International Journal of Botany Studies
ISSN: 2455-541X
Impact Factor: RJIF 5.12
www.botanyjournals.com
Volume 2; Issue 6; November 2017; Page No. 84-92

Effect of disturbance on the composition and diversity of Sal forests of north-eastern Uttar Pradesh

[1] Satish Kumar Rai, [2] Ravindra P Shukla, [*3] Sanjay Kumar Pandey
[1, 2] Forest Ecology Laboratory, Department of Botany, DDU Gorakhpur University, Gorakhpur, Uttar Pradesh, India
[3] Department of Botany, DAV PG College, Gorakhpur, Uttar Pradesh, India

Abstract
The effect of disturbance was observed on the composition and species diversity of understory of the plantation forests of sal taking the least disturbed (LD), moderately disturbed (MD) and highly disturbed (HD) stands at three different sites within north-eastern Uttar Pradesh. The intensity of fuel-wood collection, the grazing and browsing by domestic animals was used to measure the disturbance levels. A total of 92 species belonging to 45 families were reported in moderately disturbed forest stands. 74 species belonging to 37 families in least disturbed forest stand and 68 species belonging to 35 families were recorded in highly disturbed forest stand. Papilionaceae was the most abundant family in both least and moderately disturbed stand whereas Poaceae at highly disturbed forest stand. The density of herbs and shrubs was also quite high within highly disturbed forest stand and vary significantly with moderately disturbed forest stand. In both sites annual and perennial herbs are dominated and distributed contagiously. The shrub layers were dominated by seedling and saplings of *Shorea robusta* and ramets of *Clerodendron infortunatum.* The common understory species, which are locally used as medicine, includes *Curculigo orchioides, Elephantopus scaber* and *Holarrhaena antidysenterica*. The value of diversity and evenness were relatively greater for moderately disturbed forest ($\bar{H}$= 4.12, J = 0.90) as compared to highly disturbed ($\bar{H}$= 3.19, J = 0.75) and least disturb ($\bar{H}$ =3.57, J= 0.82) forest stands.

Keywords: plantation forest, disturbance regime, diversity, sal, distribution pattern

Introduction
Tropical forests occupy only 7% of the earth's land surface but they sustain more than half of the planet life-forms (Wilson 1988) [54]. The analysis of diversity and community structure of tropical forest is ecologically significant because of the species richness of medicinal and economically important plants (Dutta & Devi 2013)[6]. Floristic composition is considered as one of the major distinguishing characters of a community. The understory plants have been reported to be a major component of forest ecosystems and play an important role in many ecological functions and processes (Ramovs & Roberts 2003, Nagaike *et al*. 2006) [39, 26]. The quantification of these communities attributes become more important for understanding the resource dynamics within the forest (Moore & Allen 1999) [23]. Different disturbance events and their quantum have important roles in explaining species coexistence and spatial patterns of species population and diversity within the plant communities (Grime 1973, Connell 1978, Hubbell 1979, Sagar *et al*. 2003) [11, 4, 13, 41]. The excessive disturbance leads to the loss of late-successional species and competitive exclusion of species adapted to colonize sites immediately following a disturbance. It has been argued that the intermediate disturbance regime enables species to co-exist (Molino & Sabatier, 2001; Sheil & Burslem, 2003) [22, 44].

The regional sal forest has been described as semi-evergreen type with deciduous elements (Champion & Seth 1968) [3]. The patches of natural-growth forest are dominated by sal trees still exist within the core zone of Sohagibarwa wildlife sanctuary (Gupta & Shukla 1991, Pandey 2000) [12, 29]. *Shorea robusta* forests (hereafter referred to as Sal forests) are among the most disturbed types of forest in Southeast Asia (Sapkota *et al*., 2010) [42], due to their high timber value and socio-economic importance for fodder, fuel-wood, leaf litter and minor forest products. The regional plantation forests have replaced natural sal dominated forest vegetation mostly through the *taungya* system (Pandey & Shukla 2003) [30]. The frequent and fluctuating type of disturbance in such forests, have been investigated for decades in India (Pandey & Singh 1985, Rao *et al*. 1990, Pandey & Shukla, 2005; Tripathi & Singh 2009, Kushwaha & Nandy 2012, Dutta & Devi 2013) [6, 30, 31, 40, 51, 18]. Plant species diversity has been widely studied in the plantation forests (Kamo *et al*. 2002, Nagaike *et al*. 2006) [26, 16].

The observation on the composition and structure of sal associates in relation to the degree of disturbance may provide information to judge the suitable composition of species which can resist the disturbance and continue to exist without any outside efforts.

Methods
The sal forests stands were identified at the three disturbance level. The open site at the Ramgarh was highly disturbed (HD) and the other one which was protected by fence was least disturbed (LD). The site within Paniyara region was moderately disturbed (Figure 1). The intensity of fire was observed on the basis of the height of burnt stem or bole of trees and proportion of the ground cover. The Ramgarh forest about 10 km away while Paniyara is 32 km away from Gorakhpur town. The analysis of vegetation was carried out

through squire quadrat method. The quadrats of each of 5m x 5m size were laid randomly across the selected stands. Plant species, encountered in each quadrat were listed and identified (Srivastava 1976) [47]. The number of individuals of herbs, shrubs and climbers was counted and circumference of tree was measured at their breast height (1.37 m). Individuals having girth below 31.5 cm were considered as sapling and their basal diameter was measured for computing the basal area. The vegetal cover of herbs was also measured. Based on these values, various phytosociological indices, such as frequency, density, cover (basal/vegetal), their relative values and Importance Value Index (IVI) was measured, through conventional methods (Mueller-Dombois and Ellenberg 1974) [25]. Several other indices Abundance: Frequency Ratio (A/F ratio; Whitford 1948) and Family Importance Value (FIV = relative density + relative diversity + relative vegetative cover; Mori *et al*. 1983) [24] were also derived. The dominance-diversity curve was plotted as a log normal distribution model (Magurran 2004) [19]. Diversity indices like Simpson's Dominance Index ($Cd = \Sigma\ pi^2$), Shannon's Diversity Index ($\bar{H} = -\Sigma\ pi \ln pi$) and Pielou's Evenness Index ($J = \bar{H}/\ln S$), were derived following Magurran (2004) [19]. Where, pi represents the proportional abundance of the i^{th} species in the community; S is the species richness. Species distribution pattern was examined through abundance/ frequency (%) ratio and it was categorized into regular (< 0.025), random (0.025-0.5) and clumped (> 0.05). 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).

Fig 1

Results

A total of 123 species belonging to 103 genera, under 50 families were recorded within sal dominated forests facing three different disturbance regimes. The number of species genera and family was much greater at moderate disturbance as compared to other two disturbance levels. The species/genus ratio was greater at high disturbance, but the species /family ratio was so at moderate disturbance (Table 1). The least disturbed sal forest showed much greater number of rare species but the species total was greater for the moderately disturbed stands. Several species such as *Clerodendrum infortunatum, Echnocarpus frutiscens* and *Aerva lanata* showed over-dominance at high disturbance.

Table 1: Species composition and general distribution characteristic of sal stand at three disturbance levels

Floristic attributes	High Disturbance (HD)	Moderate disturbance (MD)	Low Disturbance (LD)
No. of species	68	92	74
No. of genera	59	84	67
No. of family	35	45	37
Species/genus ratio	1.15	1.09	1.10
Species/family ratio	1.94	2.04	2.0
General distribution			
Regular	01	07	0
Random	17	33	10
Contagious	50	52	64
Count status			
Very rare	02	03	09
Rare	12	07	16
Common	11	12	08
Dominant	05	04	03
Predominant	38	66	38

Species richness and Family Importance Value (FIV): Of total 50 families, 29 were common to each level of disturbance. 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 at moderate disturbance, 9 species at low disturbance and 4 species at high level of disturbance. The other dominant family was Poaceae, which showed 8 representative species at high disturbance and 6 species at moderate as well as low level of disturbance. Euphorbiaceae, showed 2 species at high, 7 at moderate and 6 species at low level of disturbance (Table 2).

Families such as Passifloraceae, Solanaceae and Sterculiaceae were represented by single species and occurred only at high disturbance. At moderate disturbance 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 %, 23.73 % of sum of FIV in stands facing high level, moderate or low level of disturbance respectively. At high disturbance 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 at moderate disturbance (Table 2).

Table 2: Species richness and family importance value (FIV) of constituent families within sal stands at three different disturbance levels (HD-high disturbance; MD-moderate disturbance; LD- low disturbance)

S. No	Family	Species richness			Family Importance Value (FIV)		
		HD	MD	LD	HD	MD	LD
1	Acanthaceae	2	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	2	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	4	4	4	8.78	10.98	10.8
10	Bignoniaceae	-	1	-	-	2.43	-
11	Caesalpiniaceae	4	3	3	16.38	5.73	10.7
12	Combretaceae	1	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	2	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	2	7	6	25.75	12.19	16.9
23	Flacourtiaceae	2	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	2	3	3	4.52	4.58	5.58
29	Menispermaceae	2	2	2	15.44	5.54	14.4
30	Moraceae	2	3	2	3.34	5.22	2.76
31	Myrtaceae	-	2	2	-	2.59	2.77
32	Ophioglocaceae	1	1	-	1.95	2.47	-
33	Orchidaceae	1	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	8	6	6	29	12.9	22.8
38	Rhamnaceae	1	1	1	1.55	1.15	1.46
39	Rubiaceae	1	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	4	4	2	23.69	16.42	4.80
44	Smilaceae	2	1	1	3.13	1.313	1.42
45	Solanaceae	1	-	-	2.64	-	-
46	Sterculiaceae	1	-	-	5.65	-	-
47	Tiliaceae	2	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	-

Density, Importance Value Index and distribution pattern: The density (individuals/ha) and IVI of common species varied markedly to stands at different disturbance levels. At high disturbance *Mallotus phillipensis* an undertree exhibited a density as high as 112 individuals per hectare. The density of *Shorea robusta* was highest at each of the three level of disturbance. The planted trees and regenerated seedlings and saplings of the species reached around 3000 individuals per hectare. *Clerodendrum infortunatum* a potential undertree prevailing as shrub showed very high dominance, individual density and IVI at each level of disturbance. Among climbers, *Ichnocarpus frutescens* showed the greatest dominance in level of density and IVI. *Commelina benghalensis* proposed to be in most dense (density 8168 individuals/ hectare and IVI 20.16) within highly disturbed stands. Plant species other than *Shorea robusta* showed clumped distribution at each of the three disturbance regimes. Fourteen species showed rare to very rare occurrence. A number of species such as *Cyperus rotundus, Clerodendrum infortunatum, Diospyros tomentosa, Desmodium pulchelum, Holarrhena antidysenterica, Panicum indicum, Terminalia tomentosa* and *Zizyphus oenoplia* showed almost similar occurrence pattern at each of the three disturbance levels (Table 3).

Habit wise analysis along the different disturbance regimes reveals that herbs were pre-dominant at the community facing high disturbance while, shrubs and trees were dominated at the moderately disturbed forest stand while climbers showed considerable diversity but only at low disturbance. The niche occupancy of species within a community is frequently expressed by abundance distribution curve. As evident from the curve only a few species preempted most of the niche at three levels of disturbance (Figure 2).

Table 3: comparison of diversity/ hectare, IVI and general distribution pattern of species of different habits within stands facing high, moderate or low disturbance (HD, MD and LD)

Plant species	HD			MD			LD		
	Density (/ha)	IVI	Distribution pattern	Density (/ha)	IVI	Distribution pattern	Density (/ha)	IVI	Distribution pattern
TREES									
Cassia fistula	792	2.79	Random	184	0.61	Clumped	48	1.32	Clumped
Diospyros tomentosa	56	0.36	Clumped	624	1.61	Clumped	272	1.93	Clumped
Flacortia indica	80	0.65	Clumped	360	1.56	Random	88	0.61	Clumped
Mallotus philipensis	1112	3.73	Random	712	3.01	Random	968	6.47	Clumped
Shorea robusta	312	3.93	Regular	2840	6.62	Clumped	3848	12.3	Clumped
Streblus asper	144	0.50	Clumped	608	2.53	Random	104	0.64	Clumped
Terminalia tomentosa	72	1.58	Clumped	512	1.48	Clumped	624	3.53	Clumped
Zizyphus oenoplia	96	0.71	Clumped	40	0.19	Clumped	48	0.35	Clumped
SHRUBS									
Clerodendron indicum	14960	17.80	Clumped	5232	10.28	Clumped	5520	15.93	Clumped
Desmodium pulchelum	96	0.52	Clumped	1008	2.67	Clumped	416	2.24	Clumped
Holarraena antidysentica	328	1.29	Clumped	448	1.69	Clumped	1272	5.68	Clumped
Moghania bracteata	208	0.87	Clumped	1208	3.66	Random	152	1.25	Clumped
Moghania chppar	120	0.60	Clumped	672	2.45	Random	944	4.30	Clumped

CLIMBERS									
Bauhinia vahlii	120	0.84	Clumped	264	1.54	Random	160	0.68	Clumped
Cayratia trifolia	488	2.61	Clumped	1000	3..56	Random	1040	11.85	Clumped
Cissampelos pareiria	952	9.33	Random	480	2.2	Random	520	10.20	Clumped
Dioscorea bulbifera	56	0.71	Clumped	320	1.76	Random	600	11.28	Clumped
Ichnocarpus frutescence	2328	11.72	Clumped	1032	3.70	Random	3872	41.60	Clumped
Lygodium spp.	192	1.86	Random	456	2.16	Random	624	7.75	Clumped
Smilax zaylenica	152	1.17	Random	144	0.85	Random	32	0.32	Clumped
Tiliacora acuminate	704	8.12	Random	1664	4.33	Clumped	128	3.14	Clumped
HERBS									
Achyranthus aspera	1120	4.21	Clumped	1024	4.01	Random	800	7.73	Random
Aerva lanata	3544	9.50	Clumped	1680	5.35	Random	696	3.77	Clumped
Commelina benghalensis	8168	20.16	Clumped	696	3.24	Random	848	6.98	Random
Curculigo archioides	288	3.10	Random	296	0.87	Clumped	1072	7.97	Clumped
Cyperus rotundus	40	0.18	Clumped	960	2.95	Clumped	1304	7.11	Clumped
Desmodium gangaticum	704	3.94	Clumped	776	3.48	Random	712	6.06	Clumped
Elephantopus scaber	368	2.02	Random	776	2.02	Clumped	1312	5.77	Clumped
Evolvulus nummularis	6216	15.85	Clumped	1704	5.50	Random	4656	13.98	Clumped
Panicum indicum	7404	13.87	Clumped	296	1.15	Clumped	280	1.87	Clumped
Paspalum scrobiculatum	384	2.02	Random	880	1.76	Clumped	408	3.19	Clumped
Triumfetta pentandra	3720	21.87	Clumped	680	4.16	Regular	248	4.41	Clumped
Vernonia cinerea	152	0.81	Clumped	344	1.59	Random	80	0.50	Clumped

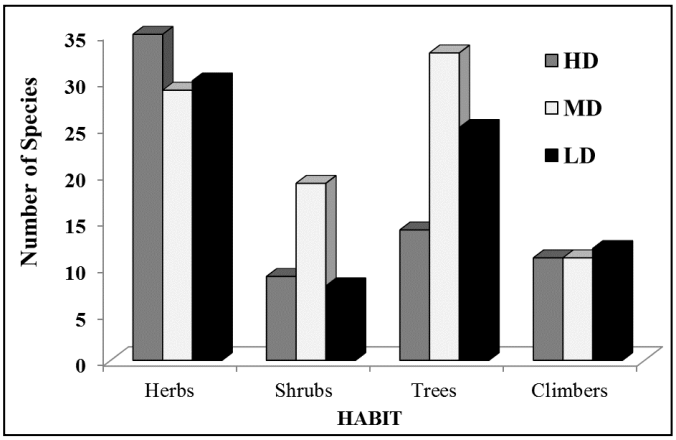


Fig 2: Number of species of different habit groups within sal forests at three different disturbance levels

Species diversity pattern: Habit-wise analysis of various disturbed 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 (Cd) and evenness (E) were significantly different for different habit groups. The value of diversity indices for herbs was greater in stands facing high disturbance. The diversity for shrubs and trees was highest for stands facing moderate level of disturbance. The climbers showed considerable diversity but only at low disturbance (Figure 3).

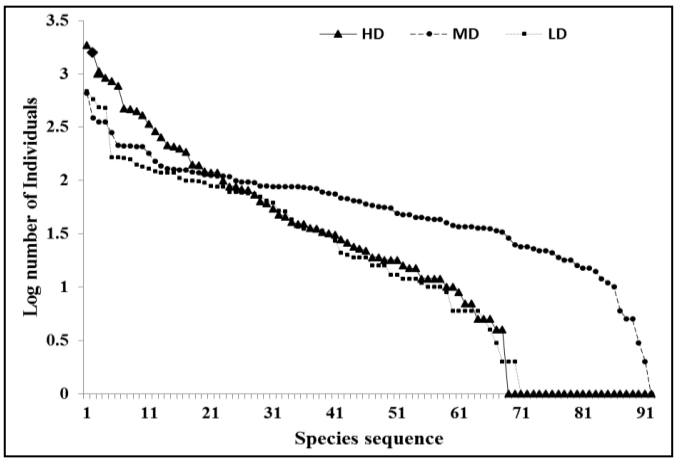
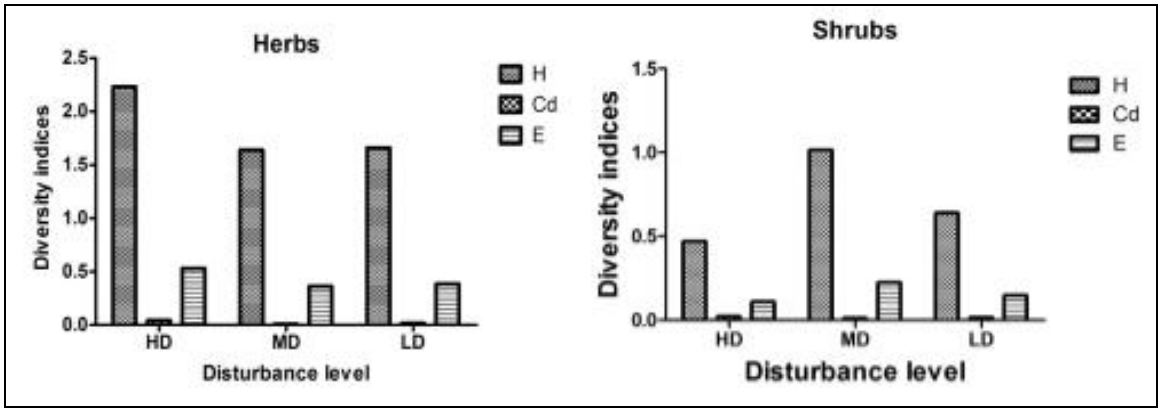


Fig 3: Rank-abundance model (dominance-diversity curve) of sal forest stands at three different disturbance levels



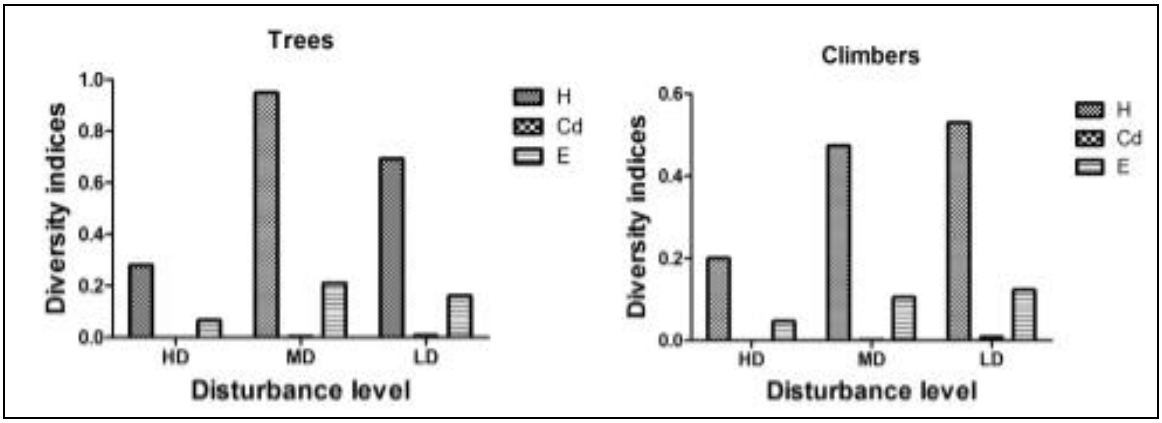


Fig 4: Comparison of diversity indices among different habit groups at three disturbance levels (HD= High Disturbance; MD = Moderate disturbance; LD = Low Disturbance)

Discussion

Plantations forests differ from natural forest ecosystems in a number of characteristics. Plantation forests may be managed to make it species rich as good as forest vegetation. The less disturbed old sal plantation forests and semi- natural forests of north- eastern Uttar Pradesh have been found to be equally rich in plant biodiversity (Pandey & Shukla 2003) [30]. The colonization of plantation forests by regional species shifts it towards semi-natural forest vegetation (Flinn & Vellend 2005) [7].

In India floristic inventories in sal forests vary dramatically in terms of species richness and stem density. The studies on sal-dominated forests presents a range from 3 species in 0.3 ha (Singh *et al.* 1995) [45] to 208 species in 24 hectare (Pandey & Shukla 2003) [30]. The high level of disturbance interferes with the proper vegetative growth, successful flowering, fruiting and regeneration (Pandey & Shukla 1999) [31]. Table 4 shows comparison of the species richness and density of different sal dominated forests of India. Whittaker (1975) [53] and Connell (1978) [4] have pointed out that moderate disturbance provides greater opportunity for species colonization and persistence of high species richness. Many of the models which explain the pattern of diversity change agree that intermediate disturbance levels maintain diversity. Moderate level of disturbance promotes a non- equilibrium species rich system. The changes in the dominance of some families may probably be due to the levels of anthropogenic disturbances on different growth habits. For example the prevalence of papilionaceae in several disturbed neo-tropical forests has been earlier reported (Gentry 1995, Pandey & Shukla 2017) [34, 8]. The community constitute a number of herbaceous as well as woody species of different growth habits, but the level of disturbance drastically change the structure as well as diversity of the community. The trees and shrubs were dominant in moderately disturbed stand. However, the richness of herbs, were highest in highly disturbed forest stand. It may be due to continued alteration of the habitat through anthropogenic disturbance. Mostly herbaceous plant species can readily establish themselves, quickly produce an herbage cover and improve soil fertility but the species which regenerate only through seeds, are less likely to maintain themselves in the community facing recurrent disturbances of grazing and trampling (Raizada *et al.* 1998) [36]. The highly disturbed forests are secondary successional communities which provide more hospitable environmental conditions for many shade intolerant species (Bormann and Likens 1979) [2]. The annual small statured herbs and several short-lived perennials forming ground layer are favoured by high disturbance (Mishra 2004) [21]. The reduction in the richness of herb and climber in moderately disturbed sal stands may be causes significant closure canopy which suppress the growth of heliophytic herbs. The frequent and enhanced fire intensity creates more niche space of the recruitment for 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 & Shukla 1999) [33]. Low disturbance also supports considerable species richness but lesser as compared to communities facing moderate disturbance. Few climbers like *Mucuna prusiens* and *Mukia madraspatna* were present only in stands facing low level of disturbance which may promote the density and abundance of climbing species (González-Teuber 2008) [9]. A few species namely *Bauhenia vahlii, cissampelos pareiria, Ichnocarpus frutescens, Dioscorea bulbifera, Tiliocora accuminata* and *Smilex zeylenica* however, occurred in most of the habitats quite irrespective of the disturbance level.

The overall stem density and density of herbs was found to be greater in highly disturbed forest than in moderately and less disturbed forests. The high density of trees and shrubs in moderately disturbed forest may have been maintained by prolific ramet producers particularly through rhizomes or root-stock. The forest opening created by disturbance, accelerate these processes (Jackson 1994, Sapkota *et al*. 2009) [42, 15]. Understorey plant species may have different patterns of density than tree species because of variable responses to different abiotic factors such as differential light regimes, nutrient and water availability (Denslow *et al*. 1990) [5]. Generally, increase in the density of understorey vegetation reflects the degree of natural or anthropogenic disturbance (Krishnankutty 2006) [17].

The planted species *Shorea robusta* contributed to maximum dominancy (IVI) at all three disturbed stands. However, *Mallotus phillipensis* was densest species among trees after *Shorea robusta* at both the moderate as well as low level of disturbance. *Clerodendrum infortunatum* was the most

dominant shrub at all the three disturbance levels which may be attributed to it's 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 & Shukla 2003) [30]. The high value of density and IVI of *Ichnocarpus frutescens* at different disturbance levels was due to its woody rootstock. Furthermore this species is also common in grasslands of the region (Srivastava *et al*. 2015) [48]. Its seeds are wind dispersed and can easily invade the forest vegetation. Pandey and Shukla (2003) [30] also reported *I. frutescens* as frequent understorey climber of managed sal forest. Among herbs, *Commelina benghalensis* had quite greater value of density and IVI under high disturbance. The anthropogenic as well as natural disturbance creates conditions for recruitment of individuals in the understory. This is also due to the availability of high moisture during rainy and early winter season in forest communities (Young & Hubbell 1991, Ramirez-Marcial *et al*. 2001) [14]. *C. benghalensis* shows luxuriant growth in forest stand facing high disturbance where as *Evolvulus nummularis* at moderate as well as low level of disturbance. 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) [20].

In the present study, the disturbed forest stands showed contiguous distribution. Similar distribution pattern has been reported in several other forest vegetations (Ralhan *et al.* 1982) [37]. It has been established that contiguous distribution is the most common pattern in nature, random distribution is only found in very uniform environment and regular distribution occurred when severe competition exist between individuals (Odum 1971) [28]. Armesto *et al.* (1986) [1] 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.

Diversity is often considered to be synthetic measure of structure, complexity and stability of community (Hubbell & Foster 1983) [14]. In the present study, the diversity indices of trees, shrubs and climbers decreased with increasing disturbance. Disturbance may increase species richness by lowering the dominance of few species, freeing resources for early successional plants and provides opportunities for herbaceous species to spread rapidly (Tripathi 1999, Sood *et al*. 2011) [50]. Species distribution are often non-random in the community and dominant species are found widely distributed while subordinate species are generally locally distributed (Kolassa 1989). The moderate level of disturbance is, therefore, compatible with the maintenance of high biodiversity of landscape (Gentry 1995, Parthasarathy *et al.* 1992, Pandey & Shukla 2003) [30, 8]. The resource sharing and occupancy of niche space are frequently expressed by dominance- diversity curve (Whittaker 1975) [53]. As evident from these curves generally fewer species in the landscape pre-empted most of the niche. The conditions like moderate grazing and trampling allowed relatively greater number of species to share community resources, thus, reducing the degree of dominance at community level as evident from the lesser steeper and more flattened curve (Raizada *et al* 1998) [36]. Disturbance has positive effects on the forest vegetation as reported earlier by some workers (Sundriyal *et. al* 1987) [49]. Further, disturbance caused by herbivores may reduce the negative effect of competition (Grace & Jutila 1999, Nautiyal *et al*. 2004) [10, 27]. The degree and type of disturbance may result into a number of patches with diverse species composition and, therefore, greater species richness. In the future no system can remain unaltered from certain degree and type of disturbances, very few core areas may be protected from direct human activity. From above observations, it may be inferred that the moderate level of disturbances provide the minimal herbage cover, required for the community attributes to manage the regional sal forest.

Table 4: Comparision of species richness as per stand density within Sal forests in different parts of India.

Study sites	Vegetation types	Specie richness	Stand density(/ha)	Reference
Managed Sal Forests				
Paniyara, Maharajganj, UP	Sal plantation	74*	1250	*Present study*
Ramgarh, Gorakhpur, UP	Sal plantation	68*	1250	*Present study*
Ramgarh, Gorakhpur, UP	Sal plantation	92*	1250	*Present study*
Sohagibarawa wildlife sanctuary, Gorakhpur	Sal plantation	208	404	Pandey and Shukla (2003)
Garo Hills, Meghalaya	Sal plantation	42	887	Kumar *et al.* (2006)
Reserve forest of Central Himalaya	Sal plantation	15	650	Kapkoti *et al.* (2016)
Natural sal-dominated forests				
Ri bhoi district, meghalaya	Khasi hill sal	95	448.3	Tripathi and Shankar (2014)
Mahananda, Darjeeling	Eastern Himalayan terai sal	87	484	Shankar (2001)
West Bengal	Moist sal	134	438	Kushwaha and Nandy(2012)
West Bengal	Dry sal	35	1006	Kushwaha and Nandy (2012)
Kamrup, Assam	Alluvial plain sal	71*	2559	Deka *et al.* (2012)
Hojai Reserve Forest, Assam	Alluvial plain sal	18	240	Dutta and Devi (2013)
Sal-Mixed Forests				
South District, Tripura	*S. robusta – Anogeissus acuminata*	105	464.8	Majumdar *et al.* (2014)
South District, Tripura	*S. robusta – Terminalia bellirica*	85	983	Majumdar *et al.* (2014)

South District, Tripura	*S. robusta – Schima wallichii*	152	872	Majumdar *et al.* (2014)
Katarniaghat wildlife sanctuary, Bahraich, UP	*S. robusta- Tectona grandis*	86*	515	Chauhan *et al.* (2008)
Mixed community forest of Central Himalaya	*S. robusta- T. grandis*	15	911	Kapkoti *et al.* (2016)
*includes herb species.				

Acknowledgements
We are thankful to Head, Department of Botany, DDU Gorakhpur University, Gorakhpur, for providing the laboratory facilities. Thanks are due to Ranger and Divisional Forest Officers of the Gorakhpur Forest Division for their active cooperation in the field work.

References

1. Armesto JJ, Mitchell JD, Villogram C. A comparison of spatial patterns of trees in tropical and temperate forests. Biotropica. 1986; 18:1-11.
2. Bormann FH, Likens GE. Catastrophic disturbance and the steady state in northern hardwood forests. Amer. Sci. 1979; 67(6):660-669.
3. Champion HG, Seth SK. A revised survey of forest types of India. New Delhi: New Delhi Govt. Publication, 1968.
4. Connell JH. Diversity in tropical rain forests and coral reefs. Science. 1978; 199:1302-1310.
5. Denslow JS, Schultz JC, Vitousek PM, Strain BR. Growth responses of tropical shrubs to treefall gap environments. Ecology. 1990; 71:165-179.
6. Dutta Gitamani, Devi Ashalata. Phenology and population structure of six tree species in tropical forest of Assam, northeast India. Tropical Ecology. 2013, 2015; 56(3):393-399.
7. Flinn KM, Vellend M, Marks PL. Environmental causes and consequences of forest clearance and agricultural abandonment in central New York. J Biogeogr. 2005; 32:439-52.
8. Gentry AH. Diversity and floristic composition of neotropical dry forests. Pp. 146–194. In: Bullock, S.H., Mooney, H.A. & Medina, E. (eds) Seasonally dry tropical forests. Cambridge University Press, Cambridge, 1995.
9. González-Teuber M, Gianoli E. Damage and shade enhance climbing and promote associational resistance in a climbing plant. Journal of Ecology. 2008; 96:122-126.
10. Grace JB, Jutila H. The relationship between species density and community biomass in grazed and ungrazed coastal meadows. Oikos. 1999; 85:398-408.
11. Grime JP. Competitive exclusion in herbaceous vegetation. Nature. 1973; 242:344-347.
12. Gupta OP, Shukla RP. The composition and dynamics of associated plant communities of sal plantations. Tropical Ecology. 1991; 32:296-309.
13. Hubbell SP. Tree dispersion, abundance and diversity in a tropical dry forest. Science. 1979; 203:1299-1309.
14. Hubbell SP, Foster RB. Diversity of canopy trees in a neotropical forest and implications for conservation. In Tropical Rain forest Ecology and Management. (eds Whitmore TC and Chadwick AC). Blackwell Scientific Publication. 1983, 25-41.
15. Jackson JK. Manual of afforestation in Nepal, second edition: Forest Research and Survey Center, Kathmandu, Nepal, 1994.
16. Kamo K, Vacharangkura T, Tiyanon S, Viriyabuncha C, Nimpila S, Doangsrisen B. Plant species diversity in tropical planted forests and implication for restoration of forest ecosystems in Sakaerat, northeastern Thailand. JARQ. 2002; 36(2):111-118.
17. Krishnankutty N, Chandrasekaran S, Jeyakumar G. Evaluation of disturbances in a tropical dry deciduous forest of Alagar hill (eastern ghats), South India. Tropical Ecology. 2006; 47:47-55.
18. Kushwaha SPS, Nandy S. Species diversity and community structure in sal (*Shorea robusta*) forests of two different rainfall regimes in West Bangal, India. Biodiversity and Conservation. 2012; 21:1215-1228.
19. Magurran AE. Measuring Biological Diversity, Oxford: Blackwell Publishing, 2004.
20. McIntosh RI. An index of diversity and the relation of certain concepts to diversity. Ecology. 1967; 48:392-404.
21. Mishra BP, Tripathi OP, Tripathi RS, Pandey HN. Effects of anthropogenic disturbance on plant diversity and community structure of scared groves in Meghalaya northeast India. Biodiversity and Conservation. 2004; 13: 421-436.
22. Molino JF, Sabatier D. Tree diversity in tropical rain forests: a validation of the intermediate disturbance hypothesis. Science 2001, 294, 1702–1704 doi:10.1126/science.1060284
23. Moore SE, Allen HL. Plantation forestry. Pgs. in M.L. Hunter Jr., ed. Maintaining biodiversity in forest ecosystems. Cambridge University Press, New York. 1999, 400-433.
24. Mori SA, Boom BM, Carvalino AM, & Santos D. The ecological importance of Myrtaceae in eastern Brazilian wet forest. Biotropica. 1983; 15:68-70.
25. Mueller-Dombois D. Ellenberg H. Aims and methods of vegetation ecology. Wiley and Sons, New York. 1974, 547.
26. Nagaike T, Hayashi A, Kubo M, Abe M, Arai N. Plant species diversity in a managed forest landscape composed of *Larix kaempferi* plantations and abandoned coppice forests in central Japan. Forest Science. 2006; 52(3):324-332.
27. Nautiyal MC, Nautiyal BP Prakash V. Effect of grazing and climatic changes on alpine vegetation of Tungnath, Garhwal Himalaya, India. The Environmentalist. 2004; 24(2):125-134.
28. Odum HT. Environment, Power and Society. Wiley, New York. 1971, 331.
29. Pandey SK. Population status and regeneration strategy of some perennial legumes in plantation forests of North-Eastern Uttar Pradesh, Ph.D. Thesis, DDU Gorakhpur University, Gorakhpur, India, 2000.
30. Pandey AN, Singh JS. Mechanism of ecosystem recovery: A case study from Kumaun Himalaya. Reclamation and Revegetation Research. 1985; 3:271-292.

31. Pandey SK, Shukla RP. Plant diversity and community patterns along the disturbance gradient in plantation forests of sal (*Shorea robusta* Gaertn. f). Current Science. 1999; 77:814-818.
32. Pandey SK. Shukla RP. Regeneration strategy and plant diversity status in degraded sal forests. Current Science. 2001; 81:95-102.
33. Pandey SK. Shukla RP. Plant diversity in managed sal (*Shorea robusta* Gaertn.) forests of Gorakhpur, India: species composition, regeneration and conservation. Biodiversity and Conservation. 2003; 12:2295-2319.
34. Pandey Sanjay Kumar and Shukla Ravindra P. Population status, regeneration and seed germination of eight legumes of *Shorea* forest in North- Eastern Uttar Pradesh. International Journal of Botany Studies, 2017; 2 (4) 2017; 04-11. (DOI: https://doi.org/10.22271/botany.2017.
35. v2.i4.02)
36. Pande SK, Shukla RP. Plant Community and Diversity Patterns within the Forested Landscape of North-eastern U. P. The Indian Forester. 2005; 131(9):1217-1226.
37. Parthasarathy NV, Kinbal Kumar LP. Plant species diversity and human impact in the tropical wet evergreen forests of southern western ghats. Indo-French Workshop on tropical forest ecosystem: Natural Functioning and Anthropogenic Impact. French Institute, Pondichery, 1992.
38. Raizada A, Joshi SP, Srivastava MM. Composition and vegetational diversity in an alpine grassland in the Garhwal Himalayas. Tropical Ecology. 1998; 39:133-141.
39. Ralhan PK, Saxena AK, Singh JS. Analysis of forest vegetation at and around Naini Tal in Kumaun Himalaya. Proceedings of Indian National Science Academy B. 1982; 48:121-137.
40. Ramírez-Marcial N, González-Espinosa M, Williams Linera G. Anthropogenic disturbance and tree diversity in Montane Rain Forests in Chiapas, Mexico. Forest Ecology and Management. 2001; 154:311-326.
41. Ramovs B, Roberts M. Understory vegetation and environment responses to tillage, forest harvesting, and conifer plantation development. Ecological Application, 2003; 13:1682-1700.
42. Rao P, Barik SK, Pandey HN, Tripathi RS. Community composition and tree population structure in a sub-tropical broadleaved forest along a disturbance gradient. Vegetatio. 1990; 88:151-162
43. Sagar R, Raghubanshi AS, Singh JS. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. Forest Ecology and Management. 2003; 186:61-71
44. Sapkota IP, Tigabu M, Odén PC. Spatial distribution, advanced regeneration and stand structure of Nepalese Sal (*Shorea robusta*) forests subject to disturbances of different intensities. For Ecol Manage. 2009; 257:1966-1975.
45. Sapkota IP, Tigabu M, Oden PC. Changes in tree species diversity and dominance across a disturbance gradient in Nepalese Sal (*Shorea robusta* Gaertn. f.) forests. Journal of Forest Research. 2010; 21:25-32.
46. Sheil D, Burslem DFRP. Disturbing hypotheses in tropical forests. Trends Ecol. Evol. 2003; 18:18-26. doi:10.1016/S0169-5347(02)00005-8.
47. Singh A, Reddy VS. Singh JS. Analysis of woody vegetation of Corbett National Park, India. Vegetatio. 1995; 120:69-79.
48. Sood SK, Kumar S, Dogra KS, Sharma R. Alien plants distribution and ecology in the temple-courtyards of Himachal Pradesh, North-West Himalaya. Himachal Pradesh Univer. J. 2011, 1-11.
49. Srivastava TN. Flora Gorakhpurensis. Today and Tomorrow's Printers and Publishers, New Delhi, India, 1976.
50. Srivastava S, Dvivedi A, Shukla RP. Commonness and rarity pattern of plant species within Terai grassland of north- eastern Uttar Pradesh, India. Tropical Grasslands - Forrajes Tropicales. 2015; 3:161-186.
51. Sundriyal RC, Joshi AP, Dhasmana R. Phenology of high altitude plants at Tungnath in the Garhwal Himalaya. Tropical Ecology. 1987; 28:289-299.
52. Tripathi SL. Plant diversity of grasslands of north-eastern U.P. with emphasis on populations of *Parthenium hysterophorus* L. Ph.D. Thesis, DDU. Gorakhpur University, Gorakhpur, 1999.
53. Tripathi KP, Singh B. Species diversity and vegetation structure across various strata in natural and plantation forests in Katarniaghat Wildlife Sanctuary, North India. Tropical Ecology. 2009; 50:191-200.
54. Whitford PB. Distribution of wood land plants in relation to succession and clonal growth. J Ecology. 1948; 30:199-208.
55. Whittaker RH, Likens GE. The biosphere and man. In: Leith, H., and Whittaker, R. H. (eds), Primary Productivity of the Biosphere. Ecological Studies, Springer-Verlag, New York, Heidelberg, Berlin. 1975; 339(14):305-328.
56. Wilson EO. (ed) Biodiversity. National Academy Press, Washington D.C., USA, 1988.
57. Young TP, Hubbell SP. Crown asymmetry, treefalls, and repeat disturbance of broad-leaved forest gaps. Ecology 1991; 72:1464-1471.