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A numerical analysis of understory plant associations in a *Pinus wallichiana* forest, Pakistan

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Abstract

The present investigation describes the structure and vegetation composition of the forest located in Murree Hills, Punjab, Pakistan. The study area is a part of Himalayans moist temperate forest. The vegetation zone entirely consists of shrubs or medium size trees. The plants give the appearance of a vast flower bed, composed principally of herbaceous species. These species are adapted to withstand the extremes of cold and desiccation. Study area range in altitude from 2100m-2300 m (A.S.L.). A total of 65 species, belonging to 62 genera and 39 families were recorded from 40 stands. Angiosperms contributed a major share while Pteridophytes contributed little to the floristic richness of the area. Data were analyzed by multivariate statistics including Cluster Analysis, Detrended Correspondence Analysis (DCA) and correlation co-efficient to detect the relations between altitudinal and some environmental factors with composition and structure of the plant communities. DCA axis 1 and axis 2 were used to interpret the data. Four vegetation types were delineated by Cluster Analysis which was then plotted on the first two axes a scattered diagram. The outcome of the cluster was confirmed by using DCA. There were significant differences in the flora composition as well as the edaphic factors along the altitudinal gradient. The results of the present investigation suggest a direct altitudinal and soil chemical factors pH, EC, cations and anions on the vegetation variation. Topography predicts species composition of the study area.

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Introduction

In northern areas of Pakistan, the Hindu Kush-Himalayan Mountains generally dispersed with natural vegetation forest patches that are dominated by *Pinus wallichiana*. Himalayan forests are essential for preventing soil erosion, water preservation and wood (Rahman *et al.,* 2017). Himalayan forests are distributed with hardwood and mixed-wood forests (Yu and Sun, 2013). Coniferous forests are lesser favourable to biodiversity than hard or mixed wood forests (Barbier *et al.,* 2008). Understory vegetation in coniferous forests proposed that, the community composition and vegetative structure of over story plant species can be predictable to influence on the understory plant species diversity (Bratton, 1976). It is necessary to revise the effect of over story species on the understory vegetation (Rahman *et al.,* 2017).

Topographically the area is characterized by series of arduous mountain ranges created 45 million years ago. These mountain range is transverse the valley in north-south direction. So the important topographic factors that exert most influence on vegetation of the study area are aspect and slope pitches. Most of the variations in community composition are due to altitudinal limits of plant vegetation types (Saima *et al*., 2009). The two habitats i.e. run on and run off often differ in plant communities in mountains (Wazir *et al*., 2008). Diverse understory plant communities preserve significant herbaceous vegetation further than any cause on growth or nutrients. Communities composition of understory vegetation shows the impact of tree line species, which have involved very little spot (Knapp, 1958), diverse vegetation stands, little stands or vegetation exact to area (Ovington, 1955). Herbaceous vegetation contributes significantly to ecological unit implementation in forests (Augusto *et al*., 2003). Conversely, little studies have compared understory vegetation along with coniferous plant species (Barbier *et al.* 2008).

Understory vegetation acting an important character in developing forest ecosystem structure and vegetation function, which facilitate the energy stream, nutrient revolving and disturbing canopy sequence like a forest ecosystem driver (Huo *et al.* 2014). Even though the understory vegetation shares comparatively modest to the entire forest plant biomass, it accounts for the major share of floristic range (Huo *et al.* 2014). Furthermore, various understory vegetation increases forest structural difficulty and gives place, shelter and food for other biotic groups (Whigham 2004).

Diversity structure and species composition, of understory forest vegetation are key to given that composite structure and conserve native vegetation inside the forests (Halpern, 1995). The understory plant species gives territory and foodstuff for vegetation communities (Felton *et al*., 2010), and perform as a driver of nutrient cycling (Hart *et al*., 2006), stand productivity (Chavez and Macdonald, 2012) and forest regeneration and succession (Nilsson and Wardle, 2005). Thus, the understory plant communities and biodiversity are important objectives for sustainable forest managing, useful woodland biodiversity preservation, and flourishing forest restitution (Hart *et al*., 2006)

Topography appears a significant feature that controls variety and yield in temperate deciduous vegetation of the study area. Topography affects environmental conditions and understanding to ordinary turbulence, such as wind, which influence the demographic process of enlargement (Whitemore, 1973), mortality and tree recruitment (Kubota *et al*., 2004). Recent it is studies that various condition of that spot contributes to the protection of species luxury (Tuomisto *et al*., 2003).

Changes in understory plant species require durable shift in plant community and landscape. However it is one of the least considered area of the forest ecology (Rees and Juday, 2002). Various study verified that active understory plant species alteration significantly with the over story species (Hart and Chen, 2006; Yu and Sun, 2013), position management (Barbier *et al*., 2008), light sources (Hart and Chen, 2006), litter properties (Yu and Sun, 2013), geography (Hart and

Chen, 2006) and edaphic factors (Chavez and Macdonald, 2010; Hart and Chen, 2006). Plant communities are divided from each other with a distinguishing floristic composition (Eshaghi-Rad *et al.,* 2009). Classification of plant communities are mostly depends on soil variable factors of spot (BiBi *et al.,* 2020). The herbaceous vegetation developed at the base of the forests, which have a small life span and less changes occurs with the ecological factors. During the high conditions varieties classification of forest site normally reported (Schmidt, 2005).

Altitudinal gradient has an overriding importance in the allocation of herbaceous vegetation and determining the boundaries of plant communities (Dasti and Malik, 1998). Comparison of wet temperate forests a contrasting altitude have shown that mountain forests are poorest in species, families and floristically distinct from low land forests (Richards, 1954). Longitudinal gradients evaluate ecological and biogeographically theory of variety richness and their interaction with climate (Korner, 2000). Climatic variables influence species richness beside the altitudinal gradients for all types of existing species (Whittaker *et al.*, 2001).

Elevation itself represents a combination of correlated climatic variables with several other ecological properties like texture and nutrients availability (Ramsay and Oxley, 1997). Inside the altitude the other factors like topography, aspect, direction of slope and soil type also effect on community composition (Holland and Steyn, 1975). Drought signifying factors such as duration of arid stage and rising water shortage are further key factor in determining the species distribution (Bongers *et al.*, 1999). Conversely, numerous others explanation have been known for a linear correlation between species richness and altitude (Sharma *et al.*, 2009).

The understory plant species supplies a major total of nutrients of forests in stand development and may possibly changes in forest ecosystem (Hornung *et al.*, 1990). Current knowledge is the correlation between vegetation and environmental parameters in various vegetation types of Pakistan. These are mostly based on ecological conditions from field experience and analysis (Haq and Khattak, 1982). It may also influence the soil micro-biota and weathering of soil nutrients (Hinsinger *et al,*. 1993).

The importance of edaphic conditions in the distribution of plant species has been studied by many workers in tropical and subtropical forests. The soils of these forests are derived from a very wide range of parent materials and are more or less immature. These soils are usually acidic in reaction. These discontinuities in edaphic conditions and small scale heterogeneity in these factors is common feature of mountain landscape. Such environmental heterogeneity is important in shaping plant communities because species differ both in space and time (Hutchings *et al*., 2000; James *et al.,* 2003). The topography had some other factor that generally influence on vegetation composition and progression as well as plant height, availability of water and nutrients. However comparable statistics are lacking from the temperate forests of Pakistan.

The main objectives of the present research are:
To provide more detailed information about vegetation composition and structure of the understory vegetation.

To understand the plant communities relationship and their effects on understory vegetation to the understory vegetation.

To investigate the effects of soil varieties on ground vegetation

Materials and methods

Study Area

The study area was located in Murree Hills, Punjab, Pakistan (Fig. 5). The reserved forest under investigation was located at 33-55 to 43-20 N Latitude and 72-20 to 73-30 E Longitudes. The overall altitude of the forest was 2,291 meters (7,516 ft) and occupied the northern slopes in a mountain landscape.

The bed rocks were sedimentary consists of limestone, shale and sandstone ranging in age from Triassic to Eocene. The soil was mostly skeletal, loamy with a good mix of sand and gravel (Saima *et al.,* 2010). The overall climate was wet temperate continental type (Fig. 1). The area was quite heterogeneous in topography and vegetation.

Fig. 1. Study area on Murree Hills.

Climate

Climatically the area was moist temperate continental type with cold winters and mild to pleasant summer (Saima *et al.*, 2010). The minimum temperature in winter season falls well below the freezing point.

The mean annual rainfall is above 1,500mm. The precipitation received in the form of snowy winters. Snowfall during winter may accumulate to 3–7m at various places. Most of the rainfall is received during monsoon period from July to August while May, June, September and October are the driest.

The south west aspect facing the monsoon winds has a much higher and better distributed rain fall than the opposite north east aspect which is rain shadow, Relative humidity measured range 60–70% (Khan, 1998,).The average annual temperature in Murree is14°C. At an average temperature of 21.0°C, June is the hottest month of the year. The lowest average temperature in the year occurs in January, when it is around 4°C.The average mean minimum and maximum temperature 10°C and 18°C respectively. November, December, January and February remain the coldest months while the other months are moderate with pleasant temperature. The monthly data of temperature in the study area is shown in Fig. (2).

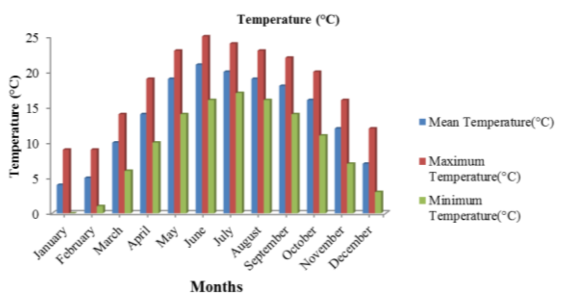

Fig. 2. Mean, Mean Maximum and Mean Minimum monthly Temperature in (°C) of Murree.

Fig. 3. Climatic condition of Murree Hills.

Precipitation

The study areas are located broadly in wet temperate forest climatic zone, with long, frozen winters and short, cold summers; in early autumn, chilly winds bring temperatures down (Fig. 3). Precipitation is received year round with two maxima, first one during winter and second one at summer July-August.

Monthly report of precipitation is given in Fig. 4. Total mean annual precipitation is 1,29mm. The average depth of snow accumulation in winter is about 1.5 m and may be more on mountain peaks. Estimated mean precipitation ranges from 900mm to 1350mm (Khan, 1989).

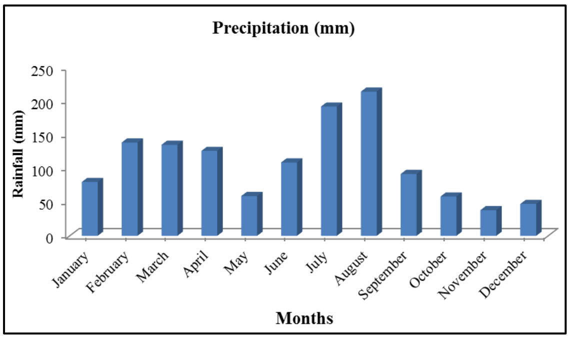

Fig. 4. Average values of monthly Rainfall in (mm) at Murree Hills.

Vegetation sampling

Sampling strategy was intended to cover the study area sufficiently to achieve maximum spatial heterogeneity in vegetation and floristic. The main focus of the present investigation was to understand the pattern understory vegetation in temperate canopied forests. Specimens of all varieties were collected in very careful ways for the determination of identification and classification. Collected plant specimen species were grouped in their taxonomic families also arranged in alphabetic forms. Standard herbarium techniques were used to preserve the plant material. To achieve the purpose a five kilometer long transect was laid across the canopied forest selected during the field survey. A total of 40 stands were delimited along the right side of the transect from south west to north east. A stand of 2 x 100 m was used to monitor vegetation parameters. The presence or absence of all the vascular plant species including ferns were noted in each stand.

Soil Sampling

During survey in each sampling point soil samples were collected. Soil samples were air dried in field. All types of debris coming from plant with soil were removed from meshed soil by using sieving method. The lasting soil samples were directed to lab and subjected to chemical analysis

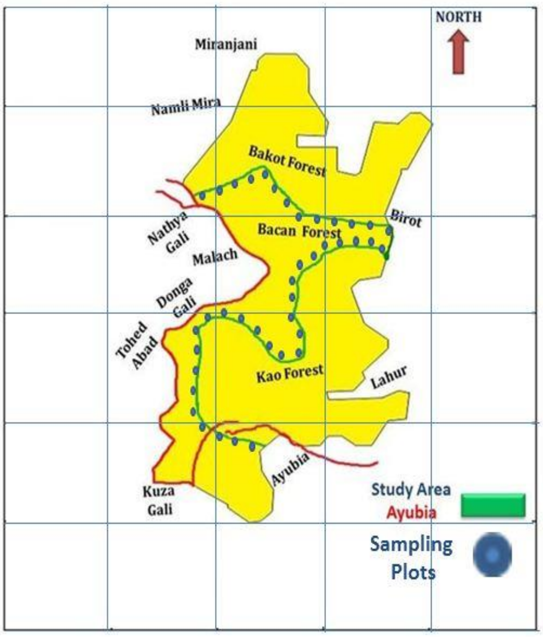

Fig. 5. Map of the Study area Ayubia National Park.

Data analysis

Diversity

A floristic data matrix of 65 species and 40 stands were used to determine the the species richness and diversity by multivariate analysis using MVSP statistical software.

Vegetation Classification and Gradient Analysis

For vegetation zonation and classification Cluster Analysis was used (Saima *et al.*, 2009). In order to explore the possible detailed pattern of distribution of species Detrended Correspondence Analysis (DCA) was performed (Shaheen *et al.,* 2011).

Environment Correlation

The correlation was made between stands score of DCA 1 and 2 axes and ecological variables. These classifications were made with the help of MINITAB- a statistical computer package. Appropriate graphs were drawn to illustrate the difference between the plant associations delineated by the cluster analysis

ANOVA

Differences in soil parameters between the associations identified by cluster analysis were assessed using the analysis of variance (ANOVA). One way analysis was preferred.

Soil Analysis

Soil chemical reactions (pH)

Soil pH of all samples was measured by using digital pH meter (Noor and Khatoon, 2013).

Electrical Conductivity (EC, dS/m)

The amounts of soluble salts from the saturated paste of soils can be quantifies following (Rhoades, 1982).

Organic matter (O.M,%)

Organic carbon was determined by following Walkely and Black's methods.

$$\% \text{ O.M} = \frac{\text{ml of } K_2Cr_2O_7}{\text{Weight of sample (g)}} \text{ x } 9.698$$

Soil available Nitrogen (N_2,%)

Soil nitrogen was determined by Kjeldhal method. It was calculated by following formula:

$$\textbf{N\%} = \frac{-14.1 \times \text{ml of titrant sample} - \text{ml of titrant for blank} \times \text{N of acid}}{\text{Weightofsample (g)}} \times 10$$

Phosphorus (P, ppm)

Available soil phosphorous was determined by spectro-photometerically.

Potassium (K^+)

The available soil cations Potassium (K^+) were measured with the help of Micro processor Flame (Model-1385, Auto gas cutoff- 2018) following BiBi *et al.*, 2020.

Results

Floristic composition

A total of 65 species, belonging to 62 genera and 39 families were recorded from 40 stands. Angiosperms contributed a major share while Pteridophytes contributed little to the floristic richness of the area. Pteridophytes included families of Pteridaceae and Dryopteridaceae. Angiosperm monocotyledonous with 3 species contributed 5% to the floristic richness of the area while dicotyledonous with 62 species contributed 92% of the total floristic riches of the area. Among these Rosaceae with 6 species (15%) followed by Lamiaceae with 5 species (13%) Asteraceae with 3 species (5%) have major contribution (Table 1).

The remaining families contributed little (< 4%) share to the floristic richness of the area. Among the life forms, herbs (74%) contributed the more share followed by shrubs (18%), climbers (5%) and fern (3%) which is shown in Fig. 6. Important herbs present *Achyranthes bidentata, Aster falconeri, Berberis vulgaris, Bergenia ciliata, Buplerum condellei, Cerastium davuricum, Corydalis stewartii, Euphorbia wallichii, Fragaria indica, Gallium aparine, Geranium rotundifolium, Geranium wallichianum, Origanum vulgare, Oxalis corniculata, Plantago lanceolata, Plantago major, Plectranthus rugosus, Polygnum humile, Polygonatum multforum, Rannunculus sceleratus, Rumex nepalensis, spirea vaccinifolia, Viola biflora* and *Wulfenia amherstiana* etc.

The shrubs included *Clematis montana, Desmodium concinum, Indigofera geradiana, Lavetra kashmerian, Lonicera webbian, Rosa microphyl, Sorberia tomentosa, Strobilenthes urticifolia, Rubus fructicosus and Vibernum cotinifolium*. The important ferns are *Adiantum venustum Dryopteris ramose and Onychium contigium* while climbers are *Dioscorea deltoid, Hedera nepalensis, Jasminium officinale* etc.

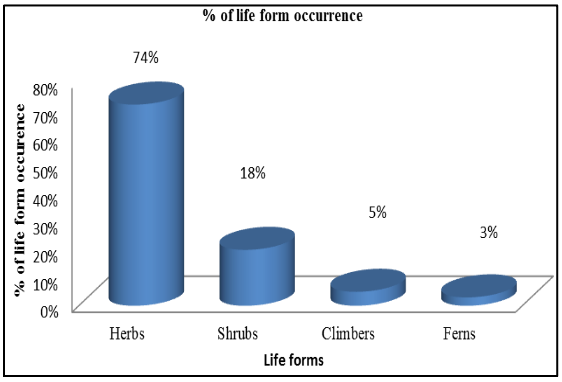

Fig. 6. Graph shows the percentage of life forms occurrence.

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

Groups		Species	Genera	Family	Percent of total (%)
Angiosperm	Dicot	59	56	33	90%
	Monocot	3	3	3	5%
Fern		3	3	3	5%
Total		65	62	39	100%

Vegetation ecology

Diversity and Floristic Richness

Species Richness and diversity indices were determined by using the presence absence data of species. Observed values of Shannon diversity (H´) in the study area ranged between 2.60 to 2.91, where high values indicate high diversity (Table 2) the values estimated for species richness (SR) ranged from 8.8 to 14.0, with high values representing high richness per unit area. The results (4.4) indicated that species richness increased with decreased in elevation along the transect. The lower end of the transect exhibited maximum value (19.0), while minimum were recorded in the top most end of the transect having species richness < 9 species per unit area. The results (Table: correlation) suggested a strong positive correlation with altitude (*P<0.05, **P<0.001, ***P<0.0001).

Table 2. Shannon's Diversity Index Evenness and Species Richness in 40 stand values.

Associations	Elevation (M A.S.L.)	H´	Species Richness
Association A	2100-2150	2.60	13.6
Association B	2150 - 2200	2.91	19.0
Association C	2200 – 2250	2.10	9.0
Association D	2250 - 2300	2.70	15.0

Normal Cluster Analysis

Four plant associations were recognized by the Normal Cluster Analysis. These associations were not arbitrary but related to soil type and altitude. These groups were delineated at four level of division hierarchical diagram (Fig.7).The association A having 8 stands (Table 3) possess *Paeonia emodii* divisor species.This species was altogether absent in rest of all the stands. At the second level 15 stands (Association B) without *Origanum vulgare, Scrophularia lateriflora* and *Spiraea vaccinifolia* were separated out from the remaining having these stands. At the third hierarchical level 5stands (Association C) *Cerastium davurcum* and *Stachys emodii* were separated from the rest of other associations (Table 4). At the fourth hierarchical level 12 stands (Association D) were separated from the rest of other associations which possess *Gerardiana heterophyla, Hypericum dyeri, Malva neglecta* and *Clematis montana* as a divisor species.

Table 3. Number and list of stands in each association identified by Normal Cluster Analysis.

Associations	No. of Stands	List of Stands
A	08	3,4,8,10,13,21,22,23.
B	15	2,5,6,7,9,11,12,14,15,16,17,24,25,26,30.
C	05	19,35,36,37,40.
D	12	1,18,20,27,28,29,31,32,33,34,38,39.

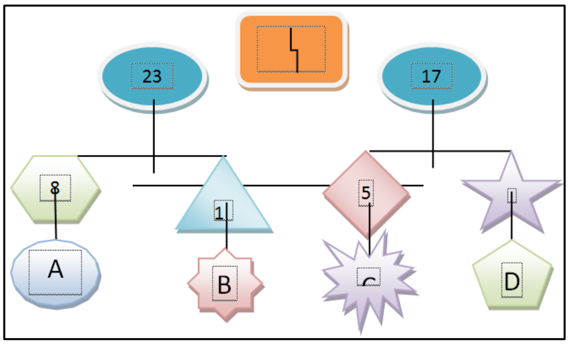

Fig. 7. The hierarchical classification on data of 40 stands obtained from Normal Cluster Analysis. Number of stands in each association is given in basic shapes.

Table 4. Four associations and their divisor species delineated by normal cluster analysis. Elevation is in meters (m) above the sea level (A.S.I.).

Associations	Elevation (M, A.S.L)	Divisor species
A	2100-2150 (m)	*Paeonia emodi*
B	2150-2200 (m)	*Origanum vulgare, Scarzonera hispenica, Scrophularia lateciflora , Spiraea vaccinifolia*
C	2200-2250 (m)	*Cerastium davurcum, Stachys emodii.*
D	2250-2300 (m)	*Gerardiana heterophyla, Hypericum dyeri,Malva neglecta, Clematus montana.*

Association A

This association was distributed from 2100 to 21500m (A.S.L) and characterized by having *Paeonia emodii* which was altogether absent from other associations separated by Normal cluster analysis (Table 4). The common ferns present in this association developed during monsoon and disappeared during the winter snow. Two fern species *Adiantum venstum* and *Onychium contiguum* were dominant and both were found in moist shady slopes. Among the shrubs, *Lonicera webbiana, Rubus fruticosus* and *Viburnum grandiflorum* were commonly found under canopy or canopy gaps (Table 5). *Desmodium concinum* and *Lavatera kashmiriana* were rare species scattered in forest meadows. *Hedera nepalensis* and *Dioscorea deltoidea were* common climbers in these temperate forests. Among the two climbers, *Hedera nepalensis* was more frequent here. The understory dominant herbaceous flora in cludes *Arisaema jacquemontii, Bergenia ciliata,Buplerum condellei, Cannabis sativa, Fragaria indica, Impatiens brachycentra, Podophyllum emodii, Polygonatum multiflorum, Salvia nubicola, Trifolium repens, Valeriana dentate* and *Viola biflora,* while *Galium aparine, Geranium wallichianum, Micromeria biflora, Rumex nepalensis, Sorbarea tomentosa, Urtica dioica* and *Wulfenia amherstiana* were rare. All these species were common on wet and damp places.

Soil

The soil of this association was slightly alkaline showing pH >7. The loam soil of this association showed intermediate values of most of the soil parameters included in the present investigation. The soil variables such as EC (2.25 ds/m), organic matter (0.84%), Phosphorus (7.63) showed moderate values but Nitrogen (48.78) and Potassium (212.7) were present in low percentage.

Association B

This association was distributed from 2150 to 2200m (A.S.L) and characterized by presence of *Origanum vulgare, Scarzonera hispenica, Scrophularia lateciflora* and *Spiraea vaccinifolia*. All these species were altogether absent from other associations recognized by Normal Cluster Analysis. The common ferns present in this association were *Adiantum venustum, Onychium contiguum* along with *Dryopteris ramose*. Among the shrubs, *Lonicera webbiana, Rubus fruticosus* and *Vibernum grandiflorum* were commonly found under canopy and forest gaps, while *Indigofera gerardiana, Lavatera kashmiriana* and *Lonicera webbiana* were rare and found on gentle slopes. *Micromeria biflora, Polygonum pubescens, Polygonum humail, Ranunculus sceleratus, Senecio chrysanthemoides, Traxacum officinale, Urtica dioica, Verbuscum Thapsus* and *Wulfenia amherstiana* were the frequent species (Table 5). The rare species were *Arisaema jacquemontii, Aster falconeri, Berberis vulgaris, Bergenia ciliata, Buplerum condellei, Corydalis stewartii, Euphorbia wallichii, Galium aparine, Heracleum maximum, Impatiens brachycentra, Nepeta erecta, Oxalis corniculata, Plantago lenceoleta, Podophyllum emodii, Rumex nepalensis* and *Valeriana dentate.*

Soil

The soil of this association was highly alkaline with pH 7.16.The soil of this association showed high values of soil attributes recorded in the present investigation, this includes high percentage of: EC (2.84 ds/m) and Organic matter (0.87%), but Nitrogen (61.13) was moderately present. Phosphorus and Potassium were present in low percentages (7.58 and 212.7 respectively).

Association C

This association was situated from the altitude of 2200 to 2250 m (A.S.L) and the ground flora consist of twenty seven species of herbs, shrubs and climbers collectively while the fern species were altogether absent from this associations recognized by Normal Cluster Analysis. Among the shrubs *Indegofera gerardiana* was found dominating in under canopy while *Desmodium concinum*, *Rosa microphyla,* and *Vibernum grandiflorum* were occasionally occuring species. The two species *Strobilanthes urticifolia* and *Rubus fructicosus* were found in rare form. Other species present more or lessin pure patche. The understory dominant herbaceous flora comprising *Arisaema jacquemontii, Cerastium davuricum* were recorded, while *Corydalis stewartii, Epilobium angustifolium, Euphorbia wallichii, Geranium rotundifolium, Geranium wallichianum, Impatiens brachycentra, Jasminium officinale, Myosotis alpestis, Oxalis corniculata, Polygonum pubescens, Plectranthus rugosus, Polygonatum multiflorum, potentella nepalensi and Stachys emodii* were commonly occurring species (Table 5).

Soil

The soil of this association was slightly alkaline with pH (7.02) delineated by normal cluster analysis. The soil of this association showed intermediate values of soil attributes recorded in the present investigation; this includes high percentage of, Phosphorus (8.68), but EC (2.74 ds/m) and Organic matter (0.80%) present in low percentage. Nitrogen (63.80) and Potassium (237.6) were present in intermediate percentage.

Association D

This association was situated from the altitude of 2250 to 2300m (A.S.L) and characterized by *Gerardiana heterophyla, Hypericum dyeri, Malva neglecta* and *Clematus montana,* which were altogether absent from other associations recognized by Normal Cluster Analysis (Table 5). The common ferns species dominated with *Adiantum venstum, dryopteris ramose* and *Onychium contiguum* were dominant and found in under moist shady rocky slopes. Among the shrubs, *Lonicera webbiana* and *Sorbarea tomentosa* were commonly found in under canopy. The *Indigofera gerardiana, Rosa microphyla, Rubus fruiticosus* and *Vibernum grandiflorum* were dominating the flora, while *Lavatera kashmiriana* was found in rare form. The typical herbaceous and dominating climber's were composed of *Hedera nepalensis and Dioscorea deltoidea*. Among these dominant species was *Hedera nepalensis*. The understory dominant herbaceous flora *Dioscorea deltoidea, Epilobium angustifolium, Euphorbia wallichii, Gallium aparine, Geranium rotundifolium, Geranium wallichianum, Heracleum maximum, Jasminium officinale, Myosotis alpestis, Oxalis corniculata, potentella nepalensis* and *Rumex nepalensis* were recorded, while *Arisaema jacquemontii* and *Impatiens brachycentra* were rare in this association.

Soil

The soil of this association was slightly acidic with pH (6.94) delineated by normal cluster analysis. The soil of this association showed intermediate values of soil attributes recorded in the present investigation; this includes high percentage of, Phosphorus (8.50), but EC (2.70 ds/m) and Organic matter (0.09%) present in low percentage. Nitrogen (65.36) and Potassium (243.7) were present in intermediate percentage.

Table 5. Relative frequency of the species in each association from the normal cluster analysis showing DCA score, axes 1.

Species Name	A	B	C	D
Ferns				
Adiantum venustum	6.42	4.56	---	1.81
Dryopteris ramose	5.50	4.56	---	1.20
Onychium contiguum	---	3.51	---	3.01
Shrubs				
Clematus montana	---	---	---	1.81
Desmodium concinum	0.92	---	6.82	4.22
Indigofera gerardiana	---	2.81	9.09	4.82
Lavatera kashmiriana	0.92	0.35	---	1.20
Lonicera webbiana	3.67	3.51	---	3.61
Rosa microphyla	0.92	1.40	6.82	1.81
Sorberiatomentosa	0.92	3.51	4.55	3.61
Strobilanthes urticifolia	---	---	2.27	1.20
Rubus fructicosus	0.92	0.70	2.27	1.81
Viburnum contigifolium	6.42	4.21	6.82	1.20
Herbs				
Achyranthus bidentata	---	0.70	---	3.01
Arisaema jacquemontii	5.50	4.21	4.55	5.42
Aster falconeri	0.92	0.70	---	1.20
Berberis vulgaris	0.92	0.35	---	3.01
Bergenia ciliata	1.83	1.75	---	0.60
Buplerum condellei	3.67	3.51	---	1.81
Cannabis sativa	2.75	2.11	---	0.60
Cerastium davurcum	---	---	4.55	---
Corydalis stewartii	4.59	2.11	2.27	---
Dioscorea deltoidea	0.92	---	4.55	0.60
Epilobium angustifolium	---	---	2.27	0.60

Species Name	A	B	C	D
Euphorbia wallichii	---	0.35	2.27	1.20
Fragaria indica	6.42	3.16	---	2.41
Gallium aparine	0.92	0.35	4.55	3.01
Geranium rotundifolium	0.90	1.70	2.28	1.80
Geranium wallichianum	0.92	1.80	2.27	1.81
Gerardiana heterophyla	---	---	---	1.81
Hedera nepalensis	7.34	2.11	---	1.20
Heracleum maximum	---	0.35	4.55	3.01
Hypericum dyeri	---	---	---	0.60
Impatiens brachycentra	5.50	1.75	2.27	5.42
Jasminium officinale	---	---	2.27	1.20
Malva neglecta	---	---	---	0.60
Micromeria biflora	0.92	2.46	---	1.81
Myosotis alpestis	---	---	2.27	1.81
Nepeta erecta	---	0.35	---	2.41
Paeonia emodi	0.54	---	---	---
Origanum vulgare	---	1.40	---	---
Oxalis corniculata	---	0.35	2.27	1.81
Polygonum pubescens	3.67	3.86	2.27	1.20
Plantego lenseoleta	---	0.35	---	0.60
Plectranthus rugosus	---	0.35	2.27	2.41
Plantago major	---	2.81	---	0.60
Podophyllum emodi	1.83	1.05	---	---
Polygonum humile	---	3.86	---	3.01
Verbuscum thapsus	---	1.05	---	0.60
Polygonatum multiflorum	2.75	0.70	2.27	0.60
Ranunculus sceleratus	3.67	4.21	---	---
Potentella nepalensis	---	---	2.27	1.20
Rumex nepalensis	1.83	1.40	6.82	3.01
Salvia nubicola	0.92	0.70	---	0.60
Scarzonera hispenica	---	1.40	---	---
Scrophularia lateriflora	---	1.40	---	---
Senecio chrysanthemoides	---	2.11	---	1.20
Spiraea vaccinifolia	---	1.05	---	---
Stachys emodi	---	---	2.27	---
Traxacum officinale	0.92	1.05	---	---
Trifolium repens	1.83	1.75	---	0.60
Urtica dioca	0.92	2.46	---	1.20
Valeriana dentate	4.59	2.46	---	---
Viola biflora	5.50	3.86	---	3.01
Wulfenia amherstiana	0.92	1.40	---	---

Environmental variables.

Among environmental variables included in present investigation, Altitude, pH, EC, Organic matter, Nitrogen, Phosphorus showed significant differences among the plant association recognized by the Normal cluster analysis (Table 6). Phosphorus showed the high F-value followed by soil pH. Other variables such as EC, organic matter, Nitrogen and Potassium showed lower F-value. The F-value indicated the relative importance of these edaphic factors in shaping the plant communities.

Table 6. Analysis of variance for all the different variables among four community types identified by Normal Cluster Analysis.

Sr. No	Soil variables	DF	SS	MS	F	P
1	No. of species	3	431.2	143.73	9.19	0.00
2	pH	3	0.30	0.10	0.54	0.66
3	E.C (ds/m)	3	2.19	0.73	1.13	0.35
4	Organic matter%	3	0.02	0.00	0.95	0.43
5	Nitrogen%	3	1540	513.5	1.14	0.34
6	Phosphorous (ppm)	3	9.091	3.03	6.51	0.00
7	Potassium (ppm)	3	8284	2761	1.43	0.25

Soil analysis

The sampling sites located at lower altitude belonging to association A showed higher value of pH (7.05) than the sampling sites at higher altitude belonging to D (6.94). These results reflected the altitudinal trends in soil pH which showed gradual decrease with increasing altitude i.e. from basic to acidic soils. Similar two fold decrease in EC was observed as one move from low to high altitude. In organic matter and nitrogenous contents differ substantially among the plant associations identified along the altitudinal gradient. Significant differences among the plant association were noted for soil Phosphorus but no clear altitudinal trends were exhibited. Other soil nutrients such as Potassium etc. were abundant in almost variable amount in all associations (Table 7). So the results suggested that the soil pH along the Altitudinal gradient had the overriding importance in the distribution of species and community compositions along the altitudinal gradient of the study area.

Table 7. Mean values and standard deviation for different variables.

Sr. No	Variables		A	B	C	D
1	No of species	Mean	14.00	19.00	8.80	15.00
		S.D	2.88	4.69	3.77	3.63
2	PH	Mean	7.05	7.16	7.02	6.94
		S.D	0.51	0.29	0.53	0.48
3	E.C dSm-1	Mean	2.25	2.84	2.74	2.70
		S.D	0.64	0.85	0.89	0.80
4	Organic Matter (%)	Mean	0.84	0.87	0.80	0.81
		S.D	0.10	0.08	0.05	0.09
5	Nitrogen (%)	Mean	48.78	61.13	63.80	65.36
		S.D	24.11	22.70	20.32	16.24
6	Phosphorus (ppm)	Mean	7.63	7.58	8.68	8.50
		S.D	0.92	0.65	0.67	0.45
7	Potassium (ppm)	Mean	212.7	212.7	237.6	243.7
		S.D	45.7	39.5	53.4	44.4

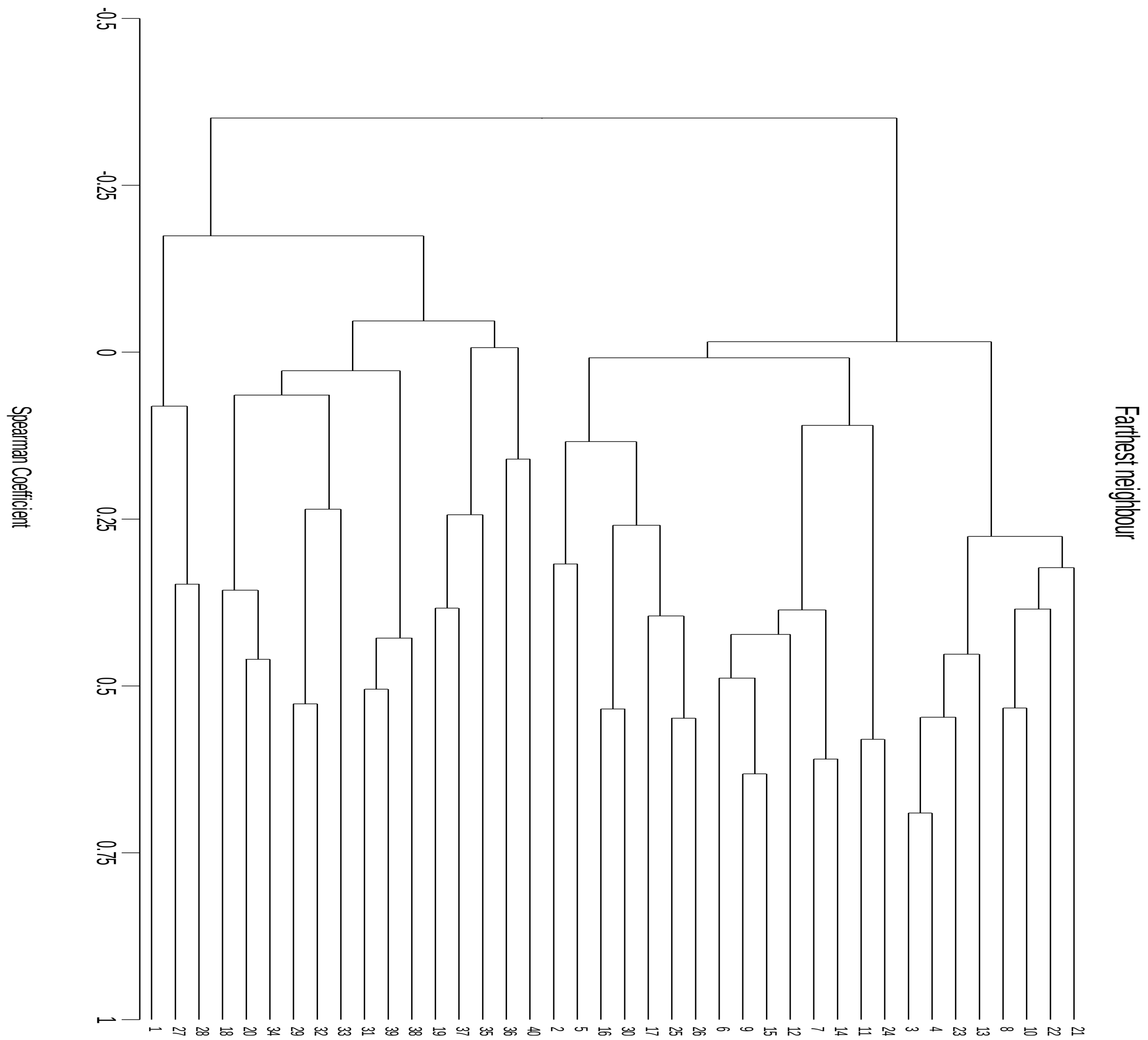

Fig. 8. Dendrogram obtained from Normal Cluster Analysis for 40 stands (Quantitivedata).

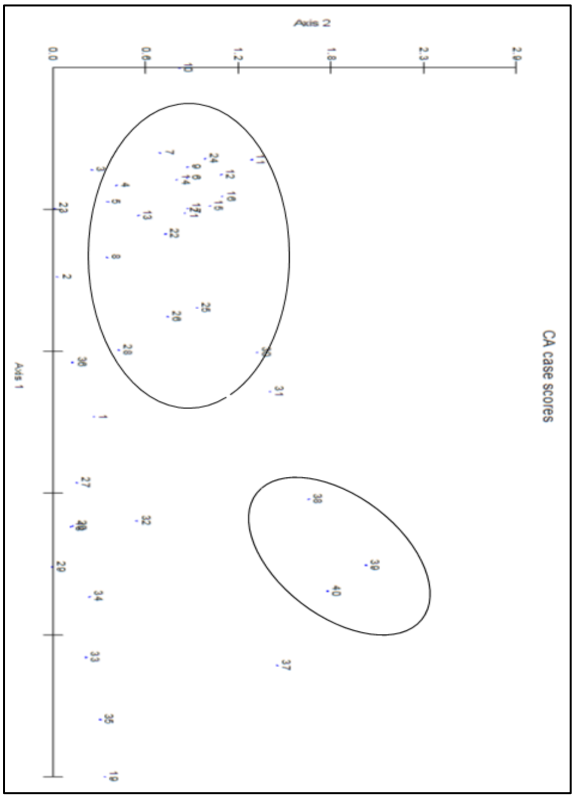

Table 8. Pearson's correlation coefficients between DCA first axes, DCA second axes, Soil parameters and altitude.

Factors	Axes1	Axes2
Altitude	0.621	0.434
Electrical Conductivity	0.030	0.181
pH	-0.214	-0.526
Organic Matter (%)	-0.263	0.341
Phosphorus(ppm)	0.419	0.385
Potassium(ppm)	0.234	0.332
Nitrogen (%)	0.157	0.189
No. of species	-0.278	-0.085

Ordination

Indirect gradient analysis was performed for the total data set, using ordination program Detrended Correspondence Analysis (DCA) (TerBraak, 1987). Rare species down weighted. Eigenvalues for the four axes of ordination (the measure of their importance) are shown in table 9 Axes 1 and 2 were most important with Eigenvalues 0. 391 and 0.222 thus DCA axis 1 and axis 2 explained most of the variations in the given data. Further axes each explained had low Eigenvalues and thus were ignored. The overlay of the cluster obtained from cluster analysis of sampling sites on the ordination axes I & II suggested the similarities between the two procedures of data simplification. Altitude explained the main floristic variation in the study area. This was confirmed by Pearson's Rank Correlation with the ordination score along DCA axis I. There was highly significant positive correlation(*r* =0.621 between the sample scores along DCA axis 1 and altitude).

Table 9. Eigenvalues and Cumulative Percentage of DCA axes 1-4.

Axes	Eigenvalues	Percent of total	Cumulative percentage
1	0.391	12.821	12.821
2	0.222	7.257	20.078
3	0.161	5.264	25.342
4	0.130	4.246	29.588

These results suggested that the samples (low score) located at the far left hand side of the ordination diagram belongs to the associations occurring at low altitude and are characterized by having *Arisaema jacquemontii, Buplerum condellei, Hedera nepalensis, Plantego lenseoleta, Onychium contigum, Podophyllum emodii, Scrophularia lateriflora, Sarberia tomentosa, Traxacum officinale* and *Urtica dioica*. These species were altogether absent in samples located at the far right hand side of the diagram and representing the plant associations located at the highest altitude where *Cerastium davuricum, Clematus montana, Epilobium angustifolium, Hypericum dyeri, Myosotis alpestis, Rubia manjith, Oxalis corniculata* and *Plectranthus rugosus* were the characteristic species.

Site ordination reveals a marked relationship between the first axes and altitude along with soil factors. Among the edaphic factors soil pH, organic matter, Nitrogen content, Phosphorus, Potassium concentration played the significant role in the distribution of plant species in the study area.

Soil pH and organic matter showed the negative, while nitrogen, phosphorous and potassium were positively related with DCA axis I. These results suggested the trends of a biotic factors and their determining the vegetation type along the altitude.

Discussion

Floristic

In recent research work the hilly areas facing major difficulties in the form of biodiversity and conservation management in vegetation (Khan *et al* 2013). Due to diverse topographic regime and complex gradient in environmental factors Himalayas provides a range of ecosystem services. The biodiversity of plant vegetation influenced by human activities present on these mountains and therefore mountainous ecosystem services delivered by the various vegetation type prerequisite widespread assessment at local scale and as well as gradient sacale (Khan *et al* 2013). Floristically the study area was dominated by *Pinus wallichiana* trees with the mixture of understory Herbs shrubs and climbers. Herbs constituted 52 species followed by shrubs of 10 species, and ferns of 3. Herbs contribute one third of the total species recorded from the understory study area. The common shrubs of the area *were Clematis montana, Desmodium concinum, Lavatera kashmiriana, Rosa microphyla, Vibernum cotinifolium, Berberis vulgaris, Indigofera gerardiana* and *Sorbarea tomentosa. Spiraea vaccinifolia, Hypercom dyeri. Hedera nepalensis*, *Fragaria indica, Galium aparine, Geranium wallichianum* and *Rumex nepalensis* were the common herbs. Common ferns was present in the shady patches were *Adiantum venustum*, *Dryopteris ramose* and *Onychium contigum* was rare. These distributions may range from anthropogenic to basic geomorphologic processes of surface movement through the action of wind, splashing and snow melting and glaciations. These factors may be contemporary or historical and range from the sweeping climatic changes to current harvesting activities by local villagers and grazer who may remove say a woody species from wide area for use as fuel. This flora is very similar to those of other parts of North Temperate Zone in Europe and America (Champion *et al.*, 1965).

Vegetation and community composition

When the four association produced by the Cluster Analysis are plotted on axis 1 and axis 2 as scatter diagram. The two procedure of data simplification can be seen to have given very similar results. The ordination axis may represent in some way the major environmental influences which affect the stands in the data and we use the plants and environment variables to discuss the over-lapping features. The first ordination axis represents a gradient from low altitude to high altitude from left to the right hand in the diagram. The samples belonging to the highest elevation are found on the extreme right hand side of the diagram while the samples from low altitudes tend to concentrate on the left side of the ordination. Besides the altitude the distribution of the species is potentially effected by soil properties (Dasti *et al.*, 2007). Analysis with DCA confirms that there is a clear relationship between soil properties and association defined by numerical analysis along the altitudinal gradient.

The DCA results showed that altitude, soil pH, Electrical conductivity, Sodium and Chloride are the most important factors for determining the composition of plant associations. The distribution of species along the altitudinal transects support the individualistic hypothesis of community organization (Khan *et al.*, 2013). The importance of altitude is not surprising but is closely associated with rainfall and redistribution of rainfall water. The run-off generated by the higher altitude will then move downward (run-on) and create moisture gradient along which vegetation change occur. Therefore, the down-slope movement of water plays an important role in floristic changes along the altitudinal gradient. Thus the first ordination axis represents a moisture gradient from upper zone (with high score, associations C & D), lower zone (with low score, associations A & B). Vegetation of the upper zone consisted of *Nepeta erecta, Gallium aparine, Geranium wallichianum, Oxalis corniculata, Arisaema jacquemontii, Rumex nepalensis, Malva neglecta, viola biflora, Fragaria indica, Salvia nubicola, Plantago lenseoleta, Polygnum humaile, Aster falconri, Euphorbia wallichii,* These species were absent at lower altitudes of study area. On the other hand *Plentago major, Urtica dioica, Pilea umbrosa, Dryopteris ramose, Adiantum venustun, Traxacum officinale,* *Podophyllum emodii, Wulfenia ambhestiana, Schrzonera hispenica, Spiraea vaccinifolia,*were confined to the lower altitude confirming the overriding importance of altitude in shaping the plant communities in mountain landscape (Dasti and Malik, 1998; Saima *et al.,* 2009, Wazir *et al.*, 2008). Numerous studies have demonstrated that the species composition and diversity of understory flora can be influenced by canopy species and structure stand management (Barbier *et al.,* 2008). The species belonging to association A occur on soil with relatively high pH as it decreases with increase in altitude. Thus the altitudinal floristic differences may partially be attributed to soil pH. Decrease in pH with decrease in altitude is largely due to downward movement of nutrients that affect the spatial distribution along the altitudinal transect (Saima *et al.,* 2018). The co-relation of soil pH with distribution and association of plant species is not surprising but already has been reported by several workers (Khan *et al.,* 2013; BiBi *et al.,* 2020).

The results of present investigation suggest a direct effect of altitude and indirect effect through its impact on soil properties. The down slope movement of water and soil particles regenerates different niches that can be occupied by different species (Berger and Puettmann, 2000). The correlation of species distribution with Potassium Phosphorus, and Nitrogen suggested that vegetation is a complex collection of substrates, specialist and generalists. It may be concluded that both classification and ordination are able to delimit the plant associations according to their environments. Topography heterogeneity at the local scale also is a very important factor governing the community structure in the mountain habitat. The complex gradients in edaphic conditions related with topography give a prospect to conduct further research, both in the laboratory and the field. Topography can also significantly alter microclimates and resource availability under the tree canopy (Chavez and Macdonald, 2010) and in turn influence understory species composition and diversity (Sharma *et al.,* 2009; Rahman *et al.,* 2017).

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