Plant diversity and community patterns along the disturbance gradient in plantation forests of sal (*Shorea robusta* Gaertn.)

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Depending upon its magnitude and recurrence, a disturbance could structure forest communities in a variety of ways. A 30 km long disturbance gradient was identified across the managed (plantation) forests of sal (*Shorea robusta* Garten.) in Gorakhpur Forest Division and the impact of different degrees of disturbance on the community attributes and diversity pattern of sal stands, arranged along this gradient, was observed. The sum of frequency for species components of different stands increased along the gradient with marked fluctuations. The sum of density, however, increased only up to a few peripheral stands and stabilized further. The trend of the two indices and fluctuations in these values indicated highly patchy and heterogeneous communities along the disturbance gradient. Several potential undertrees like *Mallotus* and *Clerodendron* dominated the shrub layer with greater abundance under high disturbance while other non-leguminous species of shrubby habit dominated the stands facing intermediate disturbance. The relative density of leguminous shrubs decreased along the gradient. The efficiently sprouting trees like *Holarrhena* and *Terminalia* had maximum importance value index (IVI) at moderate disturbance while *Scleichera oleosa* did so towards the core. A maximum Shannon's Index of Diversity *H* of 3.53 was observed for the last but three stands towards the core. The trends of dominance and β-diversity were reverse to that of α-diversity along the gradient. From these observations, it may be inferred that the disturbance should be contained at the level suited for maximum diversity beside sparing a few 'disturbance-friendly' species in highly disturbed stands from complete destruction in order to provide bare minimum herbage cover, required for ecosystem attributes of managed forests of the region.

THE world vegetation cover under natural growth forests has been fast receding and a significant portion of this area is being converted to the man-made plantation forests, mainly timber trees[1] to meet the growing need of the ever-increasing human population. The tropical deciduous plantations of Gorakhpur Forest Division[2] are mostly of sal (*Shorea robusta*). Normally the composition of these plantation forests has been found to be quite similar to that of natural growth forests of the region and the sal trees dominate the overstoreys of natural growth forests as well[3]. The species diversity of sal stands, therefore, has been at a satisfactory level in undisturbed conditions.

The conservation of plant diversity for present and future use is very essential[4,5]. We now solely depend on these managed forests for wild plant resources[6] as we can have no more cover of natural growth forests. The recurrent interventions into the forest communities for large-scale collection of fuel wood and minor forest products and the practices of grazing and trampling may alter the habitats of many species[7].

Disturbance has been considered as an important factor structuring communities[8,9] and its quantification is the major problem for study of the relationship between disturbance and community phenomenon[10]. A disturbance gradient has often been based on the per cent number of stumps of cut trees[11]. In the present case, however, trees other than planted sal were rare and, therefore, the Disturbance Index was based on the intensity of lopping and cutting of branches for fuel wood. This index was determined on the basis of the number of cut or severed woody individuals, expressed as the percentage of the total number of woody individuals per 100 m^2 area. A gradual decrease of dung per unit area also indicated that the trampling by herds was more severe towards the periphery and was least towards the core. A disturbance gradient was, therefore, envisaged as a line on which the stands were situated at increasing distance from human habitation from periphery to the core of the forest. The different quantum of disturbance may have differential impact on the patterns of community and existing plant diversity[12,13]. The present study, therefore, aims to inquire into the patterns of change in plant diversity and general community attributes along the disturbance gradient. Such information may be necessary to assess the threshold level of disturbances for maximum biodiversity and to formulate the strategy to conserve the understorey species within managed forests.

The study site lies between 27°05′ and 27°25′N latitude and 83°20′ and 84°10′E longitude, and is at an elevation of 95 m. The climate is seasonal and subtropical. The total average annual rainfall is about 1814 mm, 87% of which occurs during the wet summer or monsoon season. The soil is an old Gangetic alluvium. The texture is sandy loam and the soil reaction is circum-neutral. Sal has been planted in this region mostly through *taungya* system in which the natural growth forests are cut and the ground is cleared. The ploughed site is sown with freshly collected sal seeds in lines at intervals of about 10 feet between any two lines. The cultivation of cereals, pulses and vegetables is done between the lines for 2 to 3 consecutive years. Once the sal saplings get established, they cast shade to the culti-

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vated food crops. Since no more crops can be taken, the sal saplings are left to grow naturally and the ecological succession sets in. As the sal ages, the associated vegetation developing naturally as a result of ecological succession, gains considerable species diversity. Of these, several over- and understorey trees, a number of leguminous and other shrubs and some perennial herbs may grow as sal associates (Table 1) and the resultant community of sal plantation mimics the composition of natural growth forests in the region.

Twenty four random stands of approximately similar age (40 ± 5 years), were identified along a 30 km long disturbance gradient across the forest belt covering the three ranges, Lachhamipur, North Chowk and South Chowk of Gorakhpur Forest Division. The Disturbance Index decreased very rapidly from the periphery (94.5) up to 10th stand towards the core (27). The index for the next 10 successive stands ranged from 26 to 5. The last 4 stands, identified from the periphery to the core, were the least disturbed and the index ranged from 4 to <2.5 for the innermost stand. The area of stands ranged from 3 to 10 ha per stand. Any two adjacent stands under observation, were 500 to 1500 m apart. These stands had similar soil and topographic conditions. A sample plot or quadrat of 10 m × 10 m area was used for observations on community organization. Ten random sample plots per stand were observed and the occurrence of different species and the number and diameter of the individuals were recorded. The phytosociological data were analysed using conventional methods[14]. The frequency, density, basal cover and relative values for each species of the community were calculated. The importance value index (IVI) for different species was calculated as a sum of relative frequency, relative density and relative basal cover of each species. These values for different species of common habit were summed to compare the species groups within the same stand and those of different stands. The grand sum of frequency and density of all the species constituting different communities were also derived. The dominance (C) for each community was calculated by Simpson's index ($C = \sum pi^2$), and diversity by Shannon's index ($H = -\sum pi \ln pi$). Here, pi represents the proportional abundance of ith species in any given stand. β-diversity or species turnover was calculated by using the formula, $\beta = \gamma/\alpha$, where α is the diversity of discrete stands and γ is the diversity of forested landscape of the region[15].

A general undulating pattern for the sum of frequency and sum of density of the plant species in sal stands was observed along the gradient. In general, sum of frequency showed a clear trend of increase along the gradient while sum of density did so only in the peripheral communities up to the 8th stand on the continuum (Figure 1). As also reported elsewhere[16], the sum of frequency may be much lower in highly disturbed stands because of greater abundance of fortuitous species. At a very high disturbance level, the pool of adapted species is often small[17] and, therefore, the frequency sum is likely to be low. The peripheral stands showed lesser difference between the sum of the two indices compared to those towards the core. Thus the increasing gap be-

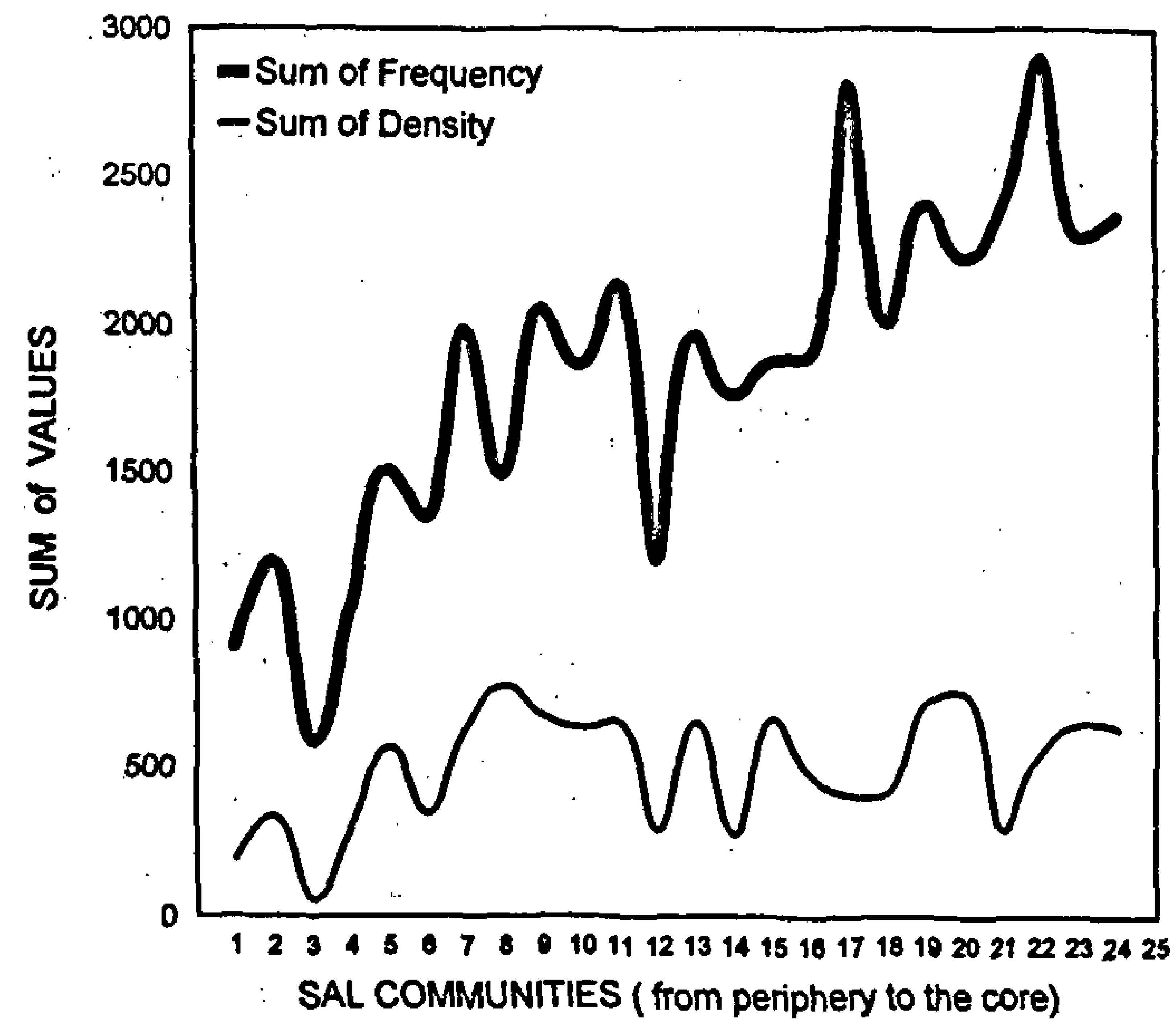

Figure 1. Sum of frequency and density of species in each of the 24 different communities of sal plantations along a disturbance gradient within a forest belt of Gorakhpur Forest Division.

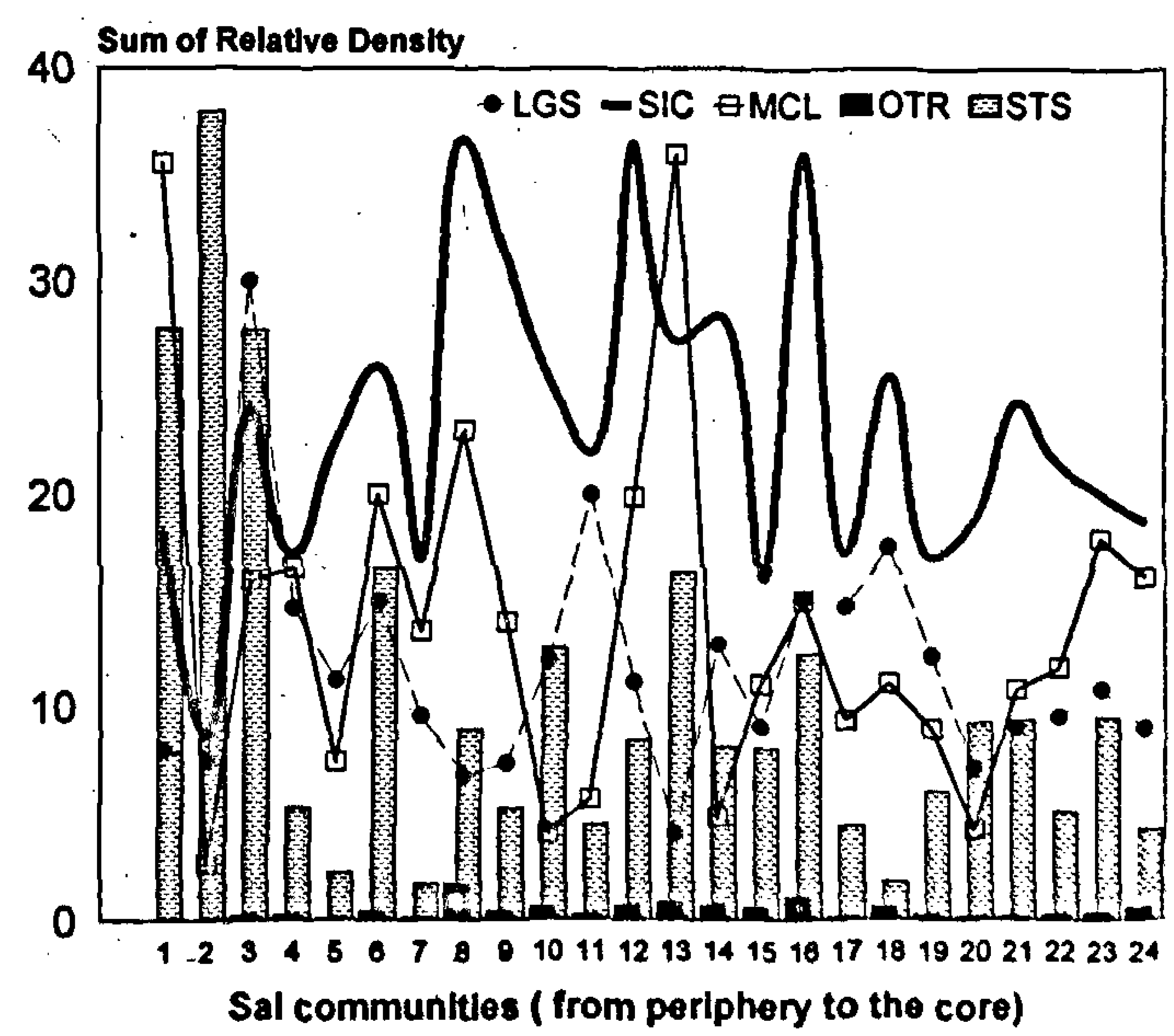

Figure 2. Sum of relative density of the species grouped under 5 components of each of the 24 different stands along the disturbance gradient. LGS, leguminous shrubs; SIC; shrubby individuals and woody climbers; MCL, *Mallotus philippensis* + *Clerodendron infortunatum;* OTR, trees (>30 cm gbh) other than sal; STS, sal trees and sal sprouts.

Table 1. List of species encountered under different habit groups in different stands of sal plantations along the disturbance gradient in Gorakhpur Forest Division. The actual habit of the species is shown against its name as T (tree), UT (undertree), S (shrub) and C (climber). Herbs are not mentioned here

Other trees (OTR)	Habit all T	Shrubby individuals and Climbers (SIC)	Habit	Leguminous shrubs (LGS)	Habit
Aegle marmelos		*Alstonia scholaris*	T	*Bauhinia malabarica*	T
**Bridelia retusa*		*Antidesma ghaesmbilla*	UT	*Bauhinia purpurea*	UT
Careya arborea		*Aristolochia* sp.	C	*Bauhinia vahlii*	C
Dillenia indica		*Asparagus racemosus*	C	*Caesalpinia bonducella*	C
**Diospyros tomentosa*		*Azadirachta indica*	T	*Caesalpinia crista*	C
**Eugenia heyneana*		*Carissa spinarum*	UT	*Cassia fistula*	UT
Ficus benghalensis		*Casearia tomentosa*	UT	*Cassia nodosa*	UT
**Ficus glomerata*		*Coolebrookia oppositifolia*	S	*Crotalaria* sp.	S
**Holarrhena*				*Desmodim heterocarpon*	S
antidysenterica		*Hymenodictyon* sp.	C	*Desmodium gangeticum*	S
Mangifera indica		*Piper* sp. 1	C	*Desmodium pulchellum*	S
**Miliusa velutina*		*Piper* sp. 2	C	*Desmodium triangulare*	S
**Mitragyna parvifolia*		*Psidium guajava*	UT	*Indigofera cassioides*	UT
**Morus laevigata*		*Rauwolfia serpentina*	S	*Moghania bracheata*	S
Phyllanthus emblica		*Smilax macrophylla*	C	*Moghania bracteata*	UT
Randia dumetorum		*Smilax lamifolia*	C	*Moghania chappar*	S
**Scleichera oleosa*		*Stereospermum suaveolens*	T	*Moghania lineata*	S
**Semicarpus anacardium*		*Thespesia lampas*	UT	*Pithecolobium dulce*	UT
**Streblus asper*		*Tiliacora acuminata*	C	*Pongamia pinnata*	T
**Tectona grandis*		*Triumfetta pentandra*	S	*Mallotus* + *Clerodendron*	(MCL)
**Terminalia tomentosa*		*Vitis* sp.	C	Shorea trees + sprouts	(STS)
**Terminalia arjuna*		*Woodfordia fruticosa*	UT		
**Trewia nudiflora*		*Zizyphus mauritiana*	UT		

*These tree species were mostly in the habit of shrub.

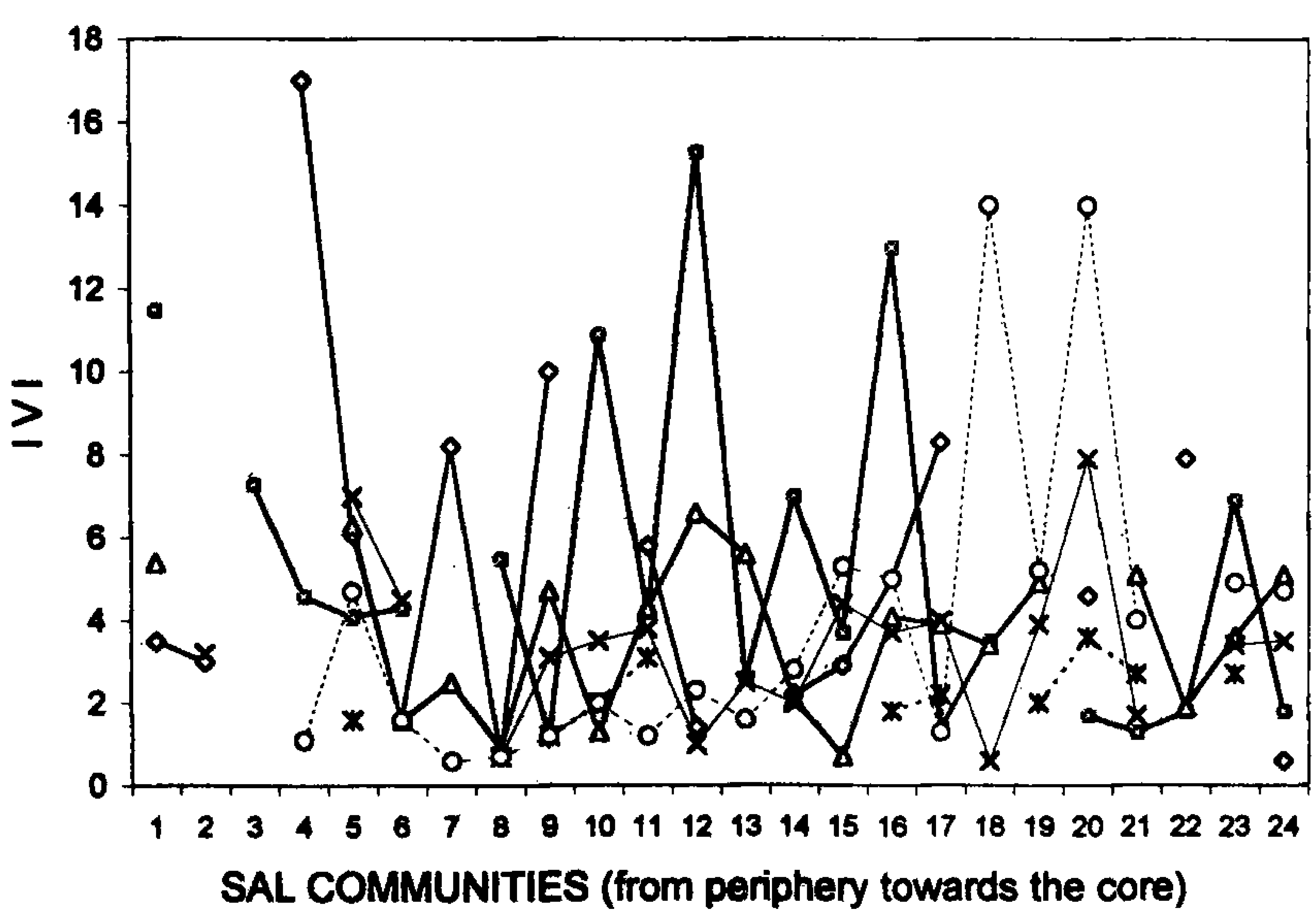

Figure 3. Importance Value Index (the sum of relative frequency, relative density and relative basal cover) of six common tree associates of *horea robusta*, —◇—, *Holarrhena antidysenterica*; —Δ—, *Diospyros tomentosa*; ---×---, *Mitragyna parvifolia*; —■—, *Terminalia tomentosa*; —×— *Bridelia squamosa*; —O—, *Scleichera oleosa*.

tween the two sums is an indication of increasing diversity of composition from the periphery to the core along the disturbance gradient. The degree of fluctuation in the sum of frequency for different stands was more conspicuous compared to that of density. It may be attributed to sudden increase in the number and abundance of a few opportunistic weedy species which appeared in several stands in response to exposed conditions. The degree of fluctuation in both the sum values tends to dampen towards the core for successive stands.

Figure 2 shows the sum of relative density of species grouped under major habit components. The two undershrubs, *Mallotus philippensis* and *Clerodendron infortunatum* (MCL) were generally encountered as shrubs and dominated the shrub layer especially in highly disturbed conditions. The ubiquity of dioecious *Mallotus* is due to its efficient sprouting at any growth phase[18] though the male and female *Mallotus* populations are known to show some bias with respect to prevailing light intensity[19]. *Clerodendron* regenerated through subsurface ramet proliferation from a horizontal root stock and the number of ramet per genet showed a direct relationship with the degree of disturbance (Sharma and Shukla, unpublished data). Several other apparent shrubs which are potential undertrees also showed efficient sprouting. All the other woody non-leguminous species of shrubby habit, irrespective of trees, shrubs or liana species, were grouped as shrubby individuals and climbers (SIC) which showed much greater density compared to other species group in majority of stands along the whole of the gradient. The sal stands which had considerable gaps in their canopies, however, showed much herbaceous cover which reduced the relative density of woody components. Leguminous shrubs (LGS) showed wide fluctuations towards periphery but their density was considerable in any stand compared to that of trees (>30 cm gbh) including *Shorea*. The relative density of trees other than sal (OTR), however, was very low especially in stands towards the core, primarily due to illicit cutting of timber. The difference in the value of relative density of different habit groups gradually decreased towards the core beyond the 18th stand along the gradient. Severe environmental perturbations may result due to the dominance of one or a few species[20] as evident here from the sum of relative density of different habit groups in some stands towards the periphery.

Figure 3 shows the pattern of change in the IVI of six common tree species growing as common associates of sal. All the individuals of a species, irrespective of tree- or shrubby habit, were considered together. (*Mallotus philippensis*, a very close associate of *Shorea*, was not considered here as it was present in every sal stand of the region). Of the six tree associates considered, *Holarrhena antidysenterica* showed much greater IVI in stands towards the periphery facing greater disturbance while *Scleichera oleosa* did so in stands towards the core of the forest facing lesser disturbance. The importance of *Terminalia tomentosa* was considerable only in stands facing comparatively moderate disturbance. *Diospyros tomentosa* and *Bridellia squamosa*, however, showed consistently low IVI along the whole of the disturbance gradient. The occurrence of *Mitragyna parvifolia* was least consistent and it also showed much lower IVI in any stand. Almost all the above species showed comparatively greater IVI in stands located at intermediate positions, i.e. 8th to 16th stand along the gradient. The IVI of some species was much lower towards the periphery and higher towards the core and vice versa for some others. Earlier studies on tropical succession of woody species conclude that the species likely to survive the patchy, frequently disturbed environment are early successional trees, best equipped to exploit the habitat conditions for maximum extension growth[21] and these are called well-dispensing weed trees[20].

The dominance, expressed in terms of Simpson's index, was markedly higher in stands towards the periphery. In general, it decreased gradually. A slight increase in its value was noticed in the least disturbed stands towards the core. The H value ranged from 1.98 to 3.08

Table 2. Dominance and diversity indices* of 24 different communities of sal plantations along the disturbance gradient

Community sequence	Simpson's Index of dominance	Shannon's Index of α-diversity	Diversity (H) β-diversity
1	0.189	1.98	2.04
2	0.155	2.13	1.90
3	0.211	2.17	1.86
4	0.130	2.48	1.63
5	0.104	2.96	1.36
6	0.109	2.52	1.60
7	0.089	2.72	1.48
8	0.067	3.08	1.31
9	0.073	2.95	1.37
10	0.065	3.09	1.31
11	0.075	2.91	1.39
12	0.057	3.22	1.25
13	0.063	3.47	1.16
14	0.066	3.06	1.32
15	0.081	3.03	1.33
16	0.049	3.35	1.21
17	0.065	3.03	1.33
18	0.056	3.28	1.23
19	0.056	3.18	1.27
20	0.069	3.09	1.31
21	0.042	3.53	1.14
22	0.055	3.42	1.18
23	0.047	3.41	1.18
24	0.050	3.36	1.20

*The γ-diversity of the forested landscape of north-eastern U.P. was measured to be 4.035 (unpublished data).

(1st to 8th stand) starting from the periphery. The intermediate stands (9th to 16th) had H in the range of 2.91 to 3.47. For the stands towards the core H ranged from 3.03 to 3.53. The values of H showed much greater fluctuations in stands towards the periphery than towards the core. Thus the diversity was maximum near the core which indicates that the disturbance in the core was enough for maximum diversity in the managed sal forests of the region. β-diversity, which shows the extent of species replacement[22] followed the reverse trend along the gradient (Table 2). It has been observed that diversity is lower in the absence of disturbance as well as in the presence of too much of disturbance[23]. Moderate levels of anthropogenic disturbances are compatible with maintenance of high biodiversity of landscape[24].

From the above observations, it may be inferred that the disturbance must be contained at the intermediate level so as to have maximum plant diversity in these plantation forests. Also, a few disturbance-friendly species like *Mallotus* and *Clerodendron* may be spared from complete destruction in peripheral stands (where high disturbance is inevitable) in order to have minimum herbage cover for conserving forest soil and to provide niches for understorey biota adapted to high disturbance zone. A threshold level of disturbance may, thus, be determined which can permit the extraction of resources without significant loss to the biodiversity of the region.

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A novel synthesis of bicyclo (3.1.0.) hexane system from Carvone

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Bicyclo (3.1.0.) hexanes have been synthesized starting with carvone, a monoterpene. The methodology involves cyclization of γ-hydroxy sulphones with p-toluene sulphonyl chloride (TsCl) and sodium hydride (NaH). These γ-hydroxy sulphones were obtained by sodium borohydride ($NaBH_4$) reduction of γ-ketosulphones which in turn were prepared by Michael addition of p-toluene sulphinic acid on carvone. Two sets of hitherto unknown bicyclo (3.1.0) hexane were isolated in 60% and 72% yield, respectively. The reaction sequence for the above methodology is shown in the scheme.

IT has been reported that addition of KCN[1,2], PhSH[3,4] and PhSeH[5] to carvone furnished, with high stereoselectivity, the isomer having the nucleophilic group axial at C-6, the equatorial isomers or the C-1 epimer[1,2] obtained in only minor amounts. Reaction of carvone (**1**) (see scheme) with p-toluene sulphinic acid (generated *in situ* from the sodium salt) in ether at 0–5°C gave a product (yield 78%), gummy in nature and homogeneous on thin layer chromatography (TLC). Based on spectral charac-

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