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Research Article
Floristics, Leaf Size Spectra and Life-form Distribution of Riparian Vegetation along a Hill Stream, Bhaderwah, Jammu and Kashmir, India

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Abstract

Background and Objective: The complexity of riparian vegetation can be analyzed through the functional groups based on a variety of characteristics, including morphology, physiology, competition and geography. The present study aimed to understand the composition, distribution pattern, phenology and physiognomic traits of riverine vegetation in Bhaderwah, Jammu and Kashmir, India. **Materials and Methods:** Organized field surveys were conducted in a mountainous riparian corridor of Neeru stream in Bhaderwah during 2016-2017. The study area forms a linear hydro-morphological unit spanning 30 km in length and ~15-100 m wide located along an elevational range of 850-2200 m. A random sampling technique was used for vegetation sampling. **Results:** The study corridor is well represented by subtropical, sub-temperate, temperate and alpine elements of vegetation. In all, 248 plant species contained in 193 genera and 78 families were recorded from 45 sampling stations surveyed for all the seasons. Asteraceae dominated the area with 27 species in 20 genera. The life-form spectra revealed thero-hemicryptophytic type of phytoclimate with the prevalence of microphylls (46.37%). **Conclusion:** The study area comprises of rich diversity of herbs followed by shrubs and trees with a pronounced mid domain effect observed for species and familial richness. The observations on leaf size and biological spectra reflect the characteristics of moderately disturbed temperate ecosystem. The flowering and fruiting commence early at the lower elevations and vegetation remains dormant during winters. Other drivers of richness and diversity of riparian vegetation needs to be integrated in future studies.

Key words: Floristics, life-form spectra, riparian corridor, phytoclimate, microphylls, mid-domain effect, Neeru stream

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The plant communities are classified mainly based on the floristics, habitat and physiognomy or geographical characteristics. Vegetation is the collective growth of plants combined in a specific area characterized by component species or structural and functional combination of features that make their physiognomy[1,2]. The vegetation forms a critical component of the ecosystem and serves to describe many facets of ecological patterns across the landscape. The flora of an area measure and record the types of plant species, their number, population size, distribution and composition within these communities[3]. The flora of any region is vital to understand the prevailing environment and the environmental interactions in the ecosystems[4]. Its documentation serves as a future reference to assess the changes in habitats and plant responses to the changing environment[5-7]. The vegetation varies across time and space in physiognomy which describes a set of functional and morphological attributes of the dominant plant communities in a particular area[8]. The climatic outlook of the vegetation is expressed in the form of life forms as the morphological adjustment to the environmental constraints.

Plants can be grouped in life-form classes based on their similarities in structure and function and plant adaptation to certain ecological conditions[9]. A life form of the plant is the sum of all life processes that evolved directly in response to the environment[10,11]. These are the critical physiognomic attributes that express the harmony between plant and its surroundings. Biological spectrum is the percentage distribution of different life-forms for a given flora[10] used as an index for comparing geographically separated plant communities in a given set of climatic and environmental factors[12,13]. While the Raunkiaer's biological spectrum defines the phytoclimate, the leaf size spectrum provides an idea of the floristic adaptation[14]. Raunkiaer[10] system of plant life form classification is based on the position, degree of protection of the perennating buds[15]. These are categorized as phanerophytes, therophytes, cryptophytes, hemicryptophytes and chamaephytes[16].

The biological spectra of the Indian region are related to specific climatic, edaphic and altitudinal factors[17]. India, as a geographical entity, expresses a phanerophytic type of phytoclimate[17]. The Hemicryptophytes are characteristics of temperate regions and the therophytes indicate desert climate[18,19]. While the life form spectra are the indicators of micro and macro climate[20], the leaf size information helps to understand the kind of physiological processes of plants and plant communities[21]. The relationship between leaf size and ecological factors plays a significant role in studying vegetation at a regional scale. The phenology, another physiological aspect that is governed by climate, involves the plant life cycle stages, such as flowering, leafing and maturation of plants. The phenology of a species includes understanding the seasonal and inter-annual difference in climate on the life-cycle actions and behaviour of the species[22]. Though a lot has been explored for the terrestrial landforms, the information on riparian life forms, especially for the Mountain Rivers is scanty for Indian Himalayan Region. Natural riparian zones are the most diverse, dynamic and complex biophysical interfaces between aquatic and terrestrial ecosystems. The nature of plant communities in the riverine ecosystems are largely influenced by altitude, total rainfall, duration of the rainy season, wind and temperature along with soil characteristics[23].

While many floristic explorations have been done in the whole Chenab valley[24-26], including the study area[27-36], the hill riparian forests received the least attention. Earlier, some of the studies highlighting life forms and phytoclimate have been reported from the study area using Raunkiaer's system[27-30]. Still, any such information on phytoclimate of the riparian forests is missing from the region. The current study aimed to find the composition of vegetation, the dominant life forms and phytoclimate of the study area.

MATERIALS AND METHODS

Study area: The study area comprised of 35 km long and ~1.5 km wide corridor lying between 32°55'32" to 33°08'26" N and 75°32'41" to 75°45'78"E along an elevational range of 850 m (its confluence with River Chenab at Pul Doda) to 2200 m near Thanalla close to its origin including the river bed, flood plain and the edge up-slopes on the either sides (Fig. 1).

Methodology: Divided into fifteen sites, the surveys were conducted in the riparian and upland matrix of 200 m on either side of the stream during March, 2016 to November, 2018. The plants were classified into different life form classes on the basis of perennating buds[10]. These included the Phanerophytes with perennating buds lying above 0.25 m from the soil surface, chamaephytes (perennating buds above 25 cm from soil surface), hemicryptophytes (perennating buds lying at the soil surface), geophytes (perennating buds buried

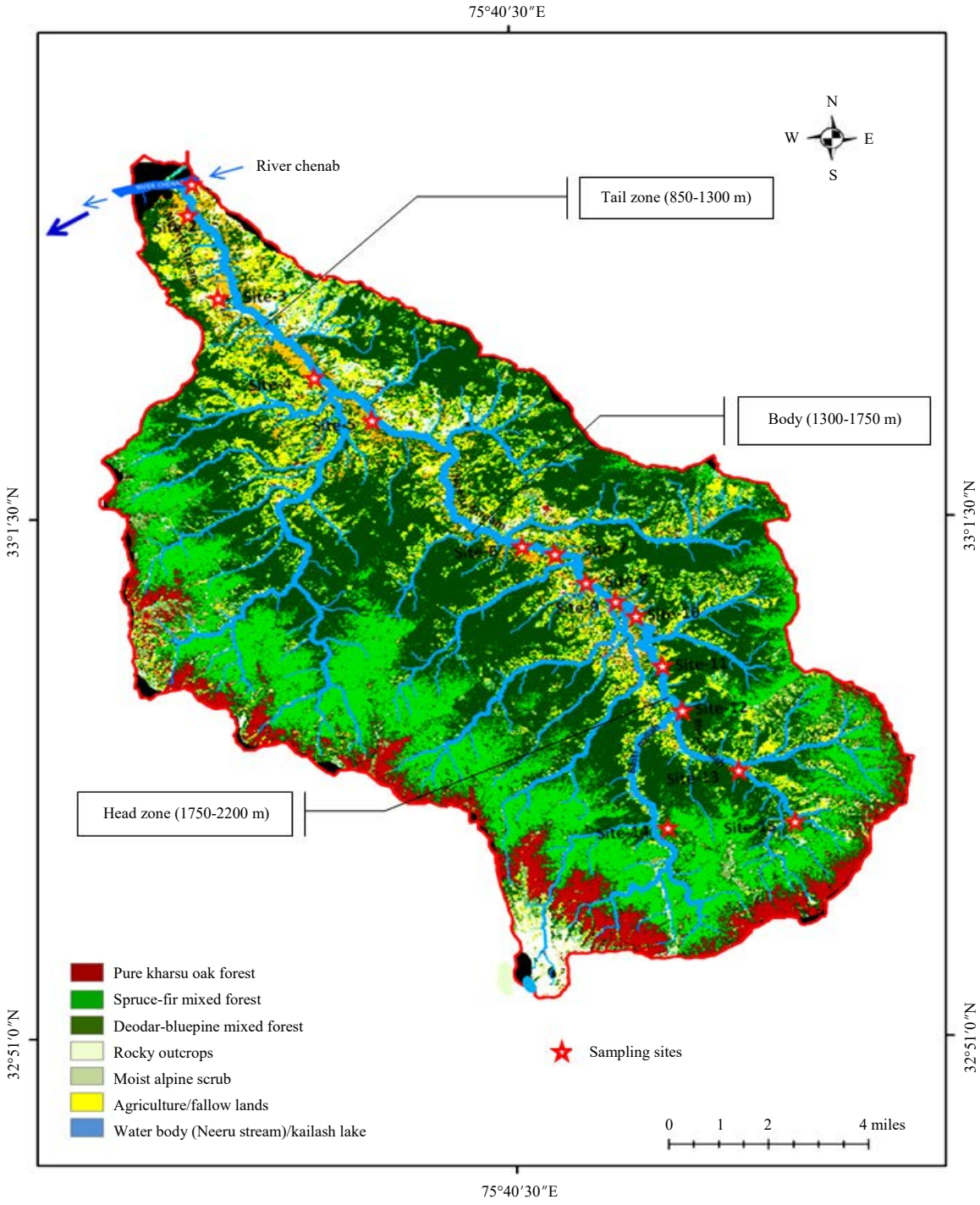

Fig. 1: Map of the study area
Source: Sharma[29]

in the soil) and therophytes (complete their life cycle from seed in one season). Life form for each species was noted and biological spectrum prepared to note the phytoclimate of the study area. The leaf size classes were classified as leptophil, nanophyll, microphyll, mesophyll, macrophyll and megaphyll following Raunkiaer[10], Hussain[37] and Haq *et al.*[38]. The identification of plants, leaf size measurement and statistical analysis of the data was performed in the forest ecology laboratory of Institute of Mountain Environment, Bhaderwah Campus.

Statistical analysis: The statistical analysis was performed in MS Excel 2007 and open source software PAST 4.0 for the creation of column/bar charts and rarefaction curves.

RESULTS

Neeru watershed is well represented by subtropical, sub-temperate, temperate and alpine elements of biodiversity along the elevational gradient. The landuse/landcover map prepared from digital classification of IRS ID LISS IV image of 2016 depicts seven different categories (Fig. 1) based on the spectral signatures of ground realities. It supports Ban Oak-Chir pine-Himalayan Alder (*Quercus leucotrichophora*, *Pinus roxburghii*, *Alnus nitida*), Moru Oak-Blue pine-Himalayan Alder (*Quercus baloot*, *Pinus wallichiana*, *Alnus nitida*, associations at lower elevations followed by Blue pine-Himalayan Alder-Deodar (*Pinus wallichiana*, *Alnus nitida*, *Cedrus deodara*), Moru Oak-Deodar-Blue pine (*Quercus baloot*, *Cedrus deodara*, *Pinus wallichiana*) at mid, and, Deodar-Spruce-Fir (*Cedrus deodara*, *Picea smithiana*, *Abies pindrow*) at higher elevations till tree line at 3200 m which is subsequently taken over by *Rhododendron-Juniper* scrub and *Krumholtz* above 3400 m.

Floristic composition: A total of 248 plant species contained in 193 genera and 78 families have been recorded from the riparian and adjoining upland forests along Neeru stream. Of these, 39 are trees (15.72%), 49 shrubs (19.75%) and 170 herbs (68.54%). The list of plant specimens collected along with their habit, habitat, life form, flowering, fruiting, leaf size, altitude wise distribution and familial description has been given in Appendix 1. Of the total species observed, 5 species namely *Pinus roxburghii*, *Pinus wallichiana*, *Cedrus deodara*, *Abies pindrow* and *Picea smithiana* are gymnosperms while 243 (97.98%) are angiosperms. All the gymnosperms are represented in a single family i.e., Pinaceae. Pteridaceae comprised of 3 species in two genera. Among the Angiosperms, Asteraceae dominates the area with 27 species (10.88%) in 20 genera followed by Rosaceae (22 species/16 genera, 8.87%), Lamiaceae (15 species/14 genera, 6.04%), Fabaceae (11species/10 genera, 4.43%), Poaceae (9 species/9 genera, 3.62%) and Moraceae (8 species/3 genera, 3.22%) respectively (Fig. 2). As many as 36 families show monotypic representation in the area as they are represented by a single genus and single species, while 42 families are polytypic.

Distributed in three elevational bands (low, mid and high), 126 species were observed in band-1 (850-1300 m), 200 in band-2 (1300-1800 m) and 192 in band-3 (1800-2200 m), clearly exhibiting the mid domain affect. 130 species were encountered along the riparian, 236 along the left and 199 species along the right banks, respectively. The species richness along various elevations ranges in general as well as species contained in ten dominant families in different elevational bands is presented in Fig. 2.

The rarefaction curves drawn for the trees, shrubs and herbs for the riparian and upland (left and right banks) have been presented as Fig. 3a-c. As the cumulative count, the riparian forests comprised 15 trees, 20 shrubs and 105 herbs while the upland forests supported 32 trees, 47 shrubs and 120 herbs. The trees exhibited less species richness and more homogeneity along the riparian corridor than the upland forests. The left bank supported more trees in comparison to the right bank (Fig. 3a). Similarly lesser number shrubs were encountered in the riparian forests followed by upland right

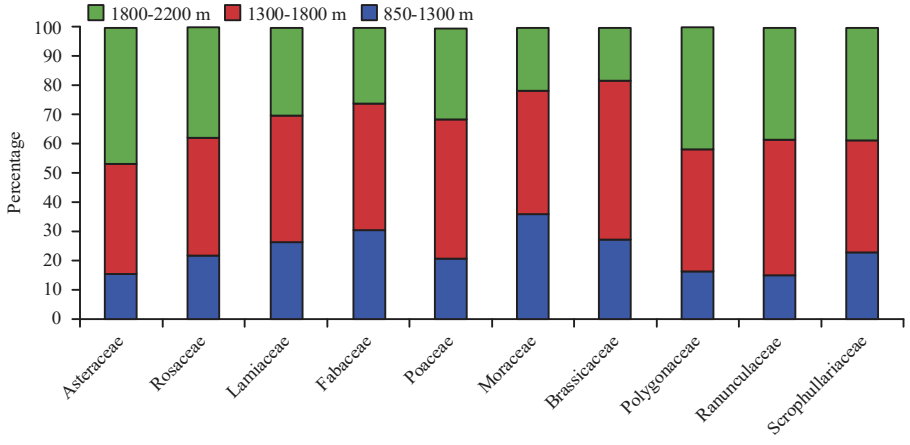

Fig. 2: Species richness of ten dominant families in different elevational bands recorded in the study area

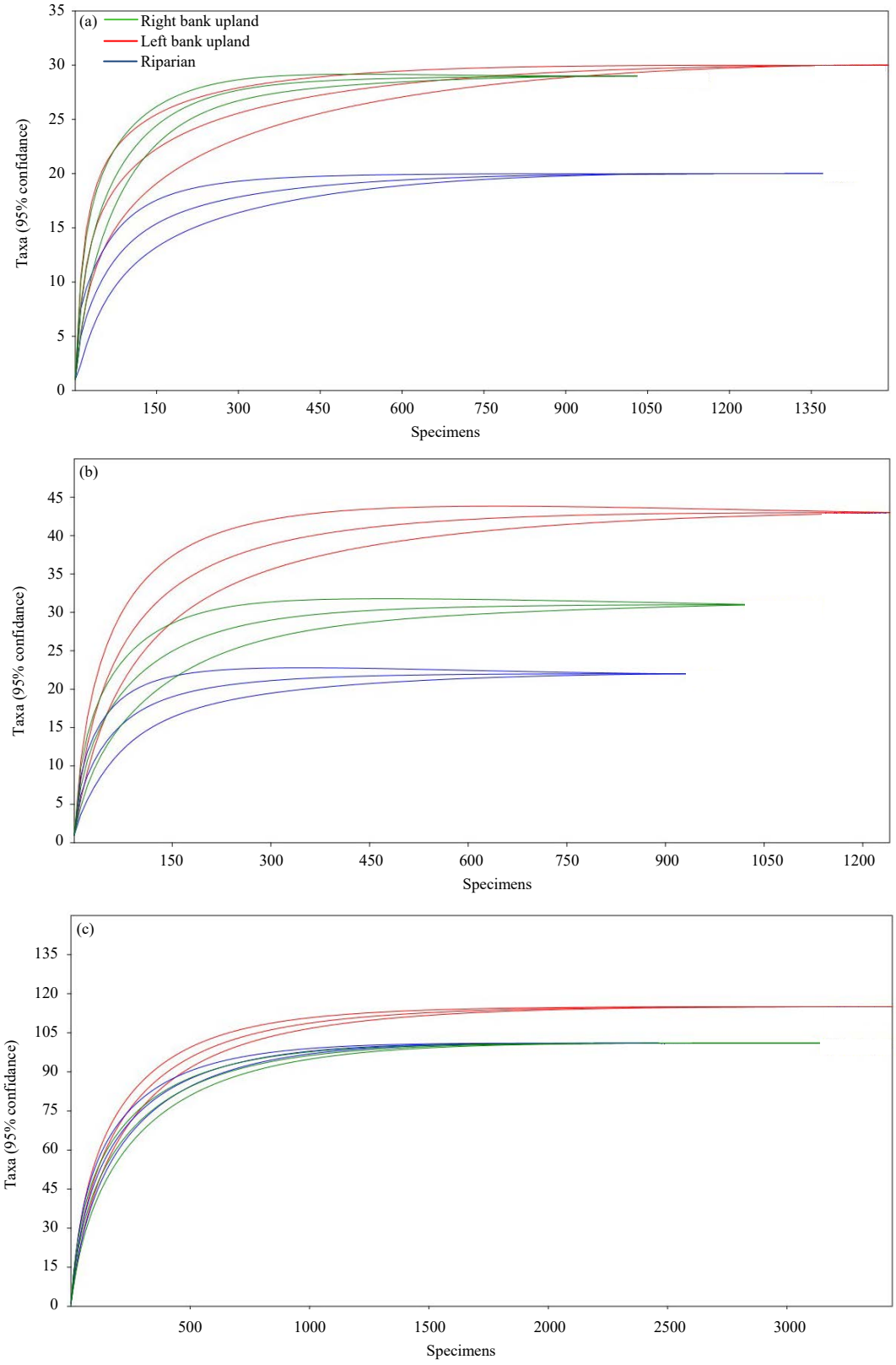

Fig. 3(a-c): Rarefaction curve for (a) Trees, (b) Shrubs and (c) Herbs at riparian (blue), left upland (red) and right upland (green) forests along the stream

Appendix 1: List of plant specimens collected along with their habit, habitat, life form, flowering, fruiting, leaf size, altitude wise distribution and familial description

	Elevation 850-2200 m								
Family/species	T	B	H	Habit	Habitat	Flowering	Fruiting	Life form	Leaf size
Acanthaceae									
Barleria cristata L.	+	-	+	Herb	LB, Rip	March-June	August-October	Therophyte	Nanophyll
Justicia adhatoda L.	-	+	+	Shrub	LB	April-May	July-August	Nanophanerophyte	Leptophyll
Strobilanthus atropurpureus Nees	-	+	+	Tree	LB, RB, Rip	May-June	August-September	Hemicryptophyte	Microphyll
Aceraceae									
Acer cappadocicum Gledt	-	-	+	Tree	LB, RB	April-May	June-July	Macrophanerophyte	Nanophyll
Platanus orientalis L.	+	+	+	Tree	LB, RB	April-May	September-October	Macrophanerophyte	Megaphyll
Aliaceae									
Allium cepa L.	+	+	-	Herb	LB, RB	May-June	July-August	Geophyte	Leptophyll
Allium sativum L.	+	+	-	Herb	LB, RB	May-June	July-August	Geophyte	Leptophyll
Amaranthaceae									
Amaranthus viridis L.	+	+	-	Herb	LB, RB, Rip	June-August	September-October	Therophyte	Microphyll
Gomphrena celosioides Mart.	_	+	+	Herb	LB, RB, Rip	June-July	August-September	Therophyte	Microphyll
Gomphrena globosa L.	+	+	-	Herb	LB, RB, Rip	May-June	July-August	Chamaeophyte	Microphyll
Anacardiaceae									
Rhus succedanea L.	+	+	+	Tree	LB, RB	May-June	July-August	Macrophanerophyte	Mesophyll
Apiaceae									
Chaerophyllum vilosum Wall. ex DC	_	+	+	Herb	LB, RB, Rip	May-June	July-August	Hemicryptophyte	Microphyll
Apocynaceae									
Nerium indicum Mill.	+	-	-	Shrub	LB, RB	May-June	July-August	Nanophanerophyte	Microphyll
Araceae									
Arisaema propinquum Schott	+	+	-	Herb	LB, RB, Rip	July-August	August-September	Geophyte	Microphyll
Saussurea costus (Falc.) Lipsch.	_	_	+	Herb	LB, RB	May-June	July-August	Hemicryptophyte	Mesophyll
Sauromattum guttatum Schott	_	+	+	Herb	LB, RB	May-June	July-August	Therophyte	Mesophyll
Araliaceae									
Hedera helix Linn.	+	+	+	Shrub	LB, Rip	May-June	July-August	Climber	Microphyll
Asclepiadaceae									
Vincetoxicum hirundinaria (Wall. ex Wight)	-	-	+	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Mesophyll
Asparagaceae									
Agave sisalana Perr. Ex Enhelm.	+	+	-	Shrub	RB	April-May	July-August	Nanophanerophyte	Megaphyll
Asteraceae									
Achillea millefolium Linn.	-	-	+	Herb	LB, RB	May-June	July-August	Hemicryptophyte	Nanophyll
Anaphalis luteo album L.	-	+	+	Herb	LB, RB, Rip	May-June	July-August	Hemicryptophyte	Microphyll
Anaphalis nepalensis (Spreng.) Hand.-Mazz.	-	-	+	Herb	LB, RB, Rip	May	September	Hemicryptophyte	Nanophyll
Anaphalis royleana DC	-	-	+	Herb	LB, RB, Rip	May-June	July-August	Hemicryptophyte	Microphyll
Anthemis cotula L.	+	+	+	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Microphyll
Arctium lappa L.	-	+	+	Herb	LB, RB, Rip	May-June	July-August	Hemicryptophyte	Microphyll
Artemisia brevefolia Wall. ex DC.	-	-	+	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Microphyll
Artemisia maritima L.	-	+	+	Shrub	LB, RB, Rip	May-June	July-August	Nanophanerophyte	Microphyll
Artemisia myriantha Wall. ex Besser	+	+	+	Shrub	LB, RB, Rip	June-July	August-September	Nanophanerophyte	Microphyll
Artemisia scoparia Waldst.	+	+	+	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Nanophyll
Artemisia vestita Wall.	-	+	+	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Microphyll
Cicerbita iberca (Duthie ex Stebbins) Mamgain and R.R. Rao	-	+	+	Herb	LB, RB, Rip	June-July	August-September	Hemicryptophyte	Nanophyll
Cirsium arvense (L.) Scop.	+	+	+	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Microphyll
Erigeron bonariensis L.	-	+	+	Herb	LB, Rip	May-June	July-August	Therophyte	Microphyll
Galinsoga parviflora Cav.	-	-	+	Herb	LB, Rip	June-July	September	Hemicryptophyte	Microphyll
Gnaphallium affine D. Don.	+	+	+	Herb	LB, Rip	July-August	August-September	Chamaephyte	Microphyll
Inula cappa DC.	-	+	+	Shrub	LB, Rip	July-August	August-September	Nanophanerophyte	Microphyll
Matricaria chamomilla L.	-	+	-	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Microphyll
Myriactis nepalensis Less.	-	+	+	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Mesophyll
Saussurea heteromala (D. Don) Hand.	-	+	+	Herb	LB, RB	July-August	August-September	Therophyte	Microphyll
Sonchus arvensis L.	-	-	+	Herb	LB, RB	March-June	July-August	Therophyte	Nanophyll
Sonchus asper Gars.	-	+	+	Herb	LB, RB	March-April	September-October	Hemicryptophyte	Microphyll
Tagetes minuta L.	+	+	+	Herb	LB, Rip	June-July	September-October	Therophyte	Microphyll
Taraxacum officinale Wigg.	+	+	+	Herb	LB, RB, Rip	March-April	May-June	Geophyte	Microphyll
Xanthium strumarium L.	+	+	-	Herb	LB, RB	July-August	September	Therophyte	Megaphyll

Appendix 1: Continued

	Elevation 850-2200 m								
Family/species	T	B	H	Habit	Habitat	Flowering	Fruiting	Life form	Leaf size
Youngia japonica (L.) DC.	-	+	-	Herb	LB, RB	March-June	July-August	Therophyte	
Balsaminaceae									
Impatiens balsamina L.	-	+	+	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Microphyll
Impatiens edgeworthii Hook. f.	-	-	+	Herb	LB, RB, Rip	June-July	September-October	Therophyte	Microphyll
Impatiens sulcata Wall.	-	-	+	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Microphyll
Berberidaceae									
Berberis lycium Royle	+	+	+	Shrub	LB, RB, Rip	May-June	August-September	Nanophanerophyte	Microphyll
Betulaceae									
Alnus nitida Endl.	+	+	+	Tree	LB, RB, Rip	May-June	July-September	Macrophanerophyte	Mesophyll
Boraginaceae									
Cynoglossum glochidiatum (Wall. ex Benth.) Kazmi	-	+	+	Herb	LB, RB, Rip	June	August	Hemicryptophyte	Nanophyll
Hackelia uncinata (Benth.) Fischer	-	-	+	Herb	LB	June-July	August	Hemicryptophyte	Microphyll
Brassicaceae									
Arabidopsis thaliana (L.) Heyn.	-	-	+	Herb	LB, RB	June-July	August	Chamaephyte	Mesophyll
Brassica campesteris L.	+	+	-	Herb	LB	March-June	July-August	Therophyte	Nanophyll
Capsella bursa-pastoris (L.) Medik.	+	+	+	Herb	LB, RB, Rip	April-May	August-September	Therophyte	Leptophyll
Cardamine impatiens L.	+	+	+	Herb	LB, RB, Rip	June-July	August	Hemicryptophyte	Nanophyll
Erysimum crassipes Fisch. and C.A.Mey.	-	+	+	Herb	LB, RB, Rip	June-July	August	Hemicryptophyte	Microphyll
Nasturtium officinale R. Br.	-	+	+	Herb	LB, Rip	April-May	September-October	Therophyte	Microphyll
Thlaspi arvense L.	-	+	+	Herb	LB, Rip	May-June	July-August	Therophyte	Microphyll
Sarcococca saligna D. Don	-	-	+	Shrub	LB, RB, Rip	April-May	September-October	Nanophanerophyte	Mesophyll
Campanula latifolia L.	-	-	+	Herb	LB, RB, Rip	May-June	July-August	Hemicryptophyte	Microphyll
Campanula palida Wall.	-	-	+	Herb	LB, RB, Rip	May-June	July-August	Chamaephyte	Microphyll
Cannabaceae									
Cannabis sativa L.	+	+	+	Herb	LB, RB, Rip	May-June	September-October	Therophyte	Microphyll
Caprifoliaceae									
Lonicera hispida (Stephan ex Fisch.)	-	-	+	Shrub	LB, RB, Rip	July-August	September	Nanophanerophyte	Microphyll
Lonicera obovata Royle ex Hook. f. and Th.	-	+	+	Shrub	LB, RB, Rip	June-July	August-September	Nanophanerophyte	Microphyll
Caryophyllaceae									
Cerastium cerastioides (L.) Britton	-	+	+	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Microphyll
Silene conoidea L.	+	+	-	Herb	LB, RB	June-July	August-September	Therophyte	Microphyll
Silene edgeworthii (Bocquet)	-	-	+	Herb	LB	May-June	July-August	Therophyte	Microphyll
Stellaria media (L.) Vill.	+	+	+	Herb	LB, RB	May-June	July-August	Hemicryptophyte	Nanophyll
Chenopodiaceae									
Chenopodium album L.	+	+	+	Herb	LB, RB, Rip	June-July	September	Therophyte	Microphyll
Convolvulaceae									
Ipomea nil (L.) Roth	+	+	+	Shrub	LB, Rip	May-June	July-August	Nanophanerophyte	Mesophyll
Ipomoea cairica (L.) Roth	-	+	+	Herb	LB, Rip	May-June	July-August	Hemicryptophyte	Mesophyll
Ipomoea purpurea (L.) Roth	-	+	+	Herb	LB, Rip	May-June	July-August	Therophyte	Microphyll
Cuscutaceae									
Cuscuta reflexa Roxb.	-	+	+	climber	LB, RB	August	September	Climber	Leptophyll
Dasticaceae									
Datisca cannabina Linn.	+	+	+	Herb	LB, Rip	May-June	July-August	Hemicryptophyte	Microphyll
Dipsacaceae									
Cryptothladia polyphylla (DC.) Cannon	-	+	+	Herb	LB, RB	April-May	July-August	Hemicryptophyte	Microphyll
Elaeagnaceae									
Elaeagnus conferta Roxb.	+	+	-	Shrub	LB, RB	April-May	July-August	Nanophanerophyte	Microphyll
Elaeagnus parviflora Wall. ex Royle	-	+	+	Shrub	LB, RB	April-May	July-August	Nanophanerophyte	Microphyll
Elaeagnus umbellata Thunb.	-	+	+	Shrub	LB, RB	May-June	September-October	Nanophanerophyte	Microphyll
Ericaceae									
Lyonia ovalifolia (Wall.) Drude	+	+	+	Tree	LB, RB	May	October	Macrophanerophyte	Microphyll
Euphorbiaceae									
Ricinus communis L.	+	-	-	Shrub	LB, RB	June	October	Macrophanerophyte	Mesophyll
Euphorbia helioscopia L.	+	+	-	Herb	LB, RB	July-August	September-October	Therophyte	Nanophyll
Fabaceae									
Astragalus leucocephalus Grah. Ex Benth.	-	+	+	shrub	LB, RB	May-June	July-August	Nanophanerophyte	Microphyll
Dalbergia sissoo DC.	+	-	-	Tree	LB, RB	April-May	July-August	Macrophanerophyte	Nanophyll

Appendix 1: Continued

Family/species	Elevation 850-2200 m T	B	H	Habit	Habitat	Flowering	Fruiting	Life form	Leaf size
Desmodium elegans DC.	+	+	+	Shrub	LB, RB	July-August	September-October	Nanophanerophyte	Microphyll
Hedysarum sp.	-	+	+	Hyd	LB, Rip	July-August	September-October	Hydrophyte	Nanophyll
Indigofera heterantha Brandis	-	+	+	Shrub	LB, RB	May-June	September-October	Nanophanerophyte	Leptophyll
Lotus cornuculatus L.	+	+	+	Herb	LB, Rip	May-June	September-October	Hemicryptophyte	Nanophyll
Medicago falcata L.	+	+	-	Herb	LB, RB	April-May	June-July	Hemicryptophyte	Microphyll
Robinia pseudoacacia L.	+	+	+	Tree	LB, RB, Rip	April-May	September-October	Macrophanerophyte	Leptophyll
Trifolium pratense L.	+	+	+	Herb	LB, RB, Rip	April-May	June-July	Hemicryptophyte	Nanophyll
Trifolium repens L.	+	+	+	Herb	LB, RB, Rip	April-May	June-July	Hemicryptophyte	Nanophyll
Trigonella emodii Benth.	-	-	+	Herb	LB, RB, Rip	May-June	August	Chamaephyte	Microphyll
Fagaceae									
Quercus baloot	+	+	+	Tree	LB, RB	March-April	June-July	Macrophanerophyte	Megaphyll
Quercus leucotrichophora A. Camus	+	+	+	Tree	LB, RB	March-April	June-July	Macrophanerophyte	Megaphyll
Fumariaceae									
Corydalis cashmeriana Royle	-	-	+	Herb	LB, Rip	June-July	August-September	Chamaephyte	Microphyll
Corydalis cornuta Royle	-	+	+	Herb	LB, Rip	July-August	September	Hemicryptophyte	Microphyll
Corydalis thyrsiflora Prain	-	-	+	Herb	LB, Rip	July-August	September	Chamaephyte	Microphyll
Fumaria indica (Haussk.)	+	+	-	Herb	LB, RB, Rip	May-June	July-August	Therophyte	Leptophyll
Gentianaceae									
Gentiana argentea Royle	-	+	+	Herb	LB, RB, Rip	May-June	July-August	Chamaephyte	Mesophyll
Geraniaceae									
Erodium cicutarium (L.) L'Herit ex Ait.	-	+	+	Herb	LB, RB, Rip	June-July	July-August	Therophyte	Microphyll
Geranium wallichianum D. Don ex Sw.	-	+	+	Herb	LB, RB, Rip	September	October	Hemicryptophyte	Microphyll
Hamamelidaceae									
Parrotiopsis jacquemontiana (Decne) Rehder	+	+	-	Shrub	LB, RB, Rip	April-May	September-October	Nanophanerophyte	Microphyll
Hippocastanaceae									
Aesculus indica (Wall.ex camb.) Hook. f.	-	+	+	Tree	LB, RB, Rip	May-June	September-October	Macrophanerophyte	Microphyll
Hypericaceae									
Hypericum oblongifoilum Choisy	+	+	+	Shrub	LB, RB	May-June	August-September	Nanophanerophyte	Nanophyll
Hypericum perforatum L.	-	+	+	Herb	LB, RB	June-August	September	Geophyte	Microphyll
Juglandaceae									
Juglans regia L.	+	+	+	Tree	LB, RB	April-May	September-October	Macrophanerophyte	Megaphyll
Lamiaceae									
Ajuga bracteosa Wall. ex. Benth.	+	+	+	Herb	LB, RB, Rip	May-June	August-September	Therophyte	Nanophyll
Ajuga parviflora Benth.	+	+	+	Herb	LB, RB, Rip	May-June	June-July	Therophyte	Microphyll
Clinopodium umbrosum (M. Beib.) C. Coch	+	+	+	Herb	LB, RB, Rip	July-August	September	Hemicryptophyte	Mesophyll
Elsholtzia cristata Willd.	-	-	+	Herb	LB, RB, Rip	May-June	June-July	Chamaephyte	Microphyll
Isodon rugosus (Wall.exBenth.) Codd	-	+	+	Herb	LB, RB, Rip	September	October	Chamaephyte	Microphyll
Lamium album Linn.	-	+	+	Herb	LB, RB, Rip	July-August	September	Therophyte	Microphyll
Mentha longifolia (L.) Huds.	+	+	-	Herb	LB, RB, Rip	May-June	July-August	Hydrophyte	Nanophyll
Micromeria biflora (Buch.-Ham. ex Don) Benth	+	+	-	Herb	LB, RB, Rip	March-April	September-October	Chamaephyte	Leptophyll
Nepeta erecta (Royle ex Benth.)	+	+	+	Herb	LB, RB, Rip	April-May	June-July	Hemicryptophyte	Microphyll
Origanum vulgare L.	+	+	-	Herb	LB, RB, Rip	April-May	September-October	Hemicryptophyte	Microphyll
Prunella vulgaris L.	-	+	+	Herb	LB, RB	May-June	September-October	Therophyte	Nanophyll
Rabdosia rugosa (Wall. ex Benth.) Hara	-	-	+	Shrub	LB, RB	July-August	September	Nanophanerophyte	Mesophyll
Salvia moorcroftiana Wall. ex Benth.	-	+	-	Herb	LB, RB	August	September	Hemicryptophyte	Microphyll
Scutellaria scandens Don	+	+	-	Herb	LB, RB	July-August	September	Hemicryptophyte	Microphyll
Thymus linearis L.	-	+	+	Herb	LB, RB, Rip	April-May	September-October	Chamaephyte	Leptophyll
Liliaceae									
Colchicum luteum Baker	+	+	+	Herb	LB, RB, Rip	July-August	September-October	Hemicryptophyte	Microphyll
Malvaceae									
Lavatera kashmeriana Camb.	-	-	+	Herb	LB, RB, Rip	July-August	September-October	Chamaephyte	Mesophyll
Malva neglecta Wall.	+	+	-	Herb	LB, RB, Rip	March-April	September-October	Hemicryptophyte	Microphyll
Malva verticillata L.	-	+	+	Herb	LB, RB, Rip	March-April	September-October	Therophyte	Microphyll
Malvastrum coromandelianum (L.) Gracke	+	+	-	Herb	LB, RB, Rip	April	October	Therophyte	Nanophyll
Meliaceae									
Melia azadarach (L.) Vern	-	+	+	Tree	LB	April-May	September-October	Macrophanerophyte	Microphyll

Appendix 1: Continued

	Elevation 850-2200 m								
Family/species	T	B	H	Habit	Habitat	Flowering	Fruiting	Life form	Leaf size
Toona ciliata M. Roem	+	+	-	Tree	LB	April-May	August-September	Macrophanerophyte	Megaphyll
Moraceae									
Engelhardtia spicata Bl.	+	-	-	Tree	RB	April-May	August-September	Macrophanerophyte	Microphyll
Ficus hederacea Roxb.	-	+	+	Shrub	LB, RB	July-August	September	Nanophanerophyte	Megaphyll
Ficus palmata Forssk.	+	+	+	Tree	LB, RB, Rip	March-April	August-September	Macrophanerophyte	Megaphyll
Ficus rumphii Bl.	+	+	-	Tree	LB, RB, Rip	March-April	August-September	Macrophanerophyte	Mesophyll
Ficus sarmentosa Buch.-Ham. ex Sm.	-	+	-	Shrub	LB, RB, Rip	April-May	July-August	Nanophanerophyte	Nanophyll
Morus alba L.	+	+	+	Tree	LB	April-May	June-July	Macrophanerophyte	Mesophyll
Morus nigra L.	+	-	-	Tree	LB	April-May	July-August	Macrophanerophyte	Mesophyll
Morus serrate Roxb.	+	+	+	Tree	LB	April-May	June-July	Macrophanerophyte	Mesophyll
Myrtaceae									
Eucalyptus lanceolata	+	-	-	Tree	RB	May-June	August-September	Macrophanerophyte	Leptophyll
Oleaceae									
Jasminum humile L.	-	+	+	Shrub	LB, RB	June	August	Nanophanerophyte	Nanophyll
Jasminum officinale L.	+	+	+	Shrub	LB, RB	June	August	Nanophanerophyte	Nanophyll
Olea europaea L. ssp. *cuspidata* (Wall. and G. Don) Cif.	+	+	+	Tree	LB, RB	April-May	July-August	Macrophanerophyte	Microphyll
Onagraceae									
Epilobium hirsutum L.	+	+	+	Herb	LB, RB, Rip	September	October	Hemicryptophyte	Nanophyll
Epilobium latifolium	+	-	-	Herb	LB, RB, Rip	July	September	Chamaephyte	Leptophyll
Oenothera rosea L. Herit. ex Ait.	+	+	+	Herb	LB, RB, Rip	April-May	September-October	Hemicryptophyte	Nanophyll
Oxalidaceae									
Oxalis corniculata L.	+	+	+	Herb	LB, RB, Rip	March-April	September-October	Hemicryptophyte	Microphyll
Papaveraceae									
Argemone mexicana L.	-	+	+	Herb	LB, RB, Rip	July-August	August-September	Therophyte	Microphyll
Papaver somniferum L.	+	-	-	Herb	LB	May-June	July-August	Therophyte	Microphyll
Phytolaccaceae									
Phytolacca acinosa Roxb.	+	+	+	Herb	LB, RB, Rip	June-July	September-October	Therophyte	Mesophyll
Pinaceae									
Abies pindrow Royle	-	-	+	Tree	LB, RB	June-July	September-October	Macrophanerophyte	Nanophyll
Cedrus deodara (Roxb.) Loud.	-	+	+	Tree	LB, RB, Rip	September	October	Macrophanerophyte	Leptophyll
Picea smithiana Wall.	-	-	+	Tree	LB, RB	May-June	September-October	Macrophanerophyte	Nanophyll
Pinus roxburghii Sarg.	+	-	-	Tree	LB, RB	May	July	Macrophanerophyte	Leptophyll
Pinus wallichiana A.B. Jacks	+	+	+	Tree	LB, RB, Rip	May-June	September-October	Macrophanerophyte	Nanophyll
Plantaginaceae									
Plantago lanceolata L.	+	+	+	Herb	LB, RB, Rip	May-June	July-August	Hemicryptophyte	Microphyll
Poaceae									
Arthraxon lancifolius (Trin.) Hochst.	+	+	+	Grass	LB, RB	May-June	September-October	Therophyte	Microphyll
Arundo donax L.	-	+	+	Grass	LB, RB	May-June	September-October	Therophyte	Mesophyll
Avena sativa L.	+	+	+	Herb	LB, RB	May-June	July-August	Therophyte	Nanophyll
Bromus japonicus thumb. Ex Murr	-	+	+	Grass	LB, RB	May-June	September-October	Therophyte	Microphyll
Chrysopogon gryllus (Nees) T.A. Cope	-	+	+	Grass	LB, RB	May-June	September-October	Therophyte	Microphyll
Imperata cylindrica (Linn.) Raeuchel	+	+	+	Grass	LB, RB, Rip	May-June	September-October	Therophyte	Leptophyll
Phalaris minor Retz.	+	+	-	Herb	LB, RB, Rip	May-June	September-October	Chamaephyte	Microphyll
Polypogon fugax Nees ex Steud	-	+	+	Grass	LB, RB	June-July	September-October	Therophyte	Nanophyll
Saccharum fillifolium Nees ex Steud.	-	+	+	Grass	LB, RB	May-June	September-October	Therophyte	Mesophyll
Podophyllaceae									
Sinopodophyllum hexandrum Royle ex Camb.	-	-	+	Herb	LB, RB, Rip	May-June	September-October	Geophyte	Mesophyll
Polygalaceae									
Polygala abbyssinica R. Br. Ex Fresen	-	-	+	Herb	Rip	May-June	August-September	Therophyte	Leptophyll
Polygonaceae									
Oxyria digyna (L.) Hill	-	+	-	Herb	LB, Rip	June	July	Geophyte	Microphyll
Persicaria hydropiper (L.) Spach	-	-	+	Herb	Rip	May-June	August-September	Therophyte	Microphyll
Persicaria amphibium L.	-	+	+	Herb	Rip	May-June	August-September	Therophyte	Microphyll
Rheum spiciforme Royle	-	-	+	Herb	LB, Rip	May-June	July-August	Therophyte	Mesophyll
Rumex acetosa L.	+	+	+	Herb	LB, RB, Rip	June-July	July-August	Hemicryptophyte	Microphyll
Rumex hastatus D. Don.	-	+	+	Herb	LB, RB, Rip	April-May	September-October	Therophyte	Microphyll
Rumex nepalensis Spreng.	+	+	-	Herb	LB, RB, Rip	June-July	September-October	Hemicryptophyte	Mesophyll

Appendix 1: Continued

Family/species	Elevation 850-2200 m T	B	H	Habit	Habitat	Flowering	Fruiting	Life form	Leaf size
Pontederiaceae									
Crassipes japonica	-	+	+	Hyd	LB, Rip	June-July	July-August	Hemicrpytophyte	Microphyll
Primulaceae									
Anagallis arvensis L.	-	-	+	Herb	LB, Rip	June-July	September-October	Hemicryptophyte	Microphyll
Androsace rotundifolia Hardw.	-	+	+	Herb	LB, Rip	June	August	Therophyte	Nanophyll
Pteridaceae									
Adiantum caudatum L.	-	+	+	Fern	LB, Rip	May-June	August-September	Geophyte	Megaphyll
Pteris cretica L.	+	+	+	Fern	LB, Rip	September	September-October	Geophyte	Microphyll
Pteris vittata L.	-	+	+	Fern	LB, Rip	June	August	Geophyte	Mesophyll
Punicaceae									
Punica granatum L.	+	+	+	Tree	LB, RB	April-May	August-September	Macrophanerophyte	Nanophyll
Ranunculaceae									
Aquilegia pubiflora Wall ex Royle	-	+	+	Herb	LB, Rip	June	August	Therophyte	Microphyll
Clematis montana Buch.–Ham. ex DC.	+	+	+	Shrub/ liana	LB, RB	May-June	August-September	Nanophanerophyte	Microphyll
Ranunculus arvensis L.	+	+	+	Herb	LB, Rip	March-April	September-October	Therophyte	Microphyll
Ranunculus laetus Wall. ex Royle	-	-	+	Herb	LB, Rip	April	September-October	Chamaephyte	Microphyll
Ranunculus leave	-	+	+	Herb	LB, Rip	April-May	June-July	Chamaephyte	Mesophyll
Ranunculus muricatus L.	+	+	+	Herb	LB, Rip	April	September-October	Hemicryptophyte	Mesophyll
Thalictrum foliolosum DC.	+	+	+	Herb	LB, RB, Rip	May-June	August-September	Therophyte	Microphyll
Rhamnaceae									
Rhamnus triquetera Wall. ex Roxb.	+	+	+	Shrub	LB, RB, Rip	June-July	August-September	Nanophanerophyte	Mesophyll
Rhamnus virgatus Roxb.	+	+	+	Shrub	LB, RB, Rip	June-July	August-September	Nanophanerophyte	Mesophyll
Zizyphus mauritiana Lamk.	+	-	-	Tree	LB, RB	May-June	August-September	Macrophanerophyte	Microphyll
Rosaceae									
Agrimonia pilosa Ledeb. ssp. japonica (Miq.)	-	-	+	Herb	LB, RB	May-June	August-September	Hemicryptophyte	Mesophyll
Cotoneaster microphylla Wall.ex Lindl.	-	-	+	Shrub	LB, RB	June-July	September-Nov	Nanophanerophyte	Nanophyll
Cotoneaster nummularia Fisch. and Mey.	-	+	+	Shrub	LB, RB	May-June	September-Nov	Nanophanerophyte	Nanophyll
Cydonia oblonga Mill.	-	+	-	Tree	LB, RB	May-June	August-September	Macrophanerophyte	Megaphyll
Duchesnea indica (Jacks.) Focke	+	+	+	Herb	LB, RB	March-April	May-June	Hemicryptophyte	Nanophyll
Filipendula vestita (Wall. ex G. Don)	+	+	-	Herb	LB, RB	June-July	August-September	Hemicryptophyte	Microphyll
Fragaria nubicola Lindl.	-	+	+	Herb	LB, RB, Rip	May-June	September	Hemicryptophyte	Nanophyll
Fragaria vesca L.	+	+	-	Herb	LB, RB, Rip	May-June	July-August	Chamaephyte	Microphyll
Potentilla microphylla D. Don.	-	-	+	Herb	LB, RB, Rip	May-June	July-August	Hemicryptophyte	Nanophyll
Potentilla nepalensis Hook.	-	+	+	Herb	LB, RB, Rip	August-September	October-Nov	Hemicryptophyte	Nanophyll
PrinSeptemberia utilis Royle	+	+	+	Shrub	LB, RB, Rip	April-May	July-August	Nanophanerophyte	Nanophyll
Prunus armeniaca L.	+	+	+	Tree	LB, RB	March	April	Macrophanerophyte	Microphyll
Pyrus malus L.	+	+	+	Tree	LB, RB	April-May	July-August	Macrophanerophyte	Microphyll
Pyrus pashia Buch.-Ham. ex Don	+	+	+	Tree	LB, RB	April	May	Macrophanerophyte	Microphyll
Rosa brunonii Lindl.	+	+	+	Shrub	LB, RB, Rip	April-May	September-October	Nanophanerophyte	Nanophyll
Rosa webbiana Wall. ex Royle	-	+	+	Shrub	LB, RB, Rip	April-May	September-October	Nanophanerophyte	Nanophyll
Rubus elipticus Sm.	+	+	+	Shrub	LB, RB, Rip	April-May	June-July	Nanophanerophyte	Nanophyll
Rubus niveus Thunb.	+	+	+	Shrub	LB, RB, Rip	April-May	June-July	Nanophanerophyte	Nanophyll
Senecio sp.	-	-	+	Herb	LB, RB	August-September	October	Chamaephyte	Mesophyll
Sorbaria tomentosa (Lindl.) Rehder	-	+	+	Shrub	LB, RB	June-July	September-October	Nanophanerophyte	Microphyll
Sorbus sp.	+	+	-	Shrub	LB, RB	May	July	Nanophanerophyte	Mesophyll
Spiraea canescens D. Don	-	+	+	Shrub	LB, RB, Rip	April-May	October-Nov	Nanophanerophyte	Nanophyll
Rubiaceae									
Galium aparine L.	-	+	+	Herb	LB, RB	July	August	Therophyte	Leptophyll
Randia tetrasperma Roxb.	+	+	-	Shrub	LB, RB	June-July	August	Nanophanerophyte	Nanophyll
Rubia cordifolia L.	+	+	-	Shrub	LB, RB	June-July	August-September	Nanophanerophyte	Microphyll
Rubia manjith Roxb. Ex Fleming	+	+	+	Shrub	LB, RB	June-July	August-September	Nanophanerophyte	Microphyll
Rutaceae									
Zanthoxylum armatum DC.	+	+	-	Shrub	LB, RB	July	September	Nanophanerophyte	Microphyll

Appendix 1: Continued

Family/species	Elevation 850-2200 m T	B	H	Habit	Habitat	Flowering	Fruiting	Life form	Leaf size
Sabiaceae									
Sabia campanulatum Wall.	-	-	+	Shrub	LB, RB	June-July	August-September	Nanophanerophyte	Microphyll
Salicaceae									
Populus ciliata Wall. ex Royle	+	+	+	Tree	LB, RB	May-July	September-October	Macrophanerophyte	Mesophyll
Salix alba L.	+	+	-	Tree	LB, RB	April	May	Macrophanerophyte	Mesophyll
Sambucaceae									
Viburnum grandiflorum Wall. ex DC.	-	-	+	Shrub	LB, RB	April-May	September-October	Nanophanerophyte	Microphyll
Saxifragaceae									
Bergenia ciliata (Haw.) Sternb.	+	+	+	Herb	LB, RB	June-July	August-September	Therophyte	Mesophyll
Scrophulariaceae									
Digitalis purpurea L.	-	-	+	Herb	LB, RB, Rip	June-July	September-October	Chamaephyte	Microphyll
Mazus surculosus D. Don.	-	+	+	Herb	LB, RB, Rip	April-May	June-July	Chamaephyte	Microphyll
Verbascum thapsus L.	+	+	+	Herb	LB, RB, Rip	April-May	September-October	Chamaeophyte	Mesophyll
Veronica anagallis aquatica L.	+	+	+	Herb	LB, Rip	June	July	Therophyte	Microphyll
Veronica laxa Benth.	-	-	+	Herb	LB, RB, Rip	May-June	September-October	Therophyte	Nanophyll
Veronica persica Poir.	+	-	-	Herb	LB, RB, Rip	May-June	July-August	Chamaephyte	Microphyll
Wulfenia amherstiana Benth.	-	+	+	Herb	LB, RB	April-May	July-August	Hemicryptophyte	Nanophyll
Simaroubaceae									
Ailanthus altissima (Mill.) Swingle.	-	+	+	Tree	LB, RB, Rip	May-June	July-August	Macrophanerophyte	Megaphyll
Smilacaceae									
Smilax aspera L.	-	+	+	Shrub	LB, RB, Rip	June-July	August-September	Nanophanerophyte	Nanophyll
Solanaceae									
Datura stramonium L.	+	+	+	Herb	LB, RB	June-July	August	Chamaeophyte	Mesophyll
Solanum indicum Linn.	+	+	-	Herb	LB, RB	June-July	August	Therophyte	Microphyll
Solanum nigrum L.	+	+	-	Herb	LB, RB	March-April	September-October	Therophyte	Microphyll
Solanum pseudo-capsicum L.	-	+	-	Shrub	LB, RB	March-April	September-October	Nanophanerophyte	Microphyll
Solanum surretense Burm.f.	+	-	-	Shrub	LB, RB	June-July	September-Nov	Nanophanerophyte	Mesophyll
Thymelaeaceae									
Daphne oleoides Schreb.	+	+	+	Shrub	LB, RB, Rip	August-September	October-Nov	Nanophanerophyte	Nanophyll
Ulmaceae									
Celtis australis L.	-	+	+	Tree	LB, RB	August-September	October-Nov	Macrophanerophyte	Microphyll
Trema politoria Planch	+	+	_	Tree	LB, RB	April-May	June-July	Macrophanerophyte	
Ulmus wallichiana Planch.	-	+	+	Tree	LB, RB	April-May	June-July	Macrophanerophyte	Microphyll
Urticaceae									
Debregasia salicifolia (D. Don.) R.	-	+	+	Shrub	LB, RB	May-June	July-August	Nanophanerophyte	Microphyll
Girardinia diversifolia (Link) Friis	+	+	+	Herb	LB, RB, Rip	May-June	July-August	Chamaephyte	Mesophyll
Pilea umbrosa Wedd.	-	-	+	Herb	LB, RB, Rip	April-May	June-July	Hemicryptophyte	Mesophyll
Urtica dioica L.	+	+	-	Herb	LB, RB, Rip	April-May	September-October	Hemicryptophyte	Microphyll
Valerianaceae									
Valeriana jatamansi Jones.	+	+	+	Herb	LB, RB, Rip	September	October	Hemicryptophyte	Mesophyll
Violaceae									
Viola betonicifolia Sm.	-	-	+	Herb	LB, RB, Rip	May-June	September-October	Hemicryptophyte	Microphyll
Viola canescens Wall. ex Roxb.	-	+	+	Herb	LB, RB, Rip	May-June	September-October	Hemicryptophyte	Microphyll
Viola patrinii DC.	+	+	+	Herb	LB, RB, Rip	April-May	June-July	Therophyte	Microphyll
Vitaceae									
Vitis parviflora Roxb.	-	-	+	Shrub	LB, RB, Rip	April-May	June-July	Nanophanerophyte	Megaphyll

T: Tail zone (850-1300 m), B: Body (1300-1800 m), H: Head (1800-2200 m), Habit: Hyd-Hydrophyte, Habitat: LB: Left bank, RB: Right bank, Rip: Riparian, Occupancy, +: Present, -: Absent

and left bank upland forests (Fig. 3b). The herbaceous layer showed the lower species richness along the riparian and right bank upland forests, while the left bank upland forests showed high richness and heterogeneity (Fig. 3c).

Biological spectrum: The assessment on the biological spectrum of the study corridor is based on the seasonal observations of life forms in a span of two years. Life forms recorded for all the species revealed the highest percentage of therophytes (TH 67 species, 27.01%) followed by

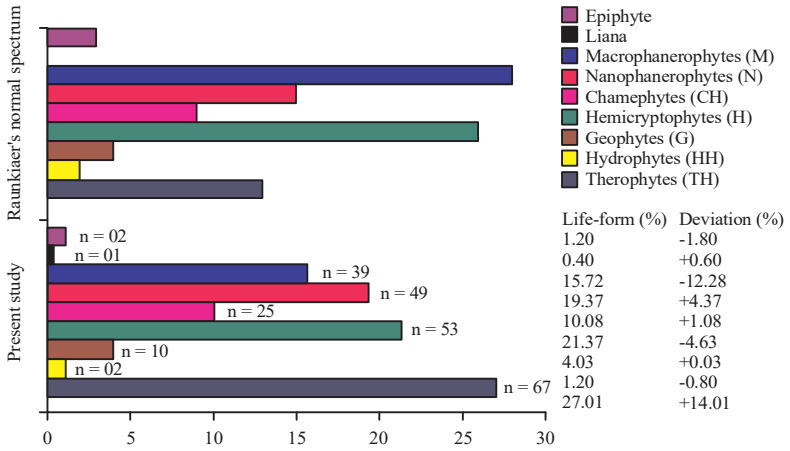

Fig. 4: Comparison of Raunkiaer's normal biological spectrum with the spectrum of study area and deviation from the former

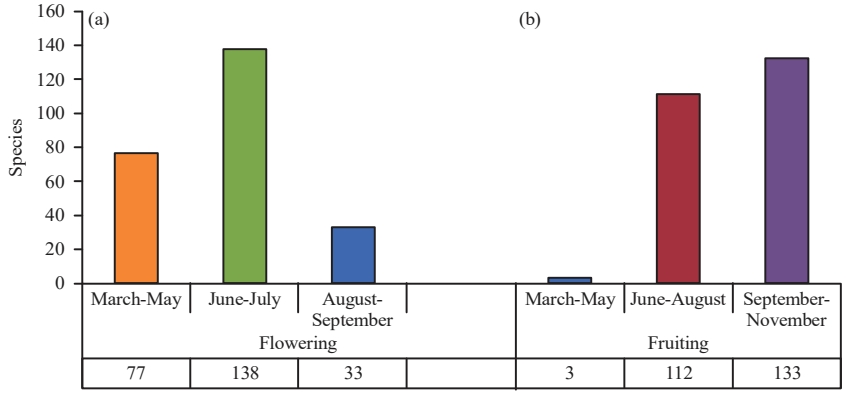

Fig. 5(a-b): Phenological observations, (a) Flowering and (b) Fruiting stages recorded for all seasons during the study period

hemicryptophytes (H 53, 21.37%), nanophanerophytes (N 49, 19.37%), macrophanerophytes (M 39, 15.72%), chamaephytes (CH 25, 10.08%), geophytes (G 10, 4.03%), hydrophytes (HH) and epiphytes (E 2, 1.20%) and Liana (L 1, 0.40%). The bio-spectrum suggests thero-hemicryptophytic type of phytoclimate. When compared with the normal spectrum of Raunkiaer, the Therophytes revealed the maximum deviation (+14.01%), while naophanerophytes show +4.37 and chamaephytes the minimum (+1.08%). On the contrary, a negative deviation of -12.28% has been observed for macrophanerophytes followed by hemicryptophytes (-4.63%) and epiphytes (-1.8). Other life forms show minor deviation from normal spectrum (Fig. 4).

Leaf spectra: An analysis of the leaf size spectra revealed that the vegetation of the study corridor is Microphyllus type with 115 species (46.37%) followed by Nanophylls (52 species, 20.96%) and Mesophylls (47 species, 18.95%). Leptophylls and Megaphylls were observed in less numbers with 19 (7.66%) and 15 plant species (6.04%) respectively, observed in the study area. The dominance of microphylls and nonophylls is attributed to the moderate slopes, dry substratum and mild climate of the study corridor.

Phenology: The phenophases (flowering and fruiting) of plants were recorded for all seasons during the study period. The plants have been grouped in three main categories which coincide with their flowering. The flowering season commences during March at lower elevations and it prolongs till September for few species. Current observations revealed that 77 i.e., 31% of plants in the study area started bearing flowers during March to May while a majority (138, 56%) bloomed during June and July. Flowering phase starts declining after July where a limited species (33.13%) were recorded bearing flowers during August and September (Fig. 5). These are mostly restricted to the tail zone of the study corridor. Most of the plants that bloomed during July and August belong to mid and higher elevations (1300-2200 m).

The fruiting corresponded with the flowering stages as a usual phenomenon. Maximum fruiting was observed post rainy season with 133 (53%) plants species recorded bearing fruits during September to November. One hundred and twelve species (45%) exhibited fruiting phenophase during moderately warm months of June, July and August. The period from March to May showed less fruiting with only three species observed bearing fruits (Fig. 5).

The senescence generally commences after September where many deciduous species start shedding their leaves. The riparian vegetation comprising of dominant trees like *Alnus nitida*, *Melia azedarach*, *Ailanthus altissima*, *Ficus palmata* and *Robinia pseudoacacia* exhibit the complete senescence by mid of November and remain dormant till late February at lower elevations. Likewise, the evergreen species like *Pinus roxburghii*, *P. wallichiana*, *Cedrus deodara* and *Picea smithiana* at mid and higher elevations also remain dormant during the autumn and winters.

DISCUSSION

The vegetation is a fundamental component of ecosystems that reflects the effect of total environment. During the surveys, a total of 248 plant species contained in 193 genera and 78 families were recorded from the riparian and adjoining upland forests along Neeru stream. Thirty nine among these were trees (15.72%), 49 shrubs (19.75%) and 170 herbs (68.54%) with a pronounced mid domain effect observed for the study corridor. Among the angiosperms, Asteraceae dominates the area with 27 species (10.88%) in 20 genera. The significant studies highlighting the composition, distribution and community structure of the vegetation in Neeru watershed include those by Dutt[27], Najeeb[28], Singh[30], Sharma[31], Sharma *et al.*[32], Sharma and Baloria[33] and Singh *et al.*[34]. All the above explorations restricted to the mountain ecosystems until the recent surveys in the riparian forests along Neeru, a typical hill stream in Bhaderwah by Sharma[29], Sharma *et al.*[35] and Sharma and Sharma[36]. The floristic explorations from the adjoining states of Himachal Pradesh and Uttarakhand (Pharswan *et al.*[39], Rana and Kapoor[40], Kumar *et al.*[41], Kanwal and Joshi[42]) and across the border in few pockets of Pakistan and Pakistan Occupied Kashmir (Khan *et al.*[43], Rahman *et al.*[44], Asif *et al.*[45], Zeb *et al.*[46], Haq *et al.*[47]) reveals the predominance of herbs followed by shrubs and trees with Asteraceae always at the top among other families. In terms of species richness, the study revealed a hump shaped distribution explaining the mid-domain effect supported by Zhang and Mi[48], Kharkwal[49], Zhang and Ru[50], Shaheen *et al.*[51], Mandal and Joshi[52] and Dar and Sundarapandian[53]. Lower and mid elevational bands are more species rich when compared to higher altitudes as observed by Kumar and Ram[54].

Different life form classes of plant species change with elevation which is evident with current results showing the predominance of therophytes (67 species, 27.01%) followed by hemicryptophytes (53, 21.37%) thus suggesting thero-hemicryptophytic type of phytoclimate. While the therophytes indicate the disturbed habitats, the hemicryptophytes are the indicators of temperate climate. These results are in consonance with the findings of Dutt[27], Najeeb[28], Sharma[29] and Sharma *et al.*[35] who worked in Neeru catchment. The dominance of hemicryptophytes and chamaephytes is typical of a temperate climate and is attributed to many factors which operate at macro, meso and micro climatic levels (Khan *et al.*[43], Zeb *et al.*[46]). The dominance of therophytes is usually associated with unfavorable dry environmental conditions (Haq *et al.*[47]). Similar results have been obtained for the ecosystems exhibiting same climatic regimes in north western Himalayas (Pharswan *et al.*[39], Khan *et al.*[43], Asif *et al.*[45], Zeb *et al.*[46], Haq *et al.*[47], Qureshi and Bhatti[55], Qureshi and Ahmed[56], Qureshi *et al.*[57], Khan *et al.*[58], Nazir *et al.*[59], Qureshi *et al.*[60]). Of the very limited studies available for the riparian habitats, Haq *et al.*[47] and Srivastava and Singh[61] recorded the dominance of therophytes followed by hemicryptophytes. The predominance of maga phanerophytes along the riparian corridors reflects the climax vegetation (Qureshi and Bhatti[55]).

The leaf size plays a significant role in studying the vegetation as it increase with humidity, rainfall and soil fertility. The leaf size spectrum in the study area shows the dominance of microphylls (115 species) followed by nanophylls (52) and mesophylls (47). Microphyllus vegetation is the characteristics of steppes and indicator of the steep conditions while nanophylls indicate dry and warm climatic conditions (Ali *et al.*[3] and Khan *et al.*[43]). The small leaf size is seen as an adaptive strategy for retaining soil moisture (Khan *et al.*[43]). Observations for the current study are in consonance with those of Khan *et al.*[43], Haq *et al.*[47], Asim *et al.*[62] who reported the dominance of similar leaf size spectra in their study areas. Phenological attributes of the plants in the Himalayas are controlled by the physiographic (mainly the elevation) and climatic factors (temperature). Our observations revealed that one third of the plants started bearing flowers during March to May, about half from June and July and only a few species post rainy season.

Interestingly, the flowering phase at lower elevation coincides with fruiting stages at higher elevations where most of the plants remain in late fruiting or dormant phase from late October to March. Similar observations were recorded by Ali *et al.*[3], Khan *et al.*[43], Asif *et al.*[45], Zeb *et al.*[46], Haq *et al.*[47], Srivastava and Singh[61], Singh and Singh[63], Rai[64] and Dar and Malik[65]. The fruiting phase was observed during June to August and September to November. Haq *et al.*[47], Asim *et al.*[62] and Malik and Malik[66] and also reported two flowering seasons in other parts of the Himalayan region.

CONCLUSION

The present documentation of taxonomic and functional diversity in a riparian hill corridor reveals rich phytodiversity with 248 species of plants, mostly herbs, dominated by the family Asteraceae. The predominance of thero-hemicryptophytic and microphyllus type of vegetation speaks of the kind of climate and nature of the habitat in the corridor. The peak flowering and fruiting were observed during July-August and September-November while most of the deciduous vegetation remains dormant during winters. The vegetation indicators call for effective ecological management of the corridor.

SIGNIFICANCE STATEMENT

The study highlights the factors that govern the phytoclimate of a typical riparian corridor. It also provides a piece of first-hand information on species response to the changing climate and human disturbances. The understanding of phenology on how species respond to the changing climatic regime and patterns need to be scientifically investigated on broader spatial and temporal scales. Other drivers of richness and diversity of riparian vegetation need to be integrated with future studies. The study helps to uncover the critical ecotones that many researchers were not able to explore in the region.

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