ISSN (Online): 2349-1183; ISSN (Print): 2349-9265
TROPICAL PLANT RESEARCH
The Journal of the Society for Tropical Plant Research

5(3): 267–274, 2018
DOI: 10.22271/tpr.2018.v5.i3.034

Research article

Population structure and regeneration potential of Sal dominated tropical dry deciduous forest in Chhattisgarh, India

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Abstract: Several biotic and abiotic factors including poor regeneration, changing environment and edaphic factor along with poor regeneration affects health and establishment of *Shorea robusta* nowadays. No systematic attempts were made to understand the dynamism of its natural regeneration and to suggest management inputs to encourage its regeneration. The present study deals with the regeneration status and population structure of four sites of Sal dominating tropical dry deciduous forest during 2016–18. Regeneration status of the forest was determined based on population size of seedlings and saplings. A total of 24 species of 19 families were encountered. Regeneration status in all the study sites is dissimilar. In the entire four sites, site quality I was good regenerating because of the high density of seedlings and saplings in forest site. The results indicated that the average number of regeneration of Sal seedlings per hectare worked out to be 2562 ha^{-1}, which are quite adequate. It was also observed that *Shorea robusta* showed uninterrupted type of distribution pattern along with abundant regeneration in the forest stand which showed healthy sign of establishment and growth of this species in the past. Other associates showed different growth patterns. Efforts are needed to conserve the forest for their diversity and existence.
Keywords: Population structure - Regeneration - Dry deciduous forest - *Shorea robusta*.

[Cite as: Raj A (2018) Population structure and regeneration potential of Sal dominated tropical dry deciduous forest in Chhattisgarh, India. *Tropical Plant Research* 5(3): 267–274]

INTRODUCTION

Tropical forests are one of the richest and complex terrestrial ecosystems supporting a variety of life forms and have a tremendous intrinsic ability for self-maintenance. The growth of forest trees is often observed to vary with changes in the soil profile. This diversity of soil and climate where forests grow determines different site qualities, where the most productive sites combine the best weather conditions, topography and soil characteristics (Skovsgaard & Vanklay 2008). This implies differences in structure and composition of vegetation, its regeneration potential and population structure of vegetation. Sal is deciduous, light demanding, gregarious and dominant tree species in its stand (Champion & Osmaston 1962, Troup 1986) comes under Dipterocarpaceae family, mainly distributed in the Northern, central and eastern region of Indian subcontinents. Sal forests extend into the tropical and subtropical regions, and to the zones where precipitation ranges from 1000 to 2000 mm and above, and the dry period does not exceed 4 months (Tewari 1995, Chaudhary *et al.* 2016). Sal forest is relatively rich in ground flora diversity. Besides tree and shrub, ground flora of Sal forest included fern, herb, grass and liana. Environmental conditions such as light, temperature, soil quality, moisture availability and drainage system affect the regeneration of Sal forest and tend into various form of even-aged, relatively pure and mixed type of vegetation (Troup 1986, Rautiainen & Suoheimo 1997, Mishra *et al.* 2013). However, there are very few attempts have been made in the context of studying and understanding the dynamic nature of natural regeneration of Sal forest and required suggestions and input for encouraging its regeneration in India. The objective of the present study was to assess the regeneration status, population structure and rarity or commonness of the species of Sal dominating forest at different sites in the tropical dry deciduous forest in Chhattisgarh.

Received: 05 July 2018 Published online: 31 October 2018
https://doi.org/10.22271/tpr.2018.v5.i3.034

MATERIAL AND METHODS

In order to assess the status of Sal regeneration and population structure of standing crop, total four contiguous sites were selected along the gradient of site quality *i.e.* edaphic quality in large tract of the Sal based mixed, dry deciduous forest located in the Dugli forest range of Dhamtari forest division (23° 21′ N and 82.85° E with an average elevation of 527 m) situated in Dhamtari district (Chhattisgarh). In each of these sites, one 100 × 100 m (1 ha.) plot, visually representative of the overall vegetation, was delineated for detailed study. The forest stand on each site was analyzed using ten randomly placed quadrats (each 10 × 10 m in size) within the representative plot of 1 ha. Girth at breast height (GBH) of each individual tree in each quadrat was measured and recorded. To show the regeneration pattern of tree species, the population structures were developed based on different tree girth classes in addition to seedlings and saplings. The total number of individuals belonging to these girth classes was calculated for each species on each site following Saxena & Singh (1984). In addition to seedling (A) and sapling (B) classes, three more size classes based on girth at breast height (GBH) *i.e.*, C) 30.1–60.0 cm; 60.1–90.0 cm; D) and E) >90 were arbitrarily established for each tree species. The total number of individuals belonging to above girth classes was computed for each species. This database is further used to determine the trend of establishment and growth of each species. The number of individuals in each girth class, for each species, was divided by the total number of individuals in all girth classes of that species. The resultant value was further multiplied by 100 to yield percent density for each girth class for different species.

The regeneration status of species was determined according to Shankar (2001) which is based on population size of seedling and sapling. The status of sampled species was assessed based on one time phytosociological data in the following categories. (a) good, if seedlings > saplings > adult; (b) fair, if seedlings > saplings ≤ adults; (c) poor, if a species survives in only sapling stage, but not as seedlings (though saplings may be less, more or equal to adults); (d) none, if a species is absent both in sapling and seedling stages, but present in adults; and (e) new, if a species has no adults, but only saplings and/or seedlings.

Raunkiaer's (1934) frequency class analysis was used to assess the rarity or commonness of the tree species (Hewit & Kellman 2002). In this classification, the percentage frequency of the species was classified as A, B, C, D, and E, where A represents rare (0–20%), B represents low frequency (20–40%), C represents intermediate frequency (40–60%), D represents moderately high frequency (60–80%), and E represents high frequency or common (80–100%).

RESULTS

Population Structure

Sal represented uninterrupted type of regeneration from saplings to mature stage of the entire growth phase. This is the good indication of formation and development of Sal. In the site I, *Shorea robusta* Gaertn. showed all the size classes of population structure (Fig. 1). The proportion of seedling size class (A) was dominant except the species like *Buchanania cochinchinensis* (Lour.) M.R.Almeida, *Desmodium oojeinense* (Roxb.) H.Ohashi, *Mitragyna parvifolia* (Roxb.) Korth. and *Terminalia chebula* Retz. The size class (A) was dominated by *Shorea robusta*, *Cleistanthus collinus* (Roxb.) Benth. ex Hook.f., *Phyllanthus emblica* L., *Terminalia tomentosa* Wight & Arn. and *Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guillem. & Perr., respectively with the contribution of more than half (60–90%) proportion in this class. The sapling size class (B) proportion of *Cleistanthus collinus* was higher. In size class C and D the highest proportion were represented by *Shorea robusta*, *Terminalia tomentosa* and *Anogeissus latifolia*. The older tree size class (E) is represented *Shorea robusta* as the highest contributors butnegligible or nil for *Terminalia tomentosa* and *Schleichera oleosa* (Lour.) Merr. The proportion of seedling size class (A) to a higher class (D) decreased gradually (*e.g.*, *Shorea robusta*, *Cleistanthus collinus*, *Schleichera oleosa*, *Anogeissus latifolia* etc). The population structure of site II (Fig. 2) indicated that seedling size class (A) was higher in which was mostly contributed by *Shorea robusta*, *Anogeissus latifolia* and *Phyllanthus emblica* of the total population. The sapling size class (B) was represented by *Phyllanthus emblica* and *Schleichera oleosa*. The young tree size class (C) was found almost for all the species on this site except for *Cleistanthus collinus*. The older tree size class (D) and (E) were negligible or nil in case of most of the species. The size class (E) was represented only by *Shorea robusta*, *Terminalia tomentosa* and *Schleichera oleosa*. In this zone *Shorea robusta* represented by all the size classes, whereas *Cleistanthus collinus* representing all size class except class (E). *Phyllanthus emblica* and *Shorea robusta* were reported maximum contribution in the seedling size class (A). The size class (C) and (D) were reported for all major species which is dominating class over the (E) whereas *Cleistanthus collinus*, *Phyllanthus emblica* and *Schleichera oleosa* were absent in older size class (E) (Fig. 3). In the site IV *Shorea robusta* showed all the size classes of population structure.

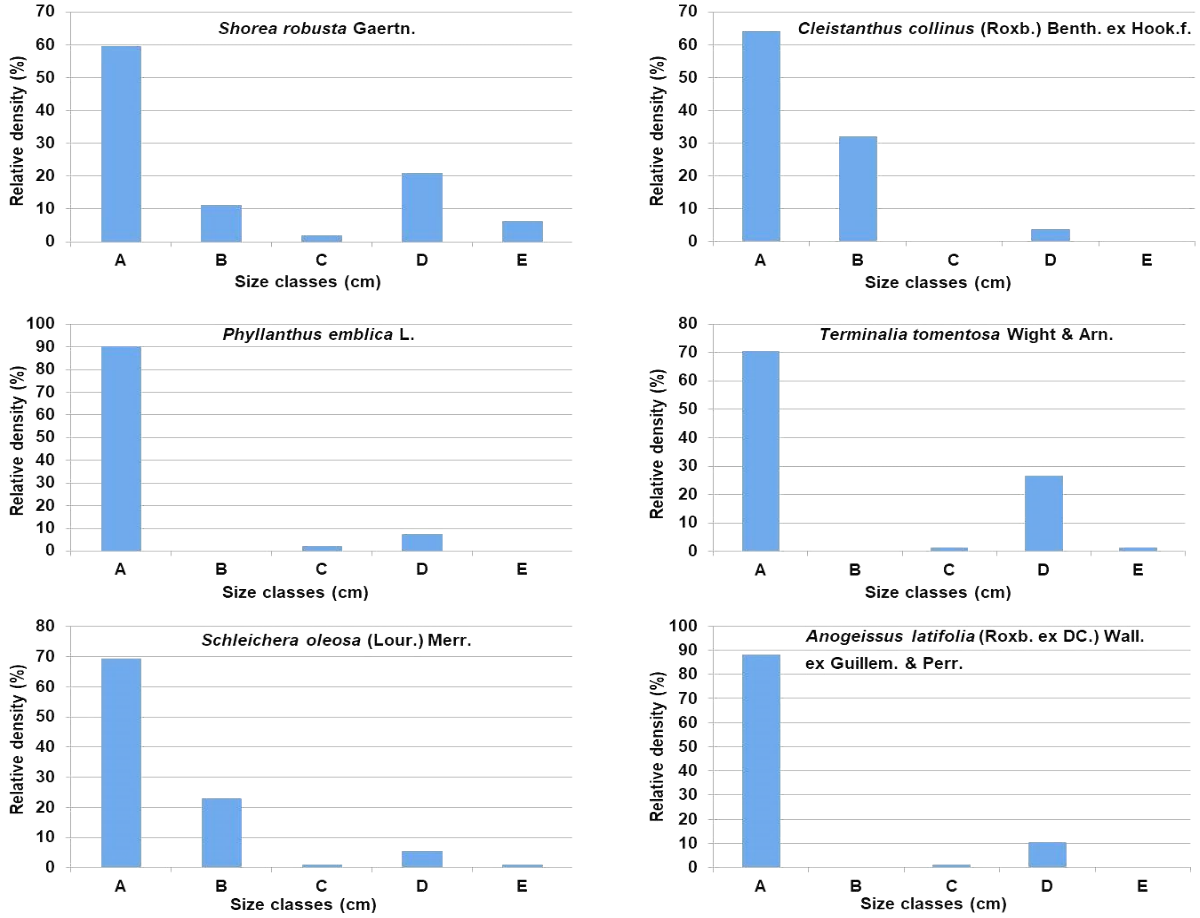

Figure 1. Population structures of major tree species of site quality I.

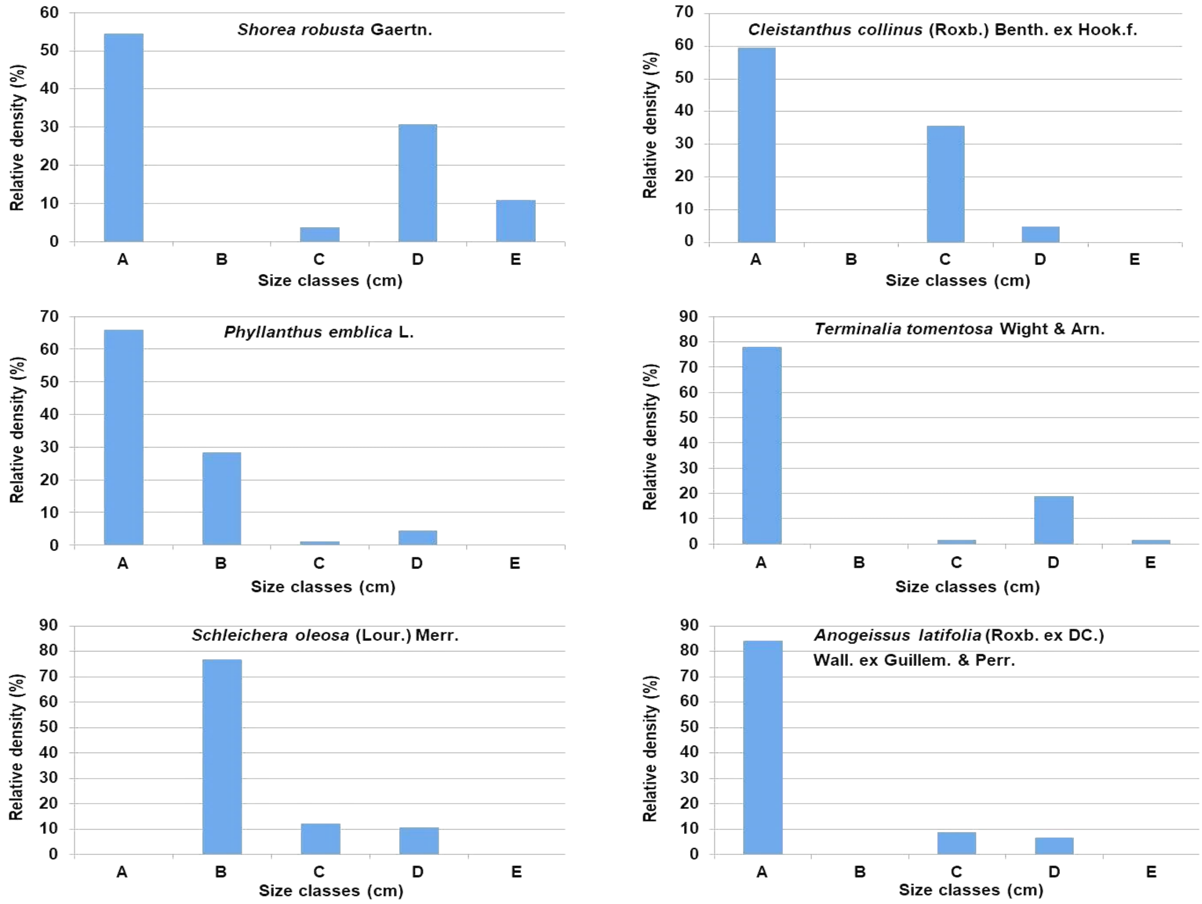

Figure 2. Population structures of major tree species of site quality II.

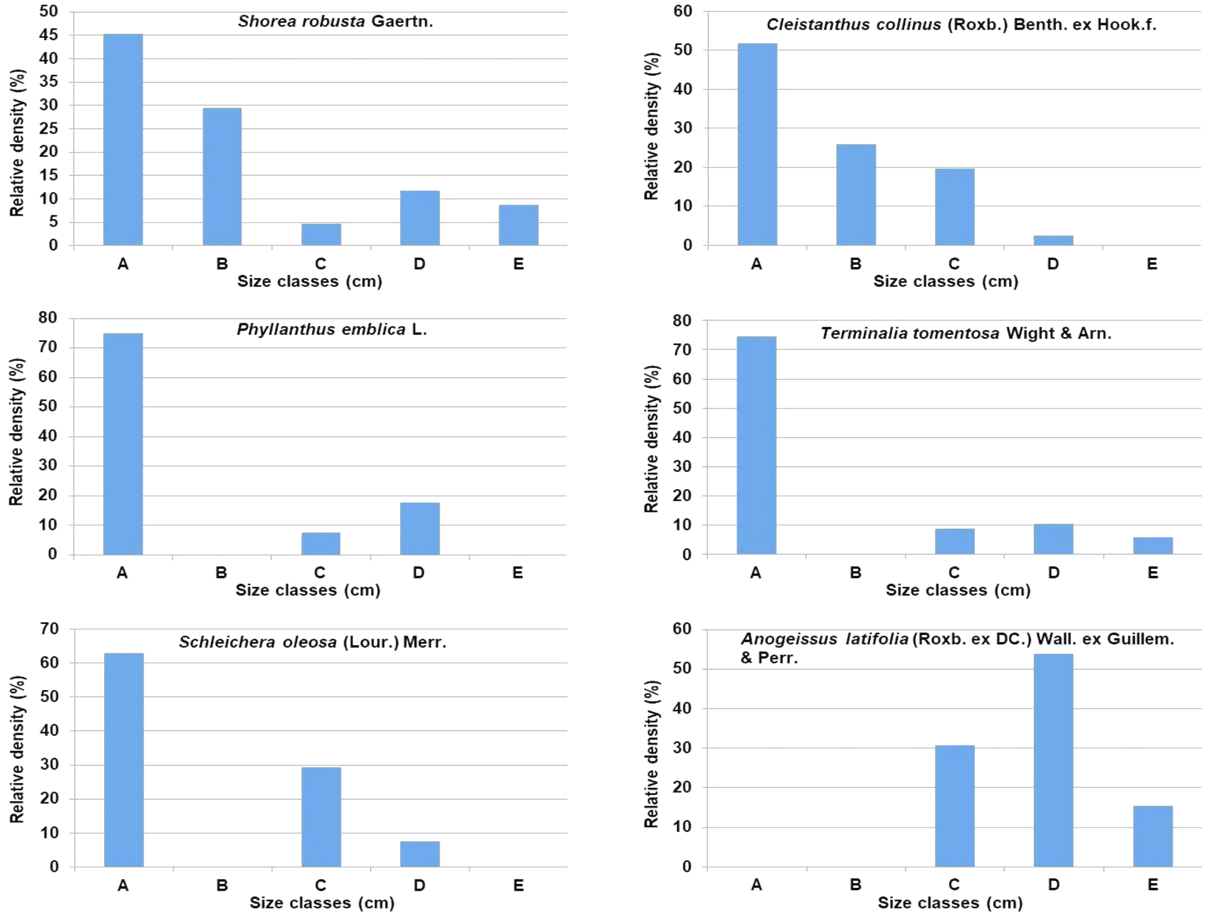

Figure 3. Population structures of major tree species of site quality III.

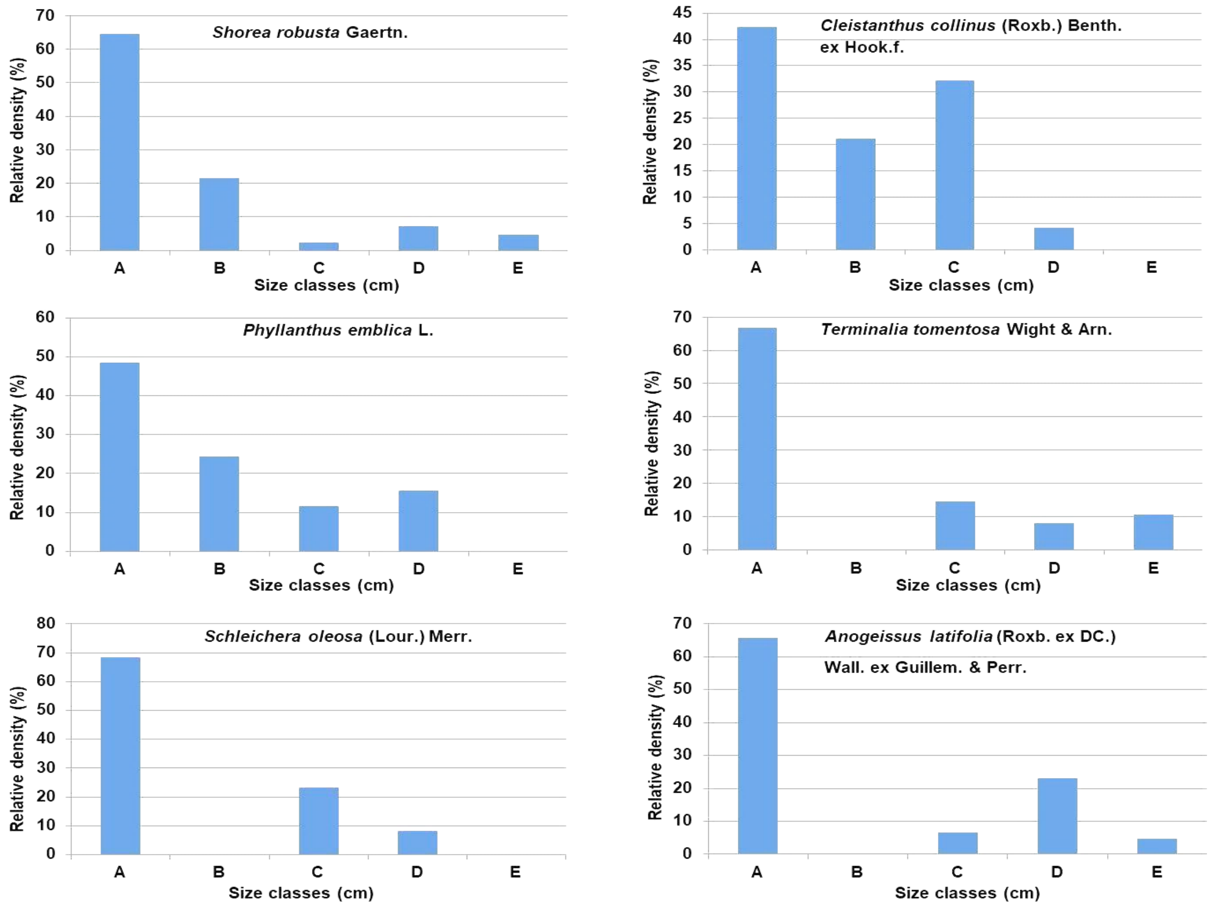

Figure 4. Population structures of major tree species of site quality IV.

Cleistanthus collinus and *Phyllanthus emblica* were represented by all classes except older class (E). Almost all the species were represented by seedling size class (A). Size class (B) was dominated by *Shorea robusta*, *Cleistanthus collinus*, *Phyllanthus emblica* but absent for *Terminalia bellirica* (Gaertn.) Roxb., *Schleichera oleosa* and *Anogeissus latifolia*. Moreover, size class (B) and (C) were dominated by *Cleistanthus collinus*. Most of the recorded species were not represented by the older size class *i.e.*, (E). The older tree size class (E) was represented by *Terminalia bellirica* but absent for *Cleistanthus collinus*, *Phyllanthus emblica* and *Schleichera oleosa* (Fig. 4). The interpretation of population structure of tree species was based on the assumption that size class corresponds with the age of individuals. Though the size class distribution often differs from the age class distribution, the former in case analyzed properly can also be useful for interpretation of patterns of population changes.

Regeneration status

The renewal of the tree crop by natural means in the form of the crop is the indication of the health of site, recruitment and establishment of regenerating plants of tree species. In the study site I out of 17 species, three species, *viz*. *Shorea robusta*, *Diospyros melanoxylon* Roxb. and *Schleichera oleosa* showed good regeneration as all these species having a good number of seedlings and saplings and seven species showed not abundant and poor regeneration. In study site II, out of 17 tree species, only one species *i.e. Phyllanthus emblica* showed good regeneration and one species (*Diospyros melanoxylon*) showed fair and 7 species recorded poor regeneration *viz.*, *Anogeissus latifolia*, *Cleistanthus collinus*, *Madhuca longifolia* var. *latifolia* (Roxb.) A.Chev., *Desmodium oojeinense*, *Terminalia chebula* and *Terminalia tomentosa* while seven species were not abundant (Table 1). One species, *viz. Mitragyna parvifolia* was not regenerating. In study site III, out of 16 species, only two species *viz.*, *Shorea robusta* and *Cleistanthus collinus* showed good regeneration and 8 species showed poor regeneration *viz. Buchanania cochinchinensis*, *Diospyros melanoxylon*, *Phyllanthus emblica*, *Madhuca longifolia* var. *latifolia*, *Desmodium oojeinense*, *Schleichera oleosa*, *Semecarpus anacardium* L.f. and *Terminalia chebula,* respectively. Six species (*Butea monosperma* (Lam.) Taub., *Catunaregam spinosa* (Thunb.) Tirveng., *Lannea coromendelica, Syzigiumcumini, Tectona grandis* L.f. and *Terminalia tomentosa*) on this site exhibited not abundant (Table 1). In study site IV out of 15 species, only one species *viz*. *Shorea robusta* showed good and 6 species showed poor regeneration *viz*. *Anogeissus latifolia, Butea monosperma, Schleichera oleosa, Tectona grandis, Terminalia chebula* and *Terminalia tomentosa*respectively.Six species *viz*., *Catunaregam spinosa, Diospyros melanoxylon, Lannea coromendelica, Madhuca longifolia var. latifolia, Semecarpus anacardium* and *Firmiana simplex* (L.) W.Wight on this site exhibited not abundant (Table 1).

Raunkiaer's frequency classes

In most of the plant life forms, there was a high number of species that occurred singly. The distribution of sapling species into Raunkiaer's frequency classes reflected that most of the species were of rare category and of low-frequency class; intermediate with moderately high and high or common frequency classes were totally absent in the study area while high-frequency class was represented in all sites of tree layers only (Table 2).

DISCUSSIONS

In all the different site qualities studied showed individuals with small girth class A (<10 cm) were high. In the seedling layer, *Shorea robusta* was the dominant species among the qualities of the entire site except site III. This species was successfully reached as a dominant species in the sapling and the tree layer due to less mortality and high density that showed Sal based mixed forest. Therefore, Species with a nearly equal distribution of individuals in the three life stages are expected to remain dominant in the near future. The Sal showed adequate regeneration with uninterrupted growth pattern in most of the stands studied, indicating a healthy sign of establishment and growth of Sal crop in the past. Thus, the growth phase of Sal showed an uninterrupted trend of regeneration from saplings to mature stage. This indicates the establishment and development of Sal in the study site. The population structure of certain species is characterized by gap phase type regeneration (interrupted). Interrupted regeneration of species may indicate that one or more climatic and/or bio-edaphic factors inhibited the regeneration completely for certain periods of time, and with the return of favorable conditions, the species was able to regenerate again. Other species comprises *Ixora parviflora* Lam. and *Gardenia latifolia* Ait. were unable to reach in the sapling and tree stages. This is because the grazing by domestic animals and cattle's due to good fodder quality of *Gardenia* species. Another cause is seedlings are not comings up frequently the species might have produced the seeds but, the environment is not supporting their proper establishment. Due to this heavy stress, the species could not reach in the tree or sapling layer. Therefore, the rising anthropological pressure of human and cattle in these forests has become a serious problem for their

Table 1. Floristic composition and regeneration status on study sites.

Species	Site I				Site II				Site III				Site IV			
	Tree	Sapling	Seedling	Reg. Status	Tree	Sapling	Seedling	Reg. Status	Tree	Sapling	Seedling	Reg. Status	Tree	Sapling	Seedling	Reg. Status
Anogeissus latifolia (Roxb. ex DC.) Wall. ex Guillem. & Perr.	110	-	750	PR	20	-	2000	PR	-	-	-	-	40	-	1000	PR
Bombax ceiba L.	10	-	750	PR	-	-	500	NA	-	-	-	-	-	-	-	-
Buchanania cochinchinensis (Lour.) M.R.Almeida	-	500	-	NA	-	-	1000	NA	10	250	-	PR	-	250	500	-
Butea monosperma (Lam.) Taub.	10	-	1500	PR	-	-	-	-	-	-	500	NA	30	-	500	PR
Cassia fistula Linn.	-	-	-	-	-	250	-	NA	-	-	-	-	-	-	-	-
Catunaregam spinosa (Thunb.) Tirveng.	-	-	250	NA		-	500	NA		-	500	NA	-	-	250	NA
Cleistanthus collinus (Roxb.) Benth. ex Hook.f.	-	500	500	NA	40	-	1000	PR	20	500	1000	GR	-	250	500	-
Desmodium oojeinense (Roxb.) H.Ohashi	-	-	-	-	90	-	500	PR	100	-	500	PR	-	-	-	-
Diospyros melanoxylon Roxb.	90	250	500	GR	60	500	500	FR	90	-	1000	PR	-	-	500	NA
Firmiana simplex (L.) W.Wight	-	-	-	-	-	-	-	-	-	-	-	-	-	250	-	NA
Gardenia latifolia Ait.	-	-	500	NA	-	-	-	-	-	-	-	-	-	-	-	-
Ixora parviflora Lam.	-	-	250	NA	-	-	-	-	-	-	-	-	-	-	-	-
Lannea coromandelica (Houtt.) Merr.	-	250	-	NA	-	-	-	-	-	250	-	NA	-	250	-	NA
Madhuca longifolia var. *latifolia* (Roxb.) A.Chev.	-	-	500	NA	10	-	750	PR	40	-	250	PR	-	-	250	NA
Mitragyna parvifolia (Roxb.) Korth.	-	-	-	-	40	-	-	NR		-	-	-	20	-	-	NR
Phyllanthus emblica L.	40	-	2000	PR	100	750	1750	GR	60	-	2500	PR	90	250	250	FR
Pterocarpus marsupium Roxb.	80	-	750	PR	-	250	-	NA		-	-	-	-	-	-	-
Schleichera oleosa (Lour.) Merr.	10	250	750	GR	-	250	-	NA	50	-	1500	PR	50	-	1000	PR
Semecarpus anacardium L.f.	70	-	1000	PR	-	250	-	NA	20	-	1000	PR	-	-	750	NA
Shorea robusta Gaertn.	450	750	4000	GR	380	-	2500	PR	350	750	1500	GR	310	750	2250	GR
Syzygium cumini (L.) Skeels	-	-	-	-	-	-	-	-	-	250		NA	-	-	-	-
Tectona grandis L.f.	-	-	-	-	-	-	-	-	-	-	750	NA	60	-	500	PR
Terminalia chebula Retz.	-	-	-	-	50	-	750	PR	50	-	750	PR	80	-	1000	PR
Terminalia tomentosa Wight & Arn.	140		500	PR	120	-	750	PR	-	-	500	NA	30	-	500	PR
Total	**1010**	**2500**	**14500**		**910**	**2250**	**12500**		**790**	**2000**	**12250**		**710**	**2000**	**9750**	

Note: GR, Good Regeneration; FR, Fair Regeneration; PR, Poor Regeneration; NA, Not Abundant; NR, No Regeneration.

sustainability as they are the main source of timber, fuelwood and other non-timber forest products (NTFPs). The fewer number of saplings recorded in relation to seedlings in this study implies that most of the saplings are transiting into young trees. Intense competition leads to mortality of seedling at very early stage (Weidelt 1988). Among the various girth classes, saplings and seedlings reflect high regeneration potential of the stand (Mishra *et al.* 2005, Khumbongmayum *et al.* 2006).

Table 2. Distribution of vegetation layers according to Raunkiaer's classification scheme.

Layers	Sites	A	B	C	D	E
Tree	I	5	2	2	0	1
	II	5	2	0	2	1
	III	4	4	1	0	1
	IV	4	4	0	0	1
Sapling	I	6	0	0	0	0
	II	5	1	0	0	0
	III	4	1	0	0	0
	IV	6	0	0	0	0
Seedling	I	8	5	1	1	0
	II	4	7	1	0	0
	III	6	5	2	0	0
	IV	9	5	0	0	0

Another type of uninterrupted growth pattern of Sal associated species was *Schleichera oleosa and Phyllanthus emblica* in all sites quality I, II, III and IV. These tree species are successfully crosses the sapling layer and attained the first tree size class. Similarly, one species, *viz. Mitragyna parvifolia* was not regenerating in site quality II. It might be due to thick litter accumulation which reduced seed germination of most canopy species (Janzen 1970, Singh & Singh 1992). The forest stands characterized by the abundance of only adults of the species or absence or very low population of seedlings and saplings are expected to face local extinction (Dalling *et al*. 1998). This type of condition was observed for tree species *Anogeissus latifolia* in site quality III. There is another pattern which consists of individuals in lower and middle girth classes but absence of seedlings. This type of population distribution was reported in *Schleichera oleosa*site II. Therefore, the densities of seedlings are influenced by the densities of large trees (Rao *et al.* 1990). Similarly, the low IVI may be attributed towards the rarest occurrence of species (Oyun *et al.* 2009), as confirmed by Raunkiaer's frequency distribution of the tree species. 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 density values of seedlings and saplings are considered as regeneration potential of the species. The presence of good regeneration potential shows the suitability of a species to a given environment (Dhaulkhandi *et al*. 2008). Edhapo-climatic factors and biotic interference influence the regeneration of different species in the vegetation. Higher seedling density values get reduced to sapling due to soil characteristics, competition for space and nutrients and biotic disturbance.

CONCLUSIONS

It is concluded that tree canopy cover, site characteristics, availability of sunlight on the ground surface and important associated species impacted the regeneration of Sal and other associated species in the region. The absence of tree species may lead to the availability of higher solar insolation to the younger plants especially light loving trees as Sal. The Sal showed adequate regeneration with uninterrupted growth pattern in most of the stands studied, indicating a healthy sign of establishment and growth of Sal crop in the past.

ACKNOWLEDGEMENTS

Authors are thankful to Department of Forestry, Dean College of agriculture, Director Research Services, Director Instructions and Hon'ble Vice-Chancellor, Indira Gandhi Krishi Vishwavidyalaya, Raipur for encouragement, inspiration and providing necessary assistance during the study.

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