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Gradient analysis and classification of vegetation pattern in himalayan moist deodar forest, Pakistan

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Abstract

The present investigation describes the structure and vegetation composition of the forest of Kaghan valley, Pakistan. The study area is a part of the Himalayans moist temperate forest. The vegetation zone entirely consists of Herbs, shrubs and tall trees. The plant gives 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 1800m- 2200 m (a.s.l). A total of 86 plant species belonging to 84 genera and 50 families were identified from the study 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 the 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 chemistry effect on the vegetation variation. Topography predicts the species composition of the study area.

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Introduction

The Kaghan valley is one of the central valleys of Western Himalayan, the world's youngest and highest mountain in Pakistan, which is characterized by obvious habitat types for their complex patterns of natural communities relating the flora of Sine-Japanese and Irano-Turanian areas of Central Asia. The Himalayan part of the country possesses an unusually rich flora i.e. one can find a huge variety of plant species within the short gap. It has obvious habitat types of species and valuable information for botanists. Due to the fact, that this part of the country remained undisturbed by any cataclysm such as glaciations and inundation for a long period, thus enabling any species to evolve and survive. The other main reason for the distribution of species in this area is the influence of landscape over mountains.

Difficult topography, the effect of altitude on the shaping of plants communities, climate and approach to the presence of rare species in deep valleys increases more entrust for studies researchers, at lower foothills of Pakistan, the flora is subtropical; the subtropical zone extends upwards to about 3200m where world's longest trees present. The other main aspects of this area are rainfall and anthropogenic disturbance. The whole area of this land is covered with evergreen forest like Conifers but lower land is cultivated up to some extent. The flora of this zone includes species that can withstand both hot summer and cold winter.

The deep valleys of Pakistan have sub-tropical flora which extends upwards to about 2200m to 1800m. The vegetation of this area has great verities of species that can tolerate both high as well as low-temperature extremes. The most common tree species of this region are *Acer caesium, Aesculus indica, Ailanthus altissima, Cedrus deodara*, *Juglans regia, Picea smithiana, Pinus wallichiana* and *Quercus dilatata*.

There is a great difference in climate occurring year to year, mainly in rainfall and snowfall, while soil differences are found in deeper layers, stoniness, pH and texture, commonly within a few meters (Rassam and Tully, 1986; Cooper *et al*., 1987; Peer *et al*., 2001, 2007). In such climates, Soil variation may be an important cause of vegetation composition than climatic variations, (Fitter, 1982; Pagnotta *et al.,* 1997). Similarly, the correlation between species abundance and the slope was measured by Sterling *et al., (*1984). The altitude had several collateral factors that influence the overall vegetation Composition and process, including plant stature, water and nutrient availability.

The topography has many aspects affecting the vegetation composition and developments. Tanner *et al.,* (1998) found that Nitrogen (N), to some extent Phosphorus (P) and Potassium (K) decreases with elevation (Tanner *et al*., l998) but similar data absent for temperate forest of Pakistan.

The specialty of plant species to soil conditions is well recognized (Saima *et al.,* 2018; BiBi *et al.,* 2020). Features that affect the species are gap formation rates, soil water availability, pH and cation exchange capacity. The specialization of plant species to specific soil conditions is well recognized. Local plant diversity increases with an increase in the intercalation of these areas and their soil plainness (Ashton, 1969). There is very little information available on the effects of soil factors on plant Species distribution where the slope is less. The studies of tropical and subtropical forests have revealed that the species distribution is associated with soil conditions (Dasti and Malik, 1998; Khan *et al.,* 2018).

Present knowledge of the relationship between plant species and environmental factors in the forest types of Pakistan is based upon the particular descriptions of environmental conditions in the field and interpretation (Haq *et al.,* 2017; Saima *et al.,* 2018; BiBi *et al.,* 2020). The complete composition of species and their relation with the complex ecological and soil variations is not known well because a mutual study of composition and structure of temperate forests in Pakistan is still not present; the purpose of the present study is to complete the overall floral picture of these areas. Techniques have been developed by the latest synecological methods for use at local and regional levels, aiming to decrease the complexity of field data set by classification and ordination of plant data and then relating the results to ecological information (Braak, 1987). Direct gradient analyses have shown many visions of natural ecological communities. Gradient analysis in wet temperate forests may particularly be challenging, as a large number of species are involved, common absence of regional taxonomic treatments, and difficulty to visit the diagnostic parts of many canopy trees, vines and epiphytes, such studies are particularly worthwhile, given a large number of species and interspecific comparison available for analysis. The basic objective of the study was to give an account of the communities of alpine plants on an altitude gradient of Kaghan valley of Pakistan.

Materials and methods

Study area

The study area is a part of a Government Reserved Forest at Kamalban, a small village in the slopes of Khanya, near Kaghan Town. The forest is located between 34°42'25.15" N 73°31'52.18" E and is broadly defined as a moist temperate forest. The area supports variety of plant species. The mountains show a very deep, steep and gentle slope.

Precipitation

The summer monsoon flora is very rich. Since the climate of Kamalban is much wetter and its flora is much richer than that of abutting heavily grazed slopes and the country surrounding the reserve forest it requires separate mention of flora and vegetation. Here winter is long and frozen while summer is usually short. The reason for long cold summer is the chilly wind which down the temperature even snowfall. The range of precipitation sometimes reaches up to 600mm. Due to this reason here humidity level remains very high.

Climate

An account of the climate and geology of the study area is given by Champion *et al.*, (1965) and Hussain and Illahi, (1991). The environment of the area varies widely along the altitudinal gradient. There is a considerable year–to–year climatic variation, especially in rainfall and winter snow accumulation. The overall climate of the study area may be classified as temperate continental with an average frost-free growing period of 204 days extending from April to October. The scarcity of metrological stations in the study area makes it impossible to give a detailed account of the climate. However, the high altitudinal ranges of both the south and north zones enjoy *Cfb* (Temperate oceanic climate; coldest month averaging above 0 °C (32 °F) (or −3 °C (27 °F), all months with average temperatures below 22 °C (71.6 °F), and at least four months averaging above 10 °C (50 °F). No significant precipitation difference between seasons (neither above-mention set of conditions fulfilled).

Lithology

The overall geology of the study area is a complex tectonic zone. The major portion of the metamorphic rocks consists of gneisses and schist, extending over granites, limestones and quartzite of Precambrian age (Champion *et al.,* 1965). The overall zone is a granitic shield covered with shallow and rocky soils. The depth of the soil and its ability to hold water, rainfall, altitude, and aspect seems to be more important than the composition of the underlying rock in determining the type of vegetation (Khan *et al.,* 2018).

Vegetation sampling

In the study area, 27 sites were selected along the altitudinal gradient. The difference in altitude between the sites was about 100m (a.s.1.). A total of 27 stands were sampled to cover possible land species. These stands were established along the altitudinal transect starting from 1800 m (a.s.l.) to 2200 m a.s.l and were mentioned by specific numbering. Three quadrats of 10m x 10m were established at each site to accommodate maximum heterogeneity of the vegetation. The presence or absence of plants, herbs, shrubs, climbers and grasses species was noted in each strand. The plant species were collected as possible.

Plants were identified in the field whenever possible, but in cases of doubt, we collected the plants. All the voucher specimens were dried then identified according to the flora of Pakistan (Nasir and Ali, 1972) dried plants were kept in the Herbarium of South Punjab Institute of Science and Technology Dera Ghazi Khan for future reference.

Vegetation analysis

Diversity and Richness

A floristic data of 98 species and 27 stands were analyzed using multivariate approaches. Multivariate Statistical Package Analysis (MVSP) (Kovack, 1999) was used. Species diversity and richness indices were calculated by using the default option 'Shannon diversity index of the diversity'.

Gradient Analysis and Vegetation Classification

In this study classification and ordination, methods were used for data analysis. Species presence/absence data were clustered on the basis of monothetic information static procedure (Hill, 1979; Causton, 1988) by incorporating the Spearman rank order dissimilarity coefficient.

The ordination of data was done for sites and species. Detrended correspondence analysis "DCA" (Hill and Gauch, 1980) was conducted to see the floristic associations among the sampling units. For analysis, the default option of the program "DECORANA" (Hill, 1979; Causton, 1988) was used. To interpret the data, DCA axis 1 and 2 were used based on their high Eigenvalue. To assess the compatibility of two methods of data simplification, Scatters of classification groups were plotted-as an overlay of ordination axes. The relationship between soil variables and DCA axes l and 2 of strand scores was determined by using the Spearman rank correlation coefficient.

Relative frequency

It is the percentage of sampling plots in which a given species occur. It is related to the degree of homogeneity of individuals of a species in an area. The frequency reveals distribution of species.

Relative frequency (%) = (frequency of species / frequency of all species) ×100

Soil sampling

Soil samples were collected randomly from the specific points on the parameter of each strand. The soil was extracted from 5cm depth of sub-soil and 2cm diameter core of topsoil (Khan *et al.,* 2018). The soil samples of each strand were mixed to form the composite sample. Thus one soil sample was made for each strand. The samples were packed in tightly sealed polythene bags, were labeled and brought to the laboratory.

Soil analysis

The soil samples were air-dried and passed through a 2mm sieve to separate the graves. The portion of soil finer than 2mm was used for physical and chemical analysis.

Chemical analysis

The chemical analysis included the measurement of pH, Electrical Conductivity (EC), Total Soluble salts (TSS), Organic matter (OM), Calcium + Magnesium, Sodium (Na) and Chlorine (C1).HM 10K digital (Richards, 1954) meter was used to measure the pH of soil. To determine the EC, Soil saturation paste was made and its extract was obtained by using a suction pump. Electrical conductivity (EC) of the extract was determined by using CM-30 ET digital conductivity meter. Organic matter contents of the soil were determined by the following method of Walker *et al.,* (2013) and Saima *et al.,* (2009). To determine Ca + Mg, 10ml of soil extract was taken in the conical flask. Few drops of Erich Rome black T were added then titrated it against 0.01 Ethylene Diamine Tetra Acetate (EDTA).To determine the soluble sodium in the solution containing the known concentration of sodium, Jenway PFP7 Photometer was used. A standard curve was obtained. The amount of sodium in the sample was found standard for meter reading obtained for the sample. Few drops of $K_2Cr_2O_7$ were added after Bicarbonate titration, as indicate and titrate it against (0.05) Ag, no solution was added until the color changed to brick red.

Data Analysis

ANOVA

Differences in soil parameters between the associations were identified by cluster analysis and estimated by using the analysis of variance (ANOVA).

Correlation

The correlations were made between strand scores of DCA 1 and 2 axes and ecological variables. These calculations were made with the help of “MINITAB” a statistical computer package.

Results

Classification

Four plant associations were recognized by the Normal Cluster Analysis Fig 1. These associations were not arbitrary but related to edaphic and altitudinal conditions. The composition of stands along the altitude of each association is given in Table 1.

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

Table 1. Number of the list of stands in each association identified by Normal Cluster.

Associations	Number of stands	List of strands
A	5	1, 2, 3, 8, 11.
B	5	4, 5, 6, 7, 12.
C	7	9, 10, 14, 15, 16, 17, 18.
D	10	13, 19, 20, 21, 22, 23, 24, 25, 26, 27.

Association A

This association was distributed from the height of 1800 m (a.s.l.) to 1900 m (a.s.l.). This association was characterized by having *Chenopodium foliosum, Dioscorea deltoidea, Ficus palmata, Nepeta clarkei* and *Rubia manjith* which were altogether absent from all the other association delineated by Normal Cluster Analysis. Among the herbs *Trifolium repens* were dominant, *Cannabis sativa*, *Rumex nepalensis*, *Viola rupestris*, *Rubia manjith* species were common, *Dioscorea deltoidea, Ficus palmata, Urtica ardens, Circium arvense, Polygonatum multiflorum* were occasional while *Chenopodium foliosum* , *Nepeta clarkei, Campanula pallida, Thalictrum secundum, Fragaria nubicola, Bupleurum falcatum, Myosotis alpestris* species were rare in this association. The common shrubs were *Cotoneaster affine, Indigofera atropurpurea, Rosa webbiana, Berberis kunawurensis, Lonicera quinquelocularis, Paeonia emodi* and *Strobilanthes attenuata*. The common trees were *Pinus wallichiana, Juglans regia* and *Cedrus deodara*. Among this association grasses were absent.

The soil of this association was characterized by slightly alkaline with the mean value of pH 7.76, having high electrical conductivity of 2.26 dS/m. The soil was poor in Organic matter 0.71 (%). Nitrogen 0.13, Phosphorous 7.74 (ppm), Potassium 206.40 (ppm), Calcium 0.60 (ppm), Magnesium 0.25, Sodium 0.45 (ppm), Chlorides 0.456 (ppm), Carbonates 3.28 (ppm) and Bicarbonates were 72.20 (ppm) in highest in quantities among all associations (Table 4).

Association B

This association is situated at an altitude ranging from 1900m to 2000m. In this association, *Euphorbia cornigera, Prunella vulgaris, Scrophularia frutescens, Verbescum thapsus, Caltha palustris,* and *Jasminum officinale* were the divisive species that were altogether absent from the rest delineated by Normal cluster analysis. Among the herbaceous species, *Geranium wallichianum, Micromeria biflora, Campanula pallida, Plantago major* and *Trifolium repens* were dominant species while *Wulfenia amherstiana* and *Urtica urdens* were recorded rare species in this association. *Berberis kunawurensis, Lonicera quinquelocularis, Rosa webbiana, Jasminum officinale, Cotoneaster affine, Indigofera atropurpurea, Salix wallichiana* and *Viburnum grandiflorum* were the prominent shrubs.

Among the conifer tree species, *Pinus wallichiana* were dominant with a little admixture of broad-leaved species, *Aesculus indica, Ailanthus altissima* and *Juglans regia*. In moist shady rocks ferns including *Dryopteris ramosa* and *Asplenium trichomanes* forming patches. *Poa alpina* grass species were common in this association. The soil of this association was also alkaline and characterized by the value of pH 7.60, having high Electrical Conductivity 2.26 dS/m. Soil having Organic matter of 0.75 (%) (Table 4). Total soil Nitrogen content 0.13, extractable Phosphorous 7.67(ppm), Potassium 216.40 (ppm), Calcium 0.58 (ppm), Magnesium 0.24(ppm), Sodium 0.44(ppm), Chlorides 0.44(ppm), Carbonates 2.90 (ppm) and Bicarbonates were 69.20 (ppm) in this association.

Table 2. Relative frequency of the species in each association from the normal cluster analysis of DCA score.

Species	A	B	C	D
Rubia manjith Roxb.	4.62	--	--	--
Ficus palmate Forssk.	3.08	--	--	--
Nepeta clarkei Hook.	1.54	--	--	--
Chenopodium foliosum Asch.	1.54	--	--	--
Dioscorea deltoidea Wall.	3.08	--	--	--
Prunella vulgaris L.	--	1.54		--
Caltha palustris L.	--	1.54	--	--
Euphorbia cornigera Boiss.	--	1.54	--	--
Jasminum officinale L.	--	3.08	--	--
Verbescum thapsus L.	--	3.08	--	--
Scrophularia frutescens	--	1.54	--	--
Caryophyllum reflexum	--	--	1.27	--
Desmodium tiliifolium D. Don.	--	--	1.27	--
Ligularia fischeri Ledeb.	--	--	1.27	--
Mentha royleana Benth.	--	--	1.27	--
Plectranthus rugosus Wall.	--	--	0.64	--
Nepeta levigata (D. Don) Hand.-Mazz	--	--	0.64	--
Stachys emodi Hedge.	--	--	0.64	--
Pilea scripta Wedd.	--	--	1.27	--
Acer caesium Wall.	--	--	0.64	--
Alliaria petiolata M. Bieb.	--	--	1.27	--
Quercus dilatata Royle.	--	--	1.27	--
Trigonella emodi Benth.	--	--	--	0.58
Spiraea hypericifolia L.	--	--	--	0.58
Polygnum aviculare L.	--	--	--	1.16
Convolvulus arvensis L.	--	--	--	0.58
Capsella bursa-pastoris L.	--	--	--	0.58
Astragalus grahamianus	--	--	--	0.58
Arisaema wallichianum Hook.	--	--	--	1.16
Taraxacum officinale Webb.	--	--	1.27	1.73
Sambucus wightiana Wall.	--	--	2.55	1.73
Ranunculus laetus Wall.	--	--	0.64	1.16
Phlomis bracteosa Royle.	--	--	1.27	5.20
Parrotiopsis jacquemontiana Dcne.	--	--	2.55	5.78
Oxalis corniculata L.	--	--	2.55	3.47
Onychium contiguum Wall.	--	--	0.64	1.73
Myosotis alpestris	--	--	0.64	0.58
Impatiens edgeworthii Hook.	--	--	2.55	2.89
Cynoglossum glochidiatum Wall.	--	--	1.91	4.62
Androsace rotundifolia Hardwicke.	--	--	0.64	1.16
Veronica serpyllifolia L.	--	1.54	0.64	2.89
Viburnum grandiflorum Wall.	--	1.54	3.82	5.20
Salix wallichiana Anderson.	--	1.54	1.91	--
Poa alpina L.	--	3.08	1.27	2.31
Plantago major L.	--	6.15	2.55	4.05

Micromeria biflora Buch.	--	3.08	2.55	1.16
Hedera nepalensis K.	--	1.54	2.55	2.89
Geranium wallichianum D.Don.	--	4.62	2.55	5.78
Asplenium trichomanes	--	3.08	3.18	0.58
Galium aparine L.	--	1.54	0.64	4.05
Pinus wallichiana A.B.Jackson.	7.69	7.69	1.27	1.16
Lonicera quinquelocularis Hardwicke.	3.08	6.15	2.55	2.31
Indigofera atropurpurea Buch.	4.62	1.54	0.64	2.31
Fragaria nubicola Hook.	1.54	1.54	2.55	1.16
Berberis kunawurensis Royle.	3.08	6.15	2.55	0.58
Trifolium repens L.	6.15	3.08	3.18	2.31
Urtica ardens Link	3.08	1.54	1.27	0.58
Dryopteris ramosa C. Hope	3.08	3.08	2.55	5.20
Cotoneaster affine Lindley	6.15	3.08	1.91	--
Thalictrum secundum Edgew	1.54	1.54	1.91	--
Juglans regia L.	4.62	3.08	3.18	--
Campanula pallida Wall.	1.54	3.08	--	--
Aesculus indica Wall.	1.54	4.62	--	--
Paeonia emodi Wall.	1.54	--	1.91	1.73
Adiantum venustum D. Don.	3.08	--	1.91	2.89
Bupleurum falcatum L.	1.54	--	0.64	--
Epilobium laxum Royle.	--	1.54	0.64	--
Rosa webbiana Wall.	4.62	4.62	--	1.16
Polygonatum multiflorum L.	3.08	--	0.64	0.58
Rumex nepalensis Spreng.	4.62	--	2.55	2.89
Myosoton aquaticum L.	1.54	--	1.27	--
Strobilanthes attenuata Nees.	1.54	--	1.91	--
Urtica ardens L.	3.08	--	--	0.58
Viola rupestris F.	4.62	--	4.46	4.05
Phytolacca latbenia Moq.	1.54	--	2.55	0.58
Cedrus deodara Roxb.	1.54	--	2.55	5.20
Cannabis sativa L.	4.62	--	0.64	--
Ailanthus altissima Mill.	--	4.62	2.55	--
Rubus biflorus	--	1.54	--	0.58
Wulfenia amherstiana Benth.	--	1.54	1.91	--

Note: Value in bold refers to divisor species for each association.

Association C

This association was distributed from the altitude of 2000m to 2100m. This association was characterized by having *Acer caesium, Caryophyllum reflexum, Alliaria petiolata, Mentha royleana, Desmodium tiliifolium, Ligularia fischeri, Plectranthus rugosus, Nepeta lavigata, Pilea scripta, Quercus dilatata* and *Stachys emodi* which were altogether absent in other associations recognized by Normal Cluster Analysis (Table 2). The most abundant species of herbs found in this associations were, *Viola rupestris,* while *Trifolium repens* was common, *Cynoglossum glochidiatum, Impatiens edgeworthii, Oxalis corniculata, Sambucus wightiana, Plantago major, Geranium wallichianum, Hedera nepalensis, Micromeria biflora, Rumex nepalensis,* and *Fragaria nubicola* were occasional while *Androsace rotundifolia, Ligularia fischeri, Myosotis alpestris, Campanula pallida, Phlomis bracteosa, Pilea scripta, Plectranthus rugosus, Ranunculus laetus, Taraxacum officinale, Veronica serpyllifolia, Epilobium laxum, Wulfenia amherstiana, Bupleurum falcatum, Myosotis alpestris, Caryophyllum reflexum, Alliaria petiolata, Mentha royleana, Pimpinella diversifolia, Podophyllum emodi, Cannabis sativa, Urtica ardens, Polygnum aviculare, Thalictrum secundum* and *Paeonia emodi* species were rare in this association (Table 2). The shrubs were *Viburnum grandiflorum, Parrotiopsis jacquemontiana, Berberis kunawurensis, Lonicera quinquelocularis, Salix wallichiana, Strobilanthes attenuate, Desmodium tiliifolium, Stachys emodi, Cotoneaster affine, Indigofera atropurpurea* and *Rosa webbiana.*

Table 3. Analysis of variance for all the different variables among four community types identified by Normal Cluster Analysis.

Source	DF	SS	MS	F	P
Altitude	3	484758	161586	24.15	0.000
EC (ds/m)	3	3.10	1.03	2.65	0.070
Ph	3	5.13	1.71	21.07	0.000
O. M (%)	3	0.06	0.02	15.95	0.000
N (ppm)	3	0.001	0.000	4.68	0.010
P (ppm)	3	7.29	2.43	19.88	0.000
K (ppm)	3	1544	515	1.35	0.280
Ca (ppm)	3	0.15	0.05	15.19	0.000
Mg (ppm)	3	0.02	0.009	4.44	0.012
Na (ppm)	3	0.04	0.01	29.13	0.000
Cl (ppm)	3	0.01	0.006	19.83	0.000
CO3 (ppm)	3	5.14	1.71	10.72	0.000
HCO3 (ppm)	3	1601.9	534.0	7.28	0.001

The tree species were *Ailanthus altissima, Juglans regia, Quercus dilatata, Acer caesium, Pinus wallichiana* and *Cedrus deodara*. Among the ferns were *Asplenium trichomanes, Dryopteris ramose* and *Adiantum venustum*. The soil of this association was characterized by the value of pH 7.11, having high Electrical Conductivity 2.58 dS/m. Soil having Organic Matter 0.79ms/cm. Nitrogen 0.13, Phosphorous 7.07, Potassium 221.50, Calcium 0.51, Magnesium 0.23, Sodium 0.38, Chlorides 0.40, Carbonates 2.33 and Bicarbonates were 64.25 in this association (Table 4).

Table 4. Mean values and standard deviation for different variables.

Source		A	B	C	D
Altitude	Mean	1874.0	1892.0	2041.8	2180.8
	St. dev	66.90	61.40	79.7	93.70
EC (ds/m)	Mean	2.26	2.26	2.57	1.79
	St. dev	0.83	0.71	0.62	0.48
pH	Mean	7.76	7.60	7.11	6.71
	St dev	0.343	0.17	0.12	0.35
O. M (%)	Mean	0.71	0.75	0.79	0.84
	St dev	0.06	0.01	0.01	0.04
N (ppm)	Mean	0.13	0.13	0.12	0.11
	St dev	0.01	0.005	0.005	0.01
P (ppm)	Mean	7.74	7.67	7.07	6.55
	St dev	0.43	0.35	0.12	0.40
K (ppm)	Mean	206.40	216.40	221.50	205.08
	St dev	31.64	15.34	14.04	18.05
Ca (ppm)	Mean	0.60	0.58	0.51	0.42
	St dev	0.04	0.02	0.03	0.07
Mg (ppm)	Mean	0.25	0.24	0.23	0.18
	St dev	0.05	0.06	0.05	0.01
Cl (ppm)	Mean	0.45	0.44	0.40	0.39
	St dev	0.03	0.02	0.009	0.007
CO_3 (ppm)	Mean	3.28	2.90	2.33	2.20
	St dev	0.89	0.420	0.05	0.14
HCO_3 (ppm)	Mean	72.20	69.20	64.25	53.91
	St dev	5.49	1.78	2.31	12.56

Association D

This association was distributed from an altitude of 2100 m to 2200m. This accusation was characterized by having *Arisaema wallichianum, Astragalus grahamianus, Capsella bursa-pastoris, Trigonella emodi, Polygnum aviculare, Convolulus arvesis* and *Spiraea hypericifolia* which were altogether absent in other associations recognized by Normal Cluster Analysis.

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

Axes	Eigenvalue	Percentage	Cum. Percentage
1	0.42	10.37	10.37
2	0.22	5.41	15.78
3	0.15	3.85	19.64
4	0.11	2.83	22.47

The most abundant and dominant species of herbs found in this associations were *Cynoglossum glochidiatum, Geranium wallichianum* and *Viola rupestris* while *Impatiens edgeworthii, Oxalis corniculata , Plantago major* and *Rumex nepalensis* was common (Table 2). *Taraxacum officinale, Veronica serpyllifolia* and *Hedera nepalensis* were occasional and *Arisaema wallichianum, Astragalus grahamianus, Capsella bursa-pastoris, Convolvulus arvensis, Delphinium roylei, Lepidium latifolium, Silene indica, Trigonella emodi, Polygnum aviculare, Androsace rotundifolia, Ligularia fischeri, Myosotis alpestris , Pileascripta, Phlomis bracteosa , Plectranthus rugosus, Ranunculus laetus, Sambucus wightiana, Micromeria biflora, Trifolium repens, Urtica ardens, Cirsium arvense, Polygonatum multiflorum, Fragaria nubicola* species were rare in this association. Among the shrubs *Parrotiopsis jacquemontiana, Viburnum grandiflorum, Indigofera atropurpurea, Spiraea hypericifolia, Salix wallichiana, Rosa webbiana, Berberis kunawurensis, Lonicera quinquelocularis, Paeonia emodi,* and *Phytolacca latbenia* were common species recorded in this association delineated by Normal cluster analysis (Table 2). The tree species were *Cedrus deodara, Quercus dilatata, Ailanthus altissima, Pinus wallichiana.* Among the ferns were *Dryopteris ramosa, Onychium contiguum, Asplenium trichomanes* and *Adiantum venustum,* The soil of this association was characterized by the value of pH 6.71, having high Electrical Conductivity 1.79 dS/m, Soil having Organic Matter 0.84 (ppm).

Nitrogen 0.11 (ppm), Phosphorous 6.55 (ppm), Potassium 205.08(ppm), Calcium 0.42 (ppm), Magnesium 0.18, Sodium 0.36 (ppm), Chlorides 0.39(ppm), Carbonates 2.20 (ppm) and Bicarbonates were 53.91(ppm) in this association (Table 4).

Table 6. Pearson's correlation coefficients between DCA first axes, DCA second axes, Soil parameters and altitude.

Parameters	Axes1		Axes 2	
	Coefficient	Significance	Coefficient	Significance
Altitude m (a.s.l)	0.94	***	0.21	NS
pH	-0.71	***	-0.05	NS
Electrical Conductivity	-0.20	NS	-0.69	**
Organic Matter (%)	0.68	**	-0.21	NS
Nitrogen (ppm)	0.69	**	-0.03	NS
Phosphorus (ppm)	-0.50	*	-0.03	NS
Soil Saturation (ppm)	0.18	NS	-0.60	**
Potassium (ppm)	0.02	NS	-0.30	NS
Calcium (ppm)	-0.21	NS	-0.31	NS
Magnesium (ppm)	-0.39	NS	-0.15	NS
Sodium (ppm)	-0.52	*	-0.13	NS
Chloride (ppm)	-0.11	NS	-0.30	NS
Carbonate (ppm)	-0.18	NS	-0.37	NS
Bicarbonates (ppm)	0.08	NS	0.22	NS
No. of Species	-0.62	***	-0.26	NS

Environmental variables

Among environmental variables included in the present investigation, Altitude, PH, EC, Organic matter, Nitrogen, Phosphorus showed significant differences among the plant association recognized by the Normal cluster analysis. Altitude showed the high F-value followed by soil pH (Table 3). Other variables such as EC, Organic Matter, Nitrogen and Phosphorus showed lower F-value.

The F-value indicated the relative importance of these edaphic factors in shaping the plant communities.

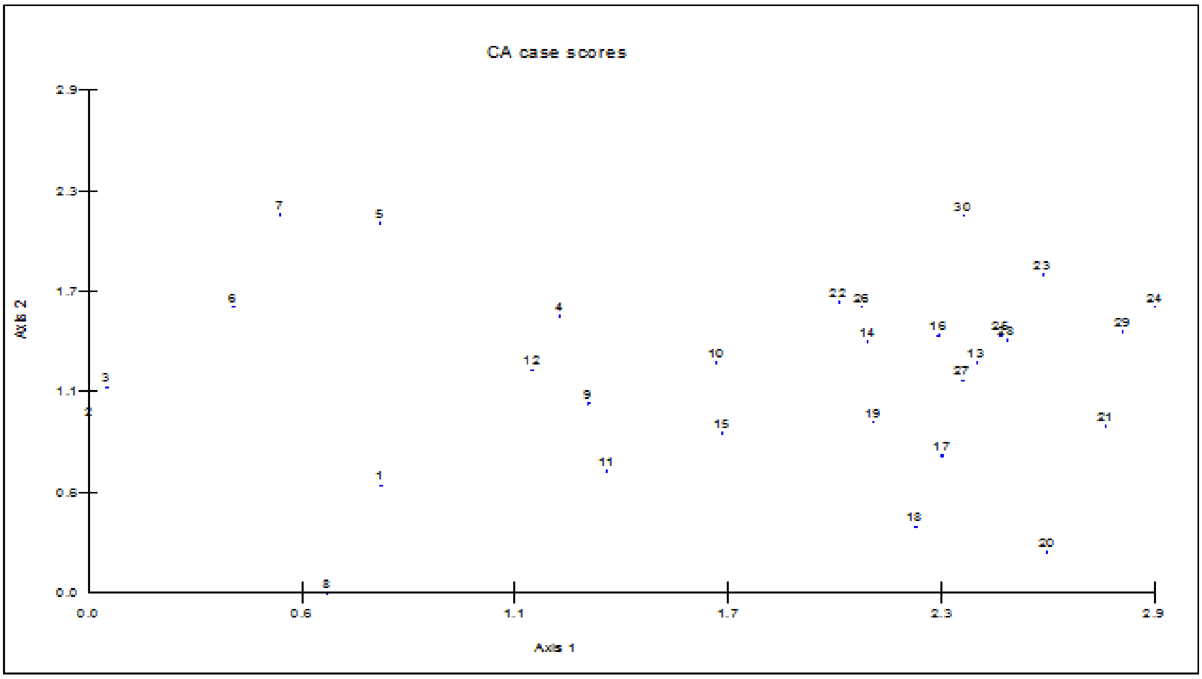

Fig. 1. Decorana (axes 1& axes 2) plot of the 27 stands from Kmalban. Stands are plotted individually and zones are shown in which each of the four associations, segregated by the cluster analysis.

Soil analysis

The sampling sites located at lower altitudes belonging to the association a showed a higher value of pH (7.76) than the sampling sites at higher altitudes belonging to D (6.71). These results reflected the altitudinal trends in soil pH which showed a gradual decrease with increasing altitude i.e from basic to acidic soils. A similar two-fold decrease in EC was observed as one moves 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 Cations and anions and clear exhibited a decreasing latitudinal trend. 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. Soil cations and anions showed significant differences with the altitudinal decrease.

Ordination

Indirect gradient analysis was performed for the total data set, using the ordination program Detrended Correspondence Analysis (DCA) (Braak, 1987). Rare species down-weighted. Eigenvalues for the four axes of ordination (the measure of their importance) are shown in Table 5. Axes 1 and 2 were most important with Eigenvalues 0.421 and 0.220 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.

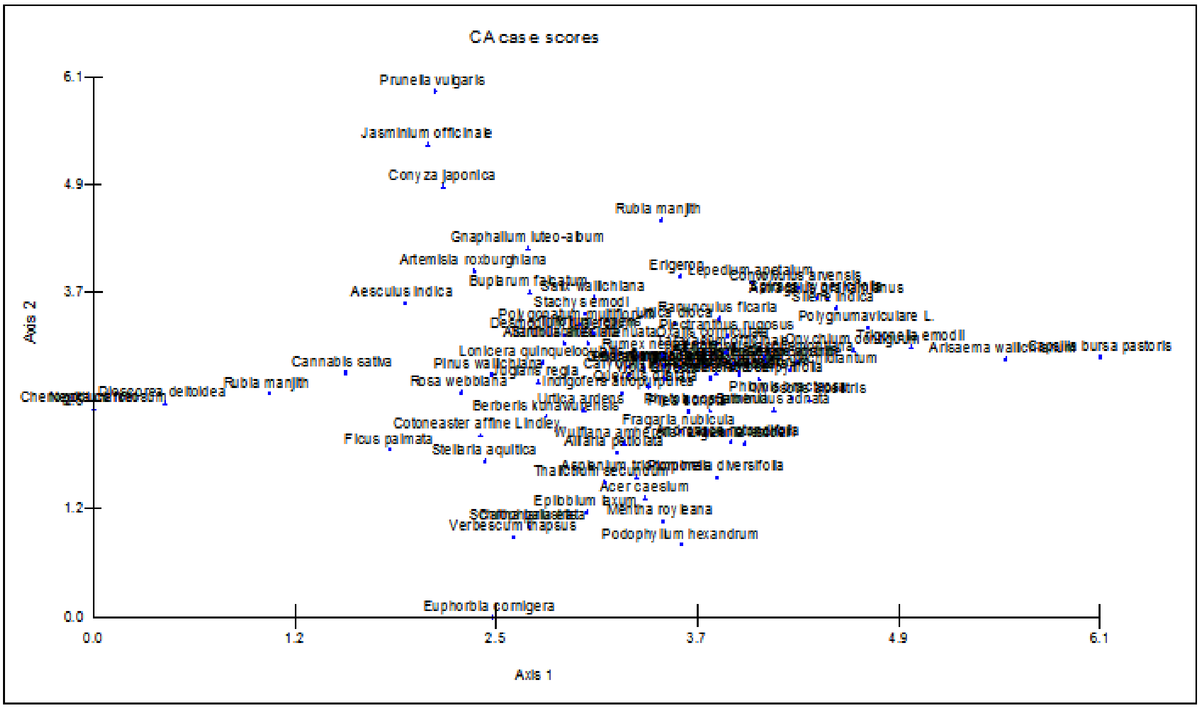

Fig. 2. Ordination of plant species along the DCA axis 1&2 among the 27 stands.

This was confirmed by Pearson's Rank Correlation with the ordination score along DCA axis I. There was a highly significant positive correlation (*r* = 0.944) between the sample scores along DCA axis 1 and altitude. These results suggested that the samples (low score) located at the far left-hand side of the ordination diagram belong to the associations occurring at low altitude and are characterized by having *Aesculus indica, Ailanthus altissima, Berberis kunawurensis, Bupleurum falcatum, Caltha palustris, Cannabis sativa, Chenopodium foliosum* , *Cotoneaster affine, Euphorbia cornigera, Jasminum officinale, Juglans regia, Lonicera quinquelocularis, Nepeta clarkei, Pinus wallichiana, Polygonatum multiflorum, Prunella vulgaris, Rosa webbiana, Rubia manjith, Salix wallichiana, Scrophularia frutescens, Myosotis alpestris, Trifolium repens, Urtica ardens* and *Verbescum thapsus* (Fig. 2). 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 *Acer caesium, Adiantum venustrum, Alliaria petiolata, Androsace rotundifolia, Arisaema wallichianum, Asplenium trichomanes, Astragalus grahamianus, Capsella bursa-pastoris, Caryophyllum reflexum, Cedrus deodara, Urtica ardens, Convolvulus arvensis, Cynoglossum glochidiatum, Delphinium roylei, Desmodium tiliifolium, Dryopteris ramosa, Epilobium laxum, Erigeron, Fragaria nubicola, Galium aparine, Geranium wallichianum, Hedera nepalensis, Impatiens edgeworthii, Indigofera atropurpurea, Ligularia fischeri, Lepidium latifolium*, *Mentha royleana, Micromeria biflora, Myosotis alpestris, Onychium contiguum, Oxalis corniculata, Paeonia emodi, Parrotiopsis jacquemontiana, Pilea scripta, Phlomis bracteosa, Phytolacca latbenia, Pimpinella diversifolia, Plantago major, Plectranthus rugosus, Poa alpina, Podophyllum emodi, Polygnum aviculare, Quercus dilatata, Ranunculus laetus, Rubia manjith, Rumex nepalensis, Sambucus wightiana, Silene indica, Spiraea hypericifolia, Stachys emodi, Strobilanthes attenuate, Taraxacum officinale, Thalictrum secundum, Trigonella emodi, Veronica serpylifolia, Viburnum grandiflorum, Viola rupestris* and *Wulfiana amherstiana* 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, Sodium concentration played a significant role in the distribution of plant species in the study area. Soil pH, Phosphorus and Sodium showed the negative while; Organic matter and soil Nitrogen were positively related to DCA axis 1. These results suggested the trends of abiotic factors and their relative importance in determining the vegetation type along with the altitude.

Discussion

Floristic structure

The study area (Kamalben Reserve forest) was dominated by evergreen conifers along with broad leaves trees, such as *Acer caesium, Ailanthus altissima* and *Quercus dilatata* were commonly recorded in the study area.

Among the conifers, Deodar, Blue Pine, Spur and Fir play a significant role in tree strata. Among the perennial shrubs *Berberis kunawurensis, Jasminum officinale, Lonicera quinquelocularis, Parrotiopsis jacquemontiana, Phytolacca latbenia, Rosa webbiana, Rubus biflorus, Salix wallichiana, Spiraea hypericifolia, Strobilanthes attenuata,* and *Viburnum grandiflorum* were recorded.

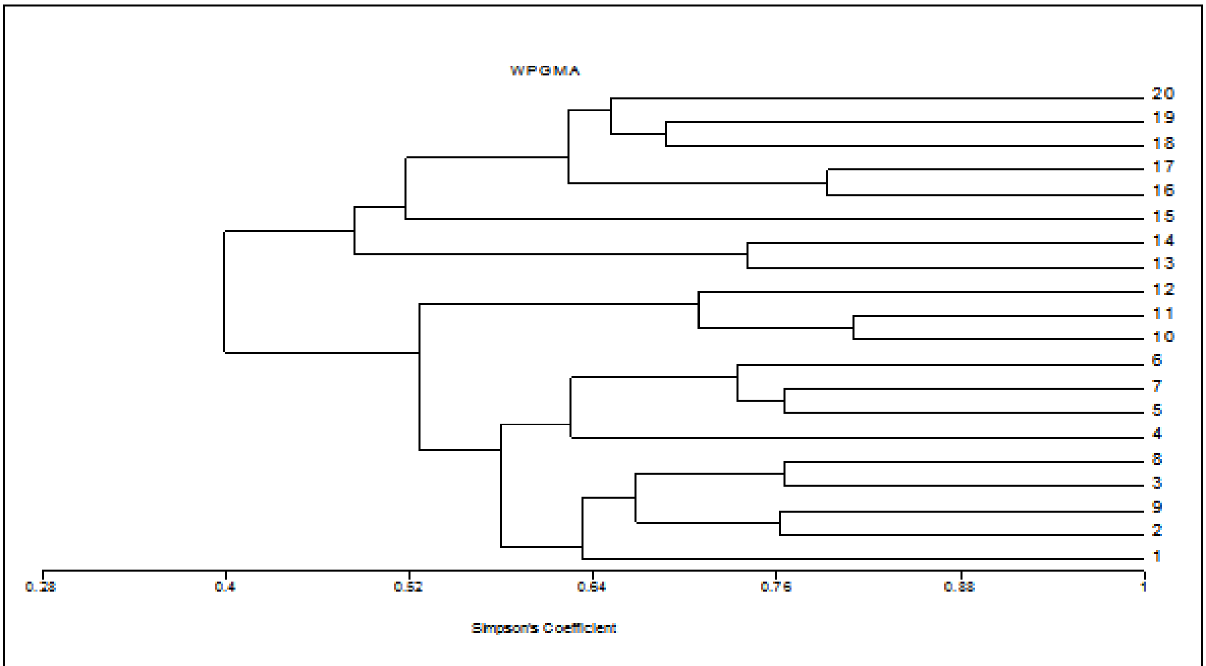

Fig. 3. Dendrogram obtained from Normal Cluster Analysis for 27 (Quantitative data).

Among the herbaceous flora, *Alliria petiolata, Androsace rotundifolia, Arisaema wallichianum, Astragalus grahamianus, Bupleurum falcatum, Calamintha vulgaris, Caltha palustris, Cannabis sativa, Capsella bursa-pastoris, Caryophyllum reflexum, Chenopodium foliosum, Convolvulus arvensis, Campanula pallida, Cynoglossum glochidiatum, Delphinium roylei, Dioscorea deltoidea, Epilobium laxum, Euphorbia cornigera, Ficus palmate, Fragaria nubicola, Geranium wallichianum, Hedera nepalensis, Impatiens edgeworthii, Lepidium latifolium, Ligularia fischeri, Mentha royleana, Micromeria biflora, Nepeta clarkei, Nepeta laevigata, Oxalis corniculata, Paeonia emodi, Phlomis bracteosa, Pilea scripta, Plantago major, Plectranthus rugosus, Poa alpina, Polygnum aviculare, Polygonatum multiflorum, Prunella vulgaris, Ranunculus laetus, Rubia manjith, Rumex nepalensis, Sambucus wightiana, Scrophularia frutescens, Silene indica, Myosotis alpestris, Taraxacum officinale, Thalictrum secundum, Trifolium repens, Trigonella emodi, Urtica ardens, Urtica dioica, Verbescum thapsus, Veronica serpyllifolia, Viola rupestris* and *Wulfenia amherstiana* were present frequently.

Community structure

The DECORANA results exhibited that elevation, soil reactions (pH), soil Electrical conductivity (EC), available anions and cations are the most important geo-climatic factors for assessment of the composition of plant communities (Table 6).

The occurrence of species across the elevational transects sustenance the individualistic hypothesis of community organization (Khan *et al.*, 2013). The role of altitude is not startling but is closely related with rainfall water redistribution in mountains temperate forests. Vegetation of the upper zone comprises of *Caryophyllum reflexum, Desmodium tiliifolium, Ligularia fischeri, Mentha royleana, Plectranthus rugosus, Nepeta levigata, Stachys emodi, Pilea scripta, Acer caesium, Alliria petiolata, Quercus dilatata, Trigonella emodi, Spirea hypericifolia, Polygnum aviculare, Convlulus arvensis, Capsella bursa-pastoris, Astragulus grahamianus* and *Arisaema wallichianum* while *Rubia manjith, Ficus palmate, Nepeta clarkei, Artemisia roxburghiana, Chenopodium foliosum, Dioscorea deltoidea, Prunella vulgaris, Caltha palustris, Euphorbia cornigera, Jasminum officinale, Verbescum thapsus* and *Scrophularia frutescens* 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; BiBi *et al.*, 2020).

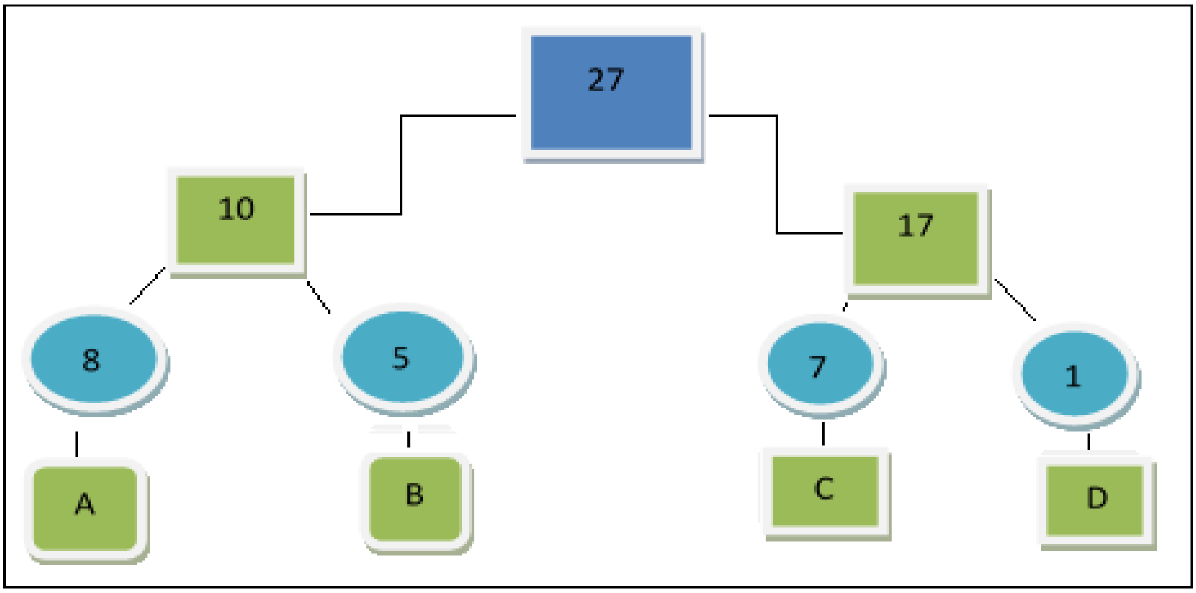

Fig. 4. The hierarchical classification on data of 27 strands obtained from Normal Cluster Analysis. Number of stands in each association is given in boxes.

Soil pH expresses important role in establishment defined plant groups across the elevation gradient. The species dominating in 'association A' prefer the relatively high pH as soil chemical reactions (pH) decreased with increase in elevation (Table 6). Thus the elevational vegetation distribution variations may mostly because of accumulation of nutrients along with water in lower slopes (Soethe *et al.*, 2008).

The results of statistical Pearson's correlation analysis showed a significant association between soil pH and distribution patterns of plant species which is already has been presented by several workers.

Conclusion

The results of present studies suggest a direct influence of elevation and indirect influence soil properties on composition. After the monsoon precipitation in mountains, the downslope movement of water also play important role in vegetation types and dominance pattern. Soil structure, texture and available soil moisture contents also cause the formation different niches that can be occupied by different species. Our results showed that all soluble soil cations and anions gradual decrease as gain in elevation it is due to down slope movement of water which transfers the greater amounts these soluble anions and cations to the forest zones located at lower elevation. 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 an important factor that governs the community structure in the mountain habitat. The complex gradients in edaphic conditions associated with topography provide an opportunity to conduct further research, both in the laboratory and the field.

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