

Diversity and Distribution Pattern of Associated Plant Species Among Different Forest Types of Gorakhpur Division, India

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ABSTRACT

The three different forests of Gorakhpur Division viz. mixed forest, sal forest and teak forest were observed for the distributional pattern, density and diversity of medicinal plants. A total of 168 plant species representing 136 genera and 63 families were recorded. The study envisaged that higher concentration of socioeconomic plant species was noticed in mixed forest followed by sal forest. In Teak forest the concentration of associated plants was least. In mixed forest, the trees like *Mallotus philippensis*, *Schleichera oleosa*, *Holarrhena antidysenterica*, *Bridelia retusa* and *Terminalia tomentosa* showed quite abundant population. On the other hand, trees like *Casearia tomentosa*, *Antidesma ghaesembilla*, *Flacourtia indica*, *Carissa spinarum*, and *Cassia fistula* were quite frequent as sprouts in mixed forests as compared to sal forests. The most abundant family in all forest type was Papilionaceae. In sal perennial herbs are most dominated and uniformly distributed. The common sal associates, which are generally used by local people includes *Clerodendron infortunatum*, *Desmodium* spp., *Curculigo orchoides*, *Elephantopus scaber*, *Dioscorea bulbifera* and *Holarrhaena antidysenterica*. While the species diversity and evenness index were almost similar for mixed forest ($H' = 3.16 \pm 0.14$, $J = 0.89$) and sal forest ($H' = 3.14 \pm 0.17$, $J = 0.81$), teak ($H' = 3.20 \pm 0.26$, $J = 0.76$) was less diverse. Study on floristic composition and diversity status of regional forest may provide some clues to make the proper management practice and also in efforts for conservation of medicinal plants of the region.

Key words: Sal, Teak, Mixed forest, diversity, distribution pattern.

INTRODUCTION

Forest wealth is judged by its community structure and diversity pattern of associated plant species. Tropical and sub-tropical forest cover only 7% land surface area but occupy the more than 50% species of the world (May and Stumpf 2000). Tropical forest of the world is being degraded due to increasing various anthropogenic activities. The regional belt of sal (*Shorea robusta* Gaertn.) forest has been converted to plantation forests of different types during the past seven decades. Though Sal has been the first choice, stands of Teak (*Tectona grandis* Linn.) Sal- Teak combination and those of few fast-growing timber trees are also available on suitable sites (Pandey and Shukla 2003). The interspersed patches of mixed natural forests are mostly the remains of old Sal forests which were felled leaving a few scattered Sal trees (Shukla and Pandey 2020). The site, left for natural regeneration without any significant management practices, developed into natural forest. These patches are, however, limited mostly to core region i.e. far away from human

settlements and serve as “seed bank” of medicinal plant species for the entire landscape. Now a days full attention is given to protect the associated plants of the region. The analysis of diversity indices and community structure of sal forest is ecologically significant because of the richness of medicinal and economically important plants (Dutta and Devi 2013). The associated plant species have been reported to be an important component of forest ecosystems and play a significant role in economics of locals (Rao et al. 2016). The importance of socioeconomic plant species to locals is well known but the diversity and distribution of these species is under threatened due to past recurrent disturbance (Pandey and Shukla 1999, 2019). Plant community is characterized by the composition of associated plant species. Different types and levels of disturbance have a pivotal role in species distribution, diversity and community pattern (Connell 1978, Sagar et al. 2003). Anthropogenic disturbance has been reported to change the forest structure and pattern of diversity in many other studies in India (Kushwaha and Nandy 2012, Tripathi and Shankar

2014, Chaturvedi et al. 2017, Kumar and Saikia 2020). Due to fast pace of disturbance sal forests of India has caused rapid declines in both density and diversity of associated species (Bhuyan et al. 2003, Pandey and Shukla 2003, Shankar and Tripathi 2017, Pandey and Shukla 2020).

Sal forest of the region is highly disturbed not only due to its higher timber value but also due to large scale extraction of non-timber forest products including fuelwood, medicinal plants and other minor forest products (Pandey and Shukla 2018, Shukla and Pandey 2020). The present study on the plant

diversity and distribution pattern of associated species in different forest type may not only provide information about their population status but also helpful in making the future planning for their sustainable use.

MATERIALS AND METHODS

Study area

The forested landscape of the region constitutes various plantation forests and mixed natural growth forests which has been dominated by moist semi-

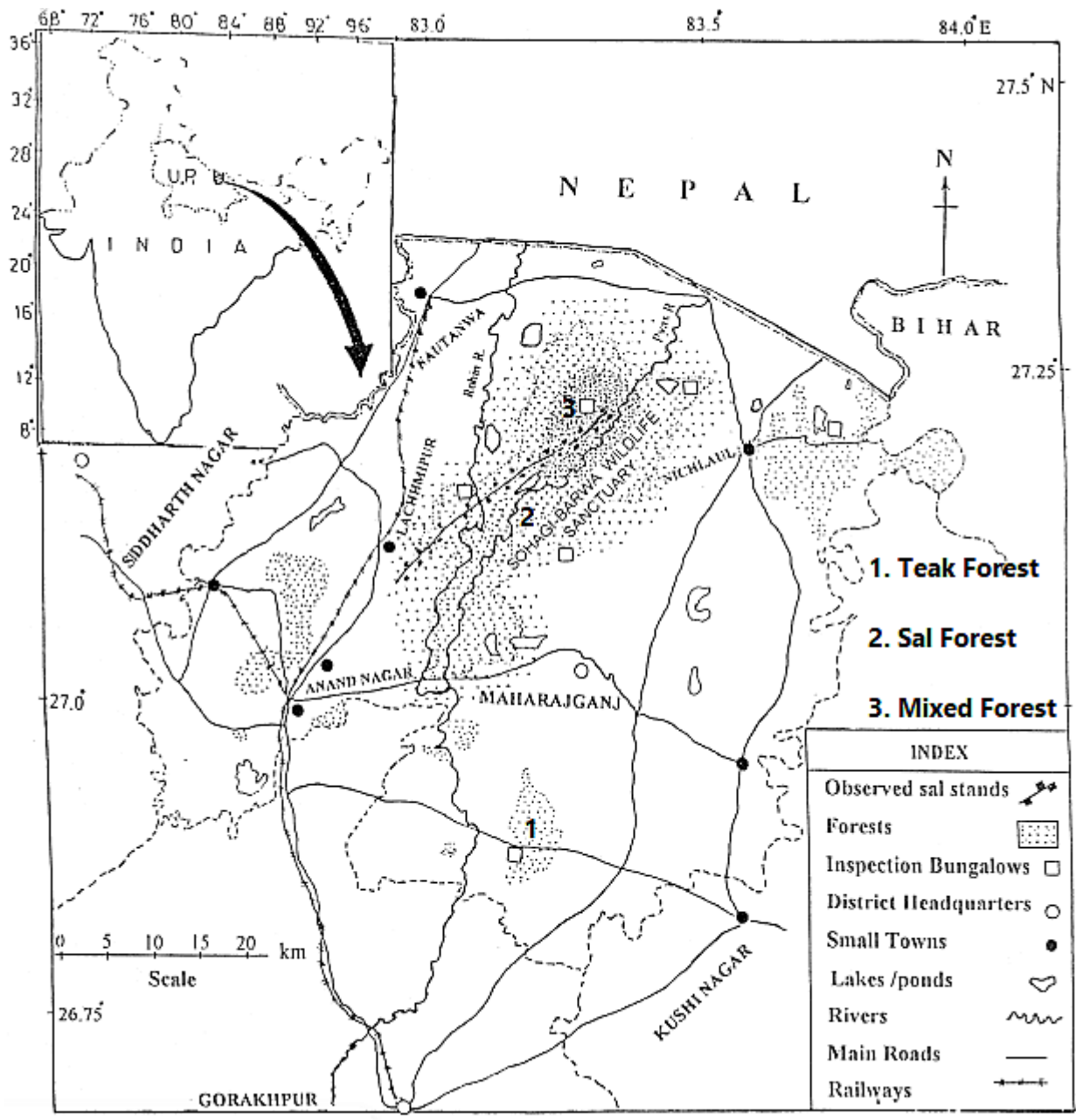


Figure 1. Study sites in the Gorakhpur Forest Division, India

evergreen component with few deciduous plant species (Champion and Seth, 1968) or tropical broad-leaved deciduous plantations (de Angelis et al. 1978). Most of the regional forests are developed through taungya plantations. Though sal has been the first choice, the teak (*Tectona grandis*) stands, sal-teak combination, Eugenia-stands and minor plantations of a few other fast-growing species are also there. The vegetation of the regional forested landscape was analysed taking into account almost all major sorts of communities spread over Gorakhpur Forest Division, lying between 27°05' to 27°40' N latitude and 83° 30' to 84° E longitude at about 95m elevation. The communities were generally named after the planted timber species dominating the overstorey. Most of the stands, identified for the analysis, were of 60±5 years age (Fig. 1). The plant diversity of regional forest is of very important due to rich is several components of socioeconomic plants species. Mixed forests of the region are sal forests with number of deciduous species situated in the patches situated far from human habitation.

Plot selection and methods

Total three forest stands were selected from three different forest types for the present study viz. mixed forest, sal forest and teak forest. One hectare-plot, each having average vegetation was selected for sampling. Each one ha (100 x 100 m) plot was divided into 100 quadrants of 10 x 10 m size. Individuals having girth below 31.5 cm were considered as sapling and their basal diameter was measured for computing the basal area. For the sampling of non-trees (<30 cm gbh), however, only 40 quadrants per hectare plot were sampled. The vegetal cover of herbs was also measured. The occurrence of individuals was expressed as per ha. The density and basal area of all tree species were calculated on the basis of all the 100 quadrants. Plant species, encountered in each quadrant were listed and identified (Srivastava 1976). The number of individuals of herbs, shrubs and climbers was counted and circumference of tree was measured at their breast height (1.37 m). Based on various phytosociological indices, such as frequency, density, cover (basal/vegetal), Relative density, Relative density, Relative vegetal cover, and Importance Value Index (IVI) was measured, through traditional

methods (Mueller-Dombois and Ellenberg 1974). Other indices like Abundance: Frequency Ratio (A/F ratio) and Family Importance Value (FIV) were calculated by method developed by Whitford (1948) and Mori et al. (1983), respectively. The dominance-diversity curve was drawn as a log normal distribution pattern (Magurran 2004). Diversity indices like Simpson's Dominance Index ($Cd = \sum pi^2$), Shannon's Diversity Index ($H' = -\sum pi \ln pi$) and Pielou's Evenness Index ($J = H'/\ln S$), were derived following Magurran (2004). The pattern of species distribution was based on Abundance: frequency ratio, while species status is derived on the basis of strength of individuals.

RESULTS

A total of 168 species belonging to 136 genera, under 63 families were recorded within three different forest types. The number of species, genera and family was much greater at mixed forest as compared to other two forests. The species/genus ratio was greater at teak forest, but the species /family ratio was maximum for mixed forest (Table 1). For general distribution pattern all the forest types followed the contagious trend. The mixed forest showed highest number of rare species. Teak and sal forest have 38 predominant species while mixed forest has 66 predominant species. Several species such as *Clerodendrum infortunatum*, *Echnocarpus fruticens* and *Aerva lanata* showed over-dominance at sal forest.

Species richness and family importance value (FIV)

Out of 63 families, 29 were present in all the three forest types of the region. Some families were quite species rich and contributing to the major share of plant species diversity of the region. Among these families Papilionaceae was most common and represented by 10 species in sal forest, 9 species in mixed and 4 species in teak forest. The other dominant family was Poaceae, which showed representative species in teak and 6 species in sal as well as mixed forest. Euphorbiaceae, show 7 in sal and 6 species in mixed forest. Families such as Passifloraceae, Solanaceae and Sterculiaceae were represented by single species and occurred only in

Table 1. Species composition and distribution characteristic of teak, sal and mixed forests of the region. The distribution status is based on the number of individuals, species were grouped into very rare (< 5 individuals), rare (5-14 individuals), common (15- 24 individuals), dominant (25-34 individuals) and predominant (> 35 individuals). Species distribution pattern was also examined through abundance/frequency (%) ratio and it was based into regular (< 0.025), random (0.025-0.5) and clumped (> 0.05).

Floristic attributes	Teak forest	Mixed forest	Sal forest
No. of species	37	92	74
No. of genera	29	84	67
No. of family	24	45	37
Tree density (Trees/ ha)	413 ± 17	428 ± 37	427 ± 28
Mean basal area (m ² /ha)	18.86	22.23	20.56
Species/genus ratio	1.28	1.09	1.10
Species/family ratio	1.54	2.04	2.0
Species distribution			
Regular	01	07	0
Random	17	33	10
Contagious	50	52	64
Distribution status			
Very rare	02	03	09
Rare	12	07	16
Common	11	12	08
Dominant	05	04	03
Predominant	38	66	38

teak forest. In sal forest Amaryllidaceae, Bignoniaceae, Dilleniaceae, Samydaceae and Zingiberaceae were represented but by single species. Family Papilionaceae shared 9.50% of total species content and contributes 8.20 and 23.73% of sum of FIV in teak, sal and mixed forest, respectively. In teak forest Passifloraceae, Solanaceae, and Sterculiaceae were monotypic and sharing only 2.00, 2.64 and 5.65% of FIV sum, respectively, like wise Amaryllidaceae, Bignoniaceae, Dilleniaceae, Samydaceae and Zingiberaceae were also represented by single species sal forest (Table 2).

Density, IVI and distribution pattern

The density (individuals/ha) and IVI of medicinal species varied markedly in different regional forest types. In sal forest *Mallotus philipensis* an undertree exhibited a density as high as 112 individuals per hectare. The planted trees and regenerated seedlings and saplings of the species reached around 3000 individuals per hectare. *Clerodendrum infortunatum* a potential medicinal undertree prevailing as shrub

showed very high dominance, individual density and IVI each forest types in the region. Among climbers, *Ichnocarpus frutescens* showed the greatest dominance in sal forest in terms of density and IVI. *Commelina benghalensis* proposed to be in most dense (density 848 individuals/ hectare and IVI 20.16) within teak forest stands. Plant species other than *Shorea robusta* showed clumped distribution at each of the three forests. Fourteen species showed rare to very rare occurrence. A number of species such as *Cyperus rotundus*, *Clerodendrum infortunatum*, *Diospyros tomentosa*, *Desmodium pulchellum*, *Holarrhena antidysenterica*, *Panicum indicum*, *Terminalia tomentosa* and *Zizyphus oenoplia* showed almost similar occurrence pattern at each forest types (Table 3). In general, habit wise species occurrence at different forest type reveals that herbs were considerable number in all the three forests while shrubs and trees were dominated in sal forest stand while climbers showed considerable diversity but only in mixed forest. Teak forest has least number of associated species of shrubs, trees

Table 2. Species richness and family importance value (FIV) of common families within teak, sal and mixed forests of the region

S. No.	Family	Species richness			FIV		
		Teak	Sal	Mixed	Teak	Sal	Mixed
1.	Acanthaceae	-	2	1	6.85	4.23	3.89
2.	Amaranthaceae	2	2	2	12.06	7.47	9.41
3.	Amaryllidaceae	-	1	-	-	2.53	-
4.	Anacardiaceae	-	3	3	-	94.73	5.59
5.	Annonaceae	-	1	-	-	2.48	-
6.	Apocynaceae	-	3	2	12.69	6.18	43.3
7.	Araceae	1	-	1	2.16	-	2.02
8.	Asclapiadaceae	-	1	1	-	1.94	2.21
9.	Asteraceae	2	4	4	8.78	10.98	10.8
10.	Bignoniaceae	-	1	-	-	2.43	-
11.	Caesalpiniaceae	1	3	3	16.38	5.73	10.7
12.	Combretaceae	-	2	-	2.75	3.28	-
13.	Commelinaceae	1	1	1	18.73	2.48	5.39
14.	Convolvulaceae	1	1	1	14.42	4.47	11.4
15.	Cucurbitaceae	1	1	1	4.42	2.19	1.45
16.	Cyperaceae	2	1	2	6.67	2.77	9.89
17.	Depterocarpaceae	1	1	1	1.78	5.54	9.64
18.	Dilleniaceae	-	1	-	-	1.15	-
19.	Dioscoreaceae	2	1	1	7.50	1.59	11.5
20.	Ebenaceae	1	1	1	1.53	2.07	1.94
21.	Ehretiaceae	-	-	1	-	-	2.09
22.	Euphorbiaceae	-	7	6	25.75	12.19	16.9
23.	Flacourtiaceae	-	1	1	3.51	1.65	1.54
24.	Lamiaceae	-	2	-	-	3.80	-
25.	Leeaceae	1	1	1	1.60	1.70	1.68
26.	Liliaceae	-	1	-	-	1.21	-
27.	Lygodiaceae	1	1	1	2.25	2.02	7.59
28.	Malvaceae	1	3	3	4.52	4.58	5.58
29.	Menispermaceae	2	2	2	15.44	5.54	14.4
30.	Moraceae	-	3	2	3.34	5.22	2.76
31.	Myrtaceae	-	2	2	-	2.59	2.77
32.	Ophiogloaceae	1	1	-	1.95	2.47	-
33.	Orchidaceae	-	1	1	3.13	1.55	7.05
34.	Papilionaceae	4	10	9	8.20	23.73	26.3
35.	Passifloraceae	1	-	-	2.00	-	-
36.	Piperaceae	-	1	1	-	1.69	3.04
37.	Poaceae	5	6	6	29	12.9	22.8
38.	Rhamnaceae	-	1	1	1.55	1.15	1.46
39.	Rubiaceae	-	3	3	2.13	4.18	4.97
40.	Rutaceae	-	1	1	-	1.125	1.39
41.	Samydaceae	-	1	-	-	1.777	-
42.	Sapindaceae	-	1	1	-	1.238	1.56
43.	Scrophulariaceae	1	4	2	23.69	16.42	4.80
44.	Smilacaceae	-	1	1	3.13	1.313	1.42
45.	Solanaceae	1	-	-	2.64	-	-
46.	Sterculiaceae	-	-	-	5.65	-	-
47.	Tiliaceae	1	1	2	22.56	3.218	7.27
48.	Verbenaceae	2	3	1	18.06	16.89	13.2
49.	Vitaceae	1	2	1	3.18	4.207	10.3
50.	Zingiberaceae	-	1	-	-	1.402	-

and climbers. The tree species were maximum in sal forest (Fig. 2).

Economically important species

Taungya and other villagers of the catchment area of regional use around 65 plant species as non-timber forest products (NTFP), for different purposes (Table 4). Most of the stands towards the periphery of regional forest are heavily disturbed due to large scale collection of NTFP, cattle grazing and trampling and the dry season fire. In general, species with good sprouting efficiency had fairly high extractable biomass at low to moderate disturbance level. On the basis of market price of the product (like tooth brushes, baskets etc.), the total value was quite impressive. Since a large chunk of this profit goes to the local poor who earn their livelihood by selling the products in the local market, these NTFPs, therefore, have considerable bearing on the local economy.

Species diversity pattern

Habit wise analysis of various forest communities indicates that the herbs were pre-dominant as compared to other habit groups such as climbers, shrubs and trees. As a result, the mean values of species diversity (H'), concentration of dominance (C_d) and evenness (E) were significantly different for different habit groups. The value of diversity indices for herbs was greater in teak forests. The diversity for shrubs and trees was highest for sal forest. The climbers showed considerable diversity but only in mixed forest (Fig. 3).

DISCUSSION

All the three forests differ from each other in a number of characteristics. However, the old aged undisturbed plantation forest mimics the mixed forest. This forest may be maintained as species rich as good as natural forests. These old aged undisturbed sal forest of the region have a good repository of various plant species (Pandey and Shukla 2003). The changes in the dominance of some families may probably be due to the levels of anthropogenic disturbances on different growth habits in different forest types. For example, the prevalence of papilionaceae in several disturbed sal forests has been

Table 3. Comparison of density/ hectare, IVI and general distribution pattern of common medicinal species of different habits within teak, sal and mixed forests

Plant species	Teak forest			Sal forest			Mixed forest		
	Density (/ha)	IVI	Distribution pattern	Density (/ha)	IVI	Distribution pattern	Density (/ha)	IVI	Distribution pattern
Trees									
<i>Cassia fistula</i>	09	2.79	Random	14	0.61	Clumped	48	1.32	Clumped
<i>Diospyros tomentosa</i>	6	0.36	Clumped	24	1.61	Clumped	27	1.93	Clumped
<i>Flacortia indica</i>	8	0.65	Clumped	36	1.56	Random	8	0.61	Clumped
<i>Mallotus philipensis</i>	13	3.73	Random	112	3.01	Random	96	6.47	Clumped
<i>Shorea robusta</i>	12	3.93	Regular	284	6.62	Clumped	384	12.3	Clumped
<i>Streblus asper</i>	4	0.50	Clumped	16	2.53	Random	24	0.64	Clumped
<i>Terminalia tomentosa</i>	12	1.58	Clumped	12	1.48	Clumped	24	3.53	Clumped
<i>Zizyphus oenopliaTect</i>	6	0.71	Clumped	40	0.19	Clumped	18	0.35	Clumped
<i>Tectona grandis</i>	312	11.8	Regular	12	1.50	Random	27	1.6	Random
Shrubs									
<i>Clerodendron indicum</i>	960	17.80	Clumped	5232	10.28	Clumped	5520	15.93	Clumped
<i>Desmodium pulchelum</i>	96	0.52	Clumped	1008	2.67	Clumped	416	2.24	Clumped
<i>Holarraena antidysentica</i>	28	1.29	Clumped	448	1.69	Clumped	1272	5.68	Clumped
<i>Moghania bracteata</i>	48	0.87	Clumped	1208	3.66	Random	152	1.25	Clumped
<i>Moghania chppar</i>	12	0.60	Clumped	672	2.45	Random	944	4.30	Clumped
Climbers									
<i>Bauhinia vahlii</i>	12	0.84	Clumped	264	1.54	Random	160	0.68	Clumped
<i>Cayratia trifolia</i>	26	2.61	Clumped	1000	3..56	Random	1040	11.85	Clumped
<i>Cissampelos pareiria</i>	5	9.33	Random	480	2.2	Random	520	10.20	Clumped
<i>Dioscorea bulbifera</i>	56	0.71	Clumped	320	1.76	Random	600	11.28	Clumped
<i>Ichnocarpus frutescence</i>	228	11.72	Clumped	1032	3.70	Random	3872	41.60	Clumped
<i>Lygodium spp.</i>	92	1.86	Random	456	2.16	Random	624	7.75	Clumped
<i>Smilax zaylenica</i>	52	1.17	Random	144	0.85	Random	32	0.32	Clumped
<i>Tiliacora acuminata</i>	204	8.12	Random	1664	4.33	Clumped	128	3.14	Clumped
Herbs									
<i>Achyranthus aspera</i>	120	4.21	Clumped	1024	4.01	Random	800	7.73	Random
<i>Aerva lanata</i>	544	9.50	Clumped	1680	5.35	Random	696	3.77	Clumped
<i>Commelina benghalensis</i>	848	10.16	Clumped	696	3.24	Random	848	16.98	Random
<i>Curculigo archioides</i>	88	3.10	Random	296	0.87	Clumped	1072	7.97	Clumped
<i>Cyperus rotundus</i>	40	0.18	Clumped	960	2.95	Clumped	1304	7.11	Clumped
<i>Desmodium gangaticum</i>	70	3.94	Clumped	776	3.48	Random	712	6.06	Clumped
<i>Elephantopus scaber</i>	36	2.02	Random	776	2.02	Clumped	1312	5.77	Clumped
<i>Evolvulus nummularis</i>	621	15.85	Clumped	1704	5.50	Random	4656	13.98	Clumped
<i>Panicum indicum</i>	44	13.87	Clumped	296	1.15	Clumped	280	1.87	Clumped
<i>Paspalum scrobiculatum</i>	384	2.02	Random	880	1.76	Clumped	408	3.19	Clumped
<i>Triumfetta pentandra</i>	720	21.87	Clumped	680	4.16	Regular	248	4.41	Clumped
<i>Vernonia cinerea</i>	152	0.81	Clumped	344	1.59	Random	80	0.50	Clumped

earlier reported (Pandey and Shukla 2001). The forest community constitutes a number of medicinal plant species of different growth habits, but the level of disturbance drastically changes the structure as well as diversity of the community. The trees and shrubs were dominant in mixed forests. However, the richness of herbs, were highest in teak. The species which regenerate only through seed are less likely

to maintain themselves in the community facing recurrent disturbances but the herbs can readily occupy these open spaces quickly (Raizada et al. 1998). The highly disturbed forests are secondary successional communities which provide more hospitable environmental conditions for many shade intolerant species (Bormann and Likens 1979). The annual medicinal herbs and several short-lived

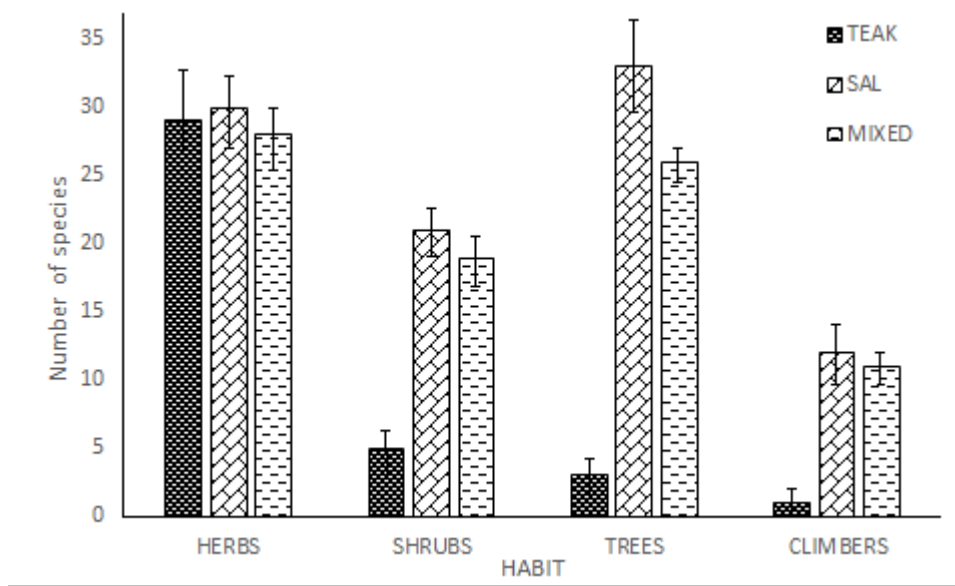


Figure 2. Number of species of different habit groups within teak, sal and mixed forests

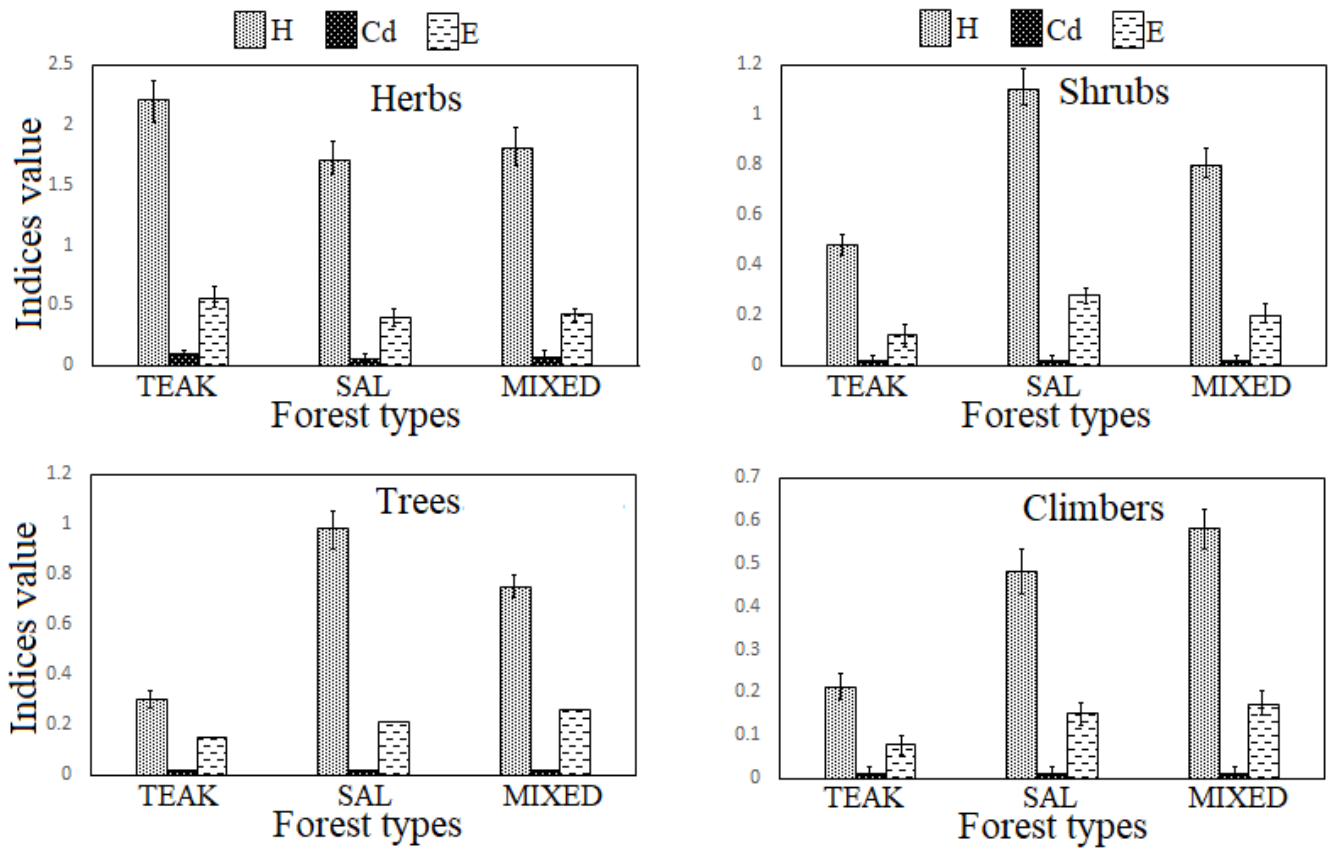


Figure 3. Comparison of diversity indices among different habit groups at three teak, sal and mixed forest types of the region

Table 4. List of commonly used plant species with current status and their uses

Scientific name	Individuals /ha	Family	Common name	Habit	Uses* (Information based on local uses)
<i>Abrus precatorius</i> Linn.	3 ± 0.5	Papilionaceae	Ratti	L	Seeds are purgative and abortifacient
<i>Achyranthes aspera</i> Linn.	83 ± 9	Amaranthaceae	Chirchita	S	External application against insect bite
<i>Acacia nilotica</i> Linn.	23 ± 6	Mimosaceae	Babul	UT	Gum from bark, wood as charcoal
<i>Acacia catechu</i> Willd.	2 ± 0.5	Mimosaceae	Khair	UT	'Katha' from heart wood
<i>Adina cardifolia</i> Roxb.	4 ± 0.5	Rubiaceae	Haldu, karma	T	Wood used for flooring
<i>Aegle marmelos</i> Linn.	9 ± 2	Rutaceae	Bel	T	Unripe fruit is astringent and digestive
<i>Azadirachta indica</i> A.Juss	4 ± 2	Miliaceae	Neem	T	Wide medicinal uses
<i>Anthocephalus cadamba</i> Roxb.	11 ± 3	Rubiaceae	Kadamba	T	Wood as packing cases and tea boxes
<i>Arundo donax</i> L.	23 ± 7	Poaceae	Giant cane	H	Bio fuel, rhizome as diuretic
<i>Asparagus racemosus</i> Willd.	11 ± 6	Liliaceae	Satawar	L	Roots as good ayurvedic medicine
<i>Aurva lanata</i> L.	41 ± 9	Amaranthaceae	Gorakhbuti	C	Traditional medicine for snakebite
<i>Bauhinia malabarica</i> Roxb.	9 ± 2	Caesalpiniaceae	Sahul	UT	Bark contain tannin, fuel wood
<i>Bauhinia vahlii</i> W. & A.	13 ± 3	Caesalpiniaceae	Pator	L	Stem used in basket making
<i>Bridelia retusa</i> Hook. F.	7 ± 0.6	Euphorbiaceae	Khaja	UT	Wood for agricultural implements
<i>Careya arborea</i> Roxb.	3 ± 0.3	Lecythidaceae	Kumbhi	UT	Fruits used to improve digestion
<i>Careya herbacea</i> Roxb.	1 ± 0.05	Lecythidaceae	Kum	H	Asanthelemtic, anti-diabetic activity
<i>Caesalpinia bonducella</i> Felming	1 ± 0.1	Caesalpiniaceae	Karanju	L	Substitute for quinine, hedge plant
<i>Cassia fistula</i> Linn.	5 ± 0.8	Caesalpiniaceae	Amaltas	UT	Bark is astringent, ripe fruit purgative
<i>Centella asiatica</i> Linn.	66 ± 8	Umbelliferae	Brahmi-buti	H	Leaves used to improve memory
<i>Clerodendron infortunatum</i> L.	966 ± 53	Verbenaceae	Bhant	UT	Fire wood, lives ate bitter tonic
<i>Costos speciosus</i> (Koenig) Smith	5 ± 2	Zingiberaceae	Kebu	H	Rhizome against rash and bronchitis
<i>Curculigo orchioides</i> Gaertn.	67 ± 11	Hypoxidaceae	Kala musli	H	Immunostimulant and hepatoprotective
<i>Diospyros tomentosa</i> Roxb.	1 ± 0.2	Ebenaceae	Tendu	T	Leaves for 'biri' wrapper, edible fruits
<i>Elephantopus scaber</i> L.	47 ± 11	Asteraceae	Elephant's foot		Used as Astringent and in rheumatism
<i>Emblica officinalis</i> Gaertn.	2 ± 0.2	Euphorbiaceae	Amla	UT	Fruit is best source of vitamin C
<i>Eugenia heyneana</i> Duthie.	17 ± 3	Myrtaceae	Kath-jamun	T	Edible fruits, firewood
<i>Ficus religiosa</i> Linn.	6 ± 0.5	Moraceae	Pipal	T	Leaves for fodder, Bark latex, tannin
<i>Ficus glomerata</i> Roxb	8 ± 1	Moraceae	Gular	T	Edible receptacle, tannin is astringent
<i>Glycosmis petaphylla</i> Correa.	1 ± 0.2	Rutaceae	Ban nimbu	UT	Leaves for eczema, twigs as tooth stick
<i>Helminthostachys zeylanica</i> L.	6 ± 0.5	Ophioglossaceae	Kamraj	H	Fronds are eaten, used to cure sciatica
<i>Holarrhena antidysenterica</i> L.	4 ± 1	Apocynaceae	Dubhi, Kurchi	UT	Plant used in diarrhoea and dysentery
<i>Hygrophilla auriculata</i> Heine	1 ± 1	Acanthaceae	Talim khana		Plant ash as ayurvedic medicine
<i>Jatropha gossypifolia</i> Linn.	34 ± 4	Euphorbiaceae	Tal, Arand	UT	Bark to cure rheumatism and leprosy
<i>Lagerstroemia parviflora</i> Roxb.	14 ± 2	Lythraceae	Adidh	UT	Durable wood, tannin extraction
<i>Lawsonia inermis</i> Linn.	12 ± 3	Lythraceae	Mehdi	UT	Leaves for itches and skin diseases
<i>Lepidogathis incurva</i> Don.	7 ± 2	Acanthaceae	Kariyat	H	Used in ear complaints
<i>Leucas cephalotes</i> Spreng.		Lamiaceae	Guma	S	Treatment for snake bite
<i>Madhuca indica</i> Gmel..	6 ± 1	Sapotaceae	Mahuwa	T	Edible fruits, beverage preparation

Scientific name	Individuals /ha	Family	Common name	Habit	Uses* (Information based on local uses)
<i>Mallotus philippensis</i> Lamk.	33 ± 7	Euphorbiaceae	Rohini	T	'Kamala' dye, firewood
<i>Mitragyna parviflora</i> Roxb.	3 ± 0.6	Rubiaceae	Tikui	T	Wood for construction purposes
<i>Moghania chappar</i> Ktze.	1588 ± 122	Papilionaceae	Kasraut	UT	Stem used as tooth brushes
<i>Morus indica</i> Linn.	3 ± 0.6	Moraceae	Shahtoot	UT	Edible fruits, leaves used in sericulture
<i>Nicotiana plumbaginifolia</i> Viv.	1 ± 1	Solanaceae	Ban tamako	H	Antispasmodic and diuretic
<i>Ocimum cannum</i> Sims	63 ± 9	Lamiaceae	Basil	S	Treat cold and parasitic infestation
<i>Pongamia pinnata</i> Linn.	3 ± 0.6	Papilionaceae	Dithori	UT	Wood in turnery articles
<i>Putranjiva roxburghii</i> Wall	1 ± 0.5	Euphorbiaceae	Putrajiv	T	Oil used in medicine
<i>Randia uliginosa</i> Dc. Prodr.	1 ± 0.5	Rubiaceae	Pendar	UT	Edible fruits, fuel wood
<i>Rauwolfia serpentine</i> Benth.	1 ± 0.2	Apocynaceae	Sarpghandha	S	Antidote to snake-bite, hypertension
<i>Schleicher oleosa</i> Lour.	9 ± 1	Sapindaceae	Kusum	T	'Magassar oil', host for lac insects
<i>Semecarpus anacardium</i> Linn.	1 ± 0.2	Anacardiaceae	Bhela, Bhilwa	T	Edible fruits used as native medicine
<i>Sida rhombifolia</i> L.	16 ± 5	Malvaceae	Atibala	S	Relieve pain and swelling
<i>Sida acuta</i> Burrm. f.	41 ± 21	Malvaceae	Baraira	S	Skin infections
<i>Smilax prolifera</i> Roxb.	1 ± 0.3	Smilacaceae	Ram datuan	T	Twig as tooth brush, strong fibres
<i>Spondias pinnata</i> Linn. f.	2 ± 0.3	Anacardiaceae	Amra	T	Fruits used in pickles preparation
<i>Streblus asper</i> Lour.	2 ± 0.2	Moraceae	Singhor	T	Rough leaves to polish wood, fire wood
<i>Strychnos nux-vomica</i> Linn.	1 ± 0.2	Loganiaceae	Kuchla	T	Seeds yield Strychine and Brucine
<i>Tamarindus indica</i> Linn.	5 ± 0.5	Caesalpiniaceae	Imli	T	Fruits for pickles preparation, firewood
<i>Terminalia bellirica</i> Roxb.	7 ± 0.5	Combretaceae	Bahera	T	Ayurvedic medicine
<i>Terminalia arjuna</i> Bedd.	3 ± 0.2	Combretaceae	Arjun	T	Bark is astringent, dyeing and tanning
<i>Terminalia chebula</i> Retz.	9 ± 0.7	Combretaceae	Harr	T	Ayurvedic medicine
<i>Thespesia lampas</i> Dalz & Girbs.	1 ± 0.2	Malvaceae	Bankapasi	UT	White strong fibre
<i>Tiliacora acuminata</i> Lamk	34 ± 2	Menispermaceae	Karwat	L	Branches used in basket making.
<i>Tinospora cordifolia</i> Willd.	5 ± 1	Menispermaceae	Gurch	L	Used in chronic bowel troubles
<i>Woodfordia fruticosa</i> Linn.	4 ± 1	Lythraceae	Dhantha	UT	Red dye, wood has anti-AIDS property
<i>Zizyphus mauritiana</i> Lamk.	8 ± 1	Rhamnaceae	Jharberi	UT	Fruit used in stomach pain

*Ali and Dixit 1989, Anonymous 1948-1976, Singh et al. 1997 and local survey

perennials forming ground layer are favoured by high disturbance (Mishra 2004). The reduction in the richness of herb and climber in sal forest stands may be caused by significant closure canopy which suppresses the growth of heliophytic herbs. The frequent and enhanced fire intensity creates more niche space for the recruitment of clonal plants and invasive species. Several shrubs can tolerate these heat stresses for example *Clerodendrum infortunatum* readily regenerated through sub-surface ramet proliferation from a horizontal root stock under high degree of disturbance (Pandey and Shukla 2018). Sal forest also supports considerable species richness but lesser as compared to mixed forest communities. The medicinal climbers like *Mucuna pruriens* and *Mukia madraspatna* were present only in mixed forest stands facing low level of disturbance which may

promote the density and abundance of climbing species (González-Teuber 2008). A few common medicinal plant species namely *Bauhenia vahlii*, *Cissampelos pareira*, *Ichnocarpus frutescens*, *Dioscorea bulbifera*, *Tiliacora acuminata* and *Smilax zeylanica* however, occurred in most of the habitats quite irrespective of forest types.

The overall stem density and density of herbs was found to be greater in mixed forest than in sal and teak forests. The high density of tree saplings and shrubs in regional forest may be due to non-seed regeneration mainly through ramet producers (Pandey and Shukla 2018). Different strata of the forest may have variable growth patterns due to different environmental factors like availability of light, moisture regime and supply of nutrients (Denslow et al. 1990). Generally, increase in the density of

understorey vegetation reflects the degree of natural or anthropogenic disturbance (Krishnankutty 2006). The planted species *Shorea robusta* contributed to maximum dominancy (IVI) at all forest types except the teak forest. However, *Mallotus philipensis* was densest species among trees after *Shorea robusta* at both the mixed and sal forest of the region. *Clerodendrum infortunatum* was the most dominant shrub at all the forest types which may be attributed to its high clonal ability in presence of disturbance. It has been also observed that sites having some degree of disturbance favor proliferation of ramet more frequently (Pandey and Shukla 2003). The high value of density and IVI of evergreen medicinal herb *Ichnocarpus frutescens* in the regional forest was due to its woody rootstock. Furthermore, this species is also common in grasslands of the region (Srivastava et al. 2015). Its seeds are wind dispersed and can easily invade the forest vegetation. Pandey and Shukla (2003) also reported *I. frutescens* as frequent understorey climber of managed sal forest. Among herbs, *Commelina benghalensis* had quite greater value of density and IVI teak forest. The anthropogenic as well as natural disturbance creates conditions for recruitment of individuals or the growth of pre-existing ones within the understory (Ramirez-Marcial et al. 2001). Also due to the availability of high moisture during rainy and early winter season in forest communities, *C. benghalensis* shows luxuriant growth in forest stand facing high disturbance whereas *Evolvulus nummularis* in sal and teak forest. This may probably due to the low light intensity at ground layer. The competitive shaded and moist condition favoures the growth of this prostrate herb. Further burning of forest floor during summer period creates maximum niche space, which is readily pre-empted by the propagules of *Evolvulus* reaching from neighbor grassland. The pattern of distribution of population of species within a community is the fundamental characteristic of that species; it is an important method of studying the community organization and species interrelationship (Mcintosh 1967). In the present study, the sal forest stands showed contiguous distribution. Similar distribution pattern has been reported in several other forest vegetations (Ralhan et al. 1982). It has been already established that the contiguous pattern of distribution is most common

type while random in uniform environment and among severely competing regular distribution of species exists (Odum 1971). Armesto et al. (1986) mentioned that the random distribution is the characteristic of those forests in which formation of canopy gap is the chief source of disturbance. But in this study contiguous distribution is not influenced by disturbance.

Large scale extraction of *Bombax ceiba*, *Urena lobata*, *Smilax macrophylla*, *Terminalia* spp, *Ficus* spp., *Gloriosa superba*, *Tinospora cordifolia*, *Helminthostachya zeylanica*, *Leea macrophylla*, *Rauwolfia serpentina*, *Woodfordia fruticosa*, *Asparagus racemosus*, *Centella asiatica* and *Bischofia javanica* have been currently reported from the regional sal forest. Due to overexploitation of these resources these important species become rare and seen at a few spiny thickets only. Forest patches facing Low or moderate level of disturbance have thickets of dense entangled mass of liana, were identified that usually associated with economically important plant species like *Rauwolfia serpentina*, *Desmodium* spp., *Crotalaria alata* and *Gloriosa superba* in addition to the other ones. These thickets are the micro-sites for conservation of important species and also act as unique niches for their habitation. As per the locals, their occurrence in these forest types was quite abundant previously. If proper and immediate steps were not taken for their conservation and sustainable utilization these species would be threatened.

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