



Species Diversity, Soil Nutrients Dynamics and Regeneration Status of Sal (*Shorea robusta*) Forests in Western Himalayan Region of India

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ABSTRACT

Sal (*Shorea robusta*) forest is found in an extensive array of conditions in Western Himalaya. It has been heavily used for commercial purposes. Thus, we did a study to gather the information on sal forests occupying a broad range of the Rajaji Tiger Reserve which spans across an extensive range in the Western Himalaya. We tested the species diversity, soil nutrients status, and regeneration potential of the Sal forest. Vegetation was sampled in 10 transects zone of 20×20 m² plots covering an area of 10.0 ha area. Trees, saplings, seedlings, shrubs, and herbs were sampled along the transects in the Chilla forest division of the tiger reserve. Samplings were done every 200 m along the transect with the help of the Nested quadrat method. Altogether 64 species were recorded: 24 trees, 12 shrubs, and 28 herbs. Environmental variables like pH, organic carbon, total nitrogen, available potassium, available phosphorous, and soil texture were also recorded to observe the effects of these environmental variables into diversity attributes. The Shannon Weiner index for trees was 1.350, for saplings 1.774, for seedlings 1.679. For shrub species, it was 1.96. The Shannon Weiner index for herbaceous species in the rainy season was 2.8, in winter it was 2.36 whereas in summer it was 2.46. We concluded that the management of sal has enhanced the diversity and soil nutrients dynamics in the study area. Sal diversity also has enhanced the growth of co-dominant species like *Mallotus philippensis*, *Aegle marmelos*, *Listea chinensis*, *Naringi crenulata*, *Ehretia laevis*, *Cassia fistula*, etc. in the study area. Although we did not find any seedlings of the sal during the present study, the regeneration potential of sal forest increasing with a greater number of associated species provide a favorable environment for sal species.

INTRODUCTION

Sal (*Shorea robusta*) is one of the most important commercial timber trees in India. *Shorea robusta* forests of Western Himalaya are monocultures due to various silvicultural tasks at the time of British rule. Under these tasks, the natural associates of *S. robusta* were removed as 'Kokat' (Chauhan 2001, Negi et al. 2002). It is one of the most dominant forest communities in the lower region of Uttarakhand Himalaya. Acknowledging the ecological and economic distribution of *S. robusta* forest, different management regimes have been proposed under different land use classes and ownership. These forest types in India also come under Protected Area Network (PAN), Government managed forested areas which include National Parks and Wildlife Sanctuaries. The forest of Sal is mainly distributed in tropical regions of India and covers about 13.30 % of the total forest in the country (Satya & Nayaka 2005). In Uttarakhand Himalaya, *S. robusta* forest covers the major parts of Rajaji tiger reserve and

Corbett tiger reserve. Sal in these reserves mainly occurs as a dominant tree under tropical moist and dry deciduous forests (Champion & Seth, 1968). In Western Himalaya, it occurs from the foothills of the Kangra region of Himachal Pradesh to the North-Eastern regions like Assam, Meghalaya, and Tripura through Uttar Pradesh, Uttarakhand, and Bihar at an altitude of 1,000 m (Satya & Nayaka 2005). It is generally found as a gregarious formation and tends to form pure to mixed forest stands in the foothills of Himalaya and the central part of India (Troup 1921). The whole Himalaya has a great diversity of plants that are still being utilized by the existing communities for their healthcare and traditional practice (Saklani et al. 2020).

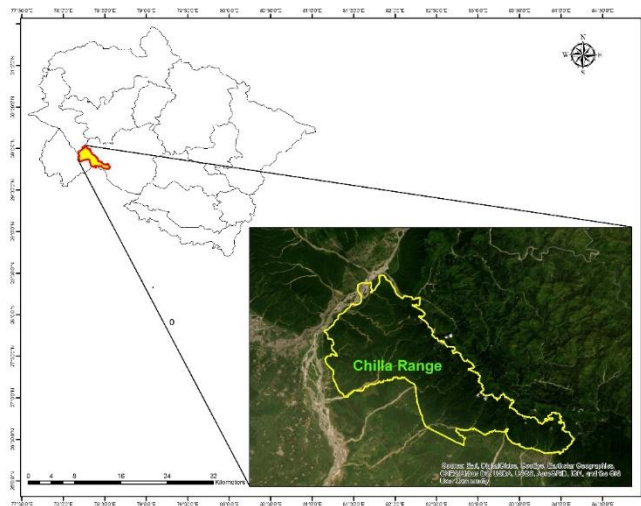
To meet the increasing demand for timber trees due to the increasing human population, the tropical forests of Sal were converted into the urban landscape, various agricultural, and industries land which led to biodiversity and habitat loss (Jacquemyn et al. 2003). On the other hand, the quantitative

inventories play important role in the invention of economically important species (Keel et al. 1993) and further have enormous implications in the management and conservation of these tropical moist and deciduous forests (Campbell & Siepen 1994).

In western Himalaya, most of the forest of Sal is largely constituted by its plantation about many years ago. In Rajaji and Corbett tiger reserve, the forest of Sal is now a mature forest community. The associated plant species fairly mimics the structure and composition of natural-dominated sal (Champion & Seth 1968). In Himalaya, as the forest cover of sal is receding fast, the management of its natural forests would be an important strategy for conservation. The composition of forest plant species is strongly co-related to environmental gradients (Currie 1991) but the knowledge

on the species composition and forest structure of the moist and dry tropical forests are still inadequate. Thus, the quantitative analysis based on species composition and structure is an important approach (Braun-Blanquet 1965). Further, it is evident that for effective conservation and management, the knowledge of forest structure and species composition is crucial (Kushwaha & Nandy 2012).

The leaves of Sal are used as fodder and also used in making various items like disposal plates (Jackson 1994). The phenology of this tree is debated in back years due to its deciduous versus evergreen paradox or nature (Troup 1921). In various parts of the world, especially the developing country, this tree fulfills the subsistence needs of humans (World Resources Institute 1996). Sal forests are also a source of timber, poles, and various medicinal wealth, mushrooms as



well as the ferns. Further, it also provides landscape-level conservation under wildlife sanctuary and national parks as it covers a large area of the forest (HMGN 2004).

STUDY AREA

Rajaji Tiger Reserve is located in Northern India at 29°51' N to 30°15' N, 077°52' E to 078°22' E at elevations from 250–1,100 above mean sea level. It falls within the Gangetic plains biogeographic zone and upper Gangetic plains province (Saklani et al. 2019). Rajaji tiger reserve (Earlier named as Rajaji National park) was established in 1983 with the aim of maintaining a viable population of Asian elephants and is designated as a protected area for 'Project Elephant' by the Ministry of Environment, Forest and Climate Change, Government of India. It spread in an area of 820.42 sq km. The tiger reserve is an essential part of the Terai landscape between the Sharda and Yamuna river in the Shivalik landscape (Saklani et al. 2018d). The study area comes under the Chilla forest division of the Rajaji tiger reserve which is an essential part of the tropical forest under Shivalik hill. The Chilla range of the reserve is one of the great centers of attraction for tourists (Saklani et al. 2018b). The Chilla forest division of Rajaji tiger reserve comes under the protected area network but undergoing rapid changes in fauna and vegetation pattern due to the large-scale anthropogenic forcing at some places in form of lopping, grazing, and hydropower project, scraping, trampling, and extraction of timber and non-timber forest products (Saklani et al. 2019). The anthropogenic gradients have rendered the system inhospitable for the growth of various associated plant species and regeneration resulting in a severe loss in plant diversity (Saklani et al. 2019, Pandey & Shukla 2001).

MATERIAL AND METHODS

The stratified random Nested sampling approach was followed for quantitative enumeration of the species survey in the present study. The sampling was carried out from 2016-2019 in all the strata viz. trees, shrubs and herbs. Quadrat size for enumeration of species was determined by the species-area-curve method (Misra 1968). For tree species, twelve 20 m × 20 m quadrat, sixty, 5 m × 5 m quadrats for shrubs, seventy-two 1 m × 1 m quadrats for herbs were laid randomly at each sample site. Further in each quadrat, circumference at breast height (CBH) of all the tree species with girthing tape was measured. A total of 60 and 50 plots were randomly laid in the forest of sal respectively and after that, the plant species were collected from the sal forest and identified by using regional flora, and all the species were confirmed from the Botanical Survey of India. Further, the herbarium was maintained in the Gurukul Kangri Universi-

ty, Haridwar, India. Plants were further confirmed from the Botanical Survey of India, Dehradun, Uttarakhand, India. Quantitative analysis of field data was done for density, abundance, frequency, and relative parameters (Curtis & McIntosh 1950). The Importance Value Index (IVI) for each tree, herb, and shrubs species was calculated (Curtis 1959). Further, all of the diversity indices were calculated in PAST Software Version 3.2. The species diversity index of both sites was determined using Shannon–Weiner Index (1949), Concentration of dominance by Simpson Index, Species richness index by Margalef, and Evenness by Jaccard Index. Analysis of variance (ANOVA) was done for statistical analysis by using the SPSS Version 20 (Statistical Package for Social Science). Species diversity profile and individual rarefaction curve of species were constructed in Paleontological Statistics (PAST) Software Program Version 3.14 based on presence and absence of plant species and the number of individual plant species in sal stand.

RESULTS AND DISCUSSION

Forest Structure and Composition

64 plant species were recorded from the stand of *S. robusta* in which 24 tree species (including saplings and seedlings), 12 shrubs, and 28 herbs of Chilla forest division of Rajaji tiger reserve representing 58 genera and 36 families were recorded within 10.0 ha of the Sal stands. The forest canopy was dominated by *S. robusta* as it was the most frequent species. After *S. robusta*, the next most frequent species were *Mallostus philippensis*, *Cassia fistula*, *Naringi crenulata*, *Ehertia laevis*, *Legerstroemia indica*, *Crateva religiosa* and *Listea chinensis*. The understory of the Sal stand was quite sparse and dominated by shrubs such as *Lantana camara*, *Murrayya koenighii*, *Helicteres isora*, etc., and herbs like *Ageratum conyzoides*, *Achyranthus aspera*, *Aerva sanguinolenta*, *Adiantum* spp., *Cleome viscosa*, etc. The total density of trees was 318.29 ha⁻¹ for saplings 12707.8 ha⁻¹, for seedlings 547.67 ha⁻¹ whereas the total basal cover was of trees was 46.61 m².ha⁻¹, for saplings 39.23 m².ha⁻¹ and seedling 543.11 cm². ha⁻¹ in the study area. The highest density of tree in Sal stand was recorded for *S. robusta* (208.25 ha⁻¹), *E. laevis* (5000 ha⁻¹) for saplings, *M. philippensis* (287.5 ha⁻¹) whereas the rest of the species has shown moderate density in the study area. The total basal cover of trees was maximum recorded for *S. robusta* (43.25 m².ha⁻¹), *E. laevis* (12.25 m².ha⁻¹) for saplings, and *M. philippensis* (251.76 m².ha⁻¹) for seedlings. For shrub species, the highest density was recorded for *L. camara* and *C. viscosum* (1766.66 ha⁻¹) and the lowest was recorded for *Cassia occidentalis* (33.33 ha⁻¹), whereas the highest basal cover was recorded for *L. camara* (0.32 m².ha⁻¹) and the lowest basal cover was recorded for *C. occidentalis* (0.001

$\text{m}^2 \cdot \text{ha}^{-1}$). In herb species, the highest individuals density was observed for *A.conyzoides* (84.72 m^2) and lowest for *Oxallis latifolia* (1.39 m^2) in the rainy season whereas in winter *Ageratum conyzoides* and *Adiantum* spp. (56.94 m^2 each) has been recorded with the highest density and lowest for *Boerhavia diffusa* (2.77 m^2). On the other hand, in summer, again highest density was observed for *A.conyzoides* (90.28 m^2) and lowest for *Oxallis latifolia* (1.38 m^2). The total basal cover was highest for *Achyranthus aspera* ($3.16 \text{ cm}^2/\text{m}^2$) in the rainy season, *A.conyzoides* ($2.12 \text{ cm}^2 \cdot \text{m}^{-2}$) in winter and summer, for *A.conyzoides* ($3.03 \text{ cm}^2 \cdot \text{m}^{-2}$) has been recorded with the highest basal cover whereas other species showed moderate basal cover in all the season.

Diversity Indices

The maximum Shannon-Weiner was observed for tree saplings viz., 1.679, Simpson Index was maximum observed for tree species (0.446), Margalef Index was a maximum recorded gain for Tree species (2.584) and Jaccard Index was for saplings (0.770). For herbaceous vegetation maximum value Shannon-Weiner in summer (2.46), Simpson Index in summer (0.07), Margalef Richness index in the rainy season (3.98), and Jaccard index was maximum in rainy and summer (0.87). Moderate diversity indices value was recorded for shrubs in the forest stand of Sal.

Regeneration Pattern

A comparison was made for the relative distribution of the total number of individuals in different girth classes. It was observed from the site that, trees girth class-wise density was highest was recorded for <10 cm diameter in comparison to other diameter classes. The density of the seedlings was highest ($6600 \text{ ind. ha}^{-1}$) followed by the trees ($3825 \text{ ind. ha}^{-1}$) and saplings ($1525 \text{ ind. ha}^{-1}$). Maximum species showed new regeneration (39.13 %) followed by 17.39 % each by good and fair regeneration and 13.04% for each poor and no regeneration.

Soil Nutrients Dynamics

The pH value varied from 5.35 ± 0.02 - 5.53 ± 0.04 which was the maximum observed in a deep layer in the study site. The value of organic carbon varied from $1.27 \pm 0.01\%$ - $1.33 \pm 0.05\%$ which was highest recorded in the top layer of the soil whereas nitrogen varied from $0.23 \pm 0.008\%$ - $0.27 \pm 0.005\%$ in which maximum content of nitrogen was also recorded in the top layer of soil. The value of Phosphorus varied from $10.33 \pm 0.88 \text{ kg. ha}^{-1}$ - $19.33 \pm 0.88 \text{ kg. ha}^{-1}$ which was highest recorded in the deep layer of the soil. Potassium varied from 165.55 ± 0.70 - 245.63 ± 0.86 which was maximum recorded in the uppermost layer of soil. The status of micronutrients for Boron was maximum observed in the upper and middle

layer while the level of manganese and molybdenum didn't vary significantly in all the studied three layers. On the other hand, copper was altogether absent in the upper, middle, and lower layers. The whole strata of sal have been observed with sandy loamy texture in which sand covered the maximum content (64.86 %) of the texture in the top layer of the soil. ANOVA showed that pH, nitrogen, organic carbon, phosphorus, and potassium of soil vary significantly ($P < 0.05$) among all the study sites.

The longest individual rarefaction curve of plant species reveals the maximum number of individuals in that strata. The longest individual rarefaction of seedlings species in Sal stand revealed that the highest number of individuals followed by trees and saplings (Fig. 3). Whereas for shrubs and herbs, the longest individual rarefaction curve has been observed for herbs in the rainy season followed by winter and summer seasons, and then for shrubs (Fig. 4). On the other hand, the diversity profile of plant species based on

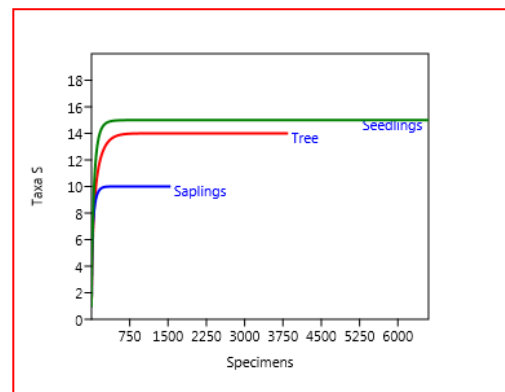


Fig. 3: Individual rarefaction curve of tree, seedlings and saplings in the Sal forest stand.

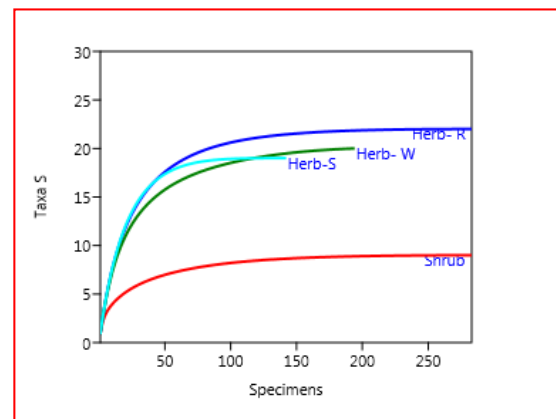


Fig. 4: Individual rarefaction curve of shrubs, herbs in rainy, winter, and summer in the Sal forest stand.

Table 1: Tree species composition of Sal forest along with ecological parameter.

Species	Family	D.ha ⁻¹	TBC	IVI
<i>Shorea robusta</i>	Dipterocarpaceae	208.25	43.65	179.35
<i>Mallotus philippensis</i>	Euphorbiaceae	41.65	0.60	35.08
<i>Aegle marmelos</i>	Rutaceae	6.25	0.10	14.25
<i>Listea chinensis</i>	Lauraceae	10.25	0.12	13.82
<i>Naringi crenulata</i>	Rutaceae	10.25	0.18	12.23
<i>Ehretia laevis</i>	Ehertiaceae	16.66	0.48	11.45
<i>Cassia fistula</i>	Fabaceae	6.25	0.27	7.70
<i>Ficus religiosa</i>	Moraceae	6.25	0.90	7.33
<i>Erythrina indica</i>	Fabaceae	2.08	0.19	4.49
<i>Miliusa velutina</i>	Annonaceae	2.08	0.07	4.28
<i>Holoptelea integrifolia</i>	Ulmaceae	2.08	0.13	2.66
<i>Schleichera oleosa</i>	Sapindaceae	2.08	0.06	2.50
<i>Crateva religiosa</i>	Capparaceae	2.08	0.04	2.46
<i>Legestromia parviflora</i>	Lythraceae	2.08	0.01	2.41

D/ha = Density/hectare, TBC= Total basal cover, IVI= Importance value index

the number of species revealed seedlings with the highest number of species followed by trees, saplings in the sal stand (Fig. 5), whereas, for herbs, the highest diversity profile was observed in the rainy season followed by summer and then winter in the study area (Fig. 6).

DISCUSSION

The richness of species in sal forest was quite high (208 species in 24 ha) as compared to those of central India (Jha & Singh 1990) but less than 208 plant species (Pandey & Shukla 2003). In the present study, the total number of tree

species was 64, which is much higher in number than that of the sal forest of eastern Himalayas (Uma Shankar 2001). In all of the above-mentioned studies of sal forest, the sampled area was a small variable which ranged from 0.2 to 2.9 ha. The present study of Sal forest is because of much greater diversity and the number of species of herbs and shrubs. The number of herbs and shrubs was quite high in the core of the tiger reserve as compared to the periphery of the reserve. This might be because lesser numbers of activities were observed in the core area of the Rajaji tiger reserve. Further, the canopy gaps of the sal forest in the Rajaji tiger reserve decrease as the periphery of the forest increases. A similar

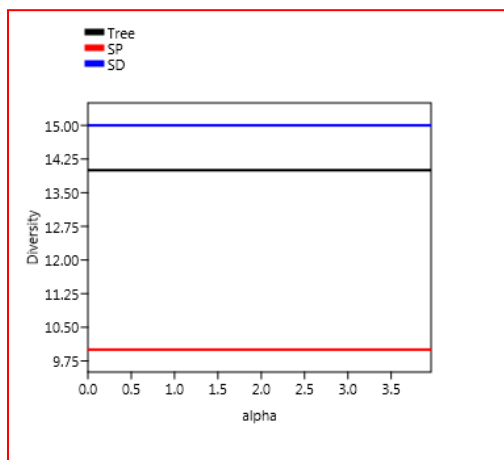


Fig. 5: Diversity Profile of tree, saplings, and seedlings.

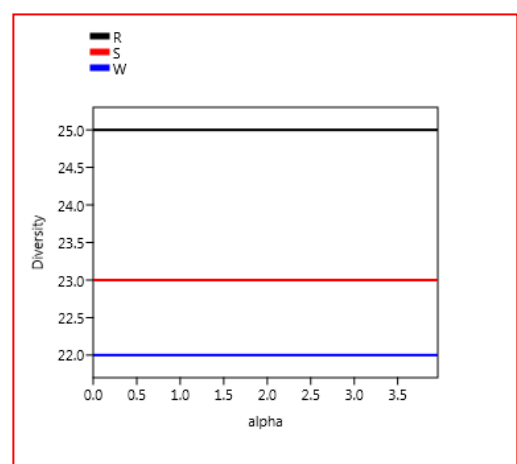


Fig. 6: Diversity Profile of herbs in rainy, winter, and summer.

Table 2: Sapling species composition of Sal forest along with ecological parameter.

Species	Family	D.ha ⁻¹	TBC	IVI
<i>Ehretia laevis</i>	Ehretiaceae	5000.0	12.25	102.71
<i>Listea chinensis</i>	Lauraceae	2083.2	7.73	46.79
<i>Mallotus philippensis</i>	Euphorbiaceae	2083.2	6.18	46.44
<i>Shorea robusta</i>	Dipterocarpaceae	1041.6	4.78	31.09
<i>Naringi crenulata</i>	Rutaceae	1250	3.85	30.36
<i>Aegle marmelos</i>	Rutaceae	416.5	1.68	14.70
<i>Salix alba</i>	Saliaceae	208.32	1.20	8.32
<i>Phyllanthus embilica</i>	Phyllanthaceae	208.32	1.04	7.85
<i>Crateva religiosa</i>	Capparaceae	208.32	0.32	6.04
<i>Trewia nudiflora</i>	Euphorbiaceae	208.32	0.20	5.71

Table 3: Seedling species composition of Sal forest along with ecological parameter.

Species	Family	D.ha ⁻¹	TBC	IVI
<i>Mallotus philippensis</i>	Euphorbiaceae	287.5	251.76	119.20
<i>Ehretia laevis</i>	Ehertiaceae	108.32	158.61	67.64
<i>Naringi crenulata</i>	Rutaceae	16.65	28.36	20.13
<i>Randia longspina</i>	Rubiaceae	14.57	64.01	19.54
<i>Aegle marmelos</i>	Rutaceae	33.33	6.48	8.91
<i>Legerstroemia indica</i>	Lythraceae	14.58	6.84	9.01
<i>Syzygium cumini</i>	Myrtaceae	12.5	3.98	8.10
<i>Schleichera oleosa</i>	Sapindaceae	8.33	7.0	7.90
<i>Phyllanthus embilica</i>	Phyllanthaceae	10.25	2.08	7.35
<i>Cedrela toona</i>	Meliaceae	8.33	2.65	7.10
<i>Legerstroemia parviflora</i>	Lythraceae	8.33	1.03	6.80
<i>Ficus benghalensis</i>	Moraceae	8.33	5.01	5.83
<i>Cassia fistula</i>	Fabaceae	6.25	0.49	4.62
<i>Holoptelea integrifolia</i>	Ulmaceae	4.15	0.33	4.21
<i>Morus alba</i>	Moraceae	6.25	4.48	3.65

interpretation was revealed by the study of Chandrashekara and Ramakrishnan (1994) while studying the forest structure of the Indian Western Ghat. The understory vegetation of the area was dominated by many shrubs like *L.camara*, *H.iso- ra*, *C.viscosum*, *Zizyphus zujupa*, etc. Lianas like *Bauhinia vahlii* were most commonly observed towards the periphery whereas the herbs were less in comparison to the core area of the tiger reserve. The present interpretation is in sharp contrast with the study of Singh and Singh (1987) in the Central Himalayan region of India where the undergrowth of Sal is herbaceous. Further, the total number of species was

higher than that of the sal forest of Doon Valley (Pandey & Shukla 2001). The richness of species observed in sal forest was 2.58 for trees, 2.19 for saplings, and 2.51 for seedlings which was almost similar to the earlier studies (Saklani et al. 2018a, b,c,d; 2019) from the forest stand of *Holoptelia integrifolia*, *Dalbergia sissoo*, *C.fistula* and *Trewia nudiflora* in Chilla forest range of the tiger reserve but much lower than that the study of (Pandey & Shukla 2001). This might be due to the anthropogenic pressures by Gujjars and their cattle which destroyed, trampled and scraped the vegetation in the study area. Although the overall regeneration for other

Table 4: Shrub species composition of Sal forest along with ecological parameter.

Species	Family	D.ha ⁻¹	IVI
<i>Lantana camara</i>	Verbenaceae	1766.66	57.62
<i>Murraya koenighii</i>	Rutaceae	1033.33	52.79
<i>Clerodendrum viscosum</i>	Laminaceae	1766.66	49.18
<i>Ziziphus jujuba</i>	Rhamnaceae	816.67	37.48
<i>Colebrookea oppositifolia</i>	Laminaceae	483.33	34.66
<i>Adatoda vesica</i>	Acanthaceae	300.0	21.91
<i>Asclepias curassavica</i>	Apocynaceae	450.0	17.91
<i>Calotropis gigantea</i>	Apocynaceae	100.0	7.71
<i>Helictres isora</i>	Malvaceae	150.0	7.39
<i>Desmodium ganeticum</i>	Fabaceae	66.67	5.04
<i>Calotropis procera</i>	Apocynaceae	83.33	4.16
<i>Cassia occidentalis</i>	Fabaceae	33.33	4.16

Table 5: Herbs species composition of Sal forest along with ecological parameter.

Species	Family	Rainy		Winter		Summer	
		D.m ⁻²	IVI	D.m ⁻²	IVI	D.m ⁻²	IVI
<i>Kyllinga monocephala</i>	Cyperaceae	40.27	17.0	33.3	17.54	38.88	24.53
<i>Ageratum conyzoides</i>	Asteraceae	84.72	52.59	56.94	48.87	90.27	70.14
<i>Adiantum spp</i>	Pteridaceae	55.55	20.01	56.94	27.47	6.25	25.72
<i>Cyprus rotundus</i>	Cyperaceae	30.55	13.39	22.22	12.23	27.77	18.82
<i>Achyranthus aspera</i>	Amaranthaceae	51.38	48.45	27.77	34.36	-	-
<i>Bidens pilosa</i>	Asteraceae	26.38	11.12	9.72	3.66	27.77	17.43
<i>Amarantus spinosus</i>	Amaranthaceae	6.94	4.43	9.72	4.99	-	-
<i>Aerva sanguinolenta</i>	Amaranthaceae	48.61	22.08	33.33	14.32	-	-
<i>Oxallis corniculata</i>	Oxallidaceae	29.16	11.89	19.44	9.33	34.72	19.3
<i>Tephrosia purpurea</i>	Fabaceae	1.38	1.01	-	-	-	-
<i>Abutilon indicum</i>	Malvaceae	0.15	6.19	25	11.99	-	-
<i>Oxallis debilis</i>	Oxallidaceae	1.3	1.01	12.5	6.06	1.38	1.38
<i>Cleome viscosa</i>	Capparaceae	13.88	13.58	13.88	18.94	20.83	28.01
<i>Euphorbia hirta</i>	Euphorbiaceae	9.72	6.09	13.88	9.96	9.72	8.31
<i>Ichnocarpus frutescens</i>	Apocynaceae	9.7	4.78	19.44	11.06	-	-
<i>Cassia tora</i>	Fabaceae	20.83	9.84	20.83	13.02	-	-
<i>Stellaria media</i>	Caryophyllaceae	5.55	2.69	-	-	-	-
<i>Cissampelos pareira</i>	Memispermaceae	45.83	15.03	-	-	-	-
<i>Christella dentata</i>	Thelpteridaceae	20.83	9.52	22.22	12.22	-	-
<i>Blumea mollis</i>	Asteraceae	16.66	8.64	16.66	8.99	16.66	12.73
<i>Portulaca grandiflora</i>	Portulacaceae	8.33	4.84	8.33	5.67	8.33	6.25
<i>Urena lobata</i>	Malvaceae	8.33	5.2	-	-	-	-
<i>Polygonum spp.</i>	Polgonaceae	11.11	4.87	20.83	10.96	20.83	13.04
<i>Lygodium flexuosum</i>	Lygodiaceae	6.94	3.70	-	-	6.94	5.91
<i>Commelina benghalensis</i>	Commelinaceae	2.77	1.95	-	-	2.77	2.67
<i>Mimosa pudica</i>	Fabaceae	-	-	6.94	2.76	6.94	3.85
<i>Oxallis latifolia</i>	Oxallidaceae	-	-	27.77	13.10	34.722	39.10
<i>Boerhavia diffusa</i>	Nyctaginaceae	-	-	2.77	2.51	2.77	2.76
Total		572.22	299.99	480.46	300.0	413.87	300.0

Table 6: Summary of the species inventory in Sal forest.

	Trees	Saplings	Seedlings	Herbs			Shrubs
				R	W	S	
Number of genera	14	10	15	24	25	16	11
Number of families	13	08	12	15	15	14	8
Basal area (m ² .ha ⁻¹)	46.61	39.23	543.11	11.05	7.50	8.38	1.69
Stand density (stems ha ⁻¹)	318.29	12707.8	547.67	572.21	480.46	413.82	7049.98
Shannon-Weiner index	1.350	1.774	1.679	2.8	2.36	2.46	1.96
Simpson index	0.446	0.214	0.321	0.06	0.06	0.07	0.17
Margalef Richness index	2.584	2.19	2.51	3.98	3.59	3.38	1.81
Jaccard Evenness index	0.511	0.770	0.620	0.87	0.76	0.87	0.79

Seedlings basal cover* = cm².ha⁻¹, Herb density* = D.m⁻², Herb basal cover* = cm².m⁻²

Table 7: Chemical parameters of soil under Sal forest.

Depth (cm)	OC (%)	N (%)	P kg/ha)	K (kg/ha)	pH
0-10	1.33±0.005	0.27±0.005	10.33±0.88	245.63±0.86	5.36±0.01
15-25	1.32±0.01	0.24±0.005	14.41±0.50	165.55±0.70	5.35±0.02
30-40	1.27±0.01	0.23±0.008	19.33±0.88	195.35±0.65	5.53±0.04

OC = organic carbon, N = nitrogen, P = phosphorus, K = potassium

Table 8: Textural parameter of soil under Sal forest in different depth.

Depth (cm)	Texture	Sand (%)	Silt (%)	Clay (%)
0-10	Sandy loam	64.86	27.02	8.10
15-25	Sandy loam	52.63	42.10	5.26
30-40	Sandy loam	50	45	5

Table 9: Micronutrients analysis of soil under Sal forest.

Depth (cm)	Micronutrients (ppm)				
	Cu	Mo	Mn	Fe	B
0-10	-	0.0-0.05	0.2-1.0	-	>2.0
15-25	-	0.0-0.05	0.2-1.0	-	>2.0
30-40	-	0.0-0.05	0.2-1.0	-	2.0

Cu = copper, Mo = molybdenum, Fe = iron, B = boron

species in the study area is fairly good, the main species *S.robusta* has shown no regeneration. It was observed that the plant species which showed poor and no regeneration in a forest stand, might show good and fair regeneration in the other sites of the study area. Similar result was observed in our earlier study (Saklani et al. 2018c, 2019) in six different sites of the Chilla forest division of the tiger reserve. Nil and poor regeneration could be due to the various anthropogenic activity such as grazing, lopping, scraping, and trampling.

Overgrazing harms the ground flora and inversely affects the regeneration pattern of the species. Many researchers like Ballabha et al. (2013) pointed out the factor like lopping, grazing, fires adversely affecting the regeneration pattern of species in Western Himalaya.

The physico-chemical property of soil always determines the status of nutrients in the soil which may change according to the type of vegetation, the climatic condition of the area (Rundel 1989). Disturbances like trampling, grazing,

scraping, and looping are the main pressures that affect the dynamism and upsetting cycling of nutrients in a forest as these pressures influence the physico-chemical property of soil in a forest [Knight 1975]. It was observed from the study area that organic carbon ($1.27 \pm 0.01\%$ - $1.33 \pm 0.05\%$), nitrogen ($0.23 \pm 0.008\%$ - $0.27 \pm 0.005\%$), and potassium ($0.23 \pm 0.008\%$ - $0.27 \pm 0.005\%$) and all the studied micronutrients like copper, molybdenum, iron, boron were maximum recorded in the top layer (0-10 cm) of the soil except for pH (5.35 ± 0.02 - 5.53 ± 0.04), and phosphorus (10.33 ± 0.88 $\text{kg} \cdot \text{ha}^{-1}$ - 19.33 ± 0.88 $\text{kg} \cdot \text{ha}^{-1}$) which was maximum found in the deep layer (30-40cm). Optimum organic carbon and nitrogen support the diversity status and regeneration potential of *S. robusta*, *M. philippensis*, *C. fistula*, etc. The nutrients status from the present study can be comparable with Bharti and Kamboj (2018) from the Haridwar forest division of Uttarakhand whose values of the physico-chemical parameter were more or less similar to the present study. The maximum amount of soil nutrients in the top layer could be due to the accumulation of the huge amount of organic matter which makes humus in the top layer. So good and fair regeneration potential of the species was observed in the sal forest. High nutrients in the lower layer are sometimes fascinated by the downwards movement of the particles of soil transfer of various nutrients of soil to the lower layer (Sukumar 1992).

The assessment of soil nutrients dynamics, diversity, and the regeneration pattern of the tree species are important for conservation, management as well as for their sustainable utilization. The present study area is rich in trees along with their saplings and seedlings except for the seedlings of Sal. Overall regeneration potential is fairly good but in some areas, there is a poor regeneration pattern of species due to anthropogenic activities. So, it is necessary to give sufficient time to the forest to reduce pressure. Therefore, the seedlings of Sal have much time established and reach the mature stage. Further, closing each compartment of the sal forest that is close to the residing locals would be the best strategies to provide vegetational regeneration. Enrichment planting in the closed compartment of Sal forest with useful species will also favor the best regeneration of species in the area.

Enhancement of Sal Forest Through Management and Species Regeneration

The management of the sal forest has played a significant contribution in the conservation of forest wildlife in the Rajaji tiger reserve. Effective and sustainable forest management of sal requires the various functions of forests which can be considered across various stands. The main objective for sal forest management is to fulfill the goals associated with

forest and requirements of the current generation and to meet their various needs. The different participatory approaches for degraded sal management are woodlot management, agroforestry, and coppice management (Alam 2006, Safa 2004). Another significant approach for the management of sal forests is the establishment of ecotourism areas. In the Rajaji tiger reserve, many ecotourism spots have already proved to be an effective tool for the management of forest communities in the area. The three aspects of ecotourism are conservation of nature along with the natural resources, participation of local inhabitants, and sustainable management of resources so that profits can be gained. The main objectives of the conservation and participatory sal coppice cannot be achieved until these strategies are aimed at reducing the rate of the vulnerability of sal stands from denudation and encroachment. For the management of forests, there are ample opportunities for the official Rajaji tiger reserve and the government in terms of woodlots and agroforestry. Local villagers and Gujjars of the tiger reserve are still using implemented small-scale agroforestry and land management which has contributed to a green economy through sustainable and renewable management of the forest inside the tiger reserve.

In the present study, it was observed that the sal forest in Chilla is fully mature as there was a lack of seedlings and saplings in the stand. Direct use of sal by local people or tribal people associated with this forest or indirect effects of their activities in past, e.g. grazing, fire, or litter collection are responsible for lack of sal saplings and seedlings. The forest of the sal stand was planted along with the natural stand about many years ago. The earlier emphasis of policies and management plans of sal forest was on increasing productivity by creating high value of timber stock through clear-felling the existing natural stands followed by artificial regeneration with exotics or fast-growing species. The financial strategies were overcome by strict implementation of the Wildlife Act, 1972, but there is, at times, less concern for the livelihoods of ethnic and local communities. Further, where possible, replanting and filling with *S. robusta* and its associated species like *M. philippensis*, *Terminalia chebula*, *Terminalia bellerica*, *Acacia catechu*, *Bombex ceiba*, *Albizia lebeck*, *Lagerstroemia parviflora* and *Cassia fistula* must be examined every year. The sal forest harbors a wide variety of medicinal plants, so protection and identification of species, and detailed study of medicinal plants of the forest are also required.

The forest of sal is a natural home for *S. robusta*, so greater attention should be on its increasing productivity rather than the replacement of other plant species. Sal coppice could be much productive than the block plantation per hectare (Rahman et al. 2005). First, in the Rajaji tiger reserve, agro-

Table 10: Stumps density (stump.ha⁻¹) regeneration status of woody species in a Sal Stand.

Species	Density (Ind./h)			
	TR	SP	SD	RS
<i>Shorea robusta</i>	2500	125		Poor
<i>Holoptelea integrifolia</i>	25	-	50	Fair
<i>Cedrela toona</i>	-	-	100	New
<i>Alstonia scholaris</i>	-	-	-	-
<i>Naringi crenulata</i>	125	150	200	Good
<i>Cassia fistula</i>	75	-	75	Fair
<i>Mallotus philippensis</i>	500	250	3475	Good
<i>Ehretia laevis</i>	200	600	1300	Good
<i>Oroxylum indicum</i>	-	-	-	-
<i>Listea chinensis</i>	125	250	-	Poor
<i>Terminalia bellirica</i>	-	-	-	-
<i>Ziziphus oenoplia</i>	-	-	-	-
<i>Aegle marmelos</i>	75	50	400	Good
<i>Crateva religiosa</i>	25	25	-	Poor
<i>Syzygium cumini</i>		-	150	New
<i>Ficus religiosa</i>	75	-	-	No
<i>Adina cordifolia</i>	-	-	-	-
<i>Morus alba</i>	-	-	75	New
<i>Celtis australis</i>	-	-	-	-
<i>Ficus palmata</i>	-	-	-	-
<i>Dalbergia sissoo</i>	-	-	-	-
<i>Trewia nudiflora</i>	-	25	-	New
<i>Cordia dichotoma</i>	-	-	-	-
<i>Phyllanthus emblica</i>	-	25	125	New
<i>Butea monosperma</i>	-	-	-	-
<i>Psidium guajava</i>	-	-	-	-
<i>F. Glomerata</i>	-	-	-	-
<i>Legerstroemia indica</i>	-	-	100	New
<i>Acacia spp.</i>	-	-	-	-
<i>Melia azadirachta</i>	-	-	-	-
<i>Acacia catechu</i>	-	-	-	-
<i>Pterospermum acirifolium</i>	-	-	-	-
<i>Caliandra haematocephala</i>	-	-	-	-
<i>Bombex ceiba</i>	-	-	-	-
<i>Bauhinia variegata</i>	-	-	-	-
<i>Holarrhena pubescens</i>	-	-	-	-
<i>Salix alba</i>	-	-		New

Table Cont....

Species	Density (Ind./h)			
	TR	SP	SD	RS
<i>Azadirachta indica</i>	-	25	-	-
<i>Schleichera oleosa</i>	25	-	100	Fair
<i>Eugenia oogenesisis</i>	-	-	-	-
<i>Delonix regia</i>	-	-	-	-
<i>Putranjiva roxburghii</i>	-	-	-	-
<i>Legerstroemia parviflora</i>	25	-	175	Fair
<i>Erythrina indica</i>	25	-	-	No
<i>Millusa velutina</i>	25	-	-	No
<i>Randia longspina</i>	-	-	175	New
<i>Ficus benghalensis</i>	-	-	100	New

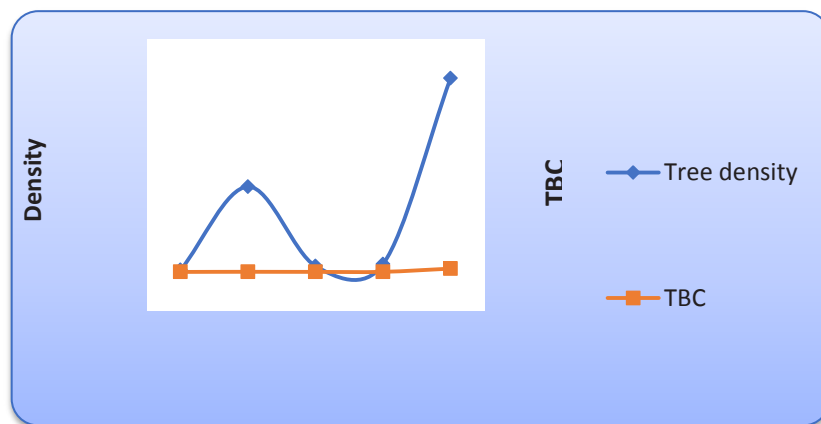


Fig.7: Trees stand density (Ind.ha) and total basal cover ($\text{m}^2.\text{ha}^{-1}$) on different girth classes (in cm) in Sal stand.

forestry should be given priority as far as the management of sal is concerned. Second, woodlots could be another better approach for conservation initiatives. Agroforestry is more viable and reliable than woodlot management in terms of budget (Safa et al. 2004). Regeneration of sal has been a serious issue in its management in different parts of India. The management of sal forest was initiated in the past few centuries which did not get the successful output. A different study suggested high soil water and poor aeration of soil are responsible for the poor regeneration pattern in sal (Hole 1921). High water in the soil is related to precipitation or drought whereas poor aeration of soil is caused by high rainfall and the dried leaves of sal as well as the grazing of animals (Troup 1986). Although dried leaf provides humus to the soil which provides essentials nutrients like N, P, and K, bad aeration to such soil is injurious. The study of Sukumar (1992) also had argued that deficient or poor aeration during

monsoon seasons and compaction of soil in the dry season, and unfavorable topographic localities are responsible for failure in sal regeneration. The important character of sal is it tends to grow and regenerate as a mass of seedlings in favorable conditions of soil, light, and good drainage of moisture (Rautiainen & Suoheimo 1997). Troup (1986) also had explored the mechanical effects of leaf litter on the seedling formation of sal by experiment and recorded that seed germinated on a layer of dead leaves under good light and moisture content with good drainage of the area. Sometimes vigorous growth of seedlings could be achieved by the complete removal of the overhead canopy (Troup 1986).

It was further observed that only a little portion of seedlings (about 4 %) of the sal-dominated forest has been recorded with seed origin and the rest were originated from coppice seedlings (Suoheimo et al. 1999), which reveals the strength of coppice origin in sal regeneration. Moreover,

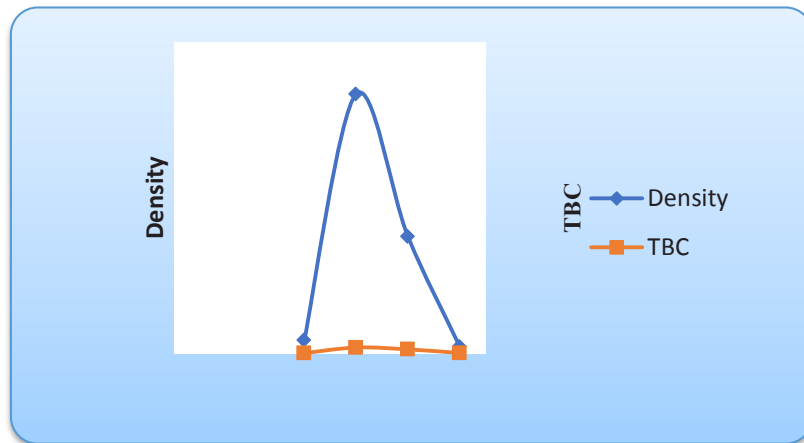


Fig. 8: Saplings density (Ind.ha⁻¹) and total basal cover (m².ha⁻¹) on different girth classes (in cm) in Sal stand.

the perennating character of sal enables it to coppice the unnecessary shoots and felling back which repeats year by year and allows the forest to regenerate. Various young sal shoots of uniform height developed from roots which had survived in the ground due to the protection against grazing of animal (Jackson 1994). In the Rajaji tiger reserve, similar conditions were observed but the poor regeneration of sal is the main problem.

CONCLUSION

Western Himalaya covers the huge stand of sal forest providing essential ecosystem services for livelihood and has a significant role in the performance of different ecological functions. Rajaji tiger reserve which is an important part of Western Himalaya is dominated by *H. integrifolia*, *D. sissoo*, *S. robusta*, *C. fistula*, and *T. nudiflora* and co-dominated with *M. philippensis*, *T. nudiflora*, *H. pubescens*, *A. cordifolia*, *P. emblica*, etc. The result of the present study revealed that the sal stand has a great diversity of 64 species. A huge canopy of trees in sal stands also provides ample nutrients in the soil which further support the growth of ground flora. It was also observed that soil parameters like pH, organic carbon, total nitrogen, available potassium, available phosphorous favor the growth of various species in sal forest. It was also concluded that the sal forest in Chilla is fully mature as there was a lack of seedlings and saplings in the stand. So, the management of sal stands through regeneration could be an important point for improving the overall diversity status of *S. robusta* in the present study area. Further, the involvement of the community in the conservation of sal should be implemented in the tiger reserve so that in the natural stand of sal, many non-wood forest products can be sustainably used by the locals.

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