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High plant endemism in an Indian *hotspot* – eastern Himalaya

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Abstract. A preliminary investigation in the Subansiri area of the eastern Himalaya recorded high plant endemism. As a regular exercise of field sampling of various forest types to map the biorich areas, the number of species observed was evaluated to analyze their endemic status in one of the important *hotspot* regions of the world. The total number of individuals, species, genera and families observed were recorded in various natural and semi-natural forest types. A total of 122 plots sampled randomly in various forest types recorded 764 plant species, of which 59 were found to be endemic. The overall species endemism is observed to be 13 per ha. These 59 species belong to 27 families and 46 genera. Fifty percent of species were from just five families, Rubiaceae, Lauraceae, Acanthaceae, Magnoliaceae and Rosaceae. Stem size class distribution of the most abundantly found endemic tree species in three primary forest types indicated a quantitative status. This study envisages the status of plant endemism carried out following a proportional stratified random sampling method for various classified vegetation cover types using satellite remote sensing data. Many primitive genera and families were recorded which are indicative of long evolutionary age and affinities of the area with respect to species endemism.

Key words: Arunachal Pradesh, eastern Himalaya, hotspot, plant endemism, Subansiri

Introduction

Plant/animal endemism is the principal criterion for *hotspot* status determination because endemic species are entirely dependent on a single area for their survival, and by virtue of their more restricted ranges, are often the most vulnerable (Myers 1988). These species, confined to highly threatened ecosystems, will almost certainly be the first to be hit by extinction processes, and hence need rapid and effective conservation action (Heywood and Watson 1995). Two main criteria, the plant endemism and degree of threat, determine the *hotspots*. The earth's 25 biodiversity *hotspot* regions collectively cover about 2% of the planet's land surface, yet claim more than 50% of all terrestrial species diversity. They have within them a phenomenal 125 635 plant species. The top 11 *hotspots* (out of 25) for plant endemism harbor 5000 or more species as endemics. It accounts for 93 214 plant species, or 37.3% of the total global plant endemics (Myers 1988).

Endemic taxa are essentially restricted to a specified geographical area. In terms of spatial distribution, endemics may occupy limited geographical ranges – i.e., have a limited 'extent of occurrence' – and also have a limited 'area of occupation' within their geographical range (Gaston 1991). Endemism may be expressed as a percentage of all extant taxa present (excluding exotics), or as the absolute number of endemics in the area. Proportionate levels of endemism increase with increasing geographical area (Major 1988). Levels of endemism may vary in a predictable way along gradients of primary environmental variables such as rainfall, temperature and productivity. Theoretically, models that accurately predict levels of endemism on the basis of easily measurable environmental variables should be useful for the rapid identification of endemics-rich areas (Hill and Keddy 1992). Mountains are often rich in endemics, in both tropical and temperate countries (Matthews et al. 1993).

Phytogeographically, the eastern Himalaya forms a distinct floristic region. The area comprises Nepal, Bhutan, and neighboring states of northern India along a continuous sector of the Yunnan province in south-west China. In the neighboring state of Sikkim (geographical area 7298 km^2), of the 4250 plant species, 2550 (60%) are endemic (Myers 1988). In Nepal, there are around 7000 plant species, many of which overlap those of India, Bhutan, and even Yunnan. Of these species, at least 500 (almost 8%) are believed to be endemic to Nepal. Bhutan possesses an estimated 5000 species, of which as many as 750 (15%) are considered to be endemic to the eastern Himalaya (Anon. 1992). This region is the meeting ground of the Indo-Malayan, Afro-tropic and Indo-Chinese biogeographical realms as well as the Himalayan and Peninsular Indian elements, formed when the peninsular plate struck against the Asian landmass, after it broke off from Gondwana land. The region is recognized as refugium of flowering plants and center of active speciation (Rao 1994). The numerous primitive angiosperm families found in this region include Magnoliaceae, Degeneriaceae, Himantandraceae, Eupomatiaceae, Winteraceae, Trochodendraceae, Tetracentraceae, and Lardizalbalaceae. The primitive genera are *Alnus*, *Aspidocarya*, *Betula*, *Decaisnea*, *Euptelea*, *Exbucklandia*, *Haematocarpus*, *Holboellia*, *Houttuynia*, *Magnolia*, *Mangelietia*, *Pycnarrhena*, and *Tetracentrol* (Malhotra and Hajra 1977). Studies have shown that northeastern India along with the contiguous region of the Chinese provinces of Yunnan and Schezwan is an active center of organic evolution and is the cradle of flowering plants (Takhtajan 1969).

Endemic plant species in India has been estimated at 33% with *ca*. 140 endemic genera but no endemic families (Anon. 1983). Hooker (1904) attributed the floristic diversity of the Indian subcontinent to the immigration of plants from different bordering countries, notably Chinese and Malayan on the east and south, of oriental, european and African on the west and of Tibetan and Siberian on the north. Out of 150 important botanical sites identified for conservation action by the World Conservation Monitoring Center (WCMC), five locations are in India, of which the eastern Himalaya is one (IUCN 1987). Of the 17000 estimated flowering plants in India,

7025–7872 or 2.8–3.2% are endemics in terms of global diversity. The flora of Arunachal Himalaya comprises well over 6000 species of flowering plants, 500 species of pteridophytes and numerous other lower cryptograms. Nearly 30–40% of these are endemic (Baishya 1999). Besides representing a high degree of diversity in orchids, Rhododendrons, Hedychiums, grasses, canes and bamboos, Arunachal Himalaya also harbors numerous plant species of medicinal and ethono-botanical values (Rao 1994). The humid conditions have resulted in speciation in several genera, thus adding to the high endemicity of the flora (Chatterjee 1939). Satellite remote sensing imagery has permitted eight-broad habitat types of natural and semi-natural vegetation cover in the area (Behera 2000). Present approach of plant survey and endemics is based on proportional stratified random sampling derived from satellite-based classification. This method has an advantage of quantitative assessment over the conventional method of plant survey along certain floristic tracts, since it takes variance into consideration.

Study area

The Subansiri area lies between 26°55′–28°42′ N latitude and 92°41′–94°37′ E longitude (Figure 1). The study area occupies an area of approx. 20000 km^2, inhabited by 206064 people (Anon. 1998). The district of Subansiri, which falls in the eastern Himalaya biogeographic zone owes its high floral and faunal diversity to its

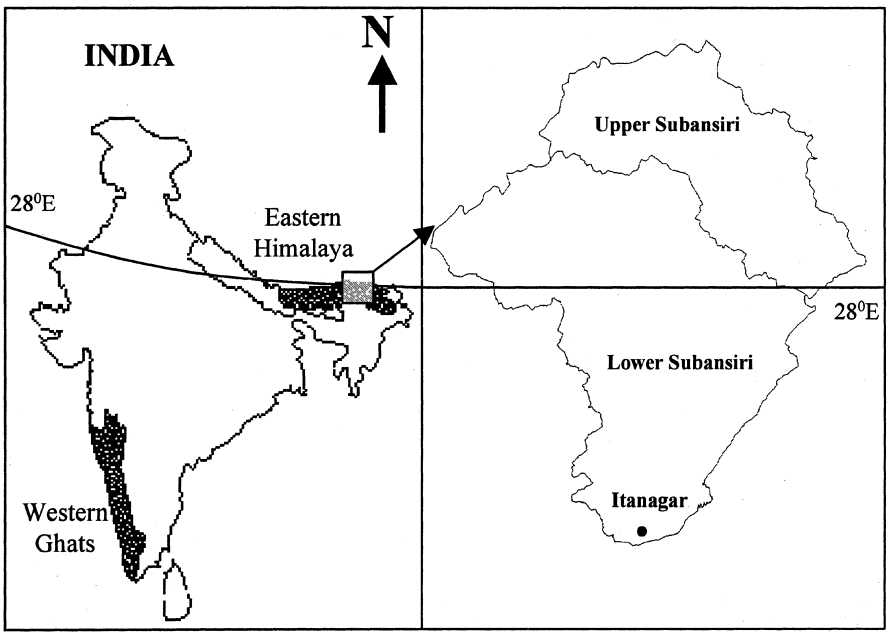

Figure 1. Location of study area (Subansiri district, Arunachal Pradesh in Eastern Himalaya).

strategic location – at the junction of three biogeographic realms viz. the paleoarctic, the Indo-Malayan and the Indo-Chinese. According to the biogeographic classification, the area resides in the Himalaya–east-Himalaya biogeographic region (Rodgers and Panwar 1988). Geologically, the region can be divided into three zones from south to north viz. (a) Sub-Himalayas, (b) Lesser Himalayas and (c) Greater Himalayas. Though no information is available on constituent rocks, it is believed that Pre-Cambrian schists, migmatites and sometimes younger granitic intrusive occur in the area (De 1999). Numerous streams and rivers dissecting the varied topography of the area maintain the natural drainage system. Rainfall is generally heavy (3000 mm annually). Temperature ranges from a minimum of 5 °C in winter to a maximum of 38 °C in summer at foothills and plains, whereas it varies from below freezing point to 25 °C at higher reaches. The present road density is only 14 km per 100 km^2 and the average distance of the habitation from the road head is extremely high.

Data and methodology

Probability proportionate stratified random sampling method was adopted for field survey using various sizes of quadrates for various growth and life forms (Roy et al. 1999). For sampling, various strata of vegetation, nested quadrat sampling mode was followed. A $20 \times 20\ m^2$ plot for trees (of $\geq$15 cm cbh, circumference at breast height), within which a $5 \times 5\ m^2$ nested plot at the center for shrub layers (shrubs/saplings of $\geq$5 cm cbh) were laid (Figure 2). For herb layer (herbs/seedlings) four $1 \times 1\ m^2$ plots of which three were laid at the three out of four corners and one randomly inside of the $20 \times 20\ m^2$ plot. The epiphytes, creepers, climbers and other lianas and their host/symbiotic plants were also noted (if present, by counting their numbers) in order to take an account of all the aboveground floral components present at a particular site. The optimal size of sample plots for each floristic type was determined using species–area curve. Detailed inventory was done in 122 sample plots, covering eight vegetation cover classes, for trees, shrubs, seedlings, saplings, epiphytes, climbers and other growth forms including herbs. Specimens were identified by reference to collection housed at the Forest Research Institute (Dehradun), Botanical Survey of India (Itanagar, Shillong and Dehradun) and State Forest Research Institute (Itanagar) herbaria. Some specimens were also named with assistance from local villages and after local names were agreed upon, specimens were cross-referenced with available literature (Kanjilal et al. 1935, 1938–1940; Bentham and Hooker 1962–1983; Haridasan and Rao 1985; Hajra et al. 1996; Haridasan 1996). The total number of endangered species occurring in the collection was checked using various available references (Kanjilal et al. 1935, 1938–1940; Bentham and Hooker 1962–1983; Haridasan and Rao 1985; Hajra et al. 1996). Stem size class for the most abundantly occurring endemic tree species was estimated in three primary forest types based on their cbh measurements. The various distribution classes were as follows:

Stem size class	Range of cbh (cm)
A	15–30
B	31–45
C	46–60
D	61–75
E	>75

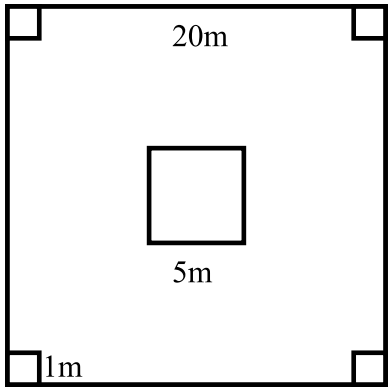

Figure 2. Sample design of nested quadrat.

The large extent of the area is combined with difficulties of access because the varied topography posed problems for extensive survey and allowed sampling in the approachable sites only. Many of the forest areas remained unsurveyed, which might contain more endemic species. It is more likely that areas nearby the road network are believed to possess general/common species, which is also evident from the investigation.

Results

In all 122 study plots, 764 species and 91 families were recorded representing 7783 individuals (Behera 2000). The extent of the area sampled, number of species, genera and families occurring in various forest types is given in Table 1. The ratio of families to species recorded was 1:8.4 for all the 122 sample plots. The proportion of genera to species, families to species and families to genera is shown in Table 1. The ratio of families to species was highest for sub-tropical evergreen forest (1:4.03) followed by tropical semi-evergreen forest (1:3.49) and temperate broad-leaved forest (1:2.84). The ratio of genera to species was highest in case of tropical semi-evergreen forest (1:1.49) followed by temperate/sub-tropical evergreen forest (1:1.43) and sub-tropical evergreen forest (1:1.39). Similarly, the ratio of families to genera was highest for sub-tropical evergreen forest (1:2.89), followed by tropical semi-evergreen forest (1:2.34) and temperate broad-leaved forest (1:2.06).

Table 1. Number of species, genera, families and their proportional account in various forest types.

Sl.	Forest types	Area (ha)	No. of families	No. of genera	No. of species	Genera: species	Families: species	Families: genera
1.	tse	1.52	83	194	290	1.49	3.49	2.34
2.	ste	1.48	95	275	383	1.39	4.03	2.89
3.	stp	0.08	18	19	23	1.21	1.28	1.06
4.	tmp	0.84	83	171	236	1.38	2.84	2.06
5.	con	0.36	20	28	40	1.43	2.00	1.40
6.	scb	0.12	5	6	6	1.00	1.20	1.20
7.	deg	0.28	40	77	90	1.17	2.25	1.93
8.	jhm	0.20	50	81	98	1.21	1.96	1.62

Codes for different forest types: tse: tropical semi-evergreen forest; ste: sub-tropical evergreen forest; stp: sub-tropical pine forest; tmp: temperate broad-leaved evergreen forest; con: temperate/sub-alpine coniferous forest; scb: sub-alpine/alpine scrubs; deg: degraded forest; jhm: abandoned jhum land.

Fifty nine endemic species were recorded from various forest types in the Subansiri area (Table 2). They are included under 27 families and 46 genera. Species richness was predominantly attributed to five plant families (i.e., Rubiaceae, Lauraceae, Acanthaceae, Magnoliaceae and Rosaceae), which accounted for 45.8% (27 species) of the total number of endemic species recorded for the 122 plots (Table 3). The ratio of endemism of families to species is found to be 1:2.19, genera to species is 1:1.28 and families to genera is 1:1.7. Tropical semi-evergreen forest harbored a maximum number of endemic species, i.e. 29 (146 individuals), followed by subtropical evergreen forest 26 (481 individuals), temperate broad-leaved evergreen forest 18 (65 individuals), abandoned jhum land 7 (33 individuals), degraded forest 3 (four individuals), temperate/sub-alpine coniferous 1 (5 individuals) and sub-tropical pine forest 1 (10 individuals) (Figures 3 and 4). There were no endemic species recorded in alpine/sub-alpine scrubland. The average density and abundance of endemism for all forest types recorded in the area is 17 and 152 respectively.

Discussion

This study indicates a high rate of endemism in the Subansiri area of the eastern Himalaya. Only 4.88 ha area was sampled for eight natural and semi-natural vegetation types and yielded 59 (7.72%) endemic species. These 59 species are from 27 families, of which 12 families had one species each and 10 families had two species each, together accounting for a total of 54.2% (32 species) endemics. The present study also indicates that the average rate of plant species endemism is 13 per ha (Table 3). The overall rate of endemism declined as we move from tropics to sub-tropics, temperate and alpine zone, which is also evident from the discussion of Heywood and Watson (1995). Myers's (1988) observation was that tropics harbor more endemic species in comparison to the other zones. This study indicates that the rate of endemism is

Table 2. Number of endemic species recorded.

Sl.	Species	Family
1.	*Alseodaphne khasyana* (Meissn.) Kost.	Lauraceae
2.	*Ardisia griffithii* Cl.	Myrsinaceae
3.	*Areca nagensis* Griff.	Arecaceae
4.	*Aristolochia cathcartii* Hk.f.	Aristolochiaceae
5.	*Arundunaria callosa* Munro.	Poaceae
6.	*Bambusa nutans* Wall.ex Munro.	Poaceae
7.	*Beilschmiedia brandisii* Hk.f.	Lauraceae
8.	*B. pseudo-microcarpa* (Purk.) Kost.	Lauraceae
9.	*Capparis assamica* Hk.f. & Thoms.	Capparaceae
10.	*Caryota obtusa* Griff.	Arecaceae
11.	*Cissus assamica* (Lawson) Crait.	Vitaceae
12.	*Coffea khasiana* Hk.f.	Rubiaceae
13.	*Cyclostemon lancifolius* Hk.f.	Euphorbiaceae
14.	*Didymocarpus pulchera* Clarke	Gesneriaceae
15.	*Dysoxylum reticulatum* King	Meliaceae
16.	*Eriobotrya anguistissima* Hk.f.	Rosaceae
17.	*Euonymus attenuatus* Laws.	Celastraceae
18.	*Glochidion khasicum* (Muell.-Arg.) Hk.f.	Euphorbiaceae
19.	*Ilex khasiana* Purk.	Aquifoliaceae
20.	*I. venulosa* Hk.f.	Aquifoliaceae
21.	*Ixora finlaysoniana* Wall. ex G. Don	Rubiaceae
22.	*Ix. subsessilis* Wall. ex D. Don	Rubiaceae
23.	*Lasianthus biermanii* King ex Hk.f.	Rubiaceae
24.	*L. hookeri* Cl. ex Hk.f.	Rubiaceae
25.	*L. tubiferus* Hk.f.	Rubiaceae
26.	*Lindera latifolia* Hk.f.	Lauraceae
27.	*Lithocarpus milroyi* (Purkayastha) Barnett	Fagaceae
28.	*Litsea meissneri* Hk.f.	Lauraceae
29.	*Livistona jenkinsiana* Griff.	Lauraceae
30.	*Maesa maxima* Mez	Myrsinaceae
31.	*Magnolia gustavi* King	Magnoliaceae
32.	*M. rabianiana* (Hk.f. & Th.) Raju & Nayar	Magnoliaceae
33.	*Michelia gobara* Parment	Magnoliaceae
34.	*Mi. oblonga* Wall.	Magnoliaceae
35.	*Miliusa macrocarpa* Hk.f. & Th.	Annonaceae
36.	*Ophiorrhiza oppositiflora* Hk.f.	Rubiaceae
37.	*Parthenocissus semicordata* (Wall.) Planch.	Vitaceae
38.	*Phlogacanthus tubiflorus* Nees.	Acanthaceae
39.	*Phoebe angustifolia* Meissn.	Acanthaceae
40.	*P. cooperiana* U.N. Kanjilal ex A. Das	Acanthaceae
41.	*Premna bengalensis* Cl.	Verbenaceae
42.	*Pre. milleflora* Cl.	Verbenaceae
43.	*Prunus arborea* (Bl) Kalkman var. *montana* (Hk.f.) Kalkman	Rosaceae
44.	*Pr. punctata* Hk.f. & Th.	Rosaceae
45.	*Quercus ferox* Roxb.	Fagaceae
46.	*Randia griffithii* Hk.f.	Rubiaceae
47.	*Rhynchotechium alternifolium* Cl.	Gesneriaceae
48.	*Sapium eugeniaefolium* Buch.-Ham.	Sapindaceae
49.	*Sarcospermum arboreum* Benth	Sapotaceae
50.	*Saurauia grifithii* (Dyer.) Hk.f.	Saurauiaceae

Table 2. Continued.

Sl.	Species	Family
51.	*Schima wallichii* ssp. *wallichiana* var *khasiana* (Dyer) Bloembergen Dyer.	Rubiaceae
52.	*Senecio pacycarpus* Clarke	Asteraceae
53.	*Shorea assamica* Dyer.	Dipterocarpaceae
54.	*Sloanea sterculiacea* (Benth.) Rehder & Wilson var assamica (Benth.) Coode	Elaeocarpaceae
55.	*Smilax glaucophylla* Klotzsch	Liliaceae
56.	*S. rigida* Wall. ex Kunth var *myrtillus* (DC.) T. Koyana	Liliaceae
57.	*Strobilanthes dalhousianus* C.B. Clarke	Acanthaceae
58.	*St. pauper* C.B. Clarke	Acanthaceae
59.	*Tylophora himalaica* Hk.f.	Asclepediaceae

Table 3. Number of endemic species and genera per family.

Family	No. of species	No. of genera
Rubiaceae	9	6
Lauraceae	6	5
Acanthaceae	5	3
Magnoliaceae	4	2
Rosaceae	3	1
Vitaceae	2	2
Verbenaceae	2	1
Poaceae	2	2
Myrsinaceae	2	2
Liliaceae	2	1
Gesneriaceae	2	2
Fagaceae	2	2
Euphorbiaceae	2	2
Arecaceae	2	2
Aquifoliaceae	2	1
Saurauiaceae	1	1
Sapotaceae	1	1
Sapindaceae	1	1
Meliaceae	1	1
Elaeocarpaceae	1	1
Dipterocarpaceae	1	1
Celastraceae	1	1
Capparaceae	1	1
Asteraceae	1	1
Asclepediaceae	1	1
Aristolochiaceae	1	1
Annonaceae	1	1
Total	27	46

more in tropics in comparison to other regions, which could probably be attributed to various climatic factors prevailing in this area. Sub-tropical evergreen forest shows high population density of endemic species, which is mostly contributed by two species viz., *Saurauia grifithii* (Dyer.) Hk.f. and *Schima wallichii* ssp. *wallichiana* var.

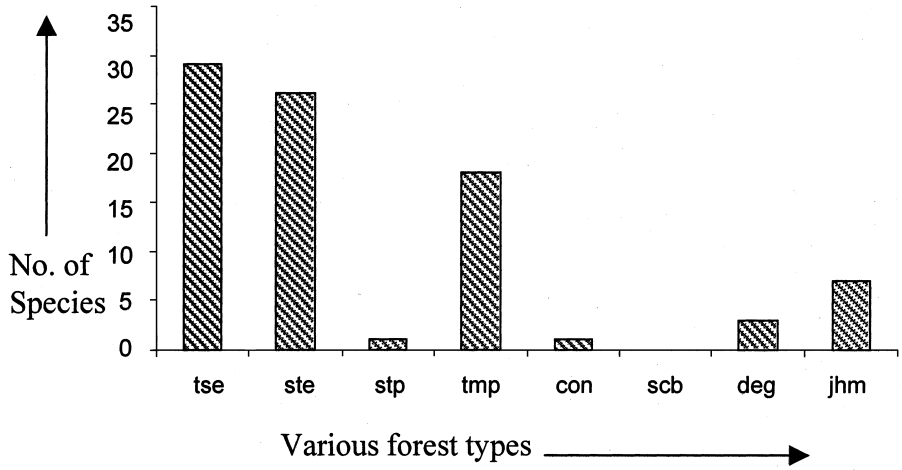

Figure 3. Number of endemic plant species in various forest types; the codes refer to various forest types as in Table 1.

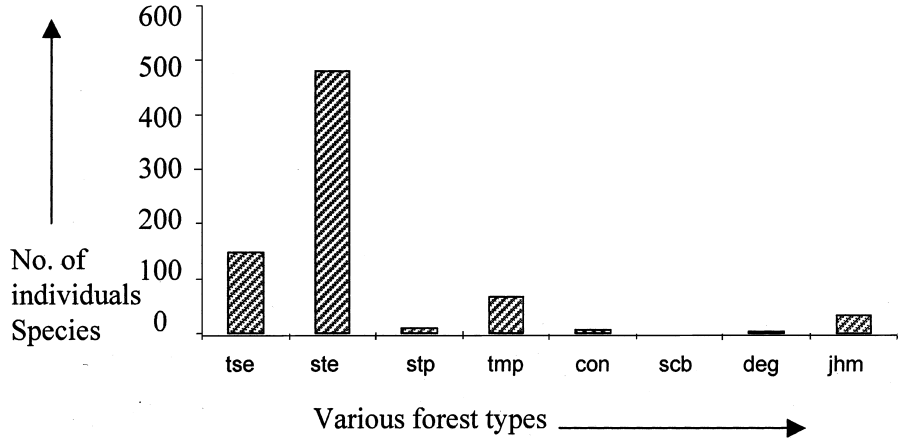

Figure 4. Number of individuals of endemic plant species in various forest types; the codes refer to various forest types as in Table 1.

khasiana (Dyer) Bloembergen Dyer. (86) and another 24 species are responsible for the rest (14) (Table 4). Abandoned jhum lands showed high population density of endemic plants.

As there is not enough table land for permanent agriculture, shifting cultivation or Jhuming is practiced in the area since time immemorial. In this practice, a patch of forest is cleared in the winter. The debris comprises the woody branches and leaves of herbaceous and shrubby habits and often the medium sized trees fully dry up, and are set on fire to prepare the ground for sowing. Usually after 2–3 years, when the yield is very low and the plot becomes unproductive due to decrease in soil fertility, the farmers move on to a fresh patch of land leaving it abandoned. After a few years a reason-

Table 4. Population density of endemic plant species in various vegetation types.

Sl.		No. of individuals
	Endemic species in tropical semi-evergreen forest	
1.	*Li. latifolia* Hk.f.	16
2.	*Ba. nutans* Wall. ex Munro.	14
3.	*Sc. wallichii* ssp *wallichiana* var *khasiana* (Dyer) Bloembergen Dyer.	13
4.	*Dy. reticulatum* King	12
5.	*G. khasicum* (Muell.-Arg.) Hk.f.	10
6.	*E. anguistissima* Hk.f.	9
7.	*D. pulchera* Clarke	7
8.	*Ph. tubiflorus* Nees.	7
9.	*M. gustavi* King	6
10.	*P. cooperiana* U.N. Kanjilal ex A. Das.	5
11.	*B. pseudo-microcarpa* (Purk.) Kost.	4
12.	*Eu. attenuatus* Laws.	4
13.	*Pa. semicordata* (Wall.) Planch.	4
14.	*Co. khasiana* Hk.f.	3
15.	*I. khasiana* Purk.	3
16.	*I. venulosa* Hk.f.	3
17.	*Liv. jenkinsiana* Griff.	3
18.	*Mi. oblonga* Wall.	3
19.	*Rh. alternifolium* Cl.	3
20.	*Sar. arboreum* Benth	3
21.	*Are. nagensis* Griff.	2
22.	*Aru. callosa* Munro.	2
23.	*O. oppositiflora* Hk.f.	2
24.	*Pre. milleflora* Cl.	2
25.	*Sh. assamica* Dyer.	2
26.	*Ar. griffithii* Cl.	1
27.	*Ari. cathcartii* Hk.f.	1
28.	*L. tubiferus* Hk.f.	1
29.	*Mil. macrocarpa* Hk.f. & Th.	
	Total	146
	Endemic species in sub-tropical evergreen forest	
1.	*Sau. grifithii* (Dyer.) Hk.f.	213
2.	*Sc. wallichii* ssp *wallichiana* var *khasiana* (Dyer) Bloembergen Dyer.	200
3.	*B. pseudo-microcarpa* (Purk.) Kost.	12
4.	*Ix. subsessilis* Wall. ex D. Don	11
5.	*I. khasiana* Purk.	5
6.	*Ci. assamica* (Lawson) Crait.	4
7.	*Cy. lancifolius* Hk.f.	4
8.	*Ba. nutans* Wall. ex Munro.	3
9.	*Co. khasiana* Hk.f.	3
10.	*L. tubiferus* Hk.f.	3
11.	*Q. ferox* Roxb.	3
12.	*Ca. obtusa* Griff.	2
13.	*Ma. maxima* Mez	2
14.	*Pre. bengalensis* Cl.	2
15.	*R. griffithii* Hk.f.	2
16.	*S. rigida* Wall. ex Kunth var *myrtillus* (DC.) T. Koyana	2
17.	*A. khasyana* (Meissn.) Kost.	1
18.	*B. brandisii* Hk.f.	1
19.	*C. assamica* Hk.f. & Th.	1

Table 4. Continued.

Sl.		No. of individuals
	Endemic species in sub-tropical semi-evergreen forest	
20.	*E. anguistissima* Hk.f.	1
21.	*G. khasicum* (Muell.-Arg.) Hk.f.	1
22.	*Ix. finlaysoniana* Wall. ex G. Don	1
23.	*Lit. milroyi* (Purkayastha) Barnett	1
24.	*M. rabianiana* (Hk.f. & Th.) Raju & Nayar	1
25.	*Pr. arborea* (Bl) Kalkman var *montana* (Hk.f.) Kalkman	1
26.	*Sl. sterculiacea* (Benth.) Rehder & Wilson var *assamica* (Benth.) Coode	1
	Total	481
	Endemic species in temperate broad leaved-evergreen forest	
1.	*L. hookeri* Cl. ex Hk.f.	9
2.	*P. cooperiana* U.N. Kanjilal ex A. Das.	9
3.	*M. rabianiana* (Hk.f. & Th.) Raju & Nayar	8
4.	*E. anguistissima* Hk.f.	7
5.	*Pr. punctata* Hk.f. & Th.	6
6.	*L. biermanii* King ex Hk.f.	4
7.	*S. glaucophylla* Klotzsch	4
8.	*I. khasiana* Purk.	3
9.	*St. dalhousianus* C.B. Clarke	3
10.	*Ix. subsessilis* Wall. ex D. Don	2
11.	*Pre. bengalensis* Cl.	2
12.	*St. pauper* C.B. Clarke	2
13.	*Lits. meissneri* Hk.f.	1
14.	*Liv. jenkinsiana* Griff.	1
15.	*Sa. eugeniaefolium* Buch.-Ham.	1
16.	*Sc. wallichii* ssp *wallichiana* var *khasiana* (Dyer) Bloembergen Dyer.	1
17.	*S. rigida* Wall. ex Kunth var *myrtillus* (DC.) T. Koyana	1
18.	*T. himalaica* Hk.f.	1
	Total	65
	Endemic species in degraded forest	
1.	*Ix. subsessilis* Wall. ex D.Don	2
2.	*P. cooperiana* U.N. Kanjilal ex A. Das.	1
3.	*R. griffithii* Hk.f.	1
	Total	4
	Endemic species in abandoned jhum land	
1.	*B. brandisii* Hk.f.	14
2.	*P. cooperiana* U.N. Kanjilal ex A. Das.	7
3.	*Pre. bengalensis* Cl.	5
4.	*Aru. callosa* Munro.	2
5.	*Liv. jenkinsiana* Griff.	2
6.	*S. rigida* Wall. ex Kunth var *myrtillus* (DC.) T. Koyana	2
7.	*Sc. wallichii* ssp *wallichiana* var *khasiana* (Dyer) Bloembergen Dyer.	1
	Total	33
	Endemic species in temperate/sub-alpine coniferous forest	
1.	*M. rabianiana* (Hk.f. & Th.) Raju & Nayar	5
	Endemic species in sub-tropical pine forest	
1.	*Sau. grifithii* (Dyer.) Hk.f.	10
	Grand Total	1473

Table 5. Stem size class distribution of the most abundantly found endemic tree species in three primary forest types.

Sl.	Species	Forest type	Stem-size class
1.	*B. pseudo-microcarpa* (Purk.) Kost.	tse & ste	A
2.	*Dy. reticulatum* King.	tse	A
3.	*E. anguistissima* Hk.f.	tmp	E
4.	*I. khasiana* Purk.	ste	A
5.	*Ix. subsessilis* Wall. ex G. Don.	ste	A
6.	*L. hookeri* Cl. ex Hk.f.	tmp	B
7.	*Li. latifolia* Hk.f.	tse	B
8.	*M. gustavi* King.	tse	B
9.	*P. cooperiana* U.N. Kanjilal ex A. Das.	tmp	D
10.	*Pr. punctata* Hk.f. & Th.	tmp	B
11.	*Sau. grifithii* (Dyer.) Hk.f.	ste	B
12.	*Sc. wallichii* sp *wallichiana* var *khasiana* (Dyer) Bloembergen Dyer.	tse & ste	C

Various stem size classes indicate; A: 15–30 cm cbh, B: 31–45 cm cbh, C: 46–60 cm cbh, D: 61–75 cm cbh, E: >70 cm cbh. The codes refer to forest types as in Table 1.

able amount of vegetation (local species) appears on the abandoned plot i.e., bamboos, grasses, weeds and other shrubs (Kushwaha et al. 1983). Hence, they harbor the species, which are generally not more than 12–15 years old (Table 5). A total number of seven endemic species accounting to 33 individuals was recorded in abandoned jhum lands, thus giving an indication about the endemic and regeneration nature of some endemic species. In satellite image, the abandoned jhum patches were found along the riversides nearby the settlement from tropics to temperate/sub-alpine zones (Roy and Kaul 1985). These areas were sampled on the ground randomly. The cosmopolitan distribution of abandoned jhum lands has led to the record of many endemic species, which is a cumulative status of various vegetation types. This is probably the reason attributed to the high density of plant endemism in abandoned jhum land.

The high degree of plant endemism indicates that much of the endemic taxa are restricted to specific geographical areas. This study also shows that a detailed survey of the so far inaccessible areas will record more number of endemic species in this area. Various primitive angiosperm families found in this region include Magnoliaceae Lardizalbalaceae etc. The primitive genera found in the area are *Alnus*, *Betula*, *Exbucklandia*, *Berberis*, *Holboellia*, *Magnolia* etc. This provides an implication that endemism of the area is attributed to primitiveness in terms of evolutionary age and affinities. The causes of this high rate of endemism in the area may probably be linked to long historical processes and contemporary historical factors. The inherent biological properties of the taxa and their combinations, low level of disturbance as well as high rainfall also could be attributed to the endemicity of the area.

This investigation reflects the rich plant wealth of the forest in the area. The humid climate with heavy rainfall facilitates luxuriant growth of plants and everything in these forests grows with utmost vigor. The flora of the Subansiri area is very luxu-

riant and shows maximum diversity. It supports several endemic plant species that have evolved locally or have survived only due to protective natural barriers. This study also supports Major's (1988) findings that the levels of plant endemism is directly proportional to the geographical area. Proportional stratified random sampling method adopted for this survey has rightly addressed the influence of sampling on determination of plant endemism. Climatic factors viz., rainfall and temperature have also contributed to endemicity of the area. Over the long run, these factors have accentuated the process of speciation. The geographic location of the area in the confluence of three biogeographic realms has probably led to organization of taxa with unique biological properties.

These natural virgin forests in the remote corner of India, at the trijunction of India, Myanmar and China, exhibiting the tropical, sub-tropical, temperate and even alpine ecosystems are so complex, delicate and fragile that a minor imbalance could be detrimental to the interest of humans that inhibit this natural environment. Recently, tropical deforestation due to biotic and other causal factors has degraded the forest to a great extent. Low plant population density of endemism in degraded forests raises an alarm for appropriate conservation measures. This preliminary investigation envisages high plant endemism and fragility nature of forest ecosystems in the eastern Himalayan *hotspot*.

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References

Anonymous (1983) Flora and Vegetation of India – an Outline. Botanical Survey of India, Calcutta, 24 pp

Anonymous (1992) World Conservation Monitoring Centre. Global Biodiversity. Chapman and Hall, London

Anonymous (1998) Statistical Abstract of Arunachal Pradesh. Directorate of Economics & Statistics, Government of Arunachal Pradesh, Itanagar, pp 11–12

Baishya AK (1999) Plant Diversity in Arunachal Pradesh: An Overview. Proceedings of National Workshop on Environmental Planning and Sustainable Development Oppurtunities and Challenges in Arunachal Pradesh. 16–18 December, Itanagar, 17 pp

Behera MD (2000) Biodiversity Characterization at Landscape Level in Subansiri District, Arunachal Pradesh (Eastern Himalaya) Using Remote Sensing and GIS. PhD Thesis, Gurkul Kangri University, Hardwar, pp 78–88

Bentham G and Hooker JD (1962–1983) Genera Plantarum, 3 Vols. London
Chatterjee D (1939) Studies on the endemic flora of India and Burma. J. Asiat. Soc. Bengal 11, 5(3): 19–67
De B (1999) Problems of Geological Mapping in Arunachal Pradesh. Proceedings of National Workshop on Environmental Planning and Sustainable Development Oppurtunities and Challenges in Arunachal Pradesh. 16–18 December, Itanagar, pp 33
Gaston KJ (1991) How large is a species' geographical range. Oikos 61: 329–335
Hajra PK, Verma DM and Giri GS (eds) (1996) Materials for the Flora of Arunachal Pradesh, Vol. I Botanical Survey of India, Calcutta
Haridasan K (1996) Botanical and Vernacular Names of Important and Common Forest Plants of Arunachal Pradesh. Forest Bulletin 3: 1–74
Haridasan K and Rao RR (1985) Forest Flora of Meghalaya, Vol I, II. Bisen Singh Mahendra Pal Singh, Dehra Dun
Heywood VH and Watson RT (1995) Global Biodiversity Assessment, pp 174–185. Cambridge University Press, New York
Hill NM and Keddy PA (1992) Prediction of rarities from habitat variables: coastal plain plants on Novia Scotian lakeshores. Ecology 73: 1852–1859.
Hooker JD (1904) A Sketch of the Flora of British India. Oxford
IUCN (1987) Centres of Plant Diversity: A Guide and Strategy for Their Conservation (Book prepared by the joint IUCN–WWF Plants Conservation Programme and IUCN Threatened Plants Unit)
Kanjilal UN, Kanjilal PC, Das A and Purkayastha C (1935) Flora of Assam, Vol I, Published under the authority of the Government of Assam, India
Kanjilal UN, Kanjilal PC and Das A (1938) Flora of Assam, Vol II, Published under the authority of the Government of Assam, India
Kanjilal UN, Das A, Kanjilal PC and De RN (1939) Flora of Assam, Vol III, Published under the authority of the Government of Assam, India
Kanjilal UN, Kanjilal PC, De RN and Das A (1940) Flora of Assam, Vol IV, Published under the authority of the Government of Assam, India
Kushwaha SPS, Ramakrishnan PS and Tripathi RS (1983) Competitive relationships of the plants of *Imperata cylindrica* established from rhizomes and from seeds. Plant Science Research 1: 53–57
Major J (1988) Endemism: a botanical perspective. In: Myers AA and Giller PS (eds) Analytical Biogeography. An integrated Approach to the Study of Animal and Plant Distributions, pp 117–146. Chapman & Hall, New York
Malhotra CL and Hajra PK (1977) Status of floristic studies in Arunachal Pradesh. Bulletin of Botanical Survey of India 19: 61–63
Matthews WS, van WYK AK and Bredenkamp GJ (1993) Endemic flora of north-eastern transval escarpment, South Africa. Biological Conservation 63: 83–94
Myers N (1988) Threatened biotas: 'hotspots' in tropical forestry. The Environmentalist 8: 1–20
Nayar MP and Sastry ARK (eds) (1987) Red Data Book of Indian Plants, Vol I. Botanical Survey of India, Calcutta
Nayar MP and Sastry ARK (eds) (1998) Red Data Book of Indian Plants, Vol II. Botanical Survey of India, Calcutta
Nayar MP and Sastry ARK (eds) (1990) Red Data Book of Indian Plants, Vol III. Botanical Survey of India, Calcutta
Rao RR (1994) Biodiversity in India: Floristic Aspects. Bisen Singh Mahendra Pal Singh, Dehra Dun
Rodgers WA and Panwar SH (1988) Biogeographical Classification of India. New Forest, Dehra Dun
Roy PS and Kaul RN (1985) Forest type stratification and delineation of shifting cultivation areas in the eastern part of Arunachal Pradesh using LANDSAT MSS data. International Journal of Remote Sensing 6(4,5): 411–418
Roy PS, Singh S, Dutt CBS, Jeganathan C, Jadav RN and Ravan SA (1999) Biodiversity Characterization at Landscape Level Using Satellite Remote Sensing and Geographic Information System. DOS-DBT User Manual, Indian Institute of Remote Sensing (NRSA), Department of Space, Government of India, 4-Kalidas Road, Dehra Dun, India
Takhtajan A (1969) Flowering Plants, Origin and Dispersal. Edinburgh