Classifying threatened species of India using IUCN criteria

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Assigning threat status to a species is essential for prioritization of species under any conservation programme, and therefore, a pre-requisite for species conservation. In India, due to inadequate data, threat status has not been assigned to several plant species, although their population sizes are quite small and they are considered important from conservation point of view. Besides, there is a need for reassessment of threat status assigned by various agencies using updated data on population size, number of mature individuals, area of occupancy, and geographic extent of occurrence. This is crucial as the natural habitats as well as populations of such species are being affected by anthropogenic activities, exotic species invasion, and climate change. In the present study, we assessed the threat status of 59 selected plant species following the IUCN criteria (ver. 3.1). The species were selected after consultation with various experts throughout the country. Field surveys were carried out in various ecoregions of India to locate the species. Population size and number of mature individuals were enumerated following quadrat/plot-based sampling. The exogenous and endogenous factors leading to decline in population and rarity were identified based on field observations as well as laboratory-based seed viability and germination tests. Based on these studies, 20 species were classified under critically endangered category, 21 under endangered, 11 under vulnerable, five under near threatened, and one species each under data deficient and least concern category. Threat assessment for 41 species was done based on number of locations and geographical range of occurrence, while for 18 species it was done based on restricted population and number of mature individuals. Over-exploitation and habitat degradation or loss were the dominant exogenous factors leading to decline in natural populations of the selected species. The major endogenous factors that lead to population decline and species rarity were low seed viability and germination, long dormancy period, less seedling recruitment, low population size, habitat specificity and narrow niche leading to restricted distribution.

Keywords: Area of occupancy, extent of occurrence, IUCN classification, population size, threatened plants.

Introduction

ANTHROPOGENIC disturbances have led to the loss of ~2.3 million sq. km of global forests[1]. Such large-scale destruction of natural habitats coupled with rise in average global temperature and invasion of alien species, have pushed one-fifth of the plant species to the verge of extinction[2]. It is projected that almost half of the estimated 10 million species, including plants would be lost because of the above factors[3]. All of these could plausibly bring about the sixth mass extinction event[4].

In the light of the above, it is imperative to take corrective measures to mitigate or at least slow down the loss of species. This calls for prioritizing species based on the threat perception for focused conservation action. This would help improving their population size and number, and conservation status, thus ensuring long-term survival on earth[5].

The International Union for Conservation of Nature (IUCN) is a focal agency for threat assessment of species worldwide. In India, several other agencies, conventions, programmes, acts and publications include/compile or develop the list of threatened plant species. These are Red Data Book of India (RDB), Conservation Assessment and Management Plan (CAMP), Environmental Information System (ENVIS), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), National Biodiversity Authority (NBA), and Wildlife Protection Act, 1972 (WPA). All these agencies have developed distinctive methods, approaches and priorities for classification of threatened plants, based on a multitude of parameters and criteria, viz. herbarium records, qualitative and quantitative scoring techniques, area of occupancy (AOO), extent of occurrence (EOO) and expert opinions. However, threat assessment of many important plant species in India is lacking, leading to below-par conservation and species prioritization efforts.

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The Indian region is bestowed with rich and diverse ecosystems with high levels of species and genetic diversity. Owing to a wide altitudinal variation, strategic biogeographical location and the mosaic nature of geoclimatic conditions, the flora and vegetation of India show enormous variation. With ever-increasing human intervention and large-scale habitat destruction, many of the plant species are facing threat of extinction. Although a number of them have been listed as threatened species, numerous others are not yet classified owing to data deficiency.

Considering the importance of biodiversity conservation in the country, the Environmental Biotechnology and Biodiversity conservation Task Force of the Department of Biotechnology, Government of India in its second meeting held on 9 and 10 August 2010, suggested that some mega network programmes should be taken up to conserve threatened species in the country. As a follow-up to this suggestion, an All-India Coordinated Project on 'Preventing extinction and improving conservation status of threatened plants through application of biotechnological tools' was conceived and launched in 2012. The present endeavour is a part of this larger study to assign threat status to selected threatened plants in India using the IUCN criteria (ver. 3.1)[6].

Materials and methods

Species selection and field survey

Fifty-nine plant species from different ecological regions of India were selected for threat assessment (Table 1). These species were selected through discussions with various experts on plant conservation in the country. Field surveys were carried out during 2012–2016 to locate the species in various ecoregions, and the geographical coordinates of their occurrence were recorded using GPS device. Population size and number of mature individuals were estimated through plot/quadrat-based sampling in the localities of their occurrence during field surveys. Factors responsible for the decline in species population were identified/inferred from field observations. Seed viability and germination tests were conducted in the laboratory to determine whether they have a role in population decline or rarity.

Threat status assessment

We employed the IUCN protocol (ver. 3.1)[6] for threat assessment and assigning conservation status to the species (Table 1). The geographic range of occurrence, population size and status, and number of existing mature individuals were the major criteria used for threat assessment and assigning conservation status. Table 1 presents details of the protocol.

Conservation rating based on geographic range

Under geographic range, extent of occurrence (EOO) and area of occupancy (AOO) were estimated considering severely fragmented populations, continuing decline or extreme fluctuations in area, extent and/or quality of habitat, number of locations or subpopulations, and number of mature individuals. We used the Conservation Assessment Tool (CAT) developed by the Royal Botanic Gardens, Kew, UK, to estimate the geographic range of the selected species[7]. CAT is an extension for ArcView 3.x, version 1.2, which is used to calculate EOO and the AOO for rapid conservation assessments based on IUCN Categories and Criteria[8]. The program calculates a variety of measures relating to a species point distribution or multiple species through a batch process, and gives a threat rating based on the IUCN Categories and Criteria.

Rating based on EOO: EOO is the area enclosed within the shortest continuous boundary drawn to incorporate all the known, inferred or projected sites of occurrence of a species, excluding cases where the species occur outside their natural home range[8]. Thus, EOO is represented through a convex hull or minimum convex polygon, which is a line drawn around all distribution points with an internal angle not exceeding 180°. The convex hull can be drawn only when there is a minimum of three unique distribution points or localities. The EOO rating is based on the values as listed under the IUCN Categories and Criteria version 3.1. The area value for EOO calculated above was compared with the thresholds set in Criterion B1 and the relevant rating was obtained (Table 1).

Rating based on AOO: AOO is the area occupied by a species within its EOO, excluding cases where the species occur outside their natural home range[8]. Species are assigned a threat rating after estimating the subpopulations based on AOO using grid adjacency technique and AOO density calculation. Under grid adjacency, all contiguous grid cells from the AOO calculations are considered to be one subpopulation and thus, the count of subpopulations is obtained. The AOO density value is a measure to describe the density and distribution of occurrence of localities for the species. The value is calculated as the number of AOO subpopulations divided by the number of AOO cells. A value between 0 and 1 is assigned where 0 is sparsely occupied, i.e. all AOO cells are isolated and 1 is densely occupied. The AOO density is calculated as follows:

$$\text{AOO density} = 1 - (\text{AOO subpopulations} / \text{AOO number of cells}).$$

As it was not feasible to go for intensive sampling due to logistic constraints, we used a standard grid cell size of

Table 1. IUCN criteria (ver. 3.1) used for assigning conservation status to threatened plants in India

		Critically endangered	Endangered	Vulnerable
B.	Geographic range in the form of either B1 (extent of occurrence) and/or B2 (area of occupancy)			
	B1 Extent of occurrence (EOO; sq. km)	<100	<5000	<20,000
	B2 Area of occupancy (AOO; sq. km) and at least two of the following three conditions:	<10	<500	<2000
	(a) Severely fragmented or number of locations	=1	≤5	≤10
	(b) Continuing decline observed, estimated, inferred or projected in any of (i) extent of occurrence, (ii) area of occupancy, (iii) area, extent and/or quality of habitat, (iv) number of locations or subpopulations and (v) number of mature individuals.			
	(c) Extreme fluctuations in any of (i) extent of occurrence, (ii) area of occupancy, (iii) number of locations or subpopulations, (iv) number of mature individuals.			

		Critically endangered	Endangered	Vulnerable
C.	Small population size and decline			
	Number of mature individuals and at least one of C1 and C2	<250	<2500	<10,000
	C1 Observed, estimated or projected continuing decline of at least (up to a maximum of 100 years in future):	25% in three years or one generation (whichever is longer)	20% in five years or two generation (whichever is longer)	10% in ten years or three generation (whichever is longer)
	C2 Observed, estimated, projected or inferred continuing decline and at least one of the following three conditions:			
	(a) (i) Number of mature individuals in each subpopulation	≤50	≤250	≤1000
	(ii) Percentage of mature individuals in one subpopulation	90–100%	95–100%	100%
	(b) Extreme fluctuations in the number of mature individuals			

		Critically endangered	Endangered	Vulnerable
D.	Very small or restricted population			
	D1 Number of mature individuals	<50	<250	D1. 1000
	D2 Only applies to the VU category			
	Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.	–	–	D2, Typically: AOO <20 sq. km or number of locations ≤5

VU, Vulnerable; CR, Critically endangered; EX, Extinct.

4 sq. km to maintain consistency and comparability of the results[8].

Conservation rating based on population size and number of mature individuals

We estimated the population size and number of mature individuals for a few species in the AOO of the selected species through quadrat and plot-based sampling method.

Conservation rating

Based on availability of data, the species were categorized using the criteria [B], [C], [D] and sub-criteria for critically endangered (CR), endangered (EN) and vulnerable (VU). The hierarchical alpha-numeric numbering system of the criteria and sub-criteria was used in threat assessment (Table 1).

Results and discussion

A comprehensive threat assessment was undertaken for 59 selected species belonging to 45 genera and 34 families. Overall, it constituted 16 tree, 15 herb, 9 orchid, 5 shrub, 4 climber, 3 rattan, 2 cycad, 2 palm, 1 bamboo, and 1 tree fern species. Orchidaceae was the dominant family represented by 9 species, followed by Arecaceae (5 species), and Ranunculaceae (4 species). Ericaceae and Apocynaceae were represented by 3 species each, while Asparagaceae, Balsaminaceae, Cycadaceae, Fabaceae, Piperaceae and Poaceae were represented by 2 species each respectively. Each of the remaining 23 families was represented by one species (Annexure 1).

A total of 860 localities were recorded for all the species, of which *Cycas sphaerica* had the highest number of records (263), followed by *Embellia ribes* (44), *Paris polyphylla* (39), *Impatiens talbotii* (34), *Lasiococca comberi* (32), *Dipterocarpus gracilis* (25), *Hypericum gaitii* (23) and *Ilex khasiana* (21). Forty-five species were

recorded from number of localities ranging between 2 and 19, while 6 species, viz. *Dipcadi goaense*, *Impatiens clavata*, *Paphiopedilum druryi*, *Paphiopedilum hirsutissimum*, *Paphiopedilum spicerianum* and *Rhododendron micromeres* were recorded from single localities.

Estimation of total population size was undertaken for 37 species, which included *Adhatoda beddomei*, *Bentinckia nicobarica*, *Brucea mollis*, *Calamus acanthospathus*, *Calamus inermis*, *Cinnamomum cacharensis*, *Cyathea spinulosa*, *Cycas beddomei*, *Cycas sphaerica*, *Dinochloa andamanica*, *Dipcadi goaense*, *Dipterocarpus gracilis*, *Elaeocarpus sphaericus*, *Ephedra gerardiana*, *Gymnocladus assamicus*, *Hydnocarpus kurzii*, *Hypericum gaitii*, *Ilex khasiana*, *Impatiens clavata*, *Kayea assamica*, *Lasiococca comberi*, *Lilium polyphyllum*, *Madhuca insignis*, *Malaxis acuminata*, *Ormosia robusta*, *Paphiopedilum druryi*, *Paphiopedilum venustum*, *Paris polyphylla*, *Phoenix rupicola*, *Piper lonchites*, *Pittosporum eriocarpum*, *Rhododendron macabeanum*, *Rhododendron micromeres*, *Schizostachyum kurzii*, *Skimmia laureola*, *Trichopus zeylanicus* and *Vanda bicolor*. The number of mature individuals was estimated for 18 species, which included *Kayea assamica* (3399), *Cycas sphaerica* (1964), *Cycas beddomei* (1004), *Ilex khasiana* (649), *Rhododendron micromeres* (343), *Lasiococca comberi* (332), *Cyathea spinulosa* (122), *Phoenix rupicola* (121), *Calamus acanthospathus* (69), *Madhuca insignis* (62), *Lilium polyphyllum* (27), *Dipterocarpus gracilis* (22), *Paphiopedilum druryi* (20), *Gymnocladus assamicus* (20), *Calamus inermis* (12), *Elaeocarpus sphaericus* (6), *Cinnamomum cacharensis* (5) and *Ormosia robusta* (3).

Factors leading to population decline/rarity

Twenty-one natural and anthropogenic factors leading to decline in natural population and the probable cause of species rarity have been enumerated (Annexure 1). Over-exploitation of the species for various purposes and habitat degradation/loss were the dominant exogenous factors leading to reduction in population size. Besides this, over-grazing, undertaking developmental activities such as construction of dams and roads in sensitive areas, quarrying activities such as sand mining, floods and pest infestation were other exogenous contributors to population decline. The endogenous factors that plausibly lead to population decline and species rarity were inviable seeds and low seed germination, longer periods of seed dormancy, low seedling recruitment, low population size and number, habitat specificity, narrow niche and restricted distribution.

Threat assessments

In the present study, 20 species were placed under critically endangered category, 21 under endangered, 11 under vulnerable, 5 under near threatened, and 1 species each under data deficient and least concern category (Table 1). Of the 59 selected species, threat assessment for 41 species was based on recorded number of locations and geographical extent of occurrence, i.e. EOO and AOO, while 18 species were classified based on their restricted distribution and number of mature individuals (Table 1).

Based on the number of locations, EOO and AOO, 10 species were categorized as critically endangered, 18 as endangered, 6 as vulnerable, 5 as near threatened, and 1 species each under data deficient and least concern categories. The species grouped under critically endangered category were *Bentinckia nicobarica*, *Brucea mollis*, *Coptis teeta*, *Cycas beddomei*, *Kayea assamica*, *Paphiopedilum insigne*, *Phoenix rupicola*, *Rhododendron macabeanum*, *Rhododendron wattii* and *Vanilla pilifera.* The species grouped under endangered category were *Aconitum nagarum*, *Amentotaxus assamicus*, *Arnebia euchroma*, *Calamus nambariensis*, *Calligonum polygonoides*, *Caralluma edulis*, *Dinochloa andamanica*, *Elaeocarpus sphaericus*, *Glossonema varians*, *Hydnocarpus kurzii*, *Ilex khasiana*, *Malaxis muscifera*, *Paphiopedilum venustum*, *Picrorhiza kurrooa*, *Piper haridasanii*, *Schizostachyum kurzii*, *Trichopus zeylanicus* and *Vanda bicolor*.

Based on population size and number of mature individuals, 10 species were categorized as critically endangered, 3 as endangered, and 5 as vulnerable. The critically endangered species included *Calamus acanthospathus*, *Calamus inermis*, *Cinnamomum cacharensis*, *Dipterocarpus gracilis*, *Gymnocladus assamicus*, *Lilium polyphyllum*, *Madhuca insignis*, *Malaxis acuminata*, *Ormosia robusta* and *Paphiopedilum druryi*. The endangered species included *Cyathea spinulosa*, *Cycas sphaerica* and *Lasiococca comberi*.

Importance of the present study and caveats

Of the 59 selected species, threat assessment of 21 species was previously done by IUCN (Table 2). Among these, 5 species were categorized as critically endangered (*Dipterocarpus gracilis*, *Gymnocladus assamicus*, *Ilex khasiana*, *Lilium polyphyllum* and *Paphiopedilum druryi*), 9 as endangered (*Aconitum heterophyllum*, *Amentotaxus assamicus*, *Bentinckia nicobarica*, *Coptis teeta*, *Cycas beddomei*, *Paphiopedilum insigne*, *Paphiopedilum spicerianum*, *Paphiopedilum venustum* and *Pittosporum eriocarpum*), 3 as vulnerable (*Malaxis muscifera*, *Paphiopedilum hirsutissimum* and *Rhododendron wattii*), 2 as data deficient (*Cycas sphaerica* and *Hydnocarpus kurzii*), 1 as near threatened (*Phoenix rupicola*), and one as extinct in the wild (*Madhuca insignis*). However, 38 species were not evaluated by IUCN due to lack of data (Table 2). In the present study, we categorized 9

Table 2. Threat assessment of the selected species using IUCN criteria

Species	Conservation assessment and status based on the present study										Existing conservation status as assigned by IUCN	
	No. of locations	No. of mature individuals	Total population size estimated (including seedlings and saplings) through present study	EOO (km^2)	EOO rating	AOO (km^2)	AOO sub-population	AOO rating	IUCN Criteria (ver 3.1)	Rating	Rating	Version
Aconitum heterophyllum Wall. ex Royle	10			12491.2	VU	3996.19	4	PNT	B1ab(iii,iv)c(iii)	VU	EN	3.1
Aconitum nagarum Stapf	11			201.4	EN	208.89	2	EN	B1b(iii,iv)c(iii) + 2b(iii)c(i,ii,iii)	EN	NE	
Adhatoda beddomei C.B. Clarke	3		110	21498.2	PNT	2253.67	3	PNT	D2	VU	NE	
Amentotaxus assamica D.K. Ferguson	12			2508.5	EN	8486.73	2	PNT	B1b(iii,iv)c(iii)	EN	EN	3.1
Arnebia euchroma (Royle) I.M. Johnst.	5			266.3	EN	112.61	5	EN	B1ab(iii,iv)c(iii) + 2b(iii)c(ii,iii)	EN	NE	
Bentinckia nicobarica (Kurz) Becc.	9		84	94.3	CR	5822.64	2	PNT	B1b(iii,iv)c(iii)	CR	EN	2.3
Brucea mollis Wall. ex Kurz	13		53	72.2	CR	20.4	3	EN	B1bc(i,ii,iii)	CR	NE	
Calamus acanthospathus Griff.	13	69	562	8093.4	VU	2087	4	PNT	C2a(i)	CR	NE	
Calamus inermis T. Anderson	10	12	14	16657.3	VU	7470.68	3	PNT	C2a(i); D	CR	NE	
Calamus nambariensis Becc.	5			138.8	EN	482.54	2	EN	B1ab(iii,iv)c(iii) + 2b(iii)c(ii,iii)	EN	NE	
Calligonum polygonoides L.	8			2545.7	EN	2254.44	4	PNT	B1b(iii,iv)c(iii)	EN	NE	
Caralluma edulis (Edgew.) Benth. ex Hook. f.	4			617.8	EN	319.55	4	EN	B1ab(iii,iv)c(iii) + 2b(iii)c(ii)	EN	NE	
Ceropegia bulbosa Roxb.	10			5647.8	VU	1608.42	5	VU	B1ab(iii,iv)c(iii) + 2b(iii)c(ii)	VU	NE	
Cinnamomum cacharensis Parker	2	5	52	0	DD	103.53	2	EN	D	CR	NE	
Coptis teeta Wall.	2			0	DD	1.54	2	CR	B2b(ii,iii,iv)c(ii,iii)	CR	EN	3.1
Cyathea spinulosa Wall. ex Hook.	19	122	193	124871	LC	42939.3	4	LC	D	EN	NE	
Cycas beddomei Dyer	10	1004	2470	0.47	CR	0.28	3	CR	B1b(i,ii,iii,iv)c(i,ii,iii) + 2b(i,ii,iii,iv)c(i,ii,iii)	CR	EN	3.1
Cycas sphaerica Roxb.	263	1964	4649	192675	LC	174894	3	LC	C2a(i)b; D	EN	DD	3.1
Delphinium cashmerianum Royle	13			9815.1	VU	2646.55	9	PNT	B1b(iii,iv)c(iii)	VU	NE	
Dinochloa andamanica Kurz	17		1309	3137.6	EN	7793.52	4	PNT	B1b(iii,iv)c(iii)	EN	NE	
Dipcadi concanense Baker	18			34765	PNT	20468	2	LC	NT	NT	NE	
Dipcadi goaense U.S. Yadav & Janarth.	1		3557	0	DD	0	0	DD	D2	VU	NE	
Dipterocarpus gracilis Blume	25	22	36	446.5	EN	187.77	5	EN	C2a(i); D	CR	CR	2.3
Elaeocarpus sphaericus (Gaertn.) K. Schum.	5	6	34	672.2	EN	181.49	3	EN	B1ab(iii,iv)c(iii) + 2b(iii,iv)c(iii,iv)	EN	NE	
Embelia ribes Burm. f.	44			930137	LC	408001	2	LC	LC	LC	NE	
Ephedra gerardiana Wall. ex C.A. Mey.	6		1407	24978.5	PNT	6902.6	3	PNT	NT	NT	NE	
Glossonema varians (Stocks) Benth. ex Hook. f.	2			0	DD	16.91	2	EN	B2b(ii,iii,iv)c(ii,iii)	EN	NE	
Gymnocladus assamicus Kanj. Ex P.C. Kanj.	14	20	20	5718.1	VU	2874.1	2	PNT	C2a(i); D	CR	CR	3.1
Hydnocarpus kurzii (King) Warb.	18		107	3536.8	EN	2130.78	2	PNT	B1b(iii,iv)c(iii)	EN	DD	2.3
Hypericum gaitii Haines	23		1484	16429.2	VU	11448.1	3	LC	B1b(iii,iv)c(iii)	VU	NE	
Ilex khasiana Purkay.	21	649	3477	378.6	EN	298.86	2	EN	B1b(i,ii,iii)c(i,ii) + 2b(iii,iv)c(iii,iv)	EN	CR	2.3
Impatiens clavata Bhaskar	1		705	0	DD	0	0	DD	D2	VU	NE	
Impatiens talbotii Baker f.	34			14534	VU	7460.17	4	PNT	B1bc(iii)	VU	NE	
Kayea assamica King & Prain	5	3399	4106	7.47	CR	5.61	4	CR	B1b(i,ii,iii,iv)c(i,ii,iii) + 2b(i,ii,iv)c(iii)	CR	NE	

(*Contd*)

Table 2. (*Contd*)

Species	Conservation assessment and status based on the present study										Existing conservation status as assigned by IUCN	
	No. of locations	No. of mature individuals	Total population size estimated (including seedlings and saplings) through present study	EOO (km^2)	EOO rating	AOO (km^2)	AOO sub-population	AOO rating	IUCN Criteria (ver 3.1)	Rating	Rating	Version
Lasiococca comberi Haines	32	332	1206	13496.5	VU	12725.2	3	LC	C2a(i)	EN	NE	
Lilium polyphyllum D. Don	6	27	129	10257.7	VU	2368.49	5	PNT	C2a(i); D	CR	CR	3.1
Madhuca insignis (Radlk.) H.J. Lam	11	62	92	32288.6	PNT	25085.4	3	LC	C2a(i)	CR	EX	2.3
Malaxis acuminate D. Don	15		232	189225	LC	156132	2	LC	C2b	CR	NE	
Malaxis muscifera (Lindl.) Grubov	3			118.4	EN	62.52	2	EN	B1ab(i,ii,iii,iv)c(iii) + 2b(iii,iv)c(iii,iv)	EN	VU	3.1
Ormosia robusta Baker	3	3	3	3.9	CR	17.24	2	EN	C2a(i); D	CR	NE	
Paphiopedilum druryi (Bedd.) Pfitzer	1	20	20	0	DD	0	0	DD	C2a(i); D	CR	CR	3.1
Paphiopedilum hirsutissimum (Lindl. ex Hook. f.) Stein	1			0	DD	0	0	DD	D2	VU	VU	3.1
Paphiopedilum insigne (Wall. ex Lindl.) Pfitzer	2			0	DD	0.04	2	CR	B2b(ii,iii,iv)c(ii,iii)	CR	EN	3.1
Paphiopedilum spicerianum (Rchb. f.) Pfitzer	1			0	DD	0	0	DD	DD	DD	EN	3.1
Paphiopedilum venustum (Wall. ex Sims) Pfitzer	6		170	3374.1	EN	2479.04	2	PNT	B1b(iii,iv)c(iii)	EN	EN	3.1
Paris polyphylla Sm.	39		193	93271.2	PNT	72665.8	2	LC	NT	NT	NE	
Phoenix rupicola T. Anderson	3	121	293	1.5	CR	29.56	3	EN	B1bc(i,ii,iii,iv)	CR	NT	2.3
Picrorhiza kurrooa Royle ex Benth.	12			2481.3	EN	848.45	5	VU	B1b(iii,iv)c(iii)	EN	NE	
Piper haridasanii Rethy & Y. Kumar	5			359.2	EN	211.03	3	EN	B1ab(iii,iv)c(iii) + 2bc(iii)	EN	NE	
Piper lonchites Schult.	6		24	68349.4	PNT	18042.1	5	LC	NT	NT	NE	
Pittosporum eriocarpum Royle	11		33	18122.6	VU	9087.51	4	PNT	B1b(iii,iv)c(iii)	VU	EN	2.3
Rhododendron macabeanum Watt ex Balf. f.	8		40	36.3	CR	53.46	3	EN	B1b(i,ii,iii,iv)c(i,ii,iii)	CR	NE	
Rhododendron micromeres Tagg	1	343	473	0	DD	0	0	DD	D2	VU	NE	
Rhododendron wattii Cowan	4			17.5	CR	175.91	2	EN	B1b(I,iii,iv)c(I,iii)	CR	VU	2.3
Schizostachyum kurzii (Munro) R.B. Majumdar	7		1305	1799.2	EN	1911.13	3	VU	B1b(iii,iv)c(iii)	EN	NE	
Skimmia laureola (DC.) Siebold & Zucc. ex Walp	12		669	25730.6	PNT	14055.1	3	LC	NT	NT	NE	
Trichopus zeylanicus Gaertn.	2		83	0	DD	17.86	2	EN	B2b(ii,iii,iv)c(ii,iii)	EN	NE	
Vanda bicolour Griff.	8		10	4110	EN	1271.66	5	VU	B1b(iii,iv)c(iii)	EN	NE	
Vanilla pilifera Holttum	5			9.9	CR	9.9	2	CR	B1b(i,ii,iii,iv)c(i,ii,iii) + 2b(i,ii,iii,iv)c(i,ii,iii)	CR	NE	

EOO, Extent of occurrence; AOO, Area of occupancy; CR, Critically endangered; E, Endangered; EX, Extinct; VU, Vulnerable; PNT, Possibly near threatened; LC, Least concern; DD, Data deficient; NE, Not evaluated.

Annexure 1. Threatened species selected for assessment of conservation status

Species	Family	Habit	Factors leading to depletion/rarity
Aconitum heterophyllum	Ranunculaceae	Herb	Over-exploitation
Aconitum nagarum	Ranunculaceae	Herb	Over-exploitation
Adhatoda beddomei	Acanthaceae	Shrub	Habitat degradation/loss
Amentotaxus assamicus	Taxaceae	Tree	Restricted distribution
Arnebia euchroma	Boraginaceae	Herb	Habitat specificity
Bentinckia nicobarica	Arecaceae	Palm	Restricted distribution, endemic, habitat degradation/loss
Brucea mollis	Simaroubaceae	Tree	Habitat degradation/loss
Calamus acanthospathus	Arecaceae	Rattan	Over-exploitation, habitat degradation/loss, low seed germination
Calamus inermis	Arecaceae	Rattan	Over-exploitation
Calamus nambariensis	Arecaceae	Rattan	Habitat degradation/loss, over-exploitation
Calligonum polygonoides	Polygonaceae	Shrub	Habitat degradation/loss
Caralluma edulis	Apocynaceae	Herb	Habitat degradation/loss, over-exploitation, pests
Ceropegia bulbosa	Apocynaceae	Climber	Habitat fragmentation, over-exploitation, poor seed germination
Cinnamomum cacharensis	Lauraceae	Tree	Habitat degradation/loss
Coptis teeta	Ranunculaceae	Herb	Poor seed germination
Cyathea spinulosa	Cyatheaceae	Giant tree fern	Habitat degradation/loss, habitat specificity
Cycas beddomei	Cycadaceae	Cycad	Habitat degradation/loss, over-exploitation
Cycas sphaerica	Cycadaceae	Cycad	Habitat degradation/loss, over-exploitation
Delphinium cashmerianum	Ranunculaceae	Herb	Habitat degradation/loss, over-exploitation
Dinochloa andamanica	Poaceae	Bamboo	Habitat degradation/loss, over-exploitation
Dipcadi concanense	Asparagaceae	Herb	Constructional activities, grazing
Dipcadi goaense	Asparagaceae	Herb	Human interference, grazing
Dipterocarpus gracilis	Dipterocarpaceae	Tree	Habitat degradation/loss
Elaeocarpus sphaericus	Elaeocarpaceae	Tree	Habitat degradation/loss, over-exploitation
Embelia ribes	Primulaceae	Climber	Over-exploitation
Ephedra gerardiana	Ephedraceae	Shrub	Over-exploitation, low seed viability
Glossonema varians	Apocynaceae	Herb	Habitat degradation/loss
Gymnocladus assamicus	Fabaceae	Tree	Over-exploitation
Hydnocarpus kurzii	Achariaceae	Tree	Habitat degradation and loss, over-exploitation
Hypericum gaitii	Hypericaceae	Shrub	Endemic, poor seed germination
Ilex khasiana	Aquifoliaceae	Tree	Habitat degradation/loss, restricted distribution
Impatiens clavata	Balsaminaceae	Herb	Over-exploitation
Impatiens talbotii	Balsaminaceae	Herb	Habitat degradation/loss
Kayea assamica	Calophyllaceae	Tree	Habitat degradation/loss, over-exploitation
Lasiococca comberi	Euphorbiaceae	Tree	Low seed viability, poor seed germination.
Lilium polyphyllum	Liliaceae	Herb	Habitat degradation/loss, grazing, over-exploitation
Madhuca insignis	Sapotaceae	Tree	Construction of dams, roads and sand mining, flood
Malaxis acuminata	Orchidaceae	Orchid	Habitat degradation/loss, over-exploitation
Malaxis muscifera	Orchidaceae	Orchid	Over-exploitation, grazing, low seed viability
Ormosia robusta	Fabaceae	Tree	Very low population
Paphiopedilum druryi	Orchidaceae	Orchid	Over-exploitation
Paphiopedilum hirsutissimum	Orchidaceae	Orchid	Over-exploitation
Paphiopedilum insigne	Orchidaceae	Orchid	Over-exploitation
Paphiopedilum spicerianum	Orchidaceae	Orchid	Over-exploitation
Paphiopedilum venustum	Orchidaceae	Orchid	Over-exploitation
Paris polyphylla	Melanthiaceae	Herb	Over-exploitation, long dormancy
Phoenix rupicola	Arecaceae	Palm	Habitat degradation/loss
Picrorhiza kurrooa	Plantaginaceae	Herb	Habitat degradation/loss, grazing, over-exploitation
Piper haridasanii	Piperaceae	Climber	Habitat degradation/loss
Piper lonchites	Piperaceae	Climber	Habitat degradation/loss
Pittosporum eriocarpum	Pittosporaceae	Tree	Habitat degradation/loss, over-exploitation, low seed germination
Rhododendron macabeanum	Ericaceae	Tree	Habitat degradation/loss, over-exploitation
Rhododendron micromeres	Ericaceae	Tree	Habitat specificity, restricted area
Rhododendron wattii	Ericaceae	Tree	Less seedling recruitment, narrow niche
Schizostachyum kurzii	Poaceae	Bamboo	Restricted distribution, endemic, Habitat degradation/loss
Skimmia laureola	Rutaceae	Shrub	Habitat degradation/loss, over-exploitation, grazing
Trichopus zeylanicus	Dioscoreaceae	Herb	Habitat degradation/loss, over-exploitation
Vanda bicolor	Orchidaceae	Orchid	Shifting cultivation, developmental activities
Vanilla pilifera	Orchidaceae	Orchid	Habitat degradation/loss, over-exploitation

species as critically endangered, 15 as endangered, 8 as vulnerable, 5 as near threatened and 1 as least concern (Table 2). *Brucea mollis*, *Calamus acanthospathus*, *Calamus inermis*, *Cinnamomum cacharensis*, *Kayea*

assamica, *Malaxis acuminate*, *Ormosia robusta*, *Rhododendron macabeanum* and *Vanilla pilifera* were the classified as critically endangered. The species classified under endangered category were *Aconitum nagarum*, *Arnebia euchroma*, *Calamus nambariensis*, *Calligonum polygonoides*, *Caralluma edulis*, *Cyathea spinulosa*, *Dinochloa andamanica*, *Elaeocarpus sphaericus*, *Glossonema varians*, *Lasiococca comberi*, *Picrorhiza kurrooa*, *Piper haridasanii*, *Schizostachyum kurzii*, *Trichopus zeylanicus* and *Vanda bicolor*. The near threatened category included *Dipcadi concanense*, *Ephedra gerardiana*, *Paris polyphylla*, *Piper lonchites* and *Skimmia laureola.* The vulnerable category included *Adhatoda beddomei*, *Ceropegia bulbosa*, *Delphinium cashmerianum*, *Dipcadi goaense*, *Hypericum gaitii*, *Impatiens clavata*, *Impatiens talbotii* and *Rhododendron micromeres*, while the least concern category included *Embelia ribes*.

Our aim was to assess species based on comprehensive and current occurrence records and population data using the latest tools for gathering species-level information. Estimation of population size and number of mature individuals could not be undertaken for all the species because of terrain inaccessibility, logistics issues and methodological challenges. The threat status of selected plant species as established through this study should help in focused and streamlined conservation efforts in the country.

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