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VEGETATION DYNAMICS ALONG ALTITUDINAL GRADIENTS IN SHIGAR VALLEY (CENTRAL KARAKORUM) PAKISTAN: ZONATION, PHYSIOGNOMY, ECOSYSTEM SERVICES AND ENVIRONMENTAL IMPACTS

ZAHEER ABBAS[1*], SHUJAUL MULK KHAN[2], JAN ALAM[3], THOMAS PEER[4], ZAINUL ABIDEEN[5], RAINER W. BUSSMANN[6] AND SAID MUHAMMAD[3]

[1]*Department of Botany, University of Education, Lahore, Pakistan*
[2]*Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan*
[3]*Department of Botany, Hazara University, Mansehra, Pakistan*
[4]*Department of Organism Biology, University of Salzburg, Salzburg, Austria*
[5]*Dr.Muhammad Ajmal Khan Institute of Sustainable Halophyte Utilization, University of Karachi, Karachi, Pakistan*
[6]*Department of Ethnobotany, Institute of Botany, Ilia State University, Tbilisi, Georgia*
[*]*Corresponding author's email: zaheer.abbas@ue.edu.pk, shujaqau@gmail.com*

Abstract

This paper provides the first insight into the altitudinal zonation of vegetation of Shigar valley, Central Karakorum Mountains, Pakistan. The study was conducted in the period of 2013-2016 and focused on floristic and structural differentiation of vegetation; ethnobotany, and environmental impacts in the region. Based on altitude, climate, and indicator species, four vegetation zones were recognized including sub-montane, montane, sub-alpine, and alpine belt. From these belts, a total of 345 plant taxa were collected. The sub-montane belt presented the highest species richness. Perennials prevailed in all vegetation types. Annuals drastically decreased with altitude. Hemicryptophytes occurred in all zones, and chamaephytes only at lower, dry and rocky sites. Phanerophytes (shrubs, trees) decreased with altitude and were almost absent in the alpine belt. Microphylls and nanophylls had an abrupt decline with altitude. Plant functional effects related to ecosystem services were sixteen and the maximum services were found in the sub-alpine (13) belt, followed by the sub-montane (12), the montane (9) and the alpine belt (4). All vegetation types were used by the local people, and twenty use categories with 83 species were found, including medicinal, beverages, edible, fuel, fence sources etc. Edible wild plants (fruits, vegetables), fuel wood, thatching, and fencing materials were provided by all vegetation belts except the alpine belt. The use of plants impaired plant functional effects in the ecosystem. Eight types of natural and human caused degradation processes were recognized, most common in the sub-montane and montane belt. The sustainable use of the resources requires appropriate monitoring activities, and regulation for conservation and management of this vulnerable mountain ecosystem.

Key words: Vegetation belts, Plant diversity, Plant adaption, Ecosystem services, Environmental risks.

Introduction

The scientific interest in altitudinal zonation of vegetation is very old and probably started with the script of Tournefort in 1717 (Clements, 1905). Since that early date, field botanists focused the subject and considerable literature focuses on alpine ecology (Daubenmire, 1943; Beals, 1969; Dickoré, 1991; Dickoré & Nüsser, 2000; Akhani *et al.*, 2013; Abbas *et al.*, 2017b ; Abbas *et al.*, 2021). Mountains cover large parts of the earth and are of remarkable biological diversity (Körner *et al.*, 2011). Mountains are characterized by rapidly changing geophysical features, climate and life zones over a short elevational distances (Körner, 2004). Therefore, altitude is frequently used as potential factor in order to assess vegetation zonation, community types, species diversity, biological spectra, and ecosystem services in the alpine ecosystems (Mani, 1978; Grytnes, 2003; Klimes, 2003; Sharma *et al.*, 2009; Saqib *et al.*, 2011; Zeb *et al.*, 2021; Iqbal *et al*., 2021). Global climate change, unsustainable land use, deforestation and high grazing pressure were identified as potential challenges in different world mountain ranges (Breckle & Wucherer, 2006; Spehn *et al.,* 2006; Noroozi *et al.,* 2011; Haq *et al*., 2021). Mountains are hotspots of biological diversity but they are considered especially susceptible to global change due to its steep climatic conditions (Kohler *et al.,* 2010; Körner *et al.,* 2017). This demands to address the potential threats, environmental degradation and human made hazards in order to design conservation plans and sustainable utilization of resources. The Karakorum Mountains are one of the famous ranges in the northern region of Pakistan. Approximately 113000 people live within the zone of Central Karakorum Range and are continuously altering the fragile montane ecosystem for their subsistence. The rapid and severe anthropogenic impacts make vegetational studies very urgent. Such studies are very limited in entire region of Baltistan, particularly in the valleys of Central Karakorum. However, some regional studies on floristic and medicinal plants exist, for instance, Hussain *et al*., (2011), Bano *et al*., (2014a), Bano *et al*., (2014b), Abbas *et al*., (2016), Abbas *et al*., (2017a); Abbas *et al*., (2017b), (Abbas *et al*., 2017b), and Abbas *et al*., (2019), but related studies on vegetation ecology and phytosociology are largely absent. The purpose of the present study, however, was to present the vegetation composition, plant adaption and ecosystem services along the altitudinal gradients within the inner alpine Shigar Valley. The research objectives were i) to elucidate how altitude effects vegetation, floristic composition, and plant adaption ii) to evaluate the use of plants by the indigenous population, and iii) how natural and anthropogenic impacts affect local plant biodiversity.

Materials and Methods

Study area: The Shigar Valley (25˚ 25'32" N and 75˚ 42'59"E) is one of the most beautiful valleys in Baltistan. It represents a newly formed district of Baltistan Region, Northern Pakistan, located at the right bank of the Indus River and surrounded by two parallel submontane systems of the Central Karakorum Range (Fig. 1). It borders with China (north), Skardu town (south), Nagar valley (west) and Ghanche (east). It extends in north east to west direction and covers 4373 km^2 spanning a height range from 2260m to 8611m above sea level (Schmidt, 2008; Agheem *et al.*, 2014). It also shares the largest catchment area of 6945 km^2 (42%) of the Central Karakorum Range. The valley is the gateway to many of the highest mountains of the world. The area includes more than 720 peaks rising above 6000 meters and more than 160 peaks rising above 7000 meters. Five peaks tower over 8000 meters (e.g. Gasherbrum-, 8068 m; Broad Peak, 8047m; Gasherbrum-II, 8035m), topped by the second highest peak of the world, the Chogori or K2 (8611m). The summits are covered by enormous snow-masses, although bare bedrock is also present. The valley belongs to the largest protected areas (10557Km^2) within the Central Karakorum National Park (CKNP), which was established in 1993. Geologically, the valley lies on the edge of the Ladakh-Kohistan Arc, a band of metamorphosed volcanic and marine sediments believed to be the remnant of an island arc that was caught between Indian and Asian plates when these plates collided (Tahirkheli, 1979). It contains both Paleozoic sedimentary rocks of the Asian plate and Cretaceous volcanic rocks of the Ladakh-Kohistan Arc, presenting 144 years ago turritellid gastropod fossils (Pudsey, 1986; Hanson, 1989). The rocks are mainly metasediments and metaigneous, along with pegmatitic dikes, belonging to the Karakorum Metamorphic Complex (Gems and gem-bearing pegmatites), (Gaetani *et al.*, 1990; Agheem *et al.*, 2014). The high alpine presents enormous ridges, scarps, screes, and gorges. Moraines, alluvial fans undulating rocky hills, gravels, wetlands (river and lake bank swamp) and sandy plains are the major physical features. Glaciers such as the Biafo and Baltoro are important sources of water. The climate is strongly continental, with hot summers, intense solar radiation and long lasting cold winters with periodical snowfall (Abbas *et al.*, 2017b). The area receives most of the rain in early spring and late summer. There is no weather station in the study area, therefore we used the data of the station near Skardu town (2,228m, regional capital). Average annual temperature is 10.3°C and average precipitation is 202mm. Shigar River is the main water course, shaped by two northern tributaries, the rivers Braldo and Basha. They are flowing from the glaciers Baltoro-Biafo and Chogo Lungma, respectively. Due to snow melting during day, alpine brooks often swell and may cause dangerous floods. The valley has an upper and a lower tree line, the upper delimited by coldness and the lower by aridity. Within these lines *Artemisia* slopes and degraded, scattered Juniper trees occur. Willow and poplars grow along watercourses up to 3000m. Birch trees (*Betula utilis*) shape the timberline, mostly accompanied by *Salix karnelii*. Conifers such as spruces, pines and cedars are missing. The growing season for native flora is generally short. In terms of phytogeographical analysis the flora belong to the Western Irano-Turanian sub region (Ali & Qaiser, 1986; Takhtajan, 1986). Central Asiatic elements are in abundance (Abbas *et al.*, 2019). Scarce vegetation found on uncultivable areas valley floors such as lower foots hills, sandy plains, side slopes, which are of desert type. Various species grow as weeds among crops. The inhabitants are traditional and laborious, and transformed the valley floor into a beautiful agricultural landscape. The recent census in 2017 reported 75,000 inhabitants, with an increase of 29678 inhabitants in 19 years (Schmidt, 2004). Villages have been established on alluvial fans, terraces and gentle slopes above the rivers, at altitudes between 2,300m (Marapi), 2,790m (Arando) and 3,050m (Askole) (Schmidt, 2000). Agriculture, mining, pastoralism, animal husbandry, fodder and forest resources are the main social livelihood.

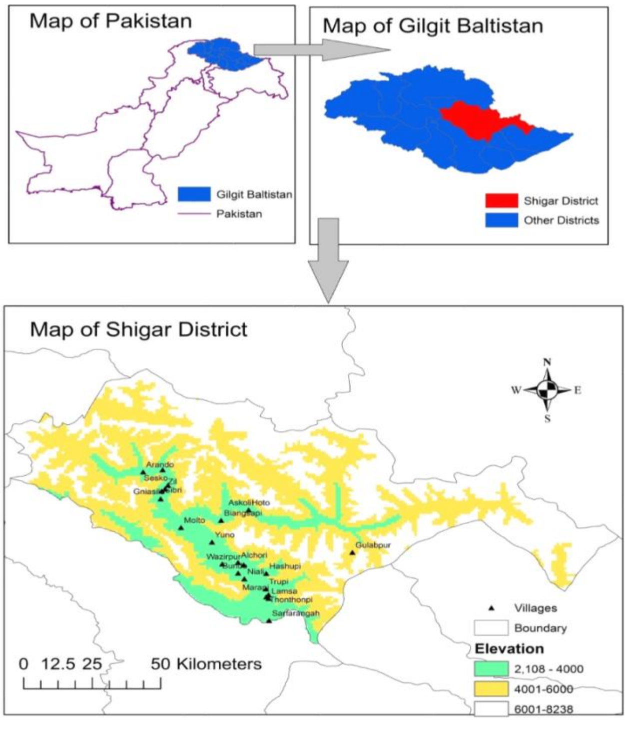

Fig. 1. Map of the study area showing its geography in Baltistan region.

Data collection: The vegetation survey was conducted between July and September each year from 2016 to 2019 at an altitudinal range of 2200-4500m. For elevational data of vegetation fourteen sites was selected alongside the river at interval distance of 15 km at different exposure. In these selected sites, 35 altitudinal transects were set vertically to the main water courses (Shigar, Basha and Braldo) to sample a maximum elevation range. Based on exposure these transects were, eastern (2), western (2), northern (8), southern (10), north eastern (5), north western (1), south eastern (4) and south western (3). The transects ended to the maximum altitudes with different topography and vegetation types depending upon the sites and accessibility. For plant sampling, belt transects (50m) were laid from the river-banks perpendicular to each other after 20m interval distance. Here, we focused the succession of vegetation types, along altitudinal gradients regarding physiognomy, ecosystem services and environmental degradation. The assessment of the vegetation belts followed Dickoré (1991); Dickoré & Nüsser (2000) Table 1). The physiognomic characteristics (growth habit, life form and leaf class) followed the studies of Hussain *et al*., (2015), Raunkiaer (1934), and Cain & Castro (1959), respectively. Based on life cycle, herbaceous plants were further classified into annual, biennial and perennial herbs. Likewise, shrubs were further classified into shrubs and dwarf shrubs, each based on their size and woody property. For ethnobotanical data, seventeen (17) villages were visited and 84 persons were interviewed by semi structured approach, as described by Martin (2004) and Cotton (1996). The local participants were asked about their use of plants along with local names, indigenous use and part used, after establishing prior informed consent. The total number of ethnobotanical plants was listed together with their services and classified by emic method (Marques, 1995; Alves and Albuquerque, 2016). These services were further assessed against each vegetation belt to know the type and number of services provided by 1, 0 method (1: service is provided & 0: service is not provided). In the data collection, maximum elevation range was included so that the environmental degradation processes could be properly and explicitly judged. Eight (8) naturally and human caused impacts, i.e. terraced agriculture, cut of trees and uprooting, drought, river erosion and overflow; flood, glacial abrasion, landslide, mining and grazing were subjectively assessed in each vegetation belt using a point scale method (1: low impact; 2: medium impact; 3: strong impact), based on different criteria given in Table 1. The grazing impact was assessed according to Westhoff & Van Der Maarel (1978) and Peer *et al*., (2001), including livestock trample paths, settlements proximity and external vegetation appearance. The specimens were properly pressed, dried and poisoned as described by Jain & Rao (1977). The specimens nomenclature was mainly based on Flora of Pakistan (Nasir, E. & Ali, S. I. (Eds.) (1970-1989), Ali, S.I. and Nasir, Y.J. (Eds.) (1989-1991), Ali, S. I. & Qaiser, M. (Eds.) (1993-2017), and Flora of China (http://www.efloras.org/flora_page.aspx? flora_id=2). The botanical names, authorities and families were based on Angiosperm Phylogeny Group (Group 2009). The collected plants were stored in the Hazara University Herbarium, Mansehra Pakistan.

Results

Altitudinal gradient: Based on elevation, climate, and indicator species, four vegetation belts could be distinguished. 1) The sub-montane (SM) belt, with *Krasheninnikovia ceratoides* and *Ephedra intermedia* as dominant species, ranges from 2300 to 2500m. 2) The montane (MN) belt, with *Juniperus excelsa* and *Tamaricaria elegans* as dominant species, from 2550 to 3000m. 3) The sub-alpine (SA) belt, with *Betula utilis* and *Salix karnelii* as dominant species, from 3000 to 3500m. 4) The alpine (AL) belt, with *Leontopodium leontopodinum* and *Rhodiola heterodonta* as dominant species, extending above 3500 m (Table 2).

Sub-montane belt: This belt included the broad valley floor, steppe, slopes and arid lower hill sides. The floristic composition was presented by 129 species, 111 genera and 39 families, including six endemic taxa (Fig. 2). Asteraceae (23 species), Poaceae (14) and Chenopodiaceae (13) were recognized as dominant families. The vegetation cover was very low and included few shrubs, dwarf shrubs and some herbaceous species, mostly belonging to Asteraceae and Chenopodiaceae. Common shrubs and dwarf shrubs were *Pistacia khinjuk, Daphne mucronata, Cotoneaster integerrimus, Capparis spinosa, Ephedra intermedia, Rosa webbiana, Tamarix leptostachya,* and *Tamarix ramosissima* (Table 1). However, *Ajania fruitculosa, Lactuca orientalis, Rumex hastatus, Krascheninnikovia ceratoides, Echinopes cornigerus, Tricholepis tibetica, Halogeton tibeticus, Haloxylon thomsonii, Kochia prostrata, Matthiola flavida, Arnebia guttata, Tribulus terrestris, Ephedra intermedia, Koeleria macrantha, Polygonum paronychioides, Dictylimon macrorrhabdos, Piptatherum laterale, Cynanchum acutum* were frequent herbaceous species. *Sophora alopecuroides, Rochela disperma, Tribulus terrestris, Peganum harmala,* and *Artemisia scoparia* were common psamophytes and covered sandy plains. Moreover, various species mostly belonging to Brassicaceae, Fabaceae and Polygonaceae were associated with crops (Wheat, Barley) on field terraces. The companion species were mostly thermo- and petrophilous in nature. All species had only few individuals; between them, the soil was open and bare. Among cultivated trees, poplars, silverberry and willows were most common. Natural forests are absent in this belt. The dry places are mostly inhabited by shrubs such as *Rosa brunonii, Ephedra intermedia, Seriphidium brevifolium.* The six endemic species were *Aquilegia fragrans, Astragalus polemius, Capparis himalayensis, Acantholimon tianschanicum, Scrophularia nudata* and *Asperula oppositifolia*.

Montane belt: In this belt 98 species, 72 genera and 32 families were recorded (Fig. 3). The dominant families were Asteraceae (25 species), Lamiaceae (9) and Fabaceae (8). Shrubs like *Ribes orientale, Ribes alpestre, Myricaria germanica, Tamaricaria elegans, Berberis orthobotrys* and *Hippophe rhamnoides* were found on river borders. *Scutellaria scandens* and *Anaphalis chitralensis* were important herbs. Where the valley gets narrower and the climate becomes coolar, a sparse Juniper forest (*Juniperus excelsa*) and more-green along the tributaries could be observed. Common species on east facing slopes were *Lactuca orientalis, Potentilla salesoviana, Inula obtusifolia, Ephedra regeliana* and *Rosa webbiana.* On west facing slopes Juniper trees were scattered, accompanied by *Nepeta discolor, Fraxinus xanthoxyloides, Chondrilla graminea,* and *Campanula cashmeriana.* This area included sporadic grain fields and cultivated crops. In between various companion species were growing such as *Solidago dahurica, Silene vulgaris, Plantago major, Saussurea costus, Euphrasia multiflora, Trifolium repens, Lactuca decipiens, Pedicularis punctata, Agrostis hissarica,* and *Bromus pectinatus. Anaphalis chitralensis*, *Berberis pseudoumbellata* subsp. *gilgitica,* and *Ranunculus palmatifidus* were endemics.

Table 1. Assessment criteria for environmental degradation processes.

Degradation processes	Low impact	Medium impact	Strong impact
Terraced agriculture	no terrace activities	rare terrace activities (two places)	intensive terrace cultivation (more than two places)
Cutting and uprooting	no wood heap, cut trees and logs observed, no uprooted heap stock observed	five heaps, cut trees and logs, five heaps of uprooted plants observed	wood heaps and wood cutters are observed at several places more five uprooted stocks observed
Drought	permanent rivulets, moderate rain fall	seasonal rivulets scares rain fall	no water channels, irregular rainfall
River erosion and overflow	minimum two river eroding sites; high vegetation cover	four shapes created by the river erosion are still visible; moderate vegetation cover	more than four river eroding sites; low vegetation cover
Landslide	two sliding sites observed	four sliding sites observed	more than four sliding sites observed
Glacial abrasion	Seen on two sites	Seen on four sites	seen on more than four sites
Mining	no mining camps and mines observed	two mines and mining camps observed	more than two mines and mining camps observed
Grazing	off vegetation season grazing areas	seasonal grazing sites	permanent grazing sites

Table 2. Climatic zone, characteristic species and vegetation belts.

		Climatic zone	Indicator species	Orographic zone
Altitude m	above 3500	Cold	*Leontopodium leontopodinum* *Rhodiola heterodonta*	Alpine belt
	3000-3500	Temperate	*Betula utilis* *Salix karnelii*	Sub-alpine belt
	2500-3000	Warm temperate	*Juniperus excelsa* *Tamaricaria elegans*	Montane belt
	2200-2500	Dry temperate	*Krasheninnikovia ceratoide* *Ephedra intermedia*	Sub-montane belt

Sub-alpine belt: Fifty-seven (57) species, 44 genera and 22 families characterized this belt; *Pyrola rotundifolia* subsp. *karakoramica* and *Hedysarum falconeri* were endemics. Depending on the terrain situation, dry grasslands, steep, wet grasslands, shrubs and trees were common. Through the more favorable, temperate climate, a shrub corridor arises, with *Juniperus communis, Sorbus tianschanica, Ribes himalense, Fragaria nubicola, Gentianodes eumarginata, Gentianopsis paludosa, Pyrola rotundifolia* ssp. *karakoramica, Myosotis alpestris, Clematis alpina* var. *sibirica, Rhodiola tibetica, Stellaria persica,* and *Astragalus rhizanthus* as common species. The soils were often moist, providing favorable environmental conditions for the growth of *Betula utilis* and *Salix karnelii* (Fig. 4). The wet grassy slopes were mostly inhabited by *Allardia glabra, Halotelephium ewersii, Saxifraga sibirica, Lomatogonium carinthiacum, Oxytropis lapponica, Rhodiola coccinea, Hedysarum falconeri, Bergenia stracheyi,* and *Pedicularis bicornuta.* On more dry sites, *Rheum tibetica, Platytaenia lasiocarpa* ssp. *thomsonii, Oxytropis microphylla,* and *Acantholimon lycopoidioides* were found.

Alpine belt: The alpine belt has a cool, moist climate, and high solar radiation during day (Fig. 5). The flora comprised 61 species, 39 genera and 19 families. *Festuca hartmannii, Aconitum violaceum* var. *weileri, Nepeta adenophyta,* and *Pediculari staintonii* were endemics. Moist grassy slopes, alpine meadows, screes and block boulders were typical in this belt. The alpine grassy slopes were colonized by a number of herbaceous species such as *Sibbaldia cuneata, Rhodiola heterodonta, Silene gonosperma, Alchemilla trollii, Bistorta affinis, Bistorta vivipara, Valeriana himalayana,* and many others. On moist sites grow, *Saxifraga flagellaris, Potentilla atrosanguinea, Leontopodium leontopodinum, Anaphalis nepalensis var. nepalensis,* and *Erigeron flaccidus.* Within unstable screes, *Fumaria adiantifolia, Nepeta erecta, Cerastium cerastoides, Geranium pratense,* and *Carex nubigena* were found. Highly unstable scree were home for *Delphinium brunonianum, Saussurea simpsoniana, Potentilla dryadanthoides, Primula warshenewskiana, Kobresia laxa,* and *Rhodiola tibetica.* The lateral moraines and terminal deposits of avalanches were colonized by *Draba winterbottomii, Chorispora sabulosa, Sibbaldea tetranda, Parrya* spp., and *Potentilla* ssp.

Species richness and endemism: A total of 345 vascular plants were sampled from the four vegetation belts, including 206 genera and 63 families. The comparative evaluation revealed the sub-montane belt as most diverse with 129 (37%) species, followed by the montane belt with 98 (28%), the subalpine belt with 57 (16%) and the alpine belt with 57(16%) presenting a typical decline with altitude. Asteraceae was the leading family in three vegetation belts, except the sub-alpine where it was replaced by Fabaceae. Overall 15 (0.043%) endemic species were documented. The highest endemism rate was found in the sub-montane belt with 5 endemics (*Scrophularia nudata, Asperula oppositifolia* subsp. *baltistanica, Astragalus polmius, Anaphalis chitralensis, Capparis himalayensis*). Five endemics occurred in the alpine belt (*Aconitum violaceum* var. *weileri, Pedicularis staintonii, Nepeta adenophyta, Festucachartmannii, Pedicularis staintonii).* Two endemics each were collected in the montane (*Ranunculus palmatifidus, Accantholimon tianschanicum*) and subalpine belts (*Hedysarum falconeri, Pyrola rotundifolia* subsp. *Karakoramica*).

Fig. 2. Sub-montane belt: A, a view of habitat; a. *Nepeta floccosa*; b. *Lactuca orientalis*; c. *Tricholepis tibetica*; d. *Capparis spinosa*

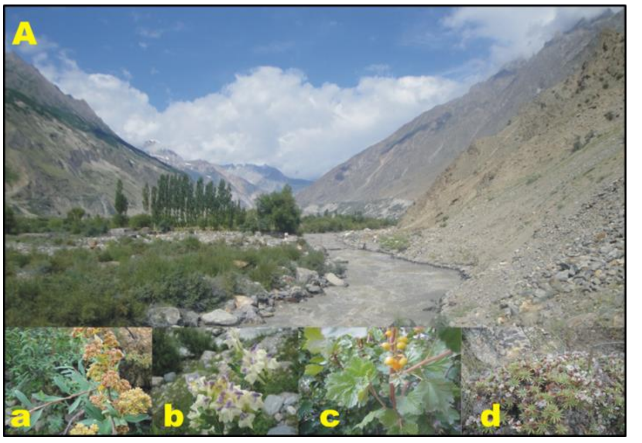

Fig. 3. Montane belt: A, a view of habitat; a. *Spiraeae canescens*; b. *Scutteleria scandens*; c. *Ribes orielntale;* d. *Accantholimon lycopioides*

Fig. 4. Sub alpine belt: A, a view of habitat; a. *Stellaria persica*; b. *Betula utilis*; c. *Lomatogonium carinthiacum*; d. *Clematis alpina* subsp. *sibirica*

Fig. 5. Alpine belt: A, a view of habitat; a. *Potentilla dryadanthoides* b. *Allardia tomentosa* c. *Chorispora sabulosa* d. *Primula warshenewskiana*

Physiognomic traits: Herbs, shrubs and trees were the main growth forms. Shrubs were more common at lower altitudes (sub-montane and montane) and decreased with altitude. No shrub was recorded in the alpine belt. Trees were very rare in the study area, with one species in the sub-montane belt (*Pistacia khinjuk*), two species in the montane belt (*Juniperus excelsa*) and one species in the sub-alpine belt (*Sorbus tianschanica*). Birch (*Betula utilis*) was typical within the sub-alpine belt. According to the classification of Raunkier, based on their perennating buds, perennials prevailed in all vegetation types, from the sub-montane to the alpine belt with 66, 63, 39, and 52 species, respectively. Hemicryptophytes were the most frequent life form, found in all four vegetation belts, with 41, 32, 29 and 37 species, respectively. They appeared uniformly distributed but had higher abundance in the sub-montane and alpine belt. Similarly, chamaephytes occurred in all vegetation belts, but had higher importance in lower dry and rocky areas. Therophytes had the same distribution range as annuals. Phanerophytes (shrubs, trees) were common at middle elevation. Concerning leaf size, microphylls and nanophylls were most common and occurred in all belts however, mainly in the sub-montane belt. This also applied to leptophylls, but they were of lower abundance (Table 3).

Ethnobotanical services: Sixteen (16) use categories for native plants were mentioned by the local population. These included medicine, affection, fodder, thatch, incense, hut and fencing; fuelwood, building materials, beverages, condiments, bio repellent, tools and handles, wild fruits, wild vegetables, poisons, utensils, dyes, weaving and brooms. The sub-alpine areas provided maximum services (13), followed by sub-montane (12), montane (9) and alpine (4) areas. All vegetation belts facilitated the local people with medicinal sources and local beverages. Wild edibles (fruits, vegetables), fuel wood, thatch, hut and fencing materials were offered in all belts, except in the alpine belt (Table 4).

Environmental impacts: The vegetation underwent various types of natural hazards and human impacts. Eight types of degradation processes were determined in the valley such as terraced agriculture, cutting and uprooting; drought, glacial abrasion, landslide, mining, grazing and floods. Summarizing all threats, which were ranked from 1 to 3, the severity is obvious. Grazing and land sliding were recorded as the most common and severe impacts, effecting all vegetation belts. Further significant events include flood, ice sliding, cutting and uprooting, as depicted in Table 5.

Table 3. Physiognomic characteristics of vegetation.

		Sub-montane	Montane	Sub- alpine	Alpine
Life cycle (Herbs)	Annuals	39	17	10	5
	Biennials	3	3	1	3
	Perennials	66	63	39	52
Habit	Shrub lets	9	1	1	1
	Shrubs	11	12	5	0
	Trees	1	2	1	0
Life form	Therophytes	36	17	10	5
	Hemicryptophytes	41	32	29	37
	Chamaephytes	32	25	7	11
	Geophytes	9	10	5	8
	Nanophanerophytes	10	12	5	0
	Megaphanerophytes	1	2	1	0
Leaf class	Microphyll	66	49	25	28
	Nanophyll	44	29	22	23
	Mesophyll	4	5	4	2
	Megaphyll	1	0	0	0
	Leptophyll	10	11	5	8
	Aphyllous	4	4	1	0

Table 4. Ecosystem services within the four vegetation belts.

Services	Sub-montane belt	Montane belt	Sub-alpine belt	Alpine belt
Medicine	1	1	1	1
Fodder	1	0	1	1
Thatching	1	1	1	0
Ritual	1	0	1	0
Hut and fencing	1	1	1	0
Fuel	1	1	1	0
Building materials	0	0	1	0
Drinks	1	1	1	1
Condiments	0	1	1	0
Bio repellent	1	0	0	0
Tool handles	0	0	1	0
Wild fruits	1	1	1	0
Wild vegetables	1	1	1	0
Poison	0	1	0	1
Dye	1	0	1	0
Broom	1	0	0	0
∑	**12**	**9**	**13**	**4**

1 = Provided, 0 = Not provided

Table 5. Natural and anthropogenic degradation of vegetation types.

	Terraced agriculture	Cutting & Uprooting	Drought	Glacial abrasion	Land sliding	Mining	Grazing	Flood	∑
Sub montane	3	3	3	0	1	0	2	2	**14**
Montane	2	3	2	2	3	2	2	3	**19**
Sub alpine	0	2	1	2	3	2	3	2	**15**
Alpine	0	0	0	2	2	2	3	2	**11**

0: No impact, 1: Low impact; 2: Medium impact; 3: Strong impact

Discussion

Tree line: Altitudinal gradients are the most powerful natural experiments allowing to test the response of biota to geophysical influences in terms of ecology and evolution (Körner, 2007). On mountain slopes, several gradients interfere in the species distribution and structure. However, altitude is considered as most influential factor in mountain ecosystem due to rapid fluctuation in climate at small distances (Körner, 2000; Lomolino, 2001). The zonation may be different at different mountains system and sometime may be different within same mountain (Hedberg, 1955). The Karakorum Mountains are characterized by great differences in altitude over a short distance. Therefore, the climate shows abrupt fluctuation with increase in elevation and shape distinct vegetation physiognomy at short distances. The vegetation limits are therefore sharp due to altitudinal climate change. Plants have to adapt very quickly, and have wide ecological amplitude, respectively. The recognized vegetation belts of the study area showed similar results to those obtained in the studies of Dickoré & Nüsser (2000) on Nanga Parbat, Western Himalayas, with some differences in plant composition within the vegetation belts. The colline belt was not separately discussed in our study, because of overlapping agricultural activities between the colline and the sub montane belts. Similar findings were reported from the Tormik valley (Karakorum) by Abbas *et al*., (2017b). Dickoré (1991) studied the vegetation of Karakorum and Kunlun mountains (China) based on same criteria and with the similar questions. However, there are considerable altitudinal differences found with different taxa. The lower belt there starts from 2100m but in the Shigar valley it starts from 2300m. The formation of vegetation belts is governed by altitude, moisture and exposition. The study area has two tree lines; the lower tree line mostly with riverine and cultivated species (Poplars, Willows, Cherry, Silver berry, Apricots, Almond, *Plantanus* etc.), while the upper tree line is formed by *Betula* and *Juniper*. The relict forests were mostly of Birch (*Betula utilis*) and rarely very small clumps of Juniper (*Juniperus excelsa*). The Birch timberline was mostly found on north facing, north-west, north east, and south west facing slopes in the study area. In the Himalayan ranges of Baltistan, distribution of Pines (*Pinus wallichiana*) reaches up to the Skoyo (Rondu valley) according to Webster & Nasir (1965) and Basho valley (Benjaminsen & Ali, 2004; Ali *et al.,* 2005). But the Karakorum of Baltistan seems to be completely deprived of conifers. Birch tree are well adapted and regarded as key species for forest development in the cold region. Climatic conditions, exposures, regeneration ability and physiological factors have been hypothesized as main factors influencing the tree line. Wardle (1971) assumed that the survival of tree taxa at high altitudes depends upon the ability of ripening of their shoot tissues. In the study area, apparently the tree limit is generally controlled by elevation together with exposure, temperature and soil moisture. It may also be related with the dispersal mechanism, germination, regeneration and survival strategies in the un-favorable conditions. Moreover, the human activities like mining and deforestation are also limiting factors.

Sometime *Betula utilis* and *Salix karelinii* Krummholz were found at the tree limit extending up to 3700m. However, in the vegetation zonation in the sub-alpine forest normally was limited to 3500m. The same pattern of distribution of Krummholz was also reported in the North facing slopes of Skardu Webster & Nasir (1965) found *Betula utilis* and *Sorbus tianshanica* at 4000-4100 m in upper Hushe valley. Uppermost Junipers grow between 3800 and 4000 at south-facing slopes in the Skardu-Khaplu area (Miehe *et al.,* 1996; Schickhoff *et al.,* 2000) but in the study area Juniper did not attain much elevation and the population has already tremendously diminished, with only sparse trees found on north facing dry slopes. In sub alpine areas moisture plays profound role in the distribution and limitation of vegetation. For instance, the clumps of *Betula utilis* and *Salix karnelii*, and dispersed trees of *Sorbus tianschanica* occurred in wetter sites at high elevation irrespective of aspect and exposure. Moreover, the *Betula* Krummholz and timberline are found at various elevations where moisture is available. The scatter trees of juniper can be seen on south west facing slopes only and no considerable clumps or population was found in contrast to Tibet Juniper forest where highest tree line reported (Miehe *et al.,* 2007). According to inhabitants (interviews) thick forest used to occur at different altitudes particularly on south facing and south west facing slopes and the severe deforestation caused their extreme decline. In the recent decades the main domestic fueling depends upon birch trees causing alteration in the forest stands like in Western Himalayan region of Pakistan (Schickhoff, 1995).

Vegetation, species richness: In addition to elevation and climate, the species richness and composition greatly changed in the different vegetation units e.g. foothills, sandy plains, sand dunes, riparian areas (sandy, rocky), dry steeps, sub-alpine dry and moist slopes, alpine screes, boulders, alpine table lands, etc. In such diffuse and patchy vegetation the most prominent associations at lower altitude were dry slopes, steppes and deserts vegetation. These slopes were distinctly heterogenous in physical settings, degree, exposure, temperature, edaphology and species composition. The slopes may be framed by geological upheavals, persistent drought and severe solar radiation. They are the prevailed vegetation unit in the entire study area and mostly inhabited by *Seriphidium brevifolium* and accompanied by different species depending upon exposition. On the north facing slopes, *Seriphidium brevifolium* was accompanied by *Ephedra intermedia, Piptatherum gracile, Koeleria micrantha, Haloxylon thomsonii, Scrophularia nudata, Salsola kali, Kochia prostrata, Rosa webbiana,* which are rather thermophilic species. On the less dry southern-facing slopes *Seriphidium brevifolia* was associated with *Ajania fruiticulosa, Ephedra gerardiana, Oxytropis microphylla, Stachys tibetica, Accantholimon lycopiodoides, Corydalis flabellate,* etc. With rising altitude the slopes become rather cool because of narrowing canyons, increase in water sheds, and considerable species substitution could be observed, for example species of *Ribes*, *Cotoneaster* and *Spiraea*, *Accantholimon* etc. Only four tree species were observed within the sub-alpine belt, Birch trees occurring in sites that are more favorable. All were deep rooting pioneer plants, which a high adaptation potential, and could survive also long lastinging snow cover. By contrast, *Juniperus excelsa* may prefer steep and hot slopes.

The sub-montane belt showed the highest species richness. This can be explained taking the agricultural and pastoral activities in the lower areas into account. Many companion species grew in crop fields, at field borders and in waste lands nearby villages. With increasing soil moisture due to result of complex water channeling and irrigation, further plants become established at lower elevations, e.g. species of *Rumex*, *Polygonum*, *Chenopodium*, *Malcomia*, and grasses. These findings contradict the study of Peer *et al*., (2007), conducted in the two villages of Basha Shigar (Arando & Beisil). In the study they focused on steppe communities and found species richness as highest in high alpine areas. They explained this with extreme overgrazing and soil degradation near villages. With decrease of grazing and trampling pressures, and improvement in climate, the species richness increased. Furthermore, the farmers of high village dwellers keep permanent domestic cattle (cows and several breeds) to improve their income with dairy products. Another reason concerns, the shepherds that have the option of different pasture for annual grazing and of course they prefer the pastures of nearby grazing lands, and animal resting places. Mostly, the alpine drifting boulders and screes experience low or no grazing pressures because the shepherds prefer the safest area for their herd, and cattle cannot reach the zone.

Life forms: Due to decrease in temperature and a shorter vegetation period at higher altitude, trees cannot survive. Instead, herbaceous plants, which are better adapted to the harsh climate, and Hhemicryptophytes and chamaepytes dominate. These are the indicators of cold climate and considered having better adaptations to confront the hostile condition (Danin & Orshan, 1990; Klimes, 2003). Especially in the inner alpine valleys of the Karakorum Range, drought and high radiation in summer at higher altitudes may hamper the spread of trees, shrubs and sub shrubs. Similar findings were also reported by Kreutzmann (2006). Karakorum climate is harsh at both extremes 1) Low areas are very dry and exhibit very low rainfall. Therefore, the plants of deserts, lower steppes, sand dunes, plains are thermo and petrophilous 2) In the sub-alpine and alpine habitats, drastic temperature fluctuation, cold wind, frost and snow prevail, therefore hygrophytes dominate, the hidden perennating buds and persistent aerial parts make the survival of the species possible. Moreover, the short life cycle is another choice for such hostile climate as considerable therophytes were also reported in the investigation. Klimešová *et al*., (2011) also explained the phenomenon from Indian Trans-Himalaya. The knowledge of leaf spectra may be useful in order to understand the physiological process of plants and their communities (Oosting, 1956). The prevailed micro and nanophllous species may be relate with the general aridity and dry soils. Drought is the common stress for plants of deserts and desert like ecosystems. In Karakorum, drought is persistent, and plants have to be adapted. They exhibit xeromorphic appearance, and this may work for their stress physiology for their survival.

Ethnobotanical services and environmental threats: Mountains often provide direct services to the local people and help them to survive in a hostile environment (Grêt-Regamey *et al.,* 2012). Despite the dryness in the inner alpine valleys, the vegetation provides various services for rural dwellers, particularly the sub-montane and sub-alpine belt. This could be explained with a higher variability of habit and habitats as the sub-montane and sub-alpine belts have a considerable number of species with herbaceous and lignified appearance. The mountain villagers have little options to buy goods like tools, utensils, dyes, brooms, blankets, etc. They are still immersed in local tradition and their income is too low to afford market commodities. Therefore, the utilization of plants is important. The rural population benefits from these services on the one hand, but it greatly alters the entire mountain ecosystem on the other hand. Deforestation (for fuel, house construction, tools, handles, etc.) and uprooting of plants may trigger flood, erosion and land sliding. The uprooting of *Seriphidium brevifolia* for fuel, *Artemisia scoparia* and *Echinops cornigerus* as fodder from lower steppes, deserts and slopes cause desertification in these already low vegetation covered areas. Furthermore, over-harvesting of herbaceous plants for medicines, dyes, beverages and other rituals provoke depletion of these vulnerable species, which are endangered and pushed towards the red list. Among the tree species, Birch and Juniper are also under severe pressure of cutting for domestic logging and fueling. The rural people may soon suffer from wood shortage in blood freezing winters if the high rate fuel wood extraction is not halted. Most of the population of Baltistan relies on woods trading from the lower areas of the Himalayan region. The current rapid population growth in these mountain regions demands more food, shelter and other daily necessities. Therefore, animal husbandry, mining, deforestation and over harvesting contribute to income generation for the entire population. However, due to the regular overuse of ecological resources may increase hazards and may lead to migration in the near future. Such a scenario must be stopped by suitable management measures to avoid the degradation of alpine habitats and species, mainly which are lignified (Nüsser & Clemens, 1996; Breckle & Wucherer, 2006). The degree of trampling and grazing vary depending upon the ground vegetation cover. The mountain slopes with loamy soil and scarce vegetation are more affected then the sub alpine grassy slopes. Daily basis movement of large herds of goat, sheep, yak and cow converted the ways very dusty due to gully erosion. The easily approachable subalpine slopes are badly affected by Yak and Bzo (sterile hybrid of cow and Yak) chaffing. In such areas only spiny, bulb and repellant species manage to escape from grazing. *Seriphidium brevifolium, Anaphalis virgate, Astragalus psilocentrose, Pulicaria* spp., *Accanthlimon* spp., *Ephedra* spp., *Daphne mucronata* are grazing resistant species.

Conclusions

The valley of Shigar represents distinct vegetation zonation, varied physiognomy and ethnobotanical services. The flora and vegetation have suffered many anthropo-natural threats. The utilization of plant-based resources is often mismanaged and unsustainable. The environmental impacts and unsustainable utilization of resources can push the inhabitants towards increasingly difficult conditions. Unintentionally, the local inhabitants are causing irreparable loss for themselves. The loss of plant species and decline in their population would directly cause the resource decline.

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