QUANTITATIVE ASPECTS OF THE KOH-E-SAFAID RANGE VEGATATION ACROSS THE ALTITUDINAL GRADIENT IN UPPER KURRAM VALLEY, PAKISTAN

HUSSAIN, W.[1*] – BADSHAH, L.[2] – ALI, A.[3]

[1]*Department of Botany, Government Post Graduate College, Parachinar, Pakistan*

[2]*Phytoecology Lab., Department of Botany, University of Peshawar, 25000 Peshawar, Pakistan (e-mail: badshahmasood1@gmail.com, phone: + 92-333-894-4128)*

[3]*Department of Botany, Government AKL Post Graduate College, Matta, Swat, Pakistan (e-mail: asghartk@gmail.com, phone: + 92-333-948-5390)*

**Corresponding author*
e-mail: wahidhussainwahid@gmail.com; phone: + 92-300-371-2148

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Abstract. This phytosociological study was conducted during 2015-2018; summed up plant 7 communities of herbs, shrubs and trees at 7 monitoring sites based on elevation, habitats and physiognomic contrast. Quadrate method was employed for the data collection 5 quadrats (10 × 10 m^2) for trees, 10 quadrats (5 × 5 m^2) for shrubs and 15 quadrats (1 × 1 m^2) for herbs at each site. Edaphic attributes were calculated by using standard methods. Based on family importance values Pinaceae was the leading family with an FIV of (374.39) followed by Lamiaceae (350.33), Asteraceae (204.43) and Poaceae (193.67). Seven communities' viz. *Berberis-Themeda-Periploca* community, *Seriphidium-Salvia-Thymus* community and *Indigofera-Quercus-Dichanthium* were established at Sub-Tropical zone. While Temperate Zone comprised of *Juniperus-Picea-Abies* community and *Quercus-Juniperus* community. *Abies-Picea-Rhododendron* community was established at Sub-Alpine zone while *Juniperus-Rheum-Kobresia* community was established at Alpine zone. However, cluster analysis using PAST software and PC-Ord software version 5, classified the vegetation into three groups and four groups based on quantitative value respectively. Vegetation structure and its productivity were governed by soil texture and its chemical composition. The physico-chemical analysis of habitat features revealed that the soil texture was mostly sandy loam and loamy sand with pH ranged from 7.3 to 7.7. Afforestation programs need to be started on wasteland of the area to overcome the impacts of deforestation.
Keywords: *vegetation, phytosociology, edaphic variables, maturity index, similarity index*

Introduction

Study of plant communities and their classification is termed as phytosociology. Primarily phytosociology helps in understanding the multilateral relationships between plants and their environment. It deals with quantitative, qualitative and synthetic attributes of plant communities. Vegetation is an ecological quantification of plant resources (Ali et al., 2018; Timilehin et al., 2017; Badshah et al., 2016). The vegetation of an area is the reflection of its climate, soil, biodiversity, anthropogenic activities and natural resources (Ilyas et al., 2015). The vegetation structure and plant population sizes also indicate species tolerance of existing ecological attributes (Kuma and Shibru, 2015; Sher et al., 2014). The presence and the establishment of the communities reveal the plant type and surroundings condition under which they developed (Hussain et al., 2015; Zhu et al., 2015; Ahmad et al., 2006). The health of any ecosystems is dependent on plant biodiversity and thus the vegetation classification is a prerequisite for ecosystem management and biodiversity conservation. Some of the most important

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environmental factors affecting the vegetation are deforestation, erosion, trampling, overgrazing and other ecological factors. In Pakistan two-third of the area is highland type and quick changes in climate and elevation aggravates differences in plant diversity. Pakistan includes variety of land-dwelling ecosystem, with in 18 main geographic regions (Khan et al., 2016; Zoq-ul-Arfeen et al., 2015). Due to non-availability of natural gas and electricity large population of the area depends upon forest wealth for domestic needs. Because of the intense browsing nearly all the pastures have been ruined and need restoration to be sustainable again. Phytosociologically the vegetation and forests of Koh-e-Safaid slopes are Sino-Japanese type (Hussain et al., 2019). The natural forests of Kurram cover about 8% of its area while the Parachinar Forest Department has planted about 6% area. The land under cultivation is 35% while the rest of 47% is barren. The major forest types of the Kurram are dry tropical forest and sub alpine scrub (Hussain et al., 2013). The area is very rich in plant resources however little ecological work has been done in the region. The dry tropical vegetation covers the Southern parts while dry temperate and alpine vegetation types are found in the Northern parts of the area. In the investigated area climate is highland type and it varies at different altitude. The observed changes in the plant communities are due to season, temperature, soil type and time of sampling of the vegetation. During spring and summer many annual show dominance and cause change in the seasonal aspects. They approach each other by sharing the species and that is why 73.5% similarity occurred. However, slight changes were observed in their cover from season to season, but the predominance of annuals changed the community composition. The recorded species exhibit different dominance value due to change in habitat and altitude condition throughout the area. The study area was unexplored in terms of its phytosociology hence present study presents first report of vegetation dynamics of this part of Pakistan.

Materials and methods

Study area

The research work was carried out in Koh-e-Safaid Range Upper Kurram. Kurram is located from 33° 20’ to 34° 10’ north latitudes and 69° 50’ to 70° 50’ east longitudes. The study area covers an area of 3380 km^2, including seven monitoring sites viz. Sub-Tropical South Hills, Sub-Tropical Plain, Sub-Tropical North Hills, Temperate South Facing slopes, Temperate North Facing slopes, Sub alpine and Alpine zone (*Fig. 1*).

Phytosociology

Phytosociological work was carried out in 7 sites based on elevation, species structure, habitats and physiognomic contrast. Vegetation was analyzed by using 5 quadrats (10×10 m^2) for trees, 10 quadrats (5×5 m^2) for shrubs and 15 quadrats (1×1 m^2) for herbs in each site. Density, frequency and cover of each species were recorded and all the values were converted in to IV (Importance value) and FIV (Family importance value). Geographical co-ordinates of each site were noted using GPS. Different plant communities were established based on highest importance value following (Ali et al., 2018; Badshah et al., 2016; Rajendran et al., 2016; Forzieri et al., 2011).

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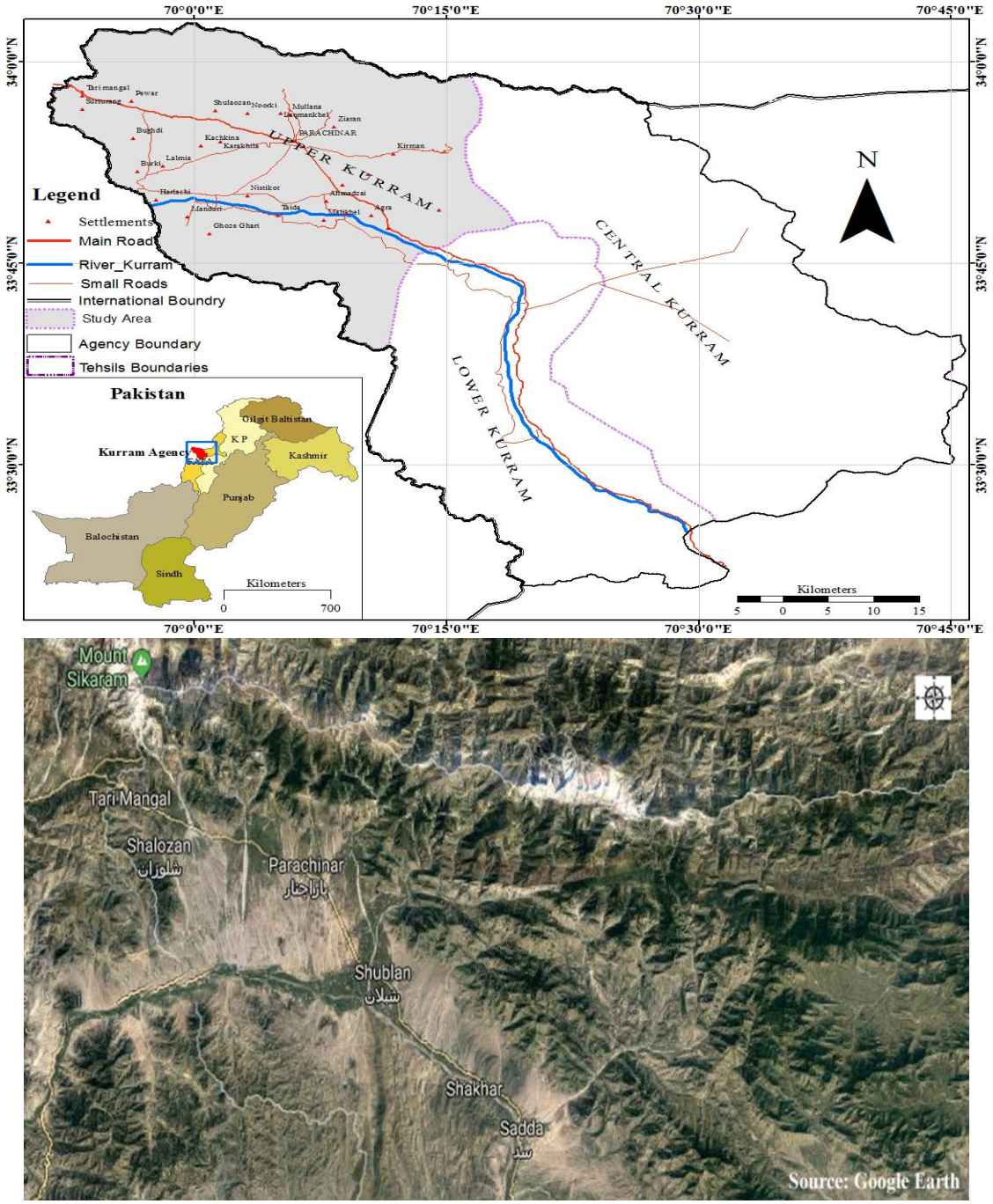

Figure 1. a *Map of the study area.* ***b*** *Google Map of the study area of Upper Kurram Valley*

Data analysis

Cluster analysis was conducted by using PAST software, Wards cluster analysis and Principal Component Analysis tools. It is a classification technique for putting similar objects into clusters. The arrangement is a hierarchical tree like structure is called a dendrogram. These clusters of sampling units may represent different biotic communities. The community classification was made by using Multivariate Statistical Package. The classification was based on structural variations among stands and

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dendrogram were made for vegetation stands of the area. A Principal Components Analysis technique was also applied to analyze spatial variations in vegetation by PC-Ord software version 5.

Importance value (IV)

Importance value of each species was calculated by adding all the relative values of RD, RF, RC (Ali et al., 2018; Badshah et al., 2016). The communities were named after the three leading species having the highest importance values.

$$IV = RD + RC + RF$$

Family importance value (FIV)

Importance value of every species in specific families was added together to obtain FIV for all the quantitatively recorded families.

Maturity index

The community maturity index of community was obtained by (Pichi-Sermolli, 1948).

$$\text{Degree of maturity index} = \frac{\text{Frequency values of all species in a stand}}{\text{Total number of species in a stand}}$$

Similarity index

It was applied to compare similarities between different communities. It is the number of species common to both communities. It was calculated by using Sorensen's index (Sorensen, 1948) as modified by (Motyka et al., 1950). It was applied to compare similarities between different communities.

$$IS_{MO} = \frac{2W}{A+B} \times 100$$

where W = Sum of lowest quantitative value of the species pair common to both communities, A = Sum of quantitative value of all species in community A, B = Sum of quantitative value of all species in community B.

Soil analysis

Soil samples of 1 kg from 7 sites were collected from 0-15 cm depth from the selected sites of the study areas. Each of the collected samples was taken in clear polythene bags which were duly labeled and sealed on the spot. Later the soil samples were dried in an oven at 25 to 30 °C. Soil samples were screened for contaminants such as stones, plant roots and other impurities. Soil samples were grounded and passed through a 2.5 mm sieve (Ryan et al., 2001). Standard methods were applied to estimate soil texture (Brady, 1990; Bouyoucos, 1936), pH (Jackson, 1962), organic matter, $CaCO_3$ (Rayan et al., 1997), electrical conductivity (Rhoades, 1996), sodium absorption ratio and sulphates (Richard, 1954). Nitrogen was determined by Kieldahl method of

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Bremner and Mulvaney (1982). Phosphorous, Potassium, Calcium and Magnesium were enumerated by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES).

Results

Present study was conducted in Koh-e-Safaid Range Upper Kurram during 2015-2018. Seven monitoring sites were established viz. Sub-Tropical South Hills, Sub-Tropical Plain, Sub-Tropical North Hills, Temperate South Facing slopes, Temperate North Facing slopes, Sub-Alpine and Alpine zone. The study area displays a unique floristic and vegetation structure. The approach of classifying vegetation into 7 different communities agrees with the work of Ali et al. (2018), Ilyas et al. (2018), Badshah et al. (2016), Siddiqui et al. (2015), Sher et al. (2014) and Ahmad et al. (2006). A total of 60 species were recorded in sampling units, of which trees were represented by 09 species, shrubs by 14 species and herbs by 37 species. Based on importance value (IV), a total of seven communities were established at seven monitoring sites. Based on family importance value Pinaceae was the leading family with an FIV of 374.39 followed by Lamiaceae (350.33), Asteraceae (204.43), Poaceae (193.67), Cupressaceae (173.97), Papilonaceae (103.93), Fagaceae (100.3), Berberidaceae (75.64), Polygonaceae (68.23) and Rosaceae with (62.55). Ranunculaceae, Saxifragaceae, Asclepiadaceae, Ericaceae, Boraginaceae, Salicaceae, Elaeagnaceae, Euphorbiaceae, Thymelaeaceae, Valerianaceae, Balsaminaceae, Oleaceae, Primulaceae, Areceaea and Scrophulariaceae had importance values ranging from 48.40 to 10.31. The study area is divided in to four zone i.e. Sub-Tropical zone, Temperate zone, Sub-Alpine and Alpine zone based on altitude, physiognomy, soil type and variance in ecological factors. Based on IV values 7 different communities were established in four ecological zones.

Sub-tropical zone

Sub-tropical south hills (site I)

1. Berberis-Themeda-Periploca community (BTP)

This plant community was reported from north facing slope at southern aspects at elevation of 1525 m. *Berberis lycium* was the dominant species with IV of 36.83. Second dominant species was *Themeda anathera* with an IV of 34.88 forming a close association with *Berberis lycium* at southern lower parts of the sub-tropical zone. *Periploca calophylla* with an IV of 30.98 mostly dispersed among the *Berberis lycium* and *Themeda anathera.* Other prominent member of this community included *Thymus linearis* (29.4 IV), *Aristida purpuea* (27.22 IV) and *Stachys parviflora* (25.54 IV) and *Androsace rotundifolia* (11.22 IV). Common shrubs growing around this community were *Daphne mucronata, Cotoneastor macrophylla, Cotoneastor microphylla, Teucrium stocksianum and Nannorrhops ritchiana.* The only one tree i.e *Olea ferruginea* was sparsely distributed in this community (*Table 2*). Similar communities were also reported by Ali et al. (2018), Badshah et al. (2016), Ilyas et al. (2015) and Forzieri et al. (2011). This plant community was established at Southern aspects at an elevation of 1328 m up to 1525 m. Nitrogen content of the soil was 0.401%, phosphorous 810 µg/g, potassium 8700 µg/g, calcium 32100 µg/g, magnesium 5100 µg/g, sulphur 187 µg/g, sodium 1900 µg/g, iron 81300 µg/g, zinc 73 µg/g,

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manganese 731 µg/g and cupper 92 µg/g. Soil pH at this monitoring site was 7.5 and organic matter was found to be 1.8% as shown in *Tables 1* and *2*.

Table 1. *Soil texture and physiochemical characteristics of different sites soil of Koh-e-Safaid Range Kurram*

S. No	Locality		Organic matter %	pH	EC Dsm-1	% Lime $CaCo_3$	HCO_3	Sulphates
1	Sub-Tropical South Hills	Loamy sand	1.8	7.50	1.31	3.9	4.0	0.4
2	Sub-Tropical plain area	Sandy loam	1.7	7.70	1.21	2.6	8.0	0.6
3	Sub-Tropical North Hills	Loamy sand	2	7.66	0.78	7.3	4.8	0.5
4	Temperate North facing slope	Loamy sand	1.9	7.48	1.06	2.8	5.0	4.1
5	Temperate South facing slope	Loamy sand	1.4	7.33	0.85	4.5	3.0	3.5
6	Sub Alpine zone	Sandy loam	2.4	6.50	0.68	7.8	3.5	1.3
7	Alpine zone	Loamy sand	2.42	7.85	1.30	3.0	5.0	7.8

Table 2. *Soil macro and micronutrients in different sites of study area*

S. No	Locality	N_2 %	P µg/g	K µg/g	Ca µg/g	Mg µg/g	S µg/g	Na µg/g	Cl µg/g	Fe µg/g	Mn µg/g	Cu µg/g	Zn µg/g
1	Sub-Tropical South Hills	0.401	810	8700	32100	5100	187	1900	2700	81300	731	92	73
2	Sub-Tropical plain area	0.280	645	7800	39700	6300	263	2600	3500	79000	976	55	84
3	Sub-Tropical North Hills	0.394	571	8300	36200	6800	221	1300	2500	81800	343	95	78
4	Temperate North Facing slope	0.455	435	6580	39800	6200	199	1600	1500	15000	776	105	68
5	Temperate South Facing slope	0.411	650	9900	39300	6500	205	1500	2000	83100	531	109	64
6	Sub-Alpine	0.333	450	5910	36500	5900	175	1800	2000	89200	418	93	53
7	Alpine	0.211	750	1090	39900	5500	163	3300	3500	73200	869	89	82

Sub-tropical plain area (site II)

2. Seriphidium-Salvia-Thymus community (SST)

This herbaceous community was recorded from plains area of Sub-Tropical Zone at an elevation of 1680 m. In this area therophytes dominated the landscape along with sparse distribution of the *Elaeagnus angustifolia.* Dominant species was *Seriphidium kurramense* with IV value of 50.50 followed by *Salvia reflexa* with IV of 42.10. *Salvia reflexa* an invasive species made thick randomly distributed patches in flooded ravines, gullies, along road side, sandy loams and on open fertile clay soils. *Thymus linearis* with an IV value 26.38 was found to be codominant. The other predominant species growing around this community were *Parthenium hysterophorus*, *Artemisia scoparia*, *Cynodon dactylon*, *Conyza canadensis*, *Tagetis minuta* and *Astragalus oplites*. The recorded shrubs in this community were *Daphne mucronata*, *Indigofera heterantha*, *Hertia intermedia* and *Berberis lyceum* (*Table 2*). Ali et al. (2018), Hussain et al. (2016), Badshah et al. (2016), Forzieri et al. (2011) and Wahab et al. (2010) have also reported similar results in their studies. Soil at this locality was sandy loam. Nitrogen content of the soil was 0.280%, phosphorous 645 µg/g, potassium 7800 µg/g, calcium 39700 µg/g, magnesium 6300 µg/g, sulphur 263 µg/g, sodium 2600 µg/g, iron 79000 µg/g, zinc 84 µg/g, manganese 976 µg/g and cupper 55 µg/g. Soil pH at this site was 7.7 and organic matter was found to be 1.7% as shown in *Tables 1* and *2*.

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Sub-tropical north hills (site III)

3. Indigofera-Quercus-Dichanthium community (IQD)

This community was recorded from the Sub-Tropical North Hills at an elevation of 2492 m. Thick shrub cover and comparatively thick trees of *Quercus baloot* near the foot hills indicated the disturbed nature of habitats which were under biotic stresses like deforestation and grazing. Dominant species was *Indigofera heterantha var. gerardiana* with an IV value of 42.20 followed by *Quercus baloot* with an IV value of 33.80. These shrubs made thick dispersed patches on mostly treeless open spaces. Codominant species was found to be *Dichanthium annulatum* with an IV value 29.39. Similar communities were recorded by Ali et al. (2018), Ilyas et al. (2015), Badshah et al. (2015 and Ali and Malik (2010). The rest of the species included *Thymus linearis, Leptorhabdos parviflora, Medicago lupulina, Cotoneastor macrophylla, Berberis lycium, Impatiens edgeworthii* and *Fragaria nubicola* (*Table 1*). Soil of the area was loamy sand. Nitrogen content of the soil was 0.394%, phosphorous 571 µg/g, potassium 8300 µg/g, calcium 36200 µg/g, magnesium 6800 µg/g, sulphur 221 µg/g and sodium 1300 µg/g. The microelements like iron was recorded 81800 µg/g, zinc 78 µg/g, manganese 343 µg/g and copper 95 µg/g. Soil pH at this site was 7.6 and organic matter was found to be 2% as shown in *Tables 1* and *2.*

Temperate Zone

Temperate north facing slope (site IV)

4. Juniperus-Picea-Abies community (JPA)

This community was recorded on North Facing Slope of Temprate Zone dominated by *Juniperus excelsa* with an IV value of 65.36, almost uniformly distributed in the locality making strong association with the second dominant *Picea smithiana* with an IV value of 51.07. The third dominant species was *Abies pendrow* with an IV 25.89. The tree species were uniformly distributed while the *Juniperus excelsa* was found in open patches among the dominant tree species. The other associated species were *Pedicularis verticilata, Aquilegia pubiflora, Phlomis bracteosa, Salex denticulate, Euphorbia wallichii, Pinus wallchiana, Valeriana jatamansi, Quercus semecarpifolia* and *Nepeta kurramensis* (*Table 1*). Badshah et al. (2016), Hussain et al. (2016) and Rashid et al. (2011) also have reported similar results in their studies. This community was recorded from Temperate Zone North facing slope at an elevation of 2200 up to 2450 m. Soil at this locality was loamy sand. Nitrogen content of the soil was 0.455%, phosphorous 435 µg/g, potassium 6580 µg/g, calcium 39800 µg/g, magnesium 6200 µg/g, sulphur 199 µg/g, sodium 1600 µg/g, iron 15000 µg/g, zinc 68 µg/g, manganese 776 µg/g and copper 105 µg/g. Soil pH at this site was 7.4 and organic matter was found to be 1.9% as shown in *Tables 1* and *2.*

Temperate south facing slope (site V)

5. Quercus-Juniperus community (CQJ)

Cedrus-Quercus-Juniperus community was recorded at an elevation of 2450 up to 2700 m on the South Facing Slopes of Temperate Zone. The area had uniformly spread *Cedrus deodara* forest mixed with *Quercus semicarpifolia* and *Juniperus excelsa*. The area was under tremendous biotic stress especially cutting of *Pinus gerardiana, Pinus*

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wallichiana, Cedrus deodara for timber wood in past and completely missing of herbage cover due to steep slopes, lacking topsoil and allelopathic effect of shading leaves of *Cedrus, Pinus* and *Juniperus* trees. In this community the dominant species was *Cedrus deodara* with an IV value of (66.39). *Quercus semicarpifolia* with an IV value of (47.71) was codominant making strong association with *Juniperus excelsa* with IV value of (35.29). Only few plants were recorded of *Pinus gerardiana* and it was abundant on Pak-Afghan border. The other important associated members of this community were *Sophora mollis, Quercus baloot, Pinus wallichiana, Piptatherum aequiglume, Daphne mucronata, Phlomis cashmeriana* and *Cotoneaster macrophylla* (*Table 1*). Our results are in line with the works of Ali et al. (2018, 2015), Bokhari et al. (2013), Badshah et al. (2015), Ilyas et al. (2015) and Forzieri et al. (2011). Soil at this locality was loamy sand. Nitrogen content of the soil was 0.411%, phosphorous 810 µg/g, potassium 8700 µg/g, calcium 39900 µg/g, magnesium 6500 µg/g, sulphur 205 µg/g, sodium 1500 µg/g, iron 83100 µg/g, zinc 64 µg/g, manganese 531 µg/g and copper 109 µg/g. Soil pH at this site was 7.3 and organic matter was found to be 1.4% as shown in *Tables 1* and *2.*

Sub alpine zone (site VI)

6. Abies-Picea-Rhododendron community (APR)

On the North Facing Slopes *Abies-Picea-Nepeta* community was recorded and comparatively there was thick forest of *Abies pendrow and Pice smithiana.* The *Rhododendron afghanicum* was uniformly distributed on the open space of forest as well as inside the forest. The dominant species was *Abies pendrow* with an IV value 44.25. *Picea smithiana* with an IV value 41.56 was codominant forming a close association with *Rhododendron afghanicum* with an IV value of 33.36. The other associated species were *Nepeta bracteosa, Pedicularis verticillata, Aquilegia pubiflora, Bistorta amplexicaulis, Cynoglossum furcatum, Cotoneaster macrophylla, Medicago lupina, Berberis vulgaris* and *Leptorhabdos parviflora* (*Table 2*). Badshah et al. (2016), Hussain et al. (2016), Forzieri et al. (2011) and Mahmood et al. (2015) also have reported similar results in their studies. Soil at this locality was loamy. Nitrogen content of the soil was 0.333%, phosphorous 450 µg/g, potassium 5910 µg/g, calcium 36500 µg/g, magnesium 5900 µg/g, sulphur 175 µg/g, sodium 1800 µg/g, iron 89200 µg/g, zinc 64 µg/g, manganese 418 µg/g and copper 93 µg/g. Soil pH at this site was 7.4 and organic matter was found to be 2.4% which is typical to the podzolic soil as shown in *Tables 1* and *2.*

Alpine zone (site VII)

7. Juniperus-Rheum-Kobresia community (JRK)

This community was recorded at an elevation of above 2850 m. This is treeless zone and only two shrubs were recorded first one was *Juniper excelsa* and the second was *Rhododendron afghanicum* and dominated by the herbs. The dominant species was *Juniper excelsa* with an IV value of 70.32. *Rheum spiciforme* with an IV value of 45.74 was codominant forming a close association with *Kobresia schoenoides* with an IV value 34.42. The other associative members of the community were *Bergenia stracheyi, Thymus serphyllum, Morina longifolia, Phlomis bracteosa* and *Trifolium repens* (*Table 3*). Badshah et al. (2016), Hussain et al. (2016) and Forzieri et al. (2011) also have reported similar results in their studies. Soil at this locality was sandy loam.

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Nitrogen content of the soil was 0.211%, phosphorous 750 µg/g, potassium 1090 µg/g, calcium 39900 µg/g, magnesium 5500 µg/g, sulphur 163 µg/g, sodium 3300 µg/g. The micronutrients like iron was present 73200 µg/g, zinc 82 µg/g, manganese 869 µg/g and copper 89 µg/g. Soil pH at this site was 7.85 and organic matter was found to be 2.42%

Table 3. *Importance value data for plant species*

S. No	Species	Site-I	Site-II	Site-III	Site-IV	Site-V	Site-VI	Site VII
1	*Abies pindrow* (Royle ex. D. Done) Royle	0	0	0	25.89	0	44.25	0
2	*Androsace rotundifolia* Hardw.	11.22	0	0	0	0	0	0
3	*Aquilegia pubiflora* Wall. ex Royle	0	0	0	21.3	12.51	0	0
4	*Aristida cyanantha* Steud.	27.22	0	0	0	0	0	0
5	*Artemisia scoparia* Waldst. & Kitam.	0	23.6	26.8	0	0	0	0
6	*Astragalus oplites* Benth. ex R. Parker	0	16.06	0	0	0	0	0
7	*Bergenia stracheyi* (Hook.f. & Thom.) Engl.	0	0	0	0	0	0	33.44
8	*Berberis lyceum* Royle	36.83	8.42	15.3	0	0	20.14	0
9	*Bistorta amplexicaulis* (D.Don) Greene	0	0	0	0	0	22.49	0
10	*Cedrus deodara* (Roxb. ex Lamb.) G. Don	0	0	0	0	66.39	0	0
11	*Cotoneaster macrophylla* Wall. ex Lindl.	14.37	0	16.3	0	10.87	22.33	0
12	*Cotoneaster microphyllus*Wall. Ex Lindl.	3.6	0	0	0	0	0	0
13	*Conyza Canadensis* (L.) Cronquist	0	24.22	0	0	0	0	0
14	*Cynodon dactylon* (L.) Pers.	22.81	0	0	0	0	0	0
15	*Cynoglossum lanceolatum* Forssk.	0	0	0	0	0	19.31	0
16	*Daphne oleoides* Schreb.	15.37	9.63	0	0	14.45	0	0
17	*Dicanthum annulatum* (Forssk.) Stapf.	0	0	29.39	0	0	0	0
18	*Elaeagnus angustifolia* L.	0	17.8	0	0	0	0	0
19	*Euphorbia wallichii* Hook.f.	0	0	0	16.71	0	0	0
20	*Fragaria nubicola* (Hook.f.) Lindl.ex Lacaita	0	0	7.9	0	0	0	0
21	*Hertia intermedia* (Bioss.) Kuntze	0	21.04	0	0	0	0	0
22	*Impatiens edgeworthii* Hook.f.	0	0	14.2	0	0	0	0
23	*Indigofera heterantha* Brandis	0	8.73	42.2	0	0	0	0
24	*Juniper excelsa* M. Bieb.	0	0	0	65.36	35.29	0	70.32
25	*Kobresia schoenoides* (C. A. Mey.) Steud.	0	0	0	0	0	0	34.42
26	*Leptorhabdos parviflora* (Benth)Benth.	0	0	0	0	0	20.31	0
27	*Medicago lupulina* L.	0	0	17.4	0	0	10.0	0
28	*Morina longifolia* Wall.	0	0	0	0	0	0	26.34
29	*Nannorrhops ritchiana* (Griff) Aitch.	13.98	0	0	0	0	0	0
30	*Nepeta bracteata* Benth	0	0	0	0	0	33.6	0
31	*Nepeta kurramensis* Reech.f.	0	0	0	7.0	0	0	0
32	*Olea ferruginea* (Sol.) Steud.	15.06	0	0	0	0	0	0
33	*Parthenium hysterophorus* L.	0	23.86	0	0	0	0	0
34	*Periploca aphylla* Decne.	30.98	0	0	0	0	0	0
35	*Perovskia atriplicifolia* Benth.	0	8.36	0	0	0	0	0
36	*Pedicularis verticilata* L.	0	0	0	23.18	0	28.57	0
37	*Phlomis bracteosa* Royle ex. Benth.	0	0	0	20.37	0	0	14.24
38	*Phlomis cshmeriana* Royle ex Benth.	0	0	0	0	6.62	0	0
39	*Picea smithiana* (Wall.) Boiss.	0	0	0	51.07	0	41.56	0
40	*Pinus gerardiana* Wall.ex. D.don.	0	0	0	0	9.81	0	0
41	*Pinus wallichiana* A. B. Jacks.	0	0	0	21.08	20.18	0	0
42	*Piptaatherium aequiglume* Roshev.	0	0	29.6	0	18.56	0	0
43	*Quercus baloot* Griff.	0	0	33.8	0	21.93	0	0
44	*Quercus semicrpypholia* Sm.	0	0	13.79	0	47.71	0	0
45	*Rhododendron afghanicum* Aitch. & Hemsl.	0	0	0	0	0	29.56	33.87
46	*Rheum speciforme* Royle	0	0	0	0	0	0	45.74
47	*Salvia reflexa* Hornem.	0	42.1	0	0	0	0	0
48	*Salex denticulate* Anderson	0	0	0	22.77	0	0	0
49	*Stachys parviflora* Benth.	20.54	0	0	0	0	0	0

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50	*Syringga afghanica* S. K. Schneid.	0	0	25.9	0	0	0	0
51	*Sericea lespedeza* (Thunb.) Miq.	14.7	0	0	0	0	0	0
52	*Seriphidium kurramense* (Qazilb.) Y.R. Ling	0	50.5	0	0	0	0	0
53	*Sophora mollis* (Royle) Baker	0	0	0	0	28.8	0	0
54	*Tagetis minuta* L.	0	16.47	0	0	0	0	0
55	*Teucrium stocksianum* Boiss.	9.85	0	0	0	0	0	0
56	*Themeda anathera* (Nees ex Steud.) Hack.	34.88	0	0	0	0	0	0
57	*Trifolium repens* L.	0	0	0	0	0	0	13.52
58	*Thymus linearis* var. *linearis* Benth.	29.4	26.38	27.7	6.54	5.57	7.0	2.63
59	*Thymus seriphylum* L.	0	0	0	0	0	0	25.45
60	*Valeriana jatamansi* Jones.	0	0	0	15.46	0	0	0

Site I (Sub-Tropical South Hills), Site II (Sub-Tropical Plain area), Site III (Sub-Tropical North hills), Site IV (Temperate South Facing slope), Site V (Temperate North Facing slope), Site VI (Sub-Alpine zone), Site VII (Alpine Zone)

Ward's cluster analysis

Cluster analysis was conducted by using PAST software applying Wards cluster analysis tool. These clusters are based on IV of the leading species at all monitoring sites and the combined IV of each specie.

Cluster I. Juniper excela – Rhododendron afghanicum community

This group had *Juniper excela* as a leading dominant with a combined IV of 171.21. This member was recorded from Site-IV (65.36 IV), Site-V (35.29 IV) and Site-VII (70.32 IV) while second dominant species was *Rhododendron afghanicum* with a combine IV of 63.43. This species was found at only two sites i.e. Site-VI (29.56 IV) and Site-VII (33.87 IV). *Rheum speciforme*, *Kobresia schoenoides* and *Bergenia stracheyi* were other important members of this group (*Table 3, Fig. 2*).

Cluster II. Picea smithiana – Thymus linearis community

This group had the highest species richness, dominated by *Picea smithiana* with a combined IV of 92.63. It was found at Site-IV (51.07 IV) and Site-VI (41.56 IV). Second dominant species was *Thymus linearis* with a combined IV of 105.22. It was found at Site-I (29.4 IV), Site-II (26.38 IV), Site-III (27.7 IV), Site-IV (6.54 IV), Site-V (5.57 IV), Site-VI (7.0 IV) and Site-VII (2.63 IV). *Berberis lyceum* (combined IV 80.69), *Abies pindrow* (combined IV70.14), *Cotoneaster macrophyla* (combined IV 53.87), *Pedicularis verticilata* (combined IV 51.75) and *Seriphidium kurramense* (combined IV 50.5) were the other prominent plant species of this cluster. This cluster also included *Olea ferruginea* and *Pinus geraardiana* but with lower IV values. *Pinus gerardiana* is an indicator species of Dry Temperate Zone which yields edible seeds (*Table 1, Fig. 2*).

Cluster III. Quercus semicarpifolia – Cedrus deodara community

Quercus semicarpifolia with 66.5 combined IV was dominant member of this group. It was found at Site-III (13.79 IV) and Site-V (52.71 IV). Second dominant species was *Cedrus deodara* having a combined IV of 66.39. *Indigofera heterantha* (50.93 IV), *Quercus baloot* (55.73), *Artimesia scuparia* (50.4 IV) and *Piptatherium aequiglume* (48.16 IV) were other important members of this group (*Table 3, Fig. 2*).

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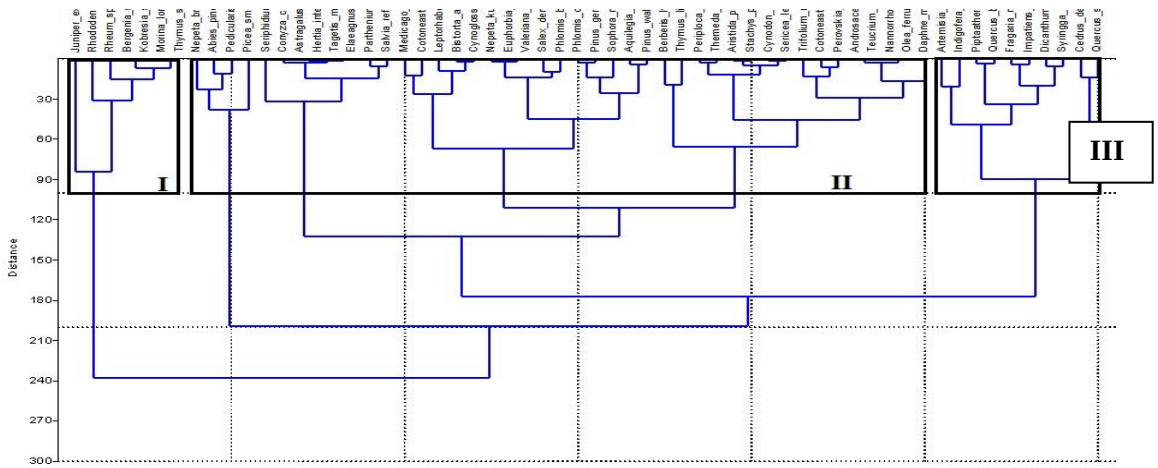

Figure 2. *Cluster dendrogram analysis showing 3 associations based on IV values*

Principal components analysis

Principal Components Analysis is one of the vegetation analysis techniques, which was applied by Pearson in ecology for the first time (Mesdaghi, 2001). Numerous studies have been carried out using PCA in various parts of the world to probe the connection between soil properties and vegetation (Rajendran et al., 2016, Forzieri et al., 2011, Salehi et al., 2005; Taleshi, 2004). Vegetation cover is an important variable in many earth system processes. The aim of this clustering is to analyze spatial variations in vegetation characteristics of Koh-e-Safaid Range Upper Kurram using principal component analysis. PCA was done by PC-Ord software version 5 which classified the vegetation data into 4 major components based on IVs of plant species as shown in the *Figure 3*.

Group 1

The dominant species in this group was *Seriphidium kurramense* with an IV of 50.50, *Berberis lycium* with an IV of 36.83, *Themeda anathera* with an IV of 34.88, *Quercus baloot* with an IV of 33.80, *Dichanthium annulatum* with an IV of 33.60, *Salvia reflex* with an IV of 32.10, *Periploca calophylla* with an IV of 30.98, *Thymus linearis* with an IV of 29.4, *Aristida purpuea* with an IV of 27.22 and *Leptorhabdos parviflora* with an IV of 26.50. The other associative species were *Stachys parviflora*, *Parthenium hysterophorus*, *Artemisia scoparia*, *Cynodon dactylon*, *Conyza canadensis*, *Tagetis minuta* and *Astragalus oplites*. Soil at this site was Sandy loam. Similarly, this group had low amount of N_2, Ca, Mg, Cu, Sulphates and high values of EC, HCO_3, P, K, Ca, Cl, Na, Fe and Zn as compare to other three groups (*Fig. 3*).

Group 2

In this group *Indigofera gerardiana* with an IV value of 52.20 followed by *Quercus baloot* with an IV of 33.80 and *Dichanthium annulatum* with an IV of 33.60 were dominant species. The rest of the associative species were *Thymus linearis*, *Leptorhabdos parviflora*, *Medicago lupulina*, *Cotoneastor macrophylla*, *Berberis lycium*, *Impatiens edgeworthii* and *Fragaria nubicola*. The soil characteristic in group 2

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Sub-Tropical North Hills was loamy sand, with low EC, N_2, P, Ca, Na, Mn, Cu, Zn, and Sulphates while $Caco_3$, HCO_3, K, Mg, S, Cl and Fe contents (*Fig. 3*).

Group 3

In this group *Cedrus deodara* with an IV of 66.39 was dominant species followed by *Quercus semicarpifolia* with an IV of 52.71 making strong association with *Juniperus excelsa* with IV of 38.29. The other important associated members of this group were *Sophora mollis*, *Quercus baloot*, *Pinus wallichiana*, *Piptatherum aequiglume*, *Daphne mucronata*, *Phlomis cashmeriana*, *Cotoneaster macrophylla* and *Pinus gerardiana*. Studies on edaphic variables of this group showed that the soil EC was lower than the soil of other groups. Similarly, the amount of HCO_3, P, Mg, Cl, Cu, Na, Mn and Zn contents were low while N, K, S, Ca, Cu, Fe and Sulphates were comparatively (*Fig. 3*).

Group 4

This group was most diverse in terms of species richness having *Juniperus excelsa* as dominant species with an IV of 70.32, *Picea smithiana* with an IV of 51.07, *Rheum speciforme* with an IV of 45.74, *Abies pindrow* with an IV of 44.25, *Kobresia schoenoides* with an IV of 34.42, *Rhododendron afghanicum* with an IV of 33.36, *Nepeta bracteosa* with an IV of 29.56 and *Pedicularis verticillata* with an IV of 28.57. The other associated members were *Thymus seriphylum*, *Morina longifolia*, *Aquilegia pubiflora*, *Bistorta amplexicaulis*, *Aquilegia pubiflora*, *Phlomis bracteosa*, *Cynoglossum furcatum*, *Salex denticulate*, *Cotoneaster macrophylla*, *Euphorbia wallichii*, *Pinus wallchiana*, *Medicago lupina*, *Valeriana jatamansi*, *Berberis vulgaris*, *Phlomis bracteosa* and *Leptorhabdos parviflora*. The characteristics of the soil associative with this group show that the soil EC was lower than the soil of other groups. Similarly, this group had low amount of N, P, Mg, S, Cl, Cu and Zn and high values of HCO_3 K, Ca, Na, Fe and Sulphates as compare to groups (*Fig. 3*).

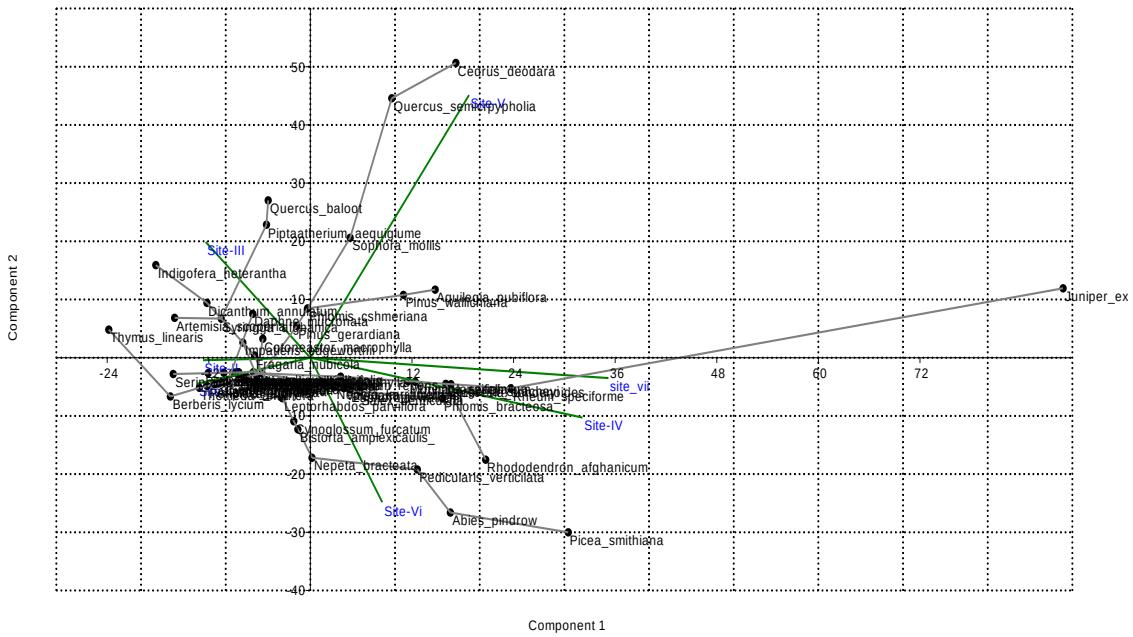

Figure 3. *Principal components analysis showing 4 associations based on IV values*

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Maturity index

During the current study the species maturity index ranged from 74.16 to 48.88. The high maturity index was recorded (74.16) both at sub-tropical north zone and temperate south facing zone followed by (72.13) at sub-tropical south zone, (67.49) at sub alpine zone, (64.89) at alpine zone, (64.84) at temperate north facing zone and (48.88) at subtropical plain zone (*Table 4*).

Table 4. *Maturity index*

Sites	Communities	Maturity index
Sub-tropical south hills	*Berberis-Themeda-Periploca*	72.13
Sub-tropical plain area	*Seriphidium-Salvia-Thymus*	48.88
Sub-tropical north hills	*Indigofera-Quercus-Dichanthium*	74.16
Temperate north facing slope	*Juniperus-Picea-Abies*	74.16
Temperate south facing slope	*Cedrus-Quercus-Juniperus*	64.84
Sub-alpine zone	*Abies-Picea- Rhododendron*	67.49
Alpine zone	*Juniperus-Rheum-Kobresia*	64.89

Index of similarity

A similarity index does not consider the relative abundance of species. It is helpful when key concern lies in the absence or presence of species. Degree of similarity between two plant communities allows combining them into an association (Badshah et al., 2010). According to the Motyka's index of similarity (Motyka et al., 1950), *Berberis-Themeda-Periploca* community of Sub-Tropical South Hills was found to be 14.90% like *Seriphedium-Salvia-Thymus* community of Sub-Tropical plain area. The similarity between *Berberis-Themeda-Periploca* community of Sub-Tropical South Hills and *Indigofera-Quercus-Dichanthium* community of Sub-Tropical North Hills was observed 15.81%. The current analysis shows that similarity between *Berberis-Themeda-Periploca* community of Sub-Tropical South Hills and that of *Juniperus-Picea-Abies* community of Temperate Zone North facing slope was 2.18%. The *Berberis-Themeda-Periploca* community of Sub-Tropical South Hills and *Cedrus-Quercus-Juniperus* community of Temperate Zone South facing slope showed 8.16% similarity. The similarity between *Berberis-Themeda-Periploca* community Sub-Tropical South Hills and *Abies-Picea-Rhododendron* of Sub-Alpine Zone was recorded 10.53%. The similarity between *Berberis-Themeda-Periploca* community of Sub-Tropical South Hills and *Juniperus-Rheum-Kobresia* of Alpine zone was 0.87%. The community of Sub-Tropical plain i.e. *Seriphedium-Salvia-Thymus* was 22.48% similar to *Indigofera-Quercus-Dichanthium* community of Sub-Tropical North hills. The *Seriphedium-Salvia-Thymus* community of Sub-Tropical plain was found 2.19% similar to *Juniperus-Picea-Abies* community of Temperate North Facing slope. The *Seriphedium-Salvia-Thymus* community of Sub-Tropical plain was similar to *Cedrus-Quercus-Juniperus* community of Temperate South Facing slope i.e. 5.10%. The *Seriphedium-Salvia-Thymus* community of Sub-Tropical plain was found 5.17% similar to *Abies-Picea-Rhododendron* community of Sub-Alpine Zone. The *Seriphedium-Salvia-Thymus* community of Sub-Tropical plain was observed 0.88% similar to the *Juniperus-Rheum-Kobresia* community of Alpine Zone. The *Indigofera-Quercus-Dichanthium* community of Sub-Tropical North Hills was 2.18% like *Juniperus-Picea-*

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Abies community of Temperate Zone North Facing slope and 19.0% similar to *Cedrus-Quercus-Juniperus* Temperate South Facing slope. The *Indigofera-Quercus-Dichanthium* community of Sub-Tropical North Hills showed 16.22% similarity with *Abies-Picea-Rhododendron* community of Sub-Alpine Zone. Similarity between *Indigofera-Quercus-Dichanthium* community Sub-Tropical North Hills and *Juniperus-Rheum-Kobresia* community of Alpine Zone was 0.87%. The *Juniperus-Picea-Abies* community of Temperate North Facing slope showed 24.61% similar to *Cedrus-Quercus-Juniperus* community at Temperate South Facing slope. The *Juniperus-Picea-Abies* community of Temperate North Facing slope was found 32.49% similar to *Abies-Picea-Rhododendron* community at Sub-Alpine Zone. The *Juniperus-Picea-Abies* community of Temperate North Facing slope and *Juniperus-Rheum-Kobresia* community at Alpine Zone showed 27.45% similarity. A 5.50% similarity was recorded between *Cedrus-Quercus-Juniperus* community of Temperate South Facing slope and *Abies-Picea-Rhododendron* community of Sub-Alpine Zone. Comparison of *Cedrus-Quercus-Juniperus* community of Temperate South Facing slope and *Juniperus-Rheum-Kobresia* community at Alpine Zone showed 12.68% similarity while *Abies-Picea-Rhododendron* community of Sub-Alpine Zone and *Juniperus-Rheum-Kobresia* community of Alpine Zone community showed 10.74% similarity (*Table 5*). The current results agree with those of Ilyas et al. (2018), Khan et al. (2016), Urooj et al. (2016), Mehmood et al. (2015), Rashid et al. (2011), Wahab et al. (2010), Ali and Malik (2010) and Mesdaghi (2001), who reported similarities among the plant communities is due to soil properties, ecological and biotic factors.

Table 5. *Similarity index for seven different communities*

	BTP	**SST**	**IQD**	**JPA**	**CQJ**	**APR**	**JRK**
BTP	X	X	X	X	X	X	X
SST	14.90	X	X	X	X	X	X
IQD	15.81	22.48	X	X	X	X	X
JPA	2.18	2.19	2.18	X	X	X	X
CQJ	8.16	5.10	19.0	24.61	X	X	X
APR	10.53	5.17	16.22	32.49	5.50	X	X
JRK	0.87	0.88	0.87	27.45	12.68	10.74	X

BTP-Berberis-Themeda-Periploca community, SST-Seriphidium-Salvia-Thymus community, IQD-Indigofera-Quercus-Dichanthium community, JPA-Juniperus-Picea-Abies community, CQJ- Cedrus-Quercus-Juniperus community, APR-Abies-Picea-Rhododendron community, JRK-Juniperus-Rheum-Kobresia community

Discussion

During the current study the vegetation of the area was classified into seven communities which is in line with the works of Ali et al. (2018, 2015), Badshah et al. (2016) Ilyas et al. (2015), Saurav and Das (2014), Sharma et al. (2014) Saglam (2013), Ahmad et al. (2010), Digiovinazzo et al. (2010), Hussain et al. (2010), Mohler et al. (2006) Munhoz et al. (2006) and Padalia et al. (2004). The research area is under tremendous anthropogenic stress, due to which the vegetation showed clumping rather than a uniform pattern of distribution due to excessive deforestation in the area. Scanty trees and comparatively thick shrub cover at Sub-Tropical North foothills and Temperate zone indicated the disturbed nature of habitat. Due to rapid population and

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construction of buildings is the chief reason behind the species loss in this locality. Impacts of soil erosion were more visible at Site I, Site II, III, IV and Site-VII where eroded soils had herbaceous members such as *Plantago major*, *Rumex hastatus*, *Thymus linearis and Verbascum thapsus* which are indicator species of eroded soils. *Indigofera gerardiana, cotoneaster microphyllus* were observed to form randomly dispersed thick patches at site III, IV, *Juniperus communis*, *Rhododendron afghanicum* and *Salex denticulate* monitoring site V and VI (*Fig. 4*).

Figure 4. *Pictorial view of the study area, (A) A beautiful view of Koh-e-Safaid Range, (B) Sub-alpine vegetation, (C) North facing slopes of temperate site (D) North facing slopes (E) Delphinium brunonianum alpine plant in flowering stage (F) Rhododendron afghanicum of sub-alpine plant in flowering stage (G) Cedrus deodara forest (H) Principal author in field at sub-tropical site at south facing slope (I) measuring canopy cover of Berberis lyceum (J) Principal author showing steep slopes of Alpine zone*

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These findings are backed by works of Ali et al. (2018), Dad (2016), Ilyas et al. (2015), Siddiqui et al. (2015) and Ahmad et al. (2010). *Cedrus-Quercus-Juniperus* community was recorded at on the South Facing Slopes of Temperate Zone. The area had uniformly spread thin *Cedrus deodara* forest mixed with *Quercus semicarpifolia* and *Juniperus excelsa*. The area was under tremendous biotic stress especially cutting of *Pinus gerardiana, Pinus wallichiana, Cedrus deodara* for timber wood in past and completely missing of herbage cover due to steep slopes, lacking topsoil and allopathic effect of shading leaves of *Cedrus, Pinus* and *Juniperus* trees. This is line with findings of Ali et al. (2018), Ahmad et al. (2016), Khan et al. (2016), Akhtar and Bergmeier (2015), Shaheen et al. (2015), Sharma et al. (2014), Hussain et al. (2010) and Jabeen and Ahmad (2009). On the North Facing Slopes of Sub-Alpine *Abies-Picea-Rhododendron* community was recorded. The *Rhododendron afghanicum* was uniformly distributed on the open space of forest as well as inside the forest. Forest at this site was found in good health. Deforestation was also not that alarming as compared to that of other monitoring sites. *Juniperus-Rheum-Kobresia* community was recorded at alpine zone. This is treeless zone and only two shrubs were recorded first one was *Juniper excelsa* and the second was *Rhododendron afghanicum* and dominated by the herbs i.e. *Kobresia schoenoides.* This site shrub growth was stunted, and trees were scanty due to unfavorable conditions. These results are in line with the works of Ali et al. (2018), Khan et al. (2016, 2012), Haq et al. (2015), Sharma et al. (2014) and Ahmad et al. (2010, 2006). The soil texture of the research area was typically sandy loam and loamy sand, with pH ranged from 7.3 to 7.7. Organic matter varied from 1.4 to 2.4% and electric conductivity from 0.6 dSm^{-1} to 1.6 dSm^{-1}. The $CaCo_3$ ranged from 2.6 to 7.8%, HCO_3 from 3.0 to 8.0% and sulphates from 0.4 to 7.8% respectively. Nitrogen concentration ranged from 0.280 to 0.569%, phosphorus from 435 to 810 μg/g, potassium from 1090 to 9900 μg/g, calcium from 32100 to 39900 μg/g, magnesium from 5100 to 6800 μg/g and sulphur from 163 to 263 μg/g. The micro nutrients such as iron ranged from 15000 to 89200 μg/g, manganese was enumerated as 343 to 976 μg/g, copper was found to be 55 to 109 μg/g and zinc varied from 53 to 84 μg/g, however, sodium was recorded from 1300 to 3300 μg/g and chlorine as 1500 to 3500 μg/g.

Conclusions

This study reveals results of vegetation mapping based on 140 sampling units at 7 monitoring sites while results of soil analysis cover 18 parameters. Spatial variation among plant communities at different monitoring sites is attributed to variations in edaphic variables, climate and different ecological parameters. Anthropogenic activities, over grazing, natural disasters and erosion are reducing the vegetation cover. Extraction of fuel wood from forest, especially during harsh winters by the local people is alarming. Impacts of anthropogenic pressure are evident from low scores for maturity index (48.88) at Sub-Tropical Plain area. Low values for maturity index indicate inability of the plant communities to cope with anthropogenic, edaphic and climatic stresses. Similarly, low values for similarity index show the heterogeneity among the reported different 7 plant communities. However, cluster analysis using PAST software and PC-Ord software version 5, classified the vegetation into three groups and four groups based on quantitative value. Afforestation programs need to be started on wasteland of the area to overcome the impacts of deforestation. There is severe deforestation pressure on woody and shrubby species especially on *Quercus baloot*,

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Quercus semicarpifolia, Cedrus deodara, Abies pindrow, Pinus wallichiana, Indigofera gerardiana, Sophora mollis and Syringa afghanica. Therefore, alternate sources of fuel/timber should be provided, and the area must be protected to promote vegetation cover. Effective measures like afforestation and control of overgrazing are needed to avoid soil erosion.

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