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Classification and ordination of upland vegetation in a temperate forest at Mukeshpuri Hills, Pakistan

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Abstract

The Himalayas in Pakistan are the mountains, possessing diverse ground and forest vegetation and hence are considered an important site for research in vegetation ecology and biodiversity management. The study was conducted on Mukeshpuri Hills in the Abbottabad District of the Khyber Pakhtunkhwa province in the north of Pakistan. The present research work was conducted from July-August 2017. All the vascular plants present along the transect lying across the altitudinal ranges from 2500 – 2800 m, between 34°03'34.2 N to 34°03'88.9 N and 073°24' 82.5 E to 073°24'92.3 E. During the field survey, a total of 82 species representing 72 genera belonging to 46 families were recorded. The major family was Lamiaceae, followed by Asteraceae, Rosaceae and Fabaceae. The other families contribute a little share in flora. Vegetation data were analyzed by multivariate statistics including cluster analysis, Detrended Correspondence Analysis (DCA) and correlation. The application of classification and the ordination suggested that the altitudinal edaphic factors play an important role in determining the boundaries of the plant communities. From the present study, we can conclude that altitude and soil pH is significantly driving the distribution patterns of vegetation.

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Introduction

In northwestern Pakistan, the Western Himalaya which belongs to earth's highest mountain systems flock together ensures high plant diversity and phytogeographical interests. Pakistani Himalaya extends over a wide range of elevational gradients and supports a high diversity of vegetation. Mukeshpuri Hills lies in the Himalayan wet temperate forest, located near the catchment of DungaGali and Ayubia National Park with an average elevation of 2,800m above the sea level. This region supports temperate forests with varying admixtures of evergreen and deciduous areas of broad-leaved forests. When the snow melts, a diversity of ferns and perennial species of plants are developed in the spring season (Saima *et al.,* 2009; Raja *et al.,* 2014).The conifers with a little admixture of deciduous broad-leaved plant species from a total forest, cover with a good height of 25-45 m. Among the broad-leaved species, *Aesculus indica, Quercus dilatata* and *Populus ciliata* are circum polar in distribution.

Ordination investigations on temperate coniferous forests were attempted on a considerable part of moist temperate regions of Western Himalayas Pakistan. Several types of plant communities have been studied along with various aspects such as species composition, divisor species, altitudinal gradients and distribution pattern. Extensive work has been done to reveal the relationship between floral communities and environmental gradients, emphasizing mainly on bioclimatic factors, particularly precipitation and temperature (Saima *et al.,* 2009; Sharma *et al.,* 2009; Qureshi *et al.,* 2016; Saima *et al.,* 2018; Hashim and Dasti, 2019). These temperate forests are most luxuriant in the Himalayas with the varying scale of coniferous species belonging to family Pinaceae. The Himalayan region, along the altitudinal gradient, exhibited the distinctive flora. The sub-tropical coniferous low-level blue pine (*Pinuswallichiana*) forest is changed by mid-*Cedrusdeodara*and broad-leaved (*Aesculus indica*) zone and upper *Abies pindrow* forests zones. As a timberline zone, this change beside the longitudinal range is characterized through the sub-tropical coniferous alpine development among the alpine grassland ecological unit and temperate forests (Dhar, 2000). These forests are the chief source of timber as fuelwood (Rahman*et al.,* 2017).

The coniferous species generally form a comparatively complete forest having a good height (Hashim and Dasti, 2019). The moist temperate Himalayas is one of the chief ecological zones in Pakistan, deserves definite interest in the protection of atmosphere and vegetation (Raja *et al.,* 2014).

The Himalayas are multifaceted and energetic ecosystems that provide diverse ecosystem services (Khan *et al*., 2012).The latest studies reveal that flora is significantly diverse in the center of the altitudinal gradient (Currie and Francis, 2004; Qureshi *et al.,* 2016). The elevation is the most important factor in determining the species diversity, which powerfully affectsthe growing season. It also related to temperature, soil saturation and the availability of soil nutrients (Soethe *et al.,* 2008). The greater part of the research is done on the temperate and tropical regions (Aiba and Kitayama, 2002; Shahbaz *et al*., 2007; Ahmad, 2012; Khan *et al.,* 2017; Bashir *et al.,* 2018; Akhlaq *et al.,* 2018). Little information about high alpine forest ecosystems has been acknowledged (Siddiqui *et al*., 1999; Shahbaz *et al*., 2007; Nizami *et al.,* 2009; Ismail *et al.,* 2018). Minimization of species richness is due to latitudinal variations, which has been explained through monotonic associations with atmospheric variations (Currie, 1991; Wright *et al*., 1993; Austin *et al*., 1996; Grytnes *et al.,* 1999).

The longitudinal resemblance in species diversity is generally considered to takeoff latitudinal distinction in species diversity (Begon *et al*., 1990; Brown and Lomolino, 1998).

Species richness shows a significant ecological variation (Von Humboldt, 1855; Wallace, 1878; Butt *et al.,* 2015; Bashir and Ahmad, 2017, 2018). Besides the altitudinal gradients various groups of floristic species have been recognized, which has a great deviation in diversity (Yoda, 1967; Hamilton, 1975;

Kessler, 2000; Ohlemuller and Wilson, 2000; Sanchez-Cordero, 2001; Kessler, 2002; Hemp, 2002; Vetaas and Grytnes, 2002). Several climatic factors along the altitudinal gradients are used to explain the divergence of species diversity (Ahmad, 2012; Zhang *et al.,* 2016; Khan *et al.,* 2017; Bashir *et al.,* 2018; Akhlaq *et al.,* 2018; Saima *et al.,* 2018).

Edaphic parameters powerfully influenced plant growth (Chawla *et al.,* 2008; Taghizadeh-Mehrjardi *et al.*, 2014; Khan *et al.,* 2015). Soil properties have been affected the community composition at diverse levels of salinity (Abadi and El-Sheikh, 2002), organic matter, and soil nutrients (Lal, 2005, 2009; Khan *et al.,* 2017). Minimum species richness has been observed in the soil where high pH observed (Saima *et al.,* 2009). The community composition and species richness is encountered by variation in soil chemical properties, available soils soluble cation and anions (Shaukat *et al.,* 1981). Elevation, aspects and slope are three major geo-climatic parameters affecting on soil properties and diversity in vegetation (Jafari *et al.*, 2004). The effects of geo-climatic factors on plant community composition can be determined by using statistical and multivariate analysis software programs that support ecologists to establish the data for different analyses (Anderson *et al.*, 2006, Saima *et al.,* 2018).

Statistical analysis minimizes the density of data by classifying plant species and then correlated with environmental variables (Chawla *et al.,* 2008; Khan *et al.,* 2015). Classification also decreases the difficulty of comprehension by summarizing field survey data in low-dimensional gaps (Malik ans Hussain, 2006, 2008; Wazir *et al.,* 2008; Saima *et al.,* 2009; Greig-Smith, 2010). Ordination and taxonomy are operational practices for multivariate analyses of community structure in vegetation ecology (Zhang, 2004; Ahmad and Quratulann, 2011). Cluster analysis is a categorization technique, which is used to classifying the biological communities and then change into associations (Amjad *et al.*, 2014). DCA (Detrended Correspondence Analysis) applies to focus on the analysis of distribution patterns of herbaceous vegetation (He *et al.*, 2007; Khan *et al.*, 2015a). This technique gives the best results without alteration as simple species data configuration, which are essential for DCA axes analysis.

In distinction, CCA (Canonical Correspondence Analysis) is a direct ascent analysis technique, which controlled the geographical distribution pattern of plant species by ecological factors and to resolve relations between them (Basnou *et al.*, 2009; Ahmad *et al.*, 2014; Urooj *et al.*, 2015, 2016).

These techniques are mainly cooperative in the classification of syntaxa and their ecological analysis (Amjad *et al.*, 2014; Barbacka *et al.*, 2015).

Ecologists try to recognize the multifarious variations in species diversity and assemblagealong the elevational gradient in the mountainous ecosystem by using the variousnumerical techniques to decrease the difficulty of the field data set (Moser *et al.,* 2008; Bhattarai *et al.,* 2014).

The use of multivariate systems such as gradient analysishas been unusual applied to the vegetation data in wide-ranging (Dasti *et al.,* 2007; Malik and Hussain, 2008; Wazir *et al.,* 2008; Saima *et al.,* 2009). Many studies have explored the changes in species diversity and soil available nutrients along elevational gradients by using numerical techniques (Henrik *et al.,* 2006; Chawla *et al.,* 2008; Ping *et al.,* 2013; Karami *et al.,* 2015; Zhang *et al.,* 2016; Saima *et al.,* 2018; Hashim and Dasti, 2019).

Present research work shows a correlation between herbaceous vegetation and atmospheric variables in a variety of forest. Previously there is little information about species composition and their reaction with a complex environment gradient. Recently ecologists have introduced modern techniques for classification and ordination of presence/absence data obtained during field survey as well to interpret these classification results with environmental variables (TerBraak, 1987; Chawla *et al.,* 2008; Khan *et al.,* 2015, 2016). With the help of direct gradient analysis, it gives information about the natural environmental ecosystem and plant communities.

The main aims of the present investigation are:
To establish the plant associations and the nature of the vegetation either continuous or discrete.
To understand the hazy nature of boundaries between the plant communities.
To identify the environmental factor of overriding importance in determining the nature of plant communities in these landscapes.
To elucidate the factors which determine the distribution of species.

Materials and methods

Study area

The study area was located in a typical moist temperate forest dominated with *Abies pindrow* along with a few broad-leaved species. Among the broad-leaved species *Acer caesium, Aesculus indica* and *Quercus dilatata* were prominent. The area is part of Himalayan mountain forests extending along with the altitude from 2,500 - 2,800 m between 34°03'34.2 N to 34°03'88.9 N and 073°24' 82.5 E to 073°24'92.3 E. It is 90 kilometers north of Islamabad, just above Donga Gali catchment near Ayubia National Park, Khyber Pakhtunkhwa (Fig. 1).

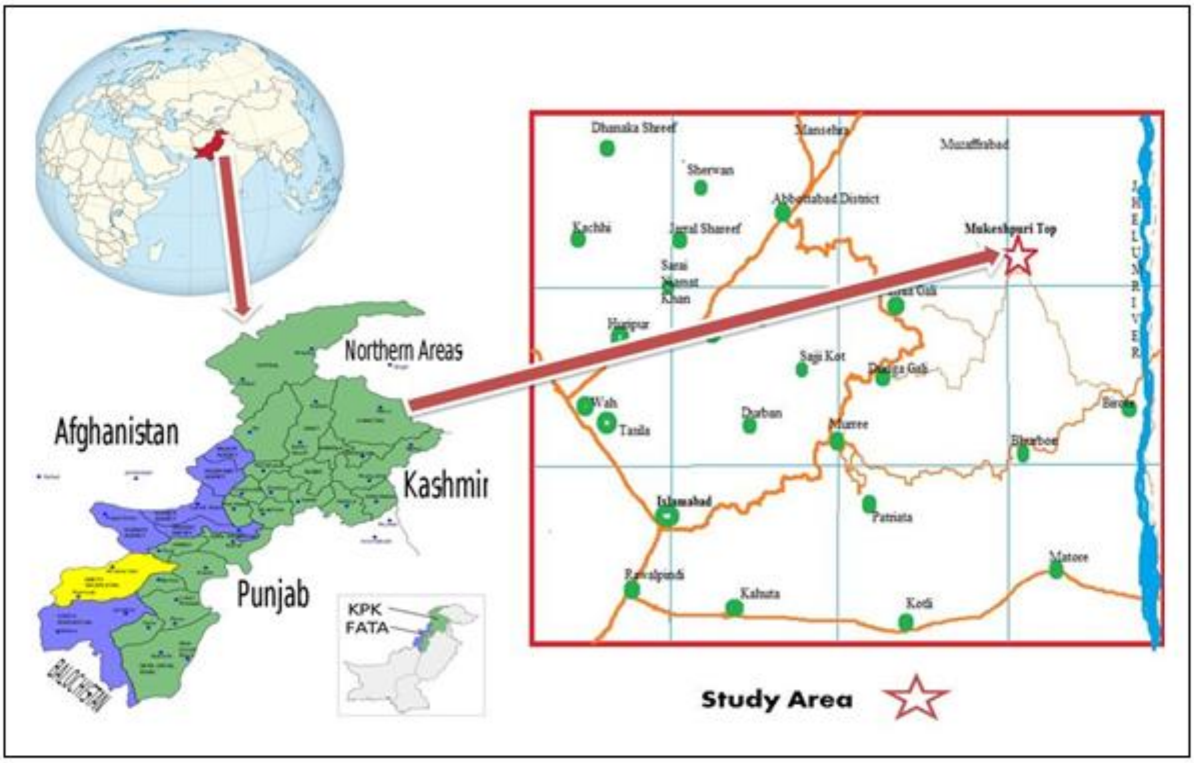

Fig. 1. Map of Study Area showing sampling sites.

Climate

The altitudinal ranges under investigation encompass lower temperate forests to high elevation subalpine conifer forests with broken canopy.

The topography of the area is mosaic of rolling hills with rock outcrops, wetland and snow-covered peaks. The weathering bad rocks that provided the bulk of loose material in these mountains are crystalline and metamorphic. There are significant climatic variations around the whole year. According to Köppon and Geiger classification, the climate of the study area is classified asCfbtype. The minimum values (-2.0) recorded for temperature in winter months (Fig. 2). An appreciate the amount of snowfall is enough for soil moisture during the summer months. They accumulated snow by its gradual melting in the early summer which sufficient moisture to permits the development of canopied forests. The average winter accumulation of snow is about 700cm (Champion *et al.,* 1965). The average rainfall is 750- 1800 mm; besides this, the area received precipitation from the south-west monsoon (Fig. 3). Throughout the area, most of the rainfall is received from July to August, while May, June, September and October are the driest. Annual rainfall accumulation, variation in temperature and humidity are the major climatic factors control the shaping of plant communities (Fig. 3).

Vegetation and Soil sampling

The comprehensive survey was done during the monsoon months (2017) because the vegetation was in full bloom and most of the species were in the flowering stage. In the study area, possibly all vascular plant species growing in study sites were collected, identified and listed. In many cases where plants were not identified in the field, vouchers were collected.

All the specimens collected very carefully with full structure. Identified plants were classified into major taxonomic groups: angiosperms, monocotyledons and dicotyledonous, ferns and gymnosperms. All the plant species were assigned their taxonomic families according to Flora of Pakistan and arranged alphabetically.

The plant material was preserved using standard herbarium techniques. A four-kilometer long transect was laid down along the elevation gradient from 2500 to 2800 m to encompass the entire vegetation variations expected along the elevation gradient. Every segment of 100 m of the main transect was marked. At each point, five 1 m^2 plots were used for recording the presence absence of ground vegetation species. While recording shrubs, we used a square of an area of 4 x 4 m. Trees were recorded by using a large quadrate of 10 x 10 m size.

The data obtained from replicated plots were pooled to a sampling stand. A total of 40 stands were monitored and used for vegetation analysis. The direction of the transect was from the south to the north. All the plots were demarked within an estimated 2.0 m to the left side of the transect (Fig. 4). During the survey, 82 plant species were noted.

Data analysis

Species and stand data matrix were used for numerical analysis. Presence/absence data were used for calculating the absolute and relative values of species occurrence. The floristic data obtained from field work (82 species × 40 stands) was used for multivariate analysis. Species diversity and richness indices were determined. The diversity indices (H') analysis showed values ranging from 1.98 to 2.53 and the evenness index (J) e ranging between 0 and 1. The highest scores of diversity indicate high diversity (Saima *et al.,* 2018). For association analysis of sites and species, cluster analysis (MVSP) was used on the presence/absence data of species. The method is based on the divisor species and is a fast and resourceful way to obtain the initial clustering of the 40 samples (Fig.7). Species frequency values were ordinated by Detrended Correspondence Analysis (DCA) using the program DECORANA. The ordination axes 1 & 2 were used for data elucidation. For both ordination and classification, a software program MVSP (Version 3.2-2018) software window 2007 was used. Spearman's rank correlation statistic default option was used to check the significance difference between communities, edaphic and climatic parameters. Ordination axes 1 and 2 were used for this purpose. ANOVA was used to realize the differences between soil parameters in each association. One way analysis of variance was preferably used in the present investigations. In the field from each stand, soil samples were collected during vegetation sampling. The sample was collected from 0-20 cm depth, dried, sieved, and stored for physio-chemical characteristics. The soil samples were passing from a 2.00 mm sieve to eliminate the stone. Four subsamples were taken from the sieved soil and used for chemical analysis. Laboratory manuals were used to standardize the analysis techniques for soil cation and anions. Soil samples were placed in an oven at 105℃ and dried to a constant weight.Soil pH of all samples was measured by using digital pH meter (Noor and Khatoon, 2013). The extract was prepared then used for analysis (1: 2, soil sample: distill water slurry). Soil E.C (1: 2, soil sample: distill water slurry) was determined by using control dynamic Digital AGB (1000) conductivity reading meter. Organic matter was determined by using standard procedure purposed by Jackson (1958).Available total nitrogen content in soil samples was resolute by Kjeldhal method (Bremner, 1965). To determine Calcium & Magnesium (Ca^{++}& Mg^{++}), an extract of soil samples were prepared and a volume of 10 ml was taken from the extract. A small number of drops of erichrome black T were poured added then titrated (Richard, 1954). The available soil cations (Na^{+}) / Potassium (K^{+}) were measured with the help of Microprocessor Flame (Model-1385, Autogas cutoff- 2018) following Qasba *et al.,* (2017). Olsen's procedure (1954) was applied for the determination of the available amount of Phosphorous in soil. The available anions (Cl^{-}) in soil were determined by titration methods (Saima *et al.,* 2018). Soil carbonates and bicarbonates were determined by methods proposed by Richard, (1954).

Results

Floristic composition

In the present research work, 82 plant species belonging to 72 genera and 46 families were recorded from the study area. Among the life form spectrum, herbs contributed the major share (68 %) followed by shrubs (16%) and trees (11%) (Fig.5).

The important trees are *Abies pindrow, Aesculus indica, Acer caesium, Cedrus deodara, Pinus wallichiana, Populus ciliata* and *Quercus dilatata*. Angiosperms contributed a major share while Pteridophytes and Gymnosperms contributed little to the floristic richness of the area (Table 1).

Table 1. Proportion (%) of family, genera and species.

Groups		Family (%)	Genera (%)	Species (%)
Angiosperm	Monocot	13	8	8
	Dicot	78	83	85
Gymnosperm		2	4	4
Pteridophytes		6	4	4

Pteridophytes included three families (Adiantaceae, Dryopteridaceae and Pteridaceae), while Gymnosperm was present with only one family (Pinaceae) with three species. Among the angiosperm monocotyledonous with six families contributed 13 % of the total floristic. Dicotyledonous with 36 families contributed 78% to the floristic richness of the area.

Major vegetation groups and environmental variability

Classification and Ordination

Three main plant communities were identified by the Normal Cluster Analysis. The stands belonging to each association are given in Table 2.

Table 2. Detail of sampling stands in each plant community type.

Associations	No. of stand	List of stand
Association A (2500 - 2600 m)	11	9,11,12,13,14,15,16,17,18,19,23.
Association B (2600 - 2700 m)	16	1,2,3,4,5,6,7,8,10,20,21,22,24,25,31,34.
Association C (2700 - 2800 m)	13	26,27,28,29,30,32,33,35,36,37,38,39,40.

The hierarchical diagram is shown in Fig.6. At the first level of division the eleven samples belonging to low altitude (Association A, 2500 to 2600 m, a.s.l.) were separated from those located at high altitude by having *Aesculus indica, Acer caesium, Androsace rotundifolia, Aquilegia pubiflora, Bergenia ciliata, Carex nubigena, Clematis montana, Dioscorea deltoidea, Galium aparine, Indigofera gerardiana, Lonicera webbiana, Parnassia nubicola, Parrotia jacquemontiana, Populus ciliata, Primula involcrata, Scrophularia frutescense* and *Trigonella emodi* altogether absent from the rest.

Table 3. The relative frequency of the species in each community type.

Species	Association A	Association B	Association C
	Trees		
Abies pindrow Royle.	6.94	6.83	1.02
Acer caesium Wall.	1.39	••	••
Aesculus indica Wall.	2.78	••	••
Pinus wallichiana A.B.Jackson.	2.08	2.48	••
Populus ciliata Wall.	0.69	••	••
Quercus dilatata Lindley.	••	0.62	••
	Shrubs		
Aquilegia pubiflora Wall.	2.08	••	••
Cotoneaster affinis Lindley.	3.47	0.62	6.12
Indigofera gerardiana Wall.	2.78	••	••
Lonicera webbiana Wall.	0.69	••	••
Parrotia jacquemontiana Decne.	0.69	••	••
Rosa macrophylla Lindley.	2.08	••	1.02
Rubus fruticosus Linnaeus.	••	0.62	1.02
Skimmia laureola DC.	••	••	1.02
Strobilanthes attenuata Nees.	4.17	4.35	2.04
Viburnum grandiflorum Wall.	1.39	6.21	8.16
	Ferns		
Adiantum venustum D.Don.	1.39	9.94	••
Dryopteris ramosa Hope.	0.69	4.97	2.04
Onychium contiguum Wall.	5.56	1.24	1.02
	Climbers		
Clematis montana Buch.	0.69	••	••
Dioscorea deltoidea Wall.	1.39	••	••
*Hedera nepalensis*K.Koch.	••	4.35	••
	Herbs		
Alliaria petiolata Cavara.	1.39	3.73	1.02
Androsace rotundifolia Hardwicke.	3.47	••	••
Arisaema wallichianum Hooker.	2.08	3.11	4.08
Bergenia ciliata Sternb.	0.69	••	••
Capsella bursa-pastoris Linnaeus.	••	0.62	2.04
Carduus nutans Linnaeus.	••	0.62	1.02
Carex nubigena D.Don.	0.69	••	••
Conyza japonica Less.	••	0.62	5.1
Euphorbia wallichii Hooker.	4.86	0.62	1.02
Fragaria indica Andrews.	4.17	4.97	11.22
Galium aparine Linnaeus.	2.08	••	••
Geranium rotundifolium Linnaeus.	2.78	2.48	1.02
Geranium wallichianum D.Don.	1.39	0.62	1.02
Impatiens bicolor Royle.	3.47	4.97	••

Impatiens brachycentra Kar&Kir.	2.08	1.86	••
Malva neglecta Wall.	••	0.62	••
*Micromeria biflora*Buch.	••	1.24	4.08
Nepeta erecta Royle.	••	••	1.02
Paeonia emodi Wall.	2.08	6.83	2.04
Parnassia nubicola Wall.	2.08	••	••
Pilea umbrosa Blume.	••	0.62	••
Plantago major Linnaeus.	2.78	1.24	••
Poa alpine Linnaeus.	2.78	3.73	5.1
Polygonatum multiflorum Linnaeus.	1.39	0.62	••
Polygonum aviculare Linnaeus.	1.39	••	1.02
*Potentilla nepalensis*Hooker	••	1.86	7.14
Primula involcrata Wall.	0.69	••	••
Prunella vulgaris Linnaeus.	••	1.24	3.06
Ranunculus sceleratus Linnaeus.	2.78	2.48	2.04
Rumex nepalensis Spreng.	1.39	••	2.04
Salvia nubicola Wall.	••	2.48	••
Scrophularia frutescense Bentham.	0.69	••	••
Senecio chrysanthemoides DC.	1.39	••	1.02
Stachys emodi Hedge.	2.78	0.62	••
Taraxacum officinale Weber.	••	••	1.02
Trifolium repens Linnaeus.	0.69	1.24	11.22
Trigonella emodi B.Royle.	1.39	••	••
Urtica dioica Linnaeus.	1.39	0.62	••
Viola biflora Wall.	4.17	6.21	8.16
Wulfenia amherstiana Wall.	••	1.86	••

*The data for *Ajuga parviflora, Arisaema jacquemontii, Aster falconeri, Berberis aristata, Cedrus deodara, Cirsium horridulum, Epilobium parviflorum, Jasminum humile, Medicago falcata, Mentha longifolia, Oxalis corniculata, Oxalis latifolia, Plantago lanceolata, Polygonum caespitosum, Potentilla atrosanguinea, Ranunculus abortivus, Rosa webbiana, Salvia moorcroftiana, Satyrium nepalense* and *Sedum ewersii* were not sufficient to include in the analysis.

On the second level of the division, samples belonging to the (Association B, 2600-2700 m, a.s.l.) were separated from the rest by having *Hedera nepalensis, Malva neglecta, Pilea umbrosa, Quercus dilatata, Salvia nubicola* and *Wulfenia amherstiana* were absent from the other associations. On the third level of division, the stands which were located at high altitude (Association C, 2700-2800 m, a.s.l.) were separated by Normal cluster analysis by having *Nepeta erecta, Skimmia laureola* and *Taraxacum officinale,* which were altogether absent from the rest. These results suggested the importance of altitude in shaping the plant communities along the altitudinal gradient. The diagnostic/divisive species for each community type are given in Table 3.

Association A (Abiespindrow-Euphorbia wallichii)

This community was distributed from 2500 - 2600 m (a.s.l.). This association was characterized by having *Aesculus indica, Acer caesium, Androsace rotundifolia, Aquilegia pubiflora, Bergenia ciliata, Carex nubigena, Clematis montana, Dioscorea deltoidea, Galium aparine, Indigofera gerardiana, Lonicera webbiana, Parnassia nubicola, Parrotia* *jacquemontiana, Populus ciliata, Primula involcrata, Scrophularia frutescense* and *Trigonella emodi*, which were altogether absent from other community types (Table 3). This association consists of herbaceous species such as *Euphorbia wallichii, Geranium rotundifolium, Geranium wallichianum, Plantago major, Polygonumaviculare, Polygonatummultiflorum, Ranunculus sceleratus, Senecio chrysanthemoides, Stachys emodi* and *Urtica dioica,* which were frequent in the study area (Table 3). *Arisaema wallichianum, Fragaria indica, Impatiens bicolor, Poa alpine, Rumex nepalensis, Trifolium repens* and *Viola biflora* were rare species.

Among the perennial shrubs, *Rosa macrophylla* was dominant. *Strobilanthes attenuata* and *Viburnum grandiflorum* were frequent while *Cotoneaster affinis* was rare in this association. In the tree strata *Abies pindrow* was dominant, while *Pinus wallichiana* was rare trees (Table 3).

Table 4. Mean values ± standard deviation and F Values for all soil variables for the three communities identified by the Normal Cluster Analysis. Differences between groups were assessed by Duncan's multiple range test.

Parameters		Associations			F-values
		A	B	C	
Altitude, m	Mean	2577.3	2689.6	2780.5	24.87
	SD	28.0	77.5	33.5	
No. of species	Mean	13.36	10.25	9.77	7.58
	SD	3.33	1.95	2.09	
Soil Reactions, pH	Mean	7.26	7.23	6.91	9.00
	SD	0.07	0.20	0.33	
Electrical Conductivity, dSm-1	Mean	0.27	2.12	1.51	8.07
	SD	0.27	0.44	0.53	
Organic Matter, %	Mean	2.03	1.91	2.05	1.18
	SD	0.27	0.34	0.02	
Nitrogen, %	Mean	0.13	0.13	0.13	0.99
	SD	0.01	0.06	0.00	
Phosphorous, ppm	Mean	0.22	0.24	0.23	2.32
	SD	0.03	0.03	0.01	
Potassium, ppm	Mean	1.40	1.33	1.50	4.59
	SD	0.15	0.15	0.15	
Soil Saturation, %	Mean	50.77	51.96	49.78	3.12
	SD	2.59	2.97	0.68	
Calcium, ppm	Mean	0.52	0.53	0.52	0.59
	SD	0.06	0.48	0.02	
Magnesium, ppm	Mean	0.24	0.23	0.21	1.52
	SD	0.05	0.05	0.02	
Sodium, ppm	Mean	0.43	0.42	0.39	2.83
	SD	0.04	0.04	0.03	
Chlorides, $meql^{-1}$	Mean	0.40	0.43	0.40	3.72
	SD	0.02	0.07	0.01	
Carbonates, $meql^{-1}$	Mean	2.35	2.58	2.33	1.88
	SD	2.35	0.52	0.03	
Bicarbonates, $meql^{-1}$	Mean	44.33	50.73	59.03	3.61
	SD	12.64	17.20	7.50	

The soil of this community showed slightly alkaline (pH >7) with low electrical conductivity (0.27 dS/m). Phosphorous, Bicarbonates, Chlorides, organic matter, total available soluble Nitrogen and Potassium was relatively in low concentrations compared to the other associations (Table 4). However, ANOVA detected a significant difference in soil pH which was significantly higher than that of association C but did not differ from pH of association B.

Table 5. Eigenvalue and Cumulative percentage of DCA Axes 1-4.

Axes	Eigenvalue	Percentage	Cum.Percentage
1	0.487	10.002	10.002
2	0.391	8.038	18.040
3	0.353	7.243	25.283
4	0.312	6.408	31.690

Association B (Impatiens bicolor~Paeoniaemodi)

This association was distributed from 2600 - 2700 m (a.s.l.) and was characterized by having *Hedera nepalensis, Malva neglecta, Pilea umbrosa, Quercus dilatata, Salvia nubicola* and *Wulfenia amherstiana,* which were altogether absent from other community types (Table 3). This association consists of herbaceous species such as *Alliaria petiolata, Impatiens bicolor* and *Paeonia emodi,* which were dominant in the study area. *Arisaema wallichianum, Fragaria indica, Geranium wallichiana, Poa alpine,Hedera nepalensis, Malva neglecta, Pilea umbrosa, Quercus dilatata, Salvia nubicola, Wulfenia amherstiana, Ranunculus sceleratus, Trifolium repens* and *Viola biflora* were frequent, while *Carduus nutans, Capsella bursa-pastoris, Conyza japonica, Euphorbia wallichii, Geranium wallichianum, Impatiens brachycentra, Micromeria biflora, Plantago major, Polygonatum multiflorum, Potentilla nepalensis, Prunella vulgaris, Stachys emodi* and *Urtica dioica* were rare species.

Among the perennial shrubs, *Strobilanthes attenuata* was dominant. *Viburnum grandiflorum* was frequent while *Cotoneaster affinis* and *Rubus fruticosus* were rare in this association.

Table 6. Correlation coefficients between axes values of DCA scores and Soil parameters and altitude.

Parameters	Axes 1		Axes 2	
	Coefficient	Significance	Coefficient	Significance
Altitude, m, a.s.l.	0.580	***	0.466	**
	0.000		0.002	
No. of species	-0.456	**	0.137	NS
	0.003		0.398	
Soil pH	-0.432	**	-0.339	*
	0.005		0.033	
Electrical Conductivity, dSm-1	-0.402	*	-0.351	*
	0.010		0.026	
Organic Matter, %	0.079	NS	0.152	NS
	0.629		0.349	
Nitrogen, %	-0.006	NS	0.190	NS
	0.969		0.240	
Phosphorous, ppm	0.058	NS	-0.184	NS
	0.723		0.256	
Potassium, ppm	0.183	NS	0.350	*
	0.258		0.027	
Soil Saturation, %	-0.195	NS	-0.322	*
	0.227		0.043	
Calcium, ppm	-0.004	NS	-0.289	*
	0.982		0.070	
Magnesium, ppm	-0.231	NS	0.062	NS
	0.152		0.705	
Sodium, ppm	-0.329	NS	-0.303	*
	0.038		0.057	
Chlorides, $meql^{-1}$	-0.011	NS	-0.501	**
	0.946		0.001	
Carbonates, $meql^{-1}$	-0.054	NS	-0.179	NS
	0.742		0.269	
Bicarbonates, $meql^{-1}$	0.399	*	0.032	NS
	0.011		0.844	

Significance indicated as *P< 0.01, **P< 0.001, ***P< 0.000.

In the tree strata *Abies pindrow* and *Pinus wallichiana* were common trees. Among the ferns *Adiantum venustum, Dryopteris ramosa* and *Onychium contiguum* were commonly found on moist shady rocky slopes (Table 3). The soil of this association was also slightly alkaline with the mean value of pH above 7 with high electrical conductivity (2.12 dS/m). The soil was rich in available total Phosphorous, Bicarbonates and Chlorides, while organic matter total Nitrogen and Potassium were relatively in low concentrations compared to the other associations (Table 4). However, ANOVA detected a significant difference in soil pH which was significantly higher than that of association C but did not differ from pH of association A.

The vegetation communities are describedbriefly below in the context of major discriminating species.

Table 7. Species Richness and Diversity indices: SR= Species Richness; H′ = Shannon Wiener Diversity Index; D' = Simpson Index, B'= Brillion Diversity index obtained from three associations type located at various elevations.

Associations	B'	H'	D'	SR
Association A (2500 - 2600 m, a.s.l.)	1.71	2.53	0.92	13.09
Association B (2600 - 2700 m, a.s.l.)	1.50	2.29	0.90	10.06
Association C (2700 - 2800 m, a.s.l.)	1.25	1.98	0.86	8.93

Association C (Fragaria indica-Trifoliumrepens)

This association was distributed from 2700 - 2800 m (a.s.l.) and showed minimum species diversity as compared to other associations.

This association is characterized by having *Nepeta erecta, Skimmia laureola* and *Taraxacum officinale,* which were altogether absent in other communities. This association consists of herbaceous species such as *Arisaema wallichianum*, *Capsella bursa-pastoris, Carduus nutans, Conyza japonica, Fragaria indica, Micromeria biflora, Poa alpine, Potentilla nepalensis, Prunella vulgaris, Rumex nepalensis, Trifolium repens* and *Viola biflora* were dominant in the study area. *Geranium wallichiana* was occasional, while *Alliaria petiolata, Geranium rotundifolium, Paeonia emodi, Polygonum aviculare, Ranunculus sceleratus* and *Senecio chrysanthemoides* were rare species. Among the perennial shrubs, *Cotoneaster affinis, Rubus fruticosus* and *Viburnum grandiflorum* were dominant, while *Rosa macrophylla* and *Strobilanthes attenuata* were rare in this association. In the tree strata, *Abies pindrow* was a very common tree in this association. *Dryopteris ramosa* and *Onychium contiguum* were commonly found on moist shady rocky slopes (Table 3).The soil of this community is slightly acidic with the mean value of pH below 7 with high Bicarbonates (59.03ppm). The soil was rich in available total organic matter and Potassium, while Carbonates, Sodium, Magnesium, total Nitrogen and soil saturation were relatively low in concentrations compared to the other associations (Table 4). However, ANOVA detected a significant difference in soil pH which was significantly lower than that of associations B and A.

Plant distribution

Ordination

Detrended Correspondence Analysis (DCA) was performed (TerBraak, 1987). The species which have very rare occurrence in the study area were down-weighted. The result showed that eigenvalues of axes 1 and 2 were most important (0.487 and 0.391) and explained the variations in distribution patterns of communities (Table 5).

The hierarchical diagram of the cluster obtained from cluster analysis and ordination analysis overlay of sampling stands suggested the similarities between the two procedures of data interpretation. The elevation gradient is a major factor that controls the variation in the floristic composition of the area under observation. The results were confirmed by Pearson's

Rank Correlation with the ordination score of axis 1 and axis 2. They showed that there was a highly significant positive correlation(r = 0.580) between the altitude and scores of axis 1 (Table 6), this suggests that along axis 1 the elevation gradient is increasing.

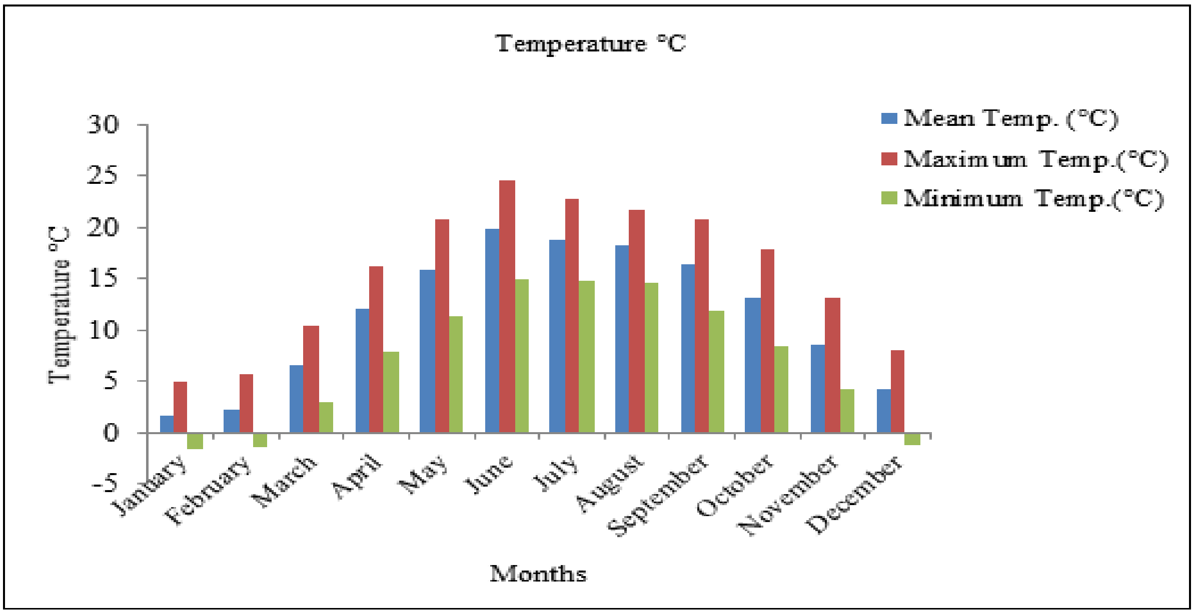

Fig. 2. Average annual temperature (°C) at Mukeshpuri Hills.

Diversity and Floristic Richness

Different indices of species richness and diversity were calculated by using species present absence data. Possible values of the Shannon Wiener Diversity Index (H) range from 1.98 to 2.53 (Table 7). The highest value was recorded in *Abiespindrow* ~ *Euphorbia wallichii* association which was distributed between 2500 – 2600 m (a.s.l.). The minimum value was recorded in community type 'C" *Fragaria indica* ~ *Trifoliumrepens*, occupying the altitudinal ranges between 2700 – 2800 m (a.s.l.). These results suggested the influence of altitude upon diversity which decreased with an increase in elevation.

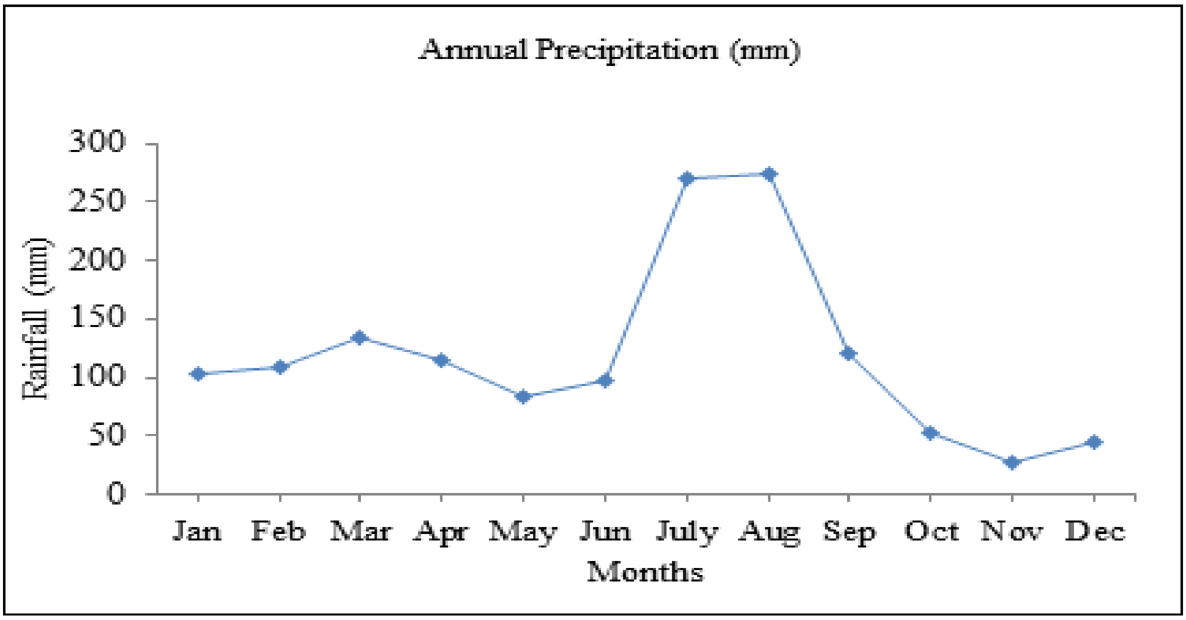

Fig. 3. Average annual precipitation (mm) at Mukeshpuri Hills.

This pattern of H′ diversity was similar to that of Simpson Index and Brillion Diversity indices.

The results (Table 7) suggested a strong negative correlation (*r* = -0.456, *P****). Species richness like diversity decreased with an increase in elevation (Table 6).

Discussion

Floristic composition

A total of 46 plant families were studied at Mukeshpuri Hills in Abbottabad District during the monsoon season of 2017. The maximum numbers of species belonging to Lamiaceae as understory vegetation were recorded under *Abiespindrow*, followed by Rosaceae and Asteraceae. Our results showed similarities with the vegetation communities of Western Himalayan parts of Hazara, Kashmir, Malakand, Swat, Gallies (Ayubia), Kaghan valley, Shogran valley and GilgitBaltistan regions of Pakistan, which were reported by many ecologists (Shaheen *et al.*,2011; Khan *et al.*, 2011a; Abbasi *et al.*, 2013; Abbas *et al.*, 2016; Khan *et al.*, 2017; Saima *et al.*, 2018).

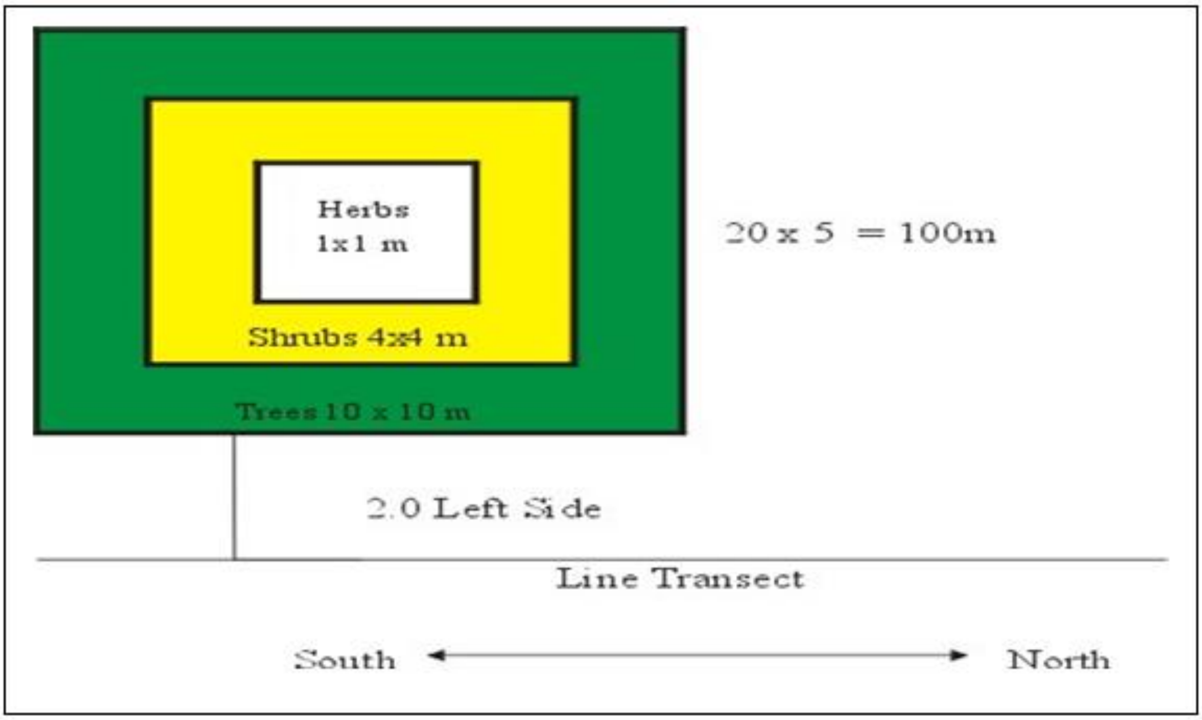

Fig. 4. Sampling scheme for vegetation studied at Mukeshpuri Hills.

The distribution patterns of individual species and different plant species in the same community and habitat type resulted in micro-climatic variations, forest dynamics and biotic relationships. According to plant habit, herbaceous growth form with 68.29 % species was the most dominant one. Our findings are similar with previous studies of many researchers conducted in associated and adjacent regions of the Himalayas, Pakistan (Ijaz, 2014; Khattak *et al.*, 2015; Shah *et al.*, 2015; Ahmad *et al.*, 2016; Rahman *et al.*, 2016a, b; Khan *et al.*, 2018; Saima *et al.*, 2018). The different life-spectra of vegetation in the defined ecological region is always indicative of interactions between plants and the environment. The most suitable reason is climatic gradient, elevation, vertical topography and environmental factor influences. In the present research work, the dominant distribution patterns of therophytes (35%) followed by nano-phanerophytes (27%), chamaephytes (11%), micro-phanerophytes (9%), mega-phanerophytes (5%), meso-phanerophytes (4%), cryptophytes (4%) and hemi-cryptophytes (4%) express the severances of climate at high elevation mountains. The presence of related natural biological spectrum in different zones of Himalayas indicates similar climatic conditions. The present findings as described in the result part were similar to Shaheen *et al.,* (2016) and Khan *et al.,* (2018), who had reported Therophytes as the leading life form in Havelian, Abbottabad and Sathan Gali, Mansehra, Pakistan respectively.

Floristically the study area was dominated by gymnosperms (conifers) with little contribution of broad-leaved trees such as *Acer caesium, Populus ciliata* and *Quercus dilatata.* These results of prominent species of coniferous trees with a little admixture of broad-leaved species and shrubs were similar to the findings of Saima *et al.,* (2009); Raja *et al.,* (2014) and Saima *et al.,* (2018) and also similar findings were described by Ahmad *et al.,* (2006) and Khan *et al.,* (2013) and in the Himalayan moist temperate forest of Pakistan. The results further reveal that the conspicuous plant diversity under the single tree species is because of variations in topography. These results are similar to the work described by Rahman *et al.,* (2017) in Swat valley, northern Pakistan.

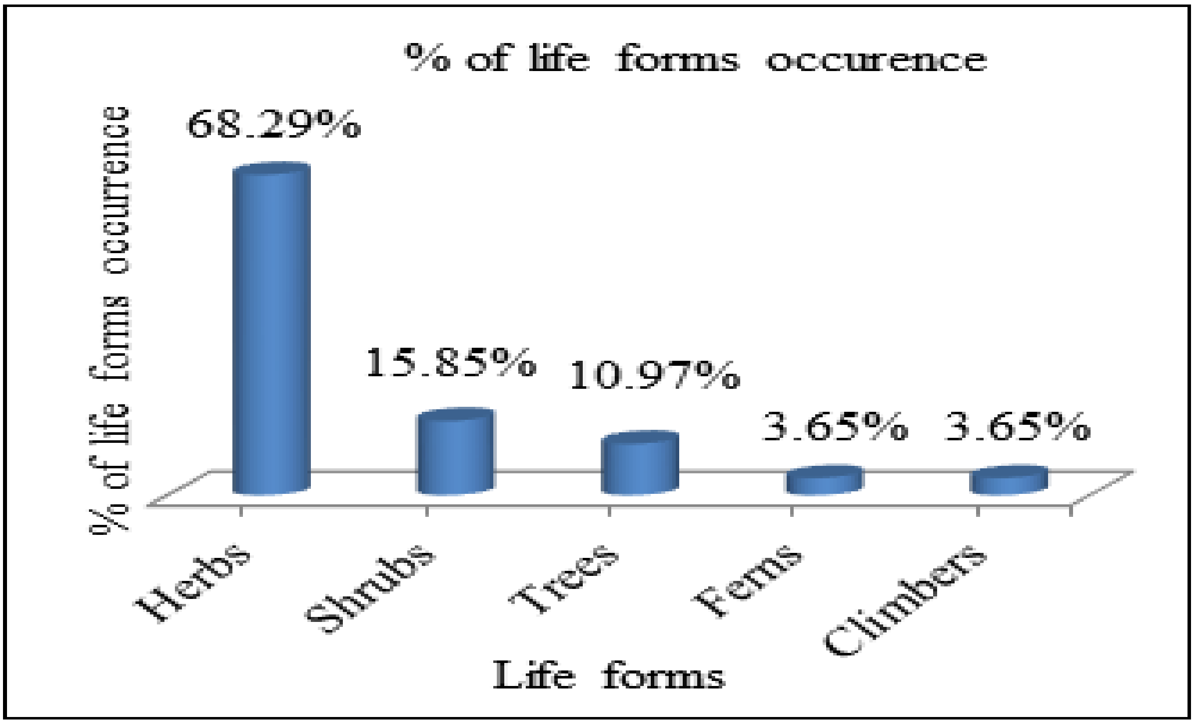

Fig. 5. Life forms spectrum (%) at Mukeshpuri Hills.

Results strongly keep our suggestions to have distinctive vegetation at an altitudinal zone and edaphological dynamics affecting three types of community composition. A total of 82 belong to 72 genera and 46 families of vascular plant species were reported in varied ecological region of the study area. Altitude was influencing directly on species distribution pattern.For the last decay assessment of vegetation types in mountainous habitat is a major problem in-term of biodiversity and conservation management (Shinwari and Qaisar, 2011; Khan *et al.,* 2013). Because of the diverse topographic regime and complex gradient in environmental factors Himalayas provides a range of ecosystem services. The characteristic species of each community was confirmed by variation in altitude having *F-value* 24.87 and *P-value* 0.000. A similar procedure for communities composition along the elevation gradients was also adopted by Shaheen *et al.*, (2011) Khan *et al.,* (2012), Ilyas *et al.,* (2012), Ahmad *et al.,* (2016), Bano *et al.*, (2017) and Hussain *et al.,(*2019) in their respective research.

Classification and ordination analyses in this regard further describe the nature of the habitat types which gradually differ from moist temperate to dry temperate mountain ecosystems along the altitudinal gradient. At the low elevation canopied forests, species richness and diversity is higher as the soil is slightly alkaline and rich in soil soluble cationsand anions and snow melts earlier as compared to the upper opened canopied forest. The monsoon winds also bring sufficient summer rainfall in this low elevated forest type as compared to the forest types located at high elevation. This type of phyto-climatic gradient showed by understory vegetation dominates the lower elevation at the hilly areas. The gradual decrease in species richness along the increasing altitude is considered a general pattern (Shaheen *et al.*, 2011; Shaheen and Shinwari, 2012; Raja *et al.,* 2014 and Hussain *et al.,* 2019). Such observable fact of species distribution has also been described from other temperate hilly sites using a more or less similar method, i.e., Anderson *et al.,* 2006; Shaheen *et al.,* 2011; Khan *et al.,* 2011a; Haq *et al.,* 2017 and Khan *et al.,* 2017.

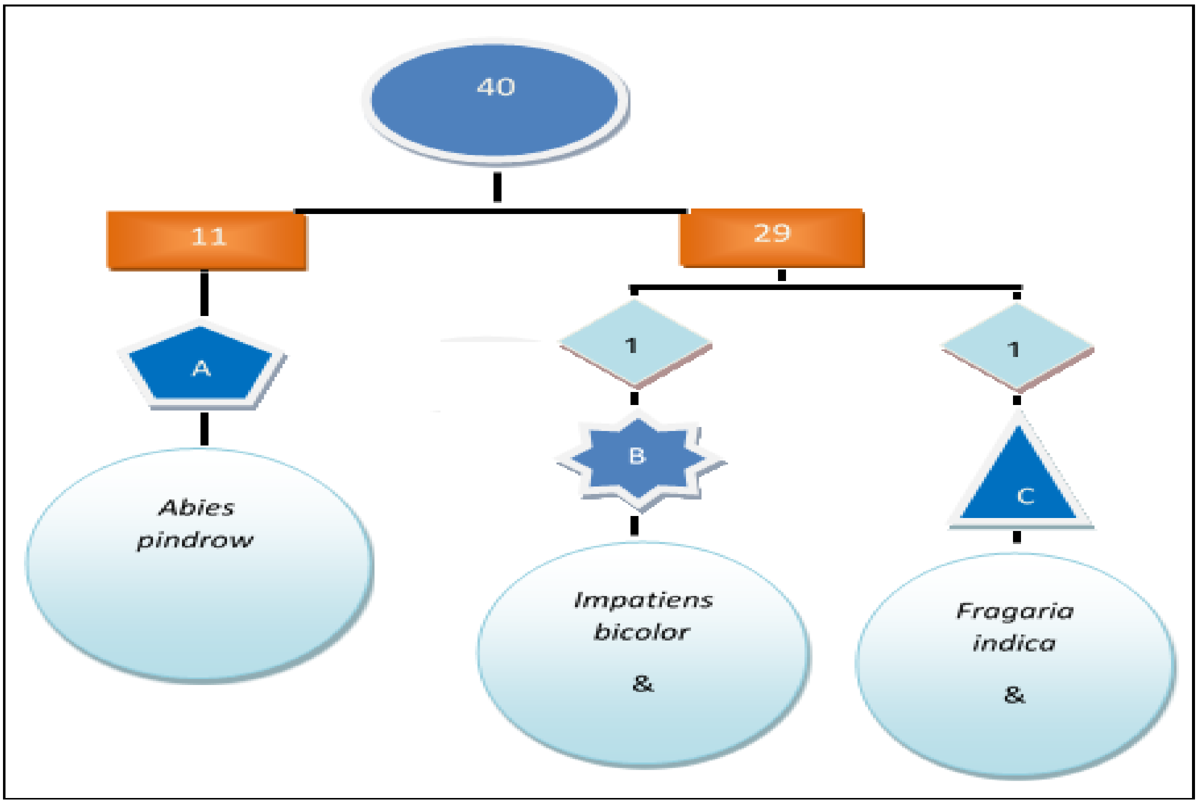

Fig. 6. The hierarchical diagram of 40 sampling stands with dominant species of each association.

Influence of elevation on community composition

The presence/absence samples data obtained in the field indicated a phyto-climatic gradient from lower canopied forests to an upper dry alpine zone located at high altitudes on the mountainous slopes. The use of modern statistical tools has reduced the problems of interpreting and summarizing the presence/ absence of field data on placing similar site-specific species close-together and different ones far apart (Khan *et al.,* 2013; Malik and Nautiyal, 2016). The altitude had an overriding effect on vegetation structure and community composition. The three associations recognized by the Normal cluster Analysis. The two procedures of data simplification provide very similar results. The ordination axis may exhibit significant environmental influences. We interpreted the altitudinal and environmental variables to explore the overlapping characteristics of the communities. These results confirm the findings of Ahmad *et al.,* 2016; Shaheen *et al.,* 2016 and Haq *et al.,* 2017.

The axis first values obtained by DCA showed a gradient from low altitude to high altitude from left to the right side in the ordination diagram. The species associated with high elevation found on the extreme right-hand side of the diagram while the plant species associated with low elevation site preferences tend to locate on the left side of the diagram. Besides the influence of altitude, the distribution patterns of species richness and diversity significantly encounter by topographic heterogeneity. When data subjected to DCA, confirmed that there is a clear relationship between soil properties and community composition recognized by normal cluster analysis. It is suggested that the narrow altitudinal range of some species in temperate vegetation provides good evidence for precise adaptation to narrow ranges of environmental conditions.

The results obtained by DCA exhibited that altitude, soil chemical reactions (pH), Electrical conductivity and Bicarbonates show a significant effect on species distribution and composition with *P-value* 0.002 and *F-value* 7.58. Such impacts were also being studied by numbers of authors in the adjacent habitats of Pakistan (Malik and Hussain, 2006, 2008; El-Moujahid *et al.,* 2017; Khan *et al.,* 2017; Saima *et al.,* 2018). Besides, any change in environmental variables and altitude cause a significant effect in the formation of communities (Chawla *et al.,* 2008; Khan *et al.,* 2017). The importance of attitude is not surprising but is closely linked with rainfall distribution pattern and run-off generated by the higher altitude (Sultan *et al.,* 2013). Besides the altitude, soil chemical properties: chemical reactions (pH), soil cations and anions exchange capacity play a significant role in community composition (Wazir *et al.*, 2008, Raja *et al.,* 2014; Saima *et al.,* 2018) and plant assemblage (Fan *et al.,* 2018). Previous researches show comparison within the nearby areas indicates similar vegetation zones Dasti and Malik, 1998; Wazir *et al.*, 2008; Saima *et al;* 2009; Amjad *et al.,* 2014; Haq *et al.,* 2015a; Khan *et al.,* 2018.

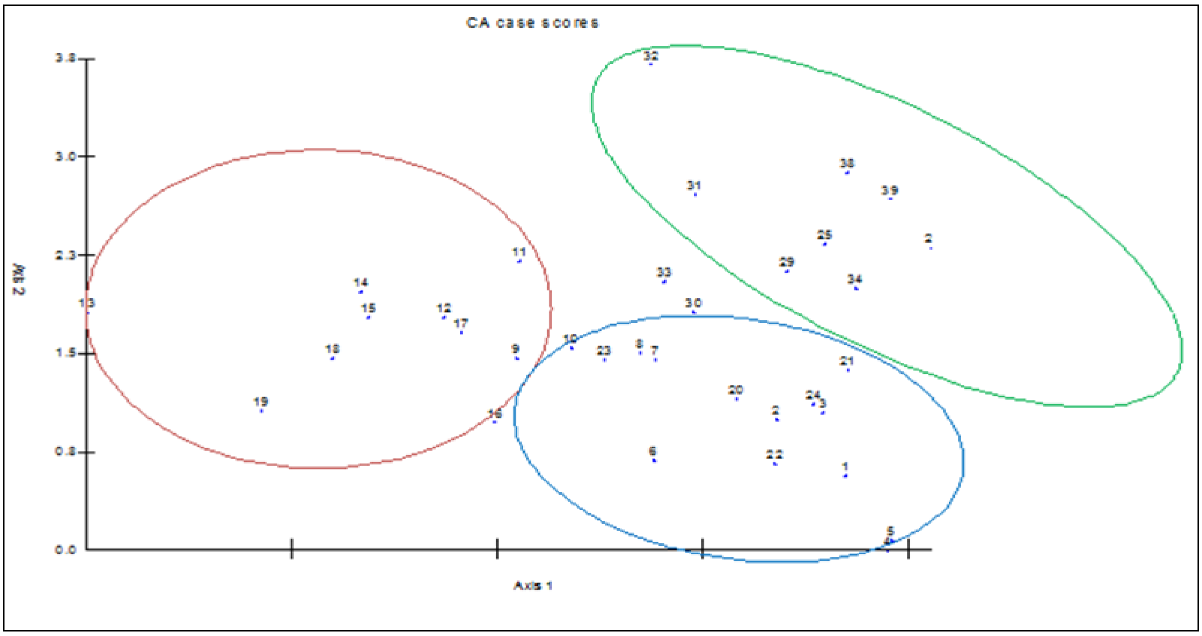

Fig. 7. Decorana (axes 1& axes 2) plot of the 40 stands at Mukeshpuri trek. Stands are plotted individually and zones are shown in which each of the three associations, segregated by the Normal Cluster Analysis.

The species confined to community type "A" occur on soil with relatively high pH at low altitude. An increase in pH with a decrease in altitude is mostly because of downward movements of nutrients dissolved in running water along the slope that affect the spatial distribution of species. The co-relation of soil chemical parameters with different plant communities is not surprising but already has been reported by many ecologists (Wana, 2002; Shaheen *et al.,* 2011; Khan *et al.,* 2012; Shaheen and Shinwari, 2012; Bashir and Ahmad, 2018). Among edaphic factors, available soil pH concentration across the elevation gradient has an important role in determining the pattern of plant communities. Although not highly significant, the relatively low species richness on the hilltop communities may have been the result of low pH. The species richness with elevation is similar to the findings of Khan *et al.,* (2012) but, contradictions with the finding of Saima *et al.,* (2018) who reported the opposite trend. Soil available cations (P, Mg & Na) and anions (Bicarbonates) were significantly higher in plant communities located at low elevation, while some soil available cations (Nitrogen, Potassium & calcium) and anions (Cl^- & Co_3^{--}) show different concentrations at diverse altitude.

Understandably, the ordination is along the altitudinal gradient from the bottom to the top of the transect. Altitude played an important role in determining community composition. It has the strongest positive correlation with elevation ($r = 0.580$) and is therefore associated with the three floristic groups of communities delineated by the cluster analysis and described above. The conclusion shows a negative correlation between most of the soil factors. It suggested that some combined effect is important. The results suggested that communities belong to higher altitudes are poor in soil nutrients that those of lower end of the transect. Low concentration at the upper end is not surprising but associated with the downward movement of nutrients along with run-off currents. The negative correlation of pH, EC, N, Ca, Na, and Mg give further support to this interpretation. This statement is further maintained by the fact that all species show diverse distribution with edaphic parameters.

The correlation analysis with elevation is similar to the findings of Dasti and Malik, (1998) who described that higher content of most soil soluble cations and anions were found in lower mountain soil but, these findings were contradicted to the results of Saima *et al.,* 2009; 2018, who reported opposite trend. From the present investigation, it can be concluded that both classification and ordination analyses recognized the plant communities according to their environments. Topographic variations at the local scale have an important role in governing the community structure in the mountain ecosystem. The detailed species composition and its response to complex elevation and edaphic variation along the study area in Pakistan are poorly known.

Conclusion

The current research work reveals species richness, diversity indices, vegetation patterns and community composition in the closed-canopy forests distributed at various altitudes of Mukeshpuri Hills and these closed canopied fir forests provide habitat for diverse understory vegetation. Our findings described that at lower elevations higher number of species richness and diversity than at higher elevations.

In the present investigation the significant correlation between altitude and DCA axis I suggested that ordination axis I appeared to be marked influenced by topography and thereof the redistribution of rainwater or melting snow which affects the plant assemblage and overall species richness. A significant negative correlation of species richness with cations, anions and positive with altitude suggests the influence of these environmental factors on species richness and overall vegetation. The significant negative correlation of soil available soluble cations and anions with the DCA axis I suggest that sampling sites located at high elevation tend to accumulate less amount of bivalent cations and anions resulting in less release of H^+ and a decrease in pH. Soil EC of the sampling plot showed a significant negative correlation with DCA axisI. Thus the distribution of species along the DCA axis Iam determined largely by soil chemistry. These findings provided valuable guidelines for forest managers interested in the forest ecosystem.

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