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Distribution of roadside plant communities along the altitudinal gradient in pine forests, Pakistan

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Abstract

In mountainous areas, road construction is accompanied by large-scale physical disturbance that drastically modify the landscape. Road construction and cutting process of mountains removes soil and rock from the hillside above the proposed road, while soil and rock are deposited on the down-slope area. The resultant roadsides are highly disturbed habitats characterized by plant communities maintained at an early successional stage. The present research was conducted along the roadside, consisting of Nathia Gali (Temperate forest), Abbottabad (Tropical forest) and Thandiani Valley (Sub alpine forest) to determine the associations and relationships between the plant communities and soil, grouping and quantification of plant communities using multivariate ordination techniques. The study area ranges in altitude from 2400 to 2700 m, a.s.l. A total 74 genera having 82 species belonging to 44 families were recorded during the field survey. The major families were Rosaceae (30%), Lamiaceae (23%) and Asteraceae (17%). Other families also contributed a good share in flora. Herbs contributed the more share followed by shrubs and trees. Presence/absence data were used to classify and ordinate for both sites and species. DCA axes 1 and 2 were used for data interpretation. The relationships between soil characters and DCA axes 1 and 2 were determined using Spearman Rank correlation. Cluster analysis identified 3 vegetation types. These vegetation types have been discussed in the context of topographic and edaphic heterogeneity.

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Introduction

Roads are designed as major channels of intercommunication between the communities existing in disparate strata of earth, yet it is pervasive disturbance with far-reaching impacts on vegetation and plant community composition (Coffin, 2007; Cui *et al.*, 2009). Vegetation recovery is essential to stabilize slopes (Fu *et al.*, 2010), increase water infiltration capacity (Walton *et al.*, 2014), and reduce erosion and sedimentation of watersheds (Donaldson *et al.*, 2013). Vegetation recovery following road construction is dynamic, variable and is strongly influenced by underlying edaphic and environmental conditions (Dong *et al.,* 2010).

Roads often traverse heterogeneous substrate e.g. parent material/rock type (Deduke *et al.,* 2016; Walker *et al.*, 2013) that directly influence additional edaphic factors (Hahm *et al.*, 2014; Ullmann *et al.,* 1995; Abella *et al.*, 2008). In particular, substrate variability influences on vegetation and species composition of roadside slopes (Neher *et al.,* 2013). For the distribution pattern of different animals and plants varieties roadsides can also considered as entranceway and habitats or barriers (Angold, 1997).

Plant communities of roadside also provides refugees for the conservation of isolated or relict population of plant species in highly modified regions where novel ecosystems are emerging (Dolley and Audet, 2013). For example, soil depth and texture are strong determinants of nutrient contents (Li *et al.,* 2016) which subsequently influence plant species diversity and long term species persistence following disturbance (Cui *et al.,* 2009; He and Monaco, 2018) and roads are mostly noted as assisting to the spatial spread of alien species, since they express the basic corridor for various invader floristic species introduction, with high reproductive rates and short life spans (Parendes and Jones, 2000).

Although mountain ecosystems are considered to be at low risk of plant invasion due to their harsh climate and limited human activities but the promotion of mountain areas, particularly the Himalayan region (Khuroo *et al.*, 2007), as global tourist destination has put these ecosystems at higher risk of invasion. Pickering and Hill (2007) described that distribution pattern of invasive plants along roadsides varied with altitude and road construction facilitated plant invasion in mountainous regions. Arevalo *et al.* (2005) revealed that at elevation of (1900-2000 m) the maximum quantity of alien vegetation present. Pauchard and Alaback, (2004) illustrated that along roadside with the variation of altitude between (280-1290 m) alien varieties richness was negatively associated with altitude.

Along the environmental gradient the various well known factors that find out the distribution of the plant species include topographic heterogeneity and particularly elevation (Liberman *et al.*, 1985), Rain fall (Hall and Swaine, 1976) and redistribution of rain fall water (Shmida *et al.*, 1986), Edaphic factors particularly Topography(Richards, 1996), Soil texture (Davis *et al.*, 1998), Light availability (Liberman *et al.*, 1995), Drainage (Hubbell and Foster, 1986), Soil nutrients (Baillie *et al.*, 1987), Light regime and the degree of anthropogenic other catastrophic disturbances (Perkins and Hatfield, 2014).

However, roadside exotic or native plant communities help in conserving landscape qualities (Khalid *et al.,* 2008). They are also essential places to observe the floristic communities, patterns of distribution and their potential for incursion into interior environment (Trombulak and Frissell, 2000). Furthermore, roadsides are helpful for discovering the effect of climatic factors on distribution pattern of plant species across a various altitudinal gradient (Antonio *et al.*, 2001).

In the present investigation, we assessed variation in vegetation structure and plant community composition along express highways radiating from Murree outward into Abbottabad and Thandiani in Northern Pakistan. Our primary objectives were to identify vegetation structure and plant community composition along the roadside and to relate roadside vegetation and environmental heterogeneity that affects the vegetation patterns along roadside crossing Himalayan forests in Pakistan.

To achieve the objectives of the present investigation, numerical analysis of the data was preferred. Multivariate analysis techniques are the swift tools for ecologist. Ordination analysis is also important statistical tool to elucidate major axes on compositional variation in vegetation data obtained from presence/absence record of species. Cluster analysis is mostly used (Charman *et al.*, 1993; Franklin *et al*., 1999). The results of species DCA were used to correlate the response of species for edaphic variations (Dasti *et al*., 2010).

The aims of the present study were

To relate roadside vegetation and environmental heterogeneity that affects the vegetation patterns along the roadside crossing Himalayan forests in Pakistan.

To identify the environmental factors of overriding importance in determining the nature of plant communities in these landscapes.

To know the factors which control the distribution pattern of species?

Materials and methods

Study area

The investigation of soil and vegetation was conducted along the roadside starting from Nathia Gali temperate forest (Figure 1) passing through the tropical zone and ended in subalpine conifer formation (Figure 4). The road runs roughly in south-north direction and cover the ranges between 34° 01.19′ N and 73° 227.571′ E to 34° 31.761′ N and 73° 270.097′ E longitude. In consequence there was a difference of about eight degrees of latitude between the two ends of the road (Table 1).

Climate

The road descended from 2500 m (a.s.l) down to 1200 m (a.s.l) near Abbottabad (tropical zone) and again ascended to 2700 m (a.s.l) near Thandiani village. Such an altitudinal range provided a sufficient elevation gradient in terms of ecological approaches. The climate changed gradually along the descending road from Cfb to Cfa type.

The climate of the starting point was more temperate than that at Abbottabad, whose lower elevations lied close to the tropical zone. The far end of the road terminated in the tree-line and the overall climate again changed from tropical to temperate but cooler than that of Nathia Gali because of higher winter snow fall (Figure 2). Annual rainfall decreased with decrease in elevation. At NathiaGali the mean annual precipitation is about 1412 mm and it decreased to 1262 mm at Abbottabad (Table 1). Similarly, temperature decreased with increasing altitude (Table1). The mean annual winter snow fall was about 680 cm (Table 1) however altitudinal variation in winter accumulation were expected.

Vegetation

The road side vegetation across the temperate forests (Figure 4) was most attractive bordered with ever green conifers: *Abies pindrow, Pinus wallichiana* and *Cedrus deodara* species. The most common herbs dominating the road sides included *Geranium wallichianum, Polygonum humile*, *Ranunculus sceleratus* and *Bupleurum candollei*.

The *Viola biflora, Micromeria biflora, Plantago major*, *Oxalis corniculata* and *Impatiens bicolor* occur generally. The common climbers of the area were *Clematis Montana* (deciduous), *Dioscorea deltoidea* (perennial) and *Hedera nepalensis*. The common Ferns growing along the road side were *Adiantum venustum, Dryopteris ramosa* and *Onychium contiguum*, while grasses (*Poa alpina*) were also dominating along the roadside (Table 2).

Vegetation sampling

A complete botanical survey of the road verges was arranged during 2018. Field sampling work was done during mid-July to mid-August, when flowering of herbaceous species maximum. A single transect was used. The continuous sampling in the study area allowed comparison of spatial variation along the road sides. All the plants growing along the road verges were identified and listed. All the samples were collected on the right side of the transect. A 2 x 500 m long segment of transect was used to collect the vegetation data. Nomenclature followed flora of Pakistan (Nasir and Ali, 1972). Identified plants and voucher specimen were then deposited in Herbarium of the campus.The geo-climatic constraints, such as elevation, longitude, latitude was recorded by the help of Applied Ballistics Meter. Beside this the Mean average annual data for rainfall and temperature were acquired from Pakistan Metrological Department (Figure 3).

Species Richness (number of species per unit area) was calculated by using the MVSP software (VERSION 3.2) by selecting the default option species data transform and diversity/ richness. Shannon, Simpson diversity index and Brillion's were calculated (Table 4; Wazir*et al.*, 2008; Saima *et al.*, 2018). Possible values of diversity indices range between 8.29 and 14.00, where the highest values indicate maximum diversity of species in the area under consideration (Table 4).

From each segment (2 x 500 m) along the main transect soil samples (0 -10 cm) were collected at three diverse points arbitrarily and assorted into a composite sample. All the soil samples thus collected were air-dried in the field. The parts of roots, gravels, and plant leaf and seed debris were carefully removed by sieving through 2.00 mm mesh. Soil samples were returned back to lab for analysis of soil chemical analysis Richards, (1954).

The pH of soil saturation extract was determined by using pH meter (FP20- Std- Kitr). Cations exchange capacity of soil extract was calculated by means of Digital EC-meter (EAI-3012).

The instruments direct display the possible values of results. Soil extract was used for further soil analysis. Standard method was used (Walkley and Black, 1934). The available content of phosphorus in soil samples were determined by using the Olsen and Mehlich Methods (Latrou *et al.*, 2014). Soil available cations were determined by the means of single channel Flame Photometer (Model-360 Flame photometer).

The possible values obtained by analysis of soil extract were recorded. Available contents of soil carbonates and bicarbonates were determined by acid digestion and two end point Titration methods following (Tiessen *et al.*, 1983). The clustering analysis were used to reveal the area of major variations in species configuration and to elucidate the environmental factors, which control the shaping floristic composition along the transect. Multivariate analysis techniques were used to explore the limit of variation in herbaceous vegetation. Species and stand data (82 species and 82 stands) were ordinated by using Detrended Correspondence Analysis (DCA) (Dasti and Agnew, 1994; Saima *et al.,* 2009). The DCA Scores were Ordinated and axes scores 1 and 2 were interpreted with soil data. The associations among elevation, soil heterogeneity and DCA axes were calculated by the means of statistical correlation analysis by using MVSP software (Version 3.2).

Statistical analysis

The Significant variations in soil of different plant communities were analyzed by analysis of variance (ANOVA) (Dasti and Agnew, 1994; Dasti and Malik, 1998). Graphs were drawn from the mean values obtained from analysis to explain the significant variances (Table 9). The association among the soil characteristics and DCA axes 1 and 2 were resolute using Pearson's correlation (Table 9).

The calculations were completed with the help of MINITAB-Version 16.0.

Results

Floristic

The results of study area showed the wild plants of road verges starting from Nathia Gali temperate forest, passing through the tropical zone and ended in subalpine conifer formation, Pakistan.

Table 1. The geo-climatic factors recorded in three study sites located at beginning, middle and terminal end of the ascending road from Murree to Thandiani.

Characteristics	Forest types		
	Temperate forest	Tropical forest	Subalpine forest
Locality/ Sites	Nathia Gali	Abbottabad	Thandiani
Altitude (m,a.s.l.)	2410	1216	2750
Longitude	N 73°38'.118	N 73°22'.149	N 73°20'59.99
Latitude	E 34°07'.301	E 34° 16'.875	E 34°13'60.00
Mean Max. Temp (°C)	19.2	33	10
Climate	Cfb	Cfa	Cfb
Mean Min. Temp(°C)	-0.2	2.4	-2
Rainfall (mm)	29- 252	28- 266	27- 233
Mean Snow accumulation (cm)	660	180	830
Wind speed (ms^{-1})	0.7- 0.3	0.5 – 0.2	0.2- 0.5

The flora of the study area consisted of 82 species of 44 families and 74 genera (Table 2). Angiosperms were dominant. Three families of Pteridophytes were recorded (Adiantaceae, Pteridaceae and Dryopteridaceae) while Gymnosperm representing the only one family (Pinaceae) having four species. Among the Angiosperm dicotyledonous families, Rosaceae (30%), Lamiaceae (23%), Asteraceae (17%) and Polygonaceae (13%) have major contribution, while Ranunculaceae present with only three species and Geraniaceae were with two species.

Table 2. Top six families with higher number of genera and species in the study area.

No. of families	No of genera	%	No of species	%
Rosaceae	7	28	9	30
Lamiaceae	7	28	7	23
Asteraceae	5	20	5	17
Polygonaceae	2	8	4	13
Ranunculaceae	3	12	3	10
Geraniaceae	1	4	2	7

Among the life forms, herbs contributed the more share followed by shrubs and trees. The important trees were *Abies pindrow, Pinus wallichiana, Populus ciliata, Aesculus indica, Cedrus deodara, Acer caesium, Quercus dilatata* and *Prunus cornuta*. Theshrubs included *Lonicera webbiana, Rosa webbiana, Indigofera gerardiana, Rosa macrophylla, Rubus fruticosus, Strobilanthes attenuata, Salix daphnoides, Sorbaria tomentosa,*etc (Table 5).

Table 3. Species Richness and Diversity Indices: SR= Species Richness; H= Shannon Wiener Diversity index; B'= Brillion Diversity index, values recorded from three association.

Associations	SR	H'	B'
A (2400-2500)	14	2.78	1.18
B (2500-2600)	12	2.58	1.62
C (2600-2700)	8.29	1.98	0.90

Vegetation ecology

Floristic richness and diversity

Diversity and species richness were estimated from the qualitative data obtained from each sampling unit, observed values of Shannon diversity (H') in the study area ranged between 1.98 to 2.78, where maximum value indicate maximum diversity (Table 3). The values for species richness (SR) estimated ranged from 8.29 to 14.0, with greater values representing high richness per unit.

Table 4. Number of total stands in each association recognized by Normal Cluster Analysis.

Associations	No. of Stands.
Association A (2400-2500 m.a.s.l)	30
Association B (2500-2600 m.a.s.l)	27
Association C (2600-2700 m.a.s.l)	25

The results demonstrated that species richness increased with decreased in elevation along transect. The lower end of transect exhibited maximum value (14.0), while minimum was recorded in the top most end of transect having species richness < 10 species per unit area. Similar elevation trends were observed for H and HB diversity indices which decreased with increasing elevation along the transect gradient. The correlation between altitude and diversity parameters was significant at $P < 0.05$ (Table 9).

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

Species Name	Axes 1	Association A	Association B	Association C	Life form
Abies pindrow	2.30	2.89	2.93	2.23	T
Acer caesium	3.49	2.89	----	----	T
Achellia millefolium	2.67	0.72	1.60	1.68	H
Achyranthes bidentata	-1.42	1.93	0.53	----	H
Adiantum venustum	1.23	1.93	0.53	1.12	F
Aesculus indica	0.40	1.69	----	----	T
Arisaema Wallichianum	-0.01	0.72	----	----	H
Bupleurum candollei	0.59	2.65	1.07	----	H
Capsella bursa-pastoris	3.90	----	----	2.79	H
Cedrus deodara	2.63	0.96	----	5.03	T
Clematis Montana	0.01	1.20	----	----	Climber
Conyza japonica	0.02	----	0.27	1.68	H
Dryopteris ramosa	1.11	3.61	1.33	1.12	F
Fragaria indica	2.12	2.89	2.93	5.03	H
Gallium aparine	4.73	----	1.07	1.68	H
Geranium rotundifolium	4.47	----	0.80	2.23	H
Geranium wallichianum	1.63	3.86	2.67	2.23	H
Hedera nepalensis	1.379	----	3.47	1.12	Climber
Heracleum maximum	0.145	1.69	0.27	----	H
Impatiens bicolor	0.469	2.17	1.60	1.68	H
Indigofera gerardiana	4.352	0.72	2.67	2.79	S
Lavatera kashmiriana	0.003	0.72	----	----	H
Lonicera webbiana	-0.94	1.93	0.53	----	S

Malva neglecta	2.19	----	1.33	----	H
Micromeria biflora	1.52	2.41	2.40	3.35	H
Myosotis alpestris	-0.71	2.41	0.53	----	H
Nepeta erecta	1.42	----	3.20	1.12	H
Onychium contiguum	1.76	2.41	4.00	0.56	F
Origanum vulgare	0.43	2.41	2.13	----	H
Oxalis corniculata	0.60	2.17	1.07	1.68	H
Paeonia emodi	2.62	0.72	0.80	3.91	H
Pinus wallichiana	1.32	3.61	1.33	4.47	T
Plantago lanceolata	1.55	1.93	3.47	----	H
Plantago major	2.04	2.41	2.93	2.79	H
Poa alpine	3.71	0.72	3.20	8.38	H
Polygonum humile	1.93	3.37	4.53	2.79	H
Populus ciliate	3.35	2.65	1.07	2.23	T
Potentilla gerardiana	0.75	1.69	----	----	H
Prunus cornuta	4.48	----	3.47	2.23	T
Ranunculus sceleratus	2.31	3.13	4.53	2.79	H
Rosa macrophylla	1.24	0.72	1.33	1.68	S
Rubus fruticosus	1.37	2.41	1.87	1.12	S
Rumex hastatus	-0.37	3.61	0.80	----	S
Rumex nepalensis	2.70	1.45	4.00	3.35	H
Salix daphnoides	0.15	0.96	----	----	S
Sonchus asper`	0.94	7.23	4.80	----	H
Stachys emodi	0.58	1.69	1.33	0.56	H
Strobilanthes attenuate	1.73	3.13	1.60	3.35	S
Taraxacum officinale	3.46	----	1.60	3.91	H
Trifolium repens	3.08	1.69	5.33	7.82	H
Urtica dioica	2.67	1.45	3.73	1.68	H
Verbascum Thapsus	0.46	----	1.87	1.12	H
Veronica biloba	1.26	1.93	2.67	0.56	H
Viburnum cotinifolium	1.97	3.86	3.47	5.59	S
Viola biflora	1.10	2.65	1.33	0.56	H

Normal cluster analysis

By the Normal Cluster Analysis as result of clustering analysis three plant groups were identified (Figure 6,7). Plants groups were related to edaphic and elevational conditions but not arbitrary. The plants groups' composition is given in the Table 4 and Figures 5.

Association A (2400-2500m)

This association was characterized by having *Lavatera kashmiriana, Clematis montana, Aesculus indica, Arisaema wallichianum, Salix daphnoides* and *Potentilla gerardiana* which were altogether absent in other associations recognized by Normal Cluster Analysis (Table 4). *Pinus wallichiana* was most dominant in the tree strata, *Abies pindrow* and *Acer caesium* were frequent but less than *Pinus wallichiana* whereas *Populus ciliata* was rarely found while *Cedrus deodara* and *Aesculus indica* were rare (Table 5).

The common shrubs were *Viburnum cotinifolium, Rumex hastatus* and *Strobilanthes attenuate,* while *Rubus fruticosus* and *Lonicera webbiana* were occasional. *Indigofera gerardiana* and *Rosa macrophylla* were rare (Table 5).

Table 6. Analysis of variance (ANOVA) of different soil parameters in three associations (A-C) identified by Normal Cluster Analysis.

Source	DF	SS	MS	*F-value*	*p- value*
Altitude (m)	2	1018875	509438	310.45	0.000
No. of Species	2	472.90	236.40	14.42	0.000
pH	2	9.55	4.77	13.88	0.000
E.C (ms/cm)	2	5.96	2.98	8.88	0.000
O.M (%)	2	0.08	0.04	8.95	0.000
N (ppm)	2	0.69	0.34	9.78	0.001
P (ppm)	2	0.03	0.01	1.65	0.000
K (ppm)	2	20.46	10.23	22.13	0.000
S.S (%)	2	28.16	14.08	1.43	0.000
Ca (ppm)	2	0.05	0.02	3.04	0.002
Mg (ppm)	2	0.04	0.02	1.12	0.000
Na (ppm)	2	0.02	0.01	1.84	0.000
Cl (ppm)	2	0.01	0.01	0.38	0.000
CO3 (ppm)	2	0.29	0.14	0.17	0.000
HCO3 (ppm)	2	388	194	0.56	0.038

In herbaceous plants; *Sonchus asper, Geranium wallichianum, Polygonum humile, Ranunculus sceleratus* and *Fragaria indica* were very common in the study area. *Viola biflora, Origanum vulgare, Oxalis corniculata, Bupleurum candollei, Micromeria biflora, Stacy's emodi* and *Plantago major* were occasionally present while *Adiantum venustum, Trifolium repens, Urtica dioica* and *Rumex nepalensis* were rare. In grasses, *Poa alpina,* was oftenly found (Table 5).In this association soil was characterized by slightly alkaline with the mean value of pH above 7 (Table 7) and high electrical conductivity (2.20 ms/cm). Soil was rich in Bicarbonates and Potassium quantity, while Nitrogen, Calcium, Chloride, Phosphorus and organic matter were in lowest quantities in this association (Table 7).

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

Variables		A	B	C	F-value
No. of species	Mean	13.83	12.88	8.24	14.42
	S.D	4.153	4.335	4.574	
Altitude (m)	Mean	2417.5	2560.0	2690.0	310.45
	S.D	44.0	39.7	36.8	
PH	Mean	7.37	6.79	6.57	13.88
	S.D	0.48	0.62	0.66	
E.C ms/cm)	Mean	2.20	1.73	1.57	8.88
	S.D	0.56	0.67	0.48	
O. m (%)	Mean	1.99	2.05	2.07	8.95
	S.D	0.088	0.058	0.056	
N (ppm)	Mean	0.35	0.23	0.13	95.78
	S.D	0.07	0.06	0.00	
P (ppm)	Mean	0.260	0.249	0.245	1.65
	S.D	0.030	0.031	0.032	
S.S (%)	Mean	49.4	50.4	49.0	1.43
	S.D	2.92	3.32	3.17	
K (ppm)	Mean	2.34	1.33	1.27	22.13
	S.D	1.07	0.24	0.23	
Ca (ppm)	Mean	0.51	0.49	0.45	3.04
	S.D	0.09	0.08	0.10	
Mg (ppm)	Mean	0.22	0.20	0.21	1.12
	S.D	0.047	0.042	0.040	
Na (ppm)	Mean	0.35	0.31	0.34	1.84
	S.D	0.08	0.09	0.07	
Cl (ppm)	Mean	0.40	0.39	0.40	0.38
	S.D	0.050	0.049	0.044	
CO3 (ppm)	Mean	2.10	2.17	2.02	0.17
	S.D	1.00	0.91	0.86	
HCO3 (ppm)	Mean	45.60	42.78	48.24	0.56
	S.D	19.90	17.63	18.04	

Association B (2500-2600m)

In this association *Malva neglecta* which was altogether absent in other associations recognized by Normal Cluster Analysis (Table 5). *Abies pindrow* and *Prunus cornuta,* were very common among tree strata, presence of *Pinus wallichiana* was occasional while *Populus ciliata* was rare (Table 5). The shrubs which were most common like *Indigofera gerardiana* and *Viburnum cotinifolium.* While *Strobilanthes attenuata* and *Rubus fruticosus* were in very small number. But *Rumex hastatus* and *Lonicera webbiana* were rare in this association (Table 5).

Table 8. Eigenvalues, Cumulative percentage of DCA axis 1&2 and Spearman Rank Correlation Coefficient between DCA axes scores, environmental, species diversity variables and soil.

Axis	Eigenvalue	percentage of total	Cumulative percentage
1	0.395	10.712	10.712
2	0.247	6.712	17.423
3	0.169	4.573	21.997
4	0.139	3.781	25.778

Table 9. Co-efficient of Pearson's Correlation of factors between DCA first axis, DCA second axis, environmental parameters, altitude and soil.

Parameters	Axis 1		Axis 2	
	Coefficient	Significance	Coefficient	Significance
Altitude(m)	0.612	***	0.340	**
	0.000		0.002	
Species richness	-0.243	*	-0.335	**
	0.028		0.002	
pH	-0.302	**	-0.298	**
	0.006		0.006	
E.C (ms/cm)	-0.298	**	-0.211	*
	0.006		0.057	
O.M (%)	0.183	*	0.235	*
	0.099		0.034	
N (ppm)	-0.655	***	-0.198	*
	0.000		0.074	
P (ppm)	-0.078	NS	-0.123	NS
	0.486		0.270	
K (ppm)	-0.289	**	-0.021	NS
	0.009		0.854	
S.S (%)	-0.006	NS	-0.055	NS
	0.960		0.622	
Ca (ppm)	0.036	NS	-0.301	**
	0.745		0.006	
Mg (ppm)	-0.033	NS	-0.066	NS
	0.765		0.554	
Na (ppm)	-0.112	NS	-0.099	NS
	0.316		0.376	
Cl (ppm)	-0.011	NS	-0.048	NS
	0.925		0.666	
CO_3 (ppm)	-0.121	NS	-0.095	NS
	0.278		0.395	
HCO_3 (ppm)	0.087	NS	0.069	NS
	0.437		0.540	

In this association the most abundant species of herbs found were *Trifolium repens, Sonchus asper, Ranunculus sceleratus, Polygonum humile* and *Rumex nepalensis*. Other species like, *Urtica dioica, Fragaria indica* and *Nepeta erecta* were in larger number, while *Geranium wallichianum, Fragaria indica, Micromeria biflora, Veronica biloba* and *Origanum vulgare* were occasional. Other species like *Viola biflora, Oxalis corniculata, Adiantum venustum* and *Bupleurum candollei* were rare. *Poa* *alpina* was the most common among grasses (Table 5). Soil was acidic with the mean value of pH less than 7 and was rich in carbonates, organic matter and greater soil saturation as compared to other associations. While Sodium, chloride, Potassium, Calcium, Magnesium and Bicarbonates were comparatively less in this association (Table 7).

Fig. 1. Roadside vegetation of temperate forests.

Association C (2600m to 2700m)

In this association *Capsella bursa-pastoris* present which was absent in other associations recognized by Normal Cluster Analysis (Table 4). Among tree strata the plants which were most abundant were *Cedrus deodara* and *Pinus roxburghii*, while *Pinus wallichiana* and *Abies pindrow* were present occasionally. *Populus ciliata* and *Prunus cornuta* were rare (Table 5). The most common shrubs were *Viburnum cotinifolium* and *Strobilanthes attenuate* while *Indigofera gerardiana* was frequent but in this association *Rubus fruticosus* and *Rosa macrophylla* were rare (Table 5). The most abundant species of herbs were, *Trifolium repens*, *Micromeria biflora*, *Rumex nepalensis*, *Fragaria indica, Paeonia emodi* and *Taraxacum officinale*. Many other species like *Capsella bursa- pastoris, Geranium wallichianum, Ranunculus sceleratus, Polygonum humile, Plantago major* and *Oxalis corniculata,* were occasional, while other species which were rare like *Viola biflora, Adiantum venustum, Achellia millefolium, Stachys emodi, Veronica biloba, Urtica dioica* and *Nepeta erecta* (Table 5).In this association the soil was characterized by slightly acidic with the mean value of pH less than 7 (Table 7) with high Bicarbonates (48.24 ppm). Soil was rich in carbonates, organic matter, and potassium. Soil has lowest calcium, Phosphorus, chlorides, sodium and calcium contents in this association (Table 7).

Environmental variables

In present research work among environmental variables studied, elevation, pH, Organic matter, Electrical conductivity, Nitrogen, and Phosphorus showed considerable variations along with the floristic associations (Table 6).

Soil

The soil results showed significant differences among the different plants associations (Table 7). The plant association located at lower slopes showed relatively high values of soil chemical reactions pH, soil EC and cations and anions (Table 7) than that of plants associations located at higher elevations which showed minimum values of all chemical characteristics of soils sampling sites at lower elevation located belonging to association A (Table 7). Contrary to pH, EC and others cations and anions organic matter increase substantially recognized by cluster analysis among the plant associations. The correlation analysis results described that along the elevation gradient the soil Nitrogen (F=95.78) had the major role in the distribution of plant species (Table 7).

Fig. 2. Thandiani roadside covered with snowfall.

Gradient analysis

Species Presence Data obtained from the field survey were used for DECORANA analysis (Shaheen *et al.*, 2011). The species which were found vary rare (presence < 3) in not included in the statistical analysis and were down weighted. The species eigenvalues of Axes 1 & 2 (0.395 & 0.247 respectively) were maximum as compared with lower order axes, and the later were ignored (Table 8). The results exhibited in (Table 9) suggested that axes 1 demonstrated considerable association with most of the geo-climatic factors. The values of DCA axis 1 showed highly significant positive correlation (r = 0.612, P < 0.001) with elevation (Table 9). The result illustrated the intervening importance of elevation as an ecological factor influencing the plant communities across the environmental gradients. Beside the elevation the first DCA axes was significantly linked with most of the soil parameters. The species results of DCA recommended that the various plant species like *Fragaria indica, Abies pindrow, Populus ciliata, Rumex hastatus, Dryopteris ramosa, Acer caesium, Origanum vulgare, Myosotis alpestris, Rubus fruticosus, Oxalis corniculata, Adiantum venustum, Trifolium repens, Stachys emodi* and *Urtica dioica* located at the left side of the graphical representation belongs to association (A) occurring at low altitude while the species like *Veronica biloba, Hedera nepalensis, Nepeta erecta, Gallium aparine, Verbascum thapsus, Prunus cornuta, Indigofera gerardiana, Paeonia emodi, Conyza japonica* and *Taraxacum officinale* distributed at the right side of the scatters diagram located at highest altitude. This distribution patterns of plants species across the elevation gradient recognized that soil chemistry performed vital role in vegetation zonation and establishment of different plants in similar groups because of specific site preferences in term of soil chemistry. The concentration of bivalent cations and anions also significantly correlated with axes 1 values negatively (Table 9).

Fig. 3. Study area, Temperate forests showing rainfall.

Discussion

Along the elevational gradient the three forest types (Temperate, Tropical and Subalpine forests) were selected with the roadside which were significantly different for majority of environmental measure used. The present research work showed 82 vascular plant species which belong to 74 genera and 44 families. Rosaceae, Lamiaceae and Asteraceae, followed by Polygonaceae, Ranunculaceae and Geraneaceae representing major share. The distribution patterns of species were depends on habitat disturbance because of natural and anthropogenic activities. The plants were very similar to those of other parts of North Temperate Zone of Western Himalayas (Champion *et al.,* 1965). The Himalayas are a recent creation in ecological terms, thus great variation in habitat and climate to be found here (Gairola *et al.,* 2008).

The areas chosen for study were those where pine trees were abundant. Present study also described that the richness of alien plant species decreased as the upright distance from the road increased. On the other hand, the native species richness increased as the upright distance from the road increased.

These results are consistent with the findings of (Tyser and Worley, 1992). Altitude is the most important of the various factors which combine to create contrast in habitat, climate and vegetation (Dasti*et al.,* 2007; Wazir*et al.,* 2008; Saima *et al.,* 2009. Altitudinal changes in forest structure from 1200 to 2700 m, a.s.l. were observed. The temperature decreased with increasing altitude. Annual rainfall increased with increasing elevation whereas the opposite trends were noted for snow accumulation. This pattern of climatic changes are common in Himalaya and are considered significant in determining the differences in forest structure, composition and function at gradient scale. So, wind velocity increased with altitude (Araki, 1995).

Community composition

The three associations were recognized by the Cluster Analysis. The two procedures have been seen to have very similar results. We used these results obtained by classification analysis to confirm the overlapping nature of association in the space defined by ordination axis. The ordination axis may exhibit the effect of environmental factors. We used the sampling stands data and environmental variables to discuss the over-lapping characteristics of plant communities. However, association confined to low altitude showed a reasonable segregation. By particular plant communities the dominance pattern is consistent with the perception that different plant species are adapted to various ecological conditions (BiBi *et al.,* 2020).

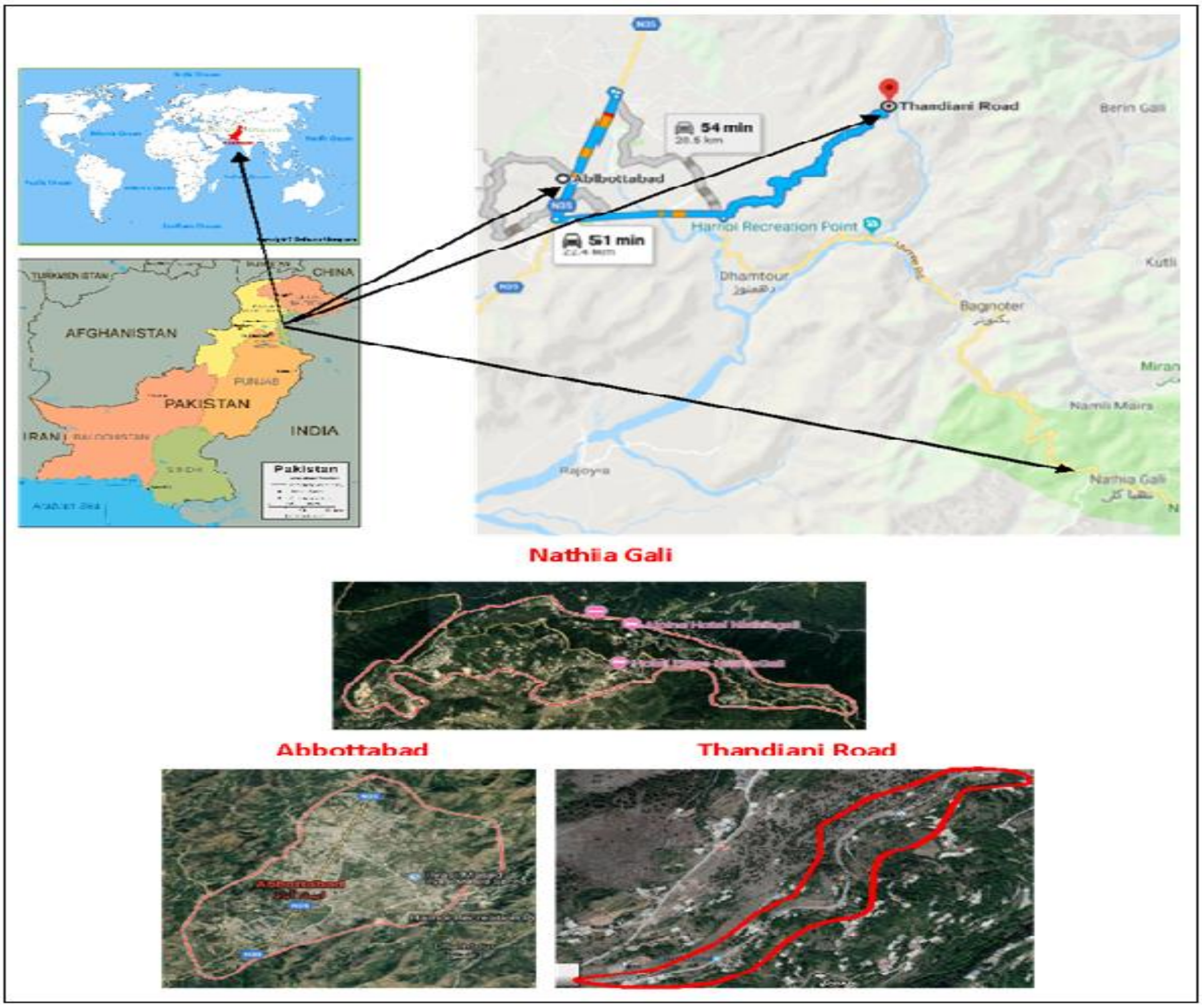

Fig. 4. Map showing the study sites (NathiaGali, Abbottabad and Thandiani).

The elevation distribution of dominant vegetation species is consistent with the individualistic hypothesis (Gleason, 1917) and with the fact that such ecological dominants differ in environmental tolerance and topographic heterogeneity, and are considered most important competitors, and thus among the most important determinants of each other's distribution (Whittaker, 1972). The ability of the species to survive, compete and reproduce successfully in different environments, resulting in each species having its own distinctive distribution. These characteristics of species affect fitness and are subject to evolution by natural selection. The vegetation at upper elevation are possibly not adversely affected by poor soil conditions or nutrient limitation compared with the forests at lower altitudes it is concluded that reduction in plant stature is primarily due to low precipitation and low temperature at high altitude forests. Similar results were noted by (Hashim and Dasti, 2019). The scores of first ordination axis showed variation in elevation from left to the right side in the ordination overlay diagram. The plant species which were site specific to low elevation were usually found on the extreme left side of the diagram, however the plants species enjoy high elevation tend to concentrate on the right side of the ordination diagram (Figure 4). The altitudinal distribution of the species was effected by soil chemistry (Dasti *et al.*, 2007; BiBi *et al.,* 2020). DCA recognized that there was a significant link among soil characteristics and plant communities segregated by numerical analysis.

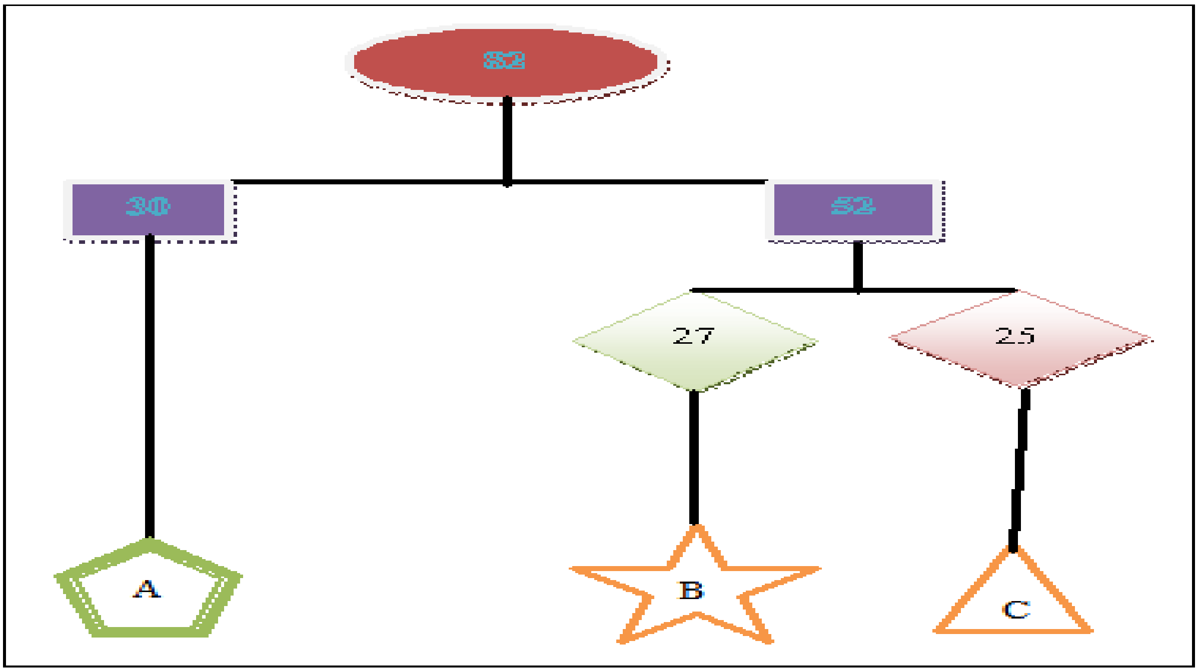

Fig. 5. The hierarchical classification on data of 82 stands obtained from Normal Cluster Analysis. Number of stands in each association is given in basic shapes.

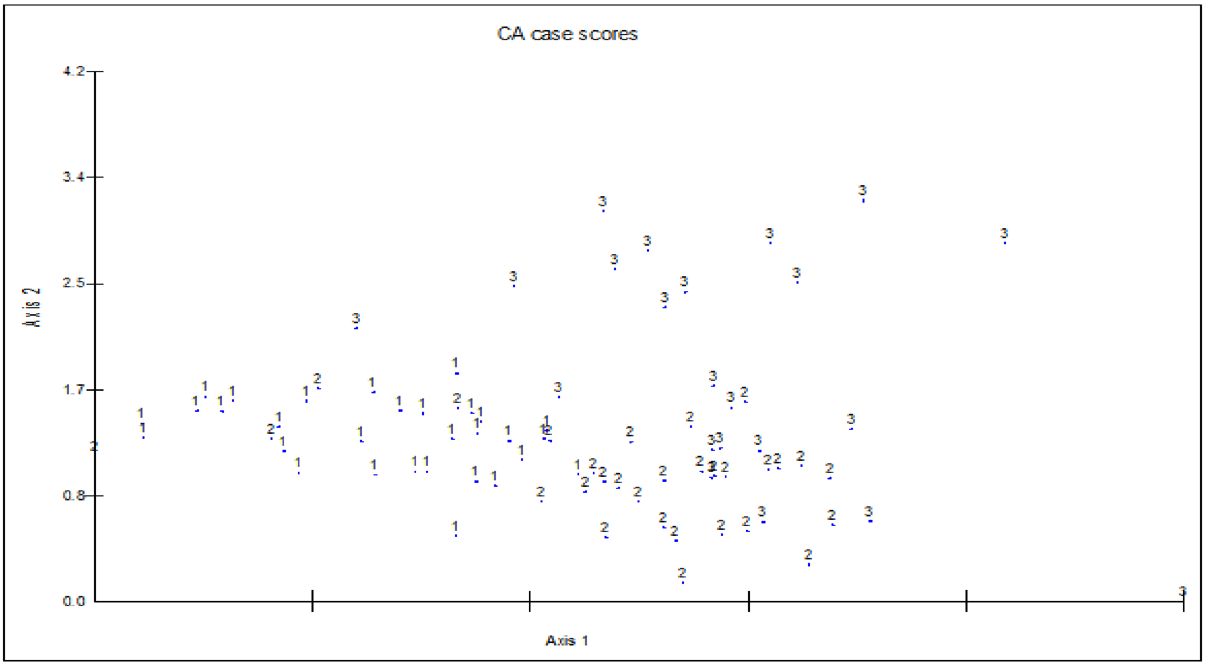

Fig. 6. Decorana (axes 1& axes 2) plot of the 82 stands from NathiaGali, Abbottabad and Thandiani. Stands are plotted individually and zones are shown in which each of the three associations, segregated by the Normal Cluster Analysis.

The DCA showed that soil soluble cations and anions were the most important ecological factors for the distribution and assemblage of plant communities. The distribution of species along the altitudinal transects support the individualistic hypothesis of community organization (Gleason, 1917).

The altitude as an environmental factor effecting plant assemblage was not surprising, showing that it had closely related with annual rain fall accumulation and re-distribution. The floristic composition variations along the altitudinal gradient had been discussed by many ecologists (Dasti and Malik, 1998). We interpret the altitudinal and environmental variables to explore the over-lapping characteristics of the plant communities. These results confirmed the findings of (Shaheen *et al.,* 2016; Haq *et al.,* 2017).Mountains topography controls the plant species diversity and richness across the elevation gradient. Modern ecologist described that topographic heterogeneity contribute to the distribution pattern of species richness.

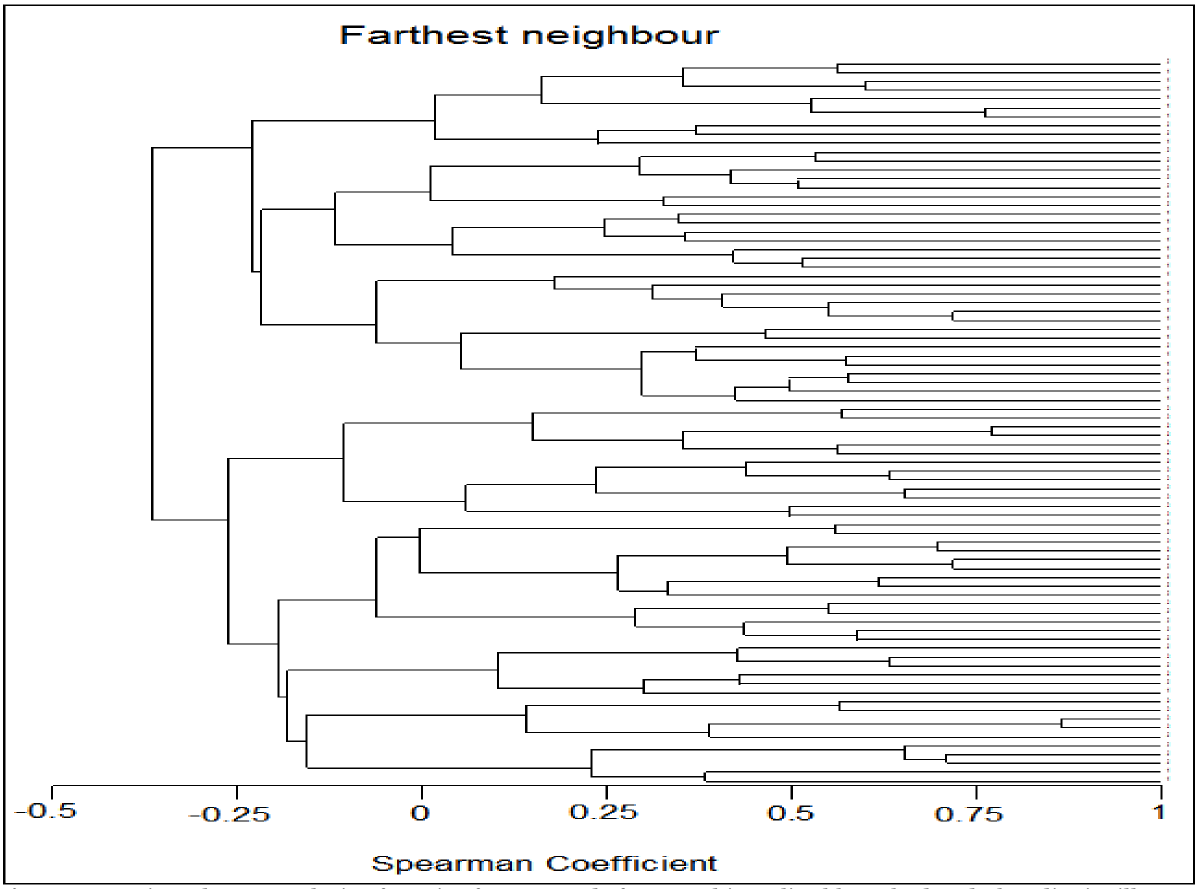

Fig. 7. Inversion Cluster Analysis of species for 82 stands from Nathia Gali, Abbottabad and Thandiani Hills.

Floristically the study area was dominated by gymnosperms (conifers) with little contribution of broad leaved trees such as *Acer caesium, Populus ciliata, Aesculus indica* and *Quercus dilatata.*

This stresses the importance of topographic preference of tree species and may reflect differences in using resources. Among the evergreen conifers species *Cedrus deodara, Abies pindrow* and *Pinus roxburghii* were commonly found in the study area these results similar to (Saima *et al.,* 2009). The common shrubs of the area were *Indigofera gerardiana, Lonicera webbiana, Strobilanthes attenuata, Rosa macrophylla, Rosa webbiana, Rubus fruticosus* and *Viburnum cotinifolium,* similar findings were described by (Khan *et al.,* 2013; Ahmad *et al.,* 2016) in Himalayan moist temperate forest of Pakistan. The first ordination axis represented a moisture gradient from lower canopied forest to upper rocky zone. The forest located at upper zone consisted of *Nepeta erecta, Prunus cornuta, Fragaria indica, Conyza japonica, Gallium aparine, Plantago major, Gallium aparine, Malva neglecta, Origanum vulgare, Rosa macrophylla* and *Taraxacum officinale* species whereas *Arisaema wallichianum, Achyranthes bidentata, Myosotis alpestris, Origanum vulgare, Plantago lanceolata, Lavatera kashmiriana, Plectranthus striatus* and *Rumex hastatus* were confined to the lower altitude (Dasti *et al.*, 2010). We used the Simpson function as an index of diversity because it weights the number of species than their equitability in importance value.

It appears that the variation in the plant grouping pattern was mostly because of elevation (Wazir *et al.*, 2008). Among edaphic factors, available soil nitrogen concentration across the elevation gradient had important role in determining the pattern of plant communities (He and Monaco, 2017), similar finding was confirmed by (Kochy and Wilson, 2001).

All the soil available cations and anions were significantly higher in plant communities located at low elevation.

The correlation analysis with elevation were similar to the findings of (Dasti and Malik, 1998) who described that higher content soil soluble cations and anions were found in lower mountain soil but, these finding were contradict to the results of (Saima *et al.,* 2009) who reported opposite trend.

The results concluded that the concentration of cations and anions content show constantly negative correlation with DCA axis 1 suggested a continuous decrease in with increase in elevation.

As a result the plant species assemblage in wet temperate forest was established by the soil heterogeneity. Several studies suggested that diverse site conditions contribute to the maintenance of species richness (Kubota, 2004).

The complex gradients in edaphic conditions that are associated with topography provide an opportunity to assemble diversity of species are important factors that determine the structural/compositional variations in plant communities (Sadia*et al.*, 2017).

Conclusion

Along the roadside, vegetation is a complex collection of plant communities. Large number of herbaceous plant species was found to be associated with roadsides with only a few shrubs and tree species. The interaction of plants of different species with each other and with their environment ensures that attempts to established species environment relationship are found to be difficult.

The relative magnitude of correlation demonstrated that in this study area two major factors that influence the species diversity and composition are altitude and soil nitrogen.

These factors play a dominant role in determining the distribution of species. Support for this interpretation comes from both the ordination and classification. These groups delineated by the cluster analysis are correlated most closely with altitude and topography.

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