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ASSESSMENT OF UNDERSTOREY VEGETATION OF MALAM JABBA FOREST, KPK AFTER CLEANUP OPERATION USING MULTIVARIATE TECHNIQUES

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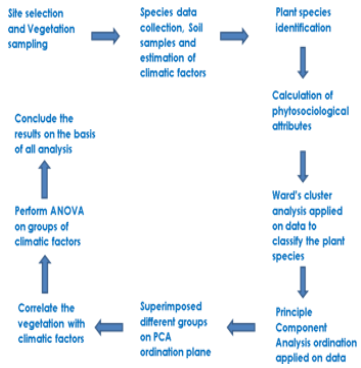
Graphical abstract



Abstract

In this study vegetation composition of understorey species of Malam Jabba forest is evaluated by multivariate analysis. Thirteen stands were quantitatively sampled by point centered quarter method. Environmental variables were recorded and correlate them with vegetation characteristic. In 13 stands 49 understory species were recorded. Multivariate techniques were employed to assess the vegetation groups and underlying group structure. Agglomerative Cluster analysis (Ward's method) discloses four main groups of vegetation while Principle Component Analysis (PCA) clearly ordinate these groups on all three axes. The most common species distributed in all four groups were *Adiantum capillus veneris, Adiantum venestum*, *Berberis lyceum, Chrysopogon aucheri, Oxalis corniculata, Pteris cretica* and *Trifolium repens* while these species were observed in three groups i.e. *Punica granatum* and *Plantago amplexicaulis.* The Group 1 comprises on 23 species and the dominant species were *Androsace rotundifolia, Aristida cynantha, Berberis lyceum, Dryopteris filix, Oxalis corniculata, Pteris cretica* and *Trifolium repens* while Group 2 comprises on 18 species, the dominant were *Pteris cretica, Adiantum venestum, Duchesnea indica* while some other species included, *Berberis lyceum, Chrysopogon aucheri, Chrysopogon aucheri, Dryopteris juxtapostia* and *Morus alba*. Group 3 & 4 comprises 31 species each, in which 18 species were common i.e. *Adiantum capillus veneris, Adiantum venustum, Arisaema jacquemontii, Berberis lyceum, Chrysopogon aucheri, Dryopteris filix, Dryopteris juxtapostia, Duchesnea indica, Oxalis corniculata, Plantago amplexicaulis, Polygala erioptera, Prunus avium, Pteris cretica, Punica granatum, Ranunculus muricatus, Rosa macrophylla, Trifolium fragiferum* and *Trifolium repens*. Among the environmental variables elevation and slope played an overriding role in the distribution of vegetation. The relationships between the six PCA ordination axes with environmental factors generally showed few significant relations, only axis 2 showed marked relationship with all edaphic variables (except pH), suggesting that the edaphic gradient has an overriding role in the composition and distribution of understorey vegetation. Some other environmental factors showed weak correlations with ordination axes, it could be spurious correlation. Malam Jabba forests are highly disturbed due to civil war and anthropogenic causes. Slope of the forests prove to be an overriding role in the distribution of vegetation as evaluated by analysis of variance.

Keywords: Understorey vegetation; operation cleanup; ward's cluster analysis; PCA ordination; Malam Jabba; Pakistan

1.0 INTRODUCTION

Malam Jabba is nearly 40 km from Saidu Sharif in Swat Valley, Khyber Pakhtunkhwa province of Pakistan. It is 314 km from Islamabad and 51 km from Saidu Sharif Airport. Malam Jabba is considered in moist temperate region [1; 2; 3; 4]. The climatic conditions in the area vary from sub-tropical; boreal to moist-temperate the sub-tropical, semi-arid climate of Saidu Sharif is comparable to that in the lower Malam Jabba. In the upper Malam Jabba Valley the climate is temperate from 1500 to 2500 m and above 2500 m it is alpine. Precipitation increases with altitude while evaporation decreases [5]. The maximum temperature 38 °C was recorded in July is and minimum was 1 °C was observed during January. The normal temperature was 21 °C (maximum) and 7 °C (minimum). The lush green meadows and thick green forests of Pine & Deodar trees of Malam Jabba was due to moderate temperatures 10C to 25 °C give way to. In the winter the temperature falls to –5 °C to –10 °C.

Current study deals with the vegetation composition and present status of understorey vegetation of Malam Jabba forest after civil war. Phytosociology of this area previously investigated by many workers i.e. [6] evaluated the vegetation description and composition from moist temperate area by using Ward's cluster analysis and PCA ordination but after civil war this is the first study to investigate the post war effects on vegetation composition.

Table 1 Site characteristics of Malam Jabba, Swat valley, Malakand division of Khyber Pakhtoonkhua

Stand No.	Location and sites	Latitude (N)	Longitude (E)	Elevation (m)	Slope (°)	Aspect	Canopy
Malam Jabba, Swat valley, Malakand division							
1	Sur Glu	33° 37' 12''	73 ° 71' 41''	2120	25°	E	Moderate
2	Mangerkot	33° 37' 12''	73 ° 71' 41''	2120	30°	N	Open
3	Bela	33° 37' 12''	73 ° 7' 41''	2240	41°	N	Moderate
4	Kuo	33° 37' 12''	73 ° 71' 41''	2330	30°	N	Open
5	Dur Sher	33° 37' 12''	73 ° 71' 41''	2410	35°	W	Open
6	Pendy	33° 37' 12''	73 ° 71' 41''	2300	25°	S	Close
7	Pechao	33° 37' 12''	73 ° 71' 41''	2400	50°	E	Close
8	Falak Gel	33° 37' 12''	73 ° 71' 41''	2110	25°	W	Moderate
9	Malikabad	33° 37' 12''	73 ° 71' 41''	2120	50°	S	Open
10	Malikabad	33° 37' 12''	73 ° 71' 41''	2100	30°	W	Open
11	Malam Jabba	33° 37' 12''	73 ° 71' 41''	2600	34°	E	Close
12	Malam Jabba	33° 37' 12''	73 ° 71' 41''	2350	30°	W	Close
13	Miandam	33° 37' 12''	73 ° 71' 41''	2700	49°	W	Moderate

2.0 OBJECTIVES OF THE STUDY

The main aim of this study is to explore the after effects of civil war on natural vegetation composition and distribution of species in Malam Jabba forests, KPK Province of Pakistan. The role of topographic and edaphic factors in controlling the abundance and distribution of vegetation. Multivariate techniques are used to explore this relationship.

3.0 MATERIALS AND METHODS

3.1 Vegetation Sampling And Computation

Undisturbed or natural sites were selected for quantitative sampling then thirteen stands were sampled by Point Centered Quarter method following [7]. Twenty circular points (2.5m radius) were taken in each stand. Frequency and relative frequency were calculated following the method of [8]. Species were identified with the help of flora of Pakistan [9] and [2].

3.2 Estimation of Soil Chemical Properties

Soil samples from the depth of 5 to 10 cm were collected from all stands using a soil auger. Three soil samples randomly collected in each stand then pooled to obtain a composite sample for each stand. Edaphic variables were analyzed by different techniques. A pH meter (Model Adwa 1000, Hungary) was used to analyze the electrical conductivity, total dissolved solids and soil pH. By the method of [10] as modified by [11] was follow for the determination of water holding capacity of soil. Organic matter of soil was determine with the help of method describe by [12].

3.3 Statistical Analysis

Agglomerative Cluster analysis, using Ward's Linkage strategy and the Euclidean (Pythagorean) as a

distance measure [13] was used to classify the plant species into different groups. For the purpose of ordination, Principle component analysis (PCA) [14] was employed to seek the compositional variation and any trend in the data set. The computations were performed using the program PC-ORD (version 5.10) [13] & [15]. Correlations were sought between ordination axes and environmental variables [16].

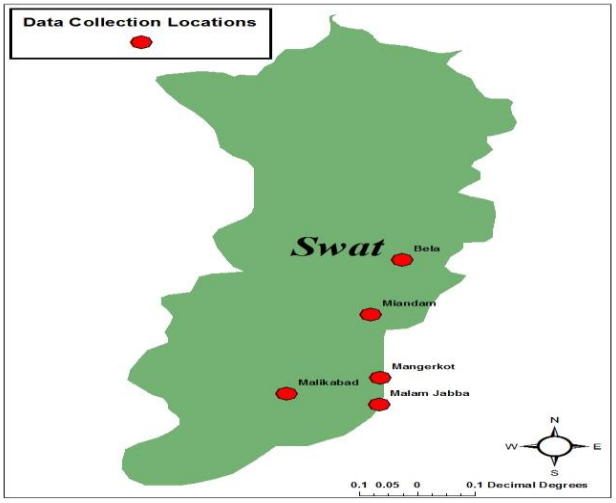


Figure 1 Study area map. Details of the sites and stands are given in Table 1

4.0 RESULTS AND DISCUSSION

To seek the group structure, species relationships with the environmental variables and trends in the vegetation data sets employed multivariate analysis. The environmental and species groups were well separated out in PCA ordination space. To explore the underlying group structure inherent in the data, two conceptually different clustering strategies were used.

4.1 Agglomerative (Ward's) Cluster Analysis of Stands

Four groups of understorey species are derived by cluster analysis (Figure 2). Species groups are discloses at a squared Euclidean distance of 9.7×10^5. Group I comprising of 2 stands (Table 4), is characterized by the predominance of *Oxalis corniculata* attained 75% frequency while *Androsace rotundifolia, Berberis lyceum* and *Trifolium repens* attained 65% frequency. Some species occupied medium frequency i.e. *Adiantum capillus veneris* and *Pteris cretica* (45% each), *Aristida cynantha* and *Indigofera heterantha* (40% each), *Adiantum venestum, Centaurea solstitialis, Dryopteris filix* and *Nepeta laevigata* (30% each). Some rare species were also reported in this group i.e. *Delphenium uncinatum, Buxus papillosa, Cynodon dactylon, Euphorbia hispida, Fragaria indica, Galium boreale, Punica granatum, Sarcococca saligna, Dryopteris juxtapostia, Hypericum perforatum* and *Chrysopogon aucheri* occupied less than 30% frequency.

Group II attained comparatively low frequency as group I. *Dryopteris juxtapostia* attained the highest frequency (20%) in this group while *Viburnum cylindricum, Onychium contiguum, Morus alba, Chrysopogon aucheri* and *Pteris cretica* occupied the frequency between 19 to 12%. The following species exhibited the frequency less than 10% i.e. *Berberis lyceum, Adiantum venestum, Duchesnea indica, Oxalis corniculata, Trifolium repens, Plantago amplexicaulis, Picea smithiana* seedling, *Adiantum capillus veneris, Rubus biflorus, Cynodon dactylon, Podophylum emodi* and *Pinus wallichiana* seedling.

Group III occupied the highest frequency among all groups; predominant by a key stone species of moist temperate area i.e. *Pteris cretica* attained 80% frequency. *Dryopteris juxtapostia, Adiantum venestum, Duchesnea indica, Prunus avium, Chrysopogon aucheri* and *Arisaema jacquemontii* attained high frequency (77, 70, 50, 50, 43 and 33% respectively).

Pteris cretica and *Berberis lycium* were the dominant species in Group IV attained 78 and 73% frequency respectively. These two species are the diagnostic species of moist temperate area. *Chrysopogon aucheri, Trifolium repens, Prunus avium, Adiantum venestum, Oxalis corniculata, Aristida cynantha, Plantago amplexicaulis, Adiantum capillus veneris* and *Podophylum emodi* also successful to retain their better position in this group (58, 55, 48, 45, 43, 40, 33, 30 and 20% frequency respectively). *Plectranthus rugosus* and *Centaurea solstitialis* (13% each), *Punica granatum* and *Polygala abyssinica* (10% each), *Ranunculus muricatus, Polygonium amplexicaule* and *Nepeta laevigata* attained (8% each frequency). *Cymbopogon jawarancusa* and *Aristida cynantha* are not actually the species of moist temperate area and may be escape from the adjoining agricultural field or other climatic region as indicated by [6]. Both the species from Sulaiman range were recorded by [17] which is dry, arid and sub-tropical area. Presence of these exotic species in the moist temperate area indicated high degree of anthropogenic disturbance. Exotic species effectively disturbed the normal vegetation due to competition. *Aristida cynantha* reorded from [18] from Alpine region (Mastuj valley), Hindukush range of Pakistan.

Table 2 Edaphic variables of sampling sites

Stand No.	Location and sites	pH	EC mmhos/cm	TDS mg/L	OM %	MWHC
Malam Jabba, Swat valley, Malakand division						
1	Sur Glu	6.255	1406	70.3	8.89	46.66
2	Mangerkot	6.279	1295	64.75	11.72	63.25
3	Bela	6.354	1250	62.5	11.52	62.54
4	Kuo	5.624	1236	61.8	11.42	61.96
5	Dur Sher	5.987	965	52.32	8.75	45.23
6	Pendy	6.104	828	41.4	8.68	41.30
7	Pechao	5.977	1131	56.55	7.57	39.02
8	Falak Gel	6.555	960	48	8.55	44.29
9	Malikabad	6.542	865	43.25	7.64	28.65
10	Malikabad	6.659	728	36.4	6.52	25.32
11	Malam Jabba	6.231	1365	68.25	10.65	52.54
12	Malam Jabba	5.875	1453	72.65	11.87	65.32
13	Miandam,	5.694	1495	74.75	11.58	66.54

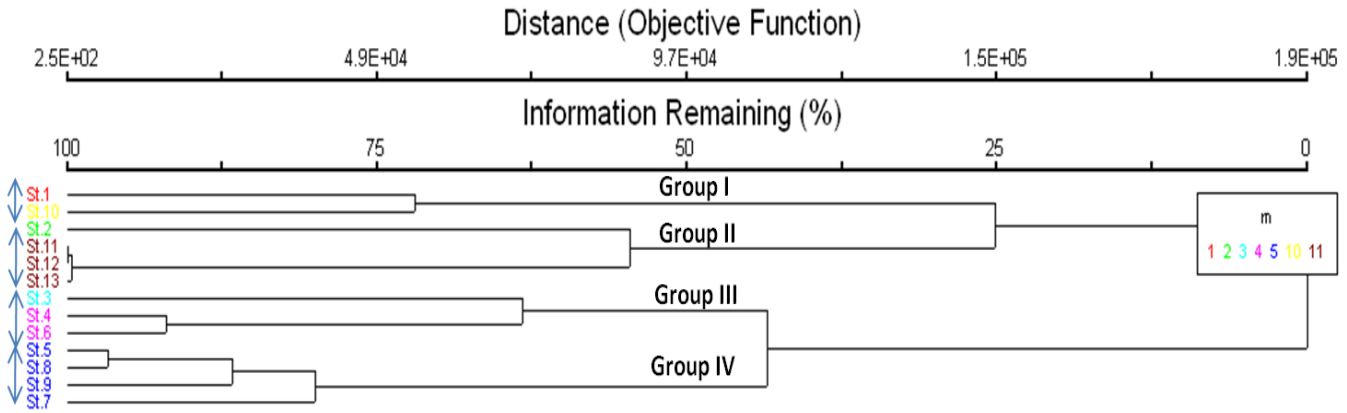


Figure 2 Dendrogram derived from Ward's cluster analysis based on understorey vegetation of 13 stands of Malam Jabba forest (moist temperate area) of Pakistan. Stands numbers are given at the base of the dendrogram

4.2 Environmental Characteristics of Groups

Ward's cluster analysis applied on understorey vegetation data, four groups of stands were extracted. On the basis of these groups, four groups of topographic and edaphic variables are formulated (Table 4) that showed some variability. Maximum elevation and slope (2442.5±130.23, 35.75±4.52) were recorded in group II while minimum elevation and slope (2110 ± 10, 27.5 ± 2.5) were observed in group I which indicated the presence of characteristic species in both the groups while remaining groups exhibited medium elevation. Highest values of edaphic variables (electrical conductivity, total dissolved solids, organic matter of soil and maximum water holding capacity) and acidic soil (6.457±0.202) were observed in group II which clearly indicated that the species of group II prefers to grow at high topographic condition as well as high values of edaphic variables and acidic soils. Slightly acidic soil (6.457±0.202), minimum organic matter and water holding capacity were the chief characteristics of group that could be predicted the low abundance of conifers in this area. Electrical conductivity and total dissolved solids have synergistic relationship that is why minimum values (980.25±55.3 and 50.03±2.86 respectively) are observed in group IV. [19] and [3] observed almost similar situations in many moist temperate area of mountainous areas of Pakistan. According to [20] and [21] numbers of environmental factors play a significant role in determining the vegetation pattern but the topographic and edaphic factors played an overriding role in vegetation distribution. Environmental factors played a great control on vegetation composition as suggested by [5]. Ordination results suggest vegetation changes to be primarily related to environmental changes occurring with electrical conductivity, pH, organic matter and water holding capacity [22]. He further observed that altitudinal increase causes decrease in temperature, soil fertility, water holding capacity and plant cover. Similarly, [5] correlated the vegetation with the of ordination axes; they found topographic factors and study sites to be the first two factors regulating the vegetation composition.

Table 3 Average frequency of understorey species in the four groups derived from Ward's cluster analysis of the circular plot data

S No.	Species name	Group I	Group II	Group III	Group IV
1	*Adiantum capillus veneris*	45	4	10	30
2	*Adiantum venestum*	30	7	70	45
3	*Androsace rotundifolia*	65	*	*	3
4	*Arisaema jacquemontii*	*	*	33	5
5	*Aristida cynantha*	40	*	*	40
6	*Berberis lycium*	65	9	27	73
7	*Buxus papillosa*	10	*	*	*
8	*Centaurea solstitialis*	30	*	27	13
9	*Chrysopogon aucheri*	25	17	43	58
10	*Cynodon dactylon*	10	3	*	*
11	*Delphenium uncinatum*	5	*	*	*
12	*Dryopteris filix*	30	*	4	3
13	*Dryopteris juxtapostia*	20	20	77	*
14	*Duchesnea indica*	*	6	50	*
15	*Euphorbia helioscopia*	*	*	17	*
16	*Euphorbia hispida*	10	*	*	*
17	*Fragaria indica*	10	*	*	3
18	*Galium boreale*	15	*	4	*
19	*Hypericum perforatum*	20	*	7	*
20	*Indigofera heterantha*	40	*	4	*
21	*Lycopodium selago*	*	*	*	3
22	*Morus alba*	*	15	7	*
23	*Nepeta laevigata*	30	*	*	8
24	*Onychium contiguum*	*	14	4	*
25	*Oxalis corniculata*	75	5	4	43
26	*Picea smithiana* seedling	*	5	17	*
27	*Pinus wallichiana* seedling	*	3	*	*
28	*Plantago amplexicaulis*	*	5	*	33
29	*Plectranthus rugosus*	*	*	*	13
30	*Podophylum emodi*	*	3	*	20
31	*Polygala abyssinica*	*	*	*	10
32	*Polygala erioptera*	*	*	27	3
33	*Polygonium amplexicaule*	*	*	10	8
34	*Potentilla desertorum*	*	*	*	3
35	*Prunus avium*	*	*	50	48
36	*Pteris cretica*	45	18	80	78
37	*Punica granatum*	15	*	7	10
38	*Quercus dilatata* seedling	*	*	*	3
39	*Ranunculus muricatus*	*	*	*	8
40	*Rosa macrophylla*	*	*	*	3
41	*Rosa webbiana,*	*	*	10	*
42	*Rubus biflorus*	*	4	10	*
43	*Rubus macilentus*	*	*	10	*
44	*Sarcococca saligna*	15	*	*	*
46	*Spiraea vaccinifolia*	*	*	7	*
47	*Trifolium fragiferum*	*	*	4	*
48	*Trifolium repens*	65	5	7	55
49	*Viburnum cylindricum*	*	12	4	*

*Shows the absence of species in a group.

Table 4 The mean values ± SE of environmental variables (topographic and edaphic) based on four groups derived from Ward's cluster analysis using understorey species data. (Mean ± SE)

Environmental Variable	Group I	Group II	Group III	Group IV
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
1- Topographic Variables of Soil				
Elevation (m)	2110 ± 10	2442.5±130.23	2290±26.458	2260±84
Slope°	27.5 ± 2.5	35.75±4.52	32±4.726	40±6.12
2- Edaphic Variables of Soil				
pH	6.457±0.202	6.02±0.141	6.027±0.214	6.26525±0.164
EC	1067±339	1402±44.78	1105±138.4	980.25±55.3
TDS	53.35±16.95	70.1±2.24	55.23±6.91	50.03±2.86
OM	7.71±1.185	11.46±0.275	10.54±0.93	8.1275±0.305
MWHC	35.99±10.67	61.91±3.197	55.267±6.98	39.2975±3.8

SE = Standard error

4.3 ANOVA (Univariate Analysis of Variance)

Univariate comparisons (single factor ANOVA) of four groups of environmental variables were analyzed by using four groups of topographic and edaphic variables (extracted with the help of groups derived from Ward's cluster analysis). Among both the environmental factors, only slope showed significant difference among the groups at the level of $p<0.05$ (Table 5) while other factors did not show significant difference among the four groups. Other groups of environmental variables did not show any effect on phytosociological attributes, could be due to long history of anthropogenic disturbance, legal or illegal cutting and grazing especially in the last 50 to 60 years or specially due to civil war in this area. [23] also used the approach of single factor analysis of variance (ANOVA) to test the differences of soil parameters between vegetation types and found significant differences.

Table 5 Analysis of variance (single factor) of individual environmental variables (topographic and edaphic variables) is evaluated. Four groups were derived by Ward's cluster analysis using species data of 13 stands of Malam Jabba forest of Pakistan
ANOVA: Single Factor **F crit = 5.409, df = 3**

Source of Variation	F-value	P-value	Significance-level
1- Topographic Variables			
1- Elevation	3.365	0.112	Ns
2- Slope	0.754	0.565	P< 0.05
2- Edaphic Variables			
1- pH	2.393	0.185	Ns
2- Electrical Conductivity	6.832	0.032	Ns
3- Total Dissolved Solids	6.832	0.032	Ns
4- Organic matter of soil	8.815	0.019	Ns
5- Water Holding Capacity	5.146	0.055	Ns

4.4 Ordination (Principle Component Analysis)

Two dimensional PCA ordination of stands and species on axes 1 and 2, axes 1 and 3 and axes 2 and 3 are represented in Figure 3. All stands and species on axes 1,2 and 1,3 distributed on right side while on axes 2,3 they distributed almost at the centre. Classification clustering strategy divided the study area into four distinct groups on the basis of floristic composition and environmental variables. These four groups of stands are somewhat superimposed on PCA ordination axes 1,2; axes 1,3 and 2,3. Some overlapping of groups was seen in all four groups and these groups separated out on ordination plane. However almost clear separation of groups are seen on axes 1,2 while on other two axes the groups are separated out with some overlapping and distance. We observed almost continuous distribution of stands across the ordination planes of all three axes. The species of concern groups are also occupied in same groups except some cases. Ordination on axes 1, 2 show that stands and species are located to the extreme right side but group I is occurred almost on left side are dominated by *Dryopteris filix, Androsace rotundifolia, Nepeta laevigata, Fragaria indica, Euphorbia hispida, Sarcococca saligna, Buxus papillosa, Galium boreale, Indigofera heterantha, Delphenium uncinatum* and *Hypericum perforatum*. Group II is situated on right side and lower bottam, occupied all the stands and species that was separated by cluster analysis. This group is dominated by *Picea smithiana* and *Pinus wallichiana* seedlings and *Viburnum nervosum, Morus alba* and *Onychium contiguum. Ranunculus muricatus, Arisaema jacquemontii, Polygonium amplexicaule* and *Polygala abyssinica.* Group occupied many species dominated by *Pteris cretica* and *Berberis lycium* were the dominant species in Group IV attained 78 and 73% frequency respectively. These two species are the diagnostic species of moist temperate area. *Chrysopogon aucheri* and *Trifolium repens*.

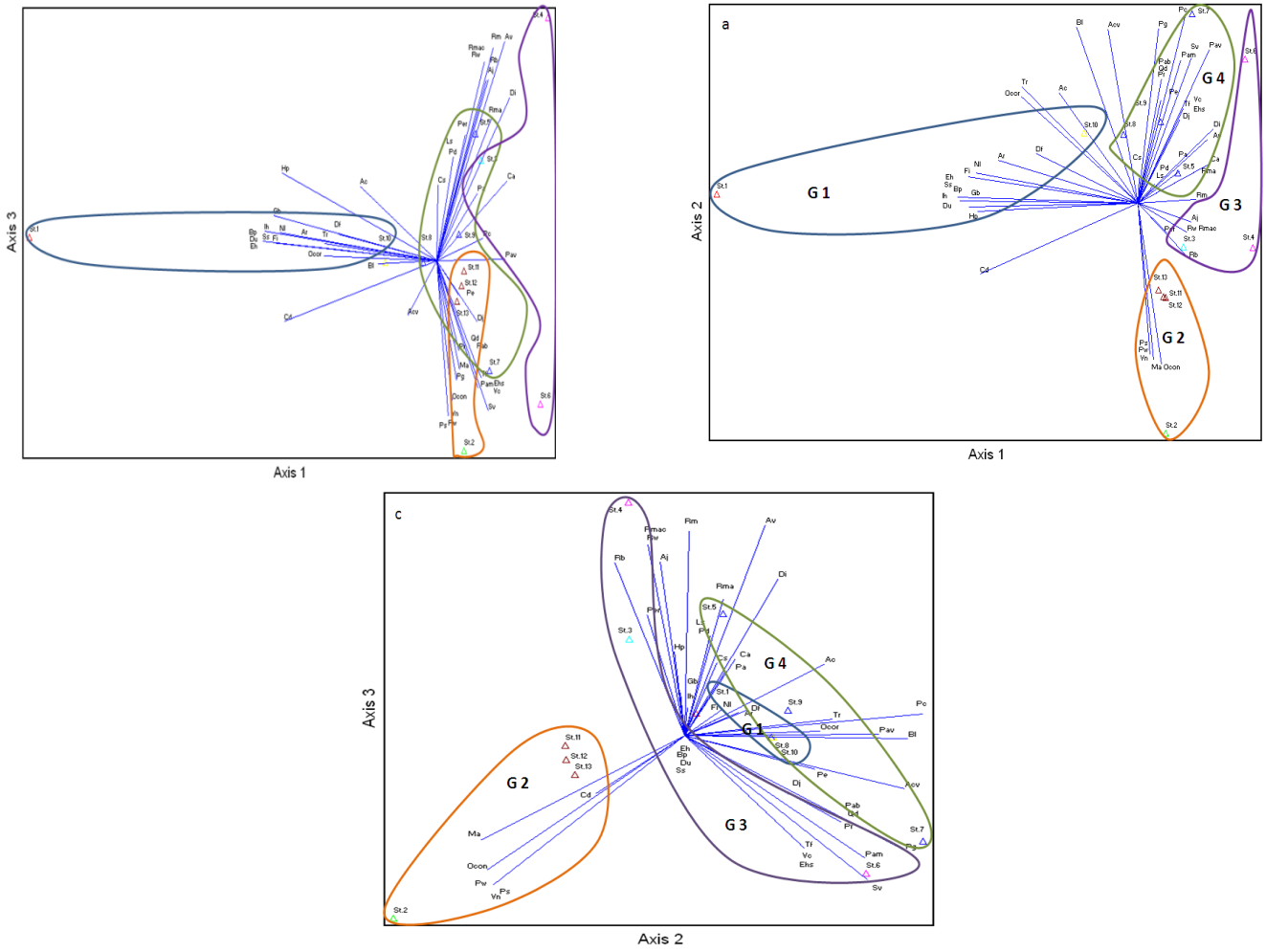


Figure 3 Two-dimensional PCA ordinations of stands, using species data of 13 stands of Malam Jabba forest of Pakistan. (a) Ordination of axis 1 & 2, (b) Ordination of axis 1 & 3, while (c) Ordination of axis 2 & 3

4.5 Relationship (Correlation Coefficient) of 6 Ordination Axes with Environmental Variables

Six axes obtained in PCA ordination that correlate with environmental variables (topographic and edaphic). Among all six axes only axis 2 showed highly significant correlations with environmental variables (Table 6). Ordination axis 2 showed highly significant correlation (negative) with organic matter of soil and maximum water holding capacity at the level of $p<0.001$ while electrical conductivity and total dissolved solids correlated at $P<0.05$. pH showed the significant correlation ($p<0.05$) with axis 4 while electrical conductivity weakly correlated ($P<0.1$) with axis 5. It is an ultimate truth that soil chemical properties have overriding role in vegetation distribution and composition, as indicated in this research. Classification and ordination can provide more detailed and more comprehensive information on the distribution of vegetation types, the association between species and co variation [24] and [23]. the use of both approaches concomitantly on the grounds that they yield complementary results and as such useful for better interpretation of ecological results, advocated by [24]. For the complex vegetation under study it is expected that a number of ecological gradients especially edaphic factors may be involved in determining the distribution pattern of vegetation.

Table 6 Relationship (correlation coefficients) of environmental variables (topographic variables and edaphic variables) with 6 PCA ordination axes obtained by tree vegetation data based on frequency of understorey species

		Axis 1		Axis 2		Axis 3	
S. No.	**Variables**	**r**	**Prob. Level**	**r**	**Prob. Level**	**r**	**Prob. Level**
1- Topographic variables							
1	Elevation	0.348	ns	0.151	Ns	-0.009	ns
2	Slope	0.288	ns	-0.173	Ns	0.036	ns
2- Edaphic variables							
1	pH	-0.289	ns	0.213	Ns	-0.203	ns
2	EC	-0.224	ns	-0.684	P < 0.01	0.011	ns
3	TDS	-0.22	ns	-0.683	P < 0.01	0.041	ns
4	OM	0.224	ns	-0.831	P < 0.001	0.105	ns
5	MWHC	0.167	ns	-0.769	P < 0.001	0.095	ns
		Axis 4		**Axis 5**		**Axis 6**	
1- Topographic variables							
1	Elevation	0.323	ns	-0.044	ns	0.353	ns
2	Slope	-0.178	ns	0.469	P < 0.1	0.393	ns
2- Edaphic variables							
1	pH	0.482	P < 0.1	0.029	ns	-0.365	ns
2	EC	-0.289	ns	0.096	ns	0.379	ns
3	TDS	-0.258	ns	0.088	ns	0.354	ns
4	OM	-0.336	ns	0.079	ns	-0.023	ns
5	MWHC	-0.323	ns	0.053	ns	0.068	ns

Key to abbreviations: r = Correlation coefficient, ns = Non significant, Prob. Level = Probability level, EC = Electrical conductivity, TDS = Total dissolved solids, MWHC = Maximum water holding capacity and OM. = Organic matter of soil in %

Summing together, it seems that the second axis of PCA ordination represent an amalgam of environmental gradients. On the basis of the results of the above investigation, it may be concluded that detailed and a better understanding of vegetation and its relation to environmental variables may be achieved by the application of a variety of multivariate techniques in conjunction with each other.

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