

Database of Himalayan Plants Based on Published Floras During a Century

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Abstract: The Himalaya is the largest mountain range in the world, spanning approximately ten degrees of latitude and elevation between 100 m asl to the highest mountain peak on earth. The region varies in plant species richness, being highest in the biodiversity hotspot of Eastern Himalaya and declining to the North-Western parts of the Himalaya. We examined all published floras (31 floras in 42 volumes spanning the years 1903–2014) from the Indian Himalayan region, Nepal, and Bhutan to compile a comprehensive checklist of all gymnosperms and angiosperms. A total of 10,503 species representing 240 families and 2322 genera are reported. We evaluated all the botanical names reported in the floras for their updated taxonomy and excluded >3000 synonyms. Additionally, we identified 1134 species reported in these floras that presently remain taxonomically unresolved and 160 species with missing information in the global plant database (The Plant List, 2013). This is the most comprehensive estimate of plant species diversity in the Himalaya.

Data Set: <https://www.gbif.org/dataset/0bddc88d-8586-4889-9340-4a86eb63abe4>

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1. Introduction

The Himalaya is the highest and largest mountain system on the earth extending over 2400 km in length and 300 km in width, with tremendous variation in topography and climate. The mountain range exhibits more tropical conditions in the Eastern lowlands, whereas it becomes more arid and seasonal towards North-Western extremes; correlated with this there is turnover in assemblages of vegetation types [1,2]. Detailed documentation of plants of the Himalaya started with Hooker in the 19th century, who studied the entire subcontinent (Hooker, 1875–1897) [3–9]. Documentation of more detailed information on vascular plants from specific localities within the Himalayan region also have a long history. Floras have been published from regions varying in size from a single administrative district to complete country e.g., Bhutan and Nepal [10–57]. Floras specific to the Himalayan region have been published for more than a century, ranging from the records of vascular plants of upper Gangetic plains and Siwalik region [10] in 1903 to a recent angiosperm flora of Darjeeling Himalaya and neighboring foothills in 2014 [57]. Many papers in peer-reviewed journals have also reported plant species checklists from different regions of the Himalaya, but the number of species reported and coverage of area is comparatively less, and they were not incorporated into this study. The floras themselves generally provide summaries of these paper and give details of plant species occurrence in a specific region, including information on both elevational ranges and taxonomy. Thus, floras provide an important resource to evaluate the Himalayan plant richness, be it a mountain or a specific region of interest.

Plant systematics involves intensive tasks of recognition, comparison, classification, and naming of millions of plants on the earth. The Himalayan region is rich in plant diversity with more than 10,000 species of seed plants. Most of the plants reported in this region are based on the work of British taxonomists. However, many of these species were not fully resolved for their taxonomic positions and sufficient information or updates are not available due to a lack of expertise and scarcity of knowledgeable taxonomists in the region [58–61]. In present times, traditional taxonomy is one of the generally neglected or avoided field due to the mistaken belief that it is a disused branch of life sciences [58,59]. Certain policies and factors such as funding inconsistencies and a lack of coordination among plant taxonomists are mainly responsible for the gradual decline in the quality of taxonomic research in the region [61]. However, modern tools for biological classification such as molecular-systematics using DNA sequence data and barcoding still require an amelioration of traditional taxonomic practices [58]. Thus, it is essential to compile the complete regional checklist of plants from already published literature. These checklists can be used for the evaluation of the prevailing taxonomic conflicts and uncertainties and will also help in the better estimation of regional plant diversity.

Not only in the Himalayan region but globally as well, plant taxonomists face problems due to a lack of information on reported species, with the result that some species are recorded under multiple names, and others have yet to be split. With the help of herbarium specimens and online plant databases, plant taxonomists are making efforts to resolve and continually update taxonomy, as exemplified by The Plant List (www.theplantlist.com) [62], which maintains a complete working list of global plants. This database shows that globally around 20% of plant names are unresolved because data sources provide no evidence as to whether the name should be accepted or not, or there were conflicting opinions that could not be readily resolved. Here, we cross-check the updated taxonomy from this list for all seed plants reported from the Himalaya. This taxonomic evaluation of regional plant checklist will provide basic information to taxonomists for conducting ecological studies and updating taxonomic information of species, which will help in better understanding of regional species diversity. Further, data available in the GBIF portal on the occurrence information of all reported species from the Himalayan sub-regions can be integrated in global level analyses on plant distribution studies.

2. Data Description

The aim of this paper is to present a complete checklist of reported plants from the Himalaya and to assess all reported names during the last century against the latest taxonomic updates. The data thus provide the most accurate estimate of plant species richness for the Himalayan region. The dataset provides information on the occurrence and elevational ranges of species in six different sub-regions of the Himalaya. Data on species occurrences is available on the GBIF portal (<https://www.gbif.org/dataset/0bddc88d-8586-4889-9340-4a86eb63abe4>).

3. Geographic Coverage

Bounding Coordinates: South West [26.5, 73.5], North East [35, 97]

The vascular plant species database includes species reported from the Himalaya covering mountainous regions of three countries viz. India, Bhutan, and Nepal. We divided the region into six sub-regions based on the geographical coverage of published floras, i.e., Arunachal Pradesh, Bhutan & Sikkim, Nepal, Uttarakhand, Himachal Pradesh, and Jammu & Kashmir (Figure 1). Flora for Bhutan includes records of species from Sikkim and the Darjeeling region of Bengal in India, which were considered together as one sub-region. Arunachal Pradesh represents the eastern most sub-region, whereas Jammu & Kashmir represents the most north-western sub-region of the Himalaya. We did not cover Himalayan regions of Pakistan or China. However, these areas are comparatively small, and

floras that specifically focus on these areas are not available. Because the remaining areas are small, we consider this to be a checklist of plants that captures essentially the entire Himalaya.

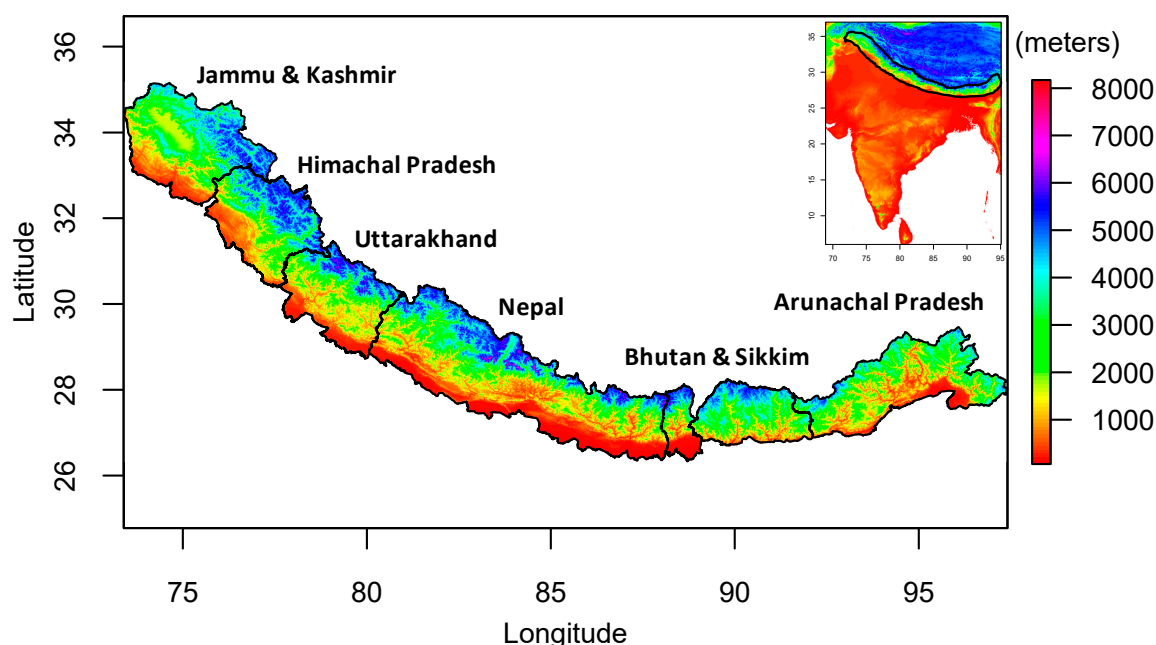


Figure 1. Map of the Himalayan region with coordinates and elevational range showing the six sub-regions for which floras were examined and information was obtained for species occurrences.

4. Temporal Coverage

The database includes plant species reported for different sub-regions of the Himalaya during the period of 1903–2014.

5. Taxonomic Coverage

The database includes all species of gymnosperms and angiosperms reported from the region. A total of 8 families of gymnosperms representing 20 genera and 51 species and 232 families of angiosperms representing 2302 genera and 10,452 species are reported. A list of families reported in the dataset is as follows.

5.1. *Gymnosperms*

Cupressaceae, Cycadaceae, Ephedraceae, Ginkgoaceae, Pinaceae, Podocarpaceae, Taxaceae, Taxodiaceae.

5.2. *Angiosperms*

Acanthaceae, Achariaceae, Actinidiaceae, Adoxaceae, Aizoaceae, Alismataceae, Amaranthaceae, Amaryllidaceae, Anacardiaceae, Annonaceae, Apiaceae, Apocynaceae, Aponogetonaceae, Aquifoliaceae, Araceae, Araliaceae, Araucariaceae, Arecaceae, Aristolochiaceae, Asclepiadaceae, Asparagaceae, Balanophoraceae, Balsaminaceae, Basellaceae, Begoniaceae, Berberidaceae, Betulaceae, Biebersteiniaceae, Bignoniaceae, Bixaceae, Boraginaceae, Brassicaceae, Bromeliaceae, Burmanniaceae, Burseraceae, Butomaceae, Buxaceae, Cactaceae, Calceolariaceae, Calycanthaceae, Calophyllaceae, Campanulaceae, Cannabaceae, Cannaceae, Capparaceae, Caprifoliaceae, Cardiopteridaceae, Caricaceae, Carlemanniaceae, Caryophyllaceae, Casuarinaceae, Celastraceae, Ceratophyllaceae, Chenopodiaceae, Chloranthaceae, Circaeasteraceae, Cleomaceae, Clethraceae, Clusiaceae, Colchicaceae, Combretaceae, Commelinaceae, Compositae, Connaraceae, Convolvulaceae,

Coriariaceae, Cornaceae, Crassulaceae, Cucurbitaceae, Cyperaceae, Daphniphyllaceae, Datisceae, Diapensiaceae, Dichapetalaceae, Dilleniaceae, Dioscoreaceae, Dipsacaceae, Dipterocarpaceae, Droseraceae, Ebenaceae, Elaeagnaceae, Elaeocarpaceae, Elatinaceae, Ericaceae, Eriocaulaceae, Euphorbiaceae, Eupteleaceae, Fagaceae, Flacourtiaceae, Garryaceae, Gentianaceae, Geraniaceae, Gesneriaceae, Gnetaceae, Grossulariaceae, Haloragaceae, Haloragidaceae, Hamamelidaceae, Hernandiaceae, Hydrangeaceae, Hydrocharitaceae, Hydroleaceae, Hypericaceae, Hypoxidaceae, Icacinaceae, Illiciaceae, Iridaceae, Iteaceae, Juglandaceae, Juncaceae, Juncaginaceae, Lamiaceae, Lardizabalaceae, Lauraceae, Lecythidaceae, Leguminosae, Lentibulariaceae, Liliaceae, Linaceae, Linderniaceae, Loganaceae, Loganiaceae, Loranthaceae, Lythraceae, Magnoliaceae, Malpighiaceae, Malvaceae, Marantaceae, Marsileaceae, Martyniaceae, Melanthiaceae, Melastomataceae, Meliaceae, Melianthaceae, Menispermaceae, Menyanthaceae, Molluginaceae, Moraceae, Morinaceae, Moringaceae, Musaceae, Myricaceae, Myristicaceae, Myrsinaceae, Myrtaceae, Nartheciaceae, Nelumbonaceae, Nitrariaceae, Nyctaginaceae, Nymphaeaceae, Ochnaceae, Olacaceae, Oleaceae, Onagraceae, Ophioglossaceae, Opiliaceae, Orchidaceae, Orobanchaceae, Osmundaceae, Oxalidaceae, Paeoniaceae, Pandanaceae, Papaveraceae, Parnassiaceae, Passifloraceae, Paulowniaceae, Pedaliaceae, Penaeaceae, Pentaphragmaceae, Phrymaceae, Phyllanthaceae, Phytolaccaceae, Piperaceae, Pittosporaceae, Plantaginaceae, Platanaceae, Plumbaginaceae, Poaceae, Podostemaceae, Polemoniaceae, Polygalaceae, Polygonaceae, Pontederiaceae, Portulacaceae, Potamogetonaceae, Primulaceae, Proteaceae, Putranjivaceae, Rafflesiaceae, Ranunculaceae, Resedaceae, Rhamnaceae, Rhizophoraceae, Rosaceae, Rubiaceae, Rutaceae, Sabiaceae, Salicaceae, Salviniaceae, Santalaceae, Sapindaceae, Sapotaceae, Saururaceae, Saxifragaceae, Schisandraceae, Scrophulariaceae, Simaroubaceae, Smilacaceae, Solanaceae, Sphenocleaceae, Stachyuraceae, Staphyleaceae, Stemonaceae, Stemonuraceae, Stylidiaceae, Styracaceae, Symplocaceae, Talinaceae, Tamaricaceae, Tetracentraceae, Tetramelaceae, Theaceae, Thelypteridaceae, Thymelaeaceae, Tiliaceae, Tofieldiaceae, Tropaeolaceae, Typhaceae, Ulmaceae, Urticaceae, Verbenaceae, Violaceae, Vitaceae, Xanthorrhoeaceae, Xyridaceae, Zingiberaceae, Zygophyllaceae.

6. Methods

We conducted an extensive literature survey of all available 31 floras comprising 42 volumes and 9 parts, published in the Indian Himalayan region, Nepal, and Bhutan [10–57]. As noted above, we divided the Himalayan range into six sub-regions i.e., Arunachal Pradesh, Bhutan & Sikkim (including parts of northern west Bengal), Nepal, Uttarakhand, Himachal Pradesh and Jammu & Kashmir (Figure 1), because floras were mostly documented for these administrative regions. Geographical coverage of published floras ranges from small areas covering an administrative district to the whole state or country in the Himalaya, e.g., Nepal and Bhutan. Thus, for the compilation of species checklists at the sub-regional level, we considered all floras together, which were published within geographical domains of the sub-region. The lowest and highest elevation range of each species was based on the maximum and minimum from any flora within the sub-region. A complete checklist of all seed plants reported from each of the six sub-regions (Figure 1) was first compiled with information on the life form and elevational distribution. Finally, a complete checklist of all seed plants reported from the entire Himalaya was collated based on the information available in the floras within six sub-regions. The number of species reported from each sub-region were used to evaluate the differences in species richness across the Himalaya.

Since species names reported in these floras ranges over a 100 year, taxonomy status of many of the species have been updated with revised classifications and taxonomic updates. Although some of the recently published floras have updated the revised nomenclature of species, such updates are still lacking for most of the Himalayan regions. Thus, we evaluated all botanical names reported in the floras for their latest taxonomic updates on www.theplantlist.com (The Plant List, 2013) [62]. This taxonomic evaluation helped us in the identification of >3000 botanical names, which were either reported as a synonym of another species from the Himalaya already reported or a synonym of another

species from outside. We eliminated all these synonyms with the latest available updated on species name. We further updated current information on the taxonomic status of all species i.e., if a species is presently accepted or unresolved (approximately 20% of all species in the Plant List are considered unresolved due to lack of information, or because of disputes among taxonomists). After completion of taxonomic assessment, species names were matched with the GBIF database www.gbif.org [63] and species occurrences in each of the six sub-regions within the Himalaya was submitted on GBIF portal with associated information on elevational ranges.

7. Data Summary

A total of 10,503 species are reported from the Himalayan region representing 240 families and 2322 genera. Of these, 1206 are reported to be alien species. Orchidaceae is the dominant family with 783 species (7.5% of all species), whereas *Carex* is the dominant genus with 124 species (1.2% of all species). Across the six sub-regions, Bhutan & Sikkim have the highest number of recorded species (6283) followed by Nepal (5516), Uttarakhand (4990), Arunachal Pradesh (4503), Himachal Pradesh (3324), and Jammu & Kashmir (2118). The number of species, genera, and families declines similarly from Bhutan & Sikkim to Jammu & Kashmir, but Arunachal Pradesh shows a lower number of taxa than Bhutan & Sikkim (Figure 2). This may be a result of under-exploration of plants in Arunachal Pradesh. Once Arunachal Pradesh is excluded, the total number of recorded species declines from Eastern Himalaya towards Northwest Himalaya. Tropical families, including the Orchidaceae and Rubiaceae, decline in species numbers from East to Northwest Himalaya, whereas families with temperate or cosmopolitan affinities representing grasses, sedges, and herbaceous life forms have the highest number of species in the central parts of the Himalaya including Bhutan, Nepal, and Uttarakhand. However, most of the families have a relatively small number of species in the largely temperate Northwest Himalayan region of Jammu & Kashmir.

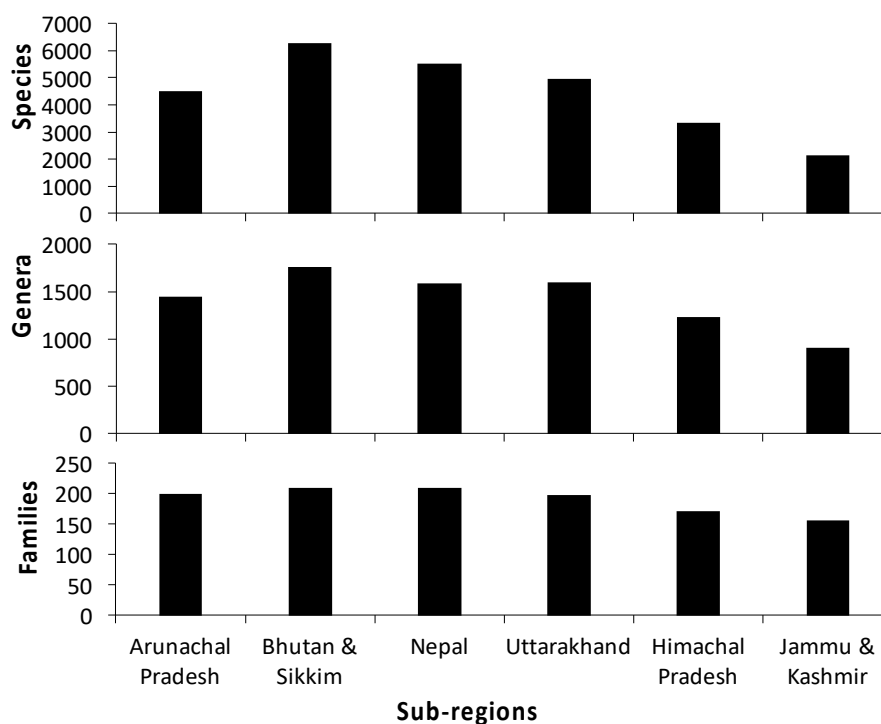


Figure 2. Number of species, genera, and families reported in each of the six sub-regions of the Himalaya. Species and genera show a prominent decline in number from Bhutan & Sikkim in East to Jammu & Kashmir in Northwest Himalaya, whereas families show a slight difference. Arunachal Pradesh in the eastern-most part of the Himalaya shows comparatively lesser taxa.

The different life forms include 1382 trees, 1542 shrubs, 6350 herbs, 573 woody climbers, 285 herbaceous climbers, and 371 epiphytes. Among the 10,503 species reported in published floras across the Himalaya, 1134 species (Appendix A) are either unassessed or unplaced taxonomically and hence are recorded as unresolved in the global working list of plants (The Plant List, 2013). Most of these unresolved species belongs to families which are under peer review process in World Checklist of Selected Plant Families (WCSP in review): <http://wcsp.science.kew.org/home.do> [64] and Tropicos: <http://www.tropicos.org> [65]. List of top ten genera with highest number of unresolved species and their percentage in respective family in Himalaya is given in Table 1. These genera and families thus needs further evaluation by conducting taxonomic and ecological studies in Himalaya. We provide information on distribution and elevational ranges of all unresolved species and a column on nomenclatural annotation in Appendix A. We further provide a link to The Plant List identifier of the species, which in turn will be linked to respective IPNI identifier and many other global plant databases for further evaluation of the taxonomic uncertainties. Additionally, 160 species (Appendix B) in the compilation were not found in The Plant List database, which may be cases of spelling variants or rare Himalayan species that have not been reported to the global plant databases. Thus, efforts are required especially from the plant taxonomists working in the Himalayan region to conduct more surveys and sampling and provide updated information for unresolved species in The Plant List (2013) database as well as for species, which are absent in this global working list of plants. Taxonomic evaluation of these data-deficient species will result in better assessment of plant species richness in the Himalaya.

Table 1. Top ten genera with highest number of unresolved species in Himalaya.

Genus	Family	Unresolved Species	Percentage
<i>Pedicularis</i>	Orobanchaceae	63	37.3
<i>Saxifraga</i>	Saxifragaceae	44	35.2
<i>Primula</i>	Primulaceae	40	18.1
<i>Impatiens</i>	Balsaminaceae	31	34.8
<i>Rubus</i>	Rosaceae	31	8.1
<i>Cotoneaster</i>	Rosaceae	25	6.5
<i>Potentilla</i>	Rosaceae	24	6.3
<i>Strobilanthes</i>	Acanthaceae	22	12.5
<i>Rhododendron</i>	Ericaceae	20	11.6
<i>Euphrasia</i>	Orobanchaceae	20	11.8

Supplementary Materials: Appendixs A and B are available online at <https://www.gbif.org/dataset/0bddc88d-8586-4889-9340-4a86eb63abe4>.

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Author Contributions: S.K.R. and G.S.R. conceived and designed the study, S.K.R. compiled the data from published floras, G.S.R. provided inputs for species with taxonomic issues, S.K.R. wrote the first manuscript and both authors finalized the paper.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The appendix contains a checklist of 1134 species reported in the floras published from the Himalaya and are under the Unresolved category of The Plant List (2013), which presently are either unassessed or unplaced for their taxonomic position due to a lack of sufficient supporting information.

Appendix B

The appendix provides a checklist of 160 species reported in the floras published from the Himalaya, but there is no information about these species in The Plant List (2013), which is the global working list of all known plants.

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