environmental sciences proceedings

MDPI

Proceeding Paper

Impact of Anthropogenic Disturbances on Alpine Floristic Diversity along the Altitudinal Gradient of Northwestern Himalayas †

Simran Tomar [1,2,*], Pooja Nautiyal [1], Sunil Puri [2], Khilendra Singh Kanwal [1] and Kamaraj Chandra Sekar [1]

1 Centre for Biodiversity, Conservation and Management, G.B Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora 263643, India
2 School of Biological Sciences, Shoolini University of Biotechnology and Management Sciences, Solan 173212, India
* Correspondence: simrntomar@gmail.com; Tel.: +91-8618114753
† Presented at the 3rd International Electronic Conference on Forests—Exploring New Discoveries and New Directions in Forests, 15–31 October 2022; Available online: https://iecf2022.sciforum.net/.

Abstract: Vegetation patterns in the high-altitude Himalayas 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 are largely determined by the level of accessibility in the Himalayas. However, with advancing urbanization and accessibility, limited efforts have been made to quantify the impact of road constructions on the alpine flora of the Himalayas. To overcome this data gap, this study aimed to quantify the impact of anthropogenic disturbance on the alpine vegetation community pattern along the altitudinal gradient, i.e., 3264–4340 m in Kullu district and 3148–4634 m 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 roads and highways (within 25–50 m), were indicative of a higher level of anthropogenic disturbances than undisturbed sites (2.56), which were located at a farther distance (more than 25–50 m) 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. In addition, 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 the Himalayas.

Keywords: anthropogenic disturbance; altitudinal gradient; Rohtang Pass; Khoksar; species diversity; Himachal Himalayas

Citation: Tomar, S.; Nautiyal, P.; Puri, S.; Kanwal, K.S.; Sekar, K.C. Impact of Anthropogenic Disturbances on Alpine Floristic Diversity along the Altitudinal Gradient of Northwestern Himalayas. *Environ. Sci. Proc.* **2022**, *22*, 43. https://doi.org/10.3390/IECF2022-13093

Academic Editor: Rodolfo Picchio

Published: 21 October 2022

1. Introduction

The biodiversity-rich alpine ecosystems (sub-alpine, moist and dry alpine scrub) range in altitude from 3500 to 4300 m and cover an area of 3,440,000 km^2 in the Indian Himalayas [1,2]. The distribution of the ecological diversity of alpine plants in the Himalayas is determined by elevation, rainfall, and temperature, showing a change in trend in the last 10 years due to climate change and increased human interventions and accessibility [2]. Among them, the construction of roads and highways has a pronounced impact on the ecological diversity of alpine ecosystem and is still underexplored 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

2.1. Study Area

The study was carried out along an altitudinal gradient, i.e., 3264–4340 m in Kullu district (latitudes 31°25′ and 32°35′ N and longitudes 76°9′ and 77°9′ E) and 3148–4634 m 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 and 6000 m in Kullu district and between 5480 meters and 6400 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 climate is hot and sub-humid tropical in the southern tracts, to more cold, alpine, and glacial in the northern and eastern mountain ranges. The average temperature in Kullu district remains between 38.8 °C and 5.2 °C, while the average temperature in Lahaul and Spiti district remains between 25 ° C and −25 °C. Kullu district covers a geographical area of 5495 sqkm, 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 the Himalayan Tahr, Western Tragopan, Monal, and Red Bear. On the other hand, Spit valley is known for threatened and unique cold desert species, such as the Blue Sheep, Snow Leopard, and Himalayan Wolf. The area is surrounded by the mountain ranges Pir Panjal, Dhauladhar, and Lower Himalayan and Great Himalayan Ranges. The transect along the Manali-Leh highway in Kullu district and Manali-Kaza highway in Lahaul-Spiti district was chosen to appropriately quantify the impact of anthropogenic disturbances on floristic diversity of the region.

2.2. Sampling Design

Intensive field surveys were conducted to identify representative disturbed and undisturbed sites along the altitudinal gradient 3264–4340 m. Disturbed and undisturbed sites were marked based on proximity and accessibility to humans. The sites near roads and highways (within 25–50 m), where higher levels of anthropogenic activities were marked as disturbed sites, while the sites distant from the roads and highways (more than 50–100 m) were marked as undisturbed sites. At each altitude, sample plots of 0.25 ha (50 m × 50 m) were laid. Within the 50 × 50 m plot, 10 quadrats of 5 × 5 m were laid to assess the shrub diversity and 20 quadrats of 1 × 1 m 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 habitat was found.

2.3. Collection and Identification of Flora

Floral samples were also collected from each survey site [3]. Information on habitat conditions, life form, and 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 [4–20]. All the species were later inventoried and analyzed [18]. Specimens were collected and preserved following Jain and Rao, 1977. Based on modern phylogenetic studies, APG III classification [21–23] was followed to classify the Angiosperm species. Similarly, Gymnosperms and Pteridophytes were classified following [24,25], respectively. Based on the geographical distribution pattern, species were classified as endemic (restricted to the Indian Himalayan Region, IHR) or near-endemic (also found in other countries) and rare [26–30].

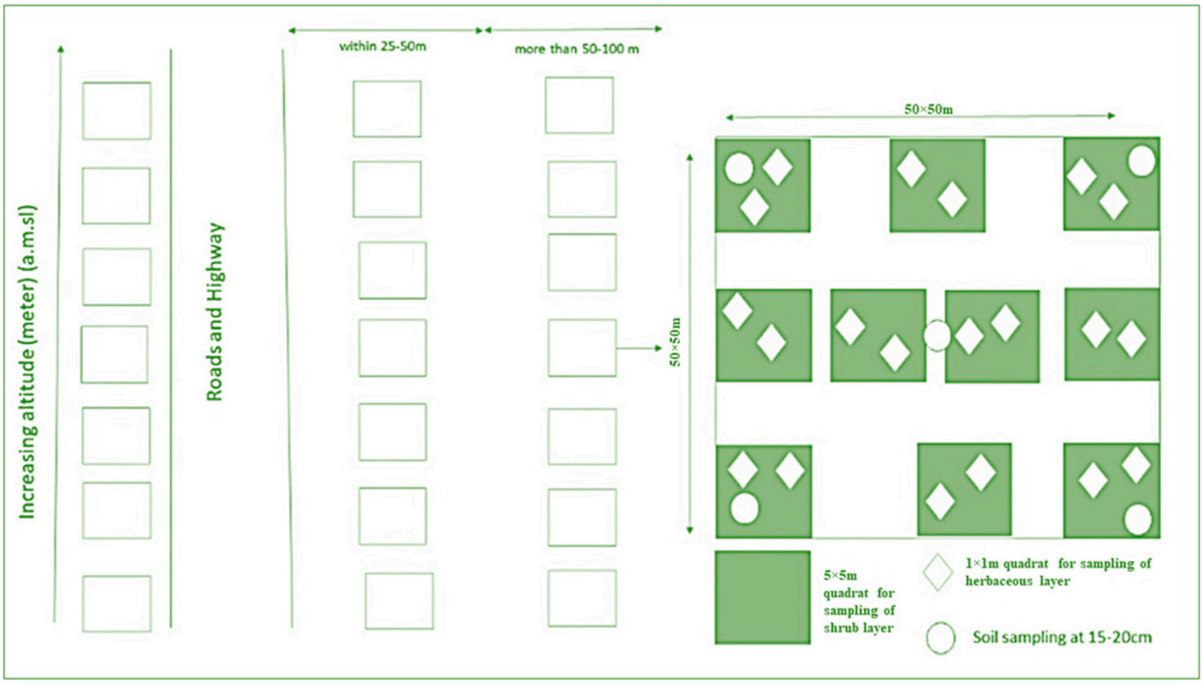

Figure 1. Schematic representation of sampling design for disturbed (within 50 m) and undisturbed sites (more than 50 m).

2.4. 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. The Shannon–Weiner Diversity Index was used [31] and is 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 was calculated by counting the total number of species observed and by Menhinik's index given by [32], as follows:

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

where S = number of species,

and n = total number of individuals of all species.

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

3. Results

3.1. Floristic Diversity

A total of 157 taxa belonging to 40 families and 109 genera were recorded (Table 1). 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), and Lamiaceae and Ranunculaceae (07 genera and 08 species). 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), and 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, 135 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 1. 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

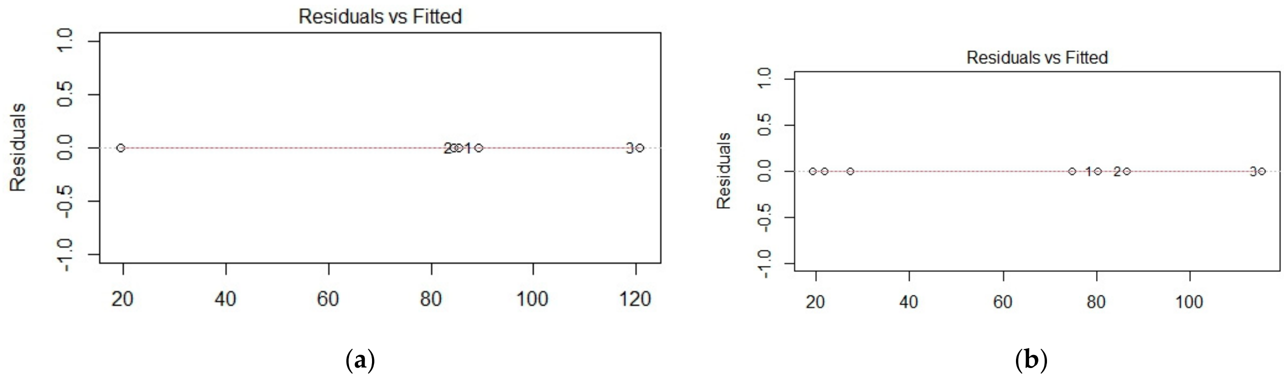

Figure 2. Linear modeling between soil parameters and density of plants: (**a**) disturbed sites and (**b**) undisturbed sites.

3.2. Rare, Endangered, and Threatened Species

For undisturbed sites, 04 critically endangered species, *Arnebia euchroma, Dactylorhiza hatagirea, Gentiana kurroo,* and *Picrorrhiza Kurooaa*; 04 endangered species, *Aconitum hererophyllum, Mecanopsis aculeata, Polygonatum verticillatum, Rheum austral*; 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*; and 10 vulnerable species, *Aconitum violaceum, Bergenia stracheyi, Corydalis govaniana, Heracleum candicans, Lagotis cashmiriana, Pleurospermum brunonis, Pleurospermum candollei, Rhododendron anthopoogon, Rhododendron lepidotum,* and *Tanacetum dolichophyllum*, were recorded.

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

3.3. Nativity and Endemism

Among the identified plants, 87 species are native to the Himalayan region and 67 species are nonnative, belong to different biogeographic regions across the globe. From undisturbed sites, 29 endemic species were recorded, and 15 endemic species were recorded from disturbed sites. From undisturbed sites, 03 near endemic species were recorded and 01 near endemic species was recorded from disturbed sites. The invasive species *Sonchus asper* was recorded only from disturbed sites [33].

3.4. Phytosociological Assessment

A higher species diversity (2.56) and species richness (179) was recorded for undisturbed sites compared to disturbed sites with species diversity (2.45) and species richness (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. Undisturbed 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. Nonmetric dimensional scaling of flora from both disturbed and undisturbed sites showed a more heterogenous composition at lower altitudes.

3.5. Soil Properties of Disturbed and Undisturbed Sites

Soil moisture, soil temperature, bulk density, porosity, percentage of sand, silt, clay, and phosphorus were recorded in a higher concentration in soil sampled from undisturbed sites. Organic carbon and nitrogen were recorded in a higher concentration from disturbed sites. An 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 (Figure 2). Further, canonical correspondence analysis was performed quantifying the relationship between soil parameters and herb distribution at disturbed sites. The distribution of herbs at disturbed sites was dependent on sand, silt, clay, and bulk density of soil rather than nitrogen, phosphorus, and organic carbon. *Phlomis bracteosa, Pleum alpinum* was more correlated to silt and clay concentration in soil. *Nepeta erecta, Arnebia euchroma, Taraxacum officinale, Oxyria digyna, Potentilla atrosanguinea, Senecio altum, Carex nubigena, Epilobeum latifolium* were less correlated with silt, clay, bulk density and sand. *Lagotis cashemriana, Ranunculus sarmentosus* were more correlated to sand concentration in soil. *Festuca kashmeriana, Androsace rotundifolia, Geum elatum, Anaphalis nepalensis* were more correlated to bulk density of soil (Figure 3).

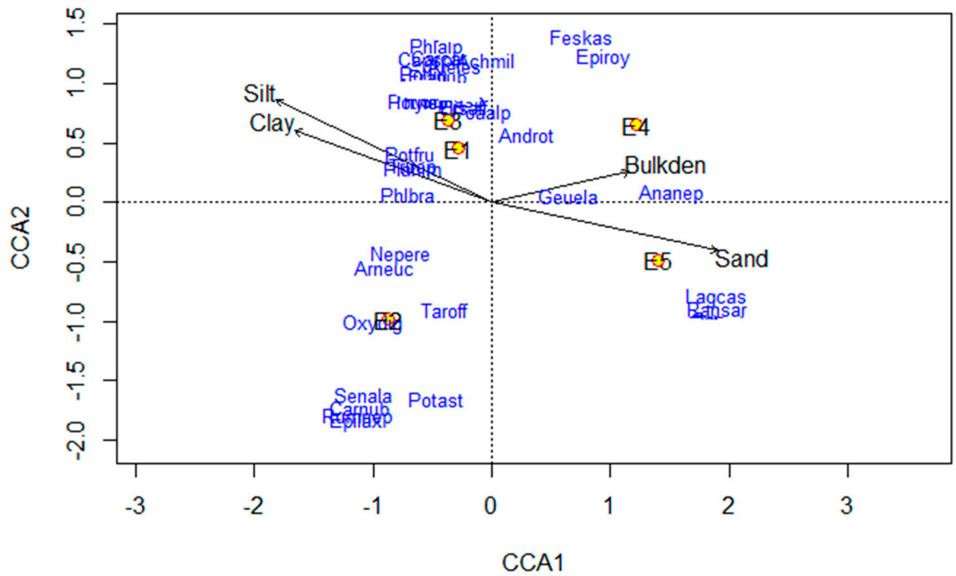

Figure 3. CCA between soil parameters and herb distribution at disturbed sites.

4. Discussion

This study reported a higher density and higher number of rare, endangered, and threatened species from undisturbed sites compared to disturbed sites. The lower 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 the low ecological diversity and higher concentration of sand, silt, and clay, due to the concentration of roads and highways at disturbed sites. The presence of invasive species at disturbed sites indicates that anthropogenic disturbances will result in a change in community composition of disturbed sites in the near future with a higher 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 the 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 the 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.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors are highly thankful to the Director, G.B, Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, and the 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 no conflict of interest. The work carried out is original and the contents of the paper are neither published before nor submitted for publication in any other journal.

References

1. Grabherr, G.; Gottfried, M.; Pauli, H. Climate Change Impacts in Alpine Environments. *Geogr. Compass.* **2010**, *4*, 1133–1153. [CrossRef]
2. Salick, J.; Ghimire, S.K.; Fang, Z.; Dema, S.; Konchar, K.M. Himalayan Alpine Vegetation, Climate Change and Mitigation. *J. Ethnobiol.* **2014**, *34*. [CrossRef]
3. Jain, S.K.; Rao, R.R. *A Handbook of Field and Herbarium Methods*; Today and Tomorrow's Printers and Publishers: New Delhi, India, 1977.
4. Hooker, J.D. *Flora of British India*; Reprint edition; Kent, L., Ed.; Reeve & Co.: England, UK, 1872; Volumes 1–7.
5. Chowdhery, H.J.; Wadhwa, B.M. *Flora of Himachal Pradesh*; Botanical Survey of India: Calcutta, India, 1984; pp. 1–3.
6. Collett, H. *Flora Simlensis*; Thacker Spink and Co., London (Reprinted 1971); Bishen Singh Mahendra Pal Singh: Dehradun, India, 1902; p. 652.
7. Polunin, O.; Stainton, A. *Flowers of the Himalaya*; Oxford University Press: Delhi, India, 1984; p. 580.
8. Sharma, M.; Dhaliwal, D.S. Additions to the Flora of Himachal Pradesh from Kullu District. *J. Bombay Nat. Hist. Soc.* **1997**, *94*, 447–450.
9. Sharma, M.; Dhaliwal, D.S. Biological Spectrum of the flora of Kullu district (Himachal Pradesh). *J. Indian Bot. Soc.* **1997**, *76*, 283–284.
10. Stainton, A. *Flowers of the Himalaya: A Supplement*; Oxford University Press: Delhi, India, 1988; p. 86. ISBN 0192177567.
11. Dhaliwal, D.S.; Sharma, M. *Flora of Kullu District (Himachal Pradesh)*; Bisen Singh Mahendra Pal Singh: Dehradun, India, 1999.
12. Chauhan, N.S. Medicinal Orchids of Himachal Pradesh. *J. Orchid Soc. India* **1990**, *4*, 99–105.
13. Chauhan, N.S. *Plant Resources of Economic Use in Himachal Pradesh*; DEE-UH & F: Solan, India, 1996; p. 77.
14. Chauhan, N.S. *Medicinal and Aromatic Plants of Himachal Pradesh*; Indus Publishing Company: New Delhi, India, 1999; p. 632.
15. Aswal, B.S.; Mehrotra, B.N. *Flora of Lahaul-Spiti (A Cold Desert in Northwest Himalaya)*; Bisen Singh Mahendra Pal Singh: Dehradun, India, 1994; p. 761.
16. Khullar, S.P. *Illustrated Fern Flora of the West Himalaya*; International Book Distributors: Dehradun, India, 1994; p. 506.
17. Khullar, S.P. *Illustrated Fern Flora of the West Himalaya*; International Book Distributors: Dehradun, India, 2000; p. 544.
18. Kala, C.P. Medicinal Plants of the high-altitude cold desert in India: Diversity, distribution & traditional uses. *Int. J. Biodivers. Sci. Ecosyst. Serv.* **2006**, *2*, 43–56.
19. 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.
20. Samant, S.S.; Dhar, U.; Palni, L.M.S. *Medicinal Plants of Indian Himalaya. Diversity Distribution Potential Values*; Gyanoghaya Prakashan: Nainital, India, 1998; p. 163.
21. 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.* **1998**, *5*, 194–203. [CrossRef]
22. 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*, 105–121. [CrossRef]
23. 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*, 128–131. [CrossRef]
24. 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* **2011**, *19*, 55–70. [CrossRef]
25. Christenhusz, M.J.M.; Zhang, X.; Schneider, H. A linear sequence of extant families and genera of lycophytes and ferns. *Phytotaxa* **2011**, *19*, 7–54. [CrossRef]
26. Dhar, U.; Samant, S.S. Endemic diversity of Indian Himalaya. I. Ranunculaceae and II. Paeoniaceae. *J. Biogeogr.* **1993**, *20*, 659–668. [CrossRef]
27. Dhar, U.; Manjkhola, S.; Joshi, M.; Bhatt, I.D.; Bisht, A.K.; Joshi, M. Current status and future strategy for development of medicinal plants sector in Uttaranchal, India. *Curr. Sci.* **2002**, *83*, 56–64.
28. 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*; Foundation for Revitalisation of Local Health Traditions: Bangalore, India, 2003.
29. Nayar, M.P.; Sastry, A.R.K. *Red Data Book of Indian Plants*; Botanical Survey of India: Calcutta, India, 1987.
30. IUCN 2020: The IUCN Red List of Threatened Species, Version 2014.3. 2020. Available online: http://www.iucnredlist.org (accessed on 10 November 2019).
31. Shannon, C.E.; Wiener, W. *The Mathematical Theory of Communication*; University of Illinois Press: Urbana, IL, USA, 1963.
32. Whittaker, R.H. Evolution of species diversity in land plant communities. *J. Evol. Biol.* **1977**, *10*, 1–67.
33. Sekar, K.C.; Manikandan, R.; Srivastava, S.K. Invasive alien plants of Indian Himalayan Region. *Proc. Natl. Acad. Sci. India Sect. B Biol. Sci.* **2012**, *82*, 375–383. [CrossRef]