Pak. J. Bot., 53(2): 665-672, 2021. DOI: http://dx.doi.org/10.30848/PJB2021-2(45)

DIVERSITY AND DISTRIBUTION PATTERN OF ALPINE VEGETATION COMMUNITIES FROM RATTI GALI LAKE AND ITS ADJACENT AREAS, KASHMIR HIMALAYAS, PAKISTAN

MUHAMMAD SHAKEEL AWAN, MUHAMMAD EJAZ UL ISLAM DAR, HAMAYUN SHAHEEN*, RAJA WAQAR AHMAD KHAN, SHAMSHAD AZIZ AND TARIQ HABIB

Department of Botany, University of Azad Jammu and Kashmir, Muzaffarabad, Pakistan.
**Corresponding author's email: shaheenecologist@gmail.com*

Abstract

Ratti Gali Lake area is an alpine area in district Neelum AJK located at altitudes > 3800 m and is an important repository of western Himalayan alpine floral taxa attributed to its unique geography and typical alpine climate. Current study was designed to investigate the floristic composition, community structure and distribution pattern of the alpine vegetation communities in the Ratti Gali area. Extensive vegetation sampling was carried out during June-August 2019 by quadrate based systematic sampling covering all the alpine microhabitats. Results revealed a total of 99 plant species recorded from the area belonging 36 families and 77 genera with Compositae as the most dominant family (16 species) followed by Rosaceae and Polygonaceae with 9 and 6 species respectively. Life form analysis revealed Hemicryptophytes as the dominant life form with 47 species (47.4%) followed by Therophytes whereas Leaf Size analysis showed the dominance of Microphylls with 35 species (35.4%) followed by Leptophylls. *Bistorta amplexicaule* was the most dominant species having an importance value of 29.0 followed by *Geranium pratense* and *Sibbaldia cunneata*. Study sites showed an average species count of 24.7; average value of Simpson's diversity as 0.91; Shannon's diversity as 2.88; species richness as 1.41; Evenness as 0.77 whereas average maturity index value as 33.07. Our findings revealed that the alpine vegetation of the area is seriously threatened due to immense anthropogenic pressure attributed to huge tourist influx, heavy over grazing, medicinal plant exploitation and soil erosion. We recommend immediate implementation of conservation measures in this fragile alpine habitat to protect the precious alpine floral wealth of the region.

Key words: Alpine; Conservation; Diversity; Floristics; Kashmir.

Introduction

Alpine rangelands in the Western Himalayas represent unique and diverse ecosystems on account of their rich floristic diversity and diverse community structure due to a delicately balanced interplay of biotic and abiotic settings in those fragile highlands (Nautiyal *et al.,* 1997). These area lying in the Western Himalaya biotic province are characterized by extreme type of Eastern Irano-Turanian climate giving rise to unique alpine vegetation communities (Rawat & Adhikari, 2005b). The Western Himalayan alpine region is much more widespread geographically and harbors relatively much higher levels of vascular plant diversity (1800-1900 Species) as compared to the Eastern Himalayan region with vascular 1200 species (Mishra & Rawat, 1998).

This floristic diversity in the alpine zone having altitude above 3500 m is mainly comprised of herbaceous taxa adopted to grow and thrive at those extreme habitats (Rawat, 2007). The distribution of plant species and community composition in alpine rangelands is determined by various natural physiognomic factors such as elevation, slope, aspect, soil moisture and soil chemistry (Kharkwal *et al.,* 2015). Anthropogenic factors, especially grazing by migratory livestock during summer-monsoon period since centuries is also known to have a major influence on the species diversity, richness and composition of plant communities (Sundriyal & Joshi, 1990).

Alpine vegetation communities hold critical scientific significance due to their vital role in ecosystem functioning and provision of dynamic ecosystem services (Dvorsky *et al.,* 2011). Alpine rangelands are also among the most susceptible habitats to the impacts of global warming (Grabherr *et al.*, 2010). The local alpines in the AJK region are also the main source of fodder for over 0.6 million grazing animals which also exert a continuous grazing pressure on the floral diversity (Dar & Khurroo, 2020). Floristic diversity in the alpine ecosystems of Kashmir has not been given due attention in the past owing to their remoteness, inaccessibility and military actions being located at line of Control between Pakistan and India (Peer *et al.,* 2007). It empirical to execute detailed investigations on the alpine floral wealth of the Kashmir region, not only focusing on the floristics, but also considering the impacts of geographic and climatic factors on species distribution (Rawat & Adhikari, 2005a); and evaluating the threats posed by the anthropogenic disturbances to the local flora in the region (Ara & Naqshi, 2003).

Current study was designed to investigate the floristic composition and community structure of alpine vegetation communities in the Ratti Gali Area in AJK. The specific objectives also include to investigate the variations in the floral diversity correlated with environmental variables as well as anthropogenic disturbances in the region.

Material and Methods

Study area: The study area Ratti Gali is located in the Neelum district in the state of Azad Jammu and Kashmir spread between latitudes 034 49.55 North and Longitudes 074 02.48 East. The investigated sites were located in an altitudinal range of 3500 to 4200 m above sea level (Fig. 1). The study area is characterized by extreme cold alpine climate and remains snow covered from November to March with temperatures below freezing (Shaheen *et al*., 2019). The growing season comprises of a short summer starting from June to August with an average day time temperatures around $10C^0$ whereas nights are near freezing. Area receives about 1100 mm precipitation annually, major part as winter snow (Pak-Met., 2018).

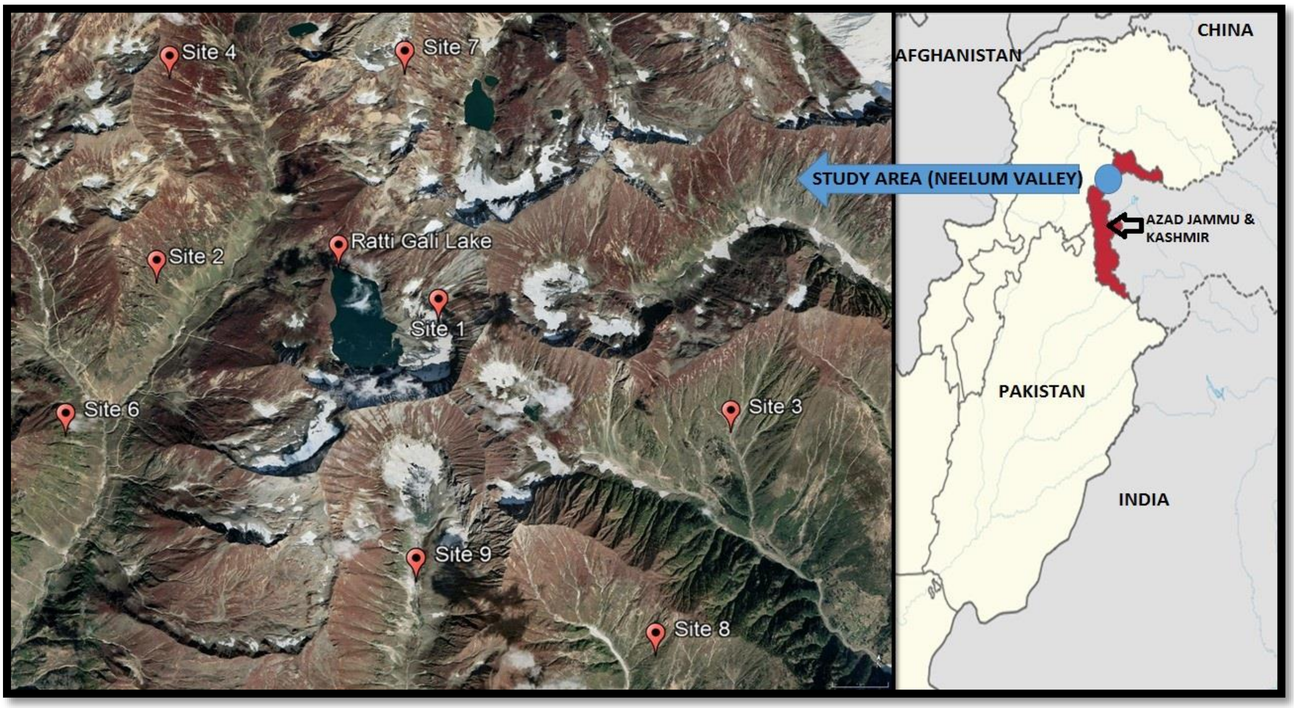

Fig. 1. Map of the study area and location of the sampling sites.

Table 1. Geographical attributes of investigated sampling sites in the Ratti Gali alpine zone.

Sr. No.	Community	Altitude (m)	Latitude (N)	Longitude (E)	Grazing class	Erosion class	Aspect
1.	*Bistorta-Geranium-Cotoneaster*	3710	34^{0}49.641	74^{0}.03.451	2	2	North
2.	*Bistorta-Swertia-Geranium*	3825	34^{0}49.555	74^{0}.03.398	1	1	North
3.	*Swertia– Sibbaldia-Primula*	3700	34^{0}49.879	74^{0}.03.474	1	2	North
4.	*Bistorta-Geranium-Sibbaldia*	3840	34^{0}50.303	74^{0}.04.365	3	2	North
5.	*Swertia-Primula-Rhodiola*	3960	34^{0}78.889	74^{0}.04.565	3	3	South
6.	*Swertia-Primula-Jurinea*	3700	34^{0}50.304	74^{0}.02.487	2	3	South
7.	*Astragalis-Geranium-Rosa*	3730	34^{0}50.303	74^{0}.02.487	2	1	South
8.	*Podophyllum-Taraxacum-Aconitum*	4100	34^{0}60.203	74^{0}.05.237	2	3	North
9.	*Taraxacum-Pteris-Sibbaldia*	4000	34^{0}40.603	74^{0}.60.297	1	1	North

Sampling methodology: A total of 9 sampling sites were taken in the Ratti Gali Lake and surrounding alpine plateau with respect to altitude, topography, hydrology and slope to get an accurate and detailed information of the local alpine floristics (Table 1). Field expeditions were carried out in July-August 2018-19. The geographic characters of the sampling sites including altitude, latitude, longitude, slope steepness and aspect were recorded at site using GPS (Model MAP 64 Hand held). A total of 25 randomized 1 x 1 m Quadrates were taken at each study sites to record the primary vegetation data including Density, frequency and Cover for all the alpine taxa following standard protocol (Cox & Lewis, 1976; Daubenmire, 1959).

The collected plant specimen were brought to the herbarium University of AJK for identification with the help of available literature and floras (Ali & Qaisar, 2007; Nasir *et al*., 1972). The intensity of grazing and soil erosion were also recorded where the sites were classified into class 1, 2 and 3 depending upon the disturbance intensity respectively. The biological spectrum of the sampled flora including Life form and leaf size classification was carried out following Raunkiaer (1934).

Data analysis: The importance values were calculated for each plant species by summing up the relative values of frequency, density and cover as $\mathrm{I.V.I} = \{\mathrm{R.F_i} + \mathrm{R.D_i} + \mathrm{R.C_i}\}$ (Ahmed & Shoukat, 2012). The index of Diversity was calculated after Simpson's (1948) as follows:

$$D=1-\sum (n (n-1))/ (N (N-1))$$

where D = Diversity index; n = Number of individual of a species; and N = Number of individual of all the species. Shannon Wiener index of diversity was calculated as $H' = \sum_{i=1}^{s} P_i \, l_n P_i$ following Shannon (1949). Species Richness was calculated as d=S/(√N) following Minhinick (1964) where S = Total no of species and N = Total no of individuals of all the species. Community Maturity was calculated after Pichi-Sermolli (1948) as Degree of maturity = Total Frequency of all the species in community/ No of species in the community.

Mutivariate Ordination Analysis of the species and sampling sites data set was carried out by using PAST software Version 4.01 for executing Principal Component Analysis (PCA) and Generalized Linear Regression Model.

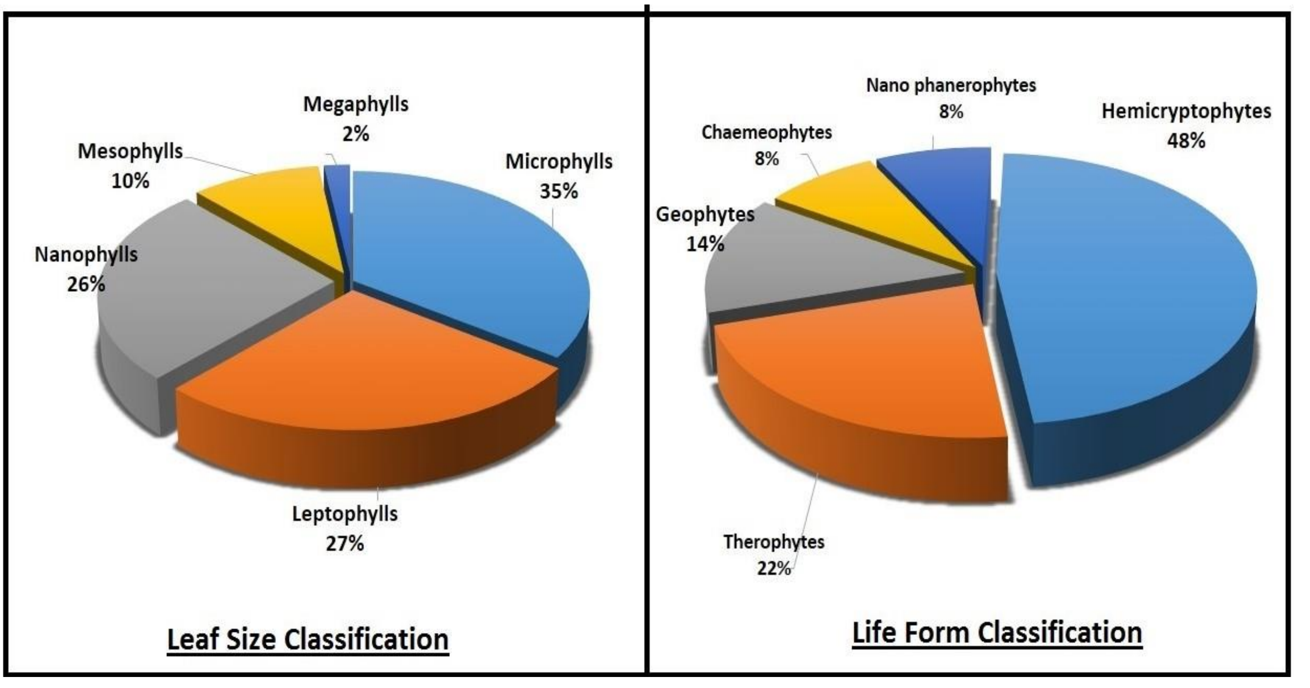

Fig. 2. Biological spectrum analysis of the investigated alpine flora.

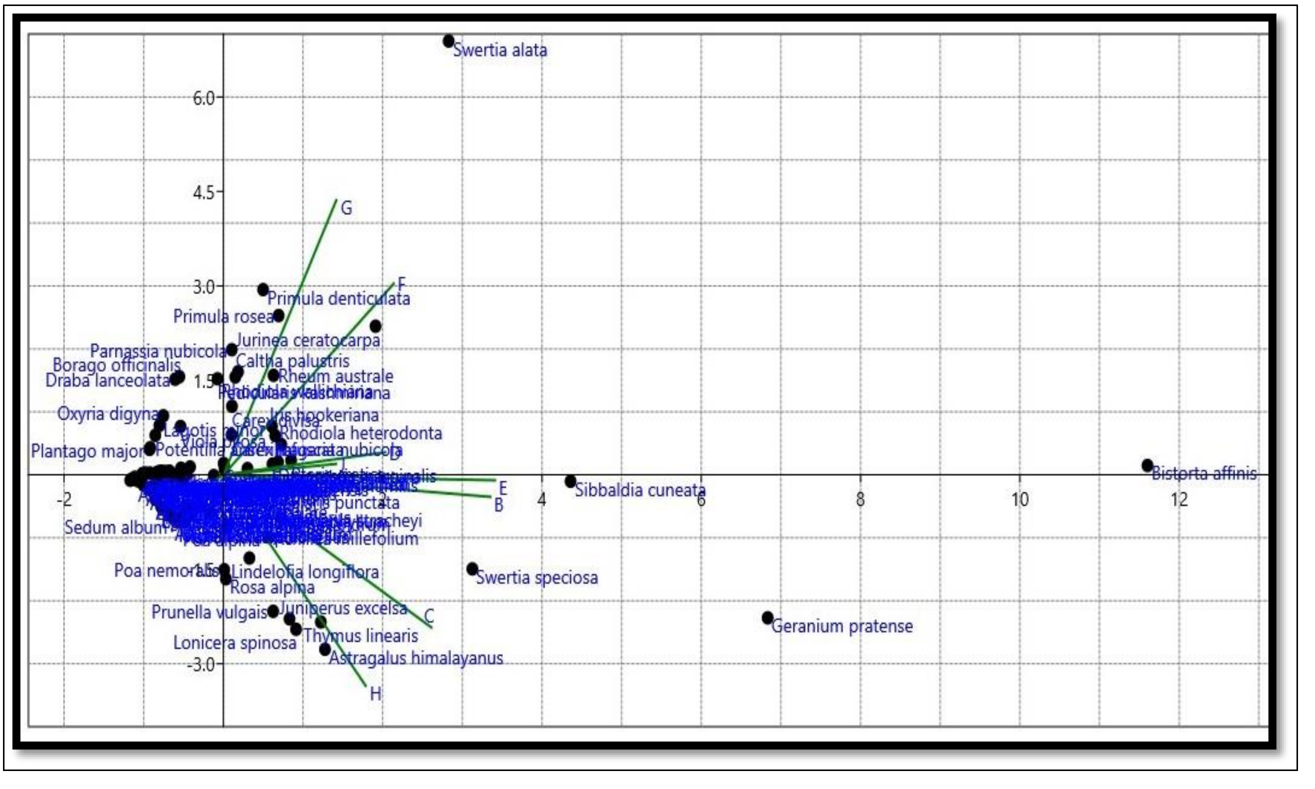

Fig. 3. Principal Component Analysis biplot of the species data matrix.

Results

Floristic composition: Results revealed that the alpine flora of the study area was comprised of 99 species, representing 77 genera and 36 families. Asteraceae was the most dominant family in terms of number of species having 14 species followed by Rosaceae (9 species), Polygonaceae and Boraginaceae (6 species each). The Codominant families included Ranunculaceae, Lamiaceae and Gentianaceae with 4 species each, followed by Primulacceae, Pteridaceae and Caprifoliaceae (3 species each). *Bistorta affinis* was the most dominant plant species having an average IVI value of 29 followed by *Geranium pratense* (18.4), *Sibbaldia cuneata* (13.61), *Swertia alata* (12.43) and *Swertia speciosa* (9.31). The Codominant taxa included *Jurinea ceratocarpa*, *Pteris cretica*, *Fragaria nubicola*, *Primula rosea* and *Rheum australe* (Table 2).

Biological spectrum of the alpine flora: Life form Analysis revealed Hemicryptophytes as the most dominant life form with 47 species (47.7%) followed by Therophytes with 22 species (22.2%) and Geophytes with 14 species (14.4%). Chaemeophytes and Phanerophytes were represented by 08 species each (8.01% each). The Leaf size classification revealed Microphylls as the leading class having 35 representative species (35.35%) followed by Leptophylls with 27 species (27.27%) and Nanophylls with 26 species (26.26%). Mesophylls had 10 species (10.10%) whereas Megaphylls had 02 members (2.02%) (Fig. 2).

Diversity and its components: The study area showed an average species count of 24.78 per site with a maximum of 34 at site 9 whereas a lowest of 16 at site 6. Average value of Simpson's diversity index was found to be 0.92 with very little variations among the investigated plant communities. Whereas Shannon's diversity index value averaged as 2.88 with a maximum value of 3.16 at site 2 whereas a minimum of 2.56 at Site 4. Average value of Evenness was 0.77 whereas equitability as 0.91. Species richness values showed significant variations having an average of 1.41 in 0.88-1.61 range (Table 3).

Principal component analysis: Principal component Analysis was applied on the species data set to identify significant correlations among the taxa with specific sites and elaborate the species distribution and abundance pattern of the plant species. The PCA explained more than 90% variance in the dataset indicating the statistical strength of the test with first 4 axis contributing more than 71% share. PCA biplot significantly explained the distribution of dominant plant taxa and identified *Bistorta affinis, Geranium pretense* and *Sibbaldia cuneata* as the keystone plant species of the investigated alpine zone attributes to their maximum abundance across all the study sites. These dominant plant species were separated from the rest of the bulk along x-axis. PCA also separated *Swertia alata* on Y-axis closely correlated with sites 6 & 7 whereas *Astragallus himalayanus, Swertia speciosa* and *Thymus linnearis* showed strong affinity with sites 3 & 8. The rest of the taxa were clustered at the center showing their generalized niches (Fig. 3).

Discussion

Current study has significantly explained the patterns of alpine plant diversity and ecological attributes of the plant communities correlated with several geographic and anthropogenic variables. The study area has showed relatively lower average species diversity of 0.9-2.88 as compared to the results of similar investigations in different Himalayan regions including 3.13 in the alpine pasture of Kashmir (Shaheen *et al*., 2011), 2.5–3.10 in the trans-Himalayan alpines of Nepal (Panthi *et al*., 2007), 1.53–2.88 in the western Himalayas (Guar & Joshi 2006), and 2.39–4.63 in the Gharwal Himalayas (Nautiyal & Guar, 1999). The study sites were also characterized with a low species count per site averaging 24.78. The lower values of species diversity in the region are attributed to the anthropogenic disturbance stimuli in the region as the area is subjected to an intense grazing pressure due to huge livestock herds during the summer season (Khan *et al.*, 2019).

Communities showed an overall dominance of few alpine herbs including *Bistorta affinis, Geranium pratense, Sibbaldia cuneata, Swertia alata, Swertia speciosa, Jurinea ceratocarpa, Pteris cretica, Fragaria nubicola, Primula rosea* and *Rheum australe.* This reflects the best fitted niches of these alpine taxa having generalized and broad ecological amplitude enabling them to dominate and establish their abundance in the communities (Ge *et al*., 2005). The analysis of biological spectrum revealed the dominance of Hemicryptophytic and Therophytic floral taxa in the region along with Microphyllous and Leptophyllous groups. These taxa are best adapted to thrive in the alpine regions because of their morphology, phenology, robust and efficient physiological makeup (Shaheen *et al*., 2011; Danin & Orshan, 1990.).

The fragile alpine plant communities limited due to harsh climate and a very short growing season are further subjected to regular disturbances which leads to the lower levels of diversity and disturbed community structure (Huang *et al*., 1997). This is also evident from a low maturity index value averaging 32.26 indicating a continuous disturbance pressure at the study sites. Lower value of maturity are due to prevailing pressures including over grazing, trampling, camping, and environmental constrains like soil erosion, chilling temperature, low availability of water and short growing season which do not allow the alpine plant communities to attain the climax stage through developmental processes (Bhattarai *et al.*, 2004).

Land-use changes and associated agro-pastoral practices comprises an important form of disturbance in many alpine plateaus (Vittoz *et al*., 2008). A continuous grazing pressure synchronized with soil erosion was recorded across the study sites reflecting the intensity of disturbance. Within the investigated area, the dispersed camping during the summer season, because of heavy tourist influx, also adversely affects the vegetation not only due to installation of tents but also due to spread of non-biodegradable waste material including the Polyethene bags, plastics bottles and rappers. These waste materials also change the soil texture and structure along with having deteriorating impacts on vegetation (William, 2005). Our study has also identified about 12 plant species having very low importance value (<0.5) showing their rarity in the region (Table 2). These rare alpine species are very vulnerable and threatened by the prevailing disturbances in the region and need immediate conservation efforts (Panthi *et al*., 2007).

Table 2. Floristic inventory, biological spectrum and average importance values of the alpine species.

No.	Species name	Family	Life form	Leaf spectra	Average I.V.I
1.	*Achillea millefolium* L.	Asteraceae	H	L	4.12
2.	*Aconitum heterophyllum* Wall. ex Royle	Ranunculaceae	G	Mi	4.58
3.	*Adiantum venustum D.Don*	Pteridaceae	G	Me	0.33
4.	*Ajuga integrifolia* Buch.-Ham. *Syn. Ajuga bractiosa* wall ex Benth	Lamiaceae	H	Mi	0.19
5.	*Alchimilla cashmiriana* var. Buser	Rosaceae	G	N	0.20
6.	*Allium fedtchenkoanum* Regel	Amaryllidaceae	Th	N	1.01
7.	*Anagallis arvensis* L.	Primulaceae	Th	L	1.25
8.	*Anaphalis nepalensis* (Spreng.) Hand.-Mazz.	Asteraceae	Th	L	1.97
9.	*Anaphalis virgata* Thomson	Asteraceae	CH	L	1.48
10.	*Angelica glauca* Edgew.	Apiaceae	H	Mg	2.25
11.	*Aquilegia fragrans* Camb.	Ranunculaceae	H	Mi	0.55
12.	*Arnebia benthamii* (Wall. ex G.Don) I.M.Johnst.	Boraginaceae	G	Mi	2.92
13.	*Artemisia annua* L.	Asteraceae	Th	N	0.47
14.	*Asplenium bulbiferum* G. Forst.	Aspleniaceae	G	Me	0.83
15.	*Aster alpinus* L.	Asteraceae	H	Mi	0.93
16.	*Aster himalaicus* C.B.Clarke	Asteraceae	H	Mi	1.93
17.	*Astragalus himalayanus* Klotzsch	Leguminosae	H	L	5.46
18.	*Astragalus melanostachys* Bunge	Leguminosae	H	Me	1.53
19.	*Oxyria digyna* (L.) Hill	Polygonaceae	Th	Mi	1.05
20.	*Berberis aitchisonii* Ahrendt	Berberidaceae	NP	L	0.68
21.	*Bergenia stracheyi* (Hook.f. & Thomson) Engl	Saxifragaceae	H	Me	3.49
22.	*Bistorta affinis* D.Don.	Polygonaceae	CH	Mi	**29.00**
23.	*Borago officinalis* L.	Boraginaceae	Th	Mi	2.10
24.	*Brassica rapa* L.	Brassicaceae	Th	Mi	1.48
25.	*Bupleurum thomsonii* C.B.Clarke	Apicaceae	H	N	0.45
26.	*Caltha palustris* var. *alba* (Cambess.) Hook.f. & Thomson	Ranunculaceae	H	Me	3.59
27.	*Carex infuscata* Nees	Cyperaceae	H	L	3.18
28.	*Carex divisa* Huds.	Cyperaceae	H	L	5.19
29.	*Chenopodium album* L.	Amaranthaceae	Th	Mi	1.33
30.	*Chasmanthium latifolium* (Michx.) H.O.Yates	Poaceae	G	L	0.90
31.	*Achillea tanasitum*	Asteraceae	Th	L	1.19
32.	*Cichorium intybus* L.	Asteraceae	Th	Mi	3.23
33.	*Cotoneaster humilis* Dunn	Rosaceae	NP	Mi	3.19
34.	*Cynoglossum lanceolatum Forssk*	Boraginaceae	Th	Me	3.10
35.	*Cyperus rotundus* L.	Cyperaceae	H	L	1.52
36.	*Draba lanceolata* Royle.	Brassicaceae	H	L	2.89
37.	*Ephedra gerardiana* Wall. ex Stapf	ENPdraceae	NP	L	0.52
38.	*Epilobium latifolium* L.	Onagraceae	H	Mi	0.69
39.	*Epilobium wallichianum Hausskn*	Onagraceae	H	Mi	0.34
40.	*Dryopteris marginalis* (L.) A. Gray	Dryopteridaceae	G	Me	3.94
41.	*Pteris cretica* L	Pteridaceae	G	Me	7.09
42.	*Fragaria nubicola* L.	Rosaceae	H	Mi	6.12
43.	*Galium boreale* L.	Rubiaceae	H	L	0.74
44.	*Gentiana alpina* Vill.	Gentianaceae	Th	N	0.19
45.	*Gentiana membranulifera* T.N.Ho *Syn. Gentionoides eumergianata* Omer	Gentianaceae	Th	Mi	0.79
46.	*Geranium pratense* L**.**	Geraniaceae	H	Mi	**18.40**
47.	*Hackelia uncinata* (Benth.) C.E.C. Fisch.	Boraginaceae	G	N	1.40
48.	*Impatiens thomsonii* Hook. f.	Balsaminaceae	Th	Mi	0.57
49.	*Iris hookeriana* Foster	Irideaceae	G	Mi	4.01
50.	*Juniperus excelsa* M.Bieb.	Cupressaceae	NP	L	3.77

Table 2. (Cont'd.).

No.	Species name	Family	Life form	Leaf spectra	Average I.V.I
51.	*Juniperus squamata* Buch.-Ham. ex D.Don	Cupressaceae	NP	L	0.95
52.	*Jurinea ceratocarpa* (Dcne.) Benth. & Hook.f	Asteraceae	Th	Mi	8.29
53.	*Lagotis minor* (Willd.) Standl. *Syn. Lagotis cashmiriana* (Royl) Rupr.	Plantaginaceae	G	L	1.26
54.	*Morina longifolia* Wall. ex DC.	Caprifoliaceae	H	Me	0.79
55.	*Lindelofia longiflora* (Benth.) Baill.	Boraginaceae	H	Mi	2.95
56.	*Lonicera hispida* Pall. ex Schult.	Caprifoliaceae	Ph	N	0.40
57.	*Lonicera spinosa* (Decne.) Jacq. ex Walp.	Caprifoliaceae	Ph	Mi	3.98
58.	*Nepeta connata* Royle ex Benth.	Lamiaceae	H	N	1.09
59.	*Parnassia nubicola* Wall. ex Royle	Celastraceae	H	Mi	3.43
60.	*Pedicularis kashmiriana* Pennell	Orobanchaceae	H	L	3.11
61.	*Pedicularis punctata* Decne.	Orobanchaceae	H	L	3.42
62.	*Phleum alpinum* L.	Poaceae	H	N	2.67
63.	*Phleum pratense* L	Poaceae	H	L	0.43
64.	*Plantago lanceolata* L.	Plantaginaceae	Th	Mi	0.16
65.	*Plantago major* L.	Plantaginaceae	Th	Mi	0.53
66.	*Poa alpina* L.	Poaceae	H	L	3.07
67.	*Poa nemoralis* L.	Poaceae	H	L	2.53
68.	*Sinopodophyllum hexandrum* (Royle) T.S.Ying	Berberidaceae	Ge	Mg	4.75
69.	*Persicaria alpina* (All.) H.Gross	Polygonaceae	H	N	0.90
70.	*Polygonum aviculare* L.	Polygonaceae	H	N	0.74
71.	*Potentilla atrosanguinea* G.Lodd. ex D.Don	Rosaceae	H	Mi	2.41
72.	*Potentilla anserina* L.	Rosaceae	H	N	0.84
73.	*Primula denticulata* Sm.	Primulaceae	H	L	4.84
74.	*Primula rosea* Royle	Primulaceae	H	L	5.54
75.	*Prunella vulgais* L.	Lamiaceae	H	L	3.62
76.	*Ranunculus pulchellus* C.A.Mey	Ranunculaceae	H	Mi	1.62
77.	*Rheum australe* D. Don	Polygonaceae	CH	N	5.49
78.	*Rhodiola heterodonta* (Hook. f. & Thomson) Boriss.	Crassulaceae	G	L	4.21
79.	*Rhodiola wallichiana* (Hook.) S.H. Fu	Crassulaceae	G	L	3.18
80.	*Rosa alpina*	Rosaceae	CH	N	2.58
81.	*Rosa moschata* Herrm.	Rosaceae	CH	N	0.55
82.	*Rosa macrophylla* Lindl.	Rosaceae	CH	N	1.17
83.	*Rumex acetosa* L.	Polygonaceae	H	N	0.72
84.	*Rumex nepalensis* Spreng.	Polygonaceae	CH	N	2.88
85.	*Salix caesia* Vill.	Salicaceae	Ph	Mi	3.69
86.	*Saussurea fistulosa* J.Anthony	Asteraceae	H	Mi	0.80
87.	*Saussurea costus* (Falc.) Lipsch.	Asteraceae	H	N	0.25
88.	*Sedum album* L.	Crassulaceae	H	N	3.11
89.	*Senecio graciliflorus* (Wall.) DC.	Asteraceae	H	Mi	2.12
90.	*Sibbaldia cuneata* Schouw ex Kunze	Rosaceae	H	Mi	**13.61**
91.	*Silene gonosperma* (Rupr.) Bocquet	Caryophylaceae	Th	N	4.01
92.	*Stellaria media* (L.) Vill.	Caryophyllaceae	Th	N	0.40
93.	*Swertia alata* C.B. Clarke	Gentianaceae	CH	N	12.43
94.	*Swertia speciosa* Wall.	Gentianaceae	H	N	9.31
95.	*Taraxacum campylodes* G.E.Haglund	Asteraceae	Th	Mi	3.78
96.	*Taraxacum tibetanum* Hand.-Mazz.	Asteraceae	H	Mi	4.45
97.	*Thymus linearis* Benth.	Lamiaceae	H	N	4.51
98.	*Verbascum thapsus* L.	Scrophulariaceae	Th	Me	1.58
99.	*Viola pilosa* Blume	Violaceae	Th	Mi	2.74

Table 3. Analytical Phytosociological attributes of the investigated vegetation communities.

Serial No.	No. of species	Simpson's index	Shannon's index	Species evenness	Species richness	Community maturity index
Site 1	26	0.9	2.74	0.6	1.5	27.3
Site 2	32	0.95	3.16	0.76	1.8	33.12
Site 3	27	0.94	3.05	0.78	1.56	32.22
Site 4	19	0.89	2.56	0.68	1.1	33.91
Site 5	16	0.92	2.62	0.92	0.88	36.87
Site 6	21	0.91	2.69	0.78	1.13	30.1
Site 7	28	0.95	3.15	0.86	1.61	45.07
Site 8	20	0.94	2.96	0.92	1.18	28.5
Site 9	34	0.92	3	0.61	1.95	23.33
Average	**24.78**	**0.92**	**2.88**	**0.77**	**1.41**	**32.26**

Conclusion

Ratti Gali alpine zone is an important repository of floral wealth of the western Himalayan mountain region. The area has diverse vegetation structure distributed in vegetation communities correlated with the geographic variables and microclimates of the region. Study area is subjected to anthropogenic pressures including tourist flux, over grazing and soil erosion which is threatening the patterns of species diversity in the region. We recommend immediate conservation measures in the area to protect the precious flora and ensure the sustainability of the local alpine ecosystem.

Acknowledgment

The authors acknowledge the support of Higher Education Commission Pakistan for providing the finances for current study under the research Project NRPU-6907.

References

Ahmed, M. and S.S. Shaukat. 2012. A textbook of vegetation Ecology: Abrar Sons.

Ali, S.I. and M. Qaiser. 1993-2007. *Flora of Pakistan*. (Eds.). No. 191-215. Islamabad, Karachi.

Ara, S. and A. Naqshi. 2003. Crop diversity in Gurais Valley (Kashmir). *Geobio*., 30(1): 85-86.

Bhattarai, K.R., O.R. Vetaas and J.A. Grytnes. 2004. A relationship between plant species richness and biomass in arid sub-alpine grassland of the central Himalayas, Nepal. *Fol. Geobot*., 39: 57-71.

Cox, T.F. and T. Lewis. 1976. A conditioned distance ratio method for analyzing spatial patterns. *Biomet*., 63: 483-491.

Danin, A. and G. Orshan. 1990. The distribution of Raunkiaer life forms in Israel in relation to the environment. *J. Veg. Sci*., 1(1): 41-48.

Dar, G.H. and A.A. Khuroo (Eds.). 2020. *Biodiversity of the Himalaya: Jammu and Kashmir State* (Vol. 18). Springer Nature.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. N.W. *Sci*., 33: 43-66.

Dvorský, M., J. Doležal, F. De Bello, J. Klimešová and L. Klimeš. 2011. Vegetation types of East Ladakh: species and growth form composition along main environmental gradients. *App. Veg. Sci*., 14(1): 132-147.

Ge, X.J., L.B. Zhang, Y.M. Yuan, G. Hao and T.Y. Chiang. 2005. Strong genetic differentiation of the East-Himalayan *Megacodon stylophorus* (Gentianaceae) detected by inter-simple sequence repeats (ISSR). *Biodiv. Cons*., 14: 849–861.

Grabherr, G., M. Gottfried and H. Pauli. 2010. Climate change impacts in Alpine environments. *Geogr. Com*., 4: 1133-1153.

Guar, R.S. and B.D. Joshi. 2006. Some medicinal flora in the riparian zone of river Ganga at Saptrishi, Haridwar, Uttaranchal. *Himalayan J. Env. Zoo*., 20(2): 237-241.

Huang, J.H., X.M. Gao, K.P. Ma and L.Z. Chen. 1997. A comparative study on species diversity in zonal forest communities. *Acta Ecol. Sinica*, 17: 611-618.

Khan, R.W.A., H. Shaheen, A. Mehmood and S.N. Awan. 2019. Grazing intensity impacts on soil carbon stocks of Western Himalayan Alpine paddocks. *Carbon Manag*., 10(6): 533-540.

Kharkwal, G., P. Mehrotra and Y.S. Rawat. 2015. Phytodiversity and growth form in relation to altitudinal gradient in the Central Himalayan (Kumaun) region of India. *Curr. Sci. Bangalore*, 89(5): 873.

Menhinick, E.F. 1964. A Comparison of some species diversity indices applied to samples of field insects. *Ecology*, 45: 859-861.

Mishra, C. and G. Rawat. 1998. Livestock grazing and biodiversity conservation: comments on Saberwal. *Cons. Biol*., 12(3): 712-714.

Nasir, E., S.I. Ali and R.R. Stewart. 1972. Flora of West Pakistan: an annotated catalogue of the vascular plants of West Pakistan and Kashmir. Fakhri Press Pakistan

Nautiyal, D.C. and R.D. Gaur. 1999. Structural attributes and productivity potential of an alpine pasture of Garhwal Himalaya. *J. Ind. Bot. Soc*., 78 (3-4): 321-329.

Nautiyal, M.C., B.P. Nautiyal and V. Prakash. 1997. Phenology and growth form distribution in an alpine pasture at Tungnath, Garhwal, Himalaya. *Mon. Res. Dev*., 21(2): 168-174.

Pak-Met. 2018. The Normals of the climatic data of Azad Jammu & Kashmir. Pakistan Meteorological Department, Islamabad.

Panthi, M.P., R.P. Chaudhary and O.R. Vetaas. 2007. Plant species richness and composition in a trans-Himalayan inner valley of Manang district, central Nepal. *Himalayan J. Sci.*, 4(6): 57-64.

Peer, T., J.P. Gruber, A. Millingard and F. Hussain. 2007. Phytosociology, structure and diversity of the steppe vegetation in the mountains of Northern Pakistan. *Phytocoenologia*, 37(1): 1-65.

Pichi-Sermolli, R.E. 1948. An index for establishing the degree of maturity in plant communities. *J. Ecol*., 36(1): 85-90.

Raunkiær, C. 1934. The Life Forms of Plants and Statistical Plant Geography, being the collected papers of C. Raunkiær. Oxford University Press, Oxford. Reprinted 1978 (Ed.): Frank, N. Egerton, Ayer Co Pub., in the History of Ecology Series, ISBN 0-405-10418-9.

Rawat, G.S. 2007. Pastoral Practices, Wild Mammals and Conservation Status of Alpine Meadows in Western Himalaya. *J. Bombay Nat. Hist. Soc*., 104(1): 5-11.

Rawat, G.S. and B.S. Adhikari. 2005a. Millenia of grazing history in eastern Ladakh, India, reflected in rangeland vegetation. *Land use Chng*. *Mount. Biodiv*., 199-210.

Rawat, S.G. and B.S. Adhikari. 2005b. Floristics and Distribution of Plant Communities across Moisture and Topographic Gradients in TsoKar Basin, Changthang Plateau, Eastern Ladakh. *Arctic, Ant. & Alp. Res*., 37(4): 539-544.

Shaheen, H., M. Ibrahim and Z. Ullah. 2019. Spatial patterns and diversity of the alpine flora of Deosai plateau, western Himalayas. *Pak. J. Bot*., 51(1): 205-212.

Shaheen, H., S.M. Khan, D.M. Harper, Z. Ullah and R.A. Qureshi. 2011. Species Diversity, Community structure, and distribution pattern in Western Himalayan alpine Pasture of Kashmir, Pakistan. *Mont. Res. Dev*., 31(2): 153-159.

Shannon, C.E. 1949. A mathematical theory of communication, Part I, Part II. *Bell. Syst. Tech. J*., 27: 623-656.

Simpson, E.H. 1948. Measurement of diversity. *Nat*., 163:688-688.

Sundriyal, R. and A. Joshi. 1990. Effect of grazing on standing crop, productivity and efficiency of energy capture in an alpine grassland ecosystem at Tungnath (Garhwal Himalaya), India. *Trop. Ecol*., 31(2): 84-97.

Vittoz, P., B. Rulence, T. Largey and F. Frelechoux. 2008. Effects of climate and land-use change on the establishment and growth of cembran pine (*Pinus cembra* L.) over the altitudinal treeline ecotone in the Central Swiss Alps. *Arctic, Ant. & Alp Res*., 40(1): 225-232.

(Received for publication 15 April 2019)