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Composition and Stand Structure of Tropical Moist Deciduous Forest of Similipal Biosphere Reserve, Orissa, India

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1. Introduction

Tropical forests are highly productive, structurally complex, genetically rich renewable genetic resources (Roy et al., 2002). The tropical deforestation contributes to increase in atmospheric CO₂ and other gases affecting the climate and biodiversity. Though such type of forests occupy less than 7% of the land surface, there have the higher distinction of harbouring 50% of all plant and animal species (Mayers, 1992). The rate of forest loss due to deforestation as reported by Food and Agriculture Organisation [FAO, (2001)] is 15.2 million hectare per year (Data from 1990-2000). Assessment of the plant diversity of forest ecosystems is one of the fundamental goals of ecological research and is essential for providing information on ecosystem function and stability (World Conservation Monitoring Centre [WCMC], 1992; Tilman 2000; Townsend et. al., 2008). It has attracted attention of ecologists because of the growing awareness of its importance on the one hand and the massive depletion on the other (Singh, 2002; Lewis, 2009). Out of sixteen major forest types of India (Champion and Seth, 1968), tropical forests occupy 38 % of the total forest area in India (Dixit, 1997). However, in Orissa forest ecosystems cover about 37.34% of the State's geographical area and about 7.66% of country's forests. Large population of the state utilizes various components of the forests for both commercial and subsistence purposes. In the past few decades, heavy human pressure has reduced the forested area in the state resulting in degradation and fragmentation of historically contiguous landscapes posing threats to plant diversity (Murthy et al., 2007). It is now high time to conserve the plant diversity and has the task become a major concern for much of the society and for many governments and government agencies at all levels (Tripathi and Singh, 2009).

The Man and Biosphere Programme launched by United Nations Educational Scientific and Cultural Organisation ([UNESCO], 1971 as cited in Parker, 1984) aims at conserving the floral wealth in protected areas established by the Govt. of India in different states. Similipal Biosphere Reserve (SBR), a northern tropical moist deciduous type of forest (Champion and

Seth, 1968) situated in the Mayurbhanj district of Orissa has over the years, played important roles in maintaining the climate and livelihood of local communities (Srivastava and Singh, 1997; Rout et al., 2010). The SBR located in Eastern Ghat has distinctly dissimilar to the forests located in Western Ghats of India and Srilanka (Table-1). Table-2 provides a comparative account of floristic richness of some tropical forests. Genera like *Ficus*, *Diospyros*, *Syzygium*, *Symplocos*, *Dalbergia*, *Glochidion* are prominently represented in all these ecosystems as shown in Table-1.

Name of genera	Number of species		
	Western Ghats	Srilanka	Similipal
<i>Goniothalamus</i> (Annonaceae)	3	5	0
<i>Garcinia</i> (Clusiaceae)	9	6	0
<i>Calophyllum</i> (Clusiaceae)	3	9	0
<i>Mesua</i> (Clusiaceae)	1	3	1
<i>Dipterocarpus</i> (Dipterocarpaceae)	2	4	0
<i>Hopea</i> (Dipterocarpaceae)	8	4	0
<i>Shorea</i> (Dipterocarpaceae)	1	14	1
<i>Stemonoporus</i> (Dipterocarpaceae)	0	22	0
<i>Pterospermum</i> (Sterculiaceae)	6	0	1
<i>Elaeocarpus</i> (Elaeocarpaceae)	6	7	0
<i>Ilex</i> (Aquifoliaceae)	5	3	0
<i>Euonymus</i> (Celastraceae)	5	3	0
<i>Holigarna</i> (Anacardiaceae)	3	0	0
<i>Semecarpus</i> (Anacardiaceae)	2	10	1
<i>Dalbergia</i> (Leguminosae)	4	1	2
<i>Humboldtia</i> (Leguminosae)	5	1	0
<i>Syzygium</i> (Myrtaceae)	29	40	2
<i>Memecylon</i> (Melastomaceae)	9	25	1
<i>Mastixia</i> (Cornaceae)	1	3	0
<i>Canthium</i> (Rubiaceae)	5	4	0
<i>Ixora</i> (Rubiaceae)	6	4	1
<i>Psychotria</i> (Rubiaceae)	14	13	0
<i>Lasianthus</i> (Rubiaceae)	9	9	0
<i>Vernonia</i> (Asteraceae)	4	11	1
<i>Ardisia</i> (Myrsinaceae)	6	6	0
<i>Palaquium</i> (Sapotaceae)	2	9	0
<i>Diospyros</i> (Ebenaceae)	16	22	5
<i>Symplocos</i> (Symplocaceae)	21	12	2
<i>Strobilanthus</i> (Acanthaceae)	9	27	0
<i>Myristica</i> (Myristicaceae)	3	3	0
<i>Cinnamomum</i> (Lauraceae)	6	8	0
<i>Actinodaphne</i> (Lauraceae)	5	9	0
<i>Litsea</i> (Lauraceae)	8	12	0
<i>Cleistanthus</i> (Euphorbiaceae)	2	5	1
<i>Drypetes</i> (Euphorbiaceae)	4	1	0
<i>Glochidion</i> (Euphorbiaceae)	10	9	2
<i>Croton</i> (Euphorbiaceae)	6	2	1
<i>Agrostistachys</i> (Euphorbiaceae)	2	3	0
<i>Mallotus</i> (Euphorbiaceae)	5	4	1
<i>Macaranga</i> (Euphorbiaceae)	2	3	1
<i>Aporosa</i> (Euphorbiaceae)	5	3	0
<i>Ficus</i> (Moraceae)	10	8	8

Table 1. Numbers of species in large woody plant genera confined to the Western Ghats, Srilanka and Similipal biosphere reserve (included under Eastern Ghats).

Forest locations	Area (ha)	Number of species	Number of genera	Number of families	Source of information
Jadkal forest	0.5	103	85	46	Vasanthraj et al., 2005
Lowland rain forest, Sabh, Malaysia	8.0	329	128	52	Campbell and Newbery, 1993
Low land dipterocarp forest, Danum Valley, Malaysia	8.0	511	164	59	Newbery et al., 1999
Keranga forest, Sarawak and Brunei	-	637	-	60	Newbery, 1991
Similipal, Orissa, India	3.6	266	204	76	Present study

Table 2. A comparative account of floristic richness of some tropical forest locations.

The National forest policy in India stipulates 33% of the total geographical area is to be under forest cover. Large area of fertile forest lands have been converted to other land uses to meet the demand of growing population. In addition opening of the close forests due to deforestation has resulted in increase in soil erosion, landslides, floods and loss of biodiversity and wildlife habitats. At the global level similar situation is reported from Brazil, Malaysia, Indonesia, Africa and Central American countries where loss of wildlife habitat ranges from 40-80% (Puri, 1995). The tropical dry forest of Costa Rica (Heinrich and Hurka, 2004) is floristically very rich and diverse compared to the dry forests of Puerto Rico (Hare et al., 1997). Compared to other tropical dry deciduous forests of Eastern Ghats of India (Krishnankutty et al., 2006) which are under various degrees of anthropogenic pressures, the SBR occupies strong ecological position in terms of species number and diversity. SBR is generally believed to be floristically rich, containing many varieties of plant life forms and medicinal plants as well (Saxena and Brahmam, 1989). Carefully compiled and up-to date information on diversity and distribution status of plant resources is however lacking. Though human-induced pressure, mainly through illegal chainsaw logging and access to non-timber forest products (NTFPs) is on the rise (Rout et al., 2009; Rout et al., 2010), a very few sporadic studies of SBR (Mishra et al., 2006, Mishra et al., 2008; Reddy et al., 2007) has so far been conducted to assess the plant diversity status. The conservation status of the biosphere reserve to be known attempting sustainable management, there should be need of proper documentation of diversity status of various plant life forms and their distribution patterns inside the reserve. Knowledge of floristic composition, structure and distribution of angiospermic plants of this biosphere reserve is critical in this direction.

2. Materials and methods

2.1 Study area

Similipal Biosphere Reserve (SBR) located between 21°28' - 22° 08' N latitude and 86°04' - 86°37' E longitude is situated in the Mayurbhanj district of Orissa stretching over an area of 5569 sq. km (Fig.1). The vast patch of forest covers of Similipal is one of the mega-biodiversity zones of the country with a rich population of flora and fauna. The elevation of valley peaks ranges from 80m to 869 m M.S.L. rolling with pockets of grassy meadows in between and traversed by a number of streams and waterfalls.

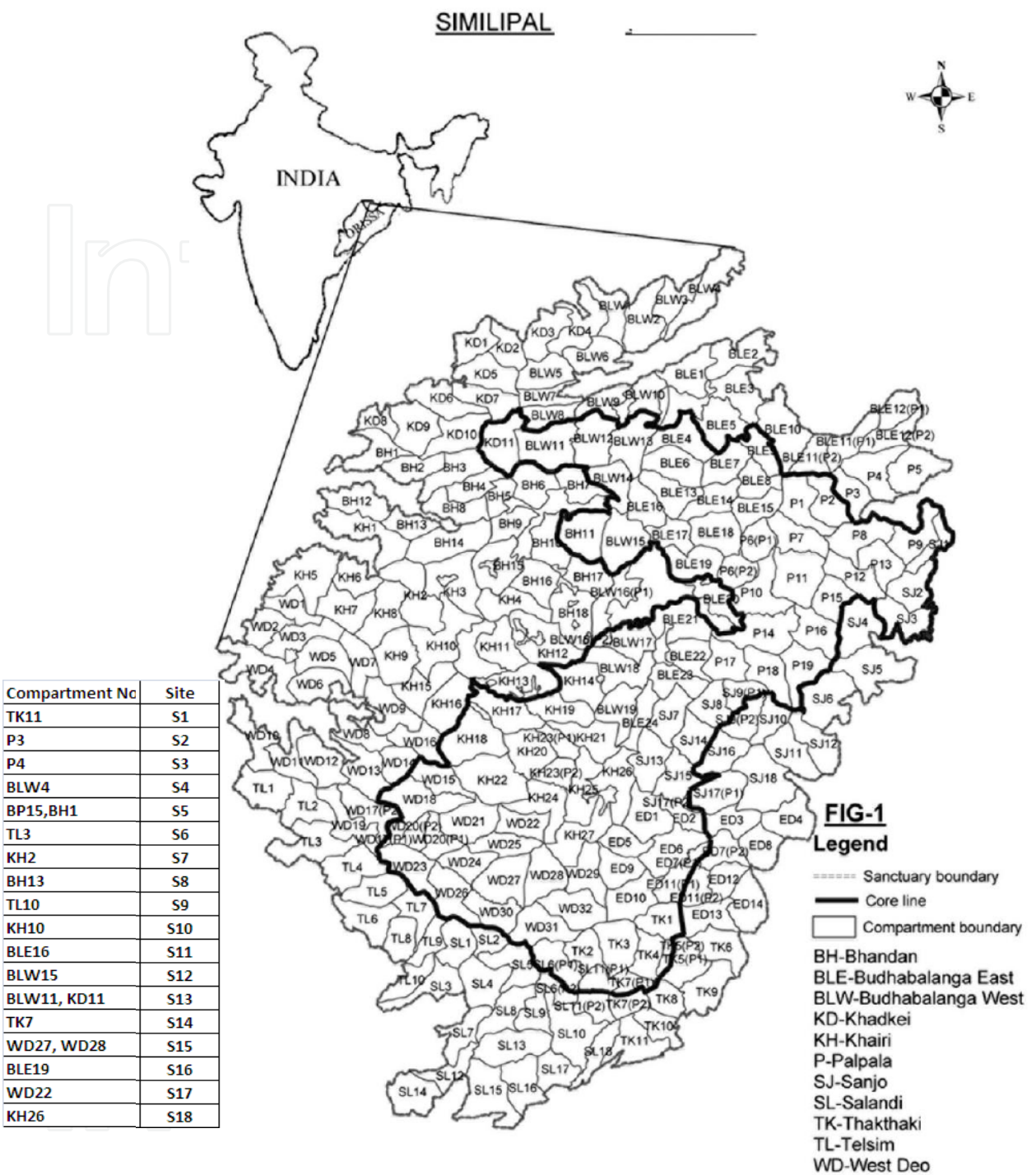


Fig. 1. Location map of sampling sites in Similipal biosphere reserve.

2.2 Climate

The climate of the reserve is influenced by a monsoon pattern of rainfall. Maximum rainfall occurs from mid June to October accounting for 75-80% of annual rainfall. In spite of high annual rainfall summer and winter are relatively dry generally with <10cm monthly rainfall (Mishra et al., 2006). The amount of average annual rainfall is not correlated with elevation and generally ranges from 28.11 to 344.96 cm. Summer is not unbearable, as the maximum

temperature rarely goes above 40 °C. Winter is severe and the temperature comes down to 4°C in some parts with frosts in valleys (Mishra et al., 2006). Spring is very pleasant. Because of good vegetation and a network of perennial streams Similipal is relatively moist throughout the year. Humidity of Similipal at 0600 hrs is around 40% and at 1800 hrs is around 81% to 93% (Srivastava and Singh, 1997).

2.3 Field methods (vegetation sampling and analysis)

To study the plant diversity status, 18 study sites were selected in East, West, North and South directions inside SBR (Fig.1). The vegetation analysis was conducted during 2005-2008 for all the six layers of the forest i.e. trees, climbers, shrubs, herbs, saplings and seedlings. The species were identified with flora guides (Saxena and Brahmam, 1994-1996; Haines, 1921-25). The tree layer was analyzed by sampling 20 quadrats of 10 m x 10 m size at each site. The size and number of samples were determined using the method of Kershaw (1973) and Mueller-Dombois and Ellenberg (1974). The abundance, density and frequency were calculated for the species. Importance Value Index (IVI) was determined as the sum of the relative frequency, relative density and relative dominance for tree layer only. Raunkiaer's frequency class (1934) analysis was used to assess the rarity or commonness of the tree species (Hewit and Kellman, 2002). In this classification the percentage frequency of the species was classed as A, B, C, D and E; where A represents rare (0-20%), B is low frequency (20-40%), C is intermediate frequency (40-60%), D is moderately high frequency (60-80%) and E is high frequency or common (80-100%). With this classification, the expected distribution of the species is $A > B > C \leq D < E$. The distribution pattern of different species was studied using the ratio of abundance to frequency (Whitford, 1949). Trees were ≥ 30 cm cbh (circumference at breast height), saplings were 10-30 cm cbh and seedlings were < 10 cm cbh (Knight, 1975). The shrub and herb layers were analyzed by randomly placing 20 quadrats of 5m x 5m size and 1m x 1m size, respectively at each site during the post monsoon season. The diversity index at each site was computed by using Shannon- Wiener information function (Shannon-Wiener, 1963) and concentration of dominance by Simpson's index (Simpson, 1949), evenness and richness index following Pielou (1975) and Margalef (1958) (as cited in Tripathi and Singh, 2009), respectively. The presence of climbers on trees affects their growth and development. They have been noted to suppress natural regeneration and delay forest recovery (Babweteera et. al., 2001). The presence or absence of climbers on the trees was scored on a 5-point scale (Alder and Synnott, 1992) whereby 1, 2, 3, 4 and 5 represented trees that were: having bore climbers; trees over grown with climbers; climbers on the stem only; climbers in the crown only and climbers both on the stem and crown, respectively.

3. Results

3.1 Floristic composition and occurrence

A total of 266 species belonging to 204 genera and 76 families were recorded from the study area, out of which 117 were tree species, 17 climber, 31 shrub and 101 herb species. Thus only approximately 24.72% of the estimated flora of Similipal (Saxena and Brahmam, 1989) was covered in the study (Table-3, 4, 5 and 6). A majority of the families were represented by only two or less species. The most common families were Euphorbiaceae and Rubiaceae, each

represented by 19 species; followed by Fabaceae (15 species), Mimosaceae = Acanthaceae (12 species each), Asteraceae (11 species), Cyperaceae= Moraceae= Caesalpinaceae = Combretaceae (9 species each), Malvaceae = Melastomataceae = Rutaceae = Poaceae (7 species each), etc. The average number of species per hectare was 74. The number of species per genus was 1.3 and that per family was 3.5. Species in various groups of plant life forms had a wide range of occurrence, ranging in frequency from 5- 72% in herbs, 5-94% in shrubs, and 5- 100% in case of trees, climbers, saplings and seedlings (Table-3, 4, 5, 6, 7 and 8).

Name of the family	Name of the plant species	Density (Plants/ha)	Basal Area (m ² /ha)	Frequency (%)	IVI	A /F
Rubiaceae	<i>Adina cordifolia</i> (Roxb.) Hook. f.ex. Brandis	11.94	1.44	77.78	6.54	0.04
Rutaceae	<i>Aegle marmelos</i> (L.) Corr.	4.72	0.353	44.44	2.81	0.05
Mimosaceae	<i>Albizia marginata</i> (Lam.) Merr.	3.33	0.37	22.22	1.80	0.14
Combretaceae	<i>Anogeissus latifolia</i> (Roxb. ex DC.) Wall ex. Guill	45.28	3.36	77.78	13.43	0.15
Bombacaceae	<i>Bombax ceiba</i> L.	10.83	1.53	55.56	5.64	0.07
Euphorbiaceae	<i>Bridelia retusa</i> (L.) Spreng.	4.72	0.45	38.89	2.73	0.06
Anacardiaceae	<i>Buchanania lanzan</i> Spreng.	19.44	0.81	66.67	6.16	0.09
Lecythidaceae	<i>Careya arborea</i> Roxb.	6.67	0.36	44.44	3.07	0.07
Flacourtiaceae	<i>Casearia graveolens</i> Dalz.	5.28	0.12	55.56	2.98	0.03
Caesalpiniaceae	<i>Cassia fistula</i> L.	6.67	0.12	44.44	3.06	0.07
Euphorbiaceae	<i>Cleistanthus collinus</i> (Roxb.) Benth. ex Hook.f.	3.33	0.06	11.11	0.94	0.54
Euphorbiaceae	<i>Croton roxburghii</i> Balak	6.11	0.21	22.22	1.92	0.25
Mimosaceae	<i>Dalbergia latifolia</i> Roxb.	2.78	0.21	22.22	1.41	0.11
Fabaceae	<i>Desmodium oojeinesis</i> (Roxb.) Ohashi	5.00	0.58	27.78	2.53	0.13
Dilleniaceae	<i>Dillenia pentagyna</i> Roxb.	29.17	2.53	77.78	10.24	0.10
Ebenaceae	<i>Diospyros embryopteris</i> Pers.	2.78	0.17	22.22	1.44	0.11
Ebenaceae	<i>Diospyros melanoxylon</i> Roxb.	8.61	0.66	44.44	3.73	0.09
Ebenaceae	<i>Diospyros montana</i> Roxb.	2.78	0.07	22.22	1.34	0.11
Burseraceae	<i>Garuga pinata</i> Roxb.	2.78	0.16	27.78	1.65	0.07
Simaroubaceae	<i>Gmelina arborea</i> Roxb.	5.28	0.44	50.00	3.21	0.04
Apocynaceae	<i>Holarrhena antidysenterica</i> Wall.ex A.DC.	2.78	0.07	22.22	1.31	0.11
Malvaceae	<i>Kydia calycina</i> Roxb.	5.56	0.22	38.89	2.51	0.07
Lythraceae	<i>Lagerstroemia parviflora</i> Roxb.	6.39	0.39	33.33	2.65	0.12
Anacardiaceae	<i>Lannea corromandelica</i> (Houtt.) Merr.	4.72	0.84	27.78	2.85	0.12

Name of the family	Name of the plant species	Density (Plants/ha)	Basal Area (m ² /ha)	Frequency (%)	IVI	A /F
Sapotaceae	<i>Madhuca latifolia</i> Gmel.	12.78	1.074	44.44	4.84	0.13
Anacardiaceae	<i>Mangifera indica</i> L.	3.61	1.08	38.89	3.48	0.05
Magnoliaceae	<i>Michelia champaca</i> L.	7.78	0.98	11.11	2.78	1.26
Oleaceae	<i>Nyctanthes arbor- tristis</i> L.	3.89	0.15	27.78	1.78	0.10
Ochnaceae	<i>Ochna obtusata</i> DC.	5.83	0.35	16.67	1.87	0.42
Fabaceae	<i>Pterocarpus marsupium</i> Roxb.	12.22	1.24	55.56	5.43	0.08
Euphorbiaceae	<i>Phyllanthus emblica</i> L.	4.17	0.2	27.78	1.88	0.11
Burseraceae	<i>Protium serratum</i> (Wall. ex Colebr.) Engl.	32.22	1.99	83.33	10.08	0.09
Mimosaceae	<i>Samanea saman</i> (Jacq.) Merr.	2.78	0.13	3.13	1.40	0.80
Sapindaceae	<i>Schleichera oleosa</i> (Lour.) Oken	13.33	1.48	33.33	5.05	0.24
Euphorbiaceae	<i>Securinega virosa</i> (Roxb. ex Willd.) Baill	11.11	1.02	33.33	4.13	0.20
Diptero carpaceae	<i>Shorea robusta</i> Gaertn.f.	284.17	27.73	100.00	77.67	0.57
Myrtaceae	<i>Syzygium cumini</i> (L.) Skeels	23.06	2.03	83.33	10.19	0.07
Myrtaceae	<i>Syzygium cerasoides</i> (Roxb.)Chatt. & Kanjlal	18.06	1.27	66.67	6.64	0.08
Combretaceae	<i>Terminalia alata</i> Heyne ex Roth.	50.28	4.37	94.44	16.13	0.11
Combretaceae	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	6.67	0.44	44.44	3.49	0.07
Combretaceae	<i>Terminalia chebula</i> Retz.	5.56	0.78	61.11	4.29	0.03
Verbenaceae	<i>Vitex leucoxylon</i> (L.f.)	5.56	0.21	38.89	2.50	0.07
Rubiaceae	<i>Wendlandia tinctoria</i> (Roxb.) DC.	3.61	0.21	27.78	1.82	0.09
Mimosaceae	<i>Xylia xylocarpa</i> (Roxb.) Taub.	2.78	0.2	16.67	1.27	0.20
Rhamnaceae	<i>Ziziphus mauritiana</i> Lam.	0.28	0.04	5.56	0.31	0.18
Rhamnaceae	<i>Ziziphus rugosa</i> Lam.	2.78	0.05	27.78	1.48	0.07
Total		793.67	71.043	-	299.75	-

Table 3. Families, species, density, basal area, frequency, distribution pattern and Importance Value Index (IVI) of trees in Similipal biosphere reserve.

Name of the family	Name of the plant species	Density (Individuals/ha)	Frequency %	Abundance	A/F
Euphorbiaceae	<i>Antidesma ghaesembila</i> Gaertn.	97.78	94.44	5.18	0.05
Myrsinaceae	<i>Ardisia solanacea</i> Roxb.	45.56	55.56	4.10	0.07
Violaceae	<i>Bixa orellana</i> L.	17.78	22.22	4.00	0.18
Rubiaceae	<i>Catunaregam spinosa</i> (Thunb.) Tirveng.	12.22	16.67	3.67	0.22
Meliaceae	<i>Cipadessa baccifera</i> (Roxb.) Miq.	3.33	5.56	3.00	0.54
Rutaceae	<i>Citrus medica</i> L.	48.89	44.44	5.50	0.12
Rutaceae	<i>Clausena excavata</i> Burm. f.	3.33	5.56	3.00	0.54
Verbenaceae	<i>Clerodendrum serratum</i> (L.) Moon	32.22	22.22	7.25	0.33
Euphorbiaceae	<i>Croton caudatus</i> Geisel.	20.00	27.78	3.60	0.13
Rubiaceae	<i>Gardenia resinifera</i> Roth	17.78	27.78	3.20	0.12
Euphorbiaceae	<i>Glochidion</i> sp.	15.56	22.22	3.50	0.16
Lamiaceae	<i>Gomphostemma parviflorum</i> Wall. ex Benth.	21.11	27.78	3.80	0.14
Tiliaceae	<i>Grewia hirsuta</i> Vahl.	22.22	27.78	4.00	0.14
Sterculiaceae	<i>Helicteres isora</i> L.	17.78	22.22	4.00	0.18
Euphorbiaceae	<i>Homonoia riparia</i> Lour.	22.22	44.44	2.50	0.06
Hypericaceae	<i>Hypericum gaitii</i> Haines	54.44	22.22	12.25	0.55
Rubiaceae	<i>Hyptianthera sticta</i> (Wild.) Wight & Arn.	144.44	66.67	10.83	0.16
Fabaceae	<i>Indigofera cassioides</i> Rottel ex DC.	125.56	50.00	12.56	0.25
Oleaceae	<i>Jasminum arborescens</i> Roxb.	10.00	27.78	1.80	0.06
Verbenaceae	<i>Lantana camara</i> L.	287.78	61.11	23.55	0.39
Vitaceae	<i>Leea asiatica</i> (L.) Ridsdale	15.56	22.22	3.50	0.16
Vitaceae	<i>Leea indica</i> (Burm. f.) Merr.	34.44	16.67	10.33	0.62
Melastomataceae	<i>Melastoma malabathricum</i> L.	122.22	50.00	12.22	0.24
Rubiaceae	<i>Pavetta tomentosa</i> Roxb. Ex Sm.	22.22	27.78	4.00	0.14
Lamiaceae	<i>Pogostemon benghalensis</i> (Burm. f.) Kuntze	341.11	55.56	30.70	0.55
Fabaceae	<i>Sesbania bispinosa</i> (Jacq.) W. F. Wight	18.89	22.22	4.25	0.19
Malvaceae	<i>Urena lobata</i> L.	46.67	38.89	6.00	0.15
Asteraceae	<i>Vernonia anthelmintica</i> (L.) Willd.	30.00	27.78	5.40	0.19
Lythraceae	<i>Woodfordia fruticosa</i> (L.) Kurz	188.89	77.78	12.14	0.16
Rubiaceae	<i>Gardenia gummiifera</i> L. f.	31.11	22.22	7.00	0.32
Fabaceae	<i>Flemingia chappar</i> Buch. – Ham. ex Benth.	73.33	50.00	7.33	0.15
Total		1944.44	-	-	-

Table 4. Families, species, density, frequency, abundance and distribution pattern of shrub layer in Similipal biosphere reserve.

Name of the family	Name of the plant species	Density (Individuals/ha)	Frequency %	Abundance	A/F
Malvaceae	<i>Abutilon indicum</i> (L.) Sweet	1944.44	16.67	23.33	1.40
Asteraceae	<i>Ageratum conyzoides</i> L.	1527.78	38.89	7.86	0.20
Acanthaceae	<i>Andrographis paniculata</i> (Burm.f.) Wall.ex. Nees	833.33	11.11	15.00	1.35
Commelinaceae	<i>Aneilema ovalifolium</i> (Wight) Hook.f.ex.	1472.22	11.11	26.50	2.39
Scrophulariaceae	<i>Bacopa monieri</i> (L.) Pennell.	2000.00	5.56	72.00	12.96
Capparaceae	<i>Cleome viscosa</i> L.	1277.78	11.11	23.00	2.07
Commelinaceae	<i>Commelina benghalensis</i> L.	1083.33	11.11	19.50	1.76
Commelinaceae	<i>Commelina palludosa</i> Bl.	583.33	5.56	21.00	3.78
Commelinaceae	<i>Commelina</i> sp.	611.11	11.11	11.00	0.99
Zingiberaceae	<i>Costus speciosus</i> (Koeing) Sm.	1555.56	5.56	56.00	10.08
Hypoxidaceae	<i>Curculigo orchoides</i> Gaertn.	6638.89	72.22	18.38	0.25
Zingiberaceae	<i>Curcuma amada</i> Roxb.	14138.89	55.56	50.90	0.92
Zingiberaceae	<i>Curcuma aromaticum</i> Salisb.	2111.11	27.78	15.20	0.55
Cyperaceae	<i>Cyperus rotundus</i> L.	7611.11	11.11	137.00	12.33
Cyperaceae	<i>Cyperus</i> sp.	1527.78	11.11	27.50	2.48
Fabaceae	<i>Desmodium trifolium</i> (L.) DC.	35888.89	27.78	258.40	9.30
Acanthaceae	<i>Dicliptera bleupleuroides</i> Mees.	861.11	11.11	15.50	1.40
Poaceae	<i>Eragrostis ciliata</i> (Roxb.) Nees	1805.56	44.44	8.13	0.18
Acanthaceae	<i>Eranthemum purpurascens</i> Nees	916.67	22.22	8.25	0.37
Convolvulaceae	<i>Evolvulus alsinoides</i> L.	21333.33	27.78	153.60	5.53
Convolvulaceae	<i>Evolvulus numularis</i> (L.) L.	14694.44	11.11	264.50	23.81
Cyperaceae	<i>Fimbristylis aestivalis</i> (Retz.) Vahl.	3138.89	11.11	56.50	5.09
Rubiaceae	<i>Knoxia sumatrensis</i> (Retz.) DC.	3861.11	11.11	69.50	6.26
Lobeliaceae	<i>Lobelia alsinoides</i> Lam.	888.89	11.11	16.00	1.44
Cyperaceae	<i>Mariscos</i> sp.	1500.00	11.11	27.00	2.43
Sterculiaceae	<i>Melotia curcurifolia</i> L.	777.78	5.56	28.00	5.04
Mimosaceae	<i>Mimosa pudica</i> L.	611.11	5.56	22.00	3.96
Orobanchaceae	<i>Orthosiphon rubicundus</i> (D.Don) Benn.	805.56	11.11	14.50	1.31
Urticaceae	<i>Pozoultia pentandra</i> (Roxb.) Benn.	1111.11	16.67	13.33	0.80
Amaryllidaceae	<i>Pancratium trifolium</i> Roxb.	1722.22	22.22	15.50	0.70
Acanthaceae	<i>Phlogacanthus</i> sp.	611.11	5.56	22.00	3.96
Areaceae	<i>Phoenix acaulis</i> Buch-Ham.ex Roxb.	888.89	22.22	8.00	0.36
Areaceae	<i>Phoenix</i> sp.	666.67	11.11	12.00	1.08
Euphorbiaceae	<i>Phyllanthus fraternus</i>	3416.67	38.89	17.57	0.45
Acanthaceae	<i>Rungia pectinata</i> (L.) Nees ex DC.	1750.00	27.78	12.60	0.45
Amaranthaceae	<i>Celosia argentia</i> (L.)	583.33	5.56	21.00	3.78
Fabaceae	<i>Shuteria involucrata</i> (Wall.) Wt. & Arn.	583.33	27.78	4.20	0.15
Malvaceae	<i>Sida cordifolia</i> L.	1111.11	11.11	20.00	1.80

Name of the family	Name of the plant species	Density (Individuals/ha)	Frequency %	Abundance	A/F
Rubiaceae	<i>Spermocoe pusilla</i> Wall.	1527.78	5.56	55.00	9.90
Acanthaceae	<i>Strobilanthus auriculatus</i> Nees	888.89	22.22	8.00	0.36
Fabaceae	<i>Uraria picta</i> (Jacq.) Desv. Ex DC.	1138.89	16.67	13.67	0.82
Fabaceae	<i>Zonia dicola</i>	1166.67	11.11	21.00	1.89
Rubiaceae	<i>Hediotys verticillata</i> (L.) Lam.	861.11	27.78	6.20	0.22
Orchidaceae	<i>Eulophia nuda</i> Lindl.	1027.78	33.33	6.17	0.19
Acanthaceae	<i>Barleria srigosa</i> (Wild.)	611.11	38.89	3.14	0.08
Cyperaceae	<i>Cyperus triceps</i> Endl.	861.11	27.78	6.20	0.22
Others	Others	14083.3	5.56 – 27.78	2 - 18	0.06 – 3.24
Total		1,69,500	-	-	-

Table 5. Families, species, density, frequency, abundance and distribution pattern of herb layer in Similipal biosphere reserve.

Name of the family	Name of the plant species	Density (Individuals/ha)	Frequency %	Abundance	A/F
Liliaceae	<i>Asparagus racemosus</i> Willd	9.44	38.89	4.86	0.12
Caesalpinaceae	<i>Bauhinia vahlii</i> wight. & Arn	13.33	100.00	2.67	0.03
Fabaceae	<i>Butea superba</i> Roxb	3.33	33.33	2.00	0.06
Combretaceae	<i>Calycopteris floribunda</i> Lam	3.61	38.89	1.86	0.05
Combretaceae	<i>Combretum roxburghii</i> Spreng	5.28	55.56	1.90	0.03
Dioscoreaceae	<i>Dioscorea bulbifera</i> L.	8.06	38.89	4.14	0.11
Mimosaceae	<i>Entada rheedii</i> Spreng	1.39	16.67	1.67	0.10
Asclepiadaceae	<i>Hemidesmus indicus</i> (L.) R.Br.	6.39	44.44	2.88	0.06
Fabaceae	<i>Millettia extensa</i> (Benth.) Baker	8.33	27.78	6.00	0.22
Asclepiadaceae	<i>Pergularia daemia</i> (Forssk.) Chiov.	13.06	44.44	5.88	0.13
Liliaceae	<i>Smilax macrophylla</i> Roxb	8.89	38.89	4.57	0.12
Liliaceae	<i>Smilax prolifera</i> Wall ex Roxb.	0.56	5.56	2.00	0.36
Apocynaceae	<i>Aganosma caryophyllata</i> (Roxb.ex sims)G.Don	1.94	16.67	2.33	0.14
Euphorbiaceae	<i>Bridelia stipularis</i> Bl.	0.83	5.56	3.00	0.54
Lygodiaceae	<i>Lygodium flexicosum</i> (L.) Sw	1.39	11.11	2.50	0.23
Araceae	<i>Pothos scandens</i> L.	1.94	16.67	2.33	0.14
Oleaceae	<i>Jasminum flexile</i> Vahl	0.83	11.11	1.50	0.14
Total		88.6	-	-	-

Table 6. Families, species, density, frequency, abundance and distribution pattern of climber layer in Similipal biosphere reserve.

Name of the family	Name of the plant species	Density (Individuals/ha)	Frequency %	Abundance	A/F
Rubiaceae	<i>Adina cordifolia</i> (Roxb.) Hook. f.ex. Brandis	18.89	44.44	2.13	0.05
Rutaceae	<i>Aegle marmelos</i> (L.) Corr.	6.67	11.11	3.00	0.27
Mimosaceae	<i>Albizia marginata</i> (Lam.) Merr.	12.22	11.11	5.50	0.50
Combretaceae	<i>Anogeissus latifolia</i> (Roxb. ex DC.) Wall ex. Guill	85.56	88.89	4.81	0.05
Barringtoniaceae	<i>Barringtonia acutangula</i> (L.) Gaertn.	11.11	16.67	3.33	0.20
Caesalpinaceae	<i>Bauhinia variegata</i> L.	8.89	16.67	2.67	0.16
Bombacaceae	<i>Bombax ceiba</i> L.	6.67	16.67	2.00	0.12
Anacardiaceae	<i>Buchanania lanzan</i> Spreng	58.89	55.56	5.30	0.10
Lecythidaceae	<i>Careya arborea</i> Roxb.	20.00	44.44	2.25	0.05
Flacourtiaceae	<i>Casearia graveolens</i> Dalz.	64.44	83.33	3.87	0.05
Caesalpinaceae	<i>Cassia fistula</i> L.	27.78	50.00	2.78	0.06
Cochlospermaceae	<i>Chochlospermum</i> <i>gossypium</i> DC.	7.78	5.56	7.00	1.26
Meliaceae	<i>Cipadessa baccifera</i> (Roxb.) Miq.	12.22	22.22	2.75	0.12
Euphorbiaceae	<i>Cleistanthus collinus</i> (Roxb.) Benth.-ex Hook. f.	18.89	16.67	5.67	0.34
Euphorbiaceae	<i>Croton roxburghii</i> Balak	14.44	27.78	2.60	0.09
Fabaceae	<i>Desmodium oojeinesis</i> (Roxb.) Ohashi	5.56	11.11	2.50	0.23
Dilleniaceae	<i>Dillenia pentagyna</i> Roxb.	50.00	61.11	4.09	0.07
Ebenaceae	<i>Diospyros malabarica</i> (Desr.) Kostel.	8.89	11.11	4.00	0.36
Ebenaceae	<i>Diospyros melanoxylon</i> Roxb.	21.11	33.33	3.17	0.10
Euphorbiaceae	<i>Glochidion lanceolarium</i> (Roxb.) Dalz.Glochidion	8.89	11.11	4.00	0.36
Simaroubaceae	<i>Gmelina arborea</i> Roxb.	8.89	22.22	2.00	0.09
Sterculiaceae	<i>Helicteres isora</i> L.	10.00	22.22	2.25	0.10
Apocynaceae	<i>Holarrhena antidysentrica</i> Wall.ex A.DC.	7.78	16.67	2.33	0.14
Flacourtiaceae	<i>Homalium nepalens</i> Benth.	40.00	61.11	3.27	0.05
Malvaceae	<i>Kydia calycina</i> Roxb.	6.67	11.11	3.00	0.27
Anacardiaceae	<i>Nothopegia heyneana</i> (Hook. f.)	5.56	5.56	5.00	0.90
Lythraceae	<i>Lagerstroemia parviflora</i>	17.78	27.78	3.20	0.12

Name of the family	Name of the plant species	Density (Individuals/ha)	Frequency %	Abundance	A/F
	Roxb.				
Sapotaceae	<i>Madhuca latifolia</i> Gmel.	13.33	27.78	2.40	0.09
Annonaceae	<i>Miliusa velutina</i> (Dunal) Hook.f . & Thomas.	7.78	16.67	2.33	0.14
Rubiaceae	<i>Mitragyna parviflora</i> (Roxb.) Korth.	5.56	11.11	2.50	0.23
Oleaceae	<i>Nyctanthes arber-tristis</i> L.	36.67	72.22	2.54	0.04
Euphorbiaceae	<i>Phyllanthus emblica</i> L.	33.33	61.11	2.73	0.04
Burseraceae	<i>Protium serratum</i> (Wall. ex Colebr.) Engl.	35.56	55.56	3.20	0.06
Sapindaceae	<i>Schleichera oleosa</i> (Lour.) Oken	45.56	66.67	3.42	0.05
Euphorbiaceae	<i>Securinega virosa</i> (Roxb. ex Willd.) Baill	38.89	50.00	3.89	0.08
Dipterocarpaceae	<i>Shorea robusta</i> Gaertn.f.	365.56	100.00	18.28	0.18
Sterculiaceae	<i>Sterculia urens</i> Roxb.	17.78	16.67	5.33	0.32
Bignoniaceae	<i>Sterospermum suaveolens</i> (Roxb.)DC.	13.33	16.67	4.00	0.24
Myrtaceae	<i>Syzygium cerasoides</i> (Roxb.)Chatt. & Kanjlal	18.89	33.33	2.83	0.09
Myrtaceae	<i>Syzgium cumini</i> (L.) Skeels	30.00	55.56	2.70	0.05
Combretaceae	<i>Terminalia alta</i> Heyne ex Roth.	74.44	88.89	4.19	0.05
Combretaceae	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	18.89	27.78	3.40	0.12
Combretaceae	<i>Terminalia chebula</i> Retz.	11.11	33.33	1.67	0.05
Rubiaceae	<i>Wendlandia tinctoria</i> (Roxb.) DC.	20.00	33.33	3.00	0.09
Mimosaceae	<i>Xylia xylocarpa</i> (Roxb.) Taub.	15.56	27.78	2.80	0.10
Rhamnaceae	<i>Ziziphus rugosa</i> Lam.	7.78	22.22	1.75	0.08
Others		148.74	5.56-16.67	1.00-4.00	0.08-0.72
Total		1524.34	-	-	-

Table 7. Families, species, density, frequency, abundance and distribution pattern of sapling layer in Similipal biosphere reserve.

Name of the family	Name of the plant species	Density (Individuals/ha)	Frequency %	Abundance	A/F
Dipterocarpaceae	<i>Shorea robusta</i> Gaertn.f.	27777.78	55.56	100.00	0.56
Euphorbiaceae	<i>Croton roxburghii</i> Balak	24250.00	145.50	33.33	4.37
Combretaceae	<i>Terminalia alata</i> Heyne ex Roth.	3416.67	9.46	72.22	0.13
Anacardiaceae	<i>Buchanania lanzan</i> Spreng.	4944.44	14.83	66.67	0.22
Ebenaceae	<i>Diospyros melanoxylon</i> Roxb.	5888.89	26.50	44.44	0.60
Euphorbiaceae	<i>Cleistanthus collinus</i> (Roxb.) Benth. Ex Hook.f.	4611.11	23.71	38.89	0.61
Sterculiaceae	<i>Sterculia urens</i> Roxb.	1861.11	22.33	16.67	1.34
Flacourtiaceae	<i>Homalium nepalens</i> Benth.	1611.11	8.29	38.89	0.21
Euphorbiaceae	<i>Phyllanthus emblica</i> L.	2138.89	12.83	33.33	0.39
Combretaceae	<i>Anogeissus latifolia</i> (Roxb. Ex DC.) Wall ex. Guill	1500.00	13.50	22.22	0.61
Rutaceae	<i>Aegle marmelos</i> (L.) Corr.	972.22	7.00	27.78	0.25
Mimosaceae	<i>Dalbergia sisoo</i> Roxb.	500.00	18.00	5.56	3.24
Sapindaceae	<i>Schleichera oleosa</i> (Lour.) Oken	805.56	4.14	38.89	0.11
Simaroubaceae	<i>Ailanthus</i> sp. Roxb.	805.56	29.00	5.56	5.22
Apocynaceae	<i>Hollarhaena antidysentrica</i> Wall.ex A.DC.	1361.11	7.00	38.89	0.18
Oleaceae	<i>Nyctanthes arbortristis</i> L.	1527.78	18.33	16.67	1.10
Rhamnaceae	<i>Ziziphus rugosa</i> Lam.	916.67	5.50	33.33	0.17
Euphorbiaceae	<i>Bridelia retusa</i> (L.) Spreng.	1277.78	11.50	22.22	0.52
Rubiaceae	<i>Ixora</i> sp.	722.22	26.00	5.56	4.68
Rubiaceae	<i>Gardenia gummifera</i> .L.f.	361.11	4.33	16.67	0.26
Fabaceae	<i>Pterocarpus marsupium</i> Roxb.	916.67	5.50	33.33	0.17
Fabaceae	<i>Desmodium oojeinensis</i> (Roxb.) Ohashi	1194.44	10.75	22.22	0.48
Myrtaceae	<i>Syzygium cumini</i> (L.) Skeels	2472.22	7.42	66.67	0.11
Rubiaceae	<i>Wendlandia</i> sp.	2000.00	72.00	5.56	12.96
Sterculiaceae	<i>Helicteres isora</i> . L.	972.22	8.75	22.22	0.39
Mimosaceae	<i>Albizia odoratissima</i> .	1222.22	22.00	11.11	1.98

Name of the family	Name of the plant species	Density (Individuals/ha)	Frequency %	Abundance	A/F
	(L.f.) Benth.				
Bignoniaceae	<i>Sterospermum suaveolens</i> (Roxb.) DC.	638.89	7.67	16.67	0.46
Combretaceae	<i>Terminalia chebula</i> Retz.	861.11	5.17	33.33	0.16
Meliaceae	<i>Trichilia connaroides</i> (Wight & Arn.) Benth.	638.89	23.00	5.56	4.14
Euphorbiaceae	<i>Securinega virosa</i> (Roxb. Ex Wild.) Baill	500.00	6.00	16.67	0.36
Flacourtiaceae	<i>Casearia graveolens</i> Dalz.	1750.00	6.30	55.56	0.11
Dilleniaceae	<i>Dillenia pentagyna</i> Roxb.	2194.44	11.29	38.89	0.29
Mimosaceae	<i>Xylia xylocarpa</i> (Roxb.) DC.	1583.33	19.00	16.67	1.14
Mimosaceae	<i>Dalbergia latifolia</i> Roxb.	805.56	29.00	5.56	5.22
Burseraceae	<i>Protium serratum</i> (Wall.ex Colebr.) Engl.	694.44	3.57	38.89	0.09
Mimosaceae	<i>Albizia marginata</i> (Lam.) Merr.	861.11	15.50	11.11	1.40
Rubiaceae	<i>Adina cordifolia</i> (Roxb.) Hook. F.ex. Brandis	361.11	6.50	11.11	0.59
Anacardiaceae	<i>Mangifera indica</i> L.	527.78	4.75	22.22	0.21
Sapotaceae	<i>Madhuca latifolia</i> Gmel.	583.33	10.50	11.11	0.95
Lecythidaceae	<i>Careya arborea</i> Roxb.	527.78	4.75	22.22	0.21
Euphorbiaceae	<i>Securinega virosa</i> (Roxb. Ex Wild.) Baill	583.33	21.00	5.56	3.78
Simaroubaceae	<i>Gmelina arborea</i> Roxb.	416.67	5.00	16.67	0.30
Mimosaceae	<i>Albizia procera</i> (Roxb.) Benth	388.89	14.00	5.56	2.52
Bombacaceae	<i>Bombax ceiba</i> L.	388.89	7.00	11.11	0.63
Euphorbiaceae	<i>Mallotus philipensis</i> (Lam.) Muell.-Arg.	416.67	15.00	5.56	2.70
Lythraceae	<i>Lagerostroemia parviflora</i> Roxb.	333.33	12.00	5.56	2.16
Rubiaceae	<i>Wendlandia tinctoria</i> (Roxb.) DC.	416.67	15.00	5.56	2.70
Meliaceae	<i>Cipadessa baccifera</i> (Roxb.) Miq	333.33	12.00	5.56	2.16
		1444.44	1.00-9.00	5.56-11.11	0.18-1.62
Total		1,13,416.7	-	-	-

Table 8. Families, species, density, frequency, abundance and distribution pattern of seedling layer in Similipal biosphere reserve.

In most of the plant life forms there were a high number of species that occurred only once. The distribution of the species into Raunkiaer’s frequency classes showed that most of the species encountered were rare and very few species were in intermediate and high or common frequency class (Table- 9). Except climbers all other groups of plant life forms do not follow the expected $A>B>C \geq \leq D<E$ frequency distribution proposed by Raunkiaer (1934) as the number of species in frequency class D is higher than frequency class E.

Frequency Class	Code	Number of species in vegetation layers						Remark
		Tree	Climber	Shrub	Herb	sapling	seedling	
0-20	A	71 (61)	7 (41)	4 (13)	78 (77)	79 (73)	34 (59)	Rare
21-40	B	27(23)	6 (35)	16 (52)	20 (20)	13 (12)	18 (31)	Low
41-60	C	9 (08)	3 (18)	7 (22)	2 (02)	7 (06)	2 (03)	Intermediate frequency
61-80	D	6 (05)	0 (0)	3 (10)	1 (01)	5 (05)	3 (05)	Moderately high frequency
81-100	E	4 (03)	1 (06)	1 (03)	0 (0)	4 (04)	1 (02)	High frequency (common)

Table 9. Distribution of vegetation layers according to Raunkiaer’s classification scheme (Values in parentheses indicate % of species).

3.2 Ecological importance of species

Importance value Index (IVI) is the measurement of ecological amplitude of species (Ludwig and Reynolds, 1988) suggesting the ability of a species to establish over an array of habitats. However, there is no single perfect way of assessing the ecological amplitude of a species. The abundance of a species can be represented by several measures such as relative density, relative frequency and Importance Value Index (IVI). Though frequency and density values are suitable for herbs and shrubs (Airi et al., 2000), IVI is an important information for tree species. On the basis of IVI, *Shorea robusta* was found as the dominant species in the SBR having IVI of 77.67 followed by *Terminalia alata* (16.13) and *Anogeissus latifolia* (13.43). *Wendlandia* sp. had IVI of 0.25 and was considered as the rare species of the reserve. All other tree species showed intermediate range of IVI (Table-3).

3.3 Distribution pattern

The distribution pattern of trees, shrubs, climbers, herbs, saplings and seedlings of the reserve is shown in Table-10. Odum (1971) stated that under natural conditions, a clumped distribution of plants is normal. A higher percentage of random and regular distribution reflects the greater magnitude of disturbance` such as grazing and lopping in natural forest stands. Most of the species of all the vegetational layers of the reserve showed generally clumped type of distribution in the present study. Regular distribution pattern is completely lacking in all the vegetation layers. Both in herb and seedling layers not a single species showed random distribution pattern (Table-10).

Plant group	Number of species in distribution pattern categories			
	Regular	Random	Contiguous	Total number of species
Tree	0	08	109	117
Climber	0	03	14	17
Shrub	0	01	30	31
Herb	0	0	101	101
Sapling	0	06	102	108
Seedling	0	0	58	58

Table 10. Distribution pattern of vegetation layers of Similipal biosphere reserve.

3.4 Distribution of climbers

Out of 794 number of trees per hectare 110 number of trees per hectare affected by 40% bore climbers, 10 % were overgrown with climbers while 15% had climbers restricted to the main stem, 12% had climbers in the crown only and 23% had climbers both the stem and in the crown (Figure. 2).

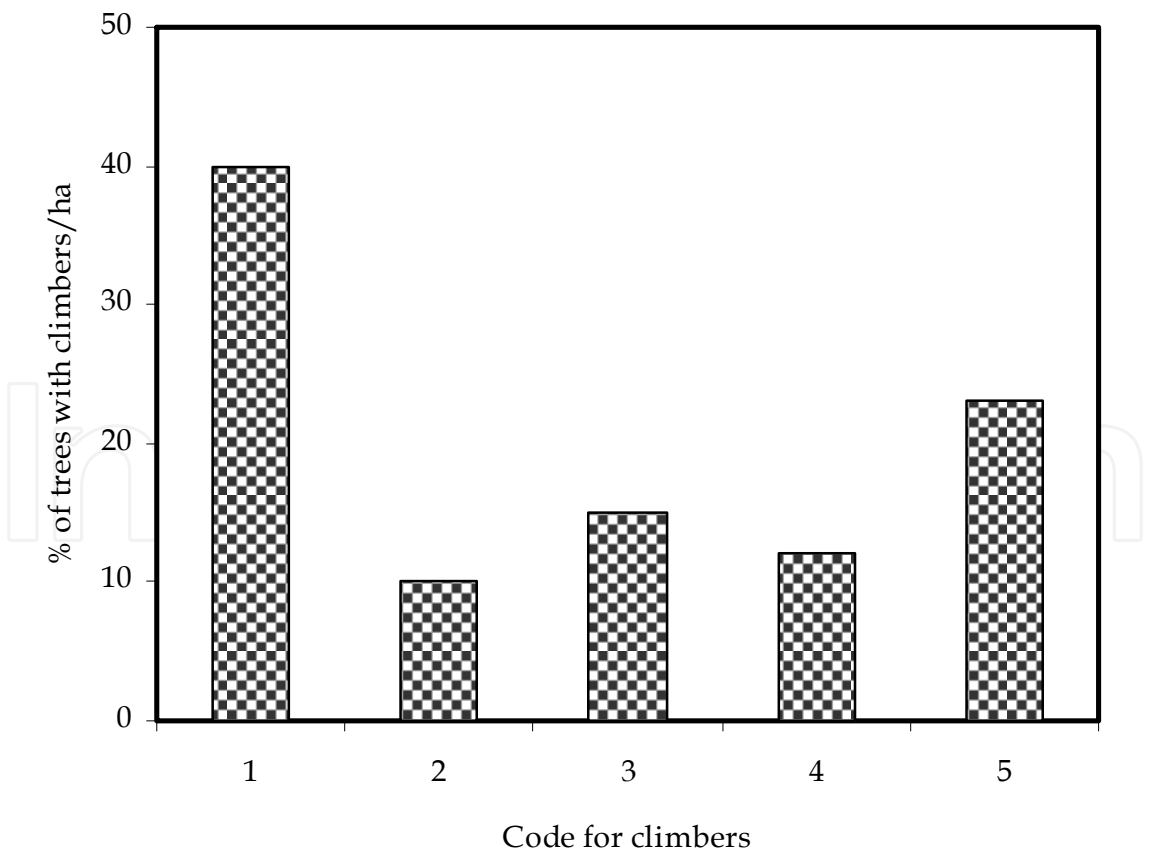


Fig. 2. Percentage distribution of climbers in Similipal biosphere reserve.

3.5 Stand structure

Species wise density of individuals having $\geq 30\text{cm}$ girth of the reserve ranged from less than one plant per hectare to 284 plants/ha and the total density of the reserve was 794 plants/ha. Maximum density (per hectare of individuals of $\geq 30\text{cm}$) was recorded for *Shorea robusta* (284) followed by *Terminalia alata* (50), *Anogeissus latifolia* (45), *Protium serratum* (32) and *Dillenia pentagyna* (29). Density was observed less than or equal to one for many species like *Antidesma acidum*, *Artocarpus lacuccha*, *Butea monosperma*,, *Casearia elliptica*, *Chionanthus intermedicus*, *Cochlospermum religiosum*, *Euonymus glaber*, etc. Some other species showed intermediate range of density per hectare. The densities of climbers in comparison to other vegetation layers of the reserve was too low. However the densities of herbs, seedlings and sapling layers were quite high in comparison to other vegetational layers. Unlike tree layer in herb, shrub and climber layers very few species showed lowest density. *Exacum bicolor* in herb layer, *Cipadesa baccifera* and *Clausena excavata* in shrub layer and, *Jasminum flexile* and *Bridelia stipularis* in climber layers values showed minimum value of density (Table-4, 5, 6, 7 and 8). Total basal area of trees of the reserve was $71.05\text{ m}^2/\text{ha}$ in which maximum was experienced by *Shorea robusta*. *Shorea robusta* contributed maximum of 39% to the basal area followed by *Terminalia alata* (6.15%), *Anogeissus latifolia* (4.73%) and *Dillenia pentagyna* (3.57%). The total contribution that resulted from this associated combination of *Shorea-Terminalia-Anogeissus-Dillenia* was 53.45%. A few families contributed most to the total basal area. These included Dipterocarpaceae (39%), Combretaceae (13 %), Myrtaceae (5%), Rubiaceae (4.5 %) and Moraceae (4 %). As a whole the tree density and basal area of 794 plants/ha and $71.05\text{m}^2/\text{ha}$, respectively are well within the reported range of various Indian tropical forests (Visalakshi, 1995; Sapkota et al., 2009).

3.6 Diversity measures

Species diversity, concentration of dominance and some mathematical indices of different vegetational layers of the reserve are given in Table -11. Measurement of biodiversity of specific area (local scale) on the basis of species richness does not provide a complete understanding about the individuals of the species in an ecosystem as it suffers from the

Plant group	Range of diversity indices			
	SD	CD	SR	SE
Tree	1.8 -3.11	0.07 - 0.316	3.36 - 6.59	0.611 - 0.951
Climber	0.63 - 1.86	0.155 - 0.36	0.55 - 2.22	0.8 - 0.931
Shrub	1.76 - 2.37	0.102 - 0.216	1.66 - 2.92	0.76 - 0.96
Herb	1.57 - 2.99	0.053 - 0.323	1.24 - 4.24	0.63 - 0.91
Sapling	2.1 - 3.03	0.061 - 0.194	2.98 - 6.15	0.816 - 0.949
Seedling	1.01 - 2.62	0.129 - 0.397	0.73 - 4.37	0.61 - 0.88

Table 11. Species diversity (SD), Concentration of dominance (CD), species richness (SR) and species evenness (SE) of different forest strata of Similipal biosphere reserve.

lack of evenness or equitability. It was observed that the richness index ranged from 3.36 to 6.59 (tree layer), 0.55 to 2.22 (climber layer), 1.24 to 4.24 (herb layer), 1.66 to 2.92 (shrub layer), 2.98 to 6.15 (sapling layer) and 0.73 to 4.37 (seedling layer). The equitability showed little variation across the vegetational layers which ranged from 0.61 to 0.95 (tree layer), 0.8 to 0.93 (climber layer), 0.63 to 0.91 (herb layer), 0.76 to 0.96 (shrub layer), 0.82 to 0.95 (sapling layer) and 0.61 to 0.88 (seedling layer). Shannon Wiener's index of diversity is one of the popular measures of species diversity. It ranged from 1.80 to 3.11, 0.63 to 1.86, 1.76 to 2.37, 1.57 to 2.99, 1.01 to 2.62 and 2.1 to 3.03 for tree, climber, shrub, herb, seedling and sapling layers, respectively, across all sites. Maximum range of species diversity of 1.8 to 3.11 was experienced by tree layer and the minimum range of 0.63 to 1.86 by climber layer indicating that tree layer of SBR was highly diverse while climber layer was the least (Table-11).

4. Discussion

4.1 Floristic composition

The species richness of a forest ecosystem depends on the number of species per unit area; the more species per unit area, the higher the species richness. A total of 266 species/ 3.6 ha or 74 species/ha in the SBR is more or less similar compared to the number of species reported by several workers in other tropical forest covers of India (Parthasarathy, 1999, 80 to 85 species/ ha in kalakad-Mundanthurai Tiger reserve; Parthasarathy and Karthikeyan, 1997, 57 species/ ha in Mylodai- Courtallum reserve forest) and also 70 to 80 species/ha that have been observed in other studies in West African tropical high forests (Lawson, 1985; Vordzogbe et al., 2005). The species richness in neotropical forests showed a wide variation, ranging from 20 species/ha in Varzea forest of Rio Xingu, Brazil (Campbell et al., 1992) to 307 species/ha in the Amazonian Equator (Valenica et al., 1994). In the old world tropics species richness ranged from 26 species/ha in Kolli hills of India (Chittibabu and Parthasarathy, 2000) to 231 species/ha in Brunei Darussalam of South East Asia (Poulsen et al., 1996). In tropical rain forests the range of species count per hectare is about 20 to a maximum of 223. The number of species in SBR was 74 per hectare and this number is at the lower side of the range given in tropical rain forests and neotropical forests. In the study of species richness of the western ghat, south India Sunderpandian and Swamy (2000) stated that pronounced dry season and relatively low annual precipitation factors might be correlated with low species richness.

4.2 Diversity and related measurements

It has become common practice in quantitative descriptive studies to use IVI, which combines the relative frequency, density and dominance into a single measure to analyze a plant community. Though vegetation can be described in terms of a number of parameters including frequency, density and cover, the use of any one of these quantitative parameters could lead to over-simplification or under-estimation of the status of the species (Kigomo et. al., 1990, Oyun et. al., 2009). Except few tree species viz. *Shorea robusta*, *Terminalia alata* and *Anogeissus latifolia*, low ecological status of most of the tree species in the present investigation, as evidenced by the IVIs, may be attributed to lack of dominance by any one of these species, suggesting positive interactions among the tree species. In other words,

resource spaces are shared to minimize negative species interactions and plants can obtain resources with relative ease (Tsingalia, 1990). The low IVIs may also imply that most of the tree species in this forest are rare (Pascal and Pellissier, 1996; Oyun et al., 2009), as confirmed by Raunkiaer's frequency distribution of the tree species (Table- 9). The rarity of species may be attributed to the occurrence of abundant sporadic species with low frequency in the stands (Oyun et al., 2009). The high percentage (>70 %) of rare species observed in various vegetational layers of the reserve confirms the generally acclaimed notion that most of the species in an ecological community are rare, rather than common (Magurran and Henderson, 2003). The range of evenness value and Simpson's diversity index of 0.61-0.96 and 0.053-0.397, respectively in vegetation layers of Similipal implies that most of the species are equitably distributed while very few species showed the degree of dominance (Pascal and Pellissier, 1996). Shannon Wiener species diversity value among vegetational layers of the reserve ranges from 0.63-3.11 indicating that SBR is highly diverse. The species diversity is generally higher for tropical forests, which is reported as 5.06 and 5.40 for young and old stand, respectively (Knight, 1975). For Indian forests the diversity index ranges between 0.83- 4.1 (Visalakshi, 1995). The diversity index of different vegetational layers of SBR is well within the reported range of the forests of Indian sub-continent (Table-11). Higher species diversity index in tropical forests as reported by Knight (1975) in comparison to the present investigation may be due to differences in the area sampled and lack of uniform plot dimensions. On the other hand, the value obtained for the concentration of dominance for vegetation layers of SBR (0.053-0.397) is greater than those recorded in Nelliampathy (0.085; Chandrashekara and Ramakrishnan, 1994) and tropical dry deciduous forests of Western India (0.08- 0.16; Nirmal Kumar et al., 2010). The high dominance value in the present study indicates single species dominance by *Shorea robusta* in tree, sapling and seedling layers of the reserve (Table-3, 7 and 8).

4.3 Distribution pattern of climbers

The distribution of climbers on the trees of the reserve was considerably low, being nearly equal to 14%. This may be due to high canopy coverage, thereby allowing low light to reach the forest floor and not triggering vigorous growth of climbers (Babweteera et al., 2001). The impact of climbers on the vitality of trees is negative (Toledo- Aceves and Swaine, 2008) causing loss of foliage and thereby reducing the surface area available for metabolic processes and reproductive potential as well as impeding or obstructing forest succession (Toledo-Aceves and Swaine, 2008). Notwithstanding their negative impacts, climbers form bridges between the forest canopies, thereby facilitating the movement of arboreal animals across the forest. They also protect weaker trees from strong winds (Schnitzer and Bongers, 2002).

4.4 Stand structure

Stand structure parameters allow predictions of forest biomass and can provide spatial information on potential determinants of plant species distributions (Couteron et al., 2005). In the present study stand structure relates to the basal area of trees, density of trees, and densities of herbs, shrubs, climbers, saplings and seedlings. The tree basal area of 71.05m²/ha is high and comparable to the reported range of various Indian tropical forests

(Visalakshi, 1995; Sapkota et al., 2009) and slightly higher than the value reported from Monteverde of Costa Rica (62 m²/ha, Nadkarni et al., 1995). High basal area is a characteristic feature of mature forest stand and serves as a reflection of high performance of the trees. It may also presuppose the development of an extensive root system used efficient nutrient absorption, growth suppressing of subordinate plants as the big trees intercept much of the solar radiation that might otherwise reach the forest floor. Dipterocarpaceae had the highest basal area in the present study, followed by Combretaceae, Myrtaceae, Rubiaceae and Moraceae. These families contain important timber species such as *Shorea robusta*, *Terminalia alata*, *Anogeissus latifolia*, *Syzygium cumini*, *Syzygium cerasoides*, *Terminalia bellirica*, *Terminalia chebula*, etc. The Barringtoniaceae, Chochlospermaceae, Clusiaceae, Malvaceae, Melastomataceae, Myrsinaceae, Ochnaceae, Rosaceae, Salicaceae, Lauraceae, Rhamnaceae, Sterculiaceae, Symplocaceae, Verbenaceae, Flacourtiaceae, and Rutaceae did not contribute much to the total basal area. In all the stands investigated, Chochlospermaceae, Sapotaceae, Salicaceae, etc. were by one individual each while Barringtoniaceae represented by two individuals and, Clusiaceae and Melastomataceae by three individuals each. This implies that very low contribution of these families to the total basal area may be due to their low numbers. Thus, these families may not be very important in terms of dominance. Species wise density of individuals having ≥ 30 cm girth of the reserve ranged from less than one plant per hectare to 284 plants/ha and the total density of the reserve was 794 plants/ha. Maximum density (per hectare of individuals of ≥ 30 cm) was recorded for *Shorea robusta* (284) followed by *Terminalia alata* (50), *Anogeissus latifolia* (45), *Protium serratum* (32) and *Dillenia pentagyna* (29). Density was observed less than or equal to one for many species like *Antidesma acidum*, *Artocarpus lacuccha*, *Butea monosperma*, *Casearia elliptica*, *Chionanthus intermedicus*, *Cochlospermum religiosum*, *Euonymus glaber*, etc. Some other species showed intermediate range of density per hectare. The tree density of 794 individuals/ha recorded in the present investigation is lower as compared to densities reported from Saddle Peak of North Andaman Islands and Great Andaman Groups (946-1137 trees/ha, Padalia et al., 2004). However, the tree density of SBR is comparable with other tropical forests e.g. Kalkad Western Ghats (575-855 trees/ha, Parthasarathy, 1999), Brazil (420-777 trees/ha, Campbell et al., 1992), seasonally deciduous forest of Central Brazil (734 trees/ha, Felfili et al., 2007), Semideciduous forest of Piracicaba, Brazil (842 trees/ha, Viana and Tabanez, 1996) and Costa Rica (617 trees/ha, Heaney and Proctor, 1990). There appears to be little literature available to compare the herb, shrub, sapling and seedling densities with at the local level. The reported densities of these vegetation layers of the reserve in the present investigation is well comparable to Mishra et al. (2008). The fewer numbers of saplings recorded in relation to seedlings in this study implies that most of the saplings are transiting into young trees. It could also mean that most of the seedlings probably die due to intense competition (Weidelt, 1988) for available resources before they reach the sapling stage. Nevertheless, the totality of saplings and seedlings is colossal and reflects high regeneration potential of the forest (Mishra et al., 2005; Khumbongmayum et al., 2006).

4.5 Comparative analysis of tree species diversity in various tropical forests

The tree diversity observed in various tropical forests has also been compared with the findings of the present study in SBR (Table-12). The species diversity in SBR can be comparable with other tropical forests. Species richness and density of tree species of the

present study (117 species and 794 plants per hectare) is well within the reported range of tropical forests in India and outside India. However, the basal area estimated for tree species in the present investigation is well within the reported range of Indian tropical forests but higher than that of tropical forests found outside India (Table-12). The high basal area of 71 m²/ha obtained in the present investigation was largely due to the contribution of the dominant tree species of the reserve, maximum by *Shorea robusta* which alone scored 39% (27.73 m²/ha) of basal area.

Forest and location	No. of species	No. of genera	No. of families	Density (Plants/ha)	Basal area (m2/ha)	Source
Indian tropical forest						
Moist deciduous forest, Similipal	117	87	42	793.67	71.04	Present study
Moist deciduous forest, Andaman	235	153	73	946	28.60	Padalia et al., 2004
Semi evergreen forest, Andaman	231	153	71	1027	33.76	Padalia et al., 2004
Evergreen forest, Andaman	264	176	81	1137	44.28	Padalia et al., 2004
Wet evergreen forest, South western ghat	122	89	41	575-855	61.7-94.64	Parthasarathy, 1999
Tropical forests outside India						
Neotropical cloud forest, Monteverde, Costa Rica	114	83	47	555	62.0	Nadkarni et al., 1995
Seasonally deciduous forest,Iaciara, Brazil	39	-	-	734	16.73	Felfili et al, 2007
Seasonally deciduous forest, Monte Alegre, Brazil	56	-	-	633	19.36	Nascimento et al., 2004
Semideciduous, Piracicaba, SP, Brazil	101	-	-	842	12.53	Viana and Tabanez, 1996
Evergreen rain forest, Ngovayang (Cameroon)	99-121	-	-	451-634	28.8-42.1	Christelle et al., 2011
Subtropical forest, Bagh district, Kashmir, Pakistan	72	-	31	344	69.31	Saheen et al., 2011
African wet tropical forest	344-494	-	-	371-486	27.8-35.8	Chuyong et al., 2011

Table 12. Tree species diversity in various tropical forests.

5. Conclusion

The overall analysis indicates that species rich communities of the moist deciduous tropical forests are not only being reduced in area but they are also becoming species poor and less diverse due to rapid deforestation and forest fragmentation. The community organization is also changing in response to increased anthropogenic disturbance. The study has shown that SBR is highly rich in plant diversity and is one of the treasure houses of good ecological wealth of Eastern ghat, India. The long history of timber exploitation prior to its conversion into a biosphere reserve has resulted in the alteration of structure of the forest whereby most of the tree species were affected by very few individuals. The ecological importance of most of the tree species was also low, which reflected rarity of most of the species. However, the abundance of small trees coupled with the colossal sum of saplings and seedlings reflects a high regeneration potential of the forest.

The forest management issues of SBR could be addressed by collection and analysis of long term ecological data which requires scientific baseline studies. We have covered extensively structural parameter analysis which is helpful to know the present state of ecological health of the ecosystem. But due to the various forms of anthropogenic pressure the habitat is destroyed with for logging, illegal hunting, and other challenges (mining in periphery, etc.). The conservation efforts have not so far yielded desired result. With continued biotic pressure and consequent change in structure and function of ecosystem, the management methodology also needs to be modified developing a Long Term Research Network. Similipal is a globally recognized ecosystem covered under UNESCO's Biosphere Reserve housing wide range of flora and fauna. We need to carry out Research and education activities to create an institutional platform to academicians, researchers and scientists. This ecosystem is under pressure. Continued destruction of old-growth and pristine forests of Similipal with high biodiversity will have a regional impact on social and ecological sustainability.

The over exploitation of natural resources in tropical world for meeting the basic needs of food, fodder and shelter of local population has disturbed the landscapes causing rapid depletion of biodiversity. Our research results may be of some help to develop management schemes for conservation of biodiversity of SBR. Lack of data base and structural and functional characters of the ecosystem at regular intervals will not help to develop a long-term strategy for sustainable development. Thus continuous collection of data as per long-term action plan on successional status of species level up external and local pressures on the ecosystem, soil fertility management and linkage between social and ecological processes is needed. The community participation and use of traditional technologies as tools for natural resource management should be integrated to achieve sustainable resource management and ecological rehabilitation.

6. Acknowledgement

We are thankful to the Director, Dy. Director and other forest officials of Similipal biosphere reserve for their active cooperation in the field work. Financial assistance from CSIR and DST, New Delhi is greatly acknowledged.

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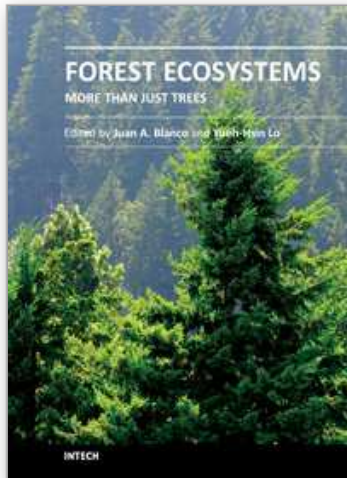
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Forest Ecosystems - More than Just Trees

Edited by Dr Juan A. Blanco

ISBN 978-953-51-0202-1

Hard cover, 464 pages

Publisher InTech

Published online 07, March, 2012

Published in print edition March, 2012

The common idea for many people is that forests are just a collection of trees. However, they are much more than that. They are a complex, functional system of interacting and often interdependent biological, physical, and chemical components, the biological part of which has evolved to perpetuate itself. This complexity produces combinations of climate, soils, trees and plant species unique to each site, resulting in hundreds of different forest types around the world. Logically, trees are an important component for the research in forest ecosystems, but the wide variety of other life forms and abiotic components in most forests means that other elements, such as wildlife or soil nutrients, should also be the focal point in ecological studies and management plans to be carried out in forest ecosystems. In this book, the readers can find the latest research related to forest ecosystems but with a different twist. The research described here is not just on trees and is focused on the other components, structures and functions that are usually overshadowed by the focus on trees, but are equally important to maintain the diversity, function and services provided by forests. The first section of this book explores the structure and biodiversity of forest ecosystems, whereas the second section reviews the research done on ecosystem structure and functioning. The third and last section explores the issues related to forest management as an ecosystem-level activity, all of them from the perspective of the other parts of a forest.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

R.K. Mishra, V.P. Upadhyay, P.K. Nayak, S. Pattanaik and R.C. Mohanty (2012). Composition and Stand Structure of Tropical Moist Deciduous Forest of Similipal Biosphere Reserve, Orissa, India, Forest Ecosystems - More than Just Trees, Dr Juan A. Blanco (Ed.), ISBN: 978-953-51-0202-1, InTech, Available from: <http://www.intechopen.com/books/forest-ecosystems-more-than-just-trees/stand-structure-of-tropical-moist-deciduous-forest-of-similipal-biosphere-reserve-orissa-india>

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