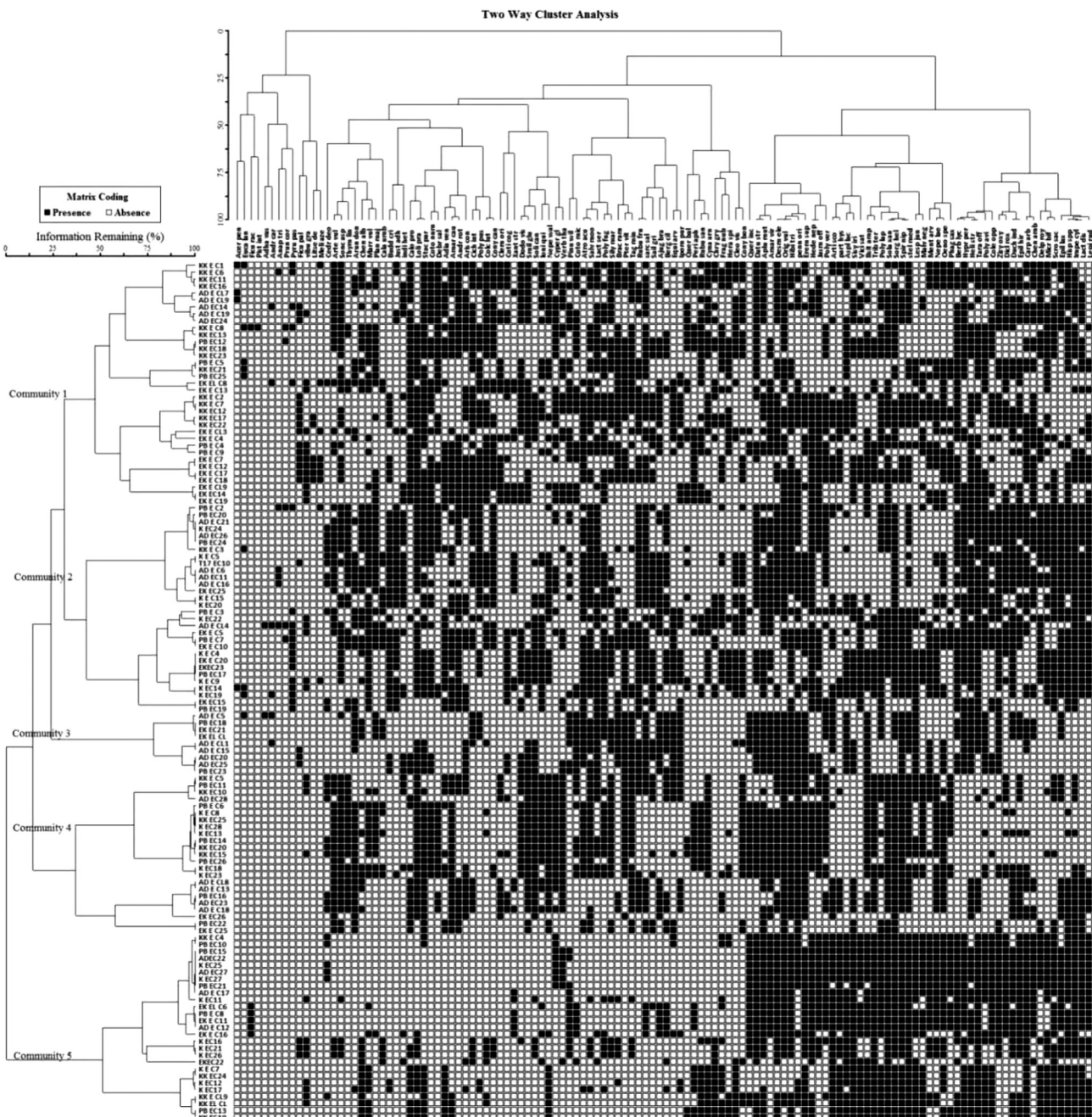


Figure 5 Different stations of 124 plant species based on Sorenson way of measuring show the Two Way Cluster Analysis through PC-ORD.

I. heterantha. The shrub layer has dominated species of *Dodonaea viscosa* followed by *Jasminium officinale* with *Colebrookea oppositifolia* and *Justicia adhatoda* rare species having minimum IVI in the community. The characteristics herbaceous layer is dominated by *Sorghum helepense*, *V. thapsus*, *N. laevigata*, *S. parviflora* and *Pennisetum orientale*. Besides this the rare species noted in community are *Brachiaria ramosa*, *H. spirea*, *C. Canadensis*, *V. sativa* and *Polygonum pusambo*.

The important value index (IVI) of indicator species i.e., *C. deodara*, *Dodonaea viscosa* and *Sorghum helepense* are 10.99, 35.73 and 76.53 respectively.

5. *Quercus – Zizyphus – Sedum* Community

The community includes 27 different stations on south-west aspect ranging from 1500 to 3700 m in the study area. The dominant plants of community in tree, shrub and herb layer are *Q. incana*, *Zizyphus oxyphylla* and *S. hispanicum* respectively. In which tree layer is dominated by *P. wallichiana* and *C. deodara* abundance and rare species are *Melia azedarach*, *E. lanceolata* and *P. pashia*. The characteristics shrub *Zizyphus oxyphylla* is followed by *D. stramonium* with rare Shrubs are *Cotinus coggygria* and *Justicia adhatoda*. The herbaceous layer

after *S. hispanicum* is followed by *Carpesium arbotanoides*, *V. sativa*, *Taraxacum officinale* and *S. xanthocarpum* with rare herbs *Arundo donex*, *Artemisia vulgaris*, *C. umbrosa*, *Smilax glucophylla* and *Thymus linearis*. The characteristic species *Q. incana*, *Zizyphus oxyphylla* and *S. hispanicum* having an important value index (IVI) of 18.34, 72.49 and 81.04 respectively.

4. Environmental gradient

Both the species and various environmental gradient variables data i.e., altitude, aspect, textural class, calcium carbonate, organic matters concentration, nitrogen, phosphors, potassium, pH, electrical Conductivity, silt and rocky soil were analyzed through CANOCO software version 4.5. Analyses show significant effect of all the environmental variables on plant species composition, distribution pattern and abundance of the Eelum Hills. In terms of statistical the significance the value of p ($p \leq 0.048$) shows that the present results are highly significant (Table 1 and Fig. 6).

5. Discussion

A total of 52 plant families were studied in the Eelum hills District Swat during the summer of 2013. It was found that these families show similarities with the vegetation communities of Western Himalayan parts of Malakand, Hazara, Kashmir and Gilgit Baltistan Regions of Pakistan where they reported Asteraceae, Lamiaceae, Rosaceae and Poaceae were the top-most dominant families (Abbas et al., 2016; Abbasi et al., 2013; Khan et al., 2011a; Shaheen et al., 2011).

Plant species by origins restricted to specific habitat and be reached in that particular habitat due to the presence of optimum environmental factors (Soil chemistry, biotic and abiotic factors) which clearly show that plant communities and vegetation composition changes along the environmental diversity from point to point. The five different plant communities were determined by using Two Way Cluster Analysis and Important value index. The identified five plant communities were (i) Community 1 having 35 different stations on North aspect from 1500 m to 3900 m located on Loamy and Sandy soil, dominated by *P. wallichiana*, *C. procera* and *C. luteum* while rare species *A. cardifolia*, *A. triplinervis* and *C. deodara*, *I. heterantha* and *S. canadensis*, containing the lowest quantity in all of the communities 2.9 also with organic matters 0.416 in the presence of clay, silt and sand 3.6%, 20% and 76.8% respectively, in Neutral environment with 0.192 electric

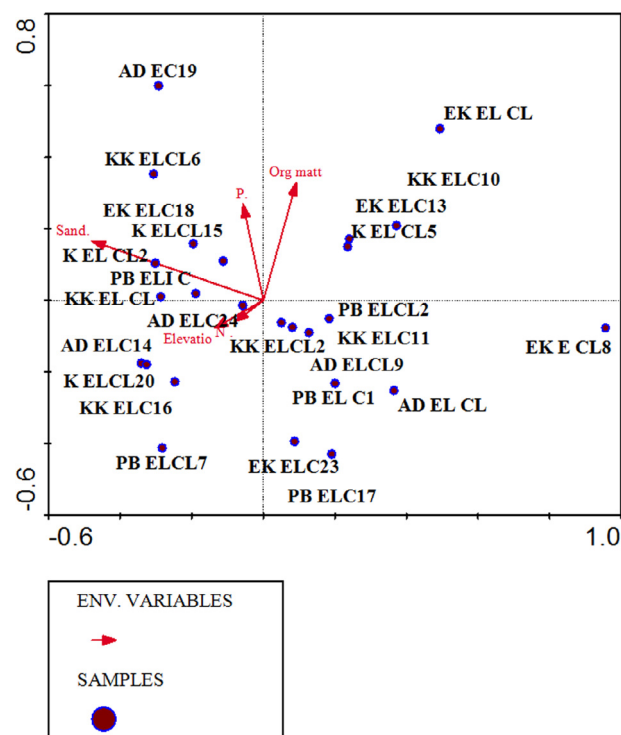


Figure 6 The Canonical Correspondence Analysis (CCA) diagram shows the distribution of 5 plant communities between 5 transects related to various environmental variables.

conductivity. (ii) Community 2 was formed on 28 different stations on North-East aspect from 1300 m to 3900 m. The community is dominated by *P. pashia*, *B. lycium* and *H. perforatum* while the rare species are *F. palmata*, *C. procera* and *X. strumarium*. The community is affected by different environmental variables i.e., CaCO_3 2.8, Nitrogen 0.326, Phosphorus 9.1 and Potassium 80.4 also with clay, silt and sand in ratio 4.6%, 31.2% and 64.4% respectively. (iii) Community 3 is composed of 09 stations on North to East aspect ranging from 1400 m to 3700 m, characterized by dominant vegetation i.e., *Q. incana*, *D. elegans* and *H. strigosum* while the rare plant species here are *Q. baloot*, *V. grandiflorum* and *Nepeta walkers* and bear soluble solutes 0.0582%, Electric conductivity 0.182% and CaCO_3 2% etc. Others variables like soil texture in a ratio of clay 4.6%, silt 26% and sand 84% with some of basic nutrients nitrogen 0.047%, phosphorus 5.54% and potassium 76.2% with neutral PH are also

Table 1 Analyses of all plants and environmental variables through CANOCO software version 4.5.

Axes	1	2	3	4	Total inertia
Eigen values	0.089	0.064	0.057	0.050	1.193
Species-environment correlations	0.890	0.857	0.886	0.883	
Cumulative percentage variance of species data	7.5	12.8	17.6	21.8	
Summary of Monte Carlo test (499 permutations under reduced model)					
Test of significance of first canonical axis	Test of significance of all canonical axes				
Eigen value	0.169	Trace	0.979		
F-ratio	1.169	F-ratio	1.198		
P-value	0.8360	P-value	0.0480		

noteworthy. (iv) Community 4 is composed of 23 different stations on North to southern aspect at 1200 m to 3600 m. Community 4 is dominated by *C. deodara*, *Dodonea viscosa* and *Sorghum helepense* while the rare species in this area are *E. lanceolata*, *C. oppositifolia* and *C. Canadensis*. Soil results show different ratios of different nutrients i.e. CaCO_3 3%, Organic matter 0.0502%, Nitrogen 0.0606%, Phosphorus 4.34% and Potassium 51% in pH 7.48 with texture of clay, silt and sand in a ratio of 4.12%, 20% and 67.164% respectively. (v) Community 5 contain 27 stations and located on South-West aspects from height 1500 m to 3700 m strongly reflect the environmental variables i.e., clay, silt and sand 0.56%, 23.2% and 13.84% respectively. The dominant plant species are *Q. incana*, *Zizyphus oxyphylla* and *S. hispanicum* and the rare are *M. azedarach*, *Justicea adhatoda* and *A. vulgaris*. The others abiotic factors like nitrogen 0.028%, phosphorus 9.96%, potassium 71.6%, CaCO_3 2.45% and organic matter 0.58 with pH 7.6. Shaheen et al. (2011), Khan et al. (2012) (Khan et al., 2012; Shaheen and Shinwari, 2012; Wana, 2002) also reported various communities of plant species in relation to environmental variables. The dominant tree species in the region included *P. wallichiana*, *P. pashia* and *Q. incana* that were also reported in the Naran Valley of western Himalayas by Khan et al. (2011b). The Canonical Correspondence Analysis (CCA) was used to show variation of 124 plant species in 124 quadrates with different microenvironments of 5 plant communities (CCA table). After observation it is analyzed that Elevation, Soil texture (Clay, Silt and Sand), Calcium carbonate, Organic matter, Nitrogen, Phosphorus and Potassium, PH, Electric conductivity (E.C), Total Soluble Solute (TSS) show significant effect on species distribution and composition with *P*-value 0.0480. Such impacts were also being study by numbers of authors in the neighboring habitats of Pakistan. In addition, any change in environmental variables and altitude cause significant effect in formation of communities (Chawla et al., 2008; Khan et al., 2014). This is now the topic of every field scientist to check and study environmental effect to find the pattern of distribution of species in different part of the area (Lomolino, 2001). The present study supplement *P. wallichiana* has a taxonomic hierarchy in the region because of the presence in all strands ranging from 1200 m to 3600 m. *Quercus balaot* was reported from lower ranking 1400 m to 3500 m. *C. deodara* reached up to 3800 m clearly indicates its threatening conservation status. *Quercus* species along with some different herbs (*Chenopodium ambrosioides*, *C. gryllus*, *Cichorium intybus*, *Cleome viscosa*, *C. luteum*, *C. bonariensis*, *C. Canadensis*, *Cynanchum arnottianum*, *C. glomeratus*, *Delphinium roylei*, *Dielliptera roxburghiana*, *Duchesnea indica*, *Epilobium hirsutum*, *Epilobium laxum*, *Equiestum arvense*, *Eremostachys superba*, *Fragaria nubicola* and *H. strigosum*) indicates the similarities of different environmental variables in different part of the Western Himalayan province in general and more specifically in Murree, Hazara and Kashmir in altitude from 1100 m to 2900 m (Khan et al., 2013; Takhtajan, 1986). In present research work the various statistical techniques were used i.e., CCA, DCA, PC-ORD and ISA to assess various environmental effects on plant species and communities distribution which were also used by Khaznadar et al. (2009) and others very extensively for baseline as well as conservation management for future.

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