CHAPTER III

Tree Diversity and Population Structure in Undisturbed and Human-Impacted Forest Stands

Introduction

The world vegetation cover under natural forests has been depleting fast and a significant portion of such areas is being converted to man-made plantation forest, mainly of timber trees (Pandey & Shukla 1999) to meet the growing need of the ever increasing human population. We now largely depend on managed forest for wild plant resources as we donot have much natural forest left. The current pressure on the forest communities for large-scale collection of fuelwood and minor forest products as well as the practice of grazing and trampling may alter the habitats of many species. As a result, there is a lot of spatial and temporal variation in species richness, composition and productivity. A thorough understanding of the dynamics of the forest can help increase the productivity, maintain species composition, limit financial inputs and develop prescription for silvicultural operations (Oliver & Larson 1990, Bhat *et al.* 2000) and conserve the plant diversity (Murali *et al.* 1996).

Tree regeneration can be predicted by the structure of their populations (Marks 1974, Veblen *et al.*1979, Pritts & Hancick 1983, Saxena & Singh 1984, Saxena *et al.* 1984, Khan *et al.* 1987). The presence of sufficient number of seedlings, saplings and young trees in a given population indicates a successful regeneration (Saxena & Singh 1984). A sustained regeneration

and growth of all species in the presence of older plants is required for better growth of any plant community (Ramakrishnan *et al.* 1981, Taylor & Zisheng 1988). Information on forest composition, effects of biotic and abiotic pressure, type of species surviving and the extent of biomass removal can help rejuvenate depleting forest through silvicultural practices and community involvement (Ramakrishnan & Toky 1981, Singh & Singh 1987, Sundriyal *et al.* 1994, Murali & Setty 2001).

The present chapter focuses on the tree diversity, population status and community attributes of the forest stands and population structure of tree species in different forests experiencing various degrees of disturbance.

Methods

Phytosociological studies were carried out during 1998-1999 using quadrat method (30 m ×30 m for trees and saplings, 10 m ×10 m for seedlings and shrubs and 1 m ×1 m for herbs within the same 30 m × 30 m quadrat). Ten quadrats were laid randomly in each forest stand for trees, saplings and seedlings. Tree species occurring in each of the quadrats were listed and their circumference was measured. The individuals in the case of tree species were separated into three categories i.e. (a) seedlings (≤10 cm collar circumference at the base), (b) saplings (10≤20 cm collar circumference at the base) and (c) trees (>20 cm circumference at breast height i.e.1.37 m). Density (trees ha^{-1}) and basal area values were calculated for each species. The importance value index for each species was computed by summing up

the relative density, relative frequency and relative dominance. Individuals with 10≥20 cm collar circumference at the base were considered regenerating plants (Saxena *et al.* 1984, Khan *et al.* 1987, Sundriyal *et al.* 1994). Regeneration was recorded for each stand to estimate the species status in different stands.

Similarity index (community coefficient) among different stands was calculated as per Jaccard (1912) as given below:

$$Cj = j / (a+b-j)$$

Where 'j' is the number of species common to both stands. 'a' is the number of species in stand A and 'b' is the number of species in stand B.

Shannon–Wiener diversity index (Shannon-Wiener 1963) was calculated from the IVI values using the formula given by Magurran (1988).

$$H = -\sum_{i=1}^{s} pi \ln pi$$

Where 'pi' is the proportion of the ith species and number of individuals of all the species (ni/N).

Simpson's Index (Simpson 1949) which measures concentration of dominance (cd) was calculated as follows:

$$Cd = -\sum_{i=1}^{s} (pi)^2$$

Where pi is the same as for Shannon-Wiener information function.

Results

Species richness, species diversity, concentration of dominance, similarity index and basal area

Species richness varied according to disturbance gradient in different stands. The mildly disturbed stand showed the highest species richness (54 of 51 genera). The species richness was the lowest (16 of 16 genera) in the highly disturbed stand. In the undisturbed stand 47 species of 42 genera were recorded while in the moderately disturbed stand 42 species of 36 genera were found. Tree species diversity index ranged from 0.7 to 2.02 in all stands. The highest species diversity was recorded in the undisturbed stand and the lowest in the highly disturbed stand. The values for concentration of dominance were recorded to be similar in the undisturbed, mildly disturbed and moderately disturbed stands whereas it was the lowest in the highly disturbed stand. The similarity index value was maximum in the undisturbed stand and minimum in the highly disturbed stand.

The forest stand density was recorded highest (5452 stems/ha) in the undisturbed stand and lowest (338 stems/ha) in the highly disturbed stand. The basal area was recorded highest in undisturbed stand (104.60m^2ha^{-1}) and lowest in moderately-disturbed stand (18.60 m^2ha^{-1}) (Table III.1). The presence of large number of buttressed trees in the undisturbed, mildly disturbed and highly disturbed stands has contributed to the high basal area.

Plant families, genera and species

Enumeration of plant families, genera and species in different stands showed the presence of 28 families with 42 genera in the undisturbed stand, 31 with 51 genera in the mildly disturbed stand, 27 with 36 genera in the moderately disturbed stand and 14 with 16 genera in the highly disturbed

stand (Table III.1). Out of 28 families in the undisturbed stand, 8 were represented by more than one genus and 20 by single genus. Out of the 28 families in the undisturbed stand, 17 families consisted of single species whereas 11 families were found to have more than one species. Only four genera contained more than one species. Dipterocarpaceae, Clusiaceae, Theaceae and Combretaceae contributed more than 90% to the total stand density. In the mildly disturbed stand, out of 31 families, 13 were represented by more than one species and 18 had single species. Only 3 genera contained more than one species. In the moderately disturbed stand, out of 27 families 11 were represented by more than one species where species of Dispterocarpaceae and Clusiaceae families were dominant. In the highly disturbed stand, out of 14 families only 2 were represented by more than one species. In this stand Dipterocarpaceae and Leguminaceae dominated over the other families (Table III.2).

Table III.1. Consolidated details of families, genera, species, diversity index, concentration of dominance, stand density and basal area in four forest stands experiencing different degree of disturbance.

Parameters	Forest stands			
	Undisturbed	Mildly disturbed	Moderately disturbed	Highly disturbed
Species richness	47	54	42	16
No. of families	28	31	27	14
No of genera	42	51	36	16
Diversity index (H)	2.02	1.93	1.99	0.7
Concentration of dominance	0.06	0.06	0.06	0.04
Similarity index	0.46	0.40	0.43	0.07
Stand density (stems/ha) (tree + sapling + seedling)	5452	5014	3656	338
Basal area (m^2ha^{-1})	104.60	51.75	18.60	43.23

Table III. 2. Tree families, genera, species richness and density (no. of trees ha^{-1})*in four* forest stands experiencing different degrees of disturbance.

Families	Undisturbed stand			Mildly disturbed stand			Moderately disturbed stand			Highly disturbed stand		
	Genera	Species	Density	Genera	Species	Density	Genera	Species	Density	Genera	Species	Density
Anacardiaceae	1	1	6	1	1	77	1	1	7	-	-	-
Apocynaceae	1	1	2	1	1	15	1	1	2	1	1	15
Araliaceae	1	1	102	2	2	7	-	-	-	-	-	-
Burseraceae	1	1	224	1	1	145	1	1	151	1	1	11
Chailetiaceae	1	1	4	-	-	-	-	-	-	-	-	-
Clusiaceae	2	2	745	2	2	784	2	2	421	1	1	20
Combretaceae	1	1	312	1	3	236	1	2	165	1	1	11
Dasticaceae	1	1	5	-	-	-	-	-	-	-	-	-
Dilleniaceae	1	1	2	-	-	-	1	1	7	-	-	-
Dipterocarpaceae	3	3	1760	3	3	1485	3	3	974	2	2	135
Elaeocarpaceae	1	2	110	1	2	48	1	1	57	1	1	7
Euphorbiaceae	3	3	93	3	3	243	3	4	241	-	-	-
Fabaceae	-	-	-	2	2	4	-	-	-	-	-	-
Fagaceae	1	1	386	1	1	332	1	1	164	-	-	-
Flacourtiaceae	-	-	-	1	1	12	-	-	-	1	1	9
Hamemeliaceae	1	1	2	1	1	9	1	1	153	-	-	-
Lauraceae	5	5	131	3	3	132	3	4	336	-	-	-
Leguminosae	-	-	-	2	2	2	1	1	64	2	2	75
Loranthaceae	1	1	2	-	-	-	-	-	-	-	-	-
Lythraceae	1	1	53	1	1	74	2	2	40	1	1	11
Magnoliaceae	3	3	285	3	4	303	1	2	186	1	1	4
Melastomataceae	1	1	4	1	1	4	-	-	-	-	-	-
Malvaceae	1	2	2	1	1	4	-	-	-	-	-	-
Meliaceae	2	3	324	3	3	453	1	2	283	1	1	13
Moraceae	-	-	-	2	2	5	1	1	4	1	1	7
Myrtaceae	1	1	73	1	1	39	1	2	3	-	-	-
Rosaceae	-	-	-	1	1	100	-	-	-	-	-	-
Rubiaceae	2	2	30	1	1	24	1	1	21	-	-	-
Sapindaceae	-	-	-	1	1	24	-	-	-	-	-	-
Sapotaceae	2	2	77	1	1	63	1	1	74	-	-	-
Simarubaceae	1	1	140	1	1	39	1	1	18	1	1	13
Sterculiaceae	1	1	7	1	1	7	1	2	100	1	1	7
Theaceae	1	1	461	1	1	122	1	1	152	-	-	-
Thymelaceae	1	1	100	1	1	5	1	1	2	-	-	-
Unknown	-	-	-	1	1	91	1	1	4	-	-	-
Urticaceae	-	-	-	-	-	-	1	1	4	-	-	-
Verbenaceae	-	-	-	3	3	126	2	2	23	-	-	-
Total	**42**	**47**	**5452**	**51**	**54**	**5014**	**36**	**42**	**3656**	**16**	**16**	**338**

Dominance and rarity

Dominance calculated as IVI of different species varied greatly in different stands. *Shorea assamica, Dipterocarpus macrocarpus, Mesua ferrea, Castanopsis indica, Terminalia chebula, Vatica lancefolia* were dominant in all stands except the highly disturbed one. The canopy layer of the strata was occupied by *Shorea assamica, Dipterocarpus macrocarpus* and *Terminalia chebula* in all the stands (Table III. 3). Species represented by a few individuals were considered rare. Rudraksh (*Elaeocarpus ganitrus*) which was found sporadically in the forest stands, belongs to the category of rare species.

Girth class wise tree density and species richness

Stand densities and species richness consistently decreased with increasing girth class of tree species from 20 to > 200 cm girth (Fig III.1, III. 2). The highest species density and species richness were recorded in the medium girth class (51-110) in all stands. In the undisturbed stand the highest stand density was found in 111-140 cm girth class, while in the mildly disturbed stand 51-80 cm girth range recorded the highest stand density. In the highly disturbed stand no tree was recorded in >140 cm girth range. The highest contribution of stand density per girth class to the total density in the undisturbed, mildly disturbed and moderately disturbed stands was recorded in the 51-80 cm girth class (47%, 31% & 28%) while in the highly disturbed stand it was maximum (54%) in the 81-110 cm girth class. *Dipterocarpus macrocarpus, Shorea assamica, Mesua ferrea, Castanopsis indica, Canarium*

Table III. 3. Importance value index of tree species in four forest stands experiencing different degrees of disturbance.

Species	Undisturbed stand	Mildly disturbed stand	Moderately disturbed stand	Highly disturbed stand
	I.V.I	I.V.I	I.V.I	I.V.I
Ailanthus excelsa Linn.	-	3.34	-	-
Ailanthus grandis Prain.	6.11	5.12	9.83	8
Albizia lucida Benth.	-	1.98	-	-
Albizia procera Benth.	-	-	-	19.44
Alstonia scholaris Brown	1.26	-	-	-
Altingia exelsa Noronha.	1.15	4.42	12.03	-
Amoora wallichii King	-	3.62	-	-
Artocarpus heterophyllus Lamk	-	2.8	-	-
Barceaura sapida Murll.	4.11	6.76	9.57	9.41
Bischofia javanica Bl.	3.17	5.91	10.72	-
Bombax ceiba Linn.	.99	2.81	-	-
Camellia chinensis Linn.	22.45	10.53	4.92	-
Canarium resiniferum Linn.	11.91	8.74	14.30	19.43
Castanopsis indica D. C.	18.65	16.31	18.37	-
Chickrassia tabularis Andr. Juss	1.4	-	1.67	-
Chrysophyllum roxburghii G.Don.	.97	-	-	-
Cinamommum tamala Nees.	3.03	8.63	2.38	-
Cryptocarya amygdalina Nees	-	2.28	-	-
Dalbergia assamica Benth.	-	2.5	-	-
Dalbergia sissoo Roxb. Ex DC	-	6.06	-	-
Dillenia indica Linn.	1.13	3.43	5.4	-
Dipterocarpus macrocarpus Veque	52.3	41.96	47.34	34.54
Duabanga grandiflora Roxb. ex DC	-	10.41	4	9.63
Dysoxyllum binectariferum HK	3.35	8.41	8.53	8.53
Dysoxyllum procera Hiern.	8	8	10	-
Elaeocarpus floribundus Roxb.	.97	2.77	5.05	-
Elaeocarpus ganitrus Roxb.	4.75	4.38	6	-
Elaeocarpus robustus Roxb.	5.17	-	-	-
Eugenia praceox Roxb.	1.56	-	-	-
Ficus sp.	-	2.74	-	5.22
Flacourtia cataphracta Roxb.	-	5.56	-	-
Garcinia sp.	7.54	7.91	5.10	-

contd.

Glochidion arboreascens Bl.	1.59	4.13	2.64	-
Gmelina arborea Roxb.	-	5.19	3.32	-
Gynocardea odorata R. Br.	-	-	-	7.43
Heteropanax fragrans (D. Don). Seem	1.59	-	3.48	-
Hodgsonia macrocarpa (Bl.)	-	3	7.42	-
Kydia calycina Roxb. Cogn	1.59	1.79	-	-
Lagerstroemia parviflora Roxb.	1.38	-	-	-
Lagerstroemia speciosa Roxb.	1.60	3.46	3.6	-
Litchi chinensis Sonnor	-	2.82	-	-
Litsea monopetela King.	1.68	5.13	3.95	-
Litsea salicifolia (Roxb.) ex Nees	2.19	-	-	-
Macropanax undulatus Seem.	1.92	-	-	-
Magnifera sylvatica Roxb.	2.59	2.10	4.04	-
Magnolia sp. Hk.	8.93	3.59	-	-
Melastoma malabathricum Linn.	8.02	2	-	-
Mesua ferrea Linn.	26.96	37.39	31.11	13.63
Michalia oblonga Wall. Ex HK	-	3.52	-	-
Mimusops elengi Linn.	2.14	4.84	6.25	-
Persea bombycina Koster	3.33	-	3.14	-
Peterospermum aecrifolium wild	2.27	2.40	5.15	6.91
Phobe goalparensis Hutch.	4.28	-	8.79	-
Premna bangalensis Clarke.	-	2.28	7.18	-
Sapium baccatum Roxb.	4.33	-	-	-
Shorea assamica Dyer.	33.68	43.64	39.46	18.45
*Skamoila**	4.09	11.15	9.62	-
Spondias mangifera Willd.	-	6.06	-	17.22
Syzygium cumini Linn.	2.46	4.07	2.47	10.72
Symplocos spicata Roxb.	9	5.38	8.73	-
Talauma hodgsonii Hk. f. & Thoms.	9.82	10.78	15.14	4.41
Talauma procera King.	9.63	8.95	-	-
Terminalia chebula Retz.	12.69	10.69	10.04	9.63
Terminalia myriocarpa Muell.	3.76	4.3	2.99	-
Tetramelos nudiflora R.Br.	3.90	-	-	-
Toona ciliata Roxb.	3.24	-	-	-
Vatica lancaefoedia Bl.	15.58	10.45	8.73	-
Vangueria spinosa Roxb.	1.13	4.9	7.69	-
Ziziphus apetala Hk. f.	2.16	-	-	-

* local name

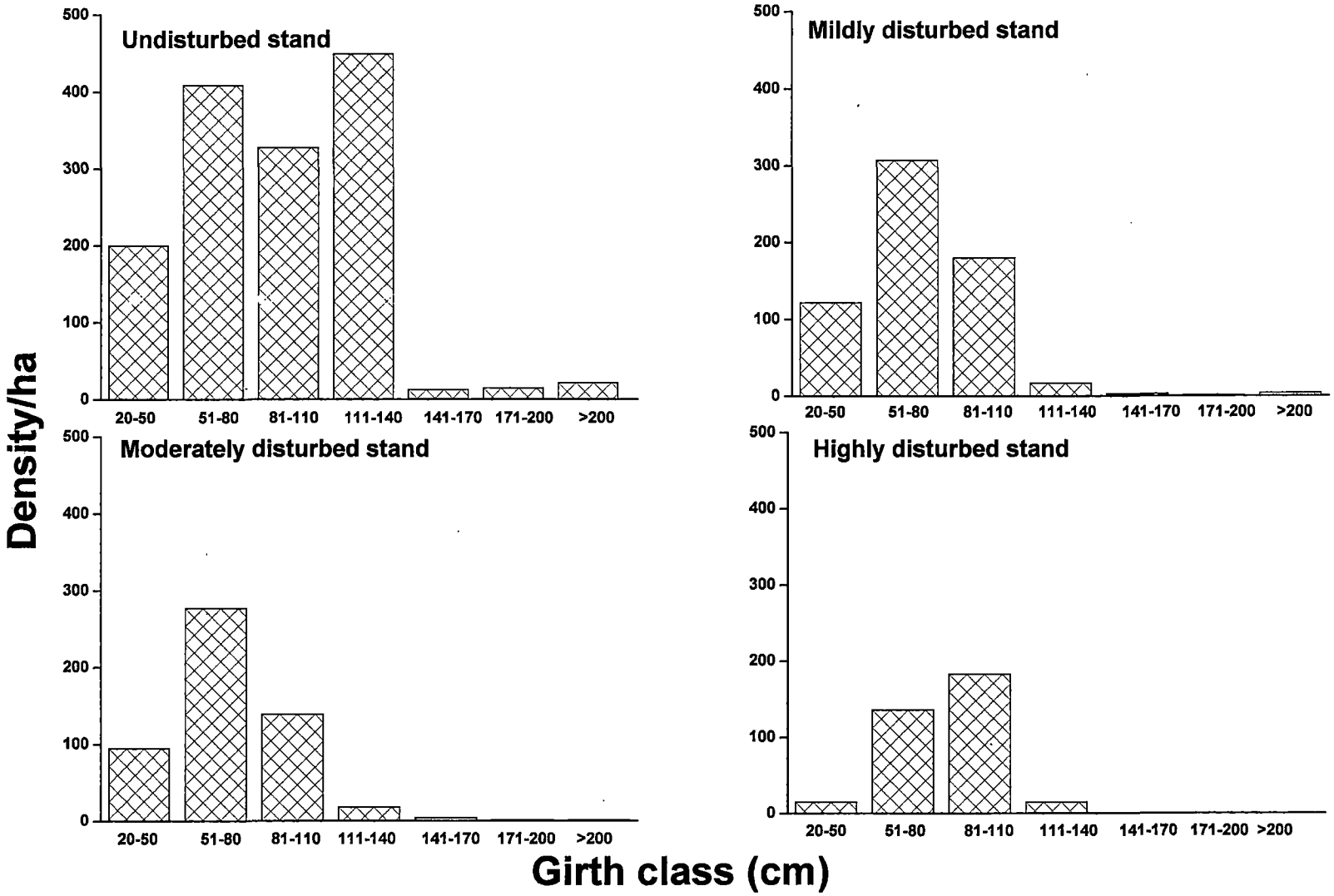


Figure III.1. Density of tree species in various girth classes in four forest stands.

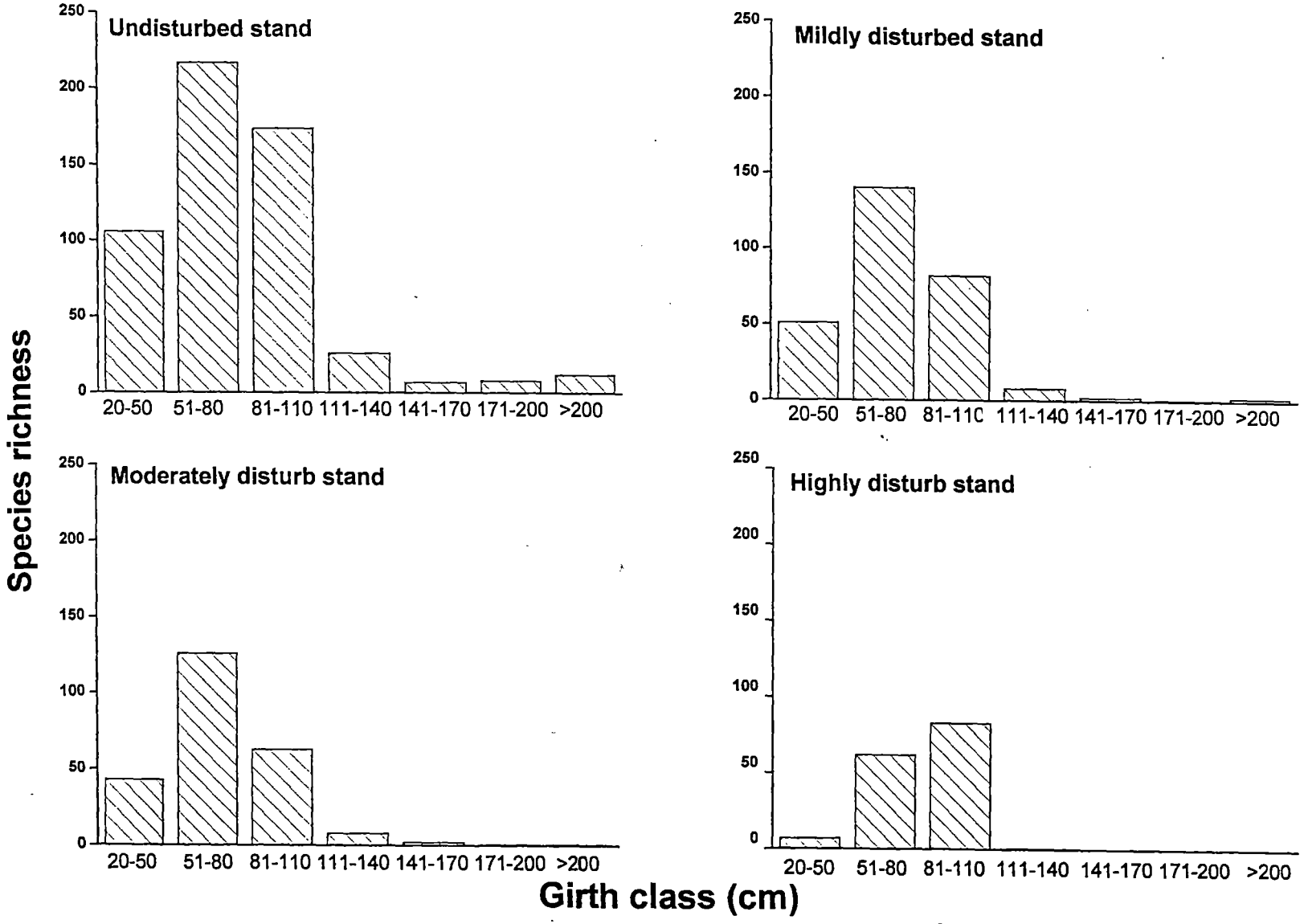


Figure III.2. Species richness of tree species among various girth classes in Four forest stands experiencing different degrees of disturbance.

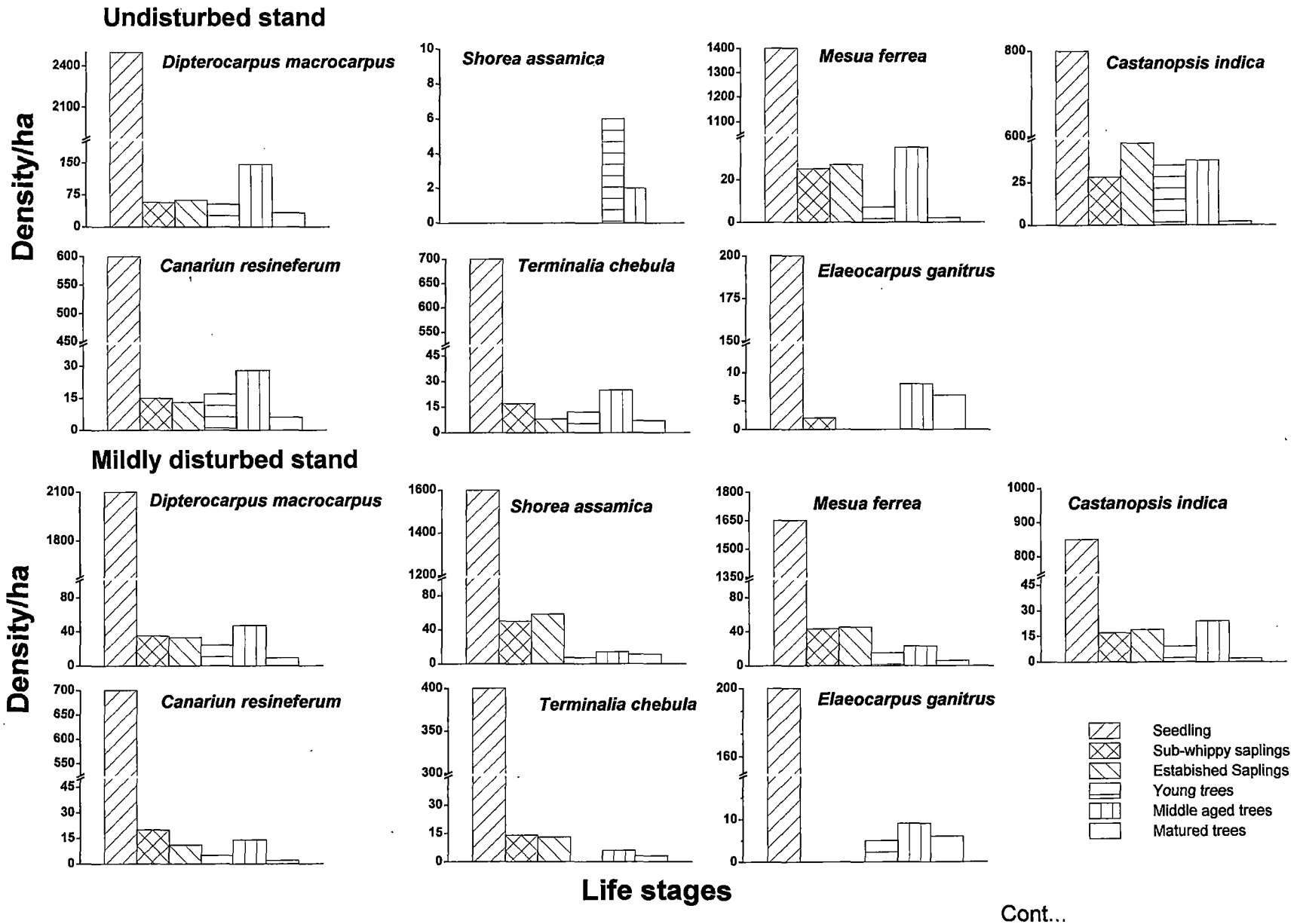
resiniferum and *Terminalia chebula* are the dominant species and these are uniformly distributed in all the forest stands. However, the distribution of these species was greatest in the 60-100 cm girth class in all the stands (Fig. III.3). Moreover, some individuals in the girth range >100 cm were also seen in the undisturbed, mildly disturbed and moderatly disturbed stands and these belonged mostly to *Dipterocarpus macrocarpus*, *Shorea assamica* and *Terminalia chebula*.

Regeneration status

Out of the 47 species in the undisturbed stand, only 26 were found to be regenerating. Twenty species showed good regeneration (predominance of saplings + seedlings), 1 species had fair regeneration and 5 species showed poor regeneration. No regeneration was recorded for other species. In the mildly disturbed stand, out of 54 species, 36 were found regenerating of which 23 species had good regeneration, 9 showed fair regeneration and 4 had poor regeneration. Out of 42 species in the moderately disturbed stand, 22 were found regenerating and good regeneration was recorded in 11 species, 7 species showed fair regeneration and 4 species had poor regeneration. No regeneration was recorded in the highly disturbed stand (Table III. 4).

Density of shrubs and herbs

Shrub and herb density are presented in tables III.5 and III.6. The highest shrub density was recorded in the undisturbed stand but the shrub species richness was maximum in the mildly disturbed stand. In all the stands


Undisturbed stand
Density/ha
Dipterocarpus macrocarpus
Shorea assamica
Mesua ferrea
Castanopsis indica
Canariun resineferum
Terminalia chebula
Elaeocarpus ganitrus
Mildly disturbed stand
Density/ha
Dipterocarpus macrocarpus
Shorea assamica
Mesua ferrea
Castanopsis indica
Canariun resineferum
Terminalia chebula
Elaeocarpus ganitrus
Seedling
Sub-whippy saplings
Estabished Saplings
Young trees
Middle aged trees
Matured trees
Life stages

Cont...

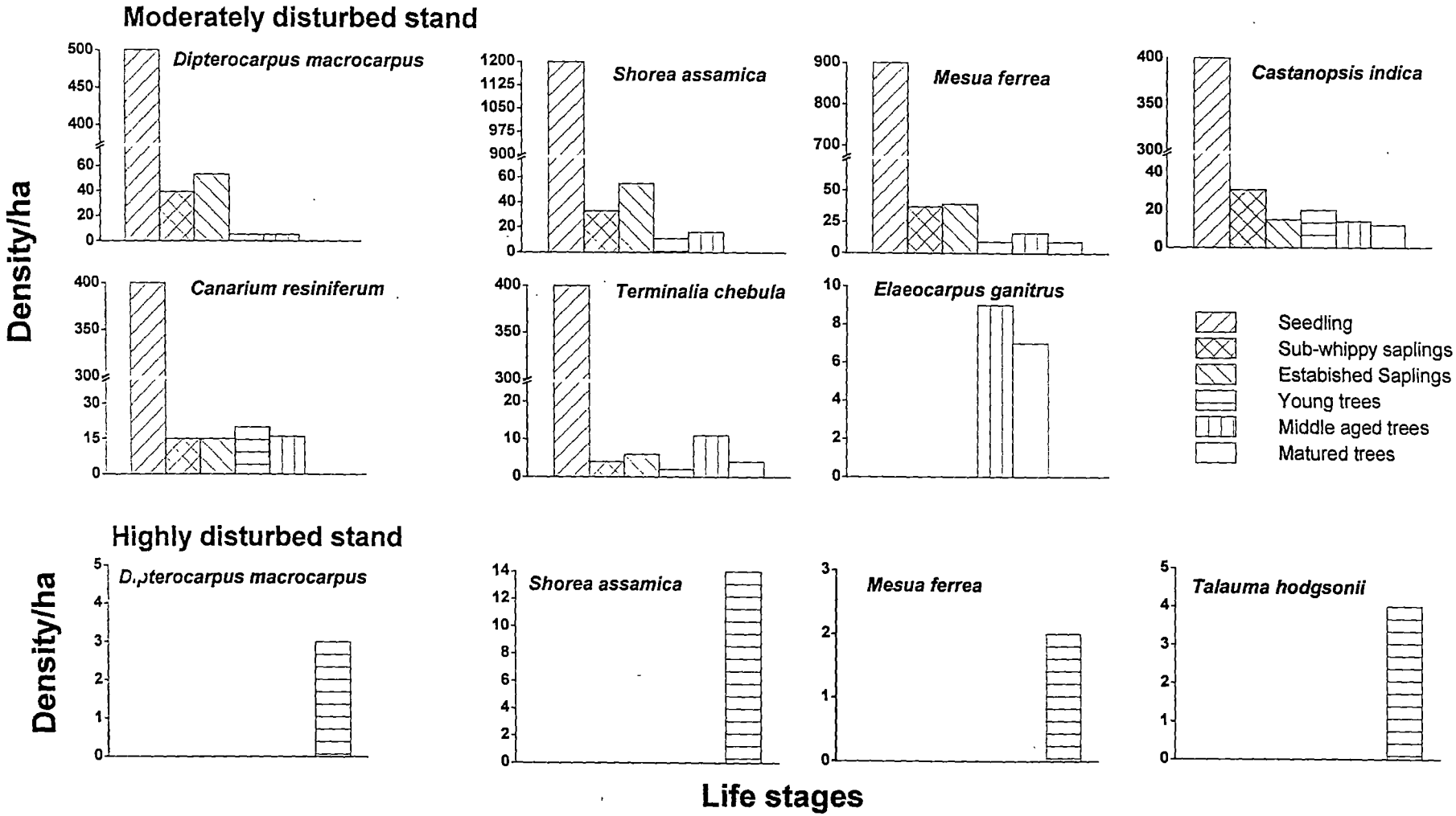


Figure III.3. Population structure of some important trees growing with *Elaeocarpus ganitrus*.

Table III. 4. Regeneration status of tree species in four forest stands experiencing different degrees of disturbance.

Species	Undisturbed stand				Mildly disturbed stand				Moderately disturbed stand				Highly disturbed stand			
	SE (ha^{-1})	SA (ha^{-1})	Prop.(%)*	Status	SE (ha^{-1})	SA (ha^{-1})	Prop.(%)*	Status	SE (ha^{-1})	SA (ha^{-1})	Prop (%)*	Status	SE (ha^{-1})	SA (ha^{-1})	Prop (%)*	Status
Ailanthus grandis Prain.	400	9	95	GR	100	6	91	GR	300	115	94	GR	-	-	-	-
Albizia lucida Benth.	-	-	-	-	-	2	#	FR	-	-	-	-	-	-	-	-
Alstonia scholaris Brown.	-	2	50	PR	-	-	-	-	-	-	-	-	-	-	-	-
Altingia exelsa *Noronha*	-	-	-	-	-	2	77	PR	-	-	-	-	-	-	-	-
Artocarpus heterophyllus Lamk..	-	-	-	GR	200	4	#	FR	-	-	-	-	-	-	-	-
Barseaura sapida Murll.	200	9	#	-	250	18	90	GR	-	-	-	-	-	-	-	-
Bischofia javanica Bl.	-	-	-	GR	-	7	31	PR	500	-	4	FR	-	-	-	-
Camellia chinensis Linn.	0	120	95	GR	600	33	57	GR	400	-	-	-	-	-	-	-
Canarium resiniferum Linn.	600	29	93	GR	700	115	96	GR	400	31	94	GR	--	--	--	-
Castanopsis indica Spach	800	78	92	FR	750	41	71	GR	100	49	91	GR	-	-	-	-
Cinnamomum tamala Nees.	-	15	78	-	100	9	85	GR	-	-	98	PR	-	-	-	-
Cryptocarya amygdalina Nees	-	-	-	-	-	4	#	FR	-	-	-	-	-	-	-	-
Dalbergia sisso. Hk.	-	-	-	-	100	-	#	PR	-	-	-	-	-	-	-	-
Dillenia indica Linn.	-	-	-	GR	-.	-	-	-	-	9	68	FR	-	-	-	-
Dipterocarpus macrocarpus Vesque	2500	120	91	GR	2500	70	96	GR	1400	93	96	GR	-	-	-	-
Dysoxylum procerum Hiern	-	-	-	-	-	-	-	-	200	-	95	PR	-	-	-	-
Elaeocarpus floribundus Bl.	-	-	-	-	-	7	#	FR	-	-	-	-	-	-	-	-
Elaeocarpus ganitrus Roxb.	200	2	92	GR	-	-	-	-	-	-	-	-	-	-	-	-
Elaeocarpus robustrus Roxb.	-	35	#	GR	-	-	-	-	-	-	-	-	-	-	-	-
Ficus sp.	-	-	-	-	-	9	#	PR	-	-	-	-	-	-	-	-
Garcinia species Linn.	600	11	95	GR	300	9	90	GR	200	4	96	FR	-	-	-	-
Glochidion multiloculare Muell.	-	-	-	-	250	4	#	FR	-	7	#	PR	-	-	-	-
Gmelina arborea Linn.	-	-	-	-	-	8	88	FR	-	20	60	GR	-	-	-	-
Heteropanax fragrans D Don	100	-	98	PR	-	-	-	-	-	-	-	-	-	-	-	-
Kydia calycina Roxb.	200	2	99	GR	-	-	-	-	-	-	-	-	-	-	-	-
Lagerstroemia speciosa (L.) pers	-	-	-	-	-	100	96	GR	-	4	30	FR	-	-	-	-

contd.

Litchi chinensis Sonnor	-	-	-	-	-	100	96	GR	-	-	-	-	-	-	-	-	-
Litsea lacta Benth.	-	2	28	PR	-	-	-	-	-	-	-	-	-	-	-	-	-
Litsea monopetala (Roxb.)	-	-	-	-	200	100	#	GR		-	-	-	-	-	-	-	-
Litsea salicifolia (Roxb.) ex Nees	100	20	#	GR				GR	13	#	FR	FR	-	-	-	-	-
Magnolia sp.	100	-	77	PR	100	4	96	GR	-	-	-	-	-	-	-	-	-
Melastoma malabathricum Linn.	500	42	31	GR	-	-	-	-	-	-	-	-	-	-	-	-	-
Mesua ferrea Linn.	1400	115	94	GR	1650	91	97	GR	900	78	92	GR	-	-	-	-	-
Michelia oblonga Wall. ex Hk	-	-	-	-	-	100	98	GR	-	-	-	-	-	-	-	-	-
Mimusops elengi Roxb.	100	2	93	GR	200	15	98	GR	-	15	68	GR	-	-	-	-	-
Premna bengalensis Cl.	-	-	-	-	-	11	#	FR	-	15	#	FR	-	-	-	-	-
Pterospermum acerifolium Willd.	-	-	-	-	-	9	#	FR	-	7	#	FR	-	-	-	-	-
Shorea assamica Dyer.	1000	153	93	GR	1600	135	84	GR	1200	89	93	GR	-	-	-	-	-
Sikamiola*	100	20	96	GR	200	46	90	GR	-	-	-	-	-	-	-	-	-
Sizygium cumuni Linn.	200	-	99	PR	150	5	94	GR	-	2	33	PR	-	-	-	-	-
Spondias magnifera Willd.	-	-	-	-	-	11	#	GR	-	-	-	-	-	-	-	-	-
Talauma hodgsonii Hk.	700	35	73	GR	600	21	96	GR	500	27	96	GR	-	-	-	-	-
Terminalia belerica Retz.	200	29	88	GR	-	-	-	-	-	-	-	-	-	-	-	-	-
Terminalia chebula Retz.	700	35	94	GR	250	18	90	GR	400	11	94	GR	-	-	-	-	-
Terminalia myriocarpa Heurck	-	-	-	-	100	7	#	FR	-	-	-	-	-	-	-	-	-
Vatica lanceaefolia Bl.	1100	51	96	GR	500	29	90	GR	200	11	95	GR	-	-	-	-	-

* local name

*Proportion (%) of seedlings and saplings in total density of a particular tree species. SE- Seedlings, SA- Saplings, GR- Good regeneration, FR- Fair regeneration, PR- Poor regeneration.

#- No mature tree present.

- Absence of saplings of a given species was taken as an indication of poor regeneration irrespective of presence of any number of seedlings of that species.

- Number of saplings was given more weightage while assigning the status of regeneration of a particular species.

Table III. 5. Density (no. of individuals 10 m^{-2}) of shrubs in four forest stands experiencing different degree of disturbances, ± SD values.

Species	Undisturbed stand	Mildly disturbed stand	Moderately disturbed stand	Highly disturbed stand
Abroma augusta Linn.	-	0.6 ± 08	0.2 ± 0.4	-
Baliospermum micranthum Muell.Arg.	-	0.2 ± 0.4	-	-
Begonia roxburghii (Miq) DC	-	0.2 ± 0.4	-	-
Beilschmiedia assamica Meissn.	-	0.2 ± 0.4	0.2 ± 0.4	-
Blastus cochichinensis Lour.	6.6 ± 2.6	3.8 ± 1.7	2 ± 0.4	-
Chasalia assamica Thw.	-	3.2± 1.1	-	-
Cinnamomum bejolghota Buch.Ham.	-	0.2 ± 0.4	1 ± 0.6	-
Cinnamomum sp.	0.6 ± 1.2	-	1.6 ± 1.2	
Clerodendrum infortunatum L.	1.2 ± 0.4	-	-	-
Clinogyne dichotoma Salisb.	-	0.2 ± 0.4	-	-
Coffea genkinsii Hk.	1.4 ± 0.4	0.2 ± 0.4	-	-
Datura stramonium Linn.	2 ± 1	-	-	-
Glycosmis pentaphylla Correa	-	0.4 ± 0.4	0.4 ± 0.8	-
Helicia nilagirica Bedd.	-	0.2 ± 0.4	-	-
Hymenodictyon sp	-	0.2 ± 0.4	0.2 ± 0.4	-
Laportea crenulata Gaud.	3.8 ± 1.4	1.4 ± 1.01	-	-
Litsea elongata Wall.	-	0.6 ± 0.4	0.2 ± 0.4	-
Litsea salicifolia Roxb.	4.6 ± 3	4 ± 2.05	1.2 ± 0.4	-
Lycianthes subtruncata Hassl.	0.4 ± 0.4	0.2 ± 0.4	1 ± 0	-
Ophiorrhiza sp.	-	0.2± 0.4	-	-
Randia dumetorum Benth.	-	0.2 ± 0.4	-	-
Saprosma ternatum Hk.	8.8 ± 2.3	3.2 ± 2.6	0.2 ± 0.4	-
Solanum torvum Swartz	0.2 ± 0.4	-	-	-
Solanum spirale Roxb.	1.8 ± 1.7	0.4 ± 0.4	-	-
Sterculia villosa Roxb.	0.2 ± 0.4	-	-	-
Tetracera sarmentosa (Linn) Vahl	4.4 ± 2.6	-	-	-
Viburnum foetidum Wall.	-	0.4 ± 0.4	-	-
Vitis bracteolata Wall.	-	1.6 ± 1.4	1 ± 0.6	-
Wendlandia sp.	1.4 ± 0.3	2.8 ± 1.2	1 ± 0.6	-

Table III. 6. Density (no. of plants m^{-2}) of herbs and vines in four forest stands experiencing different degrees of disturbance, ± SD values.

Species	Undisturbed stand	Mildly disturbed stand	Moderately disturbed stand	Highly disturbed stand
Borreria articularis Linn.	4.4± 2.5	1.6 ± 0.48	1± 0	-
Buettneria aspera Colebr. ex Wall	1± 0	1.2 ± 0.4	-	1.2 ± 0.4
Cardiospanum halicacabum Linn.	-	2 ± 1.67	1.2 ± 0.4	1.6 ± 0.4
Cerasus jenkinsii Hk.f. & Thoms.	-	0.87 ± 0.5	-	1.6 ± 0.8
Cyanotis cristata Linn.	-	2.4 ± 1.2	-	1 ± 0
Cyathula prostrata Blume.	3.1± 1.2	1.2 ± 0.4	-	-
Cynodon dactylon Pers.	9.4± 2.6	7.8 ± 4.22	2.6 ± 1.62	5.4 ± 3.8
Cyperus rotundus Linn.	4± 2.4	2.2 ± 0.54	-	1 ± 0
Forestia glabrata Linn.	10.6± 2.15	10± 3.78	1.8 ± 0.74	9.4 ± 3.92
Glycosmis sp.	-	0.6 ± 0.48	1.2 ± 0.4	-
Hedyotis scandens Roxb.	-	-	2.6 ± 1.35	-
Hypochaeris radicata Linn.	-	3.4 ± 1.62	-	0.4 ± 0.8
Hyptis sauveolens Poit.	1.2 ± 0.4	1 ± 0.4	-	3.2 ± 1.2
Myxopyrum smilacifolium Bl.	-	0.8± 0.6	1.2 ± 0.4	1.2 ± 0.4
Phrynium sp.	-	-	2.2 ± 0.4	-
Piper sp.	1 ± 0.63	-	7 ± 2.09	-
Pteris sp.	10.2 ± 3.31	4.2 ± 1.57	0.4 ± 0.8	3.4 ± 1.2
Selaginella sp.	3.2 ± 0 .97	-	-	2.4 ± 0.97
Setaria glauca Beauv.	-	-	-	1.2 ± 0.4
Setaria palmifolia Stapf.	1.2 ± 0.7	1.2 ± 0.4	0.8 ± 0.4	-
Tinospora cordifolia Hiers.	-	0.2 ± 0.4	-	1.2 ± 0.82
Trachelopermum lucidum Hk.f	-	-	-	-
Uncaria sessilifructus Roxb.	0.2 ± 0.4	-	-	0.2 ± 0.4

Blastus cochichinensis and *Litsea salicifilia* dominated over other species. No shrub was recorded in the highly disturbed stand due to cultural operations.

Herbs and vines covered the entire ground surface of the forest stands. The undisturbed stand recorded the highest herb and vine density while the lowest density of these plants was recorded in the moderately disturbed stand. Herb and vine species such as *Cyperus rotundus, Forestia glabrata and Pteris quadrissmita were* common to all the stands.

Discussion

The overall structural pattern of the forest community revealed that all the study stands were mainly dominated by *Dipterocarpus macrocarpus, Shorea assamica, Castanopsis indica, Terminalia chebula* and *Vatica lancefolia* with a few exceptions in the highly disturbed stand. Status of regeneration of *Elaeocarpus ganitrus* seems to be very poor in all the stands. All the stands had a highly heterogeneous distribution of trees and can be considered as the highly diverse forests in the Eastern Himalaya (Singh & Singh 1987). The undisturbed stand had a high density of tree species due to restricted access of human being.

The canopy layer is occupied by *Dipterocapus macrocarpus, Shorea assamica, Duabanga grandiflora* and *Terminalia* spp. in all the stands. These dominant species restrict the light availability to the sub-canopy and ground vegetation in the undisturbed and mildly disturbed stands. The presence of seedlings and saplings of these canopy species reveals that they are

regenerating adequately in all the stands in spite of competition from the sub-canopy and herbaceous species. The data on regeneration status of tree species indicate that these species show continuous establishment of seedlings and saplings because of their widespread occurrence in the forest. However, in the moderately disturbed stand the additional microsites created due to man- made interference favour the germination of other opportunist species improving their regeneration (Ohsawa *et al.* 1986). The reduced frequency of such opportunist species can be attributed to the occurrence of sporadic periods of environmental conditions favorable for their regeneration (Wilson 1991). If such periods of opportunity were repeatedly available at different times within the landscape, such species may show good germination and may even become dominant (Loucks 1970, Bormann & Likens1979). However, some species still show poor regeneration due to problems in germination of seeds even though favorable condition prevailed in forest. Sporadic regeneration of Rudraksh may be attributed to such problems.

Tropical forest is rich in species density (Richards 1952, Paijamans 1970) and many factors affect its diversity (Janzen 1970, Connell 1971, Hubbell 1979; Parthasarathy 1999). According to Whitmore (1984) in tropical rain forest, tree species number per hectare ranges from 20 to a maximum of 223. Species diversity is often correlated with rainfall, nutrient status (Hartshorn 1980) and disturbance level (Rao *et al.* 1990). Human-induced disturbance (such as mining, timber extraction etc.) and livestock grazing also

cause changes in species number, tree density and basal area (Rao *et al.* 1990). Unrestricted and open accessibility may cause enhanced utilization of resource and this may eventually lead to a species-poor state (Vetaas 1993, Murali *et al.* 1996).

Role of gaps in the regeneration of forest trees is well recognized. Tree regeneration in the gaps has been shown to be dependent upon the history of forest community, seed availability and biology of the species (Hubbell & Froster 1992). Reduction of basal area in the mildly, moderately and highly disturbed forest stands could be due to extraction of timber, debarking, rotting of boles etc. Physical processes such as hydration and dehydration affect the basal area, stand quality and species. In spite of high disturbance a greater basal area was observed in the highly disturbed forest. This happened due to the retention of over mature, mature, buttressed and bad-form inferior tree species. Further, many broad-leaved tree species are also good coppicers and coppiced shoots have faster growth (Evans 1992) and such shoots are abundant due to the extraction of trees from the highly disturbed forest stand. Species composition is related to stand productivity and decrease in basal area reported due to deteriorating stand quality (Rai 1983). According to Smiet (1992), basal area values could be related to the stand disturbance index. So, in the heavily disturbed forest stand the basal area is lower than the undisturbed and mildly disturbed stands. In the present study the regeneration of Rudraksh was found to be very poor. Though the adult trees were present in all the study stands, the density of saplings and seedlings

was very poor except in the undisturbed and mildly disturbed stands. This could be attributed to the relatively greater disturbance in the other two stands. The undisturbed stand is protected and is not accessible to the wood collectors. Therefore, the seedlings and saplings got the chance to establish and develop. On the other hand, in the mildly disturbed stand the presence of gaps created by human interference facilitated light penetration to the ground. Hence, germination of seeds was facilitated and subsequent development also occurred. Removal of overstory trees might have also favoured germination and seedling establishment through increase in solar radiation on the forest floor and consequent increase in surface temperature and reduced competition from the trees of upper canopy (Koller 1972, Noble & Slatyer 1980, Oliver 1981, Rao *et al.* 1997).

Species composition of forest in the undisturbed stand, mildly disturbed stand and moderately disturbed stand were more or less similar, which may be attributed to the similar topography, soil and climatic conditions of the study sites. However, the highly disturbed stand shows a different species composition especially at lower canopy level, due to *taungya* system of planting. Coffee bushes grew luxuriantly in the sub-canopy layer and no saplings of other species were recorded within the coffee bushes. The canopy layer is covered by *Dipterocarpus macrocarpus, Shorea assamica, Terminalia chebula, Duabanga grandiflora* etc. and regeneration of these species was abundant in the undisturbed, mildly disturbed and moderately disturbed stands. However, regeneration of Rudraksh was seen only in the undisturbed

and mildly disturbed stands wherever the small gaps were created in the canopy and the surface was burnt with low intensity of fire.

All the forest stands except the undisturbed one, were under increasing biotic pressure due to firewood, fodder and timber collection and therefore, regeneration suffered most because most of the tree species produced seeds concurrently with the peak period of collection from the forest. Moreover, seeds of most of the forest timber species were susceptible to pests due to their thin seed coat and were viable only for a limited period (Sundriyal *et al.*1994). The outbreak of a few insect pests has been a major cause of poor regeneration. The proportions of seedlings, saplings and mature trees in a given species population may help in predicting its possible future status in the forest. Species with nearly the equal distribution of individuals in the three life stages are expected to remain dominant in the near future. The population size of such species which lack either seedlings or saplings may decline in coming years. The forest stands characterized by the abundance of only adults of the canopy and sub-canopy species and absence or very low populations of seedlings and saplings are expected to face extinction of some species in due course. The increasing biotic pressure may cause a drastic reduction in regeneration of several tree species. Indiscriminate tree cutting by local people, selective felling by forest department, timber trade, use of enormous amount of wood in house construction and plantation of tea and coffee are the major causes of forest destruction in Arunachal Pradesh and

adjoining areas. These biotic stresses are also not allowing the degraded forests to regenerate properly.

However, Rudraksh and a few associated species show good regeneration in the mildly disturbed forest stand signifying the role of mild disturbance in tree regeneration. Harris & Far (1974) and Boring *et al.* (1981) have also emphasized the positive role of mild disturbance in increasing the regeneration of trees. Khan *et al.* (1987), Barik *et al.* (1996) and Maram & Khan (1998) have also reported better regeneration of tree species in mildly disturbed forests of north-east India.