*environmental sciences proceedings*

MDPI

*Proceedings*

# Impact of anthropogenic disturbances on alpine floristic diversity along the altitudinal gradient of Northwestern Himalayas

**Simran Tomar[1,3], Pooja Nautiyal[1], Sunil Puri[3], K.S Kanwal[2] and K.C Sekar[1]**

[1] G.B Pant National Institute of Himalayan Environment, Kosi-Katarmal-263643, Almora, Uttarakhand, India
2 G.B Pant National Institute of Himalayan Environment, Mohal-Kullu-175126, Himachal Pradesh, India
3 Shoolini University of Biotechnology and Management Sciences, Solan-173212, Himachal Pradesh, India
* Correspondence: simrntomar@gmail.com; Tel.: 91+ 8618114753

† **The 3rd International Electronic Conference on Forests — Exploring New Discoveries and New Directions in Forests**, Online, and 15-31 October 2022.

**Abstract:** Vegetation patterns in the high-altitude Himalaya are influenced by a complex set of biotic and abiotic factors. Anthropogenic disturbances are one of the primary factors influencing the community patterns and diversity, which is largely determined by the level of accessibility in the Himalaya. However, with advancing urbanization and accessibility, limited efforts have been made to quantify the impact of road constructions on the alpine flora of Himalaya. To overcome this data gap, this study is aimed to quantify the impact of anthropogenic disturbance on the alpine vegetation community pattern along the altitudinal gradient i.e., 3264- 4340m in Kullu district and 3148-4634m in Lahaul and Spiti district of Himachal Pradesh, Northwestern Himalayas. The impact of anthropogenic disturbance was assessed by comparing species diversity and richness between selected disturbed and undisturbed sites. The diversity profiles of disturbed sites (2.45), near to roads and highways (within 25-50m), were indicative of higher level of anthropogenic disturbances than undisturbed sites (2.56), which were located at a farther distance (more than 25- 50m) from roads and highways. The variation in diversity profiles of disturbed and undisturbed sites was further favored by lower values of soil moisture, potassium, phosphorous, and nitrogen content in disturbed sites. Also, the disturbed sites have lower numbers of threatened and endemic species (15 and 29 respectively) than undisturbed sites (30 and 15) respectively. Linear modelling between soil properties and density indicated a perfect linear relationship for both disturbed and undisturbed sites. Canonical correspondence analysis for disturbed sites indicated sand, silt, clay and bulk density as major controlling factors. The present study indicated a significant impact of anthropogenic disturbances on the alpine floristic diversity and soil properties which needs urgent mitigation actions to conserve the unique and threatened alpine floristic diversity of Himalaya.

**Keywords:** anthropogenic disturbance, altitudinal gradient, Rohtang Pass, Khoksar, Species diversity, Northwestern Himalaya

**Citation:** Tomar, S.; Nautiyal, P.; Puri, S.; Kanwal, K.S.; Sekar,K.C.; Title. *Environ. Sci. Proc.* **2022**, *4*, x. https://doi.org/10.3390/xxxxx

Academic Editor: Firstname Lastname

Published: date



## 1. Introduction

The biodiversity rich alpine ecosystems (sub-alpine, moist and dry alpine scrub) range in altitude from 3500-4300m amsl covers an area of 3440000 km$^2$ in Indian Himalayas (Grabherr, Gottfried, & Pauli, 2010; Salick et al., 2014). The distribution of ecological diversity of alpine plants in the Himalayas is determined by elevation, rainfall, temperature, showing a change in trend in the last 10 years due to climate change and increased human interventions and accessibility. (Salick et al., 2014). Among them, construction of roads and highways, has pronounced impact on the ecological diversity of alpine ecosystem and is still under explored in the pristine and fragile alpine landscapes of Trans-Himalayas. This study is an attempt to understand the impact of anthropogenic disturbances on the ecological diversity of alpine landscapes of Kullu and Trans-Himalayan alpine ecosystems of Lahaul-Spiti district of Himachal Pradesh, Northwestern Himalayas.

## 2. Material and Methods

*Study area*

The study was carried out along an altitudinal gradient i.e., 3264- 4340m in Kullu district (latitudes 31º 25′ and 32 º 35′ N and longitudes 76 º 9 and 77 º 9 E) and 3148- 4634m in Spiti valley of Lahaul and Spiti district (latitudes 31° 44′ and 32° 59′ N and longitudes 76° 46′ and 78° 41′ E) of Himachal Pradesh, Northwestern Himalayas. The altitudinal range lies between 1500 to 6000m in Kullu district and 5,480 meters and 6,400 meters in Lahaul and Spiti district. The average rainfall observed in Kullu district is about 80 Cm and 455.4 mm in Lahaul and Spiti district. The average temperature in Kullu district remains between 38.8° C to 5.2° C. The climate is hot and sub-humid tropical in the southern tracts to more cold, alpine and glacial in the northern and eastern mountain ranges. While in Lahaul and Spiti district the average temperature remains between 25 C to -25. Kullu district covers a geographical area of 5495sqkm while Lahaul and Spiti district is the largest district in the state covering an area of 13,833 $km^2$ approximately 25 % of the State geographical area. The entire study area is known for its rich biodiversity, varied topography, and extreme climatic conditions. Kullu valley is famous for its rich biodiversity in the sub-alpine and alpine forest ecosystems. It provides habitat to some of the rarest faunal species such as Himalayan Tahr, Western Tragopan, Monal, Red Bear. On the other hand, Spit valley is known for threatened and unique cold desert species like Blue Sheep, Snow Leopard, and Himalayan Wolf. The area is surrounded by mountain ranges Pir Panjal, Dhauladhar, Lower Himalayan and Great Himalayan Ranges. The transect chosen for carrying out the quantitative analysis was along the Manali-Leh highway in Kullu district and Manali-Kaza highway in Lahaul-Spiti district to appropriately quantify the impact of anthropogenic disturbances on floristic diversity of the region.

*Sampling Design*

Intensive field surveys were conducted to identify representative disturbed and undisturbed sites along the altitudinal gradient 3646-4340m. Disturbed and undisturbed sites were marked based on proximity and accessibility to humans. The sites near roads and highways (within 25-50m) with higher levels of anthropogenic activities were marked as disturbed sites while the sites distant from the roads and highways (more than 50-100m) were marked as undisturbed sites. At each altitude, sample plots of 0.25ha (50m*50m) were laid. Within the 50*50m plot, 10 quadrats of 5*5m were laid to assess the shrub diversity and 20 quadrats of 1*1m were laid to assess the herbaceous plant diversity

(Gymnosperms, Angiosperms and Pteridophytes) (Figure 1). As the altitudinal range is within the alpine regions of the study area, no tree habit was found.

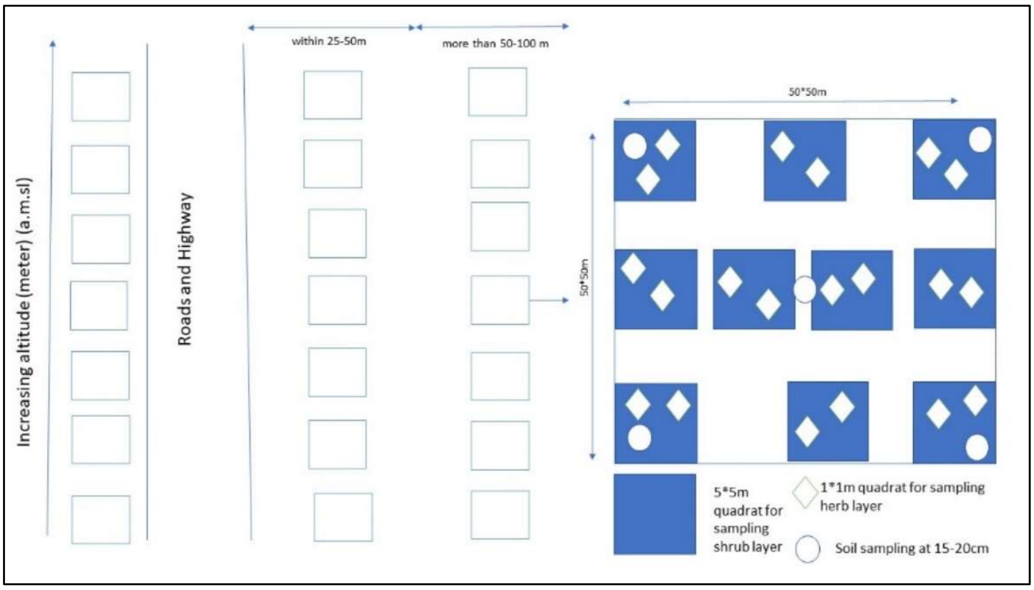


Figure 1 Schematic representation of sampling design for disturbed and undisturbed sites

*Collection and Identification of flora*

Floral samples were also collected from each survey site [17]. Information on habitat conditions, life form, altitudinal range were also noted for each plant species. The samples were later identified with the help of standard publications, monographs, taxonomic revisions, and floras (Stainton, 1988; 2, 4-7, 10, 11, 15, 18-20, 23, 27-28,]. All the species were later inventoried and analyzed [25]. Specimens were collected and preserved following [17]. Based on modern phylogenetic studies, APG III classification [1, 14] was followed to classify the Angiosperm species. Similarly, Gymnosperms and Pteridophytes were classified following [8-9] respectively. Based on the geographical distribution pattern, species were classified as endemic (restricted to Indian Himalayan Region, IHR) or near-endemic (also found in other countries) and rare [12, 16, 22, 24, 29]

*Data analysis and interpretation*

For the quantitative analysis of vegetation, the number of plants of each individual species per quadrat were counted. The communities were identified based on relative frequency. Shannon-Weiner Diversity Index was used [26]. It was calculated as follows:

$H' = \Sigma\ pi \log pi$

Where H' = Shannon-Weiner Diversity Index

And pi = the proportion of individuals of species i

Species richness will be calculated by counting the total number of species observed and by Menhinik's index given by [30]. Species richness will be calculated as follows:

Species Richness = $S/\sqrt{n}$

where, S = number of species

n = Total number of individuals of all species

For analyzing the relationship between soil properties and density of plants, linear modeling between soil parameters and plants density was done using lme4 package in R-4.2.1. The soil parameters used for linear modeling are soil temperature, moisture, bulk density, pH, clay, sand and silt concentration and nitrogen, phosphorus, and potassium concentration.

## 3. Results

*Floristic diversity*

A total of 157 taxa belonging to 40 families and 109 genera were recorded (Table 2). Out of these, 154 species were angiosperm (127 species of Dicotyledon and 27 species of Monocotyledons) and 03 species were of pteridophytes. The most represented families among dicotyledons were Asteraceae (17 genera and 27 species), Rosaceae (05 genera and 12 species), Polygonaceae (06 genera and 11 species), Lamiaceae and Ranunculaceae (07 genera and 08 species) each. Monotypic families were represented by Amaranthaceae, Balsaminaceae, Campanulaceae, Capparaceae, Malvaceae, Rubiaceae, Saxifragaceae, Solanaceae, Scrophulariaceae, Solanaceae and Valerianaceae, Among the monocotyledons, the most represented families were Poaceae (10 Genera and 14 species), Orchidaceae (03 Genera and 03 species), Plantaginaceae (03 Genera and 03 species), Amaryllidaceae (01 Genera and 02 species) (Figure 2). Monotypic families were represented by Iridaceae and Juncaeae. The pteridophytes were represented by the families Pteridaceae (01 genera and 02 species) and Equisetaceae (01 genera and 01 species). As per the life form, 134 species were herbs, 05 Shrubs, 3 ferns and 14 species were grasses. The Dominant genus were *Geranium* (05 species), *Potentilla* (05 species), *Saussurea* (04 species), and *Pedicularis* (04 species). The dominant habitat type in these sites were moist alpine, bouldery, and dry habitat. The slope varied from 30° - 46° and maximum sites were sampled in Northwest aspect followed by North, East and West aspect.

Table 2 Taxonomical description of surveyed plants

| Angiosperm | Family | Genus | Species | Herbs | Shrubs | Ferns | Grasses |
|---|---|---|---|---|---|---|---|
| Dicotyledon | 30 | 84 | 127 | 122 | 05 | - | - |
| Monocotyledon | 08 | 21 | 27 | 13 | - | - | 14 |
| Pteridophytes | 02 | 03 | 03 | - | - | 03 | - |
| Total | 40 | 108 | 157 | 135 | 05 | 03 | 14 |

*Rare, endangered, and threatened species*

For undisturbed sites, 04 Critically Endangered, *Arnebia euchroma, Dactylorhiza hatagirea, Gentiana kurroo, Picrorrhiza Kurooaa,* 04 endangered *Aconitum hererophyllum, Mecanopsis aculeata, Polygonatum verticillatum, Rheum australe* and 12 near threatened species *Caltha Palustris, Chaerophyllum villosum, Epipactis helleborine, Geranium wallichianum, Morina longifolia, , Plantago himalaica, Potentilla fulgens, Primula rosea, Rumex acetosa, Saussurea heteromalla, Swertia petiolata, Thymus linearis* 10 vulnerable species *Aconitum violaceum, Bergenia stracheyi ,Corydalis govaniana, Heracleum candicans, Lagotis cashmiriana, Pleurospermum brunonis, Pleurospermum candollei, Rhododendron anthopoogon , Rhododendron lepidotum, Tanacetum dolichophyllum* were recorded.

For disturbed sites, 02 Critically Endangered, *Arnebia euchroma, Picrorrhiza Kurooaa,* 03 endangered *Aconitum hererophyllum, Polygonatum verticillatum, Rheum australe* and 04 near threatened species *Calanthe tricarinata, Geranium wallichianum, Morina longifolia, Plantago himalaica*, 06 vulnerable species *Bergenia stracheyi, Bunium persicum, Corydalis govaniana, Hyssopus officinalis, Rhododendron lepidotum, Valeriana jatamansi* were recorded.

*Nativity and Endemism*

Among the identified plants, 87 species are native to Himalayan region and 67 species are nonnative belong to different biogeographic regions across the globe. 29 endemic species were recorded from undisturbed sites and 15 endemic species were recorded from disturbed sites. 03 near endemic species were recorded from undisturbed sites and 01 near endemic species was recorded from disturbed sites. Invasive species, *Sonchus asper* was recorded from only disturbed sites [3].

*Phytosociological assessment*

Higher species diversity (2.56) and species richness (179) was recorded for undisturbed sites than disturbed sites with species diversity and species richness (2.45) and 115 respectively. Disturbed sites were dominated by species such *as Arctium lappa, Artemisia brevifolia, Anaphalis nepalensis,Aquilegia fragrans, Bunium persicum, Clinopodium vulgare, Geranium emodii, Malva pusilla, Potentilla argyrophylla, Lagotis cachmeriana, Carex nivalis, Pedicularis albida, Rhododendron heterodonta, Epilobeum royleanum, Sibbaldia cuneata, Saussurea costus, Waldehmia tormentosa, Festuca kashmiriana, Trifolium repens* etc. Unidsturbed sites were dominated by *Aconitum heterophyllum, Anaphalis triplinervis, Artemisia maritima, Senencio elatum, Geranium wallichianum,Aconitum violaceum, Iris hookeriana, Nepeta erecta, Arnebia benthamii, Chenopodium botryts, Rheeum moorcroftianum, Rumex hastatus, Thymus serpyllum, Festuca altavista, Anaphalis triplinervis, Hyoscyamus niger, Pedicularis hoffmeister, Lagotis cahmeriana, Thymus javanicum, Gallium aparine, Clinopodium vulgare, Tenacetum dolichophyllum, Oryzopsis lateralis, Sedum ewersii, Cyananthus lobatus, Valeriana jatamansi, Sibbaldia purpurea, Geranium himalayense, Epilobeum helleborine, Ariseama jacquemontii,* etc

Shrub diversity (*Hyssopus officinalis, Lonicera asperifolia, Rosa macrophylla, Rhododendron anthopogon* and *Rhododendron lepidotum*) was recorded only from undisturbed sites. Non-metric dimensional scaling of flora from both disturbed and undisturbed sites showed more heterogenous composition at lower altitudes.

*Soil properties of disturbed and undisturbed sites*

Soil moisture, soil temperature, Bulk density, Porosity, percentage of sand, Silt, clay, and Phosphorus were recorded in higher concentration in soil sampled from Undisturbed sites. Organic carbon and nitrogen were recorded in higher concentration from disturbed sites. Equal concentration of potassium and phosphorus was recorded in soil sampled from undisturbed sites. Linear modelling between soil properties and density indicated a perfect linear relationship (all residual =0) for both disturbed and undisturbed sites. Further, canonical correspondence analysis was performed quantifying relationship between soil parameters and herbs distribution at disturbed sites. The distribution of herbs at disturbed sites were dependent on sand, silt, clay and bulk density of soil rather than nitrogen, phosphorus and organic carbon.

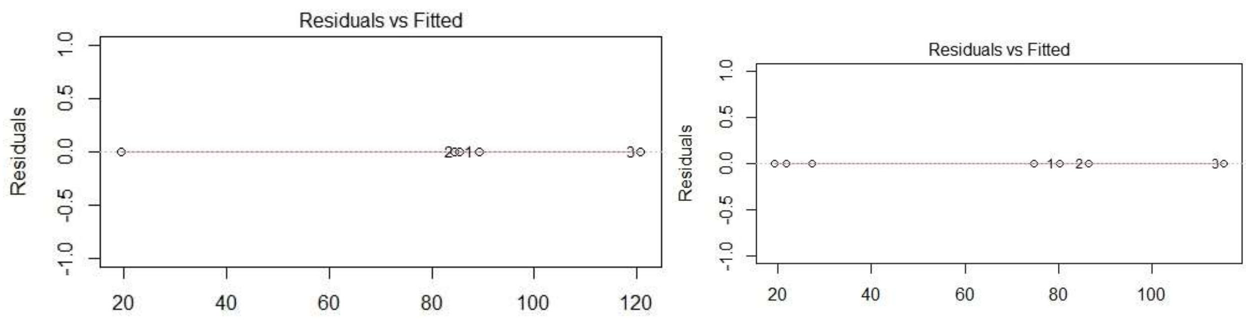


Figure 2. Linear modeling between soil parameters and density of plants: (a) Disturb sites and (b) Undisturbed sites.

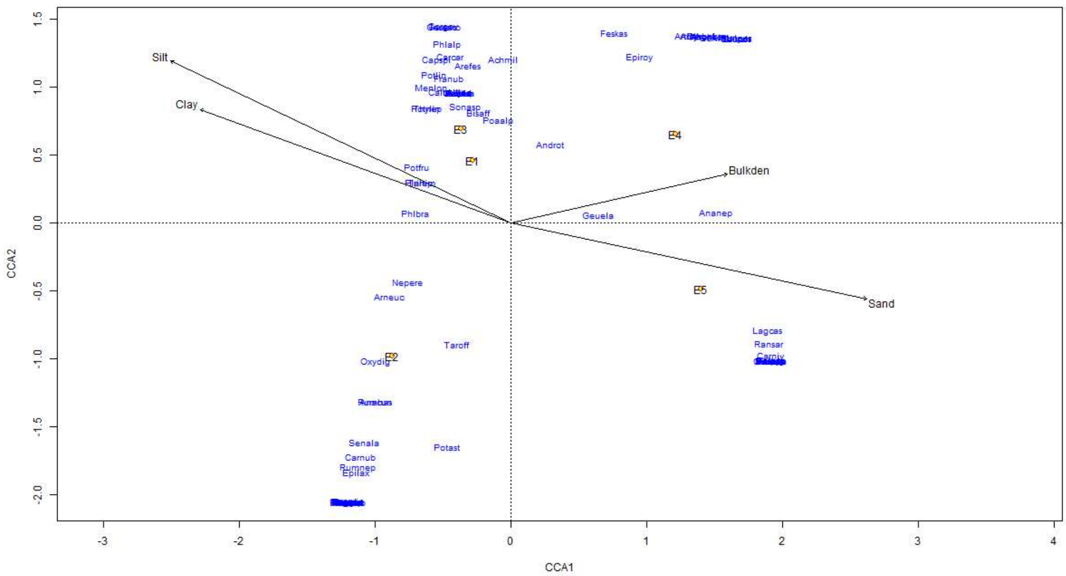


Figure 3. CCA between soil parameters and herbs distribution at disturbed sites.

## Discussion

The study reported a higher density and higher number of rare, endangered and threatened species from undisturbed sites than disturbed sites. The lesser density of rare, endangered and threatened species from disturbed sites indicates anthropogenic disturbances at these sites. The proximity to roads and highways could be a possible factor for low ecological diversity and higher concentration of sand, silt, and clay due to road and highways concentration at disturbed sites. Presence of invasive species at disturbed sites indicates that anthropogenic disturbances will result in change in community composition of disturbed sites in near future with more proportion of non-native species. Sustained urban development along with appropriate conservation measures is suggested to mitigate the impact of anthropogenic disturbances in alpine landscapes of northwestern Himalayas.

**Author Contributions:** Conceptualization, K.S.K. and S.P.; methodology, K.C.S; formal analysis, S.T and P.N.; data curation, S.T.; writing—original draft preparation, S.T. and P.N; writing—review and editing, S.T, P.N and K.S.K.; All authors have read and agreed to the published version of the manuscript.

**Funding:** The authors are thankful to Mountain Division unit of G.B Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand for financial support. The authors are also thankful to NMSHE (National Mission for Sustaining the Himalayan Ecosystems) – Task Force -3, Phase II for supporting this study. We express our sincere gratitude to Himachal Regional Centre of G.B Pant National Institute of Himalayan Environment, Himachal Regional Centre, Mohal-Kullu, Himachal Pradesh for providing the necessary support and logistics.

**Acknowledgments:** The authors are highly thankful to Director, G.B, Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, and Centre Head, Himachal Regional Centre, Mohal – Kullu for facilities and encouragement. The authors gracefully acknowledge financial support from the Mountain Division and NMSHE (National Mission for Sustaining the Himalayan Ecosystems) – Task Force -3, Phase II of the institute.

**Conflicts of Interest:** The authors declare that the work carried out is original and the contents of the paper are neither published before nor submitted for publication in any other journal and the authors have no conflict of interest.

## References

1. APG III. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Bot. J. Linn. Soc. 2009,161(2),105–121
2. Aswal, B.S.; Mehrotra, B.N. Flora of Lahaul-Spiti (A cold desert in Northwest Himalaya). Bisen Singh Mahendra Pal Singh, Dehradun, India. 1994, pp 761.
3. Sekar, K.C.; Manikandan, R.; and Srivastava, S.K. Invasive alien plants of Indian Himalayan Region. Proc. Natl. Acad. Sci. India Section B Biol. Sci. 2012,82, 375–383
4. Sekar, K.C.; Pandey, A.; Giri, L.; Floristic diversity in Milam Valley: a cold desert region of Uttarakhand. Int. J. Eng. Res 2014,2,143–147
5. Chauhan, N.S. Medicinal Orchids of Himachal Pradesh. J.Orchid Soc. India 1990,4, 99–105.
6. Chauhan, N.S. Plant resources of economic use in Himachal Pradesh. Solan: DEE-UH & F. 1996, pp 77.
7. Chauhan, N.S. Medicinal and Aromatic Plants of Himachal Pradesh. Indus Publishing Company, New Delhi. 1999,pp 632.
8. Christenhusz, M.J.M.; Reveal, J.L.; Farjon, A.; Gardner, M.F.; Mill, R.R.; Chase, M.W. A new classification and linear sequence of extant gymnosperms. Phytotaxa 2011a,19,55–70.
9. Christenhusz, M.J.M.; Zhang, X.; Schneider, H. A linear sequence of extant families and genera of lycophytes and ferns. Phytotaxa 2011b,19, 7–54.
10. Collett, H. Flora Simlensis. Thacker Spink and Co., London (Reprinted 1971). Bishen Singh Mahendra Pal Singh, Dehra Dun, India. 1902,pp 652.
11. Dhaliwal, D.S. Sharma, M. Flora of Kullu District (Himachal Pradesh). Bisen Singh Mahendra Pal Singh, Dehradun India. 1999,pp 744.
12. Dhar, U.; Samant, S.S. Endemic diversity of Indian Himalaya. I. Ranunculaceae and II. Paeoniaceae. J. Biogeogr. 1993,20:659–68.
13. Haston, E.; Richardson, J.E.; Stevens, P.F.; Chase, M.W.; Harris, D.J. The Linear Angiosperm Phylogeny Group (LAPG) III: A linear sequence of the families in APG III. Bot. J. Linn. Soc. 2009,161(2): 128–131
14. Hooker, J.D.. Flora of British India, L. Kent, England: Reeve & Co. (Reprint edition).1872–1897vols. 1–7.
15. IUCN 2020: The IUCN Red List of Threatened Species, Version 2014.3. Available online at: http://www.iucnredlist.org (accessed November 10, 2019). 2020
16. Jain, S.K and Rao, R.R. A Handbook of Field and Herbarium Methods. New Delhi: Today and Tomorrow's Printers and Publishers. 1977
17. Kala, C.P. Medicinal Plants of the high-altitude cold desert in India: diversity, distribution & traditional uses. Int. j. biodivers. sci. ecosyst. serv. 2006a,2(1):43–56.
18. Khullar, S.P. Illustrated fern flora of the West Himalaya, Vol. 1. Dehradun: International Book Distributors. 1994,pp 506.
19. Khullar, S.P. Illustrated fern flora of the West Himalaya, Vol. 2. Dehradun: International Book Distributors. 2000,pp 544.
20. Nayar, M.P, Sastry, A.R.K. Red Data Book of Indian Plants, Vol. I–III. Calcutta: Botanical Survey of India; Reprinted in 1988, 1990. 1987
21. Polunin, O.; Stainton, A. Flowers of the Himalaya. Delhi: Oxford University Press. 1984,580 pp.
22. Samant, S.S.; Dhar, U.; Palni, L.M.S. Medicinal Plants of Indian Himalaya. Diversity Distribution Potential Values. Nainital: Gyanoghaya Prakashan. 1998,pp 163
23. Samant, S.S.; Dhar, U.; Rawal, R.S. Biodiversity status of a protected area of west Himalaya: Askot Wildlife Sanctuary. Int. J. Sustain. Dev. World Ecol. 5: 1998b,194-203.
24. Shannon, C.E.; Wiener, W. The Mathematical Theory of Communication. University of Illinois Press, Urbana. 1963
25. Sharma, M.; Dhaliwal, D.S. Additions to the Flora of Himachal Pradesh from Kullu District. J. Bombay Nat. Hist. Soc. 1997a 94(2): 447–50.
26. Sharma, M.; Dhaliwal, D.S.; Biological Spectrum of the flora of Kullu district (Himachal Pradesh). J. Indian Bot. Soc 1997b,76:283–4.
27. Ved, D.K.; Kinhal, G.A.; Ravikumar, K.; Prabhakaran, V.; Ghate, U.; Vijaya Shankar, R.; Indresha, J.H. Conservation assessment and management prioritization for the Medicinal plants of Jammu & Kashmir, Himachal Pradesh & Uttaranchal. Bangalore, India: Foundation for Revitalisation of Local Health Traditions. 2003
28. Whittaker, R.H. Evolution of species diversity in land plant communities. J. Evol. Biol 1977,10:1-67.