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VEGETATION COMPOSITION AND BIOLOGICAL SPECTRA OF THE DISTRICT CHAKWAL, PAKISTAN USING MULTIVARIATE ANALYSES

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Abstract

The vegetation analysis was undertaken of the District Chakwal which is located at the beginning of the Pothwar plateau during 2015 to 2017. Stratified random vegetation sampling technique was used along the 14 altitudinal transects of 70 sampling sites with 700 plots. The Cluster Analysis classified six dominant plant communities viz., 1) *Lantana-Parthenium-Cannabis* (LPC) community, 2) *Calotropis-Chrysopogon-Melia* (CCM) community, 3) *Cynodon-Cenchrus-Tecomella* (CCT) community, 4) *Zizyphus-Zizyphus-Capparis* (ZZC) community, 5) *Dalbergia-Heteropogon-Prosopis* (DHP) community and 6) *Acacia-Justicia-Dodonaea* (AJD) community. Canonical Correspondence Analysis (CCA) tool was applied to confirm the studied climatic variables in association with the existing plant communities. The CCA results revealed that total variations in the response data were 3.827 and 32.7% as explained by the explanatory variables. On the basis of conditional (net) term effects, moisture [Pseudo-F 1.7; p(adj) 0.00243] and soil pH [Pseudo-F 1.6; p(adj) 0.00243] were detected as the most important and significant factors towards explaining the variations among different vegetation communities. It was concluded that altitude, electrical conductivity and soil pH were the significant environmental factors that play role in the formation of major plant communities in the District Chakwal. Being the dominance of natural remnant vegetation in this mountainous terrain, local inhabitants are continuously exerting pressure for utilizing the century's old vegetation especially for fuel wood and other uses so there is immediate need for proper management of this area.

Key words: Plant communities, Remnant vegetation, Detrended Correspondence Analysis, Canonical Correspondence Analysis, Pothwar plateau, District Chakwal.

Introduction

Autecology studies the plant composition in association with their environment. It provides information regarding the status of plant biodiversity status of any given area. Specifically such studies are useful in planning the conservation, implementation and monitoring activities for safeguarding the diversity (Qureshi, 2012; Khan *et al.*, 2018a). The ecological surveys or analysis are crucial across communities and the characterization of a plant community is important for assessing the variation happened in environmental factors and their response on communities of that area (Lehsten & Kleyer, 2007).

Climate and soil are closely associated with the vegetation of any given area. Any dissimilarity in these factors alters the vegetation composition. The habitat condition governs and modifies the structural composition of the flora associated with it (Biondi, 2011). Phytosociology entails structure, classification, composition and the development of a plant community due to their relationship with the environment (Allaby, 2004). It provides efficient method for studying the vegetation composition that has been used in determining existing plant communities and ultimately plays its role in conserving biodiversity (Ewald, 2003; Biondi, 2011; Khan *et al.*, 2018b). Variations in habitat and microhabitat coupled with and biotic relations establish the distribution of various plant species in a community (Khan *et al.*, 2013). A healthy ecosystem reflects the richness of plant biodiversity (Ruiz *et al.*, 2008) and therefore the vegetation analysis play a key role towards the management of an ecosystem.

It is an established fact that there is a close and direct relationship between the edaphic factors and vegetation of any given area; both are reversibly influenced by each other. A best example of soil and plants reversible influence on each other, in which soil provides nutrients and humidity for the best growth of plants, while in turn vegetation is responsible for the protection and longevity of soil cover, reduces soil erosion and enhance nutrients in soil (Eni *et al.*, 2012). A multivariate technique is very popular now days that is used for rapid classification that express interdependence between soil and environmental factors (Urooj *et al.*, 2015). To evaluate effects and relationship between the factors which govern the environment and flora of given area, the ordination technique such as Canonical Correspondence Analysis (CCA) is used by the ecologist to describe plant communities (Li *et al.*, 2012; Ahmad *et al.*, 2014). Biodiversity of any region is dependent on healthy ecosystems of that area and classification helps to realize the present vegetation status of any area for future planning regarding the conservation of diversity of area in proper way (Ruiz *et al.*, 2008).

Chakwal is a ranifed (*Barani*) district located at the embankment of the Pothwar plateau and adjacent to the famous Salt Range with with complex patterns of topography, extending from mountainous, uneven to rugged area with big gullies having typical vegetation. This area has not been explored before in terms of the multifaceted relationship of the existing vegetation with the environment, classification, and ordination by using the multivariate analysis. So, this is first ever thorough vegetation study to express the accurate picture of the distribution of plant species in the area by employing multivariate tools.

Materials and Methods

The study area: District Chakwal is a central rainfed (*Barani*) area of Punjab situated on the border of Pothwar plateau (hilly terrain) and adjacent to the famous Salt Range. The area covered an area of about 6,525 square kilometres and situated between 71° 33` to 73° 16` E longitudes and 32° 33` to 33° 12` N latitudes with elevational ranges of 450 to 1050 above mean sea level situated in the middle of Sindh Sagar Doab (Khan *et al*., 2002; Arshad, 2011). Geographically, mountains and rocky terrain located towards the south (S) and southeast (SE) of the District is dominated by scrub forests along with some plain and flat areas. While, the north (N) and northeast (NE) side comprised of mildly undulating plains, ravines, gorges with tracts of rocky segments and some desert areas locally known as *Khuddhar*. The district is bounded on the north by the Rawalpindi and Attock, to the east and south-east by the Jehlum, in the south is Khushab; while in the western side, there is Mianwali.

The temperature in the winter season ranges between 4-25°C, and in summers it normally fluctuates between 15-40°C. June is the hottest month of the year; whereas, in December, the temperature reaches up to the freezing point. The average annual rainfall is ranging between 558-635 mm and it is observed that over 70% of annual precipitation is received by summer season mostly during Monsoon (Mohammad, 1989; Anon., 2007; Ahmed *et al*., 2009). The soil is textural class ranges from slit loam to loam having 7 to 9 pH. Owing to rich in mineral contents and rock salt, the subsoil is mainly represented by the mixture of clay, gravels and fragments of broken rock.

Plant collection and identification: The entire study area was inspected during August, 2015 till September, 2017 by following transect walks, for the vegetation data and specimens collection. Stratified random sampling design was followed for the vegetation analysis. The collected plant specimens were treated for pressing, drying and mounting on standard sized herbarium sheets. Angiosperms and gymnosperms were got identified by consulting local and regional floristic materials including flora of Pakistan, China and India (Nasir & Ali, 1970-1989; Ali & Nasir, 1989-1991; Ali & Qaisar, 1993-2018; Anon., 2012a; 2012b). Accepted names were further validated from The Plant List website www.theplantlist.org. The fully identified specimens were placed in the herbarium of Pir Mehr Ali Shah (PMAS) for future reference.

Vegetation survey: Following the stratified random sampling method, a total of 700 plots along the 14 altitudinal transects encircling 70 sampling stations were examined. For determining plot size (quadrat or relevé) and species minimal area/number, curve rule method was applied by following the work of Hussain (1989) and Ilyas *et al*., (2015). For recording altitude, exposure, and slope as well as exact location, geographical positioning system (GPS) was used for each relevé. Soil samples were also gathered from the three random selections from each relevé within a depth of 15cm. For making composites, these were meticulously mixed. Approximately, one KG weight of the mixed soil was packed in ploythene bags and labelled. The soil properties were checked in the soil and water testing laboratory, Shamsabad, Rawalpindi after Koehler *et al*., (1984). Soil pH was calculated in 1: 5 soil water suspensions by using the pH meter (Mclean, 1982). For the determining lime, acid neutralization method was used (Black, 1965). The organic matter of soil was calculated by utilizing solution of FeSO4 and K2Cr2O7 as described by Nelson & Sommer (1982). The P and K were estimated from the samples from AB-DTPA or Mehlic No.3 extractable on the basis of pH of soil samples.

Ordination: For making correlation as a distance matrix, cluster dendrogram were developed by using climatic variables and associations of vegetation following the work of Khan *et al*., (2019). Multi-response permutation procedures (MRPP) test was also used for the pair-wise comparison of six plant communities of District Chakwal, Pakistan. To diagnose the indicators of distinct groups, Indicator species analysis (Dufrene & Legendre, 1997) was also used (Fig. 1).

The plant associations were named on two to three species with the highest fidelity/constancy values contributing in the main habitat type. For seeking association between species, relevés and environmental variables, Detrended Correspondence Analysis (DCA) was performed by using Canoco software (V. 5) for windows; whereas, for analyzing the role of climatic variables in explaining variations in the binary response data, canonical correspondence analysis (CCA) was used (TerBraak & Smilauer, 2012).

Results

Indicator species analysis (ISA): For the naming of vegetation classes, topmost three species of every vegetation group were placed in a chronological order. The Indicator species Analysis confirmed the top indicators of the plant communities in the region viz., 1) *Lantana-Parthenium-Cannabis* (LPC) community, 2) *Calotropis-Chrysopogon-Melia* (CCM) community, 3) *Cynodon-Cenchrus-Tecomella* (CCT) community, 4) *Zizyphus-Zizyphus-Capparis* (ZZC) community, 5) Dalb*ergia-Heteropogon-Prosopis* (DHP) community and 6) *Acacia-Justicia-Dodonaea* (AJD) community (Table 1). These species were correlated to various edaphic and environmental factors i.e. altitude, slope, soil pH, concentration of organic matter, potassium, aspect, electrical conductivity and sandy nature of soil.

Plant communities: There was diversity in the plant composition of the studied area due to distinction in the altitude, climate and aspect. Six plant communities were identified associated with the climatic factors as well as based on the highest Importance Value (IV) in the distinct zone. Detailed description for each plant community is as follows:

***Lantana-Parthenium-Cannabis* (LPC) community:** This association was developed based on the Total Importance Value Indicator (TIV) exhibited by Indicator Analysis (Table 1). The highest dominated species was *Lantana camara* with 64 TIV, followed by *Parthenium hysterophorus* (54 TIV) and *Cannabis sativa* (53 TIV). This plant association was occupied at 280-320 elevations in the area of study. Those relevés that represented this community were situated between latitudinal and longitudinal ranges of 32°04'26.78"N and 72°74'2.07"E, respectively. The plant community was located in wider range of localities such as Basharat, Saloi, Dharma Tirath, Lari Shah Nawaz, Kot Raja Dam and Jhatla with gentle slopes varying from 0-10°. This community was found associated with sandy soil. This community prefers to grow on sandy loam to loam soil. The soils are generally calcareous. The community had sodium level 0.05±0.02% and electrical conductivity 1.02±0.31%. Soil moisture was 45.51±7.61% with slightly alkaline pH 7.56. The soils contained 0.65±0.49% organic matter, 0.05±0.02% nitrogen, 6.04±3.22 phosphorus and 100.81±42.04 potassium (Table 2).

Calotropis-Chrysopogon-Melia **(MCC) community:** Based on the highest TIV values, this community was named as *Calotropis- Chrysopogon-Melia* (Table 1). The highest TIV value was recorded equally for *Calotropis procera* and *Melia azedarach* (54 each), followed by *Chrysopogon serrulatus* (47 TIV). This association was based on 42.33±9.67% vegetation cover. This association was dominated by shrubs with a cover of 41.46±29.26%, followed by herb layer 34.21±21.13%, and tree layer of 25.02±21.18% spread on elevation ranges of 380 to 420 in the study area. This community was located on latitudinal range between 32°93'26.78"N and longitudinal range between 72°24'2.07"E with gentle slopes varied between 03°-07°. The plant community was identified in Rehna Sadaat, Dharabdam Lake, Basharat, Saloi, Dharma Tirath, Lari Shah Nawaz, Kot Raja Dam and Jhatla. This community was found associated with sandy loam to loam soil. The soils are generally calcareous. The community had sodium level 0.05±0.02% and electrical conductivity 1.02±0.31%. Soil moisture was 43.33±15.17% and the soil of the community had slightly alkaline pH 7.14±0.16. The soils contained 0.63±0.51% organic matter, 0.04±0.03% nitrogen, 4.07±4.01 phosphorus and 80.51±45.81 potassium (Table 2).

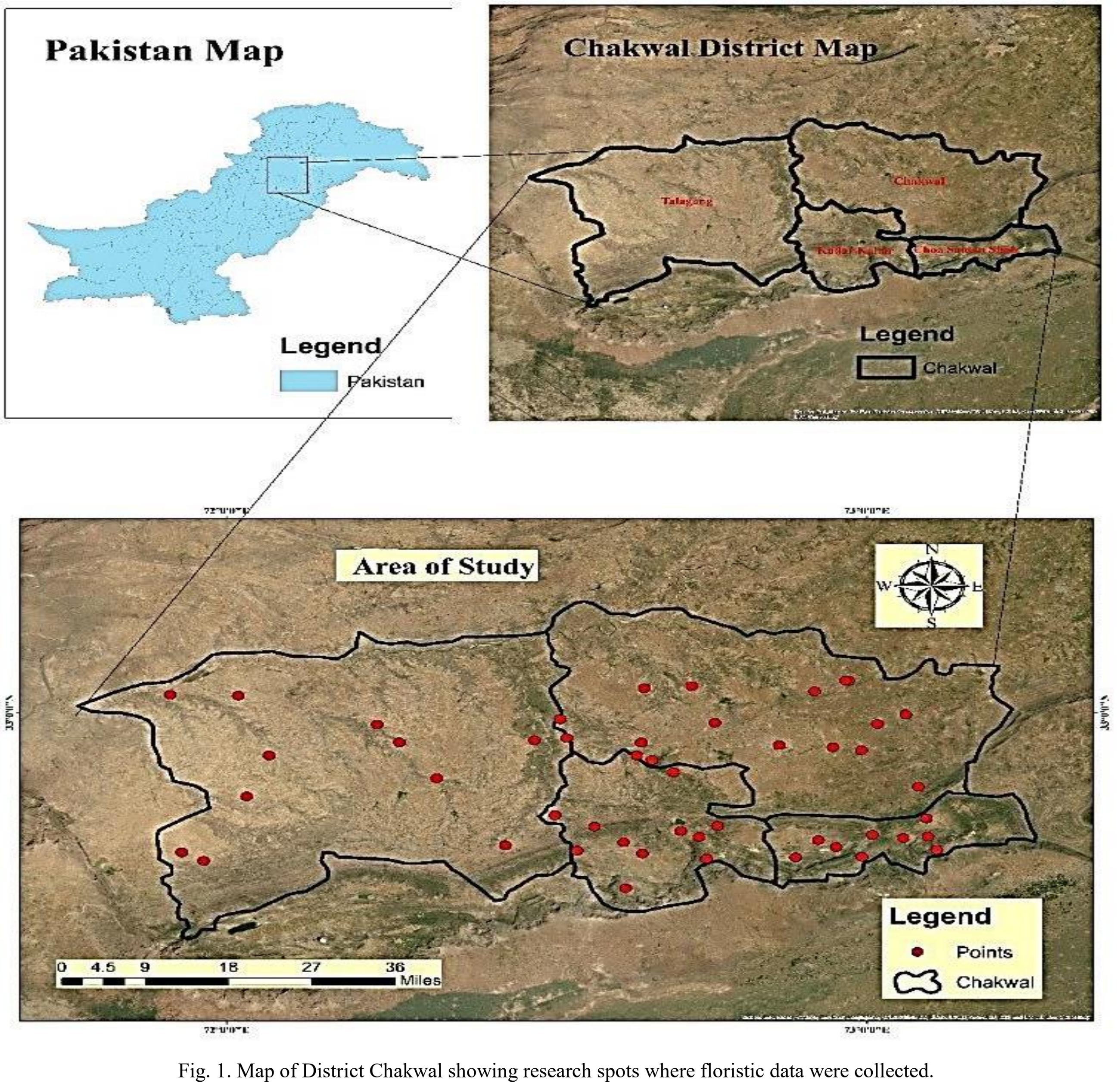

Fig. 1. Map of District Chakwal showing research spots where floristic data were collected.

Table 1. Indicator species analysis (ISA) and Monte Carlo permutation test results showing plant associations of the District Chakwal.

Spp. codes	Max. Group	Max. IV	Plant associations						TIV	Mean	SD	p-value
			1	2	3	4	5	6				
Lan.cam	1	37.9	38	17	4	0	5	0	64	15.7	4.03	0.0004
Par.hys	1	31.7	32	5	2	4	7	4	54	15.8	3.97	0.0022
Can.sat	1	25.3	25	10	11	0	2	5	53	15.5	4.15	0.0284
Cal.pro	2	19.1	13	19	2	5	11	4	54	16.5	3.89	0.2274
Chr.ser	2	27.7	0	28	0	19	0	7	54	13.5	4.6	0.0138
Mel.aze	2	29.2	2	29	2	3	0	11	47	14.2	4.42	0.0068
Cyn.dac	3	23.5	16	10	23	21	6	8	84	19.1	2.35	0.0464
Cen.cil	3	39.1	8	0	39	2	20	4	73	15.5	4.09	0.0002
Tec.und	3	24.1	5	4	24	12	9	7	61	17	3.84	0.0518
Ziz.mau	4	18.6	12	16	16	19	18	15	96	18.9	1.03	0.5929
Ziz.num	4	21	16	18	7	21	15	5	82	19.3	2.48	0.229
Cap.dec	4	18.6	3	17	16	19	16	8	79	18.6	2.6	0.4481
Dal.sis	5	25.1	14	16	11	12	25	6	84	19.2	2.2	0.0068
Het.con	5	33.5	2	3	0	23	33	18	79	16.9	3.82	0.0018
Pro.jul	5	29.3	9	26	0	8	29	4	76	18.5	3.47	0.0086
Aca.mod	6	18.9	16	16	16	14	17	19	98	18.4	0.72	0.2108
Jus.adh	6	50.4	0	0	4	9	10	50	73	14.7	4.31	0.0002
Dod.vis	6	43.2	0	0	16	5	8	43	72	15.2	4.2	0.0002

Table 2. Environmental variable and vegetation cover in the six communities of District Chakwal.

Parameters	Communities					
	1. LPC	2. CCM	3. CCT	4. ZZC	5. DHP	6. AJD
Altitude (m)	300 ± 65.89	400 ± 89.76	450 ± 102.43	290 ± 61.86	580 ± 145.56	800 ± 185.31
Slope	09.16 ± 4.33	05.58 ± 6.63	11.63 ± 7.38	04.54 ± 8.7	16.87 ± 9.19	12.86 ± 8.06
Total cover (%)	48 ± 10.9	42.33 ± 9.67	44.13 ± 38.25	43.29 ± 37.86	41.04 ± 13.86	60.01 ± 7.01
Cover tree layer (%)	20.74 ± 21.64	25.02 ± 21.18	25.31 ± 28.65	31.72 ± 32.23	26.82 ± 21.45	29.65 ± 36.35
Cover shrub layer (%)	41.91 ± 14.46	41.46 ± 29.26	29.24 ± 24.76	35.42 ± 19.81	29.22 ± 21.32	44.37 ± 32.03
Cover herb layer (%)	63.32 ± 20.82	34.21 ± 21.13	32.41 ± 17.76	41.67 ± 24.82	53.04 ± 23.41	52.07 ± 51.32
Longitude	72.74 ± 0.05	72.24 ± 0.03	72.24 ± 0.03	72.95 ± 0.06	72.37 ± 0.05	72.35 ± 0.05
Latitude	32.04 ± 0.2	32.93 ± 0.1	32.03 ± 0.03	32.82 ± 0.07	32.77 ± 0.03	33.72 ± 0.04
Moisture	45.51 ± 7.61	43.33 ± 15.17	49.77 ± 7.27	35.25 ± 13.41	38.41 ± 09.31	48.71 ± 8.53
pH	7.05 ± 0.3	7.14 ± 0.16	7.24 ± 0.04	7.50 ± 0.26	7.13 ± 0.29	7.22 ± 0.4.00
K/Kg	100.81 ± 42.04	80.51 ± 45.81	120.71 ± 31.17	80.82 ± 39.82	120.76 ± 31.02	65.33 ± 25.29
P mg/Kg	6.04 ± 3.22	4.07 ± 4.01	5.05 ± 3.32	3.09 ± 4.11	5.09 ± 3.39	4.01 ± 3.12
O.M%	0.65 ± 0.49	0.63 ± 0.51	0.55 ± 0.45	0.48 ± 0.6	0.48 ± 0.32	0.62 ± 0.41
N mg/Kg	0.05 ± 0.02	0.04 ± 0.03	0.03 ± 0.04	0.04 ± 0.03	0.06 ± 0.02	0.05 ± 0.02
EC %	1.02 ± 0.31	0.78 ± 0.11	1.01 ± 0.21	0.60 ± 0.14	0.75 ± 0.19	0.82 ± 0.28
TSS mg/Kg	512.06 ± 201.43	502.22 ± 103.3	509.14 ± 151.64	511.12 ± 116.31	498.31 ± 124.31	542.54 ± 198.21

Table 3. Statistics of detrended correspondence analysis. Eigen values and variation explained by DCA.

Axis	Axis 1	Axis 2	Axis 3	Axis 4
Eigen values	0.742	0.312	0.1392	0.1245
Explained variation (cumulative)	7.62	11.76	12.54	16.59
Gradient length	5.97	3.12	3.06	2.06
Pseudo-canonical correlation	0.8953	0.3257	0.3114	0.4467

***Cynodon-Cenchrus-Tecomella* (CCT) community:** This association was named based on the highest TIV comprised on *Cynodon-Cenchrus-Tecomella* (Table 1). The first two dominant species were grasses i.e. *Cynodon dactylon* and *Cenchrus ciliaris* with 84 and 73 TIV, respectively, followed by with *Techomella undulata* (61 TIV). This association covered on the vegetation area of 44.13+38.25 with the dominance of grasses/herbs 32.41+17.76, followed by shrub layer 29.24±24.76 and tree layer 25.31±28.65. This community was spread over latitudinal ranges between 32°03'26.78"N and longitudinal range between 72°24'2.07"E with average elevations ranges between 430 to 470. The plant community was identified in Kot Sarang, Multan Khurd, Dhok Pathan, Leti, Kotgulla, Basharat, Saloi, Dharma Tirath, Lari Shah Nawaz, Kot Raja Dam and Jhatla. The slopes were mostly gentle and varied between 0-13° with an average of 11.63+7.38. This community was associated with sandy loam to loam soils having calcareous nature. The community had sodium level 0.05±0.02% and electrical conductivity 1.02±0.31%. Soil moisture was 49.77±7.27% and the soil of the community had slightly alkaline pH 7.24±0.04. The soils contained 0.55±0.45% organic matter, 0.03±0.04% nitrogen, 5.05±3.32 phosphorus and 120.71±31.17 potassium (Table 2).

***Zizyphus-Zizyphus-Capparis* (ZZC) community:** Based on TIV values, this community was named as *Zizyphus-Zizyphus-Capparis* (Table 1). The highest TIV was recorded for *Zizyphus mauritiana* (96), followed by *Z. nummularia* (82) and *Cannabis sativa* (79). This association covered an occupied a vegetation area of 43.29±37.86% with dominance of herb layer of 41.67±24.82%, followed by shrub (35.42±19.81%) and tree layer (31.72±32.23%) on the gentle slopes between 0-7°. This association is found with elevations of 270-310 located at latitudes and longitudes of 32°82'26.78" N and 72°95'2.07"E, respectively. This plant community was identified from various study sites of Lawa, Talagang, Dhanda Shabila Wal, Dharnaal, Kot Qazi, Kot Saarang, Basharat, Saloi, Dharma Tirath, Lari Shah Nawaz, Kot Raja Dam and Jhatla. The soil of this community was sandy loam to loam sand having calcareous nature. The community had sodium level 0.04±0.03% and electrical conductivity 0.60±0.14%. Soil moisture was 35.25±13.41% % and the soil of the community had slightly alkaline pH 7.50±0.26. The soils contained 0.48±0.6% organic matter, 0.04±0.03% nitrogen, 3.09±4.11 phosphorus and 80.82±39.82 potassium (Table 2).

***Dalbergia-Heteropogon-Prosopis* (DHP) community:** The community is named as *Dalbergia-Heteropogon-Prosopis* based on the highest TIV (Table 1). Within this association, the highest TIV was recorded for *Dalbergia sissoo* (84), followed by *Heteropogon contortus* (79) and *Prosopis juliflora* (76). The vegetation cover in this association was 41.04+13.86 with the dominance of herb layer (53.04±23.41), followed by shrub layer (29.22±21.32) and tree layer (26.82±21.45) with gentle slopes varied between 0-18° with an average of 16.87±9.19. This plant association was occupied aon latitudinal ranges of 32°77'48.40"N and longitudinal ranges of 37'54.74" with elevations of 560-600. The plant community was found in Dhadial, Lakhwal, Padshahan, Neeladulla, Miwaal Dam, Haraaj, Basharat, Saloi, Dharma Tirath, Lari Shah Nawaz, Kot Raja Dam and Jhatla. This community was associated to sandy loam to loam soil. The soils are generally calcareous. The community had sodium level 0.04±0.03% and electrical conductivity 0.60±0.14%. Soil moisture was 38.41±09.31% and the soil of the community had slightly alkaline pH 7.13±0.29. The soils contained 0.48±0.32% organic matter, 0.06±0.02% nitrogen, 5.09±3.39 phosphorus and 120.76±31.02 potassium (Table 2).

***Acacia-Justicia-Dodonaea* (AJD) community:** *Acacia-Justicia-Dodonaea* association was developed on the basis of maximum highest TIV values (Table 1). *Dodonaea viscosa* was the leading species that had maximum TIV values (98), followed by *Justicia adhatoda* (73) and *Acacia modesta* (72). This montane community covered an area of 60.01±7.01, with the highest coverage of herb layer (52.07±51.32), followed by shrub layer (44.37±32.03) and tree layer (29.65±36.35) with gentle slopes varied between 0-13° with an average of 12.86±8.06. This association was stretched over latitudes and longitudes of 33°72'25.63"N and 72°35'34.64"E, respectively with elevational ranges of 630 to 800. This community was identified from Choa Saiden Shah, KallaKahar, Khandoa, Kahut, Wasnaal, Basharat, Saloi, Dharma Tirath, Lari Shah Nawaz, Kot Raja Dam and Jhatla. The soils of this community ranged from sandy loam to loam with slightly calcareous. The community had sodium level 0.05±0.02% and electrical conductivity 0.82±0.28%. Soil moisture was 48.71±8.53% % and the soil of the community had slightly alkaline pH 7.22±0.4. The soils contained 0.62±0.41% organic matter, 0.05±0.02% nitrogen, 4.01±3.12 phosphorus and 65.33±25.29 potassium (Table 2).

Ordination: Six distinct vegetation clusters were developed by employing PCORD software. Thus clustering dendrogram of vegetation samples was produced which provides the pictorial view of their grouping relationship and hierarchies for plant community analysis (Fig. 2).

Detrended Correspondence Analysis (DCA): Based on the floristic composition, all the plots were classified into six plant community. *Calotropis-Chrysopogon-Melia* (CCM) and *Acacia-Justicia-Dodonaea* (AJD) associations exhibited maximum dissimilarity because both are located far away on the ordination plot (Fig. 2). Maximum similarity was observed between the *Lantana-Parthenium-Cannabis* (LPC) and *Zizyphus-Zizyphus-Capparis* (ZZC) associations because they are closely associated.

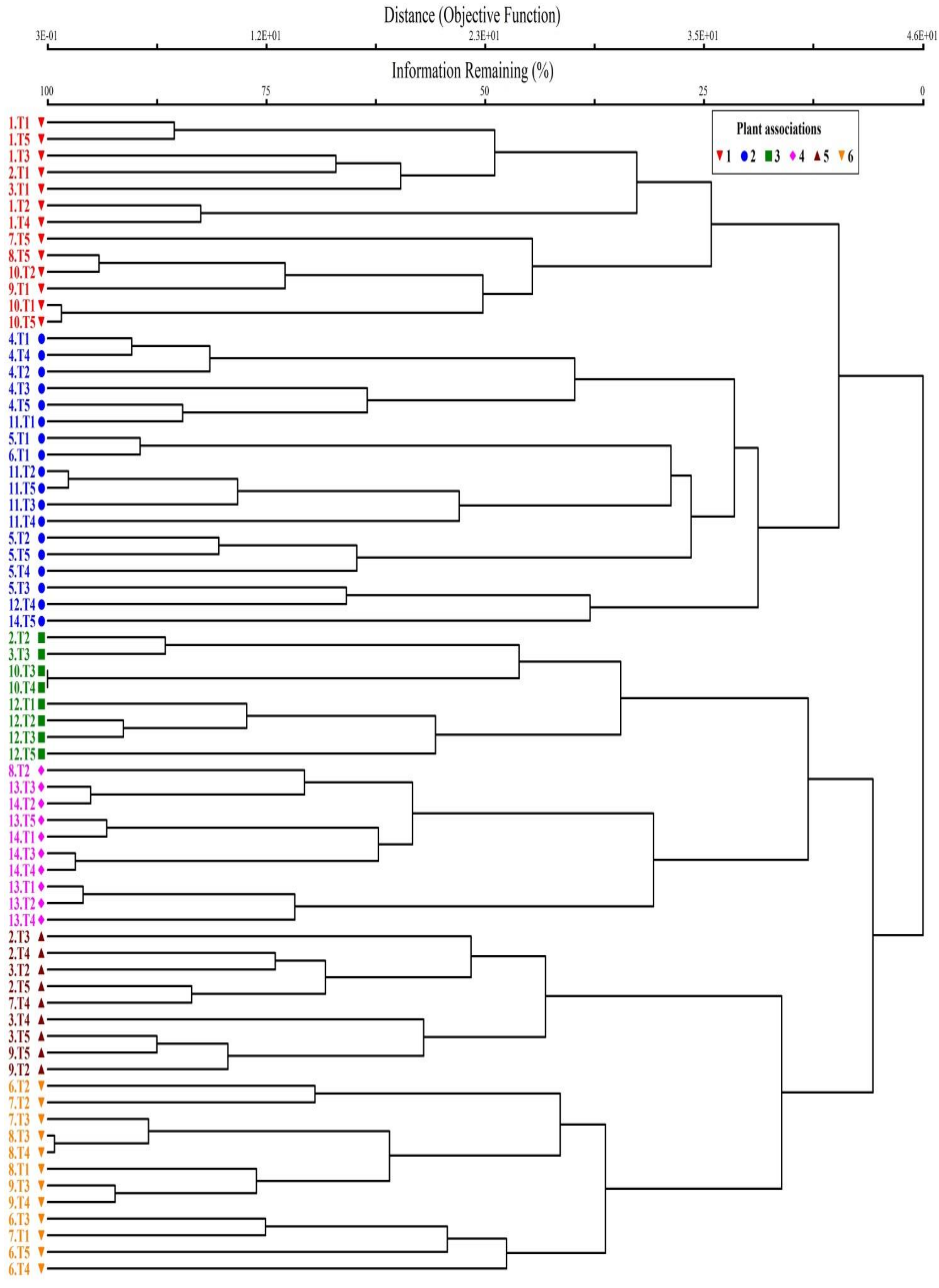

Fig. 2. Clustering dendrogram showing six groups from 70 sampling stations.

1. LPC, **2.** CCM, **3.** CCT, **4.** ZZC, **5.** DHP, **6.** AJD

Key for clustering dendrogram (Plant association number and abbreviations of the leading dominants).

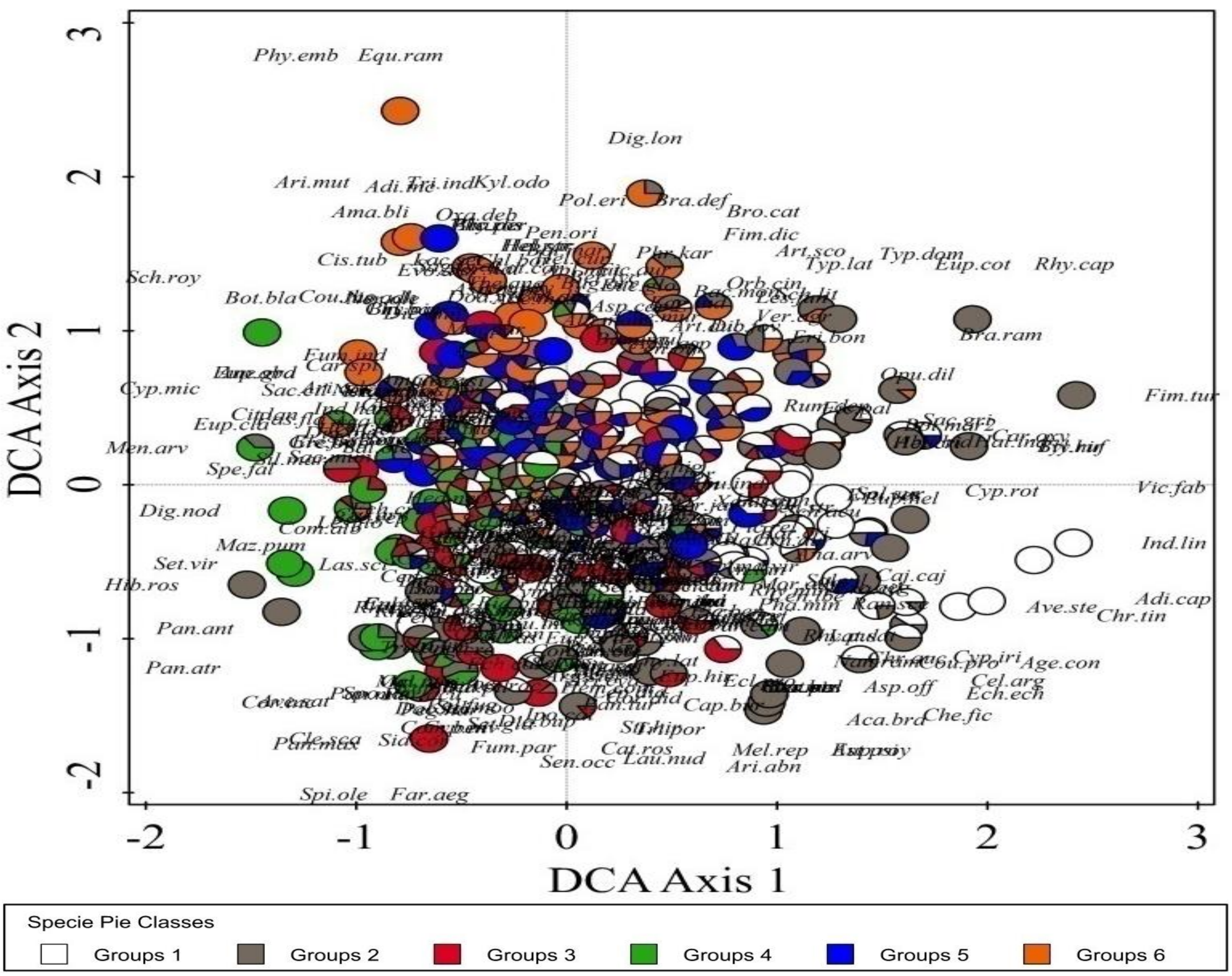

Fig. 3. DCA biplot showing distribution pattern of vegetation samples in District Chakwal.

Legend: 1. *Lantana-Parthenium-Cannabis* (LPC) community, **2.** *Calotropis-Chrysopogon-Melia* (CCM) community, **3.** *Cynodon-Cenchrus-Tecomella* (CCT) community, **4.** *Zizyphus-Zizyphus-Capparis* (ZZC) community, **5.** *Dalbergia-Heteropogon-Prosopis* (DHP) community, **6.** *Acacia-Justicia-Dodonaea* (AJD) community.

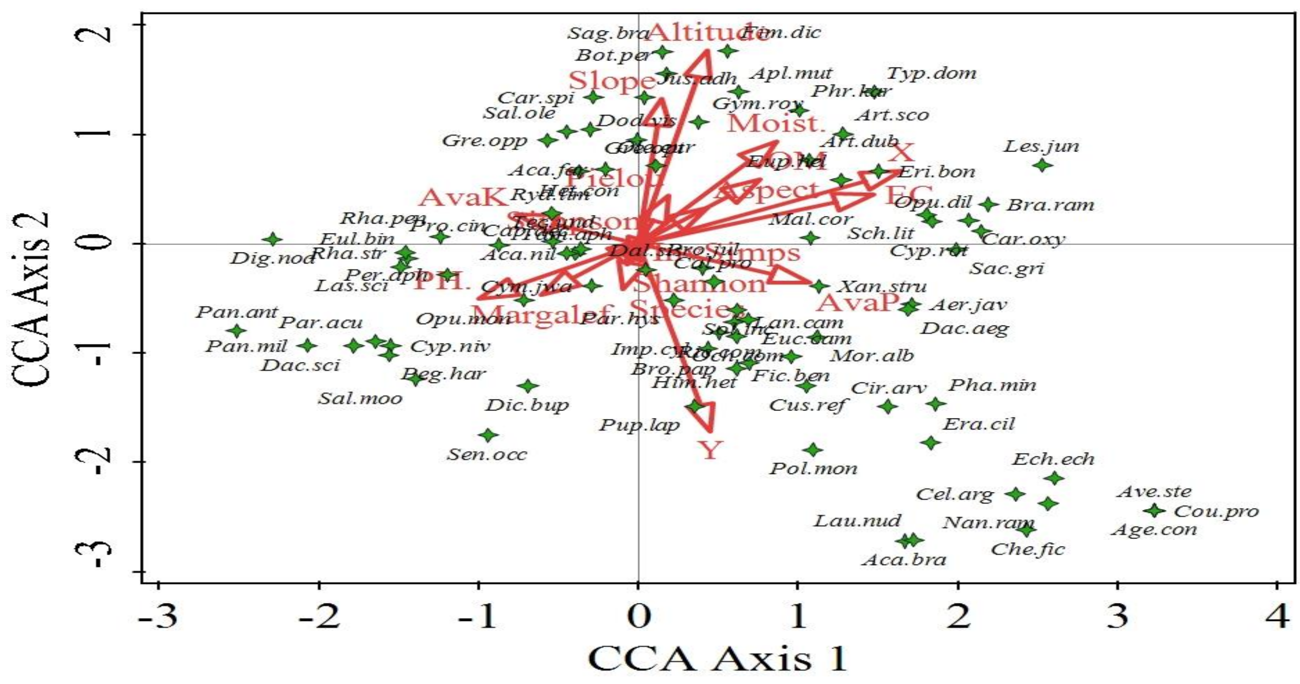

Fig. 4. CCA biplot showing relationship between vegetation samples and supplementary variables.

Table 4. Multi-response permutation procedures (MRPP) test for Pair-wise comparison of six plant communities of District Chakwal, Pakistan.

Plant associations compared			T-statistics	A-value	p-value
1	vs.	2	-7.2636846	0.0345066	0.0000085800
1	vs.	3	-8.2225472	0.0374263	0.0000025600
1	vs.	4	-8.7287948	0.0257832	0.0000000200
1	vs.	5	-12.351723	0.057184	0.0000001900
1	vs.	6	-10.33489	0.0512949	0.0000002200
2	vs.	3	-7.4406337	0.0487707	0.0000111800
2	vs.	4	-8.9493671	0.0370937	0.0000001400
2	vs.	5	-8.6786915	0.0486528	0.0000098900
2	vs.	6	-7.3402256	0.0434328	0.0000046300
3	vs.	4	-10.020669	0.0395644	0.0000000300
3	vs.	5	-7.2190874	0.0294187	0.0000057500
3	vs.	6	-8.1728011	0.044066	0.0000067500
4	vs.	5	-12.725711	0.0463798	0.0000000000
4	vs.	6	-9.1965074	0.0349049	0.0000001000
5	vs.	6	-9.0142216	0.0431533	0.0000007900

To find out the underlying environmental gradients, Detrended Correspondence Ordination (DCA) method was employed. The scattering of the sample plots along the DCA ordination axes is given in Fig. 3 enclosed with identified groups adopting TWINSPAN. The eigenvalues of the first four DCA axes were 0.74, 0.31, 0.139 and 0.124, respectively (Table 3). DCA scatter plot of species interpreted by pies instead of symbols exhibited the species richness in the constructed plant communities. The plot clearly indicated the presence of diagnostic species in particular vegetation group. Besides, it also exhibited that there is decline of plant species in the communities ranging from lower to higher elevations. It is also revealed that altitude was the highly important environmental variable which influence diversity in the plant species composition, followed by vegetation cover and density in the District Chakwal (Fig. 3).

Canonical correspondence analyses (CCA): To find out the underlying environmental gradients, Canonical Correspondence Analyses (CCA) was carried out by using CANOCO software for the understanding the correlation between vegetation and environmental gradients. The first quadrant of CCA (bi-plot diagram) revealed that higher numbers of the plant species were clustered under the influence of available phosphorous and slope (Fig. 4). While going through the second quadrant, all the plant species were assembled under the dominance of altitude, moisture, organic matter, aspect and electrical conductivity. While in the third quadrant, maximum number of plants gathered in response to pH (Fig. 4).

Variations among associations through Multi-response permutation procedure (MRPP): Six identified plant communities were pairwise matched by Multi-response permutation procedure (MRPP) to find substantial variation in the plant composition. Pairwise comparison of these plant communities revealed that that there was significant (p<0.00015) difference in all these groups in terms of their species compositions. All these pairs exhibited greater negative T-values indicating logical partitioning of the two communities. The maximum difference was noted in *Zizyphus*-*Zizyphus*-*Capparis* (ZZC) and *Dalbergia*-*Heteropogon*-*Prosopis* (DHP) plant communities with T-value of -12.725; whereas, A max = 1 when all items are similar within groups, A = 0 when heterogeneity within groups equals expectation by chance and A < 0 with more heterogeneity within groups than expected by chance. Furthermore, A-values for all the pairwise comparisons of the plant communities ranged between 0.025-0.057, this proves that within groups heterogeneity equals expectation by chance (Table 4).

Discussion

The plant associations are formed as a result of response of plants to the environment. Phytosociological studies are essentially required for the understanding structure, composition and functions of plant communities within a given environment (Allaby, 2004). It entails the vegetation composition of existing plant communities that plays a vital role for the conservation of plant biodiversity (Ewald, 2003; Biondi, 2011; Khan *et al*., 2018b). So vegetation analysis plays a key role in management practices of an ecosystem. Keeping in view, this study was carried to identify the existing plant communities of the District Chakwal, Pakistan which is a rangeland area and not studies before in terms of flora and vegetation.

The subsistence and the development of plant communities exhibit the type of plant and habitat condition in a specific (Ilyas *et al*., 2015). The climate of the District Chakwal is of subtropical type (Champion *et al*., 1965), however, owing to physiognomy, edaphic and topography, the area supports diverse plant associations. The present study elucidated six plant communities with diverse floristic composition associated along with the typical environmental variables. The floristic composition of these plant communities in the area appears to environmental factors such as altitude, topography, and edaphic conditions. The correlation of the vegetation with the environmental variables is therefore crucial for understanding the mechanism of their distribution in a given area (Eriksson & Bergstrom, 2005).

The first community *Lantana-Parthenium-Cannabis* was identified at an elevation range of about 280-320m. The topmost indicator species of this community included *Lantana camara, Parthenium hysterophorus* and *Cannabis sativa* (Table 1). The moderate soil pH influenced this community (Table 2). The 2nd community *Calotropis-Chrysopogon-Melia* was found located between 380-420m elevations. The topmost indicator species of this community included *Calotropis procera*, *Chrysopogon serrulatus*, *Melia azedarach*, *Dactyloctenium aegyptium* and *Ricinus communis*. Moderate altitude influenced *Calotropis procera* and low electrical conductivity influences *Melia azedarach*. The 3rd community *Cynodon-Cenchrus-Tecomella* was found at an elevation ranges between 430-470m. The topmost indicator species of this community included *Lantana camara*, *Parthenium hysterophorus*, *Cannabis sativa*, *Barleria cristata* and *Solanum villosum*. The fourth community viz., *Zizyphus-Zizyphus-Capparis* was appeared at an elevation ranges between 270-310m. The topmost indicator species of this community were *Zizyphus mauritiana*, *Zizyphus nummularia*, *Cannabis sativa* and *Acacia nilotica*. The 5th community composed of *Dalbergia-Heteropogon-Prosopis* was located at an elevation range between 560-600m. The slopes were mostly gentle and varied between 0-17° (Table 2). Within this association, indicator species were *Dalbergia sissoo*, *Heteropogon contortus*, and *Prosopis juliflora*. While, sixth community like *Acacia-Justicia-Dodonaea* was established at an elevation range between and 780-820m, while the soil of the community had slightly alkaline pH 7.22±0.4 (Table 2). Dominant species were *Acacia modesta, Justicia adhatod* and *Dodonaea viscosa*. The species variation was observed in sampled areas due to soil pH, composition and distance from water bodies (Ahmad *et al*., 2007).

It is an established fact that there is a close and direct relationship between the edaphic factors and vegetation of any given area; both are reversibly influenced by each other. A best example of soil and plants reversible influence on each other, in which soil provides nutrients and humidity for the best growth of plants, while in turn vegetation is responsible for the protection and longevity of soil cover, reduces soil erosion and enhance nutrients in soil (Eni *et al*., 2012).

The soil collected from the District Chakwal in general was sandy loam and loamy at some places, while the colour of soil was brown. The sand silt and clay fractions varied from 31.5-40.5%, 36.5-42.0% and 20.5-26.5% respectively (Table 2). According to the Donahue *et al*., (1983), one of the main and important soil properties is soil texture which has main function of water holding capacity, which regulates the soil fertility. The soils in general were slightly basic with pH ranging from 7.5-7.86%. The electrical conductivity ranged from 0.28-0.38 EC$x10^3$. $CaCO_3$ varied from 1.11-2.57%.On the other hand, total soluble salts ranged from 498.31-542.54mg/Kg (Table 2). Organic matter is another parameter to measure the fertility of soil. It was assessed from the results that adequate amount of organic matter ranging from 0.48-0.65% were available in all soil samples. In the presence of $CaCO_3$ both phosphorous and Sulphur in the soil form insoluble compounds and get converted into insoluble fractions at moderately higher soil pH. Identical results revealed in case of Indian soils were noted by Ghosh & Agrawal (2005).

Plant communities explains the composition of plants of a particular area (Malik *et al*., 2007, Khan *et al.,* 2018). According to, Bredenkamp *et al*., (2003), various environmental variables such as topography, altitude, geology and soil texture are the leading factors which influence the plant communities. Keeping these reviews, this study got identified six plant communities by using clustering analysis (Fig. 2). In the same lines, Khan *et al*., (2018) identified and classified plant communities with alike plant composition associated with environmental variables.

In the present study, CCA was used for ordination analysis. It is mostly used as analytical techniques in ecological studies to conclude a criticalaffiliation between environmental and floristic data (Van den Brink *et al*., 2003). In this study, CCA revealed the prevailing influence ($p<0.05$) of measured environmental factors of 6 plant associations.

Conclusions and Recommendations

This study was undertaken to identify the existing plant communities of the District Chakwal, Pakistan. Using Stratified random sampling technique along the 14 altitudinal transects and 70 sampling stations a total of 700 plots were studied. Using ordination and cluster analysis, six plant communities were identified. Canonical Correspondence Analysis (CCA) revealed that altitude, electrical conductivity and soil pH were the significant environmental factors that played role in the formation of major plant communities in the District Chakwal. Being the dominance of natural remnant vegetation in this mountainous terrain, local inhabitants are continuously exerting pressure for utilizing the century's old vegetation especially for fuel wood and other uses so there is immediate need for proper management of this area. Further research activities should be conducted in this biotic stressed and less investigated area, which will provide a criterion to safeguard phytodiversity.

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