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Sal-dominated Forests Influence the Floristic Composition, Diversity and Distribution Pattern with Special Focus on the Associated Trees in the Eastern Ghats of Odisha

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ABSTRACT

The present study investigates the influence of Sal-dominated forests on the floristic composition, diversity and distribution pattern, and population structure of associated trees in a part of Eastern Ghats. Two forest communities viz., Sal-dominated Moist Deciduous Forest (SDMDF) and Moist Deciduous Forest without Sal (MDFWS) were selected for the study. Both these forests had sandy loam and acidic soil, though organic carbon was relatively higher (0.61%) in SDMDF than MDFWS (0.22%). While the SDMDF had 77 species (28 trees, 24 shrubs and 25 herbs) belonging to 51 families and 67 genera, the MDFWS had 111 species (44 trees, 22 shrubs and 45 herbs) belonging to 64 families and 104 genera. While Dipterocarpaceae was the dominant family in SDMDF, Combretaceae was dominant family in MDFWS. Both forest types showed an inverse J-shaped population structure indicating regenerating population. *Phyllanthus emblica* in SDMDF and *Pterospermum xylocarpum* and *Schrebera swieteioides* in MDFWS showed no regeneration. The results suggest that MDFWS maintain higher species diversity and ecosystem vitality than the SDMDF.

Key words: Moist tropical forest, sal forest, Eastern Ghats, NTFPs yielding tree, Kandhamal, Phulbani

INTRODUCTION

Sal (*Shorea robusta* Gaertn, f., family Dipterocarpaceae) is a valuable tropical hardwood timber species native to South Asia. It is a climax species, grow gregariously and form dominant mono-specific canopy in forest communities extending tropical to subtropical regions between 20-32°N latitude and 75-95°E longitude. In India, sal forests cover nearly about 10 million ha area from Uttarakhand in the north to Andhra Pradesh in the south and Assam in the east to Haryana in the west (Tiwari 1995). These forests are source of many ecosystem services, harbor rich biodiversity, provide economic sustenance to resource poor people and deeply linked with culture of tribal and ethnic groups of the region.

Sal tree is known for its superior quality timber of high structural strength and durability (Satya et al. 2005). Immature young sal tree leaves and poles are used for thatching and as construction material in rural areas. Apart from fuel wood, sal forest yield fodder, seed for oil, leaves for plate making, resin from heartwood, tannin and gums from bark having domestic utility and of manufacturing importance (Chitale et al. 2014, Kumar and Saikia 2020, Kumar et al. 2016). The de-oiled seed cake is a good feed for cattle, poultry and fish (Sarkar et al. 2021). Besides this associate species of sal produce various types of NTFPs depending upon species composition (Gautam and Devoe 2006). Sal forests have good climate change mitigation potential by maintaining positive carbon balance in its ecosystems and greater sink capacity (Raj and Jhariya 2021).

Sal has wide range geographical and weather adoptability. Depending on the local microclimate, geologic and edaphic characteristics, sal forms pure or mixed forest having deciduous, semi-evergreen or evergreen phenological appearance (Kumar and Saikia 2020, Kushwaha and Nandy 2012). It prefers well drained alluvial to lateritic sandy loam soils with acidic to neutral pH. In Odisha sal forests primarily falls in two groups Northern Tropical Moist Deciduous Forest (3C) and Northern Tropical Dry Deciduous Forest (5B) with sub-type Kamrup sal, peninsular sal and coastal plain sal (Champion and Seth 1968). Sal forests spread over 24713.44 km^2 accounting 44.17% of the total forest cover of the state (Indian state of forest report 2021). It covers almost every district of the state except for a few in coastal regions like Bhadrak, Kendrapada. The plant is deeply associated with odia people socially, economically and culturally. In Hindu mythology sal tree symbolizes god Bihshnu and worshiped. It is an object of veneration for many tribes such as Banda, Oraon, Ho, Santal, and Munda; and the Sarhul festival in Northern Odisha witness to it.

Climate and geologic mass of an area has a strong influence on structure and composition of forest. The structure and composition of tropical forests are not completely deciphered and understood. Floristic inventory helps in understanding the climate-soil-vegetation relation and structure and composition of plant communities. It is also useful in quantifying ecological status of economically important as well as species of special concern, thus having an implication in biodiversity conservation and sustained utilization. Many phytosociological explorations have been conducted in sal forests to understand: soil and climate relation (Narayan and Anshumali 2016), structure and composition (Kumar and Saikia 2020, Dutta and Devi 2013, Gautam and Devoe 2006), resilience towards anthropogenic disturbances (Behera et al. 2023, Rahman et al. 2009, Sapkota et al. 2010), carbon sequestration rate potential (Raj et al. 2021, Kongkham et al. 2021) and response of sal to climate change (Shankar and Garkoti 2023, Mishra et al. 2021). Some studies also have been conducted in sal forests of Odisha (Sahoo and Davidar 2013, Behera and Mishra 2006). These studies are primarily focused on listing of plant species and information pertaining to population characteristics of economically valuable NTFP yielding species is lacking specifically in sal forest of Kandhamal district located within Eastern Ghats of Odisha.

Kandhamal is a tribal district having 67.37% of the total geographical area covered with forest. According to Champion and Seth (1968) major forest types viz. Northern Tropical Moist Deciduous Forest (3C) and Northern Tropical dry deciduous (5B) exists in the district with sparsely intermingled semi-evergreen vegetation patches. In these forest types sal forms pure as well as mixed forests depending upon the soil moisture, geology and elevation with varied associates. Under current climate change, this important forest type has been dwindling across the state. Sal tree is more sensitive to temperature rise than alteration in rainfall regime because of climate change (Patasaraiya et al. 2018). There are reports of changing phenology, fruit set timing, and failure of regeneration having a cascading effect on functioning of sal dominated ecosystems leading to lesser degree of ecosystem services (Kumar and Chopra 2018, Nandy et al. 2021). The present study aimed to analyze tree species composition, stand structures and ecological status of economically important NTFP yielding species in sal dominated moist deciduous forest (SDMDF) of the district and compared it with moist deciduous forest without sal (MDFWS). The findings of present work will be helpful in recommending species-specific silvicultural treatments intending towards sustained production of NTFPs and other usufructs including ecosystem services besides ensuring conservation of species *in-situ*.

MATERIAL AND METHODS

Study area

The study was conducted in Phulbani Forest Division of Kandhamal district (a constitute of the hilly ranges of the Eastern Ghats) which lies between 19°49'50" to 20°41'20" N and 83°46'53" to 84°35'15" E at 485 m amsl. The climate is sub-tropical, hot and dry with mean maximum temperature 45.5°C (summer) and minimum temperature 2.0°C (winter) with annual rainfall that ranges from 1523 to 1602 mm, of which 80% is received during monsoon (June to September). Soils of study site are loamy to sandy loamy and acidic. Forests of this division fall under the North Indian tropical moist deciduous forest type (Champion and Seth 1968). The characteristics features of both the forest types in terms of total area, dominant species, management practice, distance from human habitation, grazing, forest fire frequency and intensity of disturbance received by both forest types are summarized in Table 1.

Table 1. Characteristics of study sites in SDMDF and MDFWS, Eastern Ghats, Odisha

Particulars	**SDMDF**	**MDFWS**
Total area (ha)	1023	47 3
Elevation (m amsl)	403-427	514 -632
Location	20^0 25' N, 84^0 27' E	20^0 26' N, 84^0 21' E
Land type	Plain-hilly, slope <30 %	Undulating, hilly, slope <30 %
Forest type	Reserve forest, moderate to high dense canopy	Reserve forest, moderately dense canopy
Dominant tree species and associates	US - *S. robusta, B. lanzan, D. melanoxylon, P. marsupium* MS- *S. cumini, C. collinus, M. latifolia, B. retusa*	US- *T. alata, A. latifolia, D. melanoxylon,* MS- *C. collinus, D. malabarica, S. oleosa, P. emblica*
Management	Selection working circle	Selection and rehabilitation working circle
Distance from habitation	≤2.0 km	≥4.0 km
Forest produce collected	Pole, firewood, NTFP (leaf, seed, fiber, resin, flower, root, mushroom, medicinal plant, broom grass etc.)	Fire wood, bamboo, NTFP (leaf, fiber, mahua flower, seed, honey, mushroom, gum, medicinal plant, fruits etc.)
No. of families depending on forest for livelihood	215 (6 villages)	124 (3 villages)
Frequency of forest visit	4 days/week	2 days/week
Grazing intensity	50-100 cattle units/day	<50 cattle units/day
Intensity of disturbance (SBDI)*	24.0	9.5
Fire incidence	Surface fire 1-2 times a year	Ground fire occasional/rare
Quarrying (Murrum)	Partially observed	None

*Stump based disturbance index (SBDI) = basal area of felled trees by total basal area of felled trees and basal area of standing trees.SDMDF-Sal dominated moist deciduous forest; MDFWS-Moist deciduous forest without sal

Vegetation sampling and analysis

Two distinct plant communities' viz. Sal dominated Mixed Deciduous Forest Community (SDMDF) and Moist Mixed Deciduous Forest without Sal Community (MDFWS) were selected within three reserve forests (Khajuripada RF, Dutimundi RF and Dakapalla-B RF) of tropical moist deciduous forest in Phulbani Forest Division, Odisha, India for the study (Fig. 1). In each forest community five sample plots of one ha each were established totaling 10.0 ha of sampling area. Within a plot four sub-plots each of 31.5 × 31.5 m for trees, 5 × 5 m for shrubs and saplings and 1 × 1 m for herbs and seedlings were delineated randomly during 2021 following the procedures of Curtis and Cottom (1956). Tree diameter was measured at breast height (1.37 m from ground) over bark. All individuals having DBH ≥10 cm were considered as adults, DBH <10 cm and height ≥20 cm as saplings and DBH <10 cm and height <20 cm as seedlings (Sundriyal and Sharma 1996). The regeneration status of a tree was assessed based on the proportion of its individuals in tree, sapling and seedling category (Shankar 2001). All trees found in the quadrats were categorized into five diameter classes viz. 10-20, 21-30, 31-40, 41-50 and >51 cm. Distribution pattern of tree species was calculated based on the abundance to frequency ratio (Curtis and Cottam 1956). The descriptive variables for community structure viz. basal area, frequency, density, importance value index (IVI) were computed following the formulae of Mishra (1968). The diversity indices such as Shannon-Weiner diversity

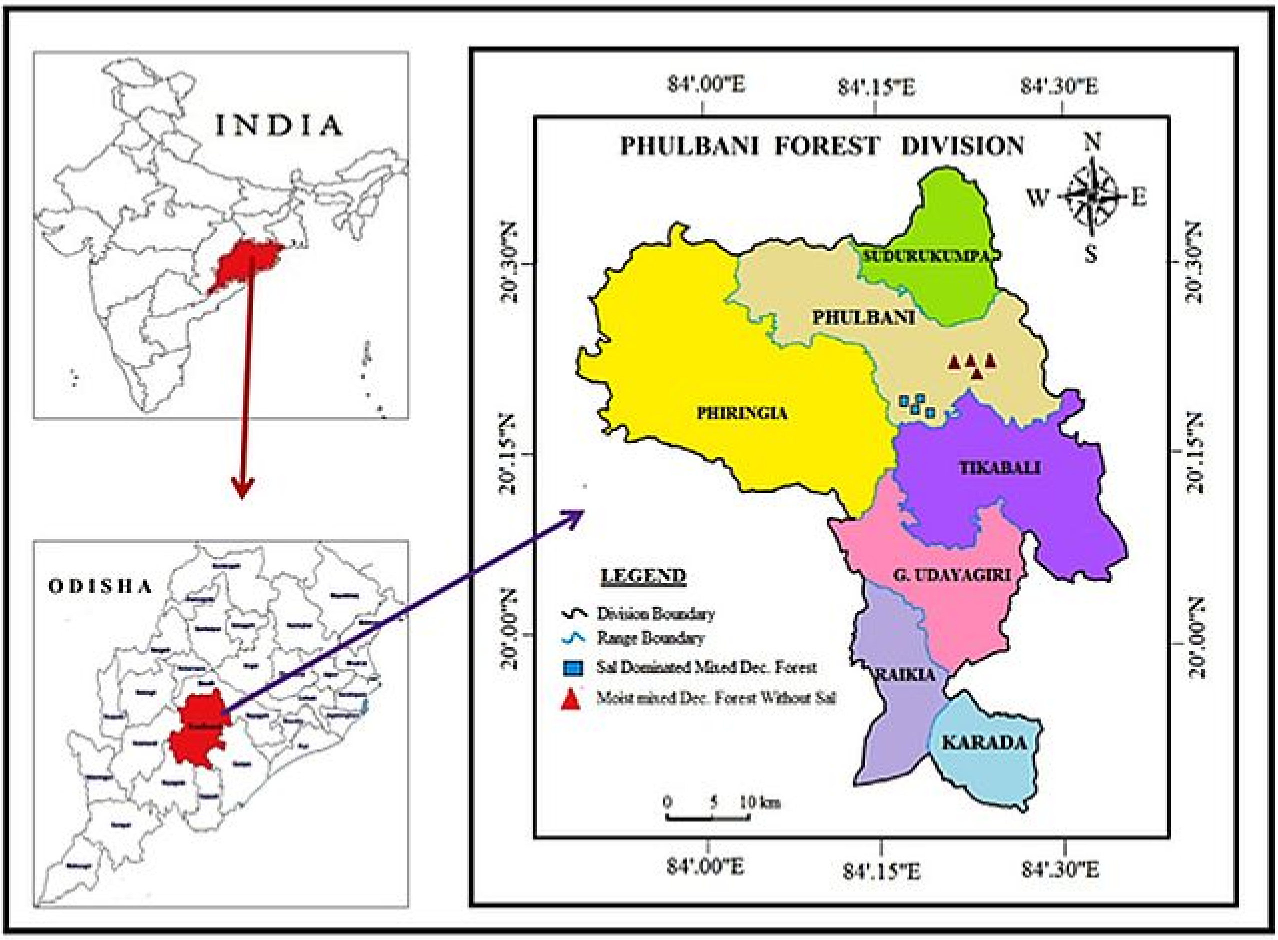

Figure 1. Map of the study area. Phulbani Forest division showing location of sampling plots (SDMDF and MDFWS) within the tropical moist deciduous forest, Eastern Ghats, India

index (H'), Simpson's dominance index (Cd), Pielou's evenness index (E), Margalef's species richness index (R), and Sorensen's index for similarity (S) were calculated according to Shannon and Weiner (1949), Simpson (1949), Pielou (1966), Margalef (1968) and Sorensen (1948). Identification of plant species was done with the help of Botanical Survey of India (Kolkata) and the Flora of the region.

Soil sampling and analysis

Soil samples were collected randomly from 40 points from the 31.5 × 31.5 quadrats at three soil depths 0-15, 15-30 and 30-45 cm of each forest community. All soil samples for a given depth and given forest community was bulked from which two composite soil samples were drawn. These composite samples were brought to the laboratory, shade-dried, sieved through a metallic 2-mm mesh, sealed in polythene bags and stored at room temperature for further physicochemical analysis. The soil texture was determined using hydrometer (Bouyoucos 1962). The bulk density (BD) was determined by soil core method and water holding capacity (WHC) by gravimetrically adopting Keen's box method. The soil pH and electrical conductivity (EC) were estimated in 1:2 soil water suspensions by using glass electrode pH meter (Jackson 1967). The organic carbon content was determined by rapid titration method (Walkley and Black 1934) available nitrogen by digestion-distillation -titration method (Subbiah and Asija1956), available phosphorus by phosphomolybdinum blue colorimetric method (Olsen et al. 1954) and available potash by ammonium acetate method (Merwin and Peech 1951).

Statistical analysis

The inventoried data were analyzed using statistical package SPSS 20. (IBM Corp, USA) and Microsoft excel for various descriptive statistics. Independent sample t-test was done to find out significance of variance soil and vegetation attributes among two forest types. Rank-abundance curve was prepared using Past Software 4.03. Pearson's correlation was carried out within and among soil physicochemical characters and vegetation attributes such as tree density and species richness.

RESULTS AND DISCUSSION

Soil physicochemical properties

The analysis of soil revealed distinct variation between the forest communities, for example, soil texture was sandy-loam in SDMDF and while it was sandy in MDFWS. The proportion of sand however, decreased from the surface (0-15 cm) towards sub-surface layer (30-45 cm) in both stands. The BD, WHC, pH increased with increasing soil depth while EC, organic carbon (OC), available N (AN), available P (AP), available K (AK) showed a reverse trend (Table 2). Clay content in the soil profile increased with depth due to hydromorphic illuviation of dispersed clay particles leading to reduced porosity at lower zones (Parimanik et al. 2020). A minor increase in bulk density with soil depth may be due to reduced organic carbon content and soil compactness along vertical dimension (Hossain et al. 2015). While the soils of SDMDF are heavy textured (clay 13.4 to17.2%), acidic in reaction (pH 5.88 to 5.92), having high-medium OC (0.97 to 0.62%), low AN (95.12 to 116.92 kg ha^{-1}), low AP (8.60 to 10.35 kg ha^{-1}) and high AK (476 to 527.15 kg ha^{-1}), the soils in MDFWS were light-textured (clay 2.2 to 41%), light acidic in reaction (pH 5.97 to 7.46), having low-medium OC (0.68 to 0.37%), low AN (94.80 to 69.52 kg ha^{-1}), low AP (14.08 to 10.57 kg ha^{-1}) and high AK (581.74 to 518.85 kg ha^{-1}).

Tropical forest soils are characteristically acidic because of organic acid formation from the partially decomposed organic matter present in the upper layer of soil profile (Narayan and Anshumali 2016). In the SDMDF the pH was comparatively low due to accumulation of higher un-decomposed floor litter than the MDFWS. Higher soil organic carbon content in SDMDF than MDFWS was probably due to the slow decomposing nature of sal leaf that contribute major share to the floor litter in the former (Singh et al. 1999). There is a direct relationship between SOC

Table 2. Physicochemical characteristics of soil in SDMDF and MDFWS forest, Eastern Ghats, Odisha

Forest type	Soil depth (cm)	Textural class (sand:silt:clay)	BD(g cm^{-3})	SMC (%)	WHC (%)	pH	SOC(%)	AN (kg ha^{-1})	AP (kg ha^{-1})	AK (kg ha^{-1})
SDMDF	0-15	77.4:9.2:13.4^{SL}	1.54±0.08	17.40±0.17	37.85±0.59*	5.88±0.06*	0.97±0.01*	116.92±1.15*	10.35±0.11*	527.15±8.82*
	15-30	75.4:9.2:15.4^{SL}	1.55±0.04	13.42±0.07	38.17±0.52*	5.91±0.03*	0.72±0.01*	102.70±0.57*	9.25±0.14*	507.60±4.04*
	30-45	74.3:8.5:17.2^{SL}	1.78±0.06	12.21±0.06	40.41±0.28*	5.92±0.01*	0.62±0.04*	95.12±1.10*	8.60±0.09*	476.00±5.57*
MDFWS	0-15	89.3:8.5:2.2^{LS}	1.60±0.03	14.08±0.15	42.26±0.58*	5.97±0.06*	0.68±0.03*	94.80±0.65*	14.08±0.20*	581.74±5.24*
	15-30	87.2:8.7:4.1^{LS}	1.76±0.02	12.03±0.59	44.65±1.16*	6.90±0.04*	0.51±0.02*	91.64±1.22*	12.66±0.11*	548.70±6.55*
	30-45	86.2:10.7:3.1^{LS}	1.79±0.04	11.64±0.35	39.34±0.71*	7.46±0.02*	0.37±0.02*	69.52±1.07*	10.57±0.03*	518.85±3.08*

*indicate significant difference between soil properties in SDMDF and MDFWS forest type ($P<0.05$); SL Sandy-Loam, LS Loamy-sand, BD-bulk density, SMC-soil moisture content, WHC-water holding capacity, AN-available nitrogen, AP-available phosphorus, AK-available potassium kg ha^{-1}). OC in tropical moist deciduous forest ranges between 1.73-2.64% (Chhabra et al. 2003) and that in sal forest from 2.42% in pure sal to 1.74% in mixed sal forest (Paudel and Sah 2003). The observed OC content in both the forest types in the present study are little low attributed to faster rate of decomposition of litter in warmer humid edapho-climatic condition.

AP ranged from 8.60 kg ha^{-1} in SDMSF to 14.08 kg ha^{-1} in MDFWS which was quite comparable to the values reported by Digal et al. (2012) for tropical forest soils. The low AP in SDMDF was due to acidic soil condition. In acidic soil conditions (pH 4.5-6.5) aluminium and iron minerals fixes phosphorous thus reducing its availability (Penn and Camberato 2019). AP in MDFWS at lower layer is quite high as compared to other layers because of neutral pH. The values for AK in the present study (476 to 581.74 kg ha^{-1}) are well within the range reported by Nayak and Sahoo (2020), but quite higher than those reported by (Kumar and Saikia 2021). This is because of soil forming parent material Khondalites, one of the major rock present in the study site. It is rich in potassium bearing feldspar (potassium alluminium sillicate) and up on weathering forms potash rich soils (Dash et al. 2019).

Floristic composition

A total of 146 species (61 trees, 38 shrubs, 59 herbs) belonging to 72 families and 131 genera were recorded from the study sites. In SDMDF 77 species (28 trees, 24 shrubs and 25 herbs) belonging to 51 families and 67 genera and in MDFWS 111 species (44 trees, 22 shrubs and 45 herbs) belonging to 64 families and 104 genera were recorded (Table 3). Dipterocarpaceae was the dominant tree family (FIV-92.49) in SDMDF while Anacardiaceae (FIV-30.55) and Phyllanthaceae (FIV-29.84) were the co-dominant families (Table 4). In SDMDF, Combretaceae was the dominant with Dipterocarpaceae while Phyllanthaceae (FIV-33.90) as the co-dominant families. In SDMDF for trees, 8 families were represented by single species, 4 families by 2-3 species and one family by four species. In MDFWS for trees, ten families were represented by single species, five families by two species, one family by 3-5 species, two families by four species and one family was by eight species. The species richness (the number of species found in the sampling sites) was primarily due to tree (37%), followed by herbs (32%) and shrubs (31%) in SDMDF and herbs (41%). In MDFWS it was trees

Table 3. Floristic characteristic of SDMDF and MDFWS in Eastern Ghats, Odisha

Floristic traits	Trees		Shrubs		Herbs	
	SDMDF	MDFWS	SDMDF	MDFWS	SDMDF	MDFWS
Species numbers	28*	44*	24	22	25*	45*
Family numbers	15	20	18	17	18*	27*
Genera numbers	26*	37*	23	22	18*	45*
Density (Ind. ha^{-1})	725	830	6300	6450	75000*	112500*
Basal area (m^{-2} ha^{-1})	21.69*	32.06*	5.98	6.58	-	-
Margalef's species richness	5.15*	7.24*	4.55	4.53	5.01*	8.47*
Shannon diversity index	2.67*	3.63*	2.98	2.91	2.98*	3.73*
Simpson dominance index	0.15*	0.03*	0.06	0.06	0.06	0.02
Pielou's evenness index	0.76*	0.97*	0.95	0.93	0.98	0.98
β-diversity	4.52*	7.10*	5.29	4.85	3.71*	6.68*
Sorensen's similarity index	66.67		52.17		38.71	
Distribution pattern						
Contiguous	67.86	90.91	70.83	68.32	66.67	77.78
Random	25.00	9.90	29.17	31.82	30.95	22.22
Regular	7.14	-	-	-	2.38	-

SDMDF-Sal dominated moist deciduous forest; MDFWS-Moist deciduous forest without sal, Trees - DBH >10 cm; Shrubs-DBH 5 cm to <10 cm, height >1.0 m; height <1.0 m; *indicate significant difference between the values in the same row at tree, shrub or herb ($p<0.05$)

Table 4. Family wise distribution of genera (G), species (S) and density (D) and family importance value (FIV) of trees in SDMDF and MDFWS, Eastern Ghats, Odisha

Sl.No	Family	Sal dominated moist deciduous forest				Moist deciduous forest without sal			
		G	S	D	FIV	G	S	D	FIV
1	Anacardiaceae	3	3	70	30.55	4	4	53	25.8
2	Bignoniaceae	-	-	-	-	1	1	3	1.46
3	Burseraceae	1	1	13	5.57	1	1	38	10.7
4	Combretaceae	2	3	55	25.81	3	5	134	45.6
5	Dipterocarpaceae	2	2	256	92.49	1	1	10	5.26
6	Ebenaceae	1	1	21	11.2	1	2	45	19.3
7	Fabaceae	2	3	56	29.8	6	8	129	45.7
8	Lecythidaceae	1	1	20	8.23	1	1	15	7.49
9	Loganiaceae	-		-	-	1	1	10	5.3
10	Lythraceae	1	1	11	6.07	1	2	21	9.86
11	Malvaceae	1	1	20	8.81	4	4	58	19.9
12	Moraceae	-	-	-	-	1	1	5	2.17
13	Myrtaceae	1	1	20	8.32	1	2	48	16.3
14	Oleaceae	2	2	31	10.47	2	2	28	10.2
15	Phyllanthaceae	3	3	83	29.84	3	3	126	33.9
16	Rubiaceae	4	4	34	15.98	2	2	43	19.5
17	Rutaceae	-	-	-	-	1	1	3	1.59
18	Sapindaceae	-	-	-	-	1	1	38	12.6
19	Sapotaceae	1	1	24	11.34	1	1	8	3.4
20	Sterculiaceae	-	-	-		1	1	15	3.97
21	Dilleniaceae	1	1	11	5.52	-	-	-	-
	Total	26	28	725	300	37	44	830	300

(39%) followed by shrubs (20%). The species richness of SDMDF of the present study is comparable with the Sal forests of Kuldiha Wildlife Sanctuary reported by others (Rout et al. 2018, Behera et al. 2021). The overall species richness (158 plant species) encountered in the study sites of Phulbani forest division is comparable with that of tropical deciduous forests of Nayagarh forest division (Sahoo et al. 2017), Boudh forest division (Sahu et al. 2007) and Badarama forest division (Devi and Behera 2003) of Odisha sharing various habitats of the Eastern Ghats. The presence of 111 species documented in MDFWS is quite close to the species richness range commonly observed in tropical dry forests of this region (Shankar 2001). With a maximum of eight species Fabaceae was the most conspicuous family among trees in SDMDF community.

The family wise distribution of trees (DBH >10 cm) reveals that many families were common to both sites. While Dilleniaceae was restricted to SDMDF, Bignoniaceae, Loganiaceae, Moraceae, Rutaceae, Sapindaceae and Sterculiaceae were restricted to MDFWS (Table 4). The number of shrub species was fairly similar in both the forest communities (24 in SDMDF and 22 in MDFWS). However, a significant (P<05) variation was observed with respect to the number of herb species and their density (Table 3).

Density and basal area

In SDMDF, density of trees was 725 plants ha^{-1} with basal area of 21.69 m^{-2} ha^{-1}. Sal being the dominant species, have IVI 94.31 (Annexure 1), accounted to 36.04% (272.50 plants ha^{-1}) of stand density and 52.97% (11.49 m^{-2} ha^{-1}) of basal area of the forest. In MDFWS density of trees was 830 plants ha^{-1} with basal area of 32.06 m^{-2} ha^{-1} and dominant tree species were having IVI in the range of 14-17. Here dominance is shared among *Terminalia alata*, *Bridelia retusa*, *Anogeissus latifolia* and *Cleistanthus collinus*. In the moist tropical forest of Similipal biosphere Mohanty et al. (2005) reported IVI in the range of 80-150 for *S. robusta* in sal dominated mixed forest. The observed density of 725-830 trees ha^{-1} in both stands were within the range of previous studies in the state i.e., in sal dominated forests of Similipal Biosphere Reserve - 741 stems ha^{-1} (Mohanta et al. 2020) and moist deciduous forests of Nayagarh forest division - 355-740 stems ha^{-1} (Sahoo et al. 2017). Difference in basal area of both the forest types is quite high as compared to density variation which is because of presence of number trees at juvenile (10-20 cm) and young (21-30 cm) diameter classes in SDMDF (Fig. 3A). Though *Cleistanthus collinus* is present in both the forest types substantially it is one of the dominant species in MDFWS but co-dominant in SDMDF. The dominance of *Cleistanthus collinus* in MDFWS is an indicative of dryness of site as evident from low soil moisture content and organic carbon content (Table 2). Common associates of *S. robusta* recorded in present study i.e., *Cleistanthus collinus*, *Buchanania lanzan*, *Pterocarpus marsupium* and *Diospyros melanoxylon* were also found as associates of sal in moist peninsular sal forest of Chhattisgarh and Madhya Pradesh (Chaubey et al. 2015).

Diversity and dominance indices

Commonly biodiversity indices are calculated in floristic studies to bring the diversity and species richness of species in various habitats to a similar scale for comparison. The higher the indices value is the greater the species richness. It is well established that higher value of woody species particularly trees are key component of forest ecosystem, architecture of forest structure and greatly influence other biotic and abiotic components. Thus higher values of diversity indices divulge a forest with high tree species diversity (Naidu and Kumar 2016). The species diversity index ranged from 2.67 to 3.63 for trees, 2.98 to 2.91 for shrubs and 2.98 to 3.73 in SDMDF and MDFWS stand, respectively (Table 3). Diversity index for trees in tropical forests of India ranged 0.83 to 4.1 and the diversity value obtained in the present study is well within the reported range (Mohanty et al. 2005, Shankar 2001, Tripathi and Sankar 2014). The concentration of dominance was highest for trees in SDMDF type because of dominance of one species i.e., *S. robusta* (Fig. 2). In contrary to this because of absence of any single dominant tree species the Pielou's evenness index value was high (0.97) in MDFWS. Being located in a similar climate and geographic region species similarity was found 66.67% for trees, 52.17% for shrubs and 38.71% for herbaceous layer. Higher dissimilarity in herb and shrub layer was due to thick layer of leaf litter from sal in SDMDF limiting soil exposure reducing germination and growth herbs. Another important reason is incidence of recurrent ground fire in sal forests during spring and summer burn seeds and propagules of ground vegetation leading to lower diversity.

Distribution pattern of species gives an idea about intrusion of humans and related activities in a forest. In natural undisturbed forests contagious distribution pattern is most common (Gogoi and Sahoo 2018). Predominance of regular and randon distribution pattern indicates frequentness of biotic interventions (Mohanty et al. 2005). In the present study nearly 32% tree species have random and regular distribution pattern in SDMDF as compared to 10% in MDFWS indicating more biotic disturbances in sal forests. This is mainly for illegal timber extraction and frequent visit of fringe dwellers to forest for collecting non timber forest produce (Behera et al. 2023). Though many species are present in SDMDF, sal saplings are much preferred as poles for various domestic uses apart from thatching and fencing and

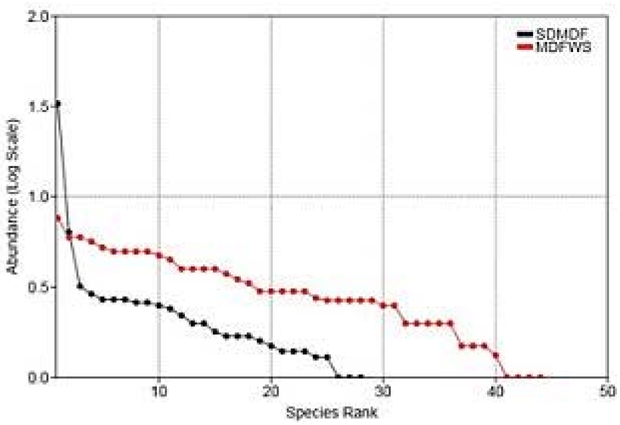

Figure 2. Species rank abundance curve for SDMDF and MDFWS

it is one of the major causes of degradation sal forest in the area.

Stand structure

In any floristic inventory emphasis is given to understand the stand structure because it gives an insight to the ecological processes going in the community. The grouping of individuals of different tree species in five diameter classes based on density showed a sharp decline from Juvenile class to over mature class i.e., a reverse J-shaped pattern in both forest types, suggesting both as climax or stable vegetation (Mishra et al. 2005, Fig. 3a). High density of trees in lower girth classes could be attributed to the repeated disturbance and rapid colonization (Gogoi and Sahoo 2018). Grouping of individuals on the basis of basal area showed a mixed trend. In SDMDF, the declining trend from juvenile to over mature individuals was observed. Juvenile and young classes contributed to nearly 64% to the total basal area of the forest (21.69 $m^2 ha^{-1}$) but in MDFWS type it was the mature and juvenile class which accounted 45% to basal area of the forest (32.06 $m^2 ha^{-1}$). In SDMDF, being dominant, *S. robusta* accounts to maximum share in terms of density (36.05%) and basal area (52.97%). The predominance of trees in juvenile and young classes is an indicative of good regeneration and growth of forest in spite of anthropogenic pressure. However, illegal felling of large sized trees of *S. robusta, T. tomentosa, B. lanzan, T. chebula* for timber trade by smugglers is also equally responsible for poor contribution of mature and over mature class to total basal area of SDMDF (Fig. 3b,c,e). Sahoo et al. (2020a) also observed illegal timber extraction is a pivotal cause of juvenility of forests in Eastern Ghats, Odisha. The

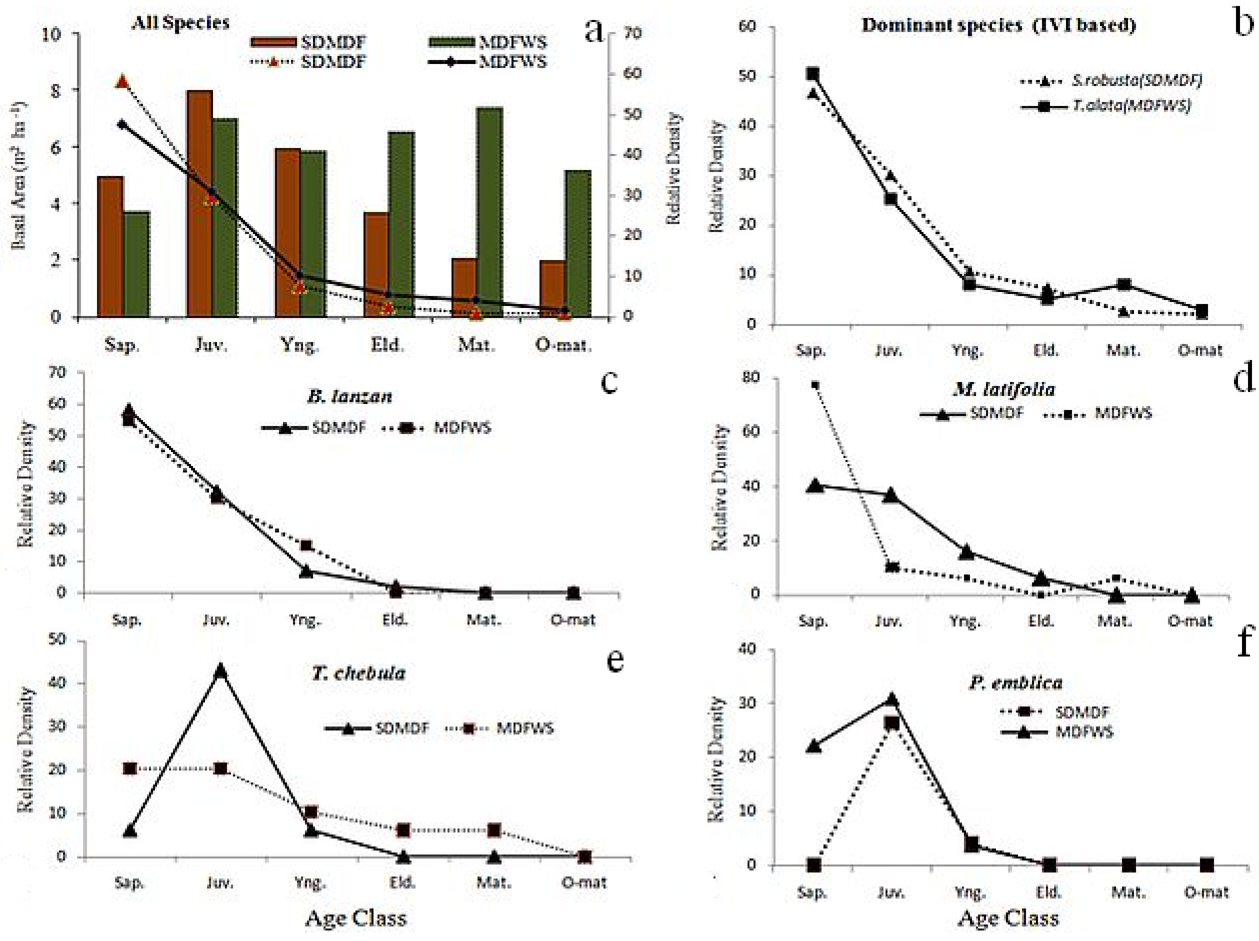

Figure 3. Stand structure and population characteristic in SDMF and MDFWS based on Basal area and relative density. DBH based age class Sap.-saplings (3.3-<10cm and height ≥20 cm), Juv.-juvenile (10-20cm), Yng.-young (21-30cm), Eld.-elder (31-40cm), Mat.-mature (41-50cm), O-mat.-over mature (>51cm)

dwindled population structure in *M. latifolia* was due to felling of large sized trees for charcoal making.

Regeneration

Forest of the study area is well known for the non-timber forest produce (NTFPs) collection and marketing by tribals. Both the forest types are rich in NTFP yielding tree species (Annexure 1). Major tree species contributing substantially to the livelihood of tribals of the area are *S. robust* (leaf, seed, resin, twigs), *D. melanoxylon* (leaf, fruit), *S. anacardium* (seed), *M. latifolia* (flower, seed), *B. lanzan* (fruit, seed), *T. chebula* (fruit), *T. belerica* (fruit), *P. emblica* (fruit), *T. indica* (fruit, seed), *Cycas circinalis* (tuberous trunk), *Bahunia bahali* (leaf, fiber), *P. aculis* (leaf) and hill broom grass (inflorescence). In both the forest types many NTFP yielding tree species are having higher number of individuals in seedling and sapling class but absent in higher age classes mostly in elder, mature and over mature classes (Fig. 3c,d,e).

Among the 28 species found in SDMDF, 43% (12 species) having good regeneration, 54% (15 species) regenerating fairly and one species (*Phyllanthus emblica*) is having poor regeneration. In MDFWS out of the 44 species 30% (13 species) having good regeneration, 59% (26 species) regenerating fairly, three species (*Bombax ceiba, Gardenia latifolia* and *Grewia tiliifolia*) having poor regeneration and two species (*Pterospermum xylocarpum* and *Schrebera swietenioides*) are having no regeneration i.e., absent in sapling and seedling class (Table 5). These two species are endemic, slow growing and sensitive to biotic disturbance (Babu and Rao 2010, Mehta et al. 2008). Another reason for comparatively less regeneration in MDFWS is due to soil condition (i.e. lower organic carbon and soil moisture), growth of woody weeds species (mostly *Chroloena ororata* and *Lantana camara*) and dense ground vegetation. Impaired natural regeneration because of poor soil condition and biotic intervention was reported in Bandipur National Park (Mehta et al. 2008). It was also observed that plant species yielding non-timber produce is subjected to fair to poor regeneration. This was because of unsustainable harvesting i.e., removing nearly all flowers, seeds or other reproductive parts from forest. Unscientific harvesting is the cause poor regeneration of *M. latifolia, T. chebula* and *P. emblica*. Secondary and tertiary branches are often lopped to collect fruit, leading to over lopping and serious damage even many times death of tree. Harvesting for firewood during lean season is also equally responsible for absence of trees in higher diameter classes in both forest types (Fig. 3f). Species centric negative impact of unsustainable NTFP collections on survival, growth and reproduction of harvested individuals has been reported by many workers (Talukdar et al. 2021, Ticktin 2004). Another important phenomenon observed in this two forest types was that, higher number of new species (15) found to be colonizing in SDMDF as compared to MDFWS (10) among which *Wendlandia tinctoria*, *Gardenia latifolia* and *Holarrhena antidysenterica* are prominent ones having seedling density within range of 4500-9000 ha^{-1}.

Tree species diversity (H') and density in relation to soil physicochemical properties

Pearson correlation matrix showed that SOC concentration was significantly positively correlated with soil moisture, available nitrogen, tree density and Shannon diversity index where as a negative significant correlation observed between bulk density and pH (Table 6). The decrease in BD along vertical scale and reduction of SOC in both the stands was due to incorporation organic matter in soil structure development (Mishra et al. 2019). Generally tree density and species richness have a positive correlation with SOC (Islam et al. 2015, Saha et al. 2009) but in the present case lower SOC in MDFWS in spite of high tree density and species diversity was due to lower forest floor litter and thin canopy layer than SDMDF. The negative correlation of BD

Table 5. Regeneration status of trees in SDMDF and MDFWS

Forest type	Tree species	Good	Fair	Poor	None	New arrivals
SDMDF	28	12	15	1	-	15
MDFWS	44	13	26	3	2	10

Table 6. Pearson correlation coefficient between soil physiochemical properties, tree density and species diversity (H')

	BD	SMC	pH	SOC	AN	AP	AK	Tree density	H'
BD	1								
SMC	-.765**	1							
pH	.640**	-.505*	1						
SOC	-.830*	.878*	-.790*	1					
AN	-.761**	.768**	-.790**	.961**	1				
AP	-.101	.198	.123	-.062	-.087	1			
AK	-.272	.285	.046	.056	.015	.875**	1		
Tree density	.422	-.392	.619**	-.669**	-.690**	.660**	.648**	1	
H'	.416	-.391	.626**	-.672**	-.698**	.654**	.665**	0.997**	1

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed), BD-bulk density, SMC-soil moisture content, WHC-water holding capacity, AN-available nitrogen, AP-available phosphorus, AK-available potash, H'-Shannon's diversity index

with SOC in tropical forest soils was reported earlier (Deb et al. 2021). As far as soil nutrients are concerned tree density has a strong correlation with AN, AP and AK. Available phosphorus and K was positively correlated with tree density and diversity whereas AN is negatively correlated. A similar correlation trend of tree density and H' with AN and AP observed in tropical sacred forest ecosystem of Niyamgiri Hill range of Odisha (Sahu et al., 2012).

CONCLUSIONS

The quantitative tree species inventory in present study reveals that sal-dominated moist deciduous forest differs significantly from the mixed deciduous forest without sal when compared with their tree and herbaceous species richness. The species similarity between two forest types was in the order tree > shrubs > herbs. Though *Shorea robusta* was dominant, Rubiaceae with four species was conspicuous in SDMDF. On the other hand Fabaceae and Combretaceae were conspicuous families in MDFWS. Both the communities are rich in NTFP yielding tree species providing livelihood to the tribals of the area but the frequency of visit to SDMDF was much more. Unsustainable collection of NTFPs coupled with periodic forest fire and grazing were the main causes of degradation of forest health and reduced provisioning services. This was evident from dwindling population structure of some of the NTFP yielding tree species such as *M. latifolia, T. chebula* and *P. emblica* in SDMDF. Conservation of existing forest resources is the need of the hour with special emphasis on assisted natural regeneration of economically valuable tree species. The quantitative floristic information of this study will be helpful to forest management authorities at division and state level to prioritize species selection process for plantation and conservation of selected tree species. The study also emphasizes role of sal dominated forest in maintaining higher SOC and thus have implication for sequestering atmospheric CO_2 and their by climate change mitigation.

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REFERENCES

Babu, M.S. and Rao, B.R.P. 2010. Diversity and quantification of trees in Seshachalam hill ranges, Eastern Ghats, India. Indian Journal of Tropical Biodiversity, 18(2), 143-161.

Behera, M.C., Mohanty, T.L. and Kar, R.K. 2021. Species diversity, population structure and regeneration of tree species in Kuldiha Wildlife Sanctuary, Odisha, India. Indian Journal of Ecology, 48(5), 1343-1352.

Behera, M.C., Sahoo, U.K., Mohanty, T.L., Prus, P., Smuleac, L. and Pascalau, R. 2023. Species composition and diversity of plants along human-induced disturbances in tropical moist sal forests of Eastern Ghats, India. Forests, 14(10), 1931. https://doi.org/10.3390/f14101931

Behera, S.K. and Misra, M.K. 2006. Floristic and structure of the herbaceous vegetation of four recovering forest stands in the Eastern Ghats of India. Biodiversity and Conservation, 15, 2263-2285. https://doi.org/10.1007/s10531-004-8215-7

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soils. Agronomy Journal, 54, 464-465. https://doi.org/10.2134/agronj1962.00021962005400050028x

Champion, H.G. and Seth, S.K. 1968. A Revised Survey of the Forest Types of India. Manager of publications, New Delhi.

Chaubey, O.P., Sharma, A. and Krishnamurthy, G. 2015. Plant diversity, edaphic status and population structure in different forest types of Madhya Pradesh and Chhattisgarh states in India. International Journal of Bio-Science and Bio-Technology, 7(2), 115-124. https://gvpress.com/journals/IJBSBT/vol7_no2/11.pdf

Chhabra, A., Palria, S. and Dadhwal, V.K. 2003. Soil organic carbon pool in Indian forests. Forest Ecology and Management, 173(1-3), 187-199. https://doi.org/10.1016/S0378-1127(02)00016-6

Chitale, V.S., Behera, M.D., Matin, S., Roy, P.S. and Sinha, V.K. 2014. Characterizing *Shorea robusta* communities in the part of Indian Terai landscape. Journal of Forestry research, 25(1), 121-128. https://doi.org/10.1007/s11676-013-0396-z

Curtis, J.T. and Cottam, G. 1956. Plant Ecology Workbook. A laboratory, field and reference manual. Burgess Publication Company, Minneapolis, Minnesota, 193 pages.

Dash, P.K., Nayak, B., Mishra, A. and Saren, S. 2019. Geomorphological Characterization of Soils under a Toposequence Located in Eastern India. Environment and Ecology, 37(4A), 1349-1359.

Deb, D., Jamatia, M., Debbarma, J., Ahirwal, J., Deb, S. and Sahoo, U.K. 2021. Evaluating the role of community-managed forest in carbon sequestration and climate change mitigation of Tripura, India. Water, Air and Soil Pollution, 232, 1-17. https://doi.org/10.1007/s11270-021-05133-z

Devi, U. and Behera, N. 2003. Assessment of plant diversity in response to forest degradation in a tropical dry deciduous forest of Eastern Ghats in Orissa. Journal of Tropical Forest Science, 15(1), 147-163. https://www.jstor.org/stable/23616332

Digal, M., Saren, S., Mishra, A., Dash, P.K., Swain, N. and Acharya, B.P. 2018. Soil fertility status of some villages in Phiringia block of Kandhamal district under North-Eastern Ghat agro climatic zone of Odisha, India. Journal of Pharmacognosy and Phytochemistry, 7(6), 658-662. https://www.phytojournal.com/archives/2018/vol7issue6/PartL/7-5-592-924.pdf

Dutta, G. and Devi, A. 2013. Plant diversity and community structure in tropical moist deciduous sal (*Shorea robusta* Gaertn.) forest of Assam, northeast India. Journal of Environmental and Applied Bioresearch, 1(3), 1-4.

Gautam, K.H. and Devoe, N.N. 2006. Ecological and anthropogenic niches of sal (*Shorea robusta* Gaertn. f.) forest and prospects for multiple-product forest management–a review. Forestry, 79(1), 81-101. https://doi.org/10.1093/forestry/cpi063

Gogoi, A. and Sahoo, U.K. and 2018. Impact of anthropogenic disturbance on species diversity and vegetation structure of a lowland tropical rainforest of eastern Himalaya, India. Journal of Mountain Science, 15(11). https://doi.org/10.1007/s11629-017-4713-4

Hossain, M.F., Chen, W. and Zhang, Y. 2015. Bulk density of mineral and organic soils in the Canada's arctic and sub-arctic. Information Processing in Agriculture, 2(3-4), 183-190.

Islam, M., Dey, A. and Rahman, M. 2015. Effect of tree diversity on soil organic carbon content in the homegarden agroforestry system of North-Eastern Bangladesh. Small-scale Forestry, 14, 91-101. https://doi.org/10.1007/s11842-014-9275-5

Jackson, M.L. 1967. Soil Chemical Analysis. Oxford IBH publishing house, Bombay.

Kongkham, B., Khanduri, V.P., Rawat, D., Singh, B., Riyal, M. and Ahmad, T. 2021. Community structure, regeneration status, carbon sequestration potential and soil properties in Shivalik Sal forests of Uttarakhand, India. Advances in Bioresearch, 12 (4), 206-215.

Kumar, R. and Saikia, P. 2020. Floristic analysis and dominance pattern of sal (*Shorea robusta*) forests in Ranchi, Jharkhand, eastern India. Journal of Forestry Research, 31(2), 415-427. https://doi.org/10.1007/s11676-018-0829-9

Kumar, R. and Saikia, P. 2021. Spatio-temporal soil nutrient dynamics and plant species diversity in selected Sal forests of Ranchi, Eastern India. Vegetos, 34(1), 235-248. https://doi.org/10.1007/s42535-020-00173-y

Kumar, S. and Chopra, N. 2018. Effect of climate change on sal (*Shorea robusta* Gaertn. f.) Forest of Kumaun Himalaya. American Journal of Environmental Sciences, 14(4), 185-194. https://thescipub.com/pdf/ajessp.2018.185.194.pdf

Kumar, S., Pradhan, R.C. and Mishra, S. 2016. Exploration of *Shorea robusta* (Sal) seeds, kernels and its oil. Cogent Food & Agriculture, 2(1), 1186140. https://doi.org/10.1080/23311932.2016.1186140

Kushwaha, S.P.S. and Nandy, S. 2012. Species diversity and community structure in sal (*Shorea robusta*) forests of two different rainfall regimes in West Bengal, India. Biodiversity and Conservation, 21, 1215-1228. https://doi.org/10.1007/s10531-012-0264-8

Margalef, R. 1968. Perspectives in Ecological Theory. University of Chicago Press, Chicago, IL, USA, 111 pages.

Mehta, V.K., Sullivan, P.J., Walter, M.T., Krishnaswamy, J. and DeGloria, S.D. 2008. Ecosystem impacts of disturbance in a dry tropical forest in southern India. Ecohydrology, 1(2), 149-160. https://doi.org/10.1002/eco.14

Merwin, H.D. and Peech, M. 1951. Exchangeability of soil potassium in the sand, silt and clay fractions as influenced by the nature of the complimentary exchangeable cations. Soil Science Society of America Journal, 15C, 125-128. https://doi.org/10.2136/sssaj1951.036159950015000C0026x

Mishra, S., Singh, K., Sahu, N., Singh, S.N., Manika, N., Chaudhary, L.B., Jain, M.K., Kumar, V. and Behera, S.K. 2019. Understanding the relationship between soil properties and litter chemistry in three forest communities in tropical forest ecosystem. Environmental Monitoring and Assessment, 191, 1-11. https://doi.org/10.1007/s10661-019-7691-x

Mishra, S.N., Gupta, H.S. and Kulkarni, N. 2021. Impact of climate change on the distribution of Sal species. Ecological Informatics, 61, 101244. https://doi.org/10.1016/j.ecoinf.2021.101244

Misra, R. 1968. Ecology Work Book. Oxford and IBH Publishing Company.New Delhi.

Mohanta, M.R., Mohanta, A., Mohapatra, U., Mohanty, R.C. and Sahu, S.C. 2020. Carbon stock assessment and its relation with tree biodiversity in Tropical Moist Deciduous Forest of Similipal Biosphere Reserve, Odisha, India. Tropical Ecology, 61, 497-508. https://doi.org/10.1007/s42965-020-00111-8

Mohanty, R.C., Mishra, R.K., Bal, S. and Upadhyay, V.P. 2005. Plant diversity assessment of *Shorea robusta* dominated forest stands of Similipal Biosphere Reserve. Journal of Indian Botanical Society 84, 21-29.

Naidu, M.T. and Kumar, O.A. 2016. Tree diversity, stand structure, and community composition of tropical forests in Eastern Ghats of Andhra Pradesh, India. Journal of Asia-Pacific Biodiversity, 9(3), 328-334. https://doi.org/10.1016/j.japb.2016.03.019

Nandy, S., Ghosh, S. and Singh, S. 2021. Assessment of sal (*Shorea robusta*) forest phenology and its response to climatic variables in India. Environmental Monitoring and Assessment, 193(9), 616. https://doi.org/10.1007/s10661-021-09356-9

Narayan, C. and Anshumali. 2016. Elemental composition of Sal forest soils around Chhotanagpur Plateau, India. Chemistry and Ecology, 32(6), 533-549. https://doi.org/10.1080/02757540.2016.1162296

Nayak, S. and Sahoo, U.K. 2020. Effect of seed source on germination and early growth in *Madhuca latifolia* in Odisha. International Journal of Ecology and Environmental Sciences, 46(2), 203-210. https://nieindia.org/Journal/index.php/ijees/article/view/2142/590

Olsen, S.R., Cole, C.V., Watandbe, F. and Dean, L. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. Journal of Chemical Information and Modeling, 53, 1689-1699. https://doi.org/10.1017/CBO9781107415324.004.

Parimanik, B.K., Mohanty, T.L. and Behera, M.C. 2020. Characterization of soil profile in Sal forest of Nayagarh district in Odisha. Journal of Pharmacognosy and Phytochemistry, 9(3S), 01-04. https://www.phytojournal.com/archives/2020/vol9issue3S/PartA/S-9-2-98-849.pdf

Patasaraiya, M.K., Sinha, B., Bisaria, J., Saran, S. and Jaiswal, R.K. 2018. Assessing impacts of climate change on teak and sal landscape using MODIS time series data. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42, 305-313. https://doi.org/10.5194/isprs-archives-XLII-5-305-2018

Paudel, S. and Sah, J.P. 2003. Physiochemical characteristics of soil in tropical sal (*Shorea robusta* Gaertn.) forests in eastern Nepal. Himalayan Journal of Sciences, 1(2), 107-110. http://nepjol.info/index.php/HJS/article/view/207/805

Penn, C.J. and Camberato, J.J. 2019. A critical review on soil chemical processes that control how soil pH affects phosphorus availability to plants. Agriculture, 9(6), 120. https://doi.org/10.3390/agriculture9060120

Pielou, E.C. 1966. Species-diversity and pattern-diversity in the study of ecological succession. Journal of Theoretical Biology, 10(2), 370-383. https://doi.org/10.1016/0022-5193(66)90133-0

Rahman, M., Nishat, A. and Vacik, H. 2009. Anthropogenic disturbances and plant diversity of the Madhupur Sal forests (*Shorea robusta* CF Gaertn) of Bangladesh. International Journal of Biodiversity Science & Management, 5(3), 162-173. https://doi.org/10.1080/17451590903236741

Raj, A. and Jhariya, M.K. 2021. Carbon storage, flux and mitigation potential of tropical Sal mixed deciduous forest ecosystem in Chhattisgarh, India. Journal of Environmental Management, 293, 112829. https://doi.org/10.1016/j.jenvman.2021.112829

Rout, S.D., Panda, S.K., and Panda, T. 2018. Phytosociological and floristic evaluation of Kuldiha wildlife sanctuary, Odisha, India. Tropical Plant Research, 5(3), 419-430. https://www.tropicalplantresearch.com/archives/2018/vol5issue3/51.pdf

Saha, H.K., Nair, P.K.R., Nair, V.D. and Kumar, B.M. 2009. Soil carbon stock in relation to plant diversity of home gardens in Kerala, India. Agroforestry Systems, 76(1), 53-65. https://doi.org/10.1007/s10457-009-9228-8

Sahoo, T., Acharya, L. and Panda, P.C. 2020. Plant diversity along disturbance gradients in Tropical Moist deciduous forests of Eastern Ghats of India. Plant Archives, 20(1), 2007-2017. http://www.plantarchives.org/20-1/2007-2017%20(5887).pdf

Sahoo, S. and Davidar, P. 2013. Effect of harvesting pressure on plant diversity and vegetation structure of Sal forests of Similipal Tiger Reserve, Odisha. Tropical Ecology, 54(1), 97-107.

Sahoo, T., Panda, P.C. and Acharya, L. 2017. Structure, composition and diversity of tree species in tropical moist deciduous forests of Eastern India: a case study of Nayagarh Forest Division, Odisha. Journal of Forestry Research, 28, 1219-1230. https://doi.org/10.1007/s11676-017-0408-5

Sahu, S.C., Dhal, N.K., Reddy, C.S., Pattanaik, C. and Brahmam, M. 2007. Phytosociological study of tropical dry deciduous forest of Boudh district, Orissa, India. Research Journal of Forestry, 1(2), 66-72.

Sapkota, I.P., Tigabu, M. and Odén, P.C. 2010. Changes in tree species diversity and dominance across a disturbance gradient in Nepalese Sal (*Shorea robusta* Gaertn. f.) forests. Journal of Forestry Research, 21(1), 25-32. https://doi.org/10.1007/s11676-010-0004-4

Sarkar, N., Chakraborty, D., Dutta, R., Agrahari, P., Bharathi, S.D., Singh, A.A. and Jacob, S. 2021. A comprehensive review on oilseed cakes and their potential as a feedstock for integrated bio-refinery. Journal of Advanced Biotechnology and Experimental Therapeutics, 4(3), 376-387.

Satya, Upreti, D.K. and Nayaka S. 2005. *Shorea robusta* - an excellent host tree for lichen growth in India. Current Science, 89, 594-595. https://currentscience.ac.in/Volumes/89/04/0594.pdf

Shankar, A. and Garkoti, S.C. 2023. Dynamics of soil bio-physicochemical properties under different disturbance regimes in sal forests in western Himalaya, India. Science of The Total Environment, 879, 163050. https://doi.org/10.1016/j.scitotenv.2023.163050

Shankar, U. 2001. A case of high tree diversity in a sal (*Shorea robusta*)-dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. Current Science, 81(7), 776-786. https://currentscience.ac.in/Volumes/81/07/0776.pdf

Shannon, C.E. and Weaver, W. 1949 The Mathematical Theory of Communication. University of Illinois Press, Urbana, USA. 117 pages.

Simpson, E.H. 1949. Measurement of diversity. Nature, 163(4148), 688-688. https://doi.org/10.1038/163688a0

Sorensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. Biologiske Skrifter, 5, 1-34. https://www.scienceopen.com/document?vid=fb7f6a95-4526-45b6-971d-e7b80e312998

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in soils. Currrent Science, 25, 259-260. https://currentscience.ac.in/Volumes/25/08/0259.pdf

Sundriyal, R.C. and Sharma, E. 1996. Anthropogenic pressure on tree structure and biomass in the temperate forest of Mamlay watershed in Sikkim. Forest Ecology and Management, 81(1-3), 113-134. https://doi.org/10.1016/0378-1127(95)03657-1

Talukdar, N.R., Choudhury, P., Barbhuiya, R.A. and Singh, B. 2021. Importance of non-timber forest products (NTFPs) in rural livelihood: A study in Patharia Hills Reserve Forest, northeast India. Trees Forests and People, 3, 100042. https://doi.org/10.1016/j.tfp.2020.100042

Ticktin, T. 2004. The ecological implications of harvesting nontimber forest products. Journal of Applied Ecology, 41(1), 11-21. https://doi.org/10.1111/j.1365-2664.2004.00859.x

Tiwari, D.N. 1995. A monograph on sal (*Shorea robusta*). International Book Distributors, Dehra Dun.

Tripathi, A.K. and Shankar, U. 2014. Patterns of species dominance, diversity and dispersion in ‘Khasi hill sal’ forest ecosystem in northeast India. Forest Ecosystems, 1, 1-20. https://doi.org/10.1186/s40663-014-0023-2

Walkley, A. and Black, I.A. 1934. An examination of degtjareff method for determining soil organic matter and a proposed modification. Soil Science, 37(1), 29-38. https://doi.org/10.1097/00010694-193401000-00003.

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Annexure 1. Density, importance value index (IVI) and utilization of tree species in SDMDF and MDFWS, Eastern Ghats, Odisha

Sl. No	Botanical name	Family	Vernacular name	SDMDF		MDFWS		Uses
				D	IVI	D	IVI	
1	*Aegle marmelos* (L.) Correa	Rutaceae	Bela	-	-	3	1.46	Fw, M, Ed
2	*Albizia lebbeck* (L.) Benth.	Fabaceae	Siris	-	-	18	7.25	T, Fw, Fo, Fp
3	*Anogeissus acuminata* (Roxb. ex DC.) Guillaum. & Perr.	Combretaceae	Phasi	-	-	10	3.2	T, Fw
4	*Anogeissus latifolia* (DC.) Wallich ex Guill. et Perr.	Combretaceae	Dhaura	11	4.68	40	12.43	T, Fw
5	*Antidesma ghaesembilla* Gaertn.	Phyllanthaceae	Jamrul	5	3.01	-	-	Fw, Fo
6	*Bauhinia variegata* L.	Fabaceae	Kanchana	-	-	10	4.4	Fw, Fo, Ed
7	*Bombax ceiba* L.	Malvaceae	Simuli	-	-	10	3.6	Fw, Co
8	*Bridelia retusa* (L.) A.Juss.	Phyllanthaceae	Kasi	-	-	45	15.24	T, Fw,
9	*Buchanania lanzan* Spreng.	Anacardiaceae	Chara	29	11.68	20	7.69	T, Fw, Ed
10	*Careya arborea* Roxb.	Lecythidaceae	Kumbhi	21	8.74	15	7.38	T, Fw, Fo
11	*Cassia fistula* L.	Fabaceae	Sunari	-	-	20	6.78	Fw, M
12	*Ceiba pentandra* (L.) Gaertn.	Malvaceae	Kanta simili	20	8.44	15	4.36	T, Fw, Co
13	*Cleistanthus collinus* (Roxb.) Benth. ex Hook.f.	Phyllanthaceae	Karda	64	17.46	48	11.93	Fw, Fp
14	*Dalbergia lanceolaria* L.f.	Fabaceae	Satpedia	-	-	10	4.61	Fw, Fo
15	*Dalbergia latifolia* Roxb.	Fabaceae	Pahadi sisu	20	9.54	13	6.56	T, Fw, Fo
16	*Dalbergia sissoo* Roxb.	Fabaceae	Sisuba	-	-	25	9.24	T, Fw, Fo
17	*Desmodium oojeinensis* (Roxb.) H.Ohashi	Fabaceae	Bandhana	14	6.49	20	6.18	T, Fw, Ae
18	*Dillenia pentagyna* Roxb.	Dilleniaceae	Rai	11	5.37	-	-	T, Fw, M
19	*Diospyros malabarica* (Desr.)	Ebenaceae	Mankada kendu	-	-	20	6.76	T, Fw, Ed
20	*Diospyros melanoxylon* Roxb.	Ebenaceae	Kendu	21	10.73	25	12.38	T, Fw, Ed, Ch, M
21	*Ficus racemosa* L.	Moraceae	Jari	-	-	5	2.1	Fw, Fo
22	*Gardenia latifolia* Aiton	Rubiaceae	Damsaradi	3	1.27	15	4.99	T, Fw
23	*Garuga pinnata* Roxb.	Burseraceae	Sidhamai	12	5.39	33	9.72	T, Fw, Fo, Ae
24	*Grewia tiliifolia* Vahl	Malvaceae	Dhamana	-	-	15	5.82	T, Fw, Ae
25	*Ixora pavetta* Andr.	Rubiaceae	Tel kurma	10	4.89	-	-	T, Ed, Fo, Ae
26	*Lagerstroemia parviflora* Roxb.	Lythraceae	Sidha	11	5.89	10	4.21	T, Fw, Ae
27	*Lagerstroemia reginae* Roxb.	Lythraceae	Patali	-	-	13	5.85	T, Fw, Ae
28	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	Mai	21	7.88	15	6.78	T, Ed, Fo
29	*Madhuca latifolia* (Roxb.) A.Chev.	Sapotaceae	Mahula	24	10.9	10	3.73	T, Fw, Ch, Ed, So
30	*Mangifera indica* L.	Anacardiaceae	Amba	-	-	10	2.43	T, Fw, M, Ed
31	*Mitragyna parvifolia* (Roxb.) Korth.	Rubiaceae	Mundi	10	5.76	28	14.4	T, Fw,
32	*Morinda coreia* Buch.-Ham.	Rubiaceae	Achu	12	3.52	-	-	Fw, D, M
33	*Nyctanthes arbor-tristis* L.	Oleaceae	Khara khari	11	3.97	10	4.41	Fw, M, D
34	*Phyllanthus emblica* L.	Phyllanthaceae	Amla	14	8.02	15	3.51	Ed, M,
35	*Pterocarpus marsupium* Roxb.	Fabaceae	Bijasal	23	11.59	20	6.47	T, Fw, M, Ae
36	*Pterospermum xylocarpum* (Gaertn.) Oken	Sterculiaceae	Kangada	-	-	15	3.9	Fw, M
37	*Schleichera oleosa* (Lour.) Oken	Sapindaceae	Kusum	-	-	33	11.69	T, FW, So, M
38	*Schrebera swietenioides* Roxb.	Oleaceae	Makha	20	6.16	20	7.03	T, Fw,
39	*Semecarpus anacardium* L. f.	Anacardiaceae	Bhalia	20	9.19	20	7.35	T, FW, M,
40	*Shorea robusta* Roth	Dipterocarpaceae	Sargi/Shal	272	94.31	10	5.22	T, Fw, Lp, Re, Fo, M,So
41	*Spathodea campanulata* Beauv.	Bignoniaceae	Padel	-	-	3	1.35	Fw, Ch
42	*Sterculia urens* Roxb.	Malvaceae	Genduli	-	-	20	6.31	G, Fo

Sl. No	Botanical name	Family	Vernacular name	SDMDF		MDFWS		Uses
				D	IVI	D	IVI	
43	*Strychnos nux-vomica* L.	Loganiaceae	Kochila	-	-	10	5.18	Fw, M
44	*Syzygium cumini* (L.) Skeels	Myrtaceae	Jamukoli	20	8.04	28	9.51	T, M, Ed, Fo
45	*Syzygium heyneanum* (Duthie) Wall. ex Gamble	Myrtaceae	Pani jamu	-	-	25	7.32	Fw
46	*Terminalia alata* Heyne ex Roth	Combretaceae	Asana	24	10.18	48	16.87	T, Fw
47	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	Bahada	-	-	13	4.43	T, Fw, M, Ed
48	*Terminalia chebula* Retz.	Combretaceae	Harida	20	8.76	20	7.97	T, Fw, M, T
49	*Vateria indica* L.	Dipterocarpaceae	Dhoopa	13	8.14	-	-	Fw, M, Re
	Total			**756**	**300**	**831**	**300**	

T-Timber, Fw-Fuel wood, Ed-Edible, Fo-Fodder, Fp-Fish poison, Ch-Charcoal making, Lp-Leaf Plate making, Re-Resin, G-Gum, So-Seed oil, D-dye