Diversity and Distribution of Medicinal Plant Species in the Central Himalaya, India

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Abstract: In this study, we examined diversity and distribution of medicinal plant species richness between 200-5800m asl altitudes considering altitudinal gradients (200m asl altitudinal differences) in the Indian central Himalaya off which 126 were trees, 129 shrubs and 548 herbs. The total number of species, genera and families observed for herbs were maximum followed by tree and shrub species. In terms of species distribution Fabaceae and Rutaceae were found to be the most dominant family in tree species; Verbenaceae and Fabaceae in shrub species whereas in case of herb species, Asteraceae was found to be the dominant family. The total number of species including all growth forms was maximum near low altitude to mid altitude due to overlapping of climatic conditions, but further increase in altitude it decreased consistently, probably due to decrease in atmospheric temperature with increase in altitudes. [Researcher. 2009;1(1):61-73]. (ISSN: 1553-9865).

Key words: Plant species, diversity, distribution, altitude, central Himalaya

Introduction

Diversity, the variety and variability of plant and animal species are the most striking feature of life, which reflects the complexity, uniqueness, and intactness of natural ecosystems (Mohammad *et. al.*, 2000). An appropriate biodiversity management strategy should take into account the distribution patterns of species (Perring and Lovett 1999). Conservation of ecosystem and maintenance of biodiversity in central Himalaya is matter of both national and international concern.

Central Himalaya is one of the biodiversity rich states of India in terms of vegetation and flora varied altitude, topography, status of soil and climatic conditions which favors high species richness and support different forest types. Deciduous and evergreen tropical forests, subtropical, semi evergreen and sub tropical pine forest are the major forest type of this state (Champion & Seth, 1968). The wide geographical and climatic diversity provides a repository of valuable medicinal and wild edible plants of the region.

The use of the plant species of the Himalaya as medicine is known since the long time and about 1750 medicinal plants is reported from Indian Himalaya by Samant *et al.,* (1998). The unique diversity of medicinal plants in the region is manifested by the presence of a number of native (31%), endemic (15.5%) and threatened elements (14%) of total Red Data Book plant species of Indian Himalaya Region (Samant *et al.,* 1998). Plants provide food and other life supporting commodities and very important for survival of human beings and other organisms, besides they protect our environment and maintain nature. Tropical forests are major reservoir of plant diversity. Those forests inhabit a large number of trees, shrubs, herbs,

climbers, faunal, wealth and a wealth of non-timber forest products including medicinal and wild edible plants. The increased demand of medicinal plants in drug and pharmaceutical industries have caused the over exploitation of many species. Many of these are close to extinction due to over harvesting or un-skilled harvesting. Some important species that need immediate attention for conservation in India are *Aconitum*, *Angelica*, *Artemisia*, *Atropa*, *Berberis*, *Dectylorhiza*, *Thalictrum*, *Hedychium* etc. To maintain the ecosystem equilibrium, awareness of the sustainable utilization of these species is important and their conservation in sustainable environment is urgently needed, keeping in view the demand among the hill communities and their drugs in the global market (Samant and Dhar, 1997; Dubay *et al.*, 2004). Wide geographical and climatic diversity provides a repository of valuable medicinal and wild edible plants of this region. Therefore the present study is an effort to identify important medicinal plants in this region based on primary and secondary resources.

The objectives of the present study were (i) to find out species richness in relation to different altitudinal range (ii) to analyze the pattern plant species variation between 200 m altitudinal gradient (iii) to examine the variation in nature of plant forms in respect to altitude.

Material and Methods

The field survey was conducted in different forest sites surrounding the Nainital catchments of Kumaun region in the Central Himalaya and the information provided by the secondary resources (Samant *et al.*, 1998) and available literature (Chopra *et al.*, 1956). The study area is located between 79°23' and 79°42' E longitude and 29°20' and 29°30' N latitude between 1500m to 2600m elevations in central Himalaya. Five sites were selected in the wide elevation range along the gradient of disturbances. Several field trips were undertaken for collection of plants during different years.

The climate is monsoon temperate and annual rainfall of the area is 2668 mm/year. The mean maximum temperature varies from 13.9 (Feb) to 23.7°C (April) and the mean minimum from 4.9 (Feb) to 16.5°C (July). The monsoon strikes in this area in the middle of June to the middle of September, which sometimes extends to late September and first week of October. The bedrock belongs to the Krol formation consists predominantly of carbonate, limestone, marl and slates in the lower part and dolomites in the upper part (Valdia, 1980).

For moisture content, 50g of fresh soil was dried in an oven at 80°C temperature till constant weight (Misra, 1968). For determination of soil pH, soil extract was assessed by digital pH meter using 1:5 proportions of soil and water. Soil organic carbon was determined using the wet oxidation method (Jackson, 1958). Percentage of organic matter was obtained by multiplying the % of organic carbon by a factor of 1.724. This factor is based upon the assumption that the organic matter of soil contains 58% carbon (Misra, 1968). Nitrogen content of soil was determined by Kjel Auto Vs-KTP Nitrogen Analyzer based on a micro-Kjeldahl technique (Misra, 1968).

The vegetation analysis of each forest site was carried out by using 10, 10m × 10m quadrats placed randomly for tree layer. The number and size of the quadrats were determined by Running Mean

Method (Kershaw, 1973) and species area curve (Misra, 1968). Shrubs were sampled by using 10, 5m × 5m quadrats randomly. For the study of herbaceous vegetation, fifteen quadrats (1m × 1m) were placed on the above selected area in each of the forest/stands (hill-base, hill-slope and hill-top). Herbaceous vegetation was studied through tiller analysis. Each tiller of grasses was considered as an individual plant (Singh, 1967). In the case of creeping plant any unit of the plant having functional roots was considered as one plant. Vegetational data were analyzed following Curtis & McIntosh (1950), Species evenness (Margalef 1968), dominance (Simpson, 1949) and diversity (Shannon-Weaver, 1963) for the primary data.

Results and Discussion

Extensive survey of the locality of Central Himalayan region of Nainital area was made for the proposed study. A total of 166 species belonging to 61 family were recorded across the study sites, of which 16 were trees, 37 were shrubs and 113 were herbs (Table 1).

Percentage of sand in soil ranged from 50% to 65%. It was maximum in highly disturbed sites and reduced with decreasing disturbances. The value of silt and clay in different sites were 17.9-30% and 11-28.8% respectively. Moisture content of soil ranged from 29% to 65% and soil pH varied from 5.3 to 8.0. It was lower in the low elevation high-disturbed sites and higher in the high elevation less disturbed sites. There was no significant difference in the organic matter in high and less disturbed sites. It was comparatively higher in the oak forests towards higher elevations. The percentage value of carbon, nitrogen and organic matter in different sites were 1.2-3.4, 0.1-0.3 and 4.0-5.9, respectively. Percentage nitrogen also increased with increase in total organic matter.

Sandy loam soil is preponderance in lower elevation and clay loam in higher elevation (above 2200m asl). The pH of the soil was slightly acidic (6.65) to neutral (6.5-7), but in higher altitudes (above 2800-3000m asl) to medium (5.5-6) was strongly acidic. Organic matter content ranged from less than 1% to 4%. The soil moisture content varied from 21-43% at -3 bar water potential and 7.6-14.8% at -15bar water potential (Singh & Singh, 1987).

There was a positive relationship between shrubs and herbs diversity, and both increased with increasing disturbances. The tree, shrub and herb density were (5.1-9.5 ind/100m^2, 1.1-7.2 ind/25m^2 and 9.3- 34.7 ind/m^2 respectively. The diversity values for tree, shrub and herb species were ranged between 0.2-1.6, 1.9-3.3 and 3.2-4.0, respectively. ANOVA tests for tree, shrub and herb species (between species richness and diversity) showed significant variation at 5% level. Significant positive relations were found between moisture and density of shrubs ($P < 0.01$), and also moisture and density of herbs ($P < 0.05$). Equitability values for tree, shrub and herb species were 1.1-4.4, 12.7-19.4 and 16.7-28.8, respectively. The concentration of dominance in tree, shrub and herb species was 0.6-0.9, 0.2-0.6 and 0.08-0.6, respectively.

Based on secondary resources, a total of 777 species were found out of which a total of 126 tree species was encountered, belonging to 49 families and 52 genera. Fabaceae and Rutaceae were the most dominant family (with nine species) followed by Moraceae (with eight species), Rubiaceae (with seven species), Caesalpiniaceae (with six species), Meliaceae and Rosaceae (with five species), Anacardiaceae,

Bignoniaceae, Combretaceae, Lauraceae (with four species), Apocynaceae, Elaegnaceae, Fagaceae, Mimosaceae, Oleaceae, Pinaceae, Pistaciaceae, Sapindaceae (with three species), Burseraceae, Capparaceae, Euphorbiaceae, Mytricaceae, Pittosporaceae, Rhamnaceae, Tiliaceae (with two species), whereas the remaining 22 families were represented by one species each (Table 2).

The study showed that tree species distributed between <200-3600m asl altitude. At 200m asl altitudinal differences species ranged between 4 and 115 species, being minimum at 3400-3600 m asl and maximum at 1000-1200m asl and it declined thereafter with increasing altitude (Fig 1). A number of tree species found in the Himalaya showed varying patterns of distribution. The extension of climatic gradient enabled several species to realize their fullest range of elevational adaptability. Distributional ranges of several species were segregated along the widened altitudinal ranges (Singh & Singh, 1992).

A total of 129 shrub species was reported belonging 40 family 87 genera in which Verbenaceae and Fabaceae was the dominant family (nine species) followed by Asclepiadaceae (eight species), Apocynaceae, Berberidaceae, Caesalpiniaceae, Rosaceae (seven species), Euphorbiaceae (six species), Asparagaceae, Vitaceae (five species), Convolvulaceae, Loranthaceae, Periplocaceae, Rhamnaceae, Rutaceae, Urticaceae (three species), Celastraceae, Ericaceae, Myrsinaceae, Oleaceae, Polygonaceae, Rubiaceae, Solanaceae, Tiliaceae (two species) and 11 family represented by single species (Table 2).

Species richness of shrubs varied from <200 to 5600m asl altitudinal range. The distribution pattern of shrub species varied from 1(5400-5600m asl) to 73 (800-1200m asl) species. From 200-1200m asl, species richness increased sharply with altitude, thereafter species richness declined towards higher altitudes (Fig. 1).

Similarly, in case of herb species, a total of 548 belonging to 85 family were encountered. Asteraceae was the dominant family (with fifty-four species), followed by Lamiaceae (with thirty seven species), Poaceae (with twenty-nine species), Fabaceae, Orchidaceae(with twenty-seven species), Ranunculaceae (with twenty-two species), Apiaceae, Gentianaceae (with nineteen species), Solanaceae, Zingiberaceae Periplocaceae (with fifteen species), Scrophulariaceae, Euphorbiaceae (with thirteen species), Rubiaceae (with twelve species), Cucurbitaceae (with eleven species), Brassicaceae (with ten species), Convolvulaceae, Linaceae, Malvaceae, (with nine species), Alliaceae, Borginaceae (with eight species), Fumariaceae, Iridaceae (with six species), Acanthaceae, Geraniaceae, Violaceae, Rosaceae, Verbenaceae, Menispermaceae, Araceae (with five species), Amaranthaceae, Commelinaceae, Dioscoreaceae, Crassulaceae, Valerianaceae, Papaveraceae, (with four species), Caryophyllaceae, Chenopodiaceae, Geraniaceae, Mimosaceae, Papaveraceae, Polygonaceae (with three species), Achyranthaceae, Asclepiadaceae, Balsminaceae, Aristolochiaceae, Cannabaceae, Peperomiaceae, Leeaceae, Linaceae, Hypericaceae, Onagraceae, Hypodixaceae, Nyctaginaceae, Plumbaginaceae, Paranassiaceae, Piperaceae, Primulaceae, (with two species) whereas the remaining 26 families were represented by one species each (Table 2).

Herbs were the largest contributor of plant richness among the others forms and were distributed between <200-5800m asl. Herb richness ranged from 1 (5600-5800 m asl) and 202 (1400-1600m asl). The

herb richness declined slightly at an elevation of 2800-3000m asl; after that it increased slightly upto 3800m asl and subsequently it declines.

It is well fact that the altitude represents a complex gradient along which many environmental variables change concomitantly. However, in general, it has been suggested that an increase of 270m asl altitudes corresponds to a fall of 1ºC in mean atmospheric pressure upto 1500m asl, above which the fall is more rapid (Osmaston, 1927). Pangtey *et al.* (1991) argued the effect of monsoon is not substantially weakened at higher altitudes and also the amount of rainfall is not much different from that of the lower altitudinal range of central Himalaya.

There were pronounced effect of elevation on different edhapic factors (elevation vs. soil moisture content, elevation vs. soil pH) and total plant species richness and a positive relation between soil moisture and plant species richness of the area but there was no relationship found between soil pH and plant species richness (Kharkwal et al., 2005). On the other hand, the distribution of plant species depends mainly on the altitude and climatic variables like temperature, rainfall, which act as the sole determinant for the species richness in this region.

The pattern of proportions of family to genera, family to species and genera to species were found to be similar for primary and secondary resources (Table 3). Margalef's index for herb species in chir-pine was maximum. Shannon-Weaver index for species diversity showed a higher value for Kharsu oak forest (Table 4). Simpson index was higher for Tilonj-oak and Chir-pine than other forests indicating that few species were dominant in that forest type (Table 4). The Simpson index was higher for Tilonj-oak and Chir-pine forest as compared to other forest indicating lower stability of these forests. Whittaker value varied for all forest types.

The various parts of plant species are used for different purposes i.e. food for humans medicine, fuel, timber and multipurpose. For example, species of *Quercus* provide excellent fuel and timber, seeds of *Myrica esulenta*, rhizome of *Valeriana wallichii* and *Hedychium spicatum* etc are traded and are source of income generation in the area (Samant and Dhar, 1997). The results of the present study open new prospect of plant materials used in traditional medicine which will promote forest conservation and ecological research through surveys, development and implementation of land use plans by proper planting, afforestation, reforestation and forest rehabilitation. Such medicinal plants could also be incorporated into primary health care, as people generally feel safer with indigenous cures and also the costs of medicine would be much lesser than modern drugs.

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Table 1. A list of plants encountered in the study sites.

Species	Family	Habit
1. Acer oblongum Wall. ex DC.	Aceraceae	T
2. Achyranthes aspera	Amaranthaceae	H
3. Achyranthes bidentata Blume	Amaranthaceae	H
4. Aesculus indica (Colebr. ex Camb.) Hook.	Hippocastanaceae	T
5. Ageratum houstonianum Mill.	Asteraceae	H
6. Agrimonia pilosa Ledeb.	Rosaceae	H
7. Ainsliaea aptera DC.	Asteraceae	H
8. Ainsliaea latifolia (D. Don) Sch.-Bip.	Asteraceae	H
9. Ajuga parviflora Benth.	Lamiaceae	H
10. Anaphalis busua (Buch-Ham. ex D. Don) DC.	Asteraceae	H
11. Anaphalis cinnamonea Clarke	Asteraceae	H
12. Anaphalis contorta (D. Don) Hook. fil.	Asteraceae	H
13. Anemone vitifolia Buch.-Ham. ex DC.	Ranunculaceae	H
14. Arisaema tortuosum (Wall.) Schott	Araceae	H
15. *Artemisia nilagarica (*C.B. Clarke) Pamp.	Asteraceae	S
16. Arthraxon prionodes (Steud.) Dandy	Poaceae	H
17. Arundinaria falcate Nees	Poaceae	S
18. Aster asperculus (DC.) Hook. fil.	Asteraceae	H
19. Aster thomsonii Clarke	Asteraceae	H
20. Athyrium foliolosum Wall. ex Smith	Athyriaceae	H
21. Athyrium rupicola (Hope) C. Chr.	Athyriaceae	H
22. Begonia picta Smith	Begnoniaceae	H
23. Berberis asiatica Roxb. ex D. Don	Berberidaceae	S
24. Bidens biternata L.	Asteraceae	H
25. Bidens pilosa L.	Asteraceae	H
26. Biota orientalis (L.) Endl.	Cupressaceae	T
27. Boenninghausenia albiflora Reich. ex Meisn.	Rutaceae	S
28. Bupleurum tenue Buch.-Ham. ex D. Don	Apiaceae	H
29. Campanula colorata Wall.	Campanulaceae	H
30. Carex cruciata Wahlenb.	Cyperaceae	H
31. Carex nubigena Tilloch &Taylor	Cyperaceae	H
32. Carpesium cernuum L.	Asteraceae	H
33. Carum anathifolium Benth.	Apiaceae	H
34. Cassia floribunda Cav.	Caelapiniaceae	S
35. Cassia laevigata Willd.	Caesalpiniaceae	S
36. Cassia mimosoides L.	Caesalpiniaceae	H
37. Cedrus deodara (Roxb. ex D. Don) G. Don	Pinaceae	T
38. Celtis tetrasperma Roxb.	Ulmaceae	S
39. Centella asiatica (L.) Urban	Apiaceae	H
40. Circaea alpina L.	Onagraceae	H
41. Circaea lutea L.	Onagraceae	H
42. Clinopodium umbrosum (M. Bieb.) Koch	Lamiaceae	H
43. Colquehonia coccinea Wall.	Lamiacaea	S
44. Commelina benghalensis L.	Commelinaceae	H
45. Conyza japonica Thunb. Lessing ex DC.	Asteraceae	H
46. Conyza stricta Willd.	Asteraceae	H
47. Coriaria nepalensis Wall.	Coriariaceae	S
48. Cornus oblonga Wall.	Cornaceae	T
49. Cotoneaster microphylla Wall. ex Lindl.	Rosaceae	S
50. Craniotome furcata (Link) Kunze	Lamiaceae	H
51. Crotalaria sessibiflora L.	Fabaceae	H
52. Cupressus torulosa D. Don	Cupressaceae	T
53. Cynoglossum glochidiatum Wall. ex Benth.	Boraginaceae	H
54. Cynoglossum lanceolatum Forsk.	Boraginaceae	H

55. *Cyperus niveus* Retz.	Cyperaceae	H
56. *Daphne cannabina* Wall.	Thymelaeaceae	S
57. *Debregeasia longifolia* (Burm. fil.) Wedd.	Urticaceae	S
58. *Debregeasia salicifolia* (D. Don) Rendle	Urticaceae	S
59. *Desmodium multiflorus DC.*	Fabaceae	H
60. *Deutzia staminea* R.Br.	Saxifragaceae	S
61. *Dicliptera bupleuroides* Nees	Acanthaceae	H
62. *Dipsacus mites* D. Don	Dipsacaceae	H
63. *Epilobium royleanum* Haussk.	Onagraceae	H
64. *Epipactis latifoila* (L.) Alloini	Orchidaceae	H
65. *Erigeron bonariensis* L.	Asteraceae	H
66. *Erigeron annua* (L.) Pers.	Asteraceae	H
67. *Erigeron karvinskianus* DC.	Asteraceae	H
68. *Eupatorium adenophorum* Spreng.	Asteraceae	S
69. *Flemingia bracteata* (Roxb.) Wight	Fabaceae	H
70. *Flemingia involucrate* Benth.	Fabaceae	S
71. *Fragaria indica* Andrews	Rosaceae	H
72. *Fraxinus micrantha* Lingelsheim	Oleaceae	T
73. *Galinsoga ciliata* (Rafines.-Sch.) Blake	Asteraceae	H
74. *Galium aparina* L.	Rubiaceae	H
75. *Galium rotundifolium* L.	Rubiaceae	H
76. *Geranium nepalense* Sweet	Geraniaceae	H
77. *Geranium wallichianum* D. Don ex Sweet	Geraniaceae	H
78. *Gerbera gossypina* (Royle) G.Beauv.	Asteraceae	H
79. *Girardiana heterophylla* (Vahl) Decne.	Urticaceae	S
80. *Goodyera repens* (L.) R.Br.	Orchidaceae	H
81. *Habernaria latilabris* (Lindl.) Hook. fil.	Orchidaceae	H
82. *Hedychium spicatum* Buch.-Ham. ex J.E.Smith	Zingiberaceae	H
83. *Hypericum oblongifolium* Choisy	Hypericaceae	S
84. *Ilex dipyrena* Wall.	Equifoliaceae	T
85. *Indigofera heterantha* Wall. ex Brandis	Fabaceae	S
86. *Jasminum humile* L.	Oleaceae	S
87. *Justicia simplex* D. Don	Acanthaceae	H
88. *Lantana camara* L.	Verbenaceae	S
89. *Lepidium virginianum* L.	Brassicaceae	H
90. *Leucas lanata* Benth.	Lamiaceae	H
91. *Lindenbergia indica* (L.) Vatke	Scrophulariaceae	H
92. *Litsea umbrosa* Nees	Lauraceae	T
93. *Lonicera quinquelocularis* Hardw.	Caprifoliaceae	S
94. *Lychnis fimbricata* Wall. ex Benth.	Caryophyllaceae	H
95. *Lyonia ovalifolia* (Wall.) Drude	Ericaceae	T
96. *Meizotropis pellita* (Hook.fil. ex Prain) Sanjappa	Fabaceae	S
97. *Melissa fllava* Benth.	Lamiaceae	H
98. *Micromeria biflora* (Buch.-Ham.ex D. Don) Benth.	Lamiaceae	H
99. *Myrica esculenta* Buch.-Ham. ex D. Don	Myricaceae	T
100. *Myrsine Africana* L.	Myrsinaceae	S
101. *Neanotis calycina* (Wall. ex Hook.fil.) Lewis	Rubiaceae	H
102. *Nervilea crispate* (Blume) Schltr.	Orchidaceae	H
103. *Onchychium cryptogrammoides* C.Chr.	Cryptogrmmaceae	H
104. *Oplismenus compositus* (L.) P.Beauv.	Poaceae	H
105. *Origanum vulgare* L.	Lamiaceae	H
106. *Oryzopsis aequiglumis* Duthie ex Hook.fil.	Poaceae	H
107. *Oxalis corniculata* L.	Oxalidaceae	H
108. *Oxalis latifolia* BHK	Oxalidaceae	H
109. *Paris polyphylla* J.E.Smith	Liliaceae	H
110. *Pilea umbrosa* Wedd.	Urticaceae	H

111. *Pilea scripta* (Buch.-Ham.ex D. Don) Wedd.	Urticaceae	H
112. *Pimpinella acuminate* (Edgew.) Clarke	Apiaceae	H
113. *Pimpinella diversifolia* DC.	Apiaceae	H
114. *Pinus roxburghii* Sarg.	Pinaceae	T
115. *Platystemma violoides* Wall.	Gesneriaceae	H
116. *Plectranthus striatus* Benth.	Lamiaceae	H
117. *Plectranthus japonicus* (Burm.fil.) Koidz.	Lamiaceae	H
118. *Polycarpaea corymbosa* (L.) Lam.	Caryophyllaceae	H
119. *Polygonum hydropiper* L.	Polygonaceae	H
120. *Polygonum amplexicaule* D. Don	Polygonaceae	H
121. *Polygonum nepalense* Meisn.	Polygonaceae	H
122. *Potentilla nepalensis* Hook.	Rosaceae	H
123. *Pouzolzia hirta* (Blume) Hassk.	Urticaceae	H
124. *Prinsepia utilis* Royle	Rosaceae	S
125. *Pteris cretica* L.	Pteridaceae	H
126. *Pyracanthus crenulata* (D. Don) M.Roem.	Rosaceae	S
127. *Quercus floribunda* Lindl. ex Rehder	Fagaceae	T
128. *Quercus leucotrichophora* A. Camus	Fagaceae	T
129. *Quercus semecarpifolia* J.E. Smith	Fagaceae	T
130. *Randia tetrasperma* (Wall.) Hook.fil.	Rubiaceae	S
131. *Rhamnus virgata* Roxb.	Rhamnaceae	S
132. *Rhododendron arboretum* Smith	Ericaceae	T
133. *Rosa moschata* Mill. ex Herrm.	Rosaceae	S
134. *Roscoea purpurea* J. E. Smith	Zingiberaceae	H
135. *Rubus ellipticus* Smith	Rosaceae	S
136. *Rubus lasiocarpus* Smith	Rosaceae	S
137. *Rumex hastatus* D. Don	Polygonaceae	H
138. *Sanicula elata* Buch.-Ham. ex D. Don	Apiaceae	H
139. *Sarcococa hookeiana* Baill	Buxaceae	S
140. *Satyrium nepalense* D. Don	Orchidaceae	H
141. *Scutellaria angulosa* Benth.	Lamiaceae	H
142. *Sedum sinuatum* Royle ex Edgew.	Crassulaceae	H
143. *Selinum wallichianum* (DC.) Raizada & Saxena	Apiaceae	H
144. *Setaria glauca* (L.) P. Beauv.	Poaceae	H
145. *Setaria homonyma* (Steud.) Choiv.	Poaceae	H
146. *Siegesbeckia orientalis* L.	Asteraceae	H
147. *Smilax vaginata* Decne.	Smilacaceae	S
148. *Solidago virg-aurea* L.	Asteraceae	H
149. *Stachys sericea* Wall. ex Benth.	Lamiaceae	H
150. *Swertia pulchella* Buch.-Ham. ex D. Don	Gentianaceae	H
151. *Swertia ciliata* Burtt.	Gentianaceae	H
152. *Synotis rufinervis* (DC.) C. Jeffrey & Y.L.Chen	Asteraceae	H
153. *Teucrium royleanum* Wall. ex Benth.	Lamiaceae	H
154. *Thalictrum foliolosum* DC.	Ranunculaceae	H
155. *Themeda anathera* (Nees ex Steud.) Hack.	Poaceae	H
156. *Torenia cordiflora* Roxb.	Scrophulariaceae	H
157. *Torilis japonicus* (Houtt.) DC.	Apiaceae	H
158. *Urena lobata* L.	Malvaceae	H
159. *Utrica dioica* L.	Urticaceae	S
160. *Valeriana wallichii* DC.	Valerianaceae	H
161. *Viburnum continifolium* D. Don	Caprifoliaceae	S
162. *Viburnum coriaceum* Blume	Caprifoliaceae	S
163. *Viola canescens* Wall.	Violaceae	H
164. *Viola pilosa* Blume	Violaceae	H
165. *Wikstroemia canescens* Meisn.	Thymelaeaceace	S
166. *Wulfenia amherstiana* Benth.	Scrophulariaceae	H

Table 2. Family-wise contribution to genera and species

Species	Tree		Shrub		Herb	
	Genus	Species	Genus	Species	Genus	Species
Acanthaceae	-	-	1	1	1	5
Achyranthaceae	-	-	-	-	1	2
Agavaceae	-	-	1	1	-	-
Alangiaceae	1	1	-	-	-	-
Alliaceae	-	-	-	-	1	8
Amaranthaceae	-	-	-	-	2	4
Amaryllidaceae	-	-	-	-	1	1
Anacardiaceae	4	4	1	1	-	-
Annonaceae	3	3	-	-	-	-
Apiaceae	-	-	-	-	16	19
Apocynaceae	1	1	7	7	-	-
Araceae	-	-	-	-	4	5
Araliaceae	1	1	1	1	-	-
Arecaceae	3	3	-	-	-	-
Aristolochiaceae	-	-	-	-	1	1
Asclepiadaeae	-	-	6	8	2	2
Asparagaceae	-	-	3	5	-	-
Asteraceae	-	-	-	-	43	54
Athyriaceae	-	-	-	-	-	-
Balsminaceae	-	-	-	-	1	2
Berberdiaceae	-	-	2	7	-	-
Betulaceae	1	1	-	-	-	-
Bignoniaceae	3	4	-	-	-	-
Bombaceae	1	1	-	-	-	-
Borginaceae	-	-	-	-	7	8
Brassicaceae	-	-	-	-	8	10
Burseraeae	2	2	-	-	-	-
Caesalpiniaceae	3	6	3	7	1	1
Campanulaceae	-	-	-	-	-	-
Cannbaceae	-	-	-	-	2	2
Capparaceae	1	2	1	2	-	-
Caprifoliaceae	1	1	-	-	-	-
Cariaceae	-	-	-	-	1	1
Caryophyllaceae	-	-	-	-	3	3
Caryophyllaceae	-	-	-	-	3	3
Celastraceae	1	1	2	2	-	-
Chenopodiaceae	-	-	-	-	2	3
Clemaceae	-	-	-	-	1	1
Combretaceae	1	4	1	1	-	-
Commelinaceae	-	-	-	-	3	4
Convolvulaceae	-	-	2	3	7	9
Costaceae	-	-	-	-	1	1
Crassulaceae	-	-	-	-	2	4
Cryptogrammaceae	-	-	-	-	-	-
Cucurbitaceae	-	-	-	-	3	11
Cyperaceae	-	-	-	-	1	1
Dioscoreaceae	-	-	-	-	1	4
Dipsacaceae	-	-	-	-	-	-
Dipterocarpaceae	1	1	-	-	-	-
Droseraceae	-	-	-	-	1	1
Elaeagnaceae	3	3	1	1	-	-
Ephederaceae	-	-	1	1	-	-

Ericaceae	1	1	1	2	1	1
Euphorbiaceae	2	2	5	6	10	13
Fabaceae	7	9	6	9	16	27
Fagaceae	3	3	-	-	-	-
Fumariaceae	-	-	-	-	2	6
Gentianaceae	-	-	-	-	9	19
Geraniaceae	-	-	-	-	2	5
Hydrangeaceae	-	-	2	2	-	-
Hypericaceae	-	-	-	-	1	2
Hypoxidaceae	-	-	-	-	1	2
Iridaceae	-	-	-	-	3	6
Julandaceae	-	-	-	-	1	1
Lamiaceae	-	-	2	2	29	37
Lauraceae	4	4	-	-	-	-
Leeaceae	-	-	-	-	1	2
Liliaceae	-	-	-	-	12	16
Linaceae	-	-	-	-	2	2
Loranthaceae	-	-	2	3	-	-
Lythraceae	-	-	1	1	-	-
Malvaceae	1	1	3	6	8	9
Meliaceae	5	5	-	-	-	-
Menispermaceae	-	-	-	-	3	5
Mimosaceae	2	3	1	1	2	3
Molluginaceae	-	-	-	-	1	1
Moraceae	3	8	-	-	-	-
Morinaceae	-	-	-	-	1	1
Musaceae	-	-	-	-	1	1
Myricaceae	1	1	-	-	-	-
Myrsinaceae	-	-	2	2	-	-
Myrtaceae	2	2	-	-	-	-
Nelumbonaceae	-	-	-	-	1	1
Nyctaginaceae	-	-	-	-	2	2
Nymphaceae	-	-	-	-	1	1
Ochnaceae	1	1	-	-	-	-
Oleaceae	2	3	2	2	-	-
Onagraceae	-	-	-	-	2	2
Orchidaceae	-	-	-	-	12	27
Oxalidaceae	-	-	-	-	2	3
Paeoniaceae	-	-	-	-	1	1
Pandanaceae	1	1	-	-	-	-
Papaveraceae	-	-	-	-	3	4
Paranassiaceae	-	-	-	-	1	2
Pedaliaceae	-	-	-	-	1	1
Pedaliaceae	-	-	-	-	1	1
Peperomiaceae	-	-	-	-	1	2
Periplocaceae	-	-	3	3	5	15
Phytolaccaceae	-	-	-	-	1	1
Pinaceae	3	3	-	-	-	-
Piperaceae	-	-	-	-	1	6
Pistaciaceae	2	3	-	-	-	-
Pittosporaceae	1	2	-	-	-	-
Plumbaginaceae	-	-	-	-	1	2
Poaceae	-	-	-	-	24	29
Podophyllaceae	-	-	-	-	1	1
Polygonaceae	-	-	2	2	1	3
Portlaceae	-	-	-	-	1	1

Primulaceae	-	-	-	-	2	2
Punicaceae	1	1	-	-	-	-
Ranunculaceae	-	-	-	-	10	22
Rhamnaceae	1	2	2	3	-	-
Rosaceae	3	5	6	7	3	5
Rubiaceae	6	7	2	2	7	12
Rutaceae	7	9	3	3	1	1
Sapindaceae	3	3	1	1	1	1
Saxifragaceae	-	-	-	-	2	4
Scrophulariaceae	-	-	-	-	12	17
Simaroubaceae	1	1	-	-	-	-
Smilaceae	-	-	1	2	-	-
Solanaceae	-	-	2	2	7	15
Steruliaceae	1	1	-	-	-	-
Symplocaceae	1	1	-	-	-	-
Tamaricaceae	-	-	1	1	-	-
Taxaceae	1	1	-	-	-	-
Tiliaceae	1	2	2	2	-	-
Trilliaceae	-	-	-	-	1	1
Typhaceae	-	-	-	-	1	1
Ulmaceae	1	1	-	-	-	-
Urticaceae	-	-	2	3	3	5
Valerianaceae	-	-	-	-	2	3
Verbenaceae	1	1	6	9	3	5
Violaceae	-	-	-	-	2	5
Vitaceae	-	-	3	5	-	-
Zingiberaceae	-	-	-	-	6	15

Table 3. Ratios of species, genus and family

Ratio	Primary resources			Secondary resources		
	Tree	Shrub	Herb	Tree	Shrub	Herb
Genus: Species	1.14	1.09	1.30	2.42	1.48	1.56
Family: Species	1.23	1.44	3.05	2.57	3.23	6.45
Family: Genus	1.08	1.32	2.35	1.06	2.18	4.14

Table 4. Diversity indices of different forest sites

Forest	Layer	Margalef	Shannon-Weaver	Simpson	Whittaker
Chir-pine	Tree	1.85	0.22	1.83	1.5
	Shrub	16.22	2.29	0.62	2.18
	Herb	28.77	3.44	0.45	1.89
Chir-pine	Tree	1.12	0.63	0.97	1.5
	Shrub	19.44	3.27	0.62	5.26
	Herb	16.67	3.92	0.06	3.62
Banj oak	Tree	3.18	1.32	0.89	2.5
	Shrub	12.57	2.25	0.27	3.09
	Herb	22.43	3.66	0.34	2.06
Tilonj oak	Tree	3.36	0.53	3.36	1.67
	Shrub	14.41	1.99	0.32	2.5
	Herb	26.37	3.27	0.44	1.71
Kharsu oak	Tree	4.44	1.56	0.56	2.09
	Shrub	15.24	2.97	0.17	2.14
	Herb	18.87	4.00	0.08	2.12

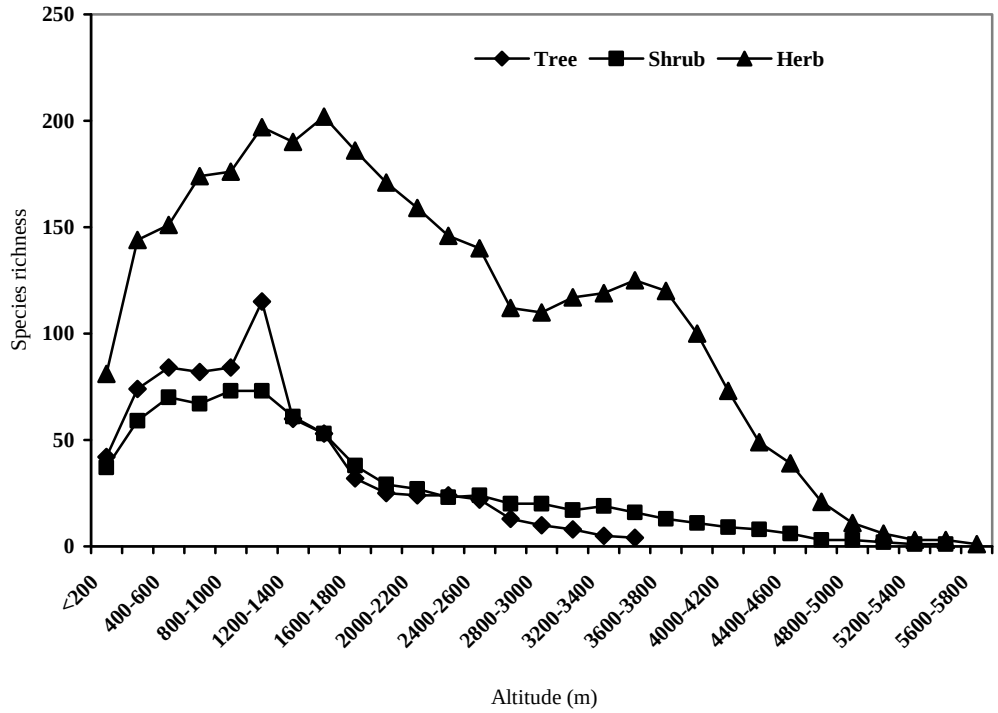

Figure 1. Total plant species richness in relation to altitude.

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