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PLANT COMMUNITIES AND ANTHROPO-NATURAL THREATS IN THE SHIGAR VALLEY, (CENTRAL KARAKORUM) BALTISTAN-PAKISTAN

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Abstract

The present study elaborates the results of the first phytosociological research conducted in the Shigar valley, Karakorum Mountains along with posed natural and human made threats. Random stratified sampling method was used in order to collect phytosociological data. During field trips carried out in 2013-2016, 14 localities and 35 altitudinal transects were sampled in the elevation range of 2200-4700m. The plant communities were determined, and the plant taxa were analyzed against environmental variables using computer packages. Each community was analyzed for potential threats by point scaling (1-3) method. In all 345 species were recorded belonging to 206 genera and 63 families including few endemic and rare taxa such as *Aconitum violaceum* var. *weilerei, Asperula oppositifolia* subsp. *baltistanica, Festuca hartmannii, Anaphalis chitralensis, Hedysarum falconeri, Pedicularis staintonii, Clematis alpine* var. *sibirica* and *Pyrola rotundifolia* subsp. *karakoramica.* Species richness was observed at middle elevations. Three communities were recognized along altitude with prevailed dry slopes residing maximum thermophilous and petrophilous species. The main controlling factors of species composition and distribution pattern along elevation were soil moisture, substrate, aspect and elevation. Grazing, uprooting, trampling and cutting were recognized as the major degradation processes of the vegetation. The mountainous vegetation of the study area possesses substantial plant biological diversity with unique assemblage with elevation. Several anthropo-natural threats were observed mostly connected with direct habitat fragmentation triggering rapid decline in vegetation cover. Nevertheless, the grazing, uprooting and cutting were potential and destructive threats for local plant biota which demand prompt conservation plans.

Key words: Phytosociology, Floristic, Degradation processes, Conservation.

Introduction

For over a century, ecologists have made continuous attempts to understand the relationship between environmental gradients and plants' composition and distribution (Gentry, 1988; Khan *et al*., 2011). The topic has long tradition and recognized in early 19th century (Humboldt, 1807). The relationship between plant associations and abiotic factors has become central in order to understand the ecology of any type of aquatic and terrestrial ecosystem. In the recent decades, the subject has gained more attention due to rapid global climate change coupled with extensive anthropogenic impacts on vegetation (Sukopp, 2004). The interrelationship between plant communities and the environment is very intricate due to simultaneous and abrupt changes in the factors such as topography, soil moisture, temperature, habitat stability, etc. However, ecologists have always endeavored to discover the governing factors of this complex interaction by using different approaches. Computer based statistical and multivariate analytical programs were commonly used to determine the community types under the influence of certain environmental variables (Anderson *et al*., 2006; Bergmeier, 2002). Abiotic factors like elevation, topography, moisture, soil nutrients, light availability and substrate stability have been frequently assessed to determine the species distribution pattern of mountain vegetation (Carpenter, 2005; Jafari *et al*., 2004; Schickhoff *et al*., 2000; Wang *et al*., 2003; Zhang *et al*., 2005). Karakorum Mountains of the northern Pakistan has arid and semi-arid climatic conditions (Dickoré, 1995; Kreutzmann, 2006). Geologically, it emerged as the result of intensive geologically recent upheavals at the end of the Mesozoic era (Searle, 1996). The range receives minimal precipitation and experiences frequent drought (Abbas *et al*., 2017). Topographically, terrain has rugged ranges and structures a typical mountainous region of Baltistan in the extreme northern territories with various astonishing valleys like Basha, Bilamik, Braldo, Chorbat, Hushe, Khaplu, Shigar, Skardu, Stak, Tormik, etc. In the research contextual Baltistan is in the exploratory phase in many scientific and social domains due to its distant geographical location. Few studies exist on the geology, floristics, ethnobotany, social livelihoods, pastoralism etc. but the studies on the phytosociological perspectives are absent. Shigar valley is the gateway for the world's second highest peak (K2, 8611m). It falls in the ambit of Central Karakorum National Park (CKNP), established in 1993. We selected the valley for the current study because, its species composition, vegetation units and degradation processes are hardly known. The study was aimed to recognize the plant communities and possible factors for their distribution pattern. It also includes the assessment of environmental impacts on plant communities.

Materials and Methods

Study area: The study conducted in the Shigar valley (25° 25'32" N and 75° 42'59"E), Central Karakorum Ranges, Baltistan Region, Northern Pakistan (Fig. 1). It covers an area of 4,373 km^2 in the elevation range of 2200 – 8,611m above sea level. The physical features of the valley changes frequently from bottom to the top. The lower reaches are rather flat with alluvial fans, dry slopes, and undulating foot hills. The elevated areas are narrow with enormous ridges, taluses, boulders and gorges. Himalaya blocks the monsoon moist air to the entire Baltistan region. Consequently, it exhibits extremely dry and harsh environmental conditions. However, most of the precipitation receives in early spring and late summer. The valley faces dry summer and harsh prolonged winter with frequent snowfall (Abbas *et al*., 2017). Shigar River is the main water course flows from the catchments of Biafo, Baltoro and Chogholungma glaciers. These glaciers' apices include the highest peaks K2, Broad Peak (8047m), Angel Peak (6858m) and Skil Brum (7360m) (Seong *et al*., 2009). Due to dry and continental climate the growing season is very short (July to August). The vegetation cover is very thin and included in dry temperate type (Champion *et al*., 1965). Based on geographical distribution the plant species of the study area falls in Irano-Turanian region (Ali and Qaiser, 1986; Takhtajan, 1986). In geographical distribution the plant taxa are mostly Irano-Turanian particularly Central Asiatic elements (sub region of Irano-Turanian). Over all the species richness is low and presents considerable number of monotypic families (Abbas *et al*., 2019). Asteraceae, Poaceae, Lamiaceae, Polygonaceae and Rosaceae are main botanical taxa. *Seriphidium brevifolia* (Asteraceae) is the most prevailing species and distributed throughout the valley. The lower cold deserts are mostly inhabited by chenopods and graminoids such as *Halogeton tibetica, Krascheninnikouvia ceratoides, Piptetharum gracile, Kochia prostrata, Koeleria macrantha, Leymus seculinus* etc. The rock faces are mostly inhabited by *Ajania fruiticulosa, Anaphalis nepelesis, Tricholepis tibetica,* while the species, *Myricaria germanica, Rosa brunonii, Myrtama elegans, Hippophe rhamnoides* develop the riverine forest. In the summer season the lower terrains remain un-grazed due to long term pastoralism in alpine pastures. But mostly species are uprooted for winter fuel and fodder purpose. In these mountain oases considerable greenery can be seen with increase in elevation particularly along water sheds. The upper tree line comprises of birch (*Betula utilis*) as leading tree accompanied with *Salix karnelii*. The long deforestation activities have almost bared the forest zone. Considerable relict forest stands are found on sub alpine slopes and sometimes in the form of Krummholz at high altitudes.

Data collection: Field trips were conducted in the study area to collect the phytosociological data from 2013-2016. Fourteen localities were positioned along the valley at the interval of 15 km besides the river. In these localities, over all 35 altitudinal transects (stands) were selected perpendicular to the water courses (Shigar, Basha and Braldo rivers) based on their aspects, topography and vegetation changes. Line transects (50m) were laid from the river banks after 20m interval. Changes in the line transect length and interval was made where necessary. In each transect all species were counted from 1m distance from both sides. Density, cover and frequency were calculated, described by Curtis and McIntosh (1950) and Braun-Blanquet (1932). The important value index was calculated by the formulae proposed by (Brower *et al*., 1998). The growth form (habit) of the collected plant species were also assessed. The degradation processes were examined by point scaling method ranges from 1 – 3 (1- low impact; 2- medium impact; 3- strong) as adopted by Nowak *et al*., (2011). In this each impact which ranges from 1 – 3 and 9 in cases of full points. But for the community type it could be calculated 33 as maximum value. Therefore, the strong impact for all eleven degradation processes, the community would score 33 points indicating maximum severity. The collected plants were identified based on Flora of Pakistan Nasir, E. & Ali, S. I. (Eds.) (1970-1989), Ali, S. I. & Nasir, Y. J. (Eds.) (1989-1991), Ali, S. I. & Qaiser, M. (Eds.) (1993-2019) and (http://www.efloras.org/flora_page.aspx?flora_id=2) Flora of China. The botanical names, authorities and families were assigned by Angiosperm Phylogeny Group (APG) (Group, 2009). The collected specimens were dried, poisoned and mounted on standard sheets and stored in the Herbarium of Hazara University, Mansehra, Pakistan.

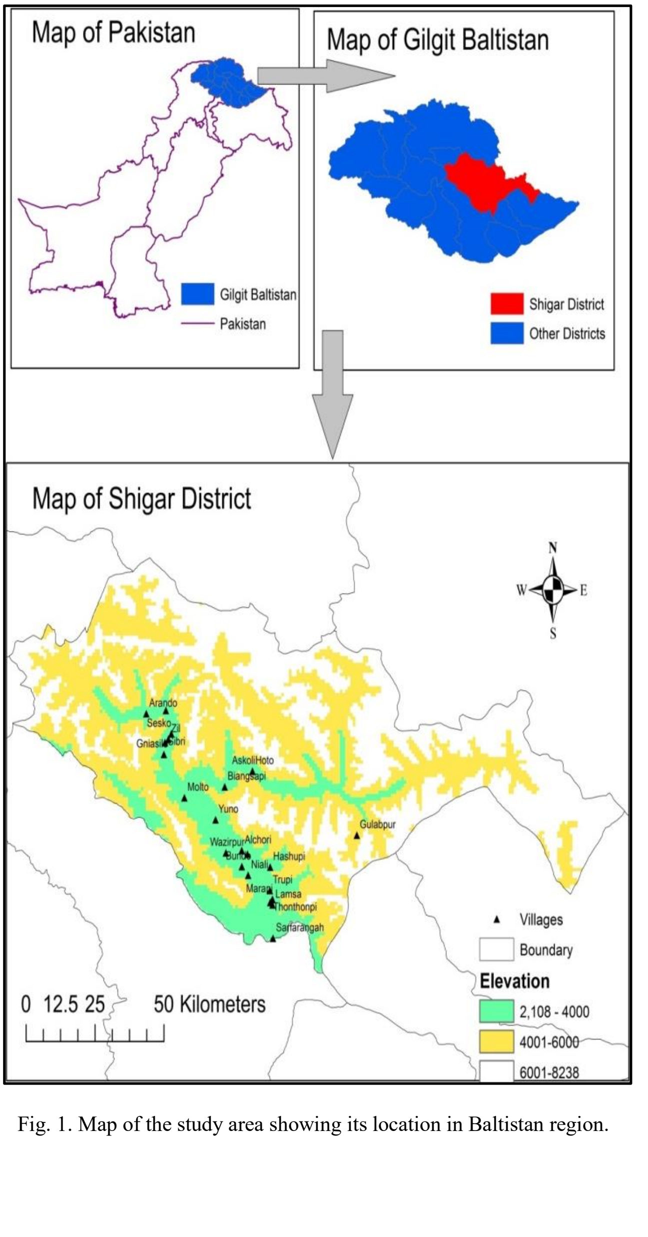

Fig. 1. Map of the study area showing its location in Baltistan region.

Environmental gradients: Seven main environmental gradients were assessed in each altitudinal transect using semi-quantitative scales (Dvorský *et al*., 2011) viz. (1) Stability of the substrate: 1 = unstable (screes, dunes, periglacial soils), 2 = partly stable (grasslands, steppes), 3 = stable (rocky crevices, boulders); (2) Light availability: 1= shaded (gorges, shaded rocky crevices), 2 = partially shaded (dense vegetation cover), 3 = full light (sparse vegetation cover) ; (3) soil moisture: 1= dry (substrate usually without visible traces of water), 2 = mesic (water not on ground surface but slightly damp) 3 = wet (water level regularly but transiently above soil surface); (4) nutrient availability: 1 = low (desert, semi-deserts, steppes), 2 = medium (habitats with considerable vegetation cover), 3= high (animal resting places); (5) soil salinity: 1 = no salt deposits on soil surface, 2 = rare salt deposits, 3) salts forming a continuous white crust; (6) altitude: altitude was measured by using GPS Garmin e Trex. HC series, vista HCx.; (7), and aspect: exposures of the stations were observed by the help of compass.

Data analysis: The computed phytosociological data was analyzed using multivariate statistics in PCORD version 5 for classification technique (McCune and Mefford, 1999). This clustering technique identified the altitudinal transects (stands) with similar floristic in order to structure the plant communities based on presence/absence method (1, 0). The plant communities were determined and named based on highest index values. CANOCO (V. 4.5) was used for ordination analyses to identify environmental gradients (Ter Braak & Smilauer, 2002). Canonical correspondence analysis was carried out between environmental variables, stands and community types in order to know their influence on species distribution.

Results

Floristic composition: A total of 345 vascular plant species were sampled distributed in 206 genera and 63 families comprising 301 (87%) herbs, 26 (7.82%) shrubs, 14 (4.05%) dwarf shrubs and 4 (1.15%) trees. The largest family was Asteraceae with 69 species (20% of all species), followed by Fabaceae, with 25 species (7.4%) and Poaceae, 24 species (6.9%). Other dominant families with less than 20 species were Lamiaceae with 18 species, Rosaceae 18 species, Polygonaceae 16 species, Chenopodiaceae 15 species, Ranunculaceae 14 species, Apiaceae 13 species, Scrophulariaceae 13 species, Caryophyllaceae 12 species and Brassicaceae 11 species. The remaining families were recorded with less than 11 species. The leading genus was *Saussurea* with 8 species. Seven species presented as sub dominating taxa i.e. *Pedicularis, Potentilla* and *Nepeta.* Whereas *Artemisia, Silene, Anaphalis, Chenopodium* and *Astragalus* were represented by 6 species each. The endemic taxa such as *Aconitum violoceum* var. *weilerei* and *Asperula oppositifolia* susp. *baltistanica* were also recorded in the current study. Likewise, *Pyrola rotundifolia* subs. *Karamkoramica* was another rare taxon with very few records from Pakistan was also documented. Other recognized endemic and rare species were *Accantholimon tianschanicum*, *Ranunculus palmatifidus*, *Scrophularia nudata, Pedicularis staintonii*, *Festuca hartmannii*, *Anaphalis chitralensis*, *Berberis pseudoumbellaeta* subsp. *gilgitica Capparis spinosa* and *Apocynum venetum*.

Plant communities: The obtained *Presence/absence* (1/0) data were assessed using cluster and 2-way cluster analysis via PCORD version 5 (Lepš & Šmilauer, 2003; McCune & Mefford, 1999). Cluster analysis determined the species data matrix of 35 altitudinal transects in three plant associations (communities) as depicted in (Fig. 2; Table 1). The first upper branch of dendrogram parted the dry temperate vegetation of lower altitudes and second branch depicted the vegetation of middle warm mountain slopes. The third branch showed the sub alpine and alpine vegetation. Further descriptions of the three communities are given below:

***Artemisia scoparia-Piptatherum gracile-Colutea paulsenii* community:** This community was recognized at valley bottom or lower reaches on either sides of river Shigar. The community included a single tree species (*Pistacia khinjuk*), dwarf shrubs, shrubs and herbaceous species. Other sub dominating species of this association were *Sophora alopecuroides, Artemisia rutifolia, Colutea paulsenii, Canabis sativa, Ephedra intermedia, Koeleria macrantha, Ajania fruticulosa* and *Perovskia abrotanoides.* The species *Rumex hastatus, Crepis sancta, Arnebia guttata, Chorispora sibirica, Ferula jaeskeana, Chenopodium botrys, Rhamnus prostata* and *Haloxylon griffthii* were rare plants of the community. The community represented mostly the chenopods and members of Asteraceae. In the growth pattern, mostly they are cushion and caespitose nature. The solar radiation was intense due to open habitat with low moisture and thin vegetation cover. Eco-physiologically, these species were xerophytic, typically adapted for dry habitat. Being at the bottom, indigenous people get easy access to the community. Consequently, it has to experience different natural and human made threats. Drought, rock weathering, floods, land sliding and intense radiation were natural hazards. The manmade impacts such as rock blasting for building purpose, sand collection, uprooting and shrubs' cutting for domestic fuel were also in practice. On the other hand the newly introduced *cold desert jeeb rally* in Baltistan region is also also conducted in the lower deserts of the project area. It is also a potential peril for the lesser xerophytic and psamophytic flora.

***Seriphidium brevifolia-Rosa webbiana- Juniperus excelsa* community:** The plant community was characterized by *Seriphidium brevifolia, Rosa webbiana* and *Juniperus excelsa. Juniperus excelsa* was the only tree taxon of the community. The characteristic species of shrub layer were *Hippophae rhamnoides* subs. *turkestanica*, *Ribes alpestre, Rhamnus prostrata, Krascheninnikouvia ceratoides while Trifolium pratens*, *Piptatherum laterale, Dactylorhiza hatagira, Pimpinella diversifolia,* and *Typha minima* were common herbaceous species. *Mellilotus indica, Selinum candidus, Sonchus oleraceous, Verbascum thapsus, Echinochloa crus-galli* and *Scrophularia nudata* were recorded sporadically. Due to human farming activities considerable moisture can be seen at lower altitudes but lessen with elevation. Therefore, the community enjoys the mesic and moist habitat at valley waste places and along water course. The plant species were in easy access of valley dwellers. They get services for domestic fuel and thatching (baskets etc.)

purposes. Agricultural expansion was one of the prevailing human pressures. Among usual calamities land sliding, rock drifting, flood and ice sliding were common. Cutting of riverine forest and dry slope scrubs, grazing, herbs cutting and land tilling for field terraces are the major hurdles for the community.

***Bistorta affinis-Betula utilis-Sibbaldia cuneata* community:** The community was a mosaic community consisting of sub alpine and alpine plant species. The characteristic species of this plant assemblage were *Bistorta affinis, Betula utilis* and *Sibbaldia cuneata.* Other common herbaceous associates were *Lindelofia longifolia, Bistorta vivipara, Leontopodium leontopodinum, Ananphalis nepalensis, Rhodiola heterodonta, Pedicularis bicornuta, Myosotis alpestre, Saxifraga flagellaris, Saxifraga sibirica, Bergenia strachye* and *Pulsatilla wallichiana. Salix karnelii and Juniperus communis* were sparsely distributed shrubs while birch (*Betula utilis*) was the common tree. This also comprised of some rare high elevation species such as *Chorispora sabulosa, Saussurea simpsoniana, Primula warshenewskiana, Kobrasia laxa, Delphinium brunonianum* etc. The community experiences various natural hazards in the form of high solar radiation, sliding of ice and avalanches. Particularly glacial abrasions affect the succession and distribution of the species of alpine screes and boulders found on the terminal and medial moraines. Although, there was no permanent hamlets at this elevation but various shepherd and cattle homes can be seen. Therefore, the community cannot be approached by all inhabitants. But the people related with mining (gemstones), wood cutting, and medicinal plants profession, frequently visit the alpine areas. Mining, over grazing trend, medicinal plants harvesting, deforestation and herbs cutting for fodder were identified as the major challenges for this high elevation community. Besides, Grazing was also potential human impact in these elevated areas.

Geo-climatic variables: Using CANOCO software version 4.5, the species and environmental data were analyzed collectively. In the mountain ecosystem various factors interfere in species surrogacy along elevation. However, the results showed that the geophysical and climatic variables greatly influence the species pattern and composition. The most influential gradients were soil moisture, substrate, aspect and elevation. The results of canonical correspondence analysis (CCA) of environmental data identified the main driving environmental variable for the constitution of a specific community type. CCA results of species versus environmental variable and stands versus environmental variables reflect the both composition and the abundance of plant species in the area. The CCA ordination procedures for samples and species indicated that the first axis was primarily correlated with elevation and aspect, the second axis was correlated with nutrients and light availability. The fundamental ecological gradient of the first axis can be clearly recognized from the biplots, related key environmental variables to plant species distribution (Figs. 3, 4 and 5).

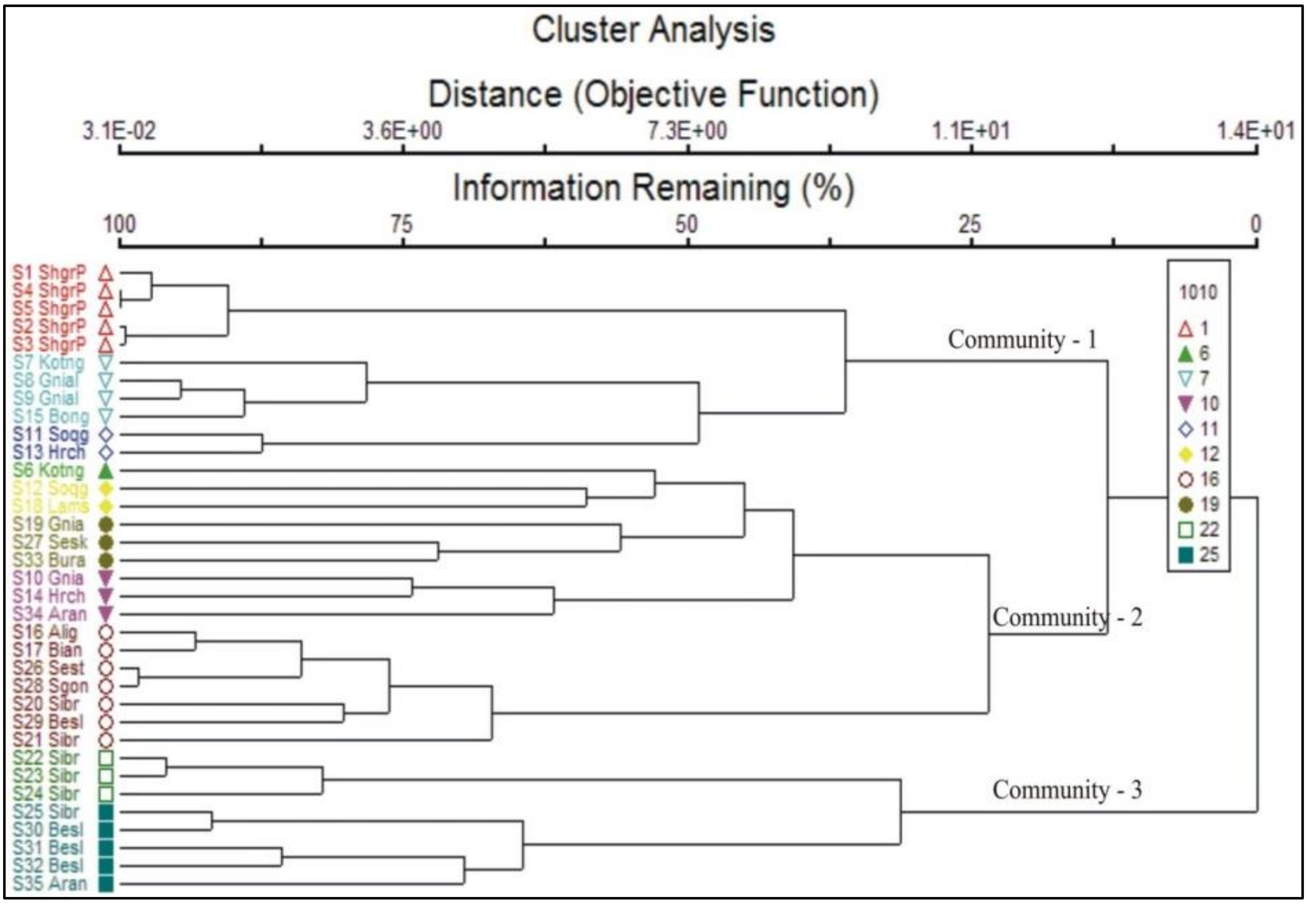

Fig. 2. Cluster dendrogram of 35 stands based on Sørensen coefficient showing 3 plant communities.

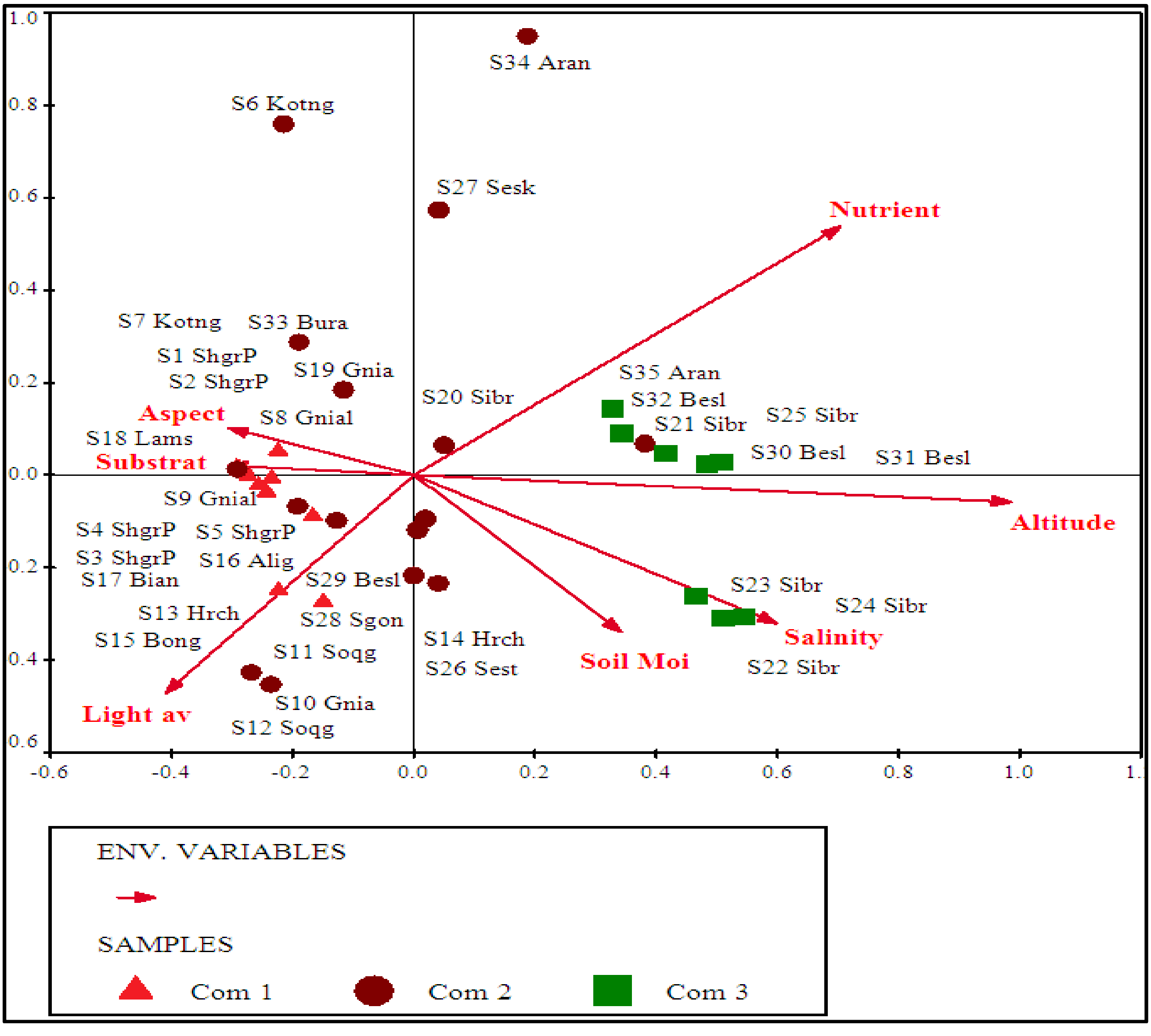

Fig. 3. CCA ordination diagram of community types and environmental variables.

Table 1. Natural and anthropogenic impacts on plant communities.

Plant communities	Major vegetation types	Land sliding	Ice sliding	Flood	Drought	Trampling	Agriculture	Erosion	Cutting	Uprooting	Mining	Grazing	∑
Artemisia scoparia-Piptatherum gracile-Colutea paulsenii community	Sub mountainous	1	2	3	2	2	3	1	2	3	0	2	21
Seriphidium brevifolia-Rosa webbiana-Juniperus excelsa community	Sub mountainous & Mountainous	3	2	2	3	3	2	2	3	3	2	3	28
Bistorta affinis-Betula utilis-Sibbaldia cuneata community	Sub alpine & Alpine	3	2	2	2	3	0	2	3	2	2	3	24
	∑	7	6	7	7	8	5	5	8	8	4	8	

Conservation: The plant communities were facing different types of natural and human made threats. A total of eleven types of impacts were identified i.e. land sliding, ice sliding, flood, drought, trampling, agricultural encroachment, erosion, cutting, uprooting, mining, and grazing. The analysis showed that the community-2 (*Seriphidium brevifolia-Rosa webbiana-Juniperus excelsa*) which was a mosaic of sub mountainous and mountainous vegetation was the most vulnerable community type with 28 score followed by *Bistorta affinis-Betula utilis-Sibbaldia cuneata* community (24) and *Artemisia scoparia-Piptatherum gracile-Colutea paulsenii* community (21). Grazing, trampling, uprooting, and cutting were the most deteriorative impacts along with land sliding, flood, ice sliding, and drought as hindrances for vegetation growth and distribution. These impacts were observed less at both elevation extremes.

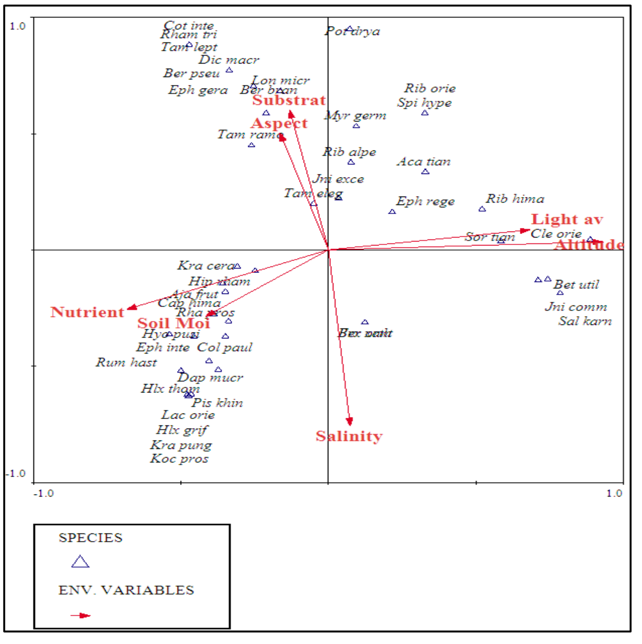

Fig. 4. CCA - ordination diagram of woody species (shrubs & trees) and variables.

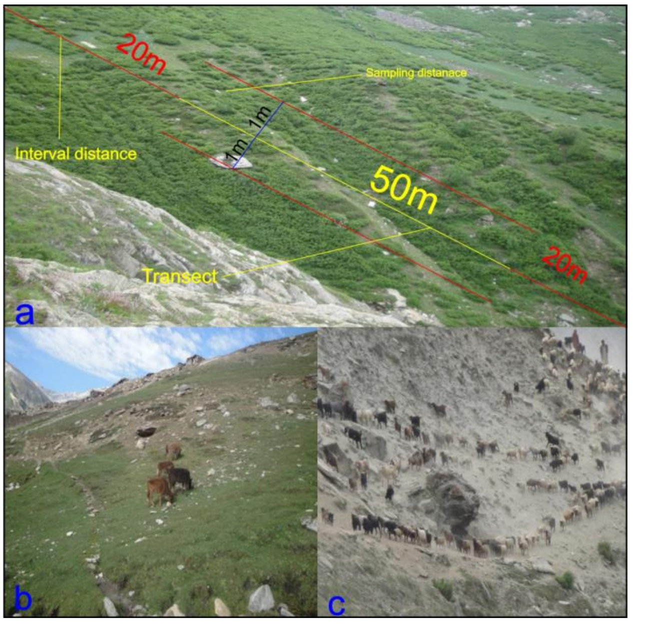

Fig. 5. a. The sub alpine steppe vegetation depicting sampling techniques b. Grazing impact in alpine slopes c. Potential trampling effect of herds (goats, sheep).

Discussion

Mountains occupy about quarter of the global terrestrial land surface and host at least one third of terrestrial plant diversity (Körner, 2007). They harbour complex and fragile ecological systems and considered more vulnerable to global change frequently (Gottfried *et al*., 2012; Huber *et al*., 2006). Therefore, anthropogenic impacts further strengthen the degradation processes in mountains (Wohl, 2006). Vegetation has primary role in the integrity of mountain biota and knowledge about its diversity, pattern and dynamics related to environmental gradients is urgent in present-day rapidly changing globe. In general the flora of the study area resembles with the flora of Nanga Parbat (Dickoré & Nüsser, 2000), Hunza valley (Eberhardt, 2004) and Ladakh (Klimeš & Dickoré, 2005). Similar findings about the main habitat types, species diversity and their distribution were reported from Karakorum/Kunlun mountains, China (Dickoré, 1991) and from Batura valley, Karakorum (Eberhardt *et al*., 2007). The findings contradict with the studies Khan (2012) and Rahman *et al*., (2016) conducted in Himalaya and Hindu Kush ranges respectively. It may be attributed with the different climatic conditions of the ranges as these mountains enjoy much rain fall as compared to Karakorum. For that reason, different species composition and substitution were observed in these two great ranges. The herbaceous habit dominated flora alike with the studies on mountain vegetation in Indian Trans Himalaya (Dvorský *et al*., 2011), and Kaghan valley Schickhoff (1995). This may be endorsed by mountainous harsh climate (Austrheim & Eriksson, 2001). The species diversity and surrogacy displayed different patterns along environmental gradients. In general the vegetation was patchily distributed throughout the landscape as stated by Zhang *et al*., (2005) in the arid land of China. Three communities were defined by cluster analysis and geo-climatic variables greatly affect their distribution pattern. The leading habitat type of the study area was dry and rocky slopes and found on both alternating northern and southern declivities in lower and middle elevations. Therefore, the laid transects faced lower dry habitat with similar species as the stands exposed overlapping in the community-2. The lower habitat was characterized by severe radiation, hot and dry condition exhibiting desert environment. These species were thermophilous in habitat preference and were mostly chenopodiaceous and species of *Artemisia*. Such characteristics of species were also discussed in dry mountain of Middle Asia (Nowak *et al*., 2014; Nowak & Nobis, 2013), Iranian mountains (Akhani *et al*., 2013) and Naran valley Western Himalaya Khan *et al*., (2013). The species of middle elevation were petrophilous, and hygrophilous in alpine areas. The canonical correspondence analysis revealed the soil moisture, substrate, aspect and elevation could be hypothesized to be the potential driving factors of species pattern and community dynamics. According to Körner *et al*., (2011) aspect is the unique and characteristic feature which distinguishes the mountains from other terrestrial ecosystem. Burke (2001) and Götzenberger *et al*., (2012) also reported that aspect influences the species distribution along with light availability and altitude. The anthropogenic impacts have been rapidly changing the environment regionally as well as globally. The areas with low vegetation cover are more vulnerable to human activities. They cause irreparable ecosystem deterioration which ultimately leads to desertification. At lower altitude uprooting of the vegetation was the common practice for domestic fuel causing habitat destruction. Cutting practices for fuel purposes were common threats for sub alpine birch forest. The community of middle elevation frequently suffers from environmental threats as compared to the other two communities. It may be because of its diversity in plants' habits and natives try to get services from available herbs, shrubs and trees for their subsistence. Grazing was observed as the potential threats in the whole study area and also exemplified in several studies of mountainous ranges (Baranova *et al*., 2016; Noroozi *et al*., 2011; Schickhoff, 1995). The study also documented some rare as well as endemic taxa which need to be conserved quickly. These species are considered more susceptible due to their narrow ecological niche (Alam, 2010). In the Baltistan region more than ten taxa are endemic and various are rare and some of them are critically endangered (Alam and Ali, 2010b). Only few species were assessed precisely across the country (Abbas *et al*., 2010; Jan & Ali, 2009; Majid *et al*., 2015). These taxa need prompt conservation strategies. *Asperula oppositifolia* susp. *baltistanica* is endemic to the region of Gilgit-Baltistan and declared as critically endangered species.

The study area displays substantial species and community diversity along altitudinal gradients. The consistent anthropogenic activities and geophysical changes have altered the susceptible mountain ecosystem at high scale due to direct habitat fragmentation. This probably hampers the vegetation flourishing in the area. The present study could be fruitful in order to conceive the management plan for safeguarding the phytodiversity, restoration ecology and sustainable resource utilization of the Central Karakorum Mountains.

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