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Vegetation patterns and composition of mixed coniferous forests along an altitudinal gradient in the Western Himalayas of Pakistan

Vegetationsmuster und Zusammensetzung gemischter Nadelwälder entlang eines Höhengradienten im westlichen Himalaya Pakistans

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Keywords: *Western Himalayan, vegetation composition, multivariate analysis, species distribution, correlation, Pakistan*

Schlüsselbegriffe: *Westlicher Himalaya, Vegetationszusammensetzung, multivariate Regression, Artenverteilung, Korrelation, Pakistan*

Abstract

The present study was conducted to quantify the diversity of species, boundaries of the plant communities along the altitudinal gradient and correlation between environmental factors and plant assemblage as little is known about the diversity and overall vegetation pattern of the study area. The study sites were located inside the Western Himalayan mixed coniferous forest at latitude ranging between 34°47'22"N 73°32'58"E in the Kaghan Valley (Pakistan). Altitude of the study sites ranges from 2100-3000 m a.s.l. The study area is characterized by having extensive development

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of coniferous species which follows a typical structural sequence along the altitudinal gradient. Vegetation parameters were recorded from 20 sites during field survey. Soil samples from each site were collected for determining soil physical and chemical properties. Classification and ordination was used to simplify the complex data set and to know the nature of boundaries of plant communities. Axes 1 and 2 of the Detrended Correspondence analysis (DCA) were used for data interpretation of both sites and species. Four diverse groups of plant species: 1 (down slope basiophyte communities), 2 (transitional communities), 3 (upslope subalpine communities), 4 (Hill top krummholz communities) were identified. Spearman's Rank Correlation Coefficient was used to detect relationship between environmental, soil variables and distribution of species in groups. The study suggests that the assemblage and distribution of the species are largely regulated by the altitude and concomitant changes in climatic and edaphic factors.

Zusammenfassung

Die vorliegende Studie wurde durchgeführt um die Diversität von Pflanzenarten sowie die Grenzen von Pflanzengemeinschaften entlang eines Höhengradienten zu untersuchen sowie die Korrelation zwischen Umweltfaktoren und Pflanzenaufkommen zu messen, da bisher nur wenig über die Artenvielfalt und allgemeinen Vegetationsmuster des untersuchten Gebietes bekannt ist. Das Untersuchungsgebiet befindet sich im gemischten Nadelwald des westlichen Himalayas (34°47'22"N 73°32'58"E) im Kaghan Valley (Pakistan) in einer Höhe von 2100-3000 m ü. NN. Dieses Gebiet zeichnet sich durch vielfaltiges Vorkommen von Nadelbäumen aus, deren Verteilung einen deutlichen Höhengradient aufweist. Die Vegetationsparameter der Felduntersuchung setzen sich aus Messungen an 20 verschiedenen Orten im Untersuchungsgebiet aus.

An jedem Untersuchungsort wurden Bodenproben entnommen, um die physischen und chemischen Bodeneigenschaften zu bestimmen. Klassifizierung und Ordination wurde verwendet um die komplexen Daten zu vereinfachen und um die Grenzen der Pflanzengemeinschaften zu bestimmen. Die Achsen 1 und 2 der Detrended Correspondence analysis (DCA) wurde für die Interpretation der Standorte der verschiedenen Arten verwendet. Vier unterschiedliche Gruppen von Pflanzenarten konnten identifiziert werden: 1 (Tieflagen-basiophyte Vorkommen), 2 (Übergangs-Vorkommen), 3 (Hochlagen-subalpine Vorkommen) und 4 (Gipfel-Krummholz Vorkommen). Mit Hilfe des Rangkorrelationskoeffizienten konnte die Beziehung zwischen Umweltvariablen (Standort) und der Artenverteilung aufgezeigt werden. Die Ergebnisse der Studie legen nahe, dass das Vorkommen und die Verteilung verschiedener Pflanzenarten nicht nur von der Höhe, sondern auch von klimatischen und edaphischen Bedingungen abhängt.

1. Introduction

The Himalayan part of Pakistan possesses an unusually rich flora due to the fact that this part of country remained undisturbed by man for a long period; this enabled many species to survive and to evolve. In this area, there is a great variation in the different type of flora even at short distances. In mountainous forests different factors play important role in the distribution and composition of plant communities e.g. altitude and closely linked edaphic and climatic factors (Gairola et al. 2008, Khan et al. 2011, Bhattarai et al. 2014), topographic heterogeneity (Zhong-hua et al. 2013, Wang et al. 2015), soil chemistry (Liberrman et al. 1985, Baillie et al. 1987, Piessens et al. 2006, Eiserhardt et al. 2011, Mishra et al. 2013), competition between different species for soil nutrients (Wang and Gong 1995, Garca-Aguirre et al 2007, He et al. 2013, Wang et al. 2014), forest productivity (Laamrani et al. 2014), soil texture (Davis et al. 1998, Dilustro et al. 2002) and availability of light (Liberrman et al. 1995, Li et al. 2011). Combination of these factors determines the conditions for the growth and thus the distribution of species. Among these factors, altitude had overriding importance in determining the species diversity, richness and distribution (Sharma et al. 2009, Karami et al. 2015, Kanagaraj et al. 2016, Zhang et al. 2016). Altitude also influences the availability of soil nutrients and water resources (Soethe et al. 2008, Ping et al. 2013) through redistribution of run-off. Dip and scarp and again concave and convex landscape often differ in moisture regime and consequently the overall flora. The accumulation of run-off takes place at various scales from small depression to large wades (run-on). Thus niches and habitats of various kinds and sizes are formed which determine the structure and composition of vegetation (Orshan 1986).

Ecologists try to understand the complex variations in species diversity and assemblage along the altitudinal gradient in mountainous ecosystem by using the various numerical techniques to reduce the complexity of the field data set (Bhattarai et al. 2014, Moser et al. 2008). The use of multivariate techniques such as gradient analysis has been rare to be applied to the vegetation data in general (Dasti et al. 2007, Malik and Hussain 2008, Wazir et al. 2008, Saima et al. 2009). Many studies have explored the changes in species richness and soil nutrient concentrations along altitudinal gradients by using numerical techniques (Chawla et al. 2008, Henrik et al. 2006, Ping et al. 2013, Karami et al. 2015, Zhang et al. 2016), few studies have considered this topic i.e. Devlal and Sharma (2008) reported tree species of Garhwal forest of Himalaya in India, Sharma et al. (2009) studied species diversity and richness in Garhwal forest of Himalaya in India and Bhattaraia et al. (2014) explored species diversity in Karnali river valley of Himalaya in Nepal and Wangchuk et al. (2014) studied species richness, diversity and density of Understory Vegetation in Himalaya forests situated in Bhutan. However, studies related to species diversity and richness using multivariate analysis of study area are lacking due to its remote location and inaccessibility.

The objectives of current study are to investigate how far the topography and edaphic variability influence the attributes of the plant communities and species spatial distribution and to investigate the link between environmental factors and plant assemblage and species distribution along the altitudinal gradient.

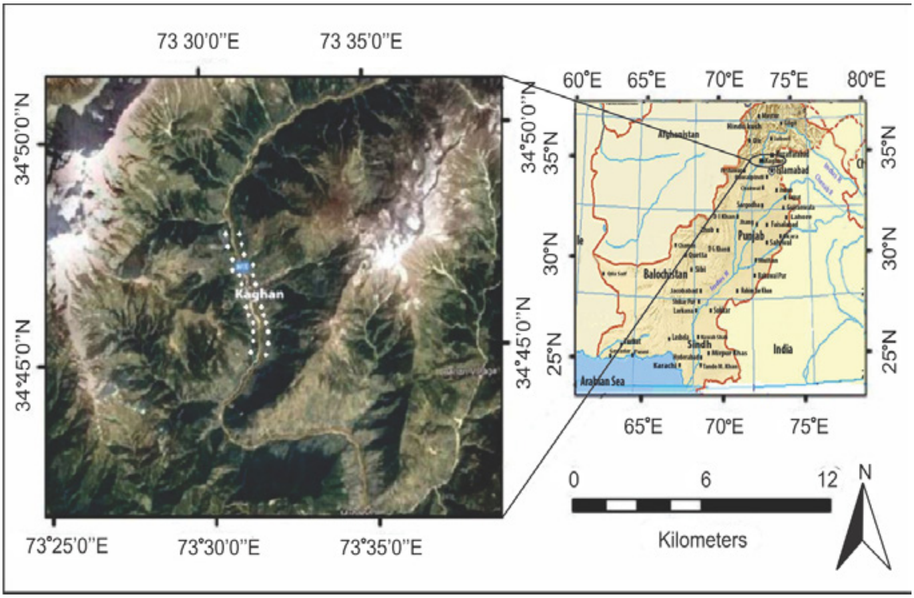

Figure 1: Map of Pakistan, showing the location of the study area (Red arrow indicate the location of weather station).

Abbildung 1: Karte von Pakistan mit dem Standort des Untersuchungsgebietes (roter Pfeil zeigt den Standort der Wetterstation an).

2. Material and Methods

2.1 Study Area

The study area is located in one of the temperate forests in Kaghan valley (Pakistan). These reserve forests are the largest protected areas of the country. Overall, human disturbances and clearing are currently sparse, and most of the forest is undisturbed. The vegetation in the study area corresponds to the siono – Japanese phytogeographical region. Physiognomically it consists of thick canopy forestland in which conifers i.e. *Pinus*, *Cedrus* and *Abies* are the dominant taxa. The herbaceous vegetation appears during summer months and persists as green forage for 3-5 months (till late September). The flora is highly diverse mostly composed of annual forbs. The studied forests are located at 34°47'22"N 73°32'58"E along the river Kunhar (Fig 1, obtained from forest department). Altitude of the study plots ranges from 2100-3000 m a.s.l. It is classified as wet temperate forest. According to 20 years record of the nearest weather station (Abbottabad at 1256m a.s.l.) the average annual rain fall is 1462 mm, distributed evenly throughout the area and annual average temperature is 18.6oC (20 years record). The highest temperature is 30oC in June and lowest is -3oC in January and December (Fig 2). Snow slides often occur and wipeout strips of forest along their course (Champion et al. 1965). The average winter accumulation of snowfall in the study area is recorded 300-450 cm (local Forest Department). The annual rain fall and the extent the snow determine the distribution of forest species in the study area (Champion et al. 1965).

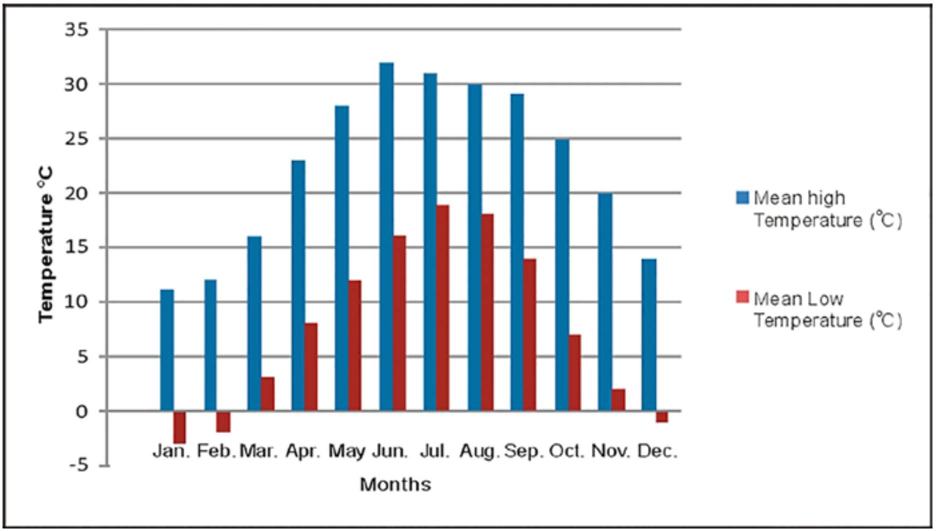

Figure 2: Average high and average low annual temperature in (°C) of the study area (data from nearby metrological station, Abbottabad).

Abbildung 2: Durchschnittliche Maximal- und Minimaljahrestemperatur in °C des Untersuchungsgebietes (Daten von der nahe gelegenen meteorologischer Messstation in Abbottabad).

Soils of the study area are poorly known. Geological maps indicate that the area cover most of the rock formations of the Himalayas and so occur chiefly on Gneisses and Schists, extended over quartzites granites, limestones, conglomerates and shales (information collected from department of geological survey of Pakistan). The soil likewise shows a wide range, but loams probably predominate. The soil pH ranges from acidic to neutral. Snow-break caused by wind and trees overloaden with snow is frequent and can created fairly large gaps.

2.2 Vegetation and Soil sampling

After repeated field surveys during April, June and September in 2016, 20 sites were selected randomly along the altitudinal gradient which cover the range of vegetation variation. Each sampling location was at least one km from every other sampling location along the altitudinal gradient. At each site five randomly placed 10 x 10 m quadrates for trees, data for shrubs were collected from four 4 x 4 m quadrats within the plot, and data for herbs were collected from 1 x 1 m quadrats along a diagonal of each shrub quadrat were fully surveyed. All the vascular plants were identified and recorded. Thus a total of 100 sub-samples were obtained containing 110 species. The taxonomy of the plants was more difficult than first anticipated, with many more species encounter than expected. In particular there were many groups with very similar species that could only be sorted accurately in the laboratory. A complete set of collection from the plot is now deposited in M. H. Bokhari herbarium Bahauddin Zakariya University Multan, Pakistan. We have identified the plants with the help of flora of Pakistan (Ali and Nasir, 1990–1992, Ali and Qaiser, 1993– 2009). The environmental variables such as altitude, humidity, aspect were collected at each site using Kestrel 4300, Japan.

From each site soil samples (0 -10 cm) were taken at three different points randomly and mixed into a composite sample. Gravels were separated by sieving through 2 mm mesh. Three subsamples were drawn from this composite sample. A portion of each composite was oven dried at 105 oC for 48 hours to determine gravimetric water content. Concentrations of exchangeable potassium, sodium and calcium were determined by flame photometer (PFP-7, Jenway Ltd. Felsted, Dunmow, Essex, U). Organic matter was determined of fresh soil by the Walkley- Black wet digestion method (Nelson and Sommers 1982). Total nitrogen was digested by the micro kjeldahl procedure with concentrated Sulphuric acid, and determined calorimetrically. Soil pH was measured on a 1: 1 fresh soil to de-ionized water solution. Soil conductivity was measured using conductivity meter (CM- 30 ET digital EC meter). The amount of available P was determined Spectro-photomatrically (Olsen et al. 1954), Soil chloride was determined using a chloride analyzer (Sherwood, Model 926). Magnessium, carbonate and bicarbonate contents were determined by titration method following Hussain (1989) and Richard (1954).

2.3 Data analysis

Classification of the vegetation data was performed using Cluster Analysis on untransformed species presence absence data. Data were clustered based on agglomerative clustering method Hill (1979) and Causton (1988) incorporating Euclidian distance as coefficient of similarity/dissimilarity. Sites (stands) which were more similar in their vegetation structure were depicted as being closer together in the hierarchical diagram. Sites that differ in score can be expected to have no species in common (Jongman et al. 1987). In order to show the possible intrinsic pattern in sites data set, site ordination through Detrended Correspondence Analysis (DCA) based on presence/absence data of these species, was applied. The default option (down weighted rare species) of the program DECORANA (Hill and Gauch 1980) was used to analyze the magnitude of change in species composition along the ordination axes. Rare species (those with relative frequency less than 1) were omitted from the analysis, and default options were used. The Eigen values obtained for DCA axis 1 and 2 was relatively greater than the subsequent axes. As DCA axis I and II explained most of the variations in the data set, only these axes were considered for further analysis. Scatter of classification groups from both procedures were plotted on overlays of ordination axes to assess the compatibility of the two methods of data simplification (Dargie and Demerdash 1991, Dasti and Agnew 1994). Species diversity was estimated from Shannon diversity index for all 20 sites by following Pielou (1975). Scores on DCA axes 1 and 2 were used to test the relationship between variation in soil characteristics and distribution of plant species using Pearson correlation. Multivariate Statistical Package (MVSP version 3.1) and MINITAB-14 was used for these analyses.

The differences in soil parameters between the plants communities were estimated by using the analyses of variance (ANOVA). The percent data were normalized by an arcsine transformation prior to analyses of variance. Duncan multiple range tests were used to detect and compare any significant difference between the means of soil parameters of different communities at the 5% level of significance. The relationships between soil characters and DCA axes I and II were determined using Spearman Rank correlation (Causton 1988).

3 Results

3.1 Floristic composition

In total 54 families having 99 genera and 110 species were recorded from the study area. Angiosperms contributed a major share to the floristic richness of the area. Among the life forms, herbs were dominant (78 %) followed by shrubs (16 %) and trees (10 %). The important trees were *Abies pindrow, Aesculus indica, Acer caesium, Cedrus deodara, Picea smithiana, Populus ciliata, Quercus dilatata* and *Pinus wallichiana*. The shrubs included *Desmodium tiliaefolium, Berberis kunawrenis, Indigofera atropurpurea, Hypericum oblongifolium, Viburnum cotinifolium, Salix daphneoides* and *Sorbaria tomentosa*. Important species in the herb layer were *Arisaema wallichianum, Calamintha vulgaris, Epilobium cylindricum, Fragaria indica, Galium boreale, Geranium rotundifolium, Indigofera atropurpurea, Myosotis alpestris, Origanum vulgare, Poa alpina, Polygonum hydropiper, Primula involucrata, Rumex nepalensis* and *Viola biflora*.

3.2 Major vegetation groups and environmental variability

Results of the numerical analyses of floristic data showed four major vegetation groups: group 1 (down slope basiophyte communities), group 2 (transitional communities), group 3 (upslope subalpine communities), group 4 (Hill top krummholz communities). The presence of *Achillea millifolium, Aesculus indica, Berberis kunawurenis, Cedrus deodara, Oxalis corniculata, Plantago major, Strobilanthes attenuatus* in the first two groups clearly separates them from group 3 and 4 in which these species were altogether absent. Further subdivision at lower information gains were regarded as minor variants and were not considered (Fig 3). The vegetation communities are described briefly in the context of major discriminating species. The composition of these groups is summarized in Table 1.

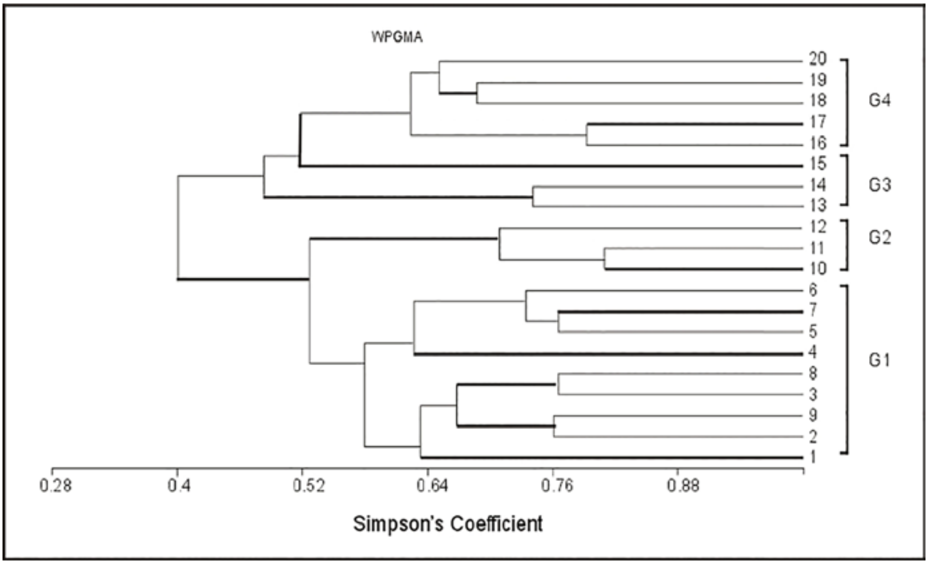

Figure 3: Dendrogram obtained from Agglomerative Hierarchical Clustering (AHC) for 20 sites (Qualitative data).

Abbildung 3: Dendrogramm von Agglomerative Hierarchical Clustering (AHC) für 20 Standorte (Qualitative Daten).

3.2.1 Group 1: Downslope basiophytic communities

This group is interpreted as an assemblage of basiophytic species. The characteristic species of this community are *Myriactis wallichii, Clematis montana, Bupleurum falcatum, Conyza japonica, Malva neglecta, Verbascum thapsus, Sedum ewersii, Medi-*

cago minima, Silybum marianum, Sarcococcca saligna and *Desmodium tiliaefolium*. This community is mostly restricted to soils with high pH, low organic matter and relatively high proportion of Phosphorus (Table 2). Healthy *Fragaria indica, Galium boreale, Pinus wallichiana* and *Viburnum cotinifolium* are the most frequent plants of this community (Table 1)

3.2.2 Group 2: Midslope Transitional communities

This group represents a transition from down slope basiophytic communities to up slope acidophytic communities. These communities share more than 80% species with group 1 and 50% with group 3 and 4. The component species occur in variety of habitats in terms of soil moisture, soil pH and nutrient input. This group is interpreted as an assemblage of generalists.

Table 1: Relative frequency of the species in each association identified from the Agglomerative Hierarchical Clustering (AHC), arranged in ascending order of DCA score, axis 1. Species having frequency value less than 1 are represented by •

Tabelle 1: Relative Häufigkeit der Arten in den vier Gesellschaften, identifiziert mittels agglomerativen hierarchischen Clustering (AHC), sortiert in aufsteigender Reihenfolge des DCA-Punktes, Achse 1. Arten mit einem Häufigkeitswert von weniger als 1 werden durch • dargestellt

Species	Group 1	Group 2	Group 3	Group 4
Abies pindrow	-----	3.03	2.298	3.049
Acer caesium	-----	-----	3.448	-----
Achillea millefolium	1.581	-----	-----	-----
Acontum hetrophyllum	-----	-----		1.829
Adiantum venustum	1.976	1.01	1.149	1.829
Aesculus indica	2.371	1.01	-----	•
Ajuga parviflora	•	2.02	-----	-----
Arabidopsis thaliana	-----	-----	1.149	1.219
Arenaria festucoides	-----	-----	1.149	1.219
Arisaema wallichianum	1.976	4.04	1.149	1.219
Aster falconeri	-----	-----	-----	1.829
Berberis kunawurenis	1.976	1.101	-----	-----
Bergenia ciliata	-----	-----	-----	1.829
Brachiaria eruciformis	1.185	-----	-----	-----
Bupleurum falcatum	•	-----	-----	-----
Calamintha vulgaris	1.976	4.04	1.149	1.829
Cannabis sativa	•	-----	-----	-----
Cedrus deodara	1.976	2.02	-----	-----
Celtis eriocarpa	•	-----	1.149	-----
Chenopodium foliosum	•	-----	-----	-----
Clematis montana	•	-----	-----	-----
Convolvulus arvensis	•	-----	-----	-----

Conyza japonica	•	-----	-----	-----
Corydalis stewartii	-----	-----	-----	•
Cuscuta reflexa	•	-----	-----	-----
Desmodium tiliaefolium	1.581	-----	-----	-----
Dryopteris ramosa	2.766	3.03	2.298	1.219
Epilobium cylindricum	•	1.01	2.298	1.829
Eragrostis poaeoides	-----	-----	2.298	1.219
Euphorbia cornigera	-----	-----	-----	3.049
Euphorbia wallichii	-----	-----	-----	1.829
Fragaria indica	3.162	4.04	3.448	3.049
Fragaria vesca	•	1.01	-----	-----
Galium boreale	3.162	3.03	3.448	•
Gentiana kurroo	-----	-----	1.149	1.829
Geranium rotundifolium	2.371	4.04	1.149	•
Geranium wallichianum	1.976	4.04	2.298	1.829
Geum urbanum	•	-----	-----	•
Hedera nepalensis	2.766	3.03	-----	-----
Hypericum oblongifolium	•	-----	-----	------
Impatiens bicolor	1.976	-----	1.149	•
Impatiens brachycentra	0.395	-----	-----	-----
Indigofera atropurpurea	2.766	3.03	1.149	-----
Inula grandiflora	•	2.02	-----	•
Iris hookeriana	•	-----	------	2.439
Jaeschkea canaliculata	-----	-----	-----	2.439
Jasminum officinale	-----	-----	1.149	------
Lactuca brunoniana	-----	-----	2.298	-----
Lavatera kashmiriana	-----	-----	1.149	-----
Lecanthus peduncularis	•	-----	2.298	-----
Leontopodium alpinum	-----	-----	2.298	•
Lamium album.	-----	-----	1.149	1.219
Malva neglecta	•		-----	------
Medicago minima	1.185	------	-----	------
Mentha longifolia	•	-----	-----	-----
Myriactis wallichii	•	------	------	------
Mysotis alpestris	1.976	2.02	2.298	3.049
Nepeta erecta	1.976	1.01	1.149	1.219
Nepeta govaniana	•	------	1.194	•
Neslia paniculata	•	------	------	-----
Origanum vulgare	-----	2.02	1.149	1.219
Oxalis corniculata	•	3.03	-----	-----
Paeonia emodii	-----	-----	3.448	1.219
Phytolacca latbenia	•	-----	2.298	-----
Picea smithiana	•	3.03	1.149	2.439
Pinus wallichiana	3.162	4.04	-----	3.049
Plantago lanceolata	•	1.01	1.149	1.829
Plantago major	1.581	1.01	-----	-----
Poa alpina	1.185	4.04	2.298	•
Podophyllum hexandrum	•	1.01	1.149	2.439
Polygonum amplexicaule	1.581	2.02	-----	-----
Polygonum hydropiper	1.976	-----	2.298	3.049
Populus ciliata	-----	-----	-----	•
Potentilla gerardiana	•	3.03	2.298	2.439
Potentilla nepalensis	•	3.03	1.149	2.439

Primula involucrata	-----	------	3.448	3.049
Prunella vulgaris	-----	3.03	1.149	3.049
Quercus dilatata	•	-----	-----	-----
Ranunculus diffuses	1.185	2.02	-----	1.219
Rosa moschata	1.581	-----	-----	-----
Rosa webbiana	•	-----	2.298	•
Rubia manjith	1.185	-----	-----	-----
Rubus biflorus	•	------	------	-----
Rumex nepalensis	1.976	4.04	3.448	2.439
Salix acmophylla	-----	-----	-----	•
Salix daphnoides	•	------	------	-----
Salvia nubicola	------	-----	2.298	-----
Sambucus wightiana	-----	-----	-----	•
Sarcococcca saligna	•	-----	-----	-----
Sauromatum guttatum	-----	-----	3.448	1.219
Sedum ewersii	•	-----	-----	-----
Senecio chrysanthemoides	-----	-----	1.149	3.049
Silybum marianum	1.185	-----	-----	-----
Sorbaria tomentosa	•	-----	-----	-----
Spiraea vaccinifolia	•	-----	-----	•
Stachys sericea	-----	-----	-----	-----
Strobilanthes attenuates	7.9	1.01	-----	-----
Taxus baccata	-----	-----	-----	•
Thalictrum foliosum	•	1.01	1.149	-----
Thymus linaris	-----	-----	-----	•
Traxacum offcinale	•	3.03	1.149	
Trifolim repens	-----	1.01	-----	•
Trifolium pretense	1.185	1.01	-----	1.219
Urtica dioica	•	-----	-----	-----
Verbascum thapsus	•	-----	-----	-----
Veronica bilobia	-----	1.01	3.448	1.219
Viburnum cotinifolium	3.162	4.04	3.448	3.049
Viola biflora	1.581	1.01	3.448	3.049
Wulfenia amherstiana	-----	-----	2.298	2.439

3.2.3 Group 3: Up slope acidophytic communities

This group represents the communities of upslope subalpine habitat. These communities occur in acidic soils (pH 6.8) rich in organic matter and total available nitrogen, but poor in phosphorus calcium and magnesium. The major species in these communities are *Acer caesium, Fragaria indica, Galium boreale, Paeonia emodi, Primula involucrata, Rumex nepalensis, Sauromatum guttatum, Veronica bilobia, Viburnum cotinifolium* and *Viola biflora*. The characteristic species linked to this community are *Jasminum officinale, Lactuca brunoniana, Lavatera kashmiriana* and *Salvia nubicola*, which were absent in groups 1 or 2.

3.2.4 Group 4: Hill top krummholz communities

This group represent the communities of alpine tree-line ecotone and follows the typical structural sequence growth forms along the altitudinal gradient, starting with vertical trees close to the timberline or forest limit (2600 m a.s.l.) to krummholz above the tree line (2700 m a.s.l.). Individuals of *Pinus wallichiana, Abies pindrow* and *Picea smithiana* represent most of the stems larger 2 m in height. The soils of these communities have a low pH of about 6.2. The associated species are almost restricted to these habitats (Table 1).

Table 2: Mean values ± standard deviation and F Values for all soil variables for the four communities identified by the Agglomerative Hierarchical Clustering (AHC). Differences between groups were assessed by Duncan multiple range test.

Tabelle 2: Mittelwerte ± Standardabweichung und F-Werte der Bodenvariablen für die vier durch das Agglomerative Hierarchical Clustering (AHC) identifizierten Gesellschaften. Unterschiede zwischen den Gruppen wurden durch Duncan-Multiple-Range-Test bewertet.

Variables	Group 1	Group 2	Group 3	Group 4	F-value
No. of species	22±11.08	24±4.5	29±2.64	33±2.39	1.96^{NS}
Altitude(m)	2310±63.4	2400±41.1	2730±80.3	3000±36.0	174.23***
Soil pH	7.67±0.32	6.6±6.430	6.38±0.29	6.2±0.17	27.06***
Electrical Conductivity dSm $^{-1}$	2.08±0.67	1.22±0.16	2.22±0.94	1.37±0.09	3.54*
Soil Saturation %	49.12±2.03	50.25±4.11	52.33±3.79	48.8±3.83	0.91^{NS}
Organic Matter %	2.01±0.02	2.02±0.07	2.11±0.08	2.08±0.008	5.21**
Nitrogen ppm	0.12±0.001	0.12±0.004	0.13±0.002	0.13±0.001	5.19**
Phosphorus ppm	0.27±0.023	0.28±0.04	0.26±0.03	0.22±0.01	3.38*
Potassium ppm	1.27±0.28	1.32±0.23	1.56±0.31	1.21±0.11	1.41^{NS}
Calcium ppm	0.54±0.094	0.45±0.1	0.48±0.005	0.48±0.08	1.13^{NS}
Magnessium ppm	0.22±0.03	0.25±0.08	0.19±0.02	0.18±0.02	2.04^{NS}
Sodium ppm	0.39±0.05	0.31±0.08	0.28±0.005	0.29±0.12	2.72*
Chloride ppm	0.41±0.04	0.46±0.08	0.38±0.4	0.39±0.01	0.90^{NS}
Carbonate ppm	2.26±1.24	2.27±1.03	2.56±0.25	1.47±0.25	1.08^{NS}
Bicarbonate ppm	46.63±23.05	33.75±23.61	40.33±3.21	51.6±9.48	0.97^{NS}

3.3 Plant distribution

The DCA revealed considerable differences in habitat preferences of the plants studied, with downslope basic soils to upslope acidic soils being the most distinct habitats (Fig 4). The first and second axis accounted for 23.5% and 17.5% respectively, of total variability in species composition, whereas the third and fourth axis accounted for only 4.3% and 2.4% respectively (Table 3). This shows that the first two axes, taken together, can be regarded as a reasonably good characterization of species spatial distribution. DCA axis 1 was positively related to altitude (Table 4), suggesting that species composition and/or abundance were different in plots at different altitude.

Table 3: Eigen value and Cumulative percentage of DCA axes 1-4.

Tabelle 3: Eigenwert und kumulativer Prozentsatz der DCA-Achsen 1-4.

Axes	Eigenvalue	Percentage	Cum.Percentage
1	0.360	23.544	23.544
2	0.116	17.551	31.095
3	0.066	4.343	35.438
4	0.037	2.445	37.883

Beside the altitude, DCA axis 1 was significantly related to soil factors. As the DCA 1 scores were correlated to the soil pH, total nitrogen and phosphorus (Table 4), indicating that plants benefiting from low pH, high total nitrogen were less common at sites with high pH and low nitrogen. The results suggested that much of the variability is continuous and associated with altitude, soil pH and nutrition input (Fig 4). Species ordination reveals that the species occupying the far left end were *Conyza japonica, Sarcocca saligna, Arabidopsis thaliana, Mentha longifolia, Acer caesium, Salix acmophylla, Bupleurum falcatum, Cannabis sativa, Lactuca brunoniana, Corydalis stewartii, Urtica dioca, Impatiens brachycentra, Populus ciliata, Lavatera kashmiriana, Myriactis wallichii*, and right hand included *Euphorbia cornigera, Aster falconeri, Neslia paniculata, Celtis eriocarpa, Medicago minima, Clematis montana, Sambucus wightiana, Convolvulus arvensis, Rubus biflorus, Euphorbia wallichii, Hypericum oblongifolium, Iris hookeriana, Malva neglecta, Sorbaria tomentosa, Verbascum thapsus*. The remainders of the species occupy ordination positions that suggest a lack of any association to the site configuration along the gradient. These are identified as habitat generalists as a group. The distribution of *Arisaema wallichianum, Calamintha vulgaris, Epilobium cylindricum, Fragaria indica, Galium boreale, Geranium rotundifolium, Geranium wallichianum, Myosotis alpestris, Nepeta erecta, Origanum vulagre, Pinus wallichiana, Poa alpina, Rumex nepalensis, Trifolium pratense, Viburnum cotinifolium* and *Viola biflora* are particularly note-worthy. Among these species *Epilobium cylindricum, Myosotis alpestris* and *Viola biflora* show marked increase in frequency as they move from basic to acidic habitats while *Fragaria indica, Nepeta erecta, Origanum vulagre, Pinus* *wallichiana* and *Rumex nepalensis* were able to maintain their frequency in all sites. *Arisaema wallichianum, Calamintha vulgaris, Galium boreale, Geranium rotundifolium, Geranium wallichianum, Poa alpina, Trifolium pratense* and *Viburnum cotinifolium* showed a pattern of decreasing frequency of occurrence extending from basic to acidic conditions. These species were absent in alpine krummholz zone.

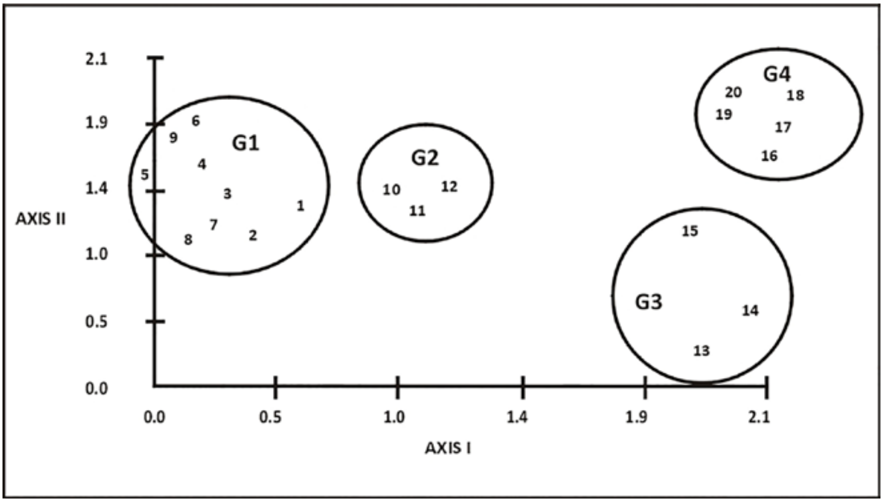

Figure 4: DECORANA (axes 1& 2) plot of the 20 sites from study area. Circles are plotted as overlay of four associations, segregated by the Agglomerative Hierarchical Clustering (AHC).

Abbildung 4: DECORANA-Diagramm (Achsen 1 und 2) der 20 Standorte aus dem Untersuchungsgebiet. Kreise werden als Überlagerung von vier Assoziationen gezeichnet, die durch das Agglomerative Hierarchical Clustering (AHC) getrennt sind.

The second axis accounted for an additional percentage of the variance and explained additional variation primarily among the sites and possibly the site-specific factors operating a smaller scale such as variation in soil moisture regime of certain partially drained sites that collect the seasonal runoff and support the mesic species. Because the DCA axis encompassed most of the variation in the data set and clearly reflected altitudinal gradient, we related species and sites distribution to the first axis.

Table 4: Pearson's correlation coefficients between DCA first and second axes, Soil parameters and altitude.

Tabelle 4: Pearsons Korrelationskoeffizienten zwischen DCA erster und zweiter Achse, Bodenparameter und Höhe.

Parameters	Axis I	Axis II
Altitude(m)	0.944***	0.212^{NS}
pH	-0.713***	-0.057^{NS}
Electrical Conductivity dSm^{-1}	-0.205^{NS}	-0.696**
Organic matter %	0.692**	-0.209^{NS}
Soil Saturation	0.187^{NS}	-0.604**
Nitrogen ppm	0.705**	-0.041^{NS}
Phosphorus ppm	-0.514*	-0.041^{NS}
Potassium ppm	0.029^{NS}	-0.306^{NS}
Calcium ppm	-0.217^{NS}	-0.310^{NS}
Magnesium ppm	-0.396^{NS}	-0.151^{NS}
Sodium ppm	-0.522*	-0.135^{NS}
Chloride ppm	-0.118^{NS}	-0.304^{NS}
Carbonate ppm	-0.187^{NS}	-0.371^{NS}
Bicarbonates ppm	0.087^{NS}	0.223^{NS}

3.4 Soil Fertility and Species Diversity and Richness

The soils of the four groups delineated by the cluster analysis showed significant differences in most of the soil parameters (Table 2). The soils of group 1 showed significantly highest pH (7.5), and the lowest was found in sites belonging to groups 3 and 4 which were not significantly different between themselves. Soils of the sites belonging to group 2 were somewhat neutral in reaction. The total phosphorus and chlorides followed the same trends. All these soil chemical properties decreased with the increase of the altitude. Opposite trends were observed for total available nitrogen, sodium and magnesium (Table 2). These nutrients show highest concentration in the lower altitude groups' intermediate values in the mid while highest values were observed at the highest altitude. No significant differences were observed in carbonates, bicarbonates, calcium, potassium and soluble salts.

The nutrient rich basic soils of the highest altitudes showed highest diversity and species richness and number of species per stand is also higher than the lower ones (Figure 5). The krummholz communities had significantly higher values of diversity than the rest which do not differ between themselves.

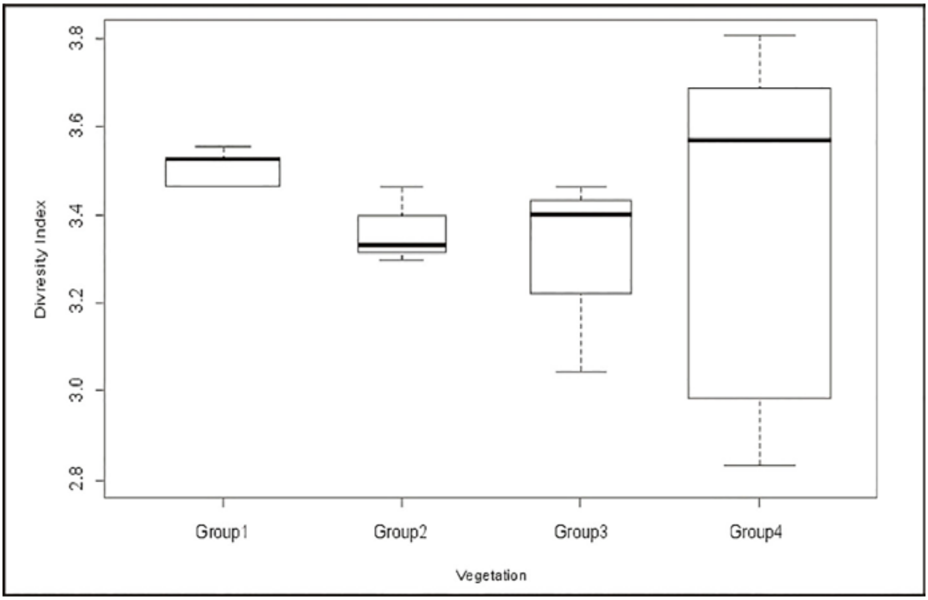

Figure 5: Boxplot showing the diversity index in the four communities identified by Agglomerative Hierarchical Clustering (AHC).

Abbildung 5: Boxplot zeigt den Diversitätsindex in den vier durch Agglomerative Hierarchical Clustering (AHC) identifizierten Gemeinschaften.

4. Discussion

Two major factors that influence the species diversity and composition in this study are altitude and soil pH. Although not highly significant, the relatively high species richness on the hilltop communities may have been the result of low pH that improved germination condition for seeds of herbaceous flora, on the other hand reduced the growth of conifers as they need an acid soil (Franklin and Bergman 2011). Our results showed a negative correlation between soil pH and species richness also agreed by Sahu et al. (2012) who showed a negative correlation between soil pH and tree density but contradicted by Jiang et al. (2016). The decline of species richness at lower slopes (Downslope basiophytes communities) might be due to the exclusion of light demanding species by the closing of tree canopy (Li et al. 2011). On the other hand at upper slopes the krummholz act as nurse plants to protect the establishment of herbaceous species. Our findings revealed that these forests have low number of species and diversity never surpasses the four. This is either natural or forests may have experienced great habitat loss.

Altitude is a determining factor of processes in mountains forests (He et al. 2016) and predicts community composition of the study area. Many species changes in abundance (% frequency) along the altitudinal gradient, and there are several species that partitioned the topographic niches very precisely (Table 1). Corresponding with species turn over, forest structure also changes from downslope to hilltop; the hilltop had stunted krummholz of *Abies pindrow* and *Pinus wallichiana* with less basal area and a lower canopy of less than 2 m height. We quantified the abundance differences across the altitudinal range, and classified species relative to the altitude using contrast between upper slopes and lower slopes. A quarter of the species differ less than 1.5 fold in frequency from upper to lower slopes and thus appear to be generalists.

Soil fertility also displayed a gradient across the four altitudinal communities delineated by the numerical analysis. Significant differences were found in several edaphic variables between these vegetation types. The increase in the amount of organic matter and extractable nitrogen in upslope communities indicates slower decomposition rates by low temperature at higher altitude than the lower slopes. Similar trends were found by previous research (Schindlbacher et al. 2010, Reich et al. 2011, Moretto and Martinez-Pastur 2014, Zachariah et al. 2015). Here the accumulation of organic matter caused lowering of pH and probably excluded the basiophytes occupying the niches at lower slopes with significantly high pH. Significantly higher extractable phosphorus at lower slopes compare to upper slopes indicates the accelerated rate of decomposition and accumulation of run off cations. The continuous negative relationship of calcium, magnesium and phosphorus along the altitudinal gradient suggested that acidiophytes were indirectly limited by soil nutrients and phosphorus. The relatively high nutrient and phosphorus availability indirectly allowed the basiophytes to inhibit the germination and seedlings survival of acidiophytes in high pH environment. These results emphasize the essential role of soil chemistry in determining the distribution trends of the plant species and shaping of the plant communities along the altitudinal gradient. This is in line with previous research (Dasti et al. 2007, Saima et al. 2009, Narhi et al. 2011, Hossain and Nuruddin 2016).

Conclusion

The present study highlights species richness, vegetation patterns and community composition in the forest area at various altitudes. Our findings revealed that at lower elevations tree cover is dense, had comparatively lower 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 from topography and thereof the redistribution of rain water or melting snow which effect the plant assemblage and overall species richness. Significant negative correlation of species richness with pH and positive with altitude suggests the influence of these environmental factors on species richness and overall vegetation. The significant negative correlation of soil pH with DCA axis I suggest that sampling sites located at high elevation tend to accumulate less amount of bivalent ions (Ca and Mg) resulting in less release of H+ and a decrease in pH. Soil EC of the sampling plot showed a significant but negative correlation with DCA axis II. Thus the distribution of species along DCA axis II is determined largely by soil chemistry. However, further research is needed to elucidate the relationships.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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