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Structure and Floristic Composition of Tropical Deciduous Forests Around Bokaro District, Jharkhand, India

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ABSTRACT

The composition and structure of plant community was studied in four one hectare (ha) plots in tropical deciduous forest around Bokaro district, Jharkhand, India. One plot each was established in Jiradih (site-I), Chargi (site-II), Sandoi (site-III) and Chiruvabera (site-IV) based on the prevalence of natural and anthropogenic factors. At each of the four sites, the plot was divided into 100 quadrats, each 10 m x 10 m in size. In each quadrat, the circumference of all the adult individuals [≥30 cm circumference at breast height (CBH, 1.37 m)] was measured with Freeman's tape. Similarly, saplings (individuals 10 to < 30 cm CBH) and established seedlings (individuals < 10 cm CBH but ≥ 30 cm height) were enumerated in each 10 m x 10 m quadrats. We inventoried a total of 38 plant species across sampled area. 23 plant species occurred in all three life stages (adult+sapling+seedling) followed by 7 species in (adult+seedling) stages, 2 species in (adult+sapling) stages, 2 species in (sapling+seedling) stages and 4 species only in adult stage. Significant variations occurred in the population structure across four sites. Total number of adult individuals varied from 290 ha^{-1} (site-I) to 455 ha^{-1} (site-III) with mean value of 368 ha^{-1}. The basal area varied from 5.10 m^2 (site-II) to 39.30 m^2 (site-I) with mean value of 17.60 m^2. Based on basal area site-I, III and IV was dominated by *Shorea robusta,* while site-II was dominated by *Butea monosperma*. The forest soil analysis showed significant variations in the physico-chemical and microbial parameters. This study provides baseline information for monitoring and sustaining plant diversity of tropical deciduous forests in the state of Jharkhand.

Key Words: Population; Dominance; Forest soil; Tropical deciduous forest.

INTRODUCTION

Dynamics of species diversity are a result of historical, ecological and evolutionary factors and these vary spatially and temporally (Barantes and Sandoval 2009). Ecologist are concerned by the effects of biological invasions and species losses resulting from deforestation events, fast rates of land cover changes, and high rates of species introductions (Chapin et al. 2000, D'Antonio and Vitousek 1992, Robinson 1992).

Dry deciduous forests are among the most exploited and endangered ecosystems of the biosphere (Murphy and Lugo 1986, Janzen 1988 and Gentry 1992). The vegetation communities of tropical dry forests have been recognized as comprising some of the most endangered ecosystems in the tropics (Hoekstra et al. 2005). Tropical forests are often referred to as one of the most species diverse terrestrial ecosystems, and generate a variety of natural resources to help sustain the livelihood of local communities (Kumar et al. 2006). Tropical dry deciduous forests are enriched with economically important species (Sagar and Singh 2005).

Champion and Seth (1968) compared various communities associated with sal forests along moisture gradients. Several studies have analyzed community structure in sal forests (Gupta and Shukla 1991, Singh et al. 1995, Pandey 1999, Shankar 2001, Kumari and Tripathi 2007). These studies identified the significance of density-diameter relationships and basal area as indicators of species dominance, stand volume or biomass and regeneration potential, the age of the forest, growth strategies of the dominant species, and anthropogenic disturbances. Species regeneration potential considers population density in three different life phases (seedling, sapling and adult). Regeneration status of tree species is quantified by recruitment potential of seedlings and saplings (Saikia and Khan 2013). Those species which have nearly equal number of representatives at each of the three life stages expected to remain dominant in the near future (Bhuyan et al. 2003). The success of regeneration can be predicted on the basis of current population structure, growth and fecundity (Guedje et al. 2003). Sagar and Singh (2005) assumed that the adult individuals on a site or a species constitute the reproductive pool. Natural constrains like availability of seeds, which are often limited for many tropical species (Wijdeven and Kuzee 2000), and competition among species for space, light and water (Holl et al. 2000) may be the reason of not regenerating.

The present study is based on four, 1-ha plots located at four sites around the Chhotanagpur region of the Bokaro district. In this paper, we tried to understand how structural parameters, species diversity and regeneration pattern change in tropical deciduous forests along the habitat conditions.

STUDY AREA

The study was conducted in the tropical deciduous forests around western part of the Bokaro district, which is a ramification of the Chhotanagpur Plateau. The study area is characterised by vast rolling topography, strewn by graded valleys and winding streams. Geographically, the study area is located between 23º 35’ 87’’ N to 23º 37’ 03’’ N latitude and 85º 48’ 30’’ E to 85º 50’ 42’’ E longitude and was covered with tropical deciduous forest (Figure 1). The regional slope of the district is towards east and controlled the alignment of the tributaries of Damodar River. The study area had two hydrogeological units namely fissured formation and porus formation (CGWB 2009). The average elevation of the undulating pediplain ranges from 200-350 m above MSL. The average rainfall of the district is 1363.57 mm. The maximum rainfall occurs during the monsoon months from mid-June to mid- October. It is characterized by hot and dry summer from March to June and cold winter from November to February. Humidity is high from July to September with mean annual humidity is nearly 60%. Total land cover in the Bokaro district is 2883 km^2 in which forest area cover 23%. The total population of the area is 2,062,330 spread with a density of 715 per km^2 (Census 2011). Sal (*Shorea robusta*) is by far the predominant species of trees in the study area. The soils of Bokaro district can be broadly grouped into the soil developed in different formations like granite or granite gneiss of Archean age, sandstone and shales of Gondwana formation and alluvial plain.

FIELD STUDY

Ecological study was carried out by establishing four one hectare (ha) plots, one each in Jiradih (site-I), Chargi (site-II), Sandoi (site-III) and Chiruvabera (site-IV) in

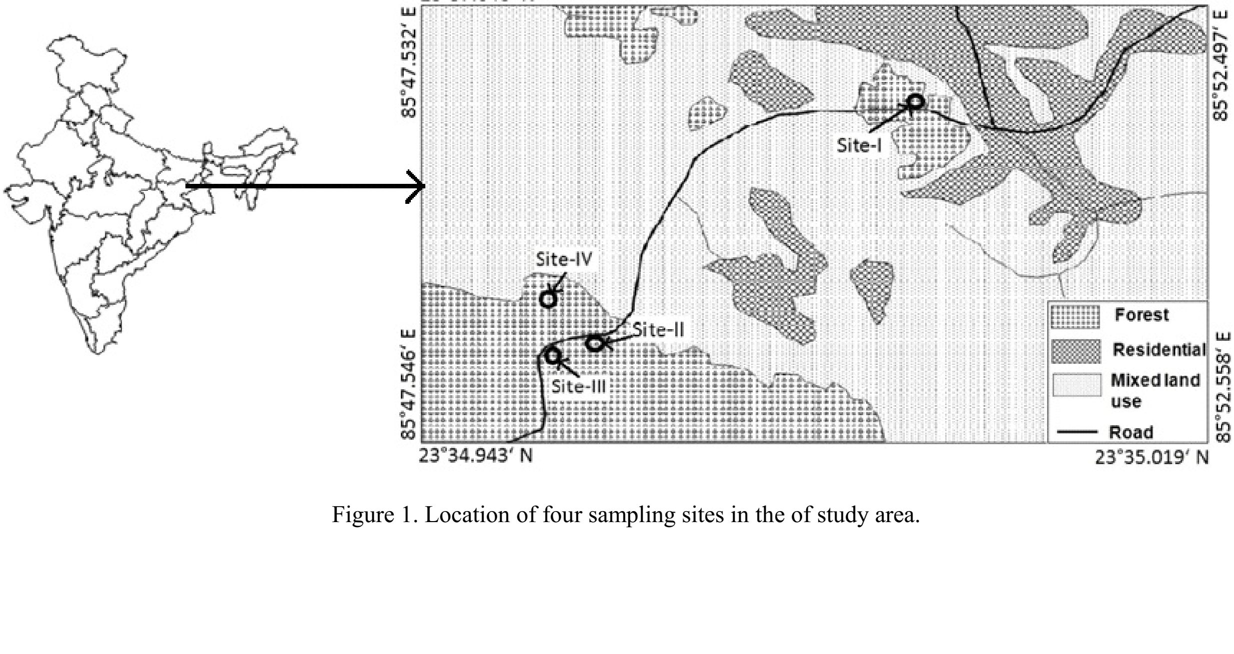

Figure 1. Location of four sampling sites in the of study area.

December 2012 in the tropical deciduous forest around Chhotanagpur plateau of Bokaro district, Jharkhand. Site I is only sal forest and other three sites are mixed forest. Sites II and IV are south facing and site III is north facing. Site I is plain area. Site I is 10 km far from the other three sites; Site II, site III and site IV are 2 km apart from each other. These sites differed in topography and were selected to represent the entire range of conditions in terms of canopy cover and disturbance regimes. Representative photographs of the four sites are given in Figure 2.

At each site, 1-ha plot (100 m x 100 m) was demarcated by nylon rope and each plot was divided into 100 quadrats of 10 m x 10 m in size. In each quadrat, the diameter at breast height (dbh) of all adult trees (≥ 9.6 cm) and saplings (≥ 3.2 to < 9.6 cm) were measured and identified. The inventory of established seedlings was carried out at diameter < 3.2 cm at ≥ 30 cm height (Sagar et al. 2003, Mishra and Anshumali 2014). The circumference of adults and sapling individuals was measured at 1.37 m from the ground and for seedlings it was measured at 10 cm above the ground. For each 10 m x 10 m quadrat, the number of species and stem density were recorded. The dbh was used in the measurement of basal area. Regional floras such as Haines (1921-25) and Mooney (1950) were used for identifying plants.

ECOLOGICAL AND STATISTICAL ANALYSIS

To estimate the population structure of each tree species, the following dbh classes were distinguished, and the number of individuals in each class was enumerated: established <3.2 cm (seedling); <9.6 cm (sapling); ≥9.6 cm (Adult); ≥19.2 cm; ≥28.8 cm; ≥38.4 cm; ≥48 cm; ≥57.6 cm and ≥67.2 cm. Diversity indices were calculated using the following equations:

$$SR = S\text{-}1/\ln(N) \quad (1)$$
$$E_w = S/\ln N_i - \ln N_s \quad (2)$$
$$H' = -\sum pi \ln pi \quad (3)$$

where, SR is the Margalef index (Margalef 1958) of species richness, S the number of species, N the total number of individuals, E_w the Whittaker index of evenness (Whittaker 1972), N_i the number of individuals of most abundant species, N_s the number of individuals of least abundant species, H' the Shannon–Wiener index (Shannon and Weaver 1949), ln the natural log (i.e. base 2.718), pi the proportion of individuals belonging to species *i*.

RESULTS

A total 38 tree species in 33 genera and 21 families were recorded in the four study sites, while two species remain unidentified (Table 1). Combretaceae and Fabaceae with 6 species each dominated the forest canopy, followed by Anacardiaceae (3), Lythraceae, Meliaceae, Moraceae, Myrtaceae and Sapotaceae (2 species each). Density-wise, Dipterocarpaceae (721 trees) and Fabaceae (187 trees) dominated the stand. Genera with a large number of plant species include *Terminalia* (4 species), *Ficus* (2) and *Syzygium* (2).

The forest stands were moderately dense with 1,470 adult stems (> 9.6 cm) in the 4 hectare (mean density 368 stems ha^{-1}). Tree density was greatest (455) in site-III and lowest (290) in site-I. Stand density was almost similar for site-I (290 stems ha^{-1}) and site-II (291 stems ha^{-1}). The stem density (> 9.6 cm) of *Shorea robusta* varied from 72 ha^{-1} to 290 ha^{-1} followed by *Butea monosperma*, *Diospyros melanoxylon*, and *Buchnania lanzan*. The density of seedling (diameter <3.2 cm) varied from 0 to 6147 ha^{-1}; while the sapling density (>3.2 to <9.6 cm) recorded in the range of 0 to 874 ha^{-1}. The *Shorea robusta* was common tree species on all sites, however, the *Bombax ceiba*, *Diospyros melanoxylon* and *Phoenix dactylifera* were common on three sites.

Basal area was lowest (5.1 m^2) in site-II and greatest (39.3 m^2) in site-I. Based on basal area site-I, III and IV was dominated by *Shorea robusta,* while site-II was dominated by *Butea monosperma*. Qualitative assessment showed 23 plant species occurred in all three life stages (adult+sapling+seedling) followed by 7 species in (adult+seedling) stages, 2 species in (adult+ sapling) stages, 2 species in (sapling+seedling) stages and 4 species only in adult stage (Table 1). The values of Shannon-Wiener index (H') varied from 0 to 2.5 with mean value of 2.1 (Table 2).

Table 2. Values of diversity indices in the study area.

Study site	Total No. of species	Total No. individuals	Species richness (SR)	Species Evenness (E_w)	Shannon-Wiener index (H')
Site-1	1	290	0	1	0
Site-2	13	291	2.1	3.6	1.9
Site-3	26	455	4.1	7.3	2.5
Site-4	18	434	2.8	4.1	1.8

Site-I (Jiradih)

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Site-II (Chargi)

Site-III (Sandoi)


Site-IV (Chiruvabera)

Figure 2. Photographs of each site, Site-I, Site-II, Site-III and Site-IV.

Table 1. Density (ha^{-1}) and basal area (m^2ha^{-1}) of tree species in different diameter classes (cm)

Diameter Class	<3.2		3.2-<9.6		≥9.6		>19.2		>28.8		>38.4		>48		>57.6		>67.2		Total	
Species	D	BA	D	BA	D	BA	D	BA	D	BA	D	BA	D	BA	D	BA	D	BA	D	BA
Site 1																				
Shorea robusta Roth.	-	-	-	-	-	-	12	0.6	116	11.1	111	15.7	38	8.1	11	3.1	2	0.7	290	39.3
Site 2																				
Acacia catechu (L. f.) Willd.	111	0.078	53	0.34	29	0.31	-	-	-	-	-	-	-	-	-	-	-	-	193	0.728
Butea monosperma (Lamk) Taubert.	1250	0.88	36	0.23	89	1.4	-	-	-	-	-	-	-	-	-	-	-	-	1375	2.51
Bombax ceiba L.	1	0.001	-		1	0.02	2	0.08	-	-	-	-	-	-	-	-	-	-	4	0.1
Boswellia serrata Roxb. ex Colebr.	29	0.02	3	0.02	10	0.25	-	-	-	-	-	-	-	-	-	-	-	-	42	0.29
Derris indica (Lam.) Benn.	1	0.001			6	0.077	-	-	-	-	-	-	-	-	-	-	-	-	7	0.078
Diospyros melanoxylon Roxb.	189	0.13	24	0.15	44	0.97	-	-	-	-	-	-	-	-	-	-	-	-	257	1.25
Ficus glabra Roxb.	-		-	-	-	-	-	-	3	0.28	-	-	-	-	-	-	-	-	3	0.28
Ficus religiosa L.	1	0.001	-	-	-	-	-	-	2	0.2	-	-	-	-	-	-	-	-	3	0.201
Nyctanthes arbortristis L.	-	-	-	-	9	0.1	-	-	-	-	-	-	-	-	-	-	-	-	9	0.1
Phoenix dactylifera L.	62	0.04	-		4	0.07	-	-	-	-	-	-	-	-	-	-	-	-	66	0.11
Shorea robusta Roth.	1280	0.9	70	0.44	72	1.0	-	-	-	-	-	-	-	-	-	-	-	-	1422	2.34
Soymida febrifuga A. Juss.	17	0.01	-	-	16	0.26	-	-	-	-	-	-	-	-	-	-	-	-	33	0.27
Ziziphus jujube (L.) Lam.	1	0.001	-	-	4	0.07	-	-	-	-	-	-	-	-	-	-	-	-	5	0.071
Total	2942	2.062	186	1.18	284	4.5	2	0.08	5	0.48									**3419**	**8.3**
Site 3																				
Anogeissus latifolia (Roxb. ex DC.) Wall. ex Guill. & Perr.	-	-	1	0.006	1	0.028	5	0.19	-	-	-	-	-	-	-	-	-	-	7	0.224
Anthocephallus kadamba (Roxb.) Miq.	22	0.015	-	-	4	0.16	-	-	-	-	-	-	-	-	-	-	-	-	26	0.175
Azadirachata indica A. Juss.	1	0.001	-		2	0.03	-	-	-	-	-	-	-	-	-	-	-	-	3	0.031
Bombax ceiba L.	4	0.002	2	0.013	3	0.11	-	-	-	-	-	-	-	-	-	-	-	-	9	0.125
Buchnania lanzan Spreng.	117	0.08	14	0.089	35	0.35	-	-	-	-	-	-	-	-	-	-	-	-	166	0.519
Cassia fistula L.	-		2	0.013	18	0.18	-	-	-	-	-	-	-	-	-	-	-	-	20	0.193
Dalbergia sissoo Miq.	-		-		1	0.02	2	0.07	-	-	-	-	-	-	-	-	-	-	3	0.09
Diospyros melanoxylon Roxb.	110	0.078	52	0.33	33	0.588	15	0.63	-	-	-	-	-	-	-	-	-	-	210	1.626
Flacourtia indica (Burm. f.) Merr.	-		-	-	3	0.05	-	-	-	-	-	-	-	-	-	-	-	-	3	0.05
Grewia serrulata Baill.	-		10	0.06	2	0.02	-	-	-	-	-	-	-	-	-	-	-	-	12	0.08
Lagerstroemia parviflora Roxb.	93	0.066	65	0.41	76	0.79	-	-	-	-	-	-	-	-	-	-	-	-	234	1.266

Table 1 (continued)

Diameter Class	<3.2		3.2-<9.6		≥9.6		>19.2		>28.8		>38.4		>48		>57.6		>67.2		Total	
Species	D	BA	D	BA	D	BA	D	BA	D	BA	D	BA	D	BA	D	BA	D	BA	D	BA
Lannea coromandelica (Houtt.) Merr.	-	-	4	0.025	21	0.32	-	-	-	-	-	-	-	-	-	-	-	-	25	0.345
Madhuca indica J. F. Gmel.	19	0.013	4	0.025	16	0.37	9	0.35	1	0.07	-	-	-	-	-	-	-	-	49	0.825
Manilkara hexandra (Roxb.) Dubard.	58	0.04	38	0.24	14	0.15	-	-	-	-	-	-	-	-	-	-	-	-	110	0.43
Miliusa tomentosa (Roxb.) J.Sincl.	2	0.0014	-	-	7	0.15	-	-	-	-	-	-	-	-	-	-	-	-	9	0.151
Moringa oleifera Lam.	-		-	-	3	0.05	-	-	-	-	-	-	-	-	-	-	-	-	3	0.05
Nyctanthes arbortristis L.	4	0.0028	1	0.006	6	0.06	-	-	-	-	-	-	-	-	-	-	-	-	11	0.069
Phoenix dactylifera L.	40	0.028	1	0.006	2	0.035	-	-	-	-	-	-	-	-	-	-	-	-	43	0.069
Pterocarpus marsupium Roxb.	1	0.001	-	--	2	0.05	2	0.08	-	-	-	-	-	-	-	-	-	-	5	0.131
Semecarpus anacardium Linn.	1	0.001	1	0.006	8	0.088	-	-	-	-	-	-	-	-	-	-	-	-	10	0.095
Shorea robusta Roth.	2205	1.558	49	0.31	47	1.13	64	2.43	4	0.37	3	0.45	1	0.18	-	-	-	-	2373	6.428
Syzygium heyneanum (Duthie) Wall.	33	0.023	2	0.013	14	0.22	-	-	-	-	-	-	-	-	-	-	-	-	49	0.256
Terminalia arjuna (Roxb.) Wit & Arn.	19	0.013	2	0.013	16	0.38	1	0.04	-	-	-	-	-	-	-	-	-	-	38	0.446
Terminalia bellirica (Gaertner) Roxb.	21	0.015	3	0.019	1	0.01	-	-	-	-	-	-	-	-	-	-	-	-	25	0.044
Terminalia chebula Retz.	-		-		2	0.019	-	-	-	-	-	-	-	-	-	-	-	-	2	0.019
Terminalia tomentosa W. & A.	-		1	0.006	6	0.15	5	0.16	-	-	-	-	-	-	-	-	-	-	12	0.316
Total	2750	1.94	252	1.6	343	5.508	103	3.95	5	0.44	3	0.45	1	0.18					**3457**	**14.06**
Site 4																				
Acacia catechu (L. f.) Willd.	52	0.018	3	0.005	8	0.087	-	-	-	-	-	-	-	-	-	-	-	-	63	0.11
Anogeissus latifolia (Roxb. ex DC.) Wall. ex Guill. & Perr.	34	0.01	14	0.038	-		4	0.17	-	-	-	-	-	-	-	-	-	-	52	0.218
Butea monosperma (Lamk) Taubert.	241	0.07	116	0.26	27	0.38	-	-	-	-	-	-	-	-	-	-	-	-	384	0.78
Bombax ceiba L.	1	0.0002	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	1	0.0002
Boswellia serrata Roxb. ex Colebr.	28	0.01	13	0.026	7	0.18	-	-	-	-	-	-	-	-	-	-	-	-	48	0.216
Buchnania lanzan Spreng.	194	0.06	14	0.046	18	0.31	-	-	-	-	-	-	-	-	-	-	-	-	226	0.416
Cassia fistula L.	4	0.002	18	0.06	3	0.028	-	-	-	-	-	-	-	-	-	-	-	-	25	0.09
Diospyros melanoxylon Roxb.	1183	0.76	229	0.47	10	0.24	2	0.07	-	-	-	-	-	-	-	-	-	-	1424	1.54
Lagerstroemia parviflora Roxb.	412	0.29	2	0.002	38	(0.39	-	-	-	-	-	-	-	-	-	-	-	-	452	0.682
Manilkara hexandra (Roxb.) Dubard.	228	0.15	25	0.07	5	0.47	-	-	-	-	-	-	-	-	-	-	-	-	258	0.69
Moringa oleifera Lam.	10	0.003	19	0.3	12	0.2	-	-	1	0.08	-	-	-	-	-	-	-	-	42	0.583
Phoenix dactylifera L.	146	0.017	15	0.02	4	0.096	1	0.03	-	-	-	-	-	-	-	-	-	-	166	0.156
Semecarpus anacardium Linn.	12	0.005	12	0.029	4	0.06	2	0.06	-	-	-	-	-	-	-	-	-	-	30	0.154
Shorea robusta Roth.	3430	2.26	305	1.58	117	2.35	87	3.2	8	0.7	12	1.84	11	2.45	5	1.5	-	-	3975	15.84
Soymida febrifuga A. Juss.	10	0.003	30	0.05	17	0.2	-	-	-	-	-	-	-	-	-	-	-	-	57	0.253
Syzygium cumini (L.) Skeels.	25	0.007	12	0.03	3	0.068	-	-	-	-	-	-	-	-	-	-	-	-	40	0.105
Terminalia arjuna (Roxb.) Wt & Arn.	120	0.03	35	0.06	21	0.28	-	-	-	-	-	-	-	-	-	-	-	-	176	0.37
Terminalia tomentosa W. & A.	12	0.003	-		-	-	5	0.2	-	-	-	-	-	-	-	-	-	-	17	0.203
Woodfordia fruticosa (L.) Kurz.	3	0.001	9	0.017	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	0.018
A*	1	0.0002	1	0.005	1	0.027	1	0.05	-	-	-	-	-	-	-	-	-	-	4	0.082
B*	1	0.0001	2	0.004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0.004
Total	6147	3.69	874	3.072	295	5.366	102	3.78	9	0.78	12	1.84	11	2.45	5	1.5			**7455**	**22.5**

Note: D, Density (ha^{-1}) and BA, Basal area ($m^2 ha^{-1}$). *A, B= Unidentified species.

DISCUSSION

Forest Structure and Density-Diameter Relationships

The site-I showed occurrence of only one species (*Shorea robusta*) without seedling and sapling. The site-II was characterized by rocky forest floor with south facing slope. This may be reason for poor species richness (13) at site-II. Maximum number of species was recorded at site-III (26) that might be due to presence of significant moisture in the microclimate of north facing slope and perennial tributary of Damodar river i.e. Mapahi Nala. The abundance of *Terminalia arjuna* and *Syzygium heyneanum* riparian zone species in site-III can be attributed to the location along the bank of Mapahi Nala. The site-IV had 18 tree species, which distributed over north and south facing slopes, especially the greater number of species and their individuals were recorded on north facing than south facing slope. The distinct species composition at four sites shows spatial variation in site representativeness, site attributes, and the extent of human interaction in the past and present. In fact, in the

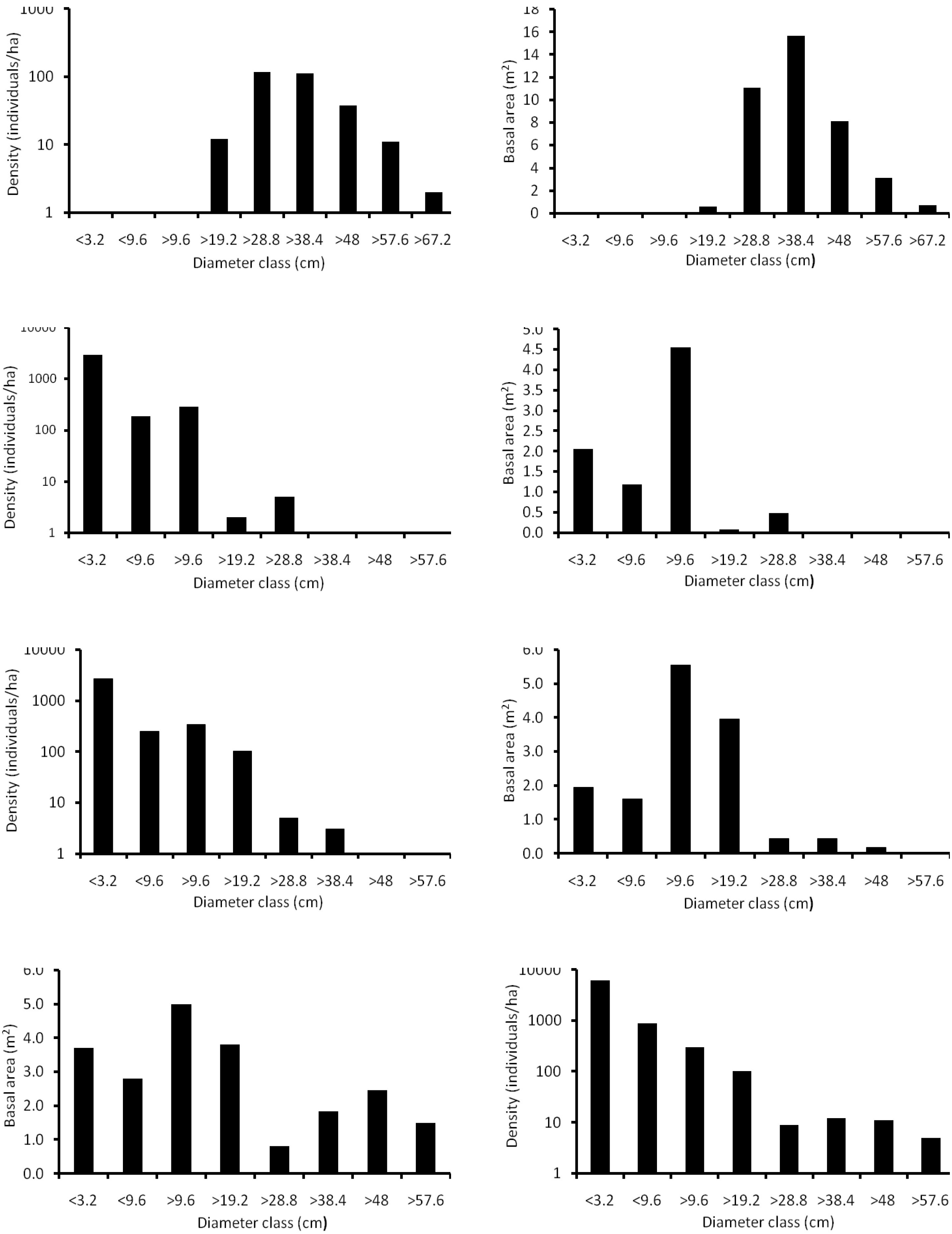

Figure 3. Population structure of tree species based on density-diameter and basal area in the study region.

tropical forests, natural vegetation often responds to several gradients simultaneously and different combinations of gradients produce divergent responses to the set of gradients (Davidar et al. 2007, Rydgren et al. 2003, Sarkar et al. 2013, Sarkar et al. 2014). Consequently, the study region is showing different level of species composition in the tropical dry forests.

A total of 1470 stems were recorded in the 4 ha area with a mean value of 368 stems ha^{-1}; on hectare basis this number ranged from 290 to 455 ha^{-1}. The stand density of site-I of top canopy species at first increases with the increase in diameter class from >19.2 to >28.8 cm and then deceased with the increase in diameter class (Figure 3). However, the diameter-density relationship showed reverse J-shaped pattern in site-II, site-III and site-IV i.e. the density decreased with the increase in diameter class. The diameter-densities of dominant tree species exhibited a reverse J-shaped pattern indicating an expanding or evolving population (Joshi and Ghose 2014, Parthasarthy 2001) and forest sites were well stratified along with seedling and sapling. The *Shorea robusta*, *Butea monosperma* and *Diospyros melanoxylon* were generally dominated plant species. The high tree density in lower girth classes could be attributed to lack of grazing, illegal cutting, forest fire etc. This leads to greater chance of young adult to produce offspring for the stability of the forest ecosystem. This indicates species have stable population with more number of individuals in the lower girth classes (Ramachandran et al. 2014). Population of top canopy species decreased with the increase in girth class, indicates open nature of forest sites. This facilitates chances of seedlings and saplings to grow and experience seasonal variations in biotic and abiotic factors, a unique feature of dry deciduous habitats.

The basal area distribution in various diameter classes varied from site to site (Figure 3). The basal area decreases with increasing diameter classes. The high value of basal area was found in > 9.6 cm diameter class. The basal area of trees ranged from 8.3 $m^2 ha^{-1}$ to 39.3 $m^2 ha^{-1}$, which is comparable with riverine forest and sal mixed forest around Katerniaghat Wildlife Sanctuary in Terai region of North India. A mean basal area of 21.04 $m^2 ha^{-1}$ recorded in the study is almost equal to the Puerto Rico dry forests which measured 21 $m^2 ha^{-1}$ (Murphy and Lugo 1986) and greater than that of Bhadra Wildlife Sanctuary (Krishnamurthy et al. 2010) and St. Lucia (Gonzalez and Zak 1996) which measured 18.2 $m^2 ha^{-1}$ and 15 $m^2 ha^{-1}$, respectively. The communities with short trees with small diameters and low basal areas had very high density; while the density of large sized trees in some other communities was low. This variability may be due to different growth rates of the tree species or different ages of the communities (Joshi and Ghose 2014).

Species Diversity

Species richness (SR) was not uniformly distributed in the forest sites; all the four sites were mosaic of low and high diversity patches. The SR depends upon number of species and number of their individuals. The greater species richness (SR) was found on site-III as a result of large number of species and less number of their individuals. The evenness is exceptionally high in site-III because the number of adult individuals of most abundant species is extremely greater than the adult individuals of least abundant species i.e. the value of (ln *Ni* –ln *Ns*) is very high. The α-diversity was found maximum at site-III (2.5) due to large number of species had greater number of individuals/ha, as a result, the proportion of individuals belonging to species i (p_i) become high at that site. This appears to be the result of the combined effect of stable environmental conditions and gap phase dynamics within the forest (Whittaker 1972) and also depends on climatic, edaphic and biotic factors (Ayyappan and Parthasarathy 1999). The degree of natural disturbance has often been cited as a critical factor in determining tropical forest species diversity (Connell 1978, Pickett and White 1985).

Regeneration

The population structures, characterized by the presence of sufficient seedlings, saplings and adults indicate a successful regeneration of forest species. In this study, 6.3 to 14.2 % seedlings become saplings and 7 to 20 % seedlings successfully progressed as adults. Sagar and Singh (2005) reported 5 to 33 % seedlings become saplings and 0.5 to 14% seedlings become adult populations in the Vindhyan forests. This comparative assessment shows that the Vindhyan forests are more disturbed than dry deciduous forests of Chhotanagpur plateau in Bokaro district.

The number of individuals at the seedling, sapling and adult (≥9.6 cm dbh) stages occurring on different sites were related with each other. These relationships were explored also across species, by pooling the data for four sites (4-ha area). Species which did not have individuals at any one of the stages were excluded from these analyses. The significant statistical relationship attained between seedling and sapling across sites indicates prevalence of normal conditions for the success of seedling conversion to sapling in three sites (Figure

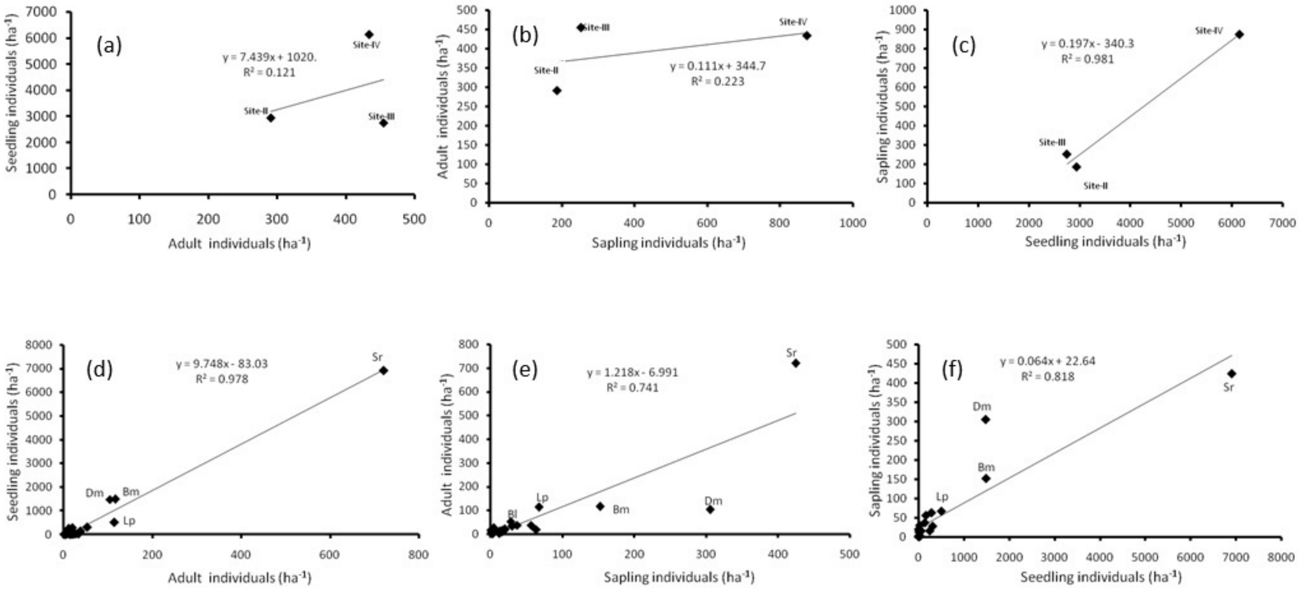

Figure 4. Relationship between life cycle stages across sites (a,b,c) and across species (d,e,f) in the study area.

4). The seedling versus adult, and sapling versus adult did not attained significant relationship across sites. Apparently, on sites-II, the conversion of seedlings to saplings/adults is less than site-III and site-IV.

On the species basis, pooling of data for all the four sites, the study indicated that the relationship between the number of seedling and adult individuals, number of saplings and adult individuals, and number of seedlings and saplings individuals of twenty three tree species were significant (Figure 4). Although some species showed poor sapling and adult populations compared to *Shorea robusta*, *Butea monosperma, Diospyros melanoxylon and Lagerstroemia parviflora*. The qualitative assessment of the study area reveals considerable mortality of seedlings and saplings across all species. As a result fifteen tree species (40 %) were excluded from the regeneration analysis. Such species under 'not regenerating' condition might have been occurred due to existing disturbance in the study sites like, grazing, firewood collection, and poor biotic potential of tree species which either affect the fruiting and seed germination or successful conversion of seedling to sapling stage. This marked spatio-temporal dynamics and demographic instability both at site and species levels indicate that fragmentation will likely to enhance the loss of species diversity (Sagar and Singh 2005). Thus, the study infers that both the habitat conditions and the life cycle stages of species strongly affect regeneration.

CONCLUSIONS

We provide new and useful information on the forest structure, basal area, and regeneration potential of tree species in the dry deciduous forests of Chhotanagpur plateau. This study has found spatial variations in species diversity at species, genus and family levels in prevailing conditions of habitats that seem conducive to sustain a mixed sal forests. In the study area, 40 % tree species were 'not regenerating' condition. This shows that the tropical deciduous forests are facing immense tree cutting, hydrological alterations, and land use change. The information generated from this study will serve as a base line and array of attributes for further research on conservation of tropical deciduous forests in the arid and semi-arid regions of the Indian subcontinent.

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