ASSESSMENT OF PLANT DIVERSITY IN RESPONSE TO FOREST DEGRADATION IN A TROPICAL DRY DECIDUOUS FOREST OF EASTERN GHATS IN ORISSA

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DEVI, U. & BEHERA, N. 2003. Assessment of plant diversity in response to forest degradation in a tropical dry deciduous forest of Eastern Ghats in Orissa. A comparison has been made between a relatively undisturbed dry deciduous forest and two degraded forests in the Badrama Reserve Forest of Bamra Division in Orissa in terms of dominant tree-species associations, number of species, tree density, basal area, IVI and FVI values, undergrowth, liana and ground (herbaceous) flora. The dominant tree species association in the undisturbed natural forest was *Shorea-Terminalia-Pterocarpus* which changed to *Shorea-Cleistanthus-Terminalia* and *Soymida-Semecarpus-Buchanania* in the disturbed forests. Diversity indices of tree, shrub and liana were maximum in the undisturbed natural forest and disturbance led to the decline in the diversity of these life forms. Disturbance in the natural forest led to the development of savannah with shrubby bushes and perennial grass species.

Key words: Forest degradation - biodiversity - species composition - importance value index

DEVI, U. & BEHERA, N. 2003. Penilaian terhadap kepelbagaian tumbuhan akibat penyahgredan di hutan daun luruh kering tropika di Ghats Timur, Orissa. Perbandingan dibuat antara hutan daun luruh kering yang tidak diganggu secara relatif dengan dua hutan ternyahgred di Hutan Simpan Badrama di Bahagian Bamra, Orissa, dari segi asosiasi spesies pokok dominan, bilangan spesies, kepadatan pokok, luas pangkal, nilai IVI dan FVI, tumbuhan bawah, liana dan flora permukaan bumi (herba). Asosiasi spesies pokok dominan di hutan semula jadi tidak diganggu ialah *Shorea-Terminalia-Pterocarpus* yang berubah kepada *Shorea-Cleistanthus-Terminalia* dan *Soymida-Semecarpus-Buchanania* di hutan terganggu. Indeks kepelbagaian pokok, pokok renek dan liana adalah maksimum di hutan semula jadi tidak diganggu dan gangguan mengakibatkan kemerosoton kepelbagaian dalam hidupan ini. Gangguan di hutan semula jadi mengakibatkan terbentuknya savana dengan semak samun dan spesies rumput perenial.

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Introduction

Forest degradation is recognised as one of the most serious environmental and economic problems for many countries in the tropical and subtropical regions of the globe (Sharma 1996, Hare *et al.* 1997). Tropical forest, accounting a major fraction of the global forest cover, nurtures and nourishes 65% of global biodiversity (Myers 1988, Chandel 1996), contributes around 69% of the earth's biological productivity (Brunig 1974) and meets nearly 80% of world's forest resource demand (Ambasht & Singh 1980). The fast depletion/degradation of tropical forest vegetation has received much attention during recent years (Grainger 1988, Lugo 1988, Bouwman 1990, Parrotta 1992, Schulze & Mooney 1993, Pimentel *et al.* 1995, Chandel 1996, Laurance *et al.* 1997, Meguro & Miyawaki 1997, Rawat & Bhainsora 1999, Shrestha *et al.* 2000). In India dense forest cover has been reduced to one-third of the ecologically desired hectarage (Madhavan 1990, Maithani 1990, Rawat 1993). About 72.1% of existing Indian forest has lost the capacity for regeneration (Rai & Saxena 1997). Forest biodiversity is considered a natural (biomass) resource base of subsistence for the people of the tropical countries. Therefore, loss of forest very often jeopardises economic progress in tropical regions. In India some 2500 species of total vascular flora fall in one or other category of threat (Jain 1991); of these the most prone are the angiosperms (Daniels & Jayanthi 1996). The disturbed fragile ecosystems need survey and documentation of their biodiversity status so as to develop appropriate strategies for their protection and conservation.

The Eastern Ghats, one of the important mountain systems in India, comprise disconnected hill ranges running more or less parallel to the east coast extending along a NE-SW strike in the Indian peninsula. The Ghats spread over three states, namely, Tamil Nadu, Andhra Pradesh and Orissa. In Orissa the Eastern Ghats constitute one of the principal mountain systems extending over 75% of the geographical area of the state; their forests serve as perennial source of subsistence for the population of the state. Dry deciduous forest is the major biome of the state contributing about 12% of India's dry deciduous forest cover. The forest vegetation of Orissa represents a confluence of northern and southern floristic elements of India (Champion & Seth 1968) due to the geographical location of the state (17 47' to 22° 34' N latitude and 81° 27' to 87° 29' E longitude), and its climatic, physiographic and edaphic diversity. Review of literature reveals that there are few recent reports about the dry deciduous forest of Eastern Ghats from Orissa (Gaussen *et al.* 1973, Dani 1992, Basu *et al.* 1996). There are some reports on the tropical moist/evergreen forest types of India (Meher-Homji 1971, Legris *et al.* 1984, Visalakshi 1995, Parthasarathy & Karthikeyan 1997a, b, Parthasarathy & Sethi 1997, Pascal & Pelissier 1996). Inventory reports on vegetation of dry deciduous forest cover, which are species-poor (Champion & Seth 1968, Hare *et al.* 1997), but heavily impacted (Murphy & Lugo 1986, Garcia & Alba 1989), are inadequate (Johnston & Gillman 1995).

Materials and methods

Study area

Location

Badrama forest, the study site, represents one of the physiographic sections of the ghats of Sambalpur district. Over the last few decades this forest has been subjected to excessive timber and fuel wood harvest, over-grazing and forest clearance. Regular incidences of forest fire and drought-induced mortality have further deteriorated soil conditions leading to poor viability, germination potential and population structure of many timber species of this zone (Devi & Behera 1999). Despite such ecodegradation, this forest area has not received adequate attention regarding its present status.

The present study was carried out in Badrama Reserve Forest area of Bamra forest division in western Orissa. Badrama Reserve Forest lies between latitude 21° 12' to 22° 05' N and 84° 08' to 84° 13' E, encompassing all the forest reserves of Bamra ex-State. The total forest area of the division is about 1357 km^2. The whole tract is a hilly country interspersed by valleys. The elevation is around 300 m above mean sea level. The study site is situated 20 km north-east of Sambalpur town and houses the Ushakothi wildlife sanctuary.

Climate

Climate of the area is tropical monsoonal with three seasons, namely, rainy (June to September), winter (October to February) and summer (March to May). The mean annual rainfall recorded at the nearest observatory (Hirakud Research Station, 20 km west of the forest reserve) is 1533 mm; about 90% rainfall occurs during the south-west monsoon. Mean monthly temperature varies from a minimum of 15 °C in January to a maximum of 43 °C in May. Relative humidity averages between 46 to 85%.

Geology and soil

The parent rock types from which the soil is derived are khondalites and charnockites of Archaean metamorphics of Eastern Ghats orogeny (Panigrahi 1970). The soil is brownish due to the presence of manganiferous material and is coarse-textured (dominated by sand particles and often with pebbles). The soil is well-drained with a bulk density range of 1.11 to 1.50 g cm^{-3}, porosity of 43.39 to 58.01% and water holding capacity of 33.92 to 48.38%. The soil is slightly acidic with pH ranging from 6.1 to 6.7. Soil organic carbon and total nitrogen varies between 1.11 and 2.70% and 0.141 and 0.246% respectively.

Vegetation profile

The tropical dry deciduous forest displays a three-tiered profile. The overstorey is formed of trees (height 15 to 25 m) like *Adina cordifolia, Anogeissus latifolia, Bauhinia refusa, Chloroxylon swietenia, Dalbergia latifolia, Diospyros melanoxylon, Lannea coromandelica, Mitragyna parviflia, Pterocarpus marsupium, Shorea robusta, Terminalia tomentosa* and *Vitex peduncularis.* The understorey with trees 10 to 15 m high, includes *Acacia catechu, Bauhinia variegata, Careya arborea, Cleistanthus collinus, Phyllanthus emblica* and *Ziziphus xylopyra.* The common lianas associated with the canopy are *Aristolochia indica, Bauhinia vahlii, Butea superba, Combretum decandrum, Cryptolepis buchanani, Dioscorea bulbifera and Mimosa himalayana.* In addition, tender climbers such as *Asparagus racemosus, Hemidesmus indicus* and *Ichnocarpus frutescens* are found associated with undergrowth and coppices. The third tier includes shrub species such as *Clerodendrum viscosum, Dendrocalamus strictus, Flemingia chappar, Holarrhena antidysenterica, Justicia adhatoda* and *Woodfordia fruticosa* and herb flora like *Andrographis paniculata, Biophytum sersitivum, Curculigo orchioides, Curcuma angustifolia, Elephantopus scaber* and *Vernonia cinerea. Shorea-Terminalia-Pterocarpus* form the dominant tree association. The forest of Badrama has a rich wildlife which includes elephant, barking deer, wild pig, leopard and tiger. The area was represented by a virgin forest till 1940. In the early 1940s construction of road-ways led to fragmentation of the forest tract and subsequently, this led to biotic interference and degradation.

Study site

Our survey was undertaken in Badrama forest within a radius of 20 km. On the basis of vegetation characteristics and estimated canopy density (scale determined by local forest authority), three study sites were selected as follows:

(a) relatively undisturbed forest: This site is with luxuriant vegetation with a canopy density of 0.8. Subsequently this site is referred to as natural forest (NF).

(b) degraded forest (1): With 0.3 canopy density this site has widely located tree stands interspersed by coppices and shrubs (DF_1).

(c) degraded forest(2): This site is a degraded scrub savannah with few stunted bushy trees, coppices and shrubs (DF_2).

Sampling

The phytosociological analysis of the forest was done in 10 × 10 m quadrats on five separate 100 × 100 m plots laid at each site. Each sample consisted of 10 randomly placed quadrats. The size and number of quadrats needed were determined using the species-area curve (Misra 1968). For sampling herb species, 1 × 1 m workable quadrats were used. Field work on quantitative

enumeration was carried out from July 1997 till June 1998. Botanical exploration was made previously from January 1996 to June 1997. Species encountered during the survey were identified using the key of Haines (1961) and Saxena and Brahmam (1994–1996) and listed. All trees of 15-cm gbh in each quadrat were measured and recorded individually for each species.

Analysis

The vegetation of the study sites was quantitatively analysed for frequency, density and dominance. The importance value index (IVI) for individual species was determined as the sum of relative frequency, relative density and relative dominance (Cottam & Curtis 1956). Family importance value (FIV) for tree species was calculated by summing the relative density, relative diversity (number of species) and relative dominance of all the species within the family. FIV indices for the shrubs, lianas and herbs were calculated by summing relative density and relative diversity. For species diversity and dominance, Shannon's index of diversity ($\bar{H}$) and Simpson's concentration of dominance (Cd) were computed respectively following Magurran (1988).

Results

Floristic composition and phytosociological features

Floristic composition and phytosociological features of the forest are presented in Tables 1 to 4. Table 5 refers to species and family richness data. In the relatively undisturbed forest (NF), 55 tree species belonging to 25 families were recorded. In degraded forest sites DF_1 and DF_2, number of tree species and family recorded were 31, 18 and 14, 11 respectively. The total number of tree species showing 100% frequency are 14, 9 and 4 in NF, DF_1 and DF_2 respectively. In NF, *Shorea robusta* was the most dominant species in terms of frequency, density, basal area and IVI. It is followed by *Terminalia tomentosa* and *Pterocarpus marsupium* as successive codominants. In DF_1, *Shorea robusta* was also the dominant species but successive codominant species were *Cleistanthus collinus* and *T. tomentosa.* In DF_2, on the basis of IVI, the most dominant species was *Soymida febrifuga* and the successive codominants were *Semecarpus anacardium* and *Buchanania lanzan. Butea monosperma,* with IVI of only 3.28 in NF and 8.93 in DF_1, exhibited a value of 30.73 in DF_2, which is comparable with that of *Buchanania lanzan* at the same site. In DF_2, *Shorea robusta,* exhibiting only 30% frequency and low density, basal area and IVI, was ranked as the sixth species. Frequency, density and basal area of some of the economically important common species in the natural forest like *P. marsupium, T. tomentosa, Madhuca indica, Diospyros melanoxylon, Schleichera oleosa* and *Careya arborea* showed a decline in the degraded forest sites. Species like *Cleistanthus collinus* and *Anogeissus latifolia,* which showed comparatively higher frequency, density and basal area in DF_1 compared with NF, exhibited a substantial decline in the most degraded site, DF_2.

Table 1 Phyrosociological characteristics of tree species in natural and degraded forest sites

Species	Family	Frequency (%)	Density (No ha^{-1})	Total basal area (m^2 ha^{-1})	Importance value index (IVI)
Natural forest					
Acacia catechu (L.f.) Will	Mimosaceae	30	4	0.07	1.44
Adina cordifolia Hook f.	Rubiaceae	100	19	0.87	7.33
Aegle marmelos (L.) Corre	Rutaceae	80	24	0.43	6.02
Albizia odoratissima (L.f.) Benth.	Mimosaceae	70	7	1.21	6.27
Albizia procera (Roxb.) Benth.	Mimosaceae	60	6	1.02	5.32
Anogeissus acuminata Roxb.ex.DC	Combretaceae	40	4	0.20	2.11
Anogeissue latifolia (Roxb.ex.DC) Wall	Combretaceae	60	8	0.09	2.76
Antidesma diandrum (Roxb.) Roth.	Euphorbiaceae	30	8	0.14	2.06
Bauhinia malabarica Roxb.	Caesalpiniaceae	60	10	0.12	3.05
Bauhinia retusa (Roxb.)	Caesalpiniaceae	60	10	0.12	3.06
Bauhinia variegata L.	Caesalpiniaceae	30	6	0.17	1.95
Bombax ceiba L.	Bombacaceae	40	7	0.26	2.61
Bridelia retusa (L.) Spreng.	Euphorbiaceae	80	8	1.99	8.60
Buchanania lanzan Spreng.	Anacardiaceae	100	48	0.22	8.49
Butea monosperma (Lam.) Taub	Fabaceae	40	14	0.24	3.28
Careya arborea Roxb.	Lecythidaceae	70	10	0.29	3.84
Casearia tomentosa Roxb.	Flacourtiaceae	100	23	0.17	5.67
Cassia fistula L.	Caesalpiniaceae	100	27	0.26	6.38
Cassine glauca (Rottb.) Kuntze	Calastraceae	70	12	0.34	4.20
Chloroxylon swietenia DC	Meliaceae	100	33	0.20	6.83
Cleistanthus collinus (Roxb.) Benth.	Euphorbiaceae	70	10	0.18	3.51
Cochlospermum gosyipium DC	Bixaceae	60	6	0.66	4.24
Dalbergia latifolia Roxb.	Fabaceae	50	7	0.77	4.41
Dalbergia paniculata Roxb.	Fabaceae	60	9	0.56	4.28
Diospyros embryopteris Pers.	Ebenaceae	20	3	0.20	1.46
Diospyros melanoxylon Roxb.	Ebenaceae	100	52	0.37	9.34
Diospyros montana Roxb.	Ebenaceae	40	4	0.26	2.29
Gardenia larifolia Aiton.	Rubiaceae	80	14	0.77	5.98
Garuga pinnata Roxb.	Burseraceae	60	8	0.43	3.77
Gmelina arborea Roxb.	Verbenaceae	80	18	0.32	5.05
Lagerstroemia parviflora Roxb.	Lythraceae	70	12	0.32	4.15
Lannea coromandelica (Houtt) Merr.	Anacardiaceae	60	9	0.45	3.94
Madhuca indica Gmel.	Sapotaceae	100	58	1.59	13.61
Mangifera indica L.	Anacardiaceae	40	4	0.35	2.56
Mitragyna parvifolia (Roxb.) Korth	Rubiaceae	100	23	0.81	7.60
Morinda coreia Buch-Ham.	Rubiaceae	100	11	0.57	5.60
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	40	6	0.34	2.73
Ougeinia dalbergeoides Benth.	Fabaceae	40	4	0.25	2.24
Phyllanthus ekblica L.	Euphorbiaceae	100	22	0.14	5.48
Pongamia pinnata (L.) Pierre.	Fabaceae	40	6	0.71	3.84
Pterocarpus marsupium Roxb.	Fabaceae	100	62	2.27	16.1
Schleichera oleosa Lour. Oken.	Sapindaceae	70	7	0.39	3.70
Semecarpus anacardium L.f.	Anacardiaceae	70	14	0.35	4.45
Shorea robusta Gaertn.	Dipterocarpaceae	100	119	5.15	30.7
Soymida febrifuga (Roxb.) A. Juss.	Meliaceae	50	7	0.88	4.71
Stereospermum suaveolens (Roxb.) DC.	Bignoniaceae	70	9	0.46	4.25
Streblus asper Lour.	Moraceae	30	3	0.12	1.48
Syzygium cumini (L) Skeels	Myrtaceae	80	12	0.22	4.12
Tamarindus indica L.	Caesalpiniaceae	60	13	0.59	4.76
Terminalia arjuna Wigth & Arn.	Combretaceae	20	2	0.60	2.55
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	60	8	0.48	3.91
Terminalia chebula Retz.	Combretaceae	50	6	0.65	3.94

continued

Table 1 (continued)

Species	Family	Frequency (%)	Density (No ha^{-1})	Total basal area (m^2 ha^{-1})	Importance value index (IVI)
Terminalia tomentosa Wight & Arn	Combretaceae	100	65	3.63	20.5
Vitex peduncularis L.f.	Verbenaceae	40	4	0.07	1.72
Zizyphus xylopyrus (Retz.) will.	Rhamnaceae	100	39	0.9	7.43
Total = 55 species					
Degraded forest 1					
Acacia catechu (L.f.) Willd.	Mimosaceae	60	10	0.16	6.41
Adina cordifolia Hook f.	Rubiaceae	70	7	0.32	7.36
Anogeissus larifolia (Roxb.ex.DC.) Wall.	Combretaceae	100	21	0.39	12.8
Bauhinia veriegata L.	Caeslpinieaceae	60	12	0.15	6.83
Buchanania lanzan Spreng.	Anacardiaceae	100	27	0.39	14.21
Butea monosperma (Lam.) Taub	Fabaceae	80	17	0.14	8.93
Careya arborea Roxb.	Lecythidaceae	60	7	0.17	5.80
Casearia tomentosa Roxb.	Flacourtiaceae	100	24	0.12	11.5
Cassia fistula L.	Caeslpinieaceae	40	7	0.03	3.80
Chloroxylon swietenia DC	Meliaceae	100	15	0.20	9.86
Cleistanthus collinus (Roxb.) Benth.	Euphorbiaceae	100	28	1.34	21.73
Dalbergia paniculata Roxb.	Fabaceae	40	5	0.13	4.05
Diospyros melanoxylon Roxb.	Ebenaceae	100	16	0.34	11.13
Diospyros Montana Roxb.	Ebenaceae	60	6	0.13	5.24
Gmelina arborea Roxb.	Verbenaceae	60	8	0.37	7.54
Largerstroemia parviflora Roxb.	Lythraceae	80	9	0.48	9.55
Madhuca indica Gmel.	Sapotaceae	100	18	1.31	19.00
Mangifera indica L.	Anacardiaceae	20	3	0.07	2.20
Mitragyna parvifolia (Roxb.) Korth	Rubiaceae	40	6	0.13	4.28
Ougeinia dalbergeoides Benth.	Fabaceae	60	6	0.05	4.64
Phyllanthus emblica L.	Euphorbiaceae	70	15	0.09	7.64
Pterocarpus marsupium Roxb.	Fabaceae	40	5	2.1	4.65
Schleichera oleosa Lour. Oken	Sapindaceae	40	4	0.32	5.26
Semecarus anacardium L.f.	Anacardiaceae	80	14	0.07	7.64
Shorea robusta Gaertn.	Dipterocarpaceae	100	50	2.95	39.44
Soymida febrifuga (Roxb.) A. Juss.	Meliaceae	60	8	0.73	10.27
Stereospermum suaveolens (Roxb.) DC	Bignoniaceae	60	6	0.08	4.87
Syxygium cumini (L.) Skeels	Myrtaceae	100	11	0.25	9.21
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	60	6	0.36	6.96
Terminalia chebula Retz.	Combretaceae	40	5	0.40	6.04
Terminalia tomentosa Wight & Arn.	Combretaceae	100	27	1.30	21.21
Total = 31 species					
Degraded forest 2					
Anogeissus latifolia (Roxb.ex.DC) Wall.	Combretaceae	30	3	0.19	14.76
Buchanania lanzan Spreng.	anacardiaceae	100	12	0.09	32.00
Butea monosperma Lam (Taub)	Fabaceae	100	11	0.09	30.73
Careya arborea Roxb.	Lecythidaceae	40	4	0.03	11.54
Cleistanthus collinus (Roxb.) Benth	Euphorbiaceae	20	3	0.03	7.62
Diospyros melanoxylon Roxb.	Ebenaceae	40	4	0.27	20.50
Madhuca indica Gmel.	Sapotaceae	40	4	0.50	28.81
Pterocarpus marsupium Roxb.	fabaceae	30	4	0.08	11.88
Schleichera oleosa Lour. (Oken)	Sapindaceae	30	3	0.28	18.22
Semecarpus anacardium Lf.	Anacardiaceae	100	18	0.14	40.87
Shorea robusta Gaertn.	Dipterocarpaceae	30	3	0.43	23.70
Soymida febrifuga (Roxb.) A. Juss.	Meliaceae	100	11	0.39	41.96
Syzygium cumini (L) keels	Myrtaceae	20	2	0.08	8.30
Terminalia tomentosa Wight & Arn.	Combretaceae	20	2	0.10	9.06
Total = 14 species					

Table 2 Phytosociological characteristics of shrub species in natural and degraded forest sites

Species	Family	Importance value index		
		NF	DF_1	DF_2
Antidesma ghaesembilla Hook	Euphorbiaceae	4.59	-	-
Canthium didynum Roxb.	Rubiaceae	10.68	16.26	17.83
Clerodendrum viscosum Vent.	Verbenaceae	9.76	-	-
Dendrocalanus strictus (Roxb.) Nees.	Poaceae	5.13	-	-
Embelia robusta Roxb.	Myrsinaceae	7.87	-	-
Flacourtia indica (Burm.f.) Merr.	Flacourtiaceae	14.27	21.54	21.14
Flemingia chappar (Buch-Ham.ex. Benth)	Fabaceae	22.15	-	-
Gardenia gummifera L.f.	Rubiaceae	17.31	30.40	29.88
Glochidion lanceolarium (Roxb.) Dalz.	Euphorbiaceae	9.34	15.92	15.27
Grewia elastica Royle.	Tiliaceae	4.22	9.75	-
Helicteres isora L.	Sterculiaceae	13.55	-	-
Holarrhena antidysenterica Wall.	Apocynaceae	24.66	31.25	30.63
Indigofera pulchella Roxb.	Fabaceae	3.67	7.02	7.95
Ixora arborea Roxb. & Sm.	Rubiaceae	11.22	17.45	16.77
Justicia adhatoda L.	Acanthaceae	8.41	-	–
Phoenix acaulis (Buch.) Ham.	Arecaceae	11.49	9.92	19.48
Wendlandia exserta (Roxb.) DC	Rubiaceae	11.40	18.30	17.83
Woodfordia fruticosa (L.) Kurz.	Lythraceae	10.15	22.05	17.22
Zizyphus fruticosa Haines	Rhamnaceae	-	-	5.95

NF: Natural forest; DF_1: degraded forest 1; DF_2: degraded forest 2

On the basis of density, a species with less than 10 individuals per hectare is considered as a rare species (Parthasarathy & Karthikeyan 1997a, b). In NF, out of the 55 tree species, 28 (51%) were categorised as rare species; 18 of these were not present in the degraded forests. Some of the important rare species were *Dalbergia latifolia, Bridelia retusa, Albizia procera, Lannea coromandelica, Garuga pinnata, Cochlospermum gossypium, Bombax ceiba, Neolamarckia cadamba, Anogeissus acuminata* and *Terminalia arjuna.* The number of rare tree species in DF_1 and DF_2 are 16 (88%) and 10 (71%) respectively.

The number of shrub species in NF was 18 (in 13 families) (Table 2). DF_1 and DF_2 each had 11 shrub species comprising eight families. Species such as *Antidesma ghaesembilla, Clerodendrum viscosum, Dendrocalamus strictus, Embelia robusta, Flemingia chappar, Helicteres isora* and *Justicia adhatoda,* recorded from NF, were not observed in both the degraded forest sites. On the basis of IVI, *Holarrhena antidysenterica* was the most dominant species at all the sites followed by *Flemingia chappar* and *Gardenia gummifera* in NF and by *G. gummifera* and *Woodfordia fruticosa* in DF_1 and *G. gummifera* and *Flacourtia indica* in DF_2.

Twenty liana species (13 families) were recorded in NF (Table 3). Corresponding figures for DF_1 and DF_2 were 16 (11) and 12 (10) respectively. *Combretum decandrum,* on the basis of IVI, was the dominant species in the NF. *Ichnocarpus frutescens,* which was second to *C. decandrum* in the NF, was the dominant species in DF_1 and DF_2. *Aristolochia indica, Bauhinia vahlii, Butea parviflora* and *Combretum albidum,* recorded in NF, were absent in the degraded forests.

Table 3 Phytosociological characteristics of liana species in natural and degraded forest sites

Species	Family	Importance value index		
		NF	DF_1	DF_2
Abrus precatorius L.	Fabaceae	4.62	6.73	11.40
Acacia torta (Roxb.) Craib	Mimosaceae	7.99	16.08	16.80
Aristolochia indica L.	Aristolochiaceae	2.10	-	-
Asparagus racemosus Willd.	Liliaceae	11.59	18.55	-
Bauhinia vahlii Wight & Arn.	Caesalpiniaceae	9.31	-	-
Butea parvijlora Roxb.	Fabaceae	8.61	-	-
Butea superba Roxb.	Fabaceae	8.79	7.06	9.22
Combretum decandrum Roxb.	Combretaceae	17.18	17.93	17.71
Combretum albidum G.Don	Combretaceae	12.29	-	-
Cryptolepis buchanani Roem & Schult	Asclepiadaceae	10.19	7.23	-
Cuscuta reflexa Roxb.	Convolvulaceae	8.06	18.75	22.68
Dioscorea bu/bifera L.	Dioscoreaceae	5.97	4.55	4.72
Hemidesmus indicus (L.)R.Br.	Asclepiadaceae	14.04	17.41	22.28
Ichnocarpus frutescens (L.)R.Br .	Apocynaceae	16.17	42.08	48.08
Jasminum angustifolium (L.) Willd.	Oleaceae	3.94	4.71	-
Millettia auriculata Baker.ex.Brandis	Fabaceae	6.84	7.25	-
Mimosa himalayana Gamble.	Mimosaceae	14.21	12.77	17.94
Olax scandens Roxb.	Olacaceae	12.11	16.91	15.20
Smilax macrophylla Roxb.	Liliaceae	10.19	8.06	2.77
Zizyphus oenoplia (L.)Mill	Rhamnaceae	15.96	12.07	13.12

NF: Natural forest; DF_1: degraded forest 1; DF_2: degraded forest 2

From the floor of the NF, 27 herbaceous species (belonging to 15 families) were recorded (Table 4). For DF_1 and DF_2 there were 30 (15) and 37 (15) respectively. *Andrographis paniculata* had maximum IVI and was the dominant species in NF followed by *Evolvulus alsinoides*. The latter was found to be the dominant species in DF_1. However, in DF_2, the seasonal grass *Chloris barbata* (neither recorded in NF nor DF_1) was the most dominant species. Further, a total of 13 species were absent in NF and DF_1 but were observed in DF_2. On the other hand, *Biophytum sensitivum, Leucas linifolia, Typhonium trilobatum* and *Vernonia teres* were present in NF but were not in DF_1 and DF_2.

Family importance value index

Table 6 refers to the FIV of different families and their contribution to species number and density of tree, shrub, liana and herb life forms at the three study sites. In NF, Combretaceae and Fabaceae contributed the maximum number (six) of tree species. In DF_1 and DF_2 these two families also contributed the maximum number of tree species, four and two respectively. In addition, Anacardiaceae in DF_2 was also represented by two tree species. The numbers of monospecific families in NF, DF_1 and DF_2 were 15, 10 and 8 respectively. In terms of tree density, the maximum contribution in NF was from the monospecific family Dipterocarpaceae. However, in DF_1 and DF_2, the maximum was noted from Combretaceae and Anacardiaceae respectively. On the basis of FIV, Combretaceae was the dominant family in NF and DF_1 whereas in DF_2 it was Anacardiaceae.

Table 4 Phytosociological characteristics of herb species in natural and degraded forest sites

Species	Family	Importance value index		
		NF	DF_1	DF_2
Ageratum conyzoides L.	Asteraceae	-	3.08	2.58
Alloteropsis cimicina Stapf.	Poaceae	8.34	8.57	9.64
Alysicarpus vaginalis (L.)DC	Fabaceae	7.36	7.57	5.48
Andrographis paniculata Burm.f. Wall.	Acanthaceae	17.07	10.98	4.09
Aristida adscensionis L.	Poaceae	4.62	-	4.13
Atylosia scarabaeoides (L.)Benth	Fabaceae	10.23	15.48	3.56
Barleria cristata L.	Acanthaceae	7.03	5.74	-
Biophytum sensitivum (L.)DC	Oxalidaceae	7.29	-	-
Blumea lacera (Burm.f.)DC	Asteraceae	4.17	2.78	-
Cansora decussata (Roxb.) Sch.	Gentianaceae	-	4.37	5.28
Chloris barbata Sw.	Poaceae	-	-	32.37
Curculigo orchioides Gaertn.	Amaryllidaceae	9.73	2.91	3.88
Curcuma angustifolia Roxb.	Zingiberaceae	7.03	7.91	-
Cynodon dactylon (L.)Pers.	Poaceae	11.8	12.82	5.67
Cynoglossum lanceolatum Forsk	Boraginaceae	-	7.66	3.79
Cyperus rotundus L.	Cyperaceae	9.18	6.91	10.26
Dactyloctenium aegyptium (L.) P. Beauv.	Poaceae	-	-	2.26
Desmodium latifolium DC	Fabaceae	-	7.41	-
Desmodium trijlorum (L.) DC	Fabaceae	7.48	7.44	6.19
Elephantopus scaber L.	Asteraceae	5.04	8.90	4.30
Eragrostis gangeticas (Roxb.)Steud.	Poaceae	-	-	7.48
Evolvulus alsinoides L.	Convolvulaceae	12.86	15.73	17.63
Fimbristylis aestivalis (Retz.) Vahl.	Cyperaceae	-	-	3.06
Hemigraphis latebrosa–(Hyene ex.Roth) Nees.	Acanthaceae	-	-	2.82
Hybanthus enneaspermus (L.) F.	Violaceae	-	-	6.48
Indigofera linifolia (L.f.) Retz.	Fabaceae	-	5.16	3.08
Knoxia corymbosa Willd.	Rubiaceae	4.51	4.49	-
Kyllinga brevifolia Rottb.	Cyperaceae	-	-	8.67
Lepidagathis fasciculata (Retz.) Nees.	Acanthaceae	-	4.15	2.72
Lepidagathis hamiltoniana Wall.	Acanthaceae	-	5.24	-
Leucas linifolia (Roth.) Spreng.	Lamiaceae	6.5	-	-
Melilotus indicus (L.) All.	Fabaceae	4.38	5.57	2.12
Mollugo sp.	Molluginaceae	-	-	3.06
Ocimum gratissimum L.	Lamiaceae	9.55	6.41	1.84
Panicum sp.	Poaceae	-	-	5.69
Phaseolus trilobus Ait.	Fabaceae	6.09	4.07	2.28
Phyllanthus fraternus Webster.	Euphorbiaceae	7.76	3.91	3.44
Pouzolzia auriculata Wight.	Urticaceae	-	4.49	-
Rungia pectinata L.	Acanthaceae	-	5.74	4.80
Saccharum spontaneum L.	Poaceae	-	-	3.16
Setaria verticillata (L.) P.Beauv.	Poaceae	-	-	3.15
Sida rhombifolia L.	Malvaceae	2.59	-	3.35
Sida veronicaefolia Lam.	Malvaceae	-	3.78	-
Tephrosia purpurea (L.)Pers	Fabaceae	-	-	1.29
Typhonium trilobatum (L.)Schott	Araceae	4.85	-	-
Vernonia cinerea (L.)Less.	Asteraceae	9.17	4.74	5.19
Vernonia teres DC	Asteraceae	6.5	-	-
Vetiveria zizanioides (L.) Nash.	Poaceae	-	-	2.46
Vicoa indica (L.) DC	Asteraceae	7.82	5.57	-
Zizyphus nummularia (Burm.f.)Wight & Arm	Rhamnaceae	2.85	-	2.32

NF: Natural forest; DF_1: degraded forest 1; DF_2: degraded forest 2

In NF as many as six families contained less than 10 individuals and were thus categorised as rare families. These included Bixaceae, Bombacaceae, Burseraceae and Moraceae which were absent in the degraded forest sites. Combretaceae, Dipterocarpaceae, Ebenaceae, Euphorbiaceae and Sapindaceae, with considerable density in NF, were rare families in DF_2.

With respect to shrubs, Rubiaceae contributed the maximum number of species, density and FIV at all the three sites. Fabaceae contributed the maximum of four and three liana species in NF and DF_1 respectively. In DF_2 Fabaceae and Mimosaceae each contributed two liana species. On the basis of density as well as FIV, Combretaceae was the dominant family in NF and Apocynaceae was dominant in DF_1 and DF_2. Among the herbaceous families, Fabaceae was the dominant with maximum number of species, density and FIV in NF and DF_1. However, in DF_2, with 10 species, Poaceae was the dominant family, contributing highest density and FIV. Convolvulaceae and Cyperaceae, which did not contribute much to herbaceous density in NF, were important contributors in DF_2.

Diversity and dominance indices

In the NF, DF_1 and DF_2 the respective Shannon's diversity indices ($\bar{H}$) were 3.74, 3.22 and 2.50 for trees, 2.75, 2.30 and 2.31 for shrubs, 2.89, 2.55 and 2.28 for liana and 3.20, 3.28 and 3.35 for herbs. Dominance indices (Cd) for trees, shrubs and lianas were recorded to be the least (0.03, 0.07 and 0.06 respectively) in NF. With respect to herbaceous species, maximum dominance was observed in DF_2 (0.52). However, dominance indices for NF and DF_1 were comparable (0.04 for each of the site).

Stand density and basal area

Tree density was recorded to be maximum in NF (944 stems ha^{-1}) and showed a substantial decline in DF_1 (403 stems ha^{-1}) and DF_2 (84 stems ha^{-1}). However, shrub density showed the reverse trend with maximum density in DF_2 (664 stems ha^{-1}) and minimum in NF (558 stems ha^{-1}). Density of lianas was more in DF_1 (604 stems ha^{-1}) compared with NF (572 stems ha^{-1}) and DF_2 (438 stems ha^{-1}). Total basal area of tree species varied from 2.70 m^2 ha^{-1} in DF_2 to a maximum of 35.74 $m^2 ha^{-1}$ in NF.

Table 5 Species richness (SR) and family richness (FR) of different life forms in natural and degraded forest sites

Site	Tree		Shrub		Liana		Herb		Total	
	SR	FR	SR	FR	SR	FR	SR	FR	SR	FR
NF	55	25	18	13	20	13	27	15	120	46
DF_1	31	18	11	8	16	11	30	15	88	39
DF_2	14	11	11	8	12	10	37	15	74	34

NF: Natural forest; DF_1: degraded forest 1; DF_2: degraded forest 2

Table 6 Contribution of species and density and family importance value (FIV) index to tree, shrub, liana and herb life forms by families in natural and degraded forest sites

Family	Natural forest			Degraded forest 1			Degraded forest 2		
	S	D	FIV	S	D	FIV	S	D	FIV
Tree									
Anacardiaceae	4	75	19.08	3	44	24.54	2	30	58.63
Bignoniaceae	1	9	4.08	1	6	5.34	-	-	-
Bixaceae	1	6	4.30	-	-	-	-	-	-
Bombacaceae	1	7	3.28	-	-	-	-	-	-
Burseraceae	1	8	3.86	-	-	-	-	-	-
Caesalpiniaceae	5	66	19.60	2	19	12.80	-	-	-
Celastraceae	1	12	5.44	-	-	-	-	-	-
Combretaceae	6	93	36.62	4	59	46.13	2	5	30.94
Dipterocarpaceae	1	119	28.83	1	50	38.0	1	3	26.53
Ebenaceae	3	59	14.02	2	22	15.48	1	4	21.90
Euphorbiaceae	4	48	19.70	2	43	28.00	1	3	11.90
Fabaceae	6	102	35.30	4	33	25.07	2	15	38.32
Flacourtiaceae	1	23	4.73	1	24	10.10	-	-	-
Lecythidaceae	1	10	3.70	1	7	6.25	1	4	12.98
Lythraceae	1	12	4.00	1	9	9.09	-	-	-
Meliaceae	2	40	10.90	2	23	19.22	1	11	34.80
Mimosaceae	3	17	13.70	1	10	6.88	-	-	-
Moraceae	1	3	2.47	-	-	-	-	-	-
Myrtaceae	1	12	3.70	1	11	7.85	1	2	12.56
Rhamnaceae	1	39	6.47	-	-	-	-	-	-
Rubiaceae	5	73	26.22	2	13	13.03	-	-	-
Rutaceae	1	24	5.57	-	-	-	-	-	-
Sapindaceae	1	7	3.54	1	14	6.64	1	3	21.08
Sapotaceae	1	58	12.43	1	18	17.61	1	4	30.27
Verbenaceae	2	22	7.06	1	8	8.01	-	-	-
Shrub									
Acanthaceae	1	22	9.50	-	-	-	-	-	-
Apocynaceae	1	96	22.76	1	123	30.07	1	37	29.72
Araceae	1	35	11.82	1	22	12.84	1	63	18.58
Euphorbiaceae	2	32	16.84	1	33	14.71	1	35	14.36
Fabaceae	2	63	22.40	1	11	10.96	1	13	11.05
Flacourtiaceae	1	38	12.36	1	66	20.33	1	74	20.23
Lythraceae	1	15	8.24	1	69	20.84	1	48	16.32
Myrsinaceae	1	19	8.96	-	-	-	-	-	-
Poaceae	1	12	7.70	-	-	-	-	-	-
Rhamnaceae	-	-	-	-	-	-	1	13	11.05
Rubiaceae	4	143	47.85	4	242	77.60	4	281	78.68
Sterculiaceae	1	34	11.64	-	-	-	-	-	-
Tiliaceae	1	7	6.81	1	21	12.66	-	-	-
Verbenaceae	1	42	13.08	-	-	-	-	-	-
Liana									
Apocynaceae	1	57	16.0	1	203	39.86	1	165	46.00
Aristolochiaceae	1	5	5.87	1	8	7.57	-	-	-
Asclepiadaceae	2	68	21.90	2	67	23.59	1	52	20.20
Caesalpiniaceae	1	18	8.14	-	-	-	-	-	-
Combretaceae	2	98	26.08	1	68	17.51	1	32	15.63
Convolvulaceae	1	32	10.60	1	22	9.89	1	45	18.60
Dioscoreaceae	1	13	7.27	1	7	7.41	1	7	9.93
Fabaceae	4	58	30.13	3	35	24.54	2	31	23.74
Liliaceae	2	54	19.44	2	39	18.95	1	3	9.02

continued

Table 6 (continued)

Family	Natural forest			Degraded forest 1			Degraded forest 2		
	S	D	FIV	S	D	FIV	S	D	FIV
Mimosaceae	2	67	21.71	2	72	24.42	2	61	30.60
Olacaceae	1	34	10.74	1	51	14.70	1	21	13.12
Oleaceae	1	12	7.10	-	-	-	-	-	-
Rhamnaceae	1	56	14.80	1	32	11.55	1	21	13.12
Herb									
Acanthaceae	2	55	21.88	5	167	30.57	4	80	14.64
Amaryllidaceae	1	21	9.23	1	8	4.00	1	20	3.66
Araceae	1	7	5.54	-	-	-	-	-	-
Asteraceae	5	58	33.78	5	126	27.15	3	84	12.13
Boraginaceae	-	-	-	1	47	7.24	1	18	3.56
Convolvulaceae	1	26	10.68	1	144	15.32	1	292	16.67
Cyperaceae	1	12	6.86	1	38	6.49	3	266	20.83
Euphorbiaceae	1	12	6.86	1	20	5.00	1	26	3.94
Fabaceae	5	65	35.62	7	331	50.90	7	141	25.66
Gentianaceae	-	-	-	1	21	5.08	1	34	4.33
Lamiaceae	2	29	15.03	1	32	5.99	1	5	2.94
Malvaceae	1	3	4.50	1	14	4.50	1	24	3.85
Molluginaceae	-	-	-	-	-	-	1	18	3.56
Oxalidaceae	1	14	7.38	-	-	-	-	-	-
Poaceae	3	53	25.06	2	167	20.57	10	1005	75.1
Rhamnaceae	1	4	4.75	-	-	-	1	18	3.56
Rubiaceae	1	8	5.80	1	18	4.83	-	-	-
Urticaceae	-	-	-	1	18	4.83	-	-	-
Violaceae	-	-	-	-	-	-	1	59	5.52
Zingiberaceae	1	13	7.12	1	50	7.50	-	-	-

S = Number of species
D = Density of individuals

Discussion

The floristic survey of the study area, which includes natural as well as degraded forest sites, revealed the presence of 120 plant species belonging to 46 families. Tree species contributed 46%, shrubs and herbs 37% and the lianas, as an associated group, accounted for 17% of the total species richness in the natural forest. The observed floristic distribution pattern in the natural forest site is comparable with that of tropical dry deciduous forest in general (Murphy & Lugo 1986) and dry deciduous forests of peninsular India in particular (Meher-Homji 1977). Contributions of tree species to total species in DF_1 and DF_2 were 35 and 19% respectively. Thus, increasing intensity of forest degradation resulted in a considerable decline in the number of tree species. Contrary to this, the contribution of shrub and herb species increased to as high as 65% in the most degraded site DF_2. Decline in tree species and their density as a consequence of degradation led to the disruption and opening of forest canopy and this contributed to increasing species richness of undergrowth shrub and herbaceous layer on the forest floor (Joshi *et al.* 1990).

Analysis of IVI provides information about social status of a species and can be used to recognise the pattern of association of dominant species in a community (Parthasarathy & Karthikeyan 1997a, b). In the natural forest, the dominant species association was formed by *Shorea robusta, Terminalia tomentosa* and *Pterocarpus marsupium* which agrees with the observations of Dani *et al.* (1991) and also Devi and Behera (1998, 1999). Climatic and edaphic suitability makes *Shorea robusta* the dominant species in the forest of the region (Meher-Homji 1977). A shift with respect to species association was observed in the degraded forest sites with prominent emergence of *Cleistanthus collinus, Semecarpus anacardium, Buchanania lanzan* and *Butea monosperma.* Specifically *Butea monosperma* shared a substantial increase in IVI with increasing intensity of degradation. The prominence of these species is reported to be an indicative symptom of deciduous forest degradation (Panigrahi 1970). Shrubs like *Flemingia chappar* (considered to be an associate of *Shorea robusta* (Panigrahi 1970)), *Clerodendrum viscosum, Embelia robusta, Helicteres isora, Justicia adhatoda* and the bamboo *Dendrocalamus strictus* and also woody climbers like *Combretum albidum, Bauhinia vahlii, Butea parviflora* and *Aristolochia indica,* which occur in natural forest, were not present in the degraded forests. The woody lianas in the degraded forests are replaced by herbaceous climbers like *Ichnocarpus frutescens* and the stem parasite *Cuscuta reflexa.* Although the number of families remained unchanged in the natural and degraded forests, an increase in the herbaceous species was noted in the latter. However, those recorded in the degraded sites were observed to be non-forest species which substituted the common forest ground flora. This was due to the entry of exotic species with increased extent of accessibility through biotic interference in the degraded sites.

A comparative analysis of FIV indicated differences in the dominance of tree, liana and herb species among the three sites. The most dominant tree family Combretaceae in NF and DF_1 was replaced by Anacardiaceae in DF_2. The increased density of the shrub Rubiaceae, with increased intensity of degradation, confirms the abundance of Rubiaceous species in dry deciduous forest of this zone (Puri *et al.* 1989). The change in floristic composition among all the life forms at the three sites was a major consequence of forest degradation.

Diversity indices for tree, shrub and liana were always observed to be maximum in natural forest; degradation led to a decline in the floristic diversity of these strata. However, with respect to the herbaceous layer, diversity was found to be comparatively greater in the disturbed sites than that of the natural forest. This can be due to the invasion and subsequent establishment of many large perennial grasses and sedges which mostly propagate through rhizomes and spread through wind-dispersed seeds. Opening of canopy favours their invasion (Whittaker & Niering 1965, Moral 1972). As reported by Whittaker (1972) the relationship between forest canopy cover and herbaceous density is negative. This suggests that a declining canopy can boost herbaceous species richness and density and this agrees with observations in the present study. Comparison with dominance indices indicated the usual inverse relationship between diversity and dominance, which agrees with the views of Singh and Misra (1969), Murthy and Pathak (1972) and Joshi and Behera (1991).

The density and basal area of the trees in the present natural forest site are comparable with the values for Indian tropical forests (Singh & Misra 1978, Dani *et al.* 1991); both parameters declined with increased degradation. On the other hand, shrub and herbaceous densities exhibited increasing trend. In the dry tropics, natural forest degradation leads to development of savannah (Singh *et al.* 1985), where shrubs grow as bushes and many perennial grasses exploit the situation by propagating and growing vigorously. Occasional fire in the savannah also stimulates growth of grasses. Mature parts of these grasses, being unpalatable to grazers, are left as standing dead material and thus increase the risk of fire in the area. Very often fire from these sites spreads to adjacent forest areas causing damage to the flora and fauna.

Tropical dry deciduous forest forms a climatic climax vegetation of much of peninsular India (Meher-Homji 1977). This vegetation has several economic and environmental functions including climatic control over eastern as well as peninsular India. Accelerated forest loss coupled with poor forest growth paves the way for massive soil erosion and hydrological imbalance. These, in turn, have been cited as root causes of incidence of floods and droughts, jeopardising the socio-economic status of the people of this area. Further, soil impoverishment and consequent failure of forest regeneration result in the loss of floral and faunal diversity of the forest. Thus, it is imperative that the existing forest cover and the natural biodiversity of the Eastern Ghats are protected through proper conservation and management strategies.

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