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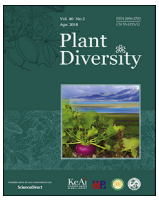

Plant endemism in the Nepal Himalayas and phytogeographical implications

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ABSTRACT

Nepal is located in the central part of the greater Himalayan range with a unique series of mountain chains formed by recent mountain building geological events. As one of the youngest mountains in the world it contributes to diversity of plants and also provided barriers to and corridors through which plants migrated during the ice ages. The higher altitudinal variation with the high mountains, deep river valleys and lowland plains combine with the effects of the summer monsoon and dry winter result with an extraordinary diversity of ecosystems including flora and fauna in a relatively small land area. The existing checklists for Nepal record some 6000 species of flowering plants and about 530 ferns. However, the botanical experts estimate that numbers may go up to 7000 when the poorly known remote regions are fully explored. The information on plant endemism in Nepal Himalaya is not adequately known as Nepal is still struggling to complete long awaited Flora of Nepal project. Endemic species are confined to specific areas and are the first to be affected by land use and other global changes. We sought to explore the spatial distribution of endemic plant species in Nepal in relation to the consequences associated with climatic and geologic changes over time in the region with the help of published literature. It was found that the endemism showed marked spatial variation between open moist habitat and dry inner valleys, the former with higher endemism. The updated records showed 312 flowering plant species to be endemic to Nepal with higher endemism around the elevation of 3800–4200 m at sea level. The recent human population explosion, intensified deforestation, habitat fragmentation and modern day environmental changes are posing greater threats to endemic plant in Nepal. The conservation status and threats to these peculiar species are unknown. Nevertheless, environmental degradation and high poverty rates create a potent mix of threats to biodiversity in this landscape.

1. Introduction

Nepal occupies a unique geographic position on Earth, possessing high elevational and climatic variation within the small area (147,181 km^2) which ranges from 59 m to 8848 m, the highest point in the world. Nepal is considered a crossroad of plant migration in the Himalayan region, with rich floral diversity due to the overlap of eastern and western Himalayan floral elements (Shrestha and Joshi, 1996).

It is well understood that both species and species diversity are not distributed randomly in space (Rosenzweig, 1995), rather they have distinct spatial patterns (Orme et al., 2005; Stohlgren et al., 2005) distributed along environmental gradients (Hortal et al., 2013; Slaton, 2015). Multiple overlapping and interacting gradients based on topography and climate are active in a heterogeneous landscape (Dewar and Richard, 2007; Slaton, 2015), such as in Nepal, forming a unique distribution of plant species. Although

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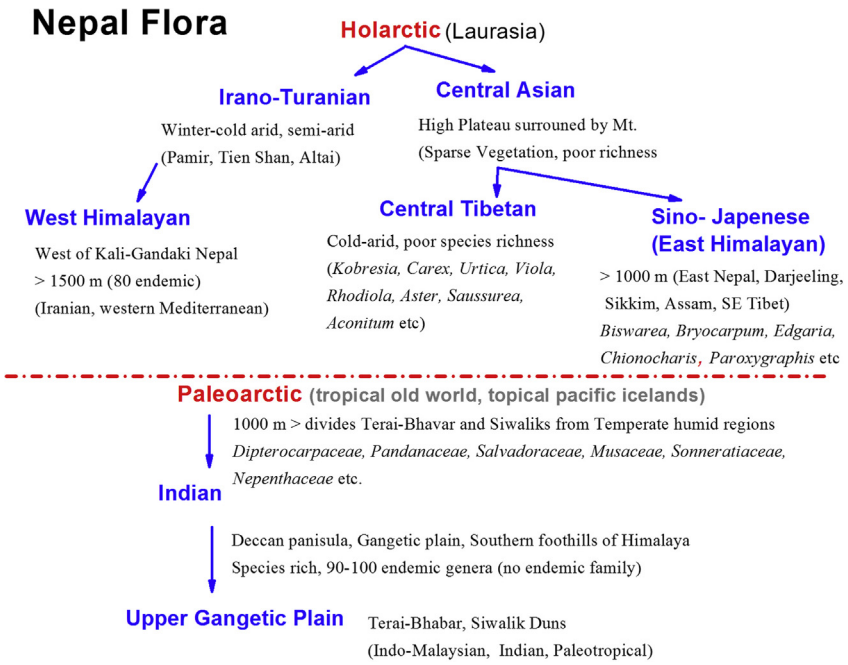

Fig. 1. Major floristic elements forming Flora of Nepal.

Nepal is a repository of unique biodiversity, the documentation of plant diversity is not adequate and many areas in the Nepal Himalayas are still unexplored due to their remote and inaccessible locations and lack of resources. Assessing spatial distribution, conservation status, and threats is necessary for the formulation of effective conservation actions and their implementation in order to conserve rare plant species. There is currently a major gap in knowledge regarding the conservation status and threats to endemic plant species in Nepal.

In this review we seek to analyze the diversity and distribution patterns of endemic flowering plants of Nepal and their conservation status, further illuminating the flora of Nepal and its biogeographical implications.

1.1. Plant diversity in Nepal

Nepal occupies a unique zone in the central Himalayas. Its phytogeographical provinces comprise various vegetation types, including tropical lowland rain forest (*Shorea robusta* forests), temperate forests of oak and conifers in the mid hills to dwarf scrubs of rhododendron and alpine meadows in the higher regions (Miehe et al., 2015). Within Nepal the amalgamation of various floristic elements includes drier Western and Central Asiatic floral provinces, a more humid Sino-Japanese province, South East Asiatic elements penetrating into the foothills of Eastern Nepal, African-Indian desert elements towards the western part of Nepal, and typical Indian floristic elements in the southern part (Welk, 2016) (see Fig. 1). Moreover, Nepal is situated in the central portion of the Himalayas, which is the transitional zone between the floras of the eastern and western Himalaya (Shrestha and Joshi, 1996).

Current plant checklists for Nepal record some 6076 species of flowering plants (Press et al., 2000) and about 534 ferns (DPR, 2013). However, expert assessment suggests that when poorly known remote regions are fully explored the number of flowering plants may rise to ~7000. Information on plant endemism in Nepal Himalayas is not adequately catalogued. Nepal is still struggling to complete the long-awaited Flora of Nepal project despite an early start of botanical exploration in Nepal Himalayas by Buchanan–Hamilton (1802-03) and N. Wallich (1820-21) (Miehe et al., 2015; Rajbhandari and Rai, 2017).

The Flora of Nepal is important for understanding the effects of the area's unique geographic position, elevational and climatic variations, documenting the names of Nepalese plants and to provide the much-needed baseline data for environmental and climate change studies, biodiversity inventories, conservations prioritization, and the sustainable use of natural resources. The

Table 1
Enumeration history of Flora of Nepal.

Family	Genus	Total taxa	Publication	Authors, Year
203		5036	An enumeration of the flowering plants of Nepal	Hara and Williams (1978); Hara et al. (1978, 1982)
		5199	Name list of the flowering plants and gymnosperms of Nepal	Koba et al. (1994)
229		6076	Annotated checklist of the flowering plants of Nepal	Press et al. (2000)
		5495	Flowering plants of Nepal, added to flora of Nepal	Rajbhandari (2002a, 2002b, 2003); Rajbhandari et al., 2003; Rajbhandari (2002-2003) (Rajbhandari and Joshi, 2001; Rajbhandari and Dahal, 2004)
21	123	600	Flora of Nepal Vol. 3 (Magnoliaceae-Rosaceae)	Watson et al. (2011)
58	421	1715	A Handbook of the Flowering Plants of Nepal Volume One	Rajbhandari and Rai. (2017)
91	696	3004	Handbook of Flowering Plants of Nepal (Volume 1, Cycadaceae–Betulaceae)	Shrestha et al., 2018

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summary of gradual progress of plant documentation in Nepal is presented in Table 1. The publication of the 'Flora of Nepal' is a major nation-building event and a crucial tool in maintaining Nepal's fragile habitats (Watson et al., 2011).

1.2. Geological history and modern landscape features

The Himalaya mountain system extends over 2400 km in an almost east-west direction from northern Pakistan to Namche Barwa (Gansser, 1964), and consists of complex topographical features, accommodates a wide variety of climates and soils, and consequently gives rise to a remarkable assemblage of vegetation types. The Himalayas reach a latitude as far north as 35°50′N at their northwestern limit, where there is very scant rainfall; the southeastern limit lies at 27°N, which receives very high monsoon rain. Within this range, the Himalayan system has a wide elevational range, from tropical foothills to the highest elevation on the earth (8848 m). Between these extremes many types of vegetation complexes have been observed, depending on the climate, topography, and edaphic conditions.

The Himalayas are the youngest mountains on Earth, lifted by the collision between India and Eurasia (Wang et al., 2014; Ding et al., 2017). Although the exact time is uncertain, the collision is believed to have begun during the early Eocene, around 45-35 million years ago (Ma) (Wang et al., 2014; Favre et al., 2015). Isotopic models on elevation estimates show that Himalaya mountains achieved their present height—or part of it (5 km)— either within the last 15 Ma (Garzione et al., 2000; Rowley et al., 2001; Saylor et al., 2009) or by 15 Ma (Gebelin et al., 2013), and the subsequent elevation in the later stages. The exact quantification of uplift of Himalaya is quite challenging due to the overall erosional environment of the mountain system in which the historical record is continuously being destroyed. However, plant fossil records and sediments from the remnant Indian plate on the southern edge of Tibetan Plateau indicate that the rise of the Himalayas began soon after the last deposition of Tethyan ocean sediments at ~58 Ma (Ding et al., 2017), then rose rapidly in the early Miocene, followed by ongoing uplift today.

The evolution of the Himalayas played a significant role in regional as well as global climate patterns, particularly in establishing an active South Asian Monsoon (Boos and Kuang, 2010; Molnar et al., 2010) and the drying of Tibet (Ding et al., 2017). Southern Asia is believed to have been exposed to Inter Tropical Convergence Zone monsoon climates since at least the early Eocene (and probably long before), and these monsoon climates have predominated the region even in the absence of an elevated Tibetan Plateau or the Himalaya mountains (Spicer, 2017). The Himalayas form a topographic barrier to the summer-time warm monsoon winds coming from the Indian Ocean and the winter-time cold winds coming from Siberia, resulting in cold dry climate in Tibet but plenty of rainfall on the valleys and plains to the south. Hence this region supports a rich diversity of flora and fauna extending from the almost sea-level plains upward in to the Higher Himalayas.

2. Plant endemism in Nepal

Endemic taxa refer to any species, or taxonomic unit, whose distribution is confined within a single restricted geographical area, and the phenomenon is known as endemism (Good, 1974; Gaston, 1991). Endemism may also be expressed as a percentage of all extant taxa present (excluding exotics), or as the absolute number of endemics in a given area. Thus, increases in geographical area proportionally increase the levels of endemism (Major, 1988). The levels of endemism may vary in a predictable way along gradients of primary environmental variables such as rainfall, temperature, productivity, and microtopography. The model-based predictions that accurately predict levels of endemism on the basis of quantifiable environmental variables could be useful for rapid recognition of endemic-rich areas (Hill and Keddy, 1992). At global scales, mountains are often rich in plant endemism in both tropical and temperate regions (Matthews et al., 1993). Phytogeographically, Nepal hosts high levels of plant endemism mainly because of its complex topography (Schickhoff, 2005), which generates extreme niche proximity, and the fusion of the eastern and western Himalayan elements, admixed with southern Tibetan and North Indian floristic elements. Topographic complexity likely results in increased species richness (Hortal et al., 2009), which offers micro refugia during periods of environmental changes (e.g. during past climatic fluctuations, or even during rare extreme weather events; Ashcroft et al., 2012). These refugia can decrease extinction risks, consequently maintaining species richness and endemic richness over time (Mee and Moore, 2014), which is crucial for isolated oceanic islands with low colonization rates. Topographic complexity may also cause gene-flow barriers among diverging populations, supporting reproductive isolation and hence local differentiation (Gillespie and Roderick, 2014).

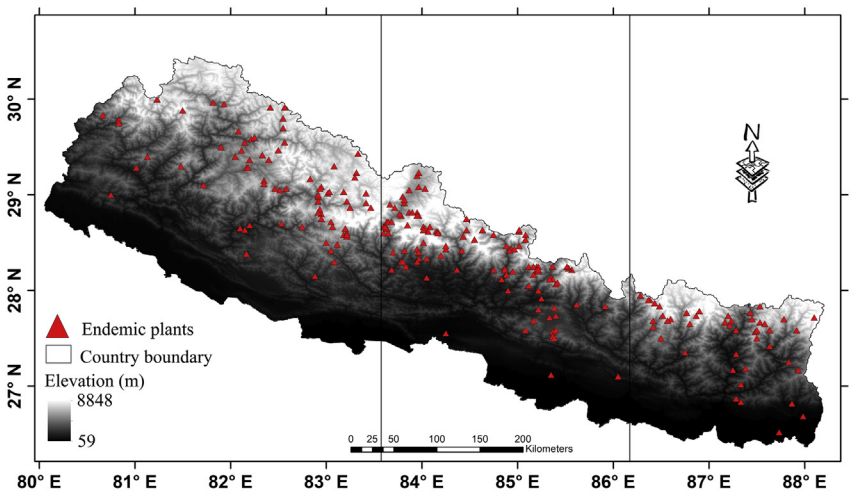

Fig. 2. Distribution of endemic flowering plants of Nepal (DPR, 2017, 2018).

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Table 2
Number of endemic species and genera per family.

Family	Genus	Species
Acanthaceae	*Justicia*	*Justicia tukuchensis*
	Strobilanthes	*Strobilanthes bheriensis, S. nutans, S. saccata*
	Thunbergia	*Thunbergia nepalensis*
Amaranthaceae	*Chenopodium*	*Chenopodium harae*
Amaryllidaceae	*Allium*	*Allium hypsistum*
Apiaceae	*Acronema*	*Acronema bryophilum, A. cryptosciadeum, A. dyssimetriradiata, A. johrianum, A. mukherjeeanum, A. phaeosciadeum, A. pneumatophobium, A. refugicolum*
	Conioselinum	*Conioselinum nepalense*
	Cortia	*Cortia staintoniana*
	Cortiella	*Cortiella lamondiana*
	Dolpojestella	*Dolpojestella shrestaeanum*
	Keraymonia	*Keraymonia nipaulensis, K. triradiata*
	Lalldhwojia	*Lalldhwojia pastinacifolia, L. staintonii*
	Oreocome	*Oreocome depauperata, O. involucellata*
	Pimpinella	*Pimpinella acronemastrum, P. inundata, P. kawalekhensis*
	Rohmooa	*Rohmooa kirmzii*
	Sinocarum	*Sinocarum normanianum, S. staintonianum*
	Synclinostyles	*Synclinostyles denisjordanii, S. exadversum*
	Tetrataenium	*Tetrataenium lallii*
	Vicatia	*Vicatia nepalensis*
Apocynaceae	*Brachystelma*	*Brachystelma nepalense*
	Ceropegia	*Ceropegia meleagris, C. polunininana*
Asparagaceae	*Asparagus*	*Asparagus penicillatus*
Asteraceae	*Artemisia*	*Artemisia mustangensis, A. nepalica*
	Cicerbita	*Cicerbita nepalensis*
	Cirsium	*Cirsium flavisquamatum, C. phulchokiense*
	Crepis	*Crepis himalaica*
	Leontopodium	*Leontopodium makianum, L. montisganeshii*
	Saussurea	*Saussurea bhutkesh, S. chrysotricha, S. dhwojii, S. kanaii, S. linearifolia, S. platyphyllaria, S. rolwalingensis, S. ramchaudharyi*
	Senecio	*Senecio brunneo-villosus, S. topkegolensis*
	Synotis	*Synotis managensis, S. panduriformis*
	Taraxacum	*Taraxacum amabile, T. nepalense, T. staintonii*
Balsaminaceae	*Impatiens*	*Impatiens arunensis, I. bajurensis, I. gorepaniensis, I. harae, I. kathmanduensis, I. kharensis, I. mallae, I. reticalcarata, I. scullyi, I. williamsii*
Begoniaceae	*Begonia*	*Begonia flagellaris, B. leptoptera, B. minicarpa, B. nuwakotensis, B. taligera, B. tribenensis*
Berberidaceae	*Berberis*	*Berberis mucrifolia, B. pendryi*
Boraginaceae	*Arnebia*	*Arnebia nepalensis*
	Microula	*Microula mustangensis*
	Onosma	*Onosma bheriense, O. verruculosum, O. wallichianum*
Brassicaceae	*Aphragmus*	*Aphragmus hinkuensis, A. nepalensis*
	Draba	*Draba macbeathiana, D. polunininana, D. staintonii*
	Lepidostemon	*Lepidostemon williamsii*
	Noccaea	*Noccaea nepalensis*
	Solms-laubachia	*Solms-laubachia haranensis, S. nepalensis*
Campanulaceae	*Codonopsis*	*Codonopsis bragaensis, C. reflexa*
	Cyananthus	*Cyananthus hayanus, C. himalaicus*
Caryophyllaceae	*Arenaria*	*Arenaria mukerjeeana, A. paramelanandra*
	Silene	*Silene davidlongii, S. fissicalyx, S. greywilsonii, S. hellebriflora, S. hideakiohbae, S. stellariifolia, S. vautierae*
Crassulaceae	*Rhodiola*	*Rhodiola nepalica*
	Rosularia	*Rosularia marnieri*
	Sedum	*Sedum pseudomulticaule*
Cucurbitaceae	*Gomphogyne*	*Gomphogyne nepalensis*
Cyperaceae	*Carex*	*Carex esbirajbhandarii, C. himalaica, C. mallae, C. rhombifructa, C. gandakiensis, C. rufulistolon*
Elaeagnaceae	*Elaeagnus*	*Elaeagnus tricholpis*
Ericaceae	*Rhododendron*	*Rhododendron cowanianum, R. lowndesii*
Eriocaulaceae	*Eriocaulon*	*Eriocaulon exsertum, E. kathmanduense, E. obclavatum, E. trisectoides*
Euphorbiaceae	*Croton*	*Croton nepalensis*
	Mallotus	*Mallotus bicarpellatus*
Fabaceae	*Astragalus*	*Astragalus barclayanus, A. chateri, A. jumlaensis, A. lobbichleri, A. nakaoi, A. nepalensis, A. notabilis, A. polunini, A. pseudorigidulus*
	Colutea	*Colutea multiflora*
	Crotolaria	*Crotolaria kanaii*
	Hedysarum	*Hedysarum manaslense*
	Millettia	*Millettia nepalensis*

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Table 2 (*continued*)

Family	Genus	Species
	Oxytropis	*Oxytropis arenae-ripariae, O. fasciculiflorum, O. graminetorum, O. morenarum, O. nepalensis, O. torrentium, O. williamsii*
	Rhynchosia	*Rhynchosia nepalensis*
Gentianaceae	*Gentiana*	*Gentiana chateri, G. pentasticta, G. radicans, G. sagarmathae, G. tetramerus*
	Gentianella	*Gentianella glanduligera, G. lowndesii*
	Swertia	*Swertia acaulis, S. barunensis, S. nepalensis*
Hypericaceae	*Hypericum*	*Hypericum cordifolium*
Iridaceae	*Iris*	*Iris staintonii*
Juncaceae	*Juncus*	*Juncus mustangensis*
Lamiaceae	*Clinopodium*	*Clinopodium nepalense*
	Discretitheca	*Discretitheca nepalensis*
	Eriophyton	*Eriophyton nepalense, E. staintonii*
	Isodon	*Isodon dhankutanus, I. namikawanus, I. phulchokiensis*
	Microtena	*Microtena nepalensis*
	Nepeta	*Nepeta staintonii*
	Salvia	*Salvia transhimalaica*
Lauraceae	*Machilus*	*Machilus pubescens*
Lythraceae	*Rotala*	*Rotala rubra*
Oleaceae	*Jasminum*	*Jasminum amabile*
Onagraceae	*Epilobium*	*Epilobium brevisquamatum, E. staintonii*
Orchidaceae	*Bulbophyllum*	*Bulbophyllum nepalense, B. raskotii*
	Eria	*Eria annapurnensis, E. baniaii, E. nepalensis, E. pokharensis*
	Gastrochilus	*Gastrochilus nepalensis*
	Herminium	*Herminium fimbriatum, H. hongdeyuanii*
	Liparis	*Liparis langtangensis*
	Malaxis	*Malaxis dolpensis, M. tamurensis*
	Neottia	*Neottia chandrae, N. nepalensis*
	Odontochilus	*Odontochilus nandae*
	Oreorchis	*Oreorchis porphyranthes*
	Pleione	*Pleione coronaria*
Orobanchaceae	*Euphrasia*	*Euphrasia nepalensis*
	Pedicularis	*Pedicularis annapurnensis, P. anserantha, P. chamissonoides, P. cornigera, P. muguensis, P. odontoloma, P. oxyrhyncha, P. pseudoregeliana, P. tamurensis, P. terrenoflora, P. yalungensis, P. yamazakiana, P. breviscaposa*
Papaveraceae	*Corydalis*	*Corydalis calycina, C. clavibracteata, C. megacalyx, C. simplex, C. spicata, C. stipulate, C. terracina, C. uncinata, C. uncinatella*
	Meconopsis	*Meconopsis autumnalis, M. chankeliensis, M. ganeshensis, M. gracilipes, M. lamjungensis, M. manasluensis, M. nepaulensis, M. regia, M. simikotensis, M. staintonii, M. taylorii*
Plantaginaceae	*Lagotis*	*Lagotis nepalensis*
	Veronica	*Veronica emodi*
Poaceae	*Borinda*	*Borinda emeryi*
	ELymus	*ELymus nepalensis*
	Eulaliopsis	*Eulaliopsis sykesii*
	Festuca	*Festuca eriobasis, F. nepalica, F. poluninii*
	Himalayacalamus	*Himalayacalamus asper, H. cupreus, H. fimbriatus, H. planatus, H. porcatus*
	Poa	*Poa hideaki-ohbae, P. muktinathensis*
	Saccharum	*Saccharum williamsii*
	Stipelula	*Stipelula staintonii*
	Thamnocalamus	*Thamnocalamus chigar*
Polygonaceae	*Bistorta*	*Bistorta confusa, B. diopetes, B. milletiodes*
	Fagopyrum	*Fagopyrum megacarpum*
	Fallopia	*Fallopia filipes*
Primulaceae	*Primula*	*Primula didyma, P. poluninii, P. ramzane, P. sharmae, P. wigramiana*
Ranunculaceae	*Aconitum*	*Aconitum amplexicaule, A. angulatum, A. bhedingense, A. dhwojii, A. poluninii, A. staintonii, A. tabatae, A. williamsii*
	Anemone	*Anemone fuscopurpurea*
	Clematis	*Clematis bracteolata, C. phlebantha*
	Delphinium	*Delphinium himalayai, D. unifolium, D. williamsii*
	Oxygraphis	*Oxygraphis nepalensis*
	Ranunculus	*Ranunculus himalaicus, R. makaluensis*
Rosaceae	*Potentilla*	*Potentilla makaluensis, P. turfosoides*
	Prunus	*Prunus jajarkotensis, P. taplejungnica, P. topkegolensis, P. himalaica*
	Sibbaldia	*Sibbaldia emodi*
	Sorbus	*Sorbus sharmae*
Rubiaceae	*Galium*	*Galium nepalense, G. saipalense*
	Ophiorrhiza	*Ophiorrhiza nepalensis*

(*continued on next page*)

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Table 2 (*continued*)

Family	Genus	Species
Salicaceae	*Salix*	*Salix nepalensis, S. plectilis, S. staintoniana*
Saxifragaceae	*Saxifraga*	*Saxifraga alpigena, S. amabilis, S. cinerea, S. excellens, S. ganeshii, S. harae, S. hypostoma, S. jaljalensis, S. lowndesii, S. mallae, S. micans S. mira, S. namdoensis, S. neopropagulifera, S. poluninana, S. rhodopetala S. rolwalingensis, S. roylei, S. staintonii, S. williamsii, S. zimmermannii*
Scrophulariaceae	*Scrophularia*	*Scrophularia bheriensis, S. laportiifolia*
Urticaceae	*Pilea*	*Pilea kanaii*
Zingiberaceae	*Roscoea*	*Roscoea ganeshensis, R. nepalensis, R. tumjensis*

Plant endemism forms the principal criterion for the determination of biodiversity hotspots because endemic species are heavily dependent on a restricted area/habitat for their survival; hence they are often the most vulnerable species (Myers, 1988). When these species are confined to highly threatened ecosystems, they will almost certainly be the first to be affected by extinction processes. Consequently these species need rapid and effective conservation actions (Heywood and Watson, 1995). Biodiversity hotspots are determined mainly by two main criteria; the plant endemism and degree of threat. Earth's 25 biodiversity hotspot regions collectively cover only about 2% of the planet's land surface, yet claim more than 50% of all terrestrial species diversity (Myers, 1988), hence biodiversity hotspots are crucial for conservation.

The first comprehensive inventory of endemic flowering plants of Nepal was carried out in 1985 as an interim report for Royal Nepal Academy (Shrestha et al., 1986). The publication of endemic plants of Nepal was in a paper in the 'Proceedings of National Conference on Science and Technology' (Bajracharya et al., 1989). The report evolved into a book entitled *Rare, Endemic and Endangered Plants of Nepal*; published by WWF Nepal Program (Shrestha and Joshi, 1996) that included 246 species of endemic flowering plants of Nepal. Several publications (Joshi and Joshi, 1991; Rajbhandari, 1994; Bhuju et al., 2007) followed this book which has become a standard reference. The Department of Plant Resources (Government of Nepal) has published the compilation on endemic flowering plants of Nepal in three parts; Part I includes 98 species belonging to 18 families; Part II reported 100 species listed under 15 families; and Part III described 84 species placed in 10 families (Rajbhandari and Dhungana, 2010). The Department of Plant Resources (GON) has then reported 284 endemic flowering plants in Nepal (DPR, 2013). Recent updated information published by the Department of Plant Resources, Ministry of Forests and Environment (Rajbhandari and Rai, 2017), has described 312 species of flowering plants from 46 families and 126 genera as endemic to Nepal (Fig. 2, Table 2). This documentation is very important for understanding the general description and distribution of each endemic plant in Nepal. However, population demography and conservation status are still unknown for most taxa. After Rana et al. (2018) reported *Saussurea ramchaudharyi* Ghimire & Rana from northwestern region of Nepal the total number of endemic species increased to 313; however, more recently, *Begonia panchtharensis* S. Rajbh. (Begoniaceae), which was previously reported as an endemic species in Nepal, has been also reported from India (Pradhan et al., 2019). Here, we therefore present a total of 312 species of flowering plants endemic to Nepal Himalayas.

Endemics from the Nepal Himalayas are broadly described under two categories, holo-endemics and neo-endemics. However, some of these endemics are only reported from their type localities (Shrestha and Joshi, 1996), and a few are relict species which are extinct elsewhere (Ghimire, 2005). As home to the most recently formed mountains on Earth, Nepal and its young geological environment harbors large numbers of neo-endemics (Fiedler and Ahouse, 1992). Some taxa have not had time to expand their range since their origin due to both climatic and geological thresholds; rather they tend to evolve new forms in response to climatic and ecological changes within a confined distribution range. On the other hand, holo-endemic species are not evolutionarily young, but have had little opportunity to spread to other areas due to narrow geological and climatic tolerances (Ghimire, 2005).

While plant endemism in Nepal can be attributed to its topographic and climatic heterogeneity as well as its location between eastern and western Himalayan floristic regions, both plant species richness and endemism in Nepal is low compared to the eastern Himalayas. The eastern Himalayan region comprises eastern Nepal, Bhutan, and neighboring states of northern India adjoining Yunnan province in southwest China. In the neighboring state of Sikkim alone 4250 plant species (geographical area 7298 km^2) have been recorded and 2550 (60%) of those are endemic (Myers, 1988). In Nepal, out of more than 6000 flowering plants (Press et al., 2000), many also occur in India, Bhutan, and even Yunnan. Bhutan, despite being a small country, possesses an estimated 5000 species, of which as many as 750 (15%) are considered endemic to the eastern

Fig. 3. Some endemic flowering plants of Nepal *(Photo credit; Prabin Bhandari)*.

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Himalayas (Anonymous, 1992). Recent studies have found that 66% of the angiosperm genera in China did not originate until early in the Miocene epoch (23 Ma) and many lineages of angiosperms have originated as recent topographic changes and climatic shifts—such as the formation of the Qinghai–Tibetan Plateau and the development of the monsoon—provided new habitats that promoted remarkable radiation (Lu et al., 2018).

The number of endemic flowering plants reported from Nepal is very low compared to those in the much larger neighboring countries of India and China. India is very rich in plant endemism, and possesses high biodiversity owing to its larger climatic and topographic gradient. India has been estimated to harbor more than 18,259 species of angiosperms (FSI, 2011; Singh et al., 2015). A recent record indicates that 4381 taxa (Angiosperms-4303, Gymnosperms-12, Pteridophytes-66) are endemic to India, and that at least 23% of the flowering plants in India are endemic. The higher plant endemism in India is mainly due to rich diversity in the Western Ghats, followed by the eastern and western Himalayas (Singh et al., 2015). Similarly, the plant life of China is enormously rich; some 31,000 native plant species have been recorded, representing nearly one-eighth of the world's total plant species, including thousands of plants found nowhere else on Earth. About 10,000 species of vascular plants are endemic to China; including more than 30% of the flowering plants. Unfortunately, nearly 3000 vascular plants in China are in danger of extinction (http://flora.huh.harvard.edu/china/mss/plants.htm).

2.1. Diversity and distribution map

All 312 species of endemic flowering plants in Nepal are distributed across 46 families; of these, 24 families are monogenic and 22 families are polygenic (Table 2). Some endemic plants of Nepal are presented in Fig. 3. The largest contributing families to plant endemism in Nepal are the Apiaceae, Asteraceae, Fabaceae, Saxifragaceae and Papaveraceae (Fig. 4). Spatial analysis has revealed that the largest numbers of endemic plants are located at elevations between 3800 and 4200 m in central Nepal (Fig. 5), where the transition zone between the western and eastern Himalayas exists together with a Southern Tibetan floristic component. Notably, previous work has reported higher endemism in the Annapurna Conservation Area (ACA) in central Nepal. ACA was established in 1986 and its rich biodiversity is a treasure trove,

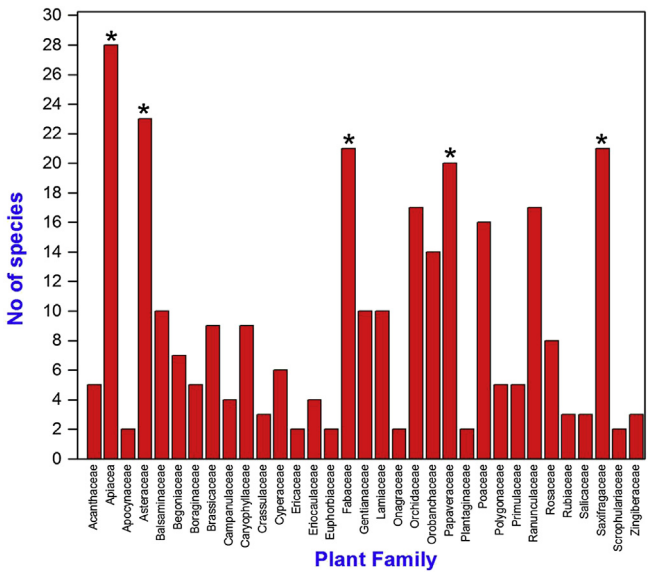

Fig. 4. Polygeneric families of endemic plants of Nepal.

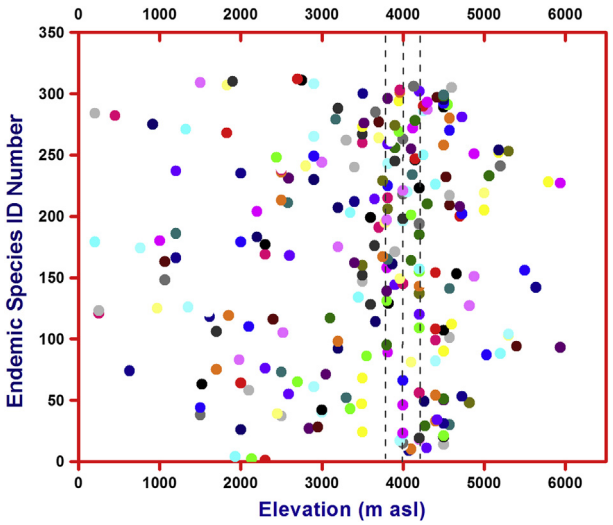

Fig. 5. Altitudinal distribution of endemic flowering plants of Nepal.

with 1226 species of flowering plants, 102 species of mammals, 474 species of birds, 39 species of reptiles, and 22 species of amphibians (NTNC, 2012). Due to the sharp contrast in climate and topography, this region potentially hosts more endemic species than previously reported. For example, the ACA contains the highest rainfall region (Ghandruk, Kaski) and the driest place in Nepal (Lomanthang, Upper Mustang) (see reports Government of Nepal, 2015).

Increased endemism at higher elevations has been attributed to increased isolation, which promotes speciation, population persistence and divergence (see Rahbek, 1995; Heaney, 2001; Lomolino, 2001). Whereas endemism generally increases proportionally with elevation, in the case of the Nepal Himalayas, the absolute number of endemic species decreases above around 4000 (3500–4500) m due to the sharp decrease in species richness (Vetaas and Grytnes, 2002). The elevational gradients of species richness are more frequently discussed than elevational gradients of endemism. Corresponding to species richness–elevation relationships, there are two well documented primary patterns; increasing (Berry et al., 1995; Kessler, 2000, 2002) and unimodal (Vetaas and Grytnes, 2002; Kluge and Kessler, 2006; Zhang et al., 2009). These models differ according to the elevation belt, especially in mountains and plains. The southern plains of Nepal offer reduced opportunities for isolation because the local environment is more similar to those across the extensive plains of northern India where the physical environment varies less; however, the opposite scenario has been observed in the high mountains in the northern parts of Nepal (Vetaas and Grytnes, 2002).

Regional studies also indicate that higher flowering plant endemism occurs in high mountain landscapes (Joshi et al., 2000; Ghimire, 2005). A comprehensive study of endemic plants of Dolpo (Trans-Himalaya, western Nepal) reported 84 endemic flowering plants, with maximum endemism observed in the elevation belt between 4000 and 4500 m (Ghimire, 2005). Floristic studies are considered as a part of continuous research and are highly important in context of Nepal, since the complete flora of the region has not been published yet. Hence, continuous verification is required as many previously considered endemic plants have since been reported to occur outside Nepal.

2.2. Threats to endemic plants and conservation needs

Endemic plants in Nepal are inadequately documented or understood with knowledge of their distribution being poor and little or no information is documented about their ecology and

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conservation status. Recent initiatives to study the conservation status of these plants has produced scant new information to date. This is largely because type specimen collection locations are either not properly identified or the habitats from where these species were recorded are degraded/lost (Uprety, 2015). Nevertheless, forest fire, deforestation, habitat degradation and loss, river bank erosion, land use change, and grazing are some of the threats to endemic plants of Nepal. Though equal importance for both flora and fauna has been given in policy documents plant diversity conservation is often over-shadowed by animal conservation initiatives in Nepal. The intimate relationship between plants and animals is ignored at our peril. This calls for priority to be given to endemic plants that provide food and shelter for the faunal elements of the diverse ecosystems of the Himalaya. Specific species conservation plans are required to address the conservation issues of endemic plants.

Because endemic species are confined to restricted habitats with narrow geographic ranges and are often considered rare, they demand special conservation efforts (Joshi and Janarthanam, 2000). The uniqueness of flora drives the degree of endemism for a given area, which is critical for prioritizing 'pocket areas' and 'key species' for conservation (Bonn et al., 2002). The rarity of endemic species is not only caused by restricted distribution with small geographic ranges but also by small population size and highly specified habitats, or both (Kruckeberg and Rabinowitz, 1985). The distribution of endemic species is also driven by environmental history, disturbance regimes, and interference; furthermore, particularly in the Nepal Himalayas, endemism is driven by human-induced scarcity, a phenomenon that is common along the southern slopes of the Himalayas (Schickhoff, 2005).

3. Conclusions

Current data on plant diversity in Nepal is still unconsolidated as the Flora of Nepal is not complete. However, on the basis of regional floristic studies, experts have suggested that the total number of flowering plant in Nepal may reach 7000. Our review indicates that in Nepal there are 312 endemic species of flowering plants, belonging to 46 families and 126 genera to be endemic in Nepal. The highest endemism is found in the elevation belt ranging between 3800 and 4200 m. At the higher elevations of the Himalayas, the influence of the climate on migration of high mountain forests (Tiwari et al., 2017; Sigdel et al., 2018) may create a mismatch in the distribution of vegetation and habitat fragmentation as well as the emergence of new species. The conical shape of the mountains may lead to range loss and 'mountain-top extinctions' due to the upslope movement of forests, including, in extreme cases, treelines (Colwell et al., 2008). Hence, to regularly monitor population status and regeneration of endemic plants in Nepal, establishing long-term observation plots at high mountain elevations is critical.

More detailed studies are required to understand the phytogeography of Nepal Himalayas, being one of the youngest mountains in the world and important landscape for diversification and distribution of flowering plants. Proper documentation, timely updates and more data are highly important to improve our understanding on the distribution and diversification patterns of endemic plants in Nepal. As Nepal is experiencing rapid warming, especially at higher elevations, as well as higher rates on deforestation and forest degradation, conservation efforts are needed to protect endemic plant species throughout the region.

Conflicts of interest

The authors declare that there is no conflict of interest regarding this manuscript. All the authors agreed to submit this manuscript.

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