Research Article

Trends in Tree Diversity and Stand Structure during Restoration: A Case Study in Fragmented Moist Deciduous Forest Ecosystems of Northeast India

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Ecological implications for the conservation of fragmented forests to managed local plant diversity have recently drawn much attention of most conservationists. Present study investigates the importance of fragmented forests using different quantitative measures of species diversity and stand structure as indicators of natural restoration from past disturbances. Eleven independent 500 m × 10 m belt transects (5.5 ha) were established within fragmented low land moist deciduous forests of Tripura. All woody plants ≥10 cm girth at breast height (GBH) were measured. A total of 7,134 individuals with mean density of 648.55 stems ha⁻¹ and 16.36 m² ha⁻¹ of basal area were recorded, which represented 134 species, 93 genera, and 43 families of woody plants. Diversity-dominance curve showed that maximum number of species were ranked >10 due to low abundance value. Maximum distributions of stems (>50%) were recorded at lowest girth class (10–30 cm) as an indication of advanced regeneration and significantly declined towards upper girth ($r^2_{\text{adj}} = 0.93$; $P < 0.0001$) and height ($r^2_{\text{adj}} = 0.95$; $P < 0.0001$) classes, which also indicated that some plants were adopted with ongoing disturbances through both seeded and nonseeded regeneration. Species richness ($r^2_{\text{adj}} = 0.49$; $P = 0.05$), dominance ($r^2_{\text{adj}} = 0.68$; $P = 0.009$), and density ($r^2_{\text{adj}} = 0.62$; $P = 0.02$) were significantly increased at different disturbance intensities. Disturbances strongly influenced typical community association and structure by increasing diversity and population at certain magnitude and thereby showed declining trend towards maturation. Fragmented moist deciduous forests seek immediate attention as they represent spatial habitat for many economical or ecological important species, thus sustaining local biodiversity for livelihoods.

1. Introduction

Small forest fragments or areas lying outside fully protected zones maintain a significant number of species and their genetic diversity [1, 2]. Even forest patches of less than 1 ha in size could play major roles in maintenance of regional biodiversity [3]. During the past several years, large complexes of natural habitat have been converted into agricultural, industrial, or urbanized landscapes, leading to severe loss of the original habitat and an increasing fragmentation of the remnant patches [4]. High fragmentation rate stimulate

habitat modifications and the loss of valuable portions of the forest ecosystem, the number of rare and shade – tolerant species increases due to fragmentation especially during recovery at the early successional stage [5]. Tree species with small population will be the first to be lost in the process of forest fragmentation [6]. Tree species diversity is an important and fundamental aspect to total forest ecosystem biodiversity [7, 8]; they provide resource and habitat for almost all other species [9]. Tree diversity in tropical forests varies greatly from place to place, mainly due to variation in biogeography, climatic responses, habitat suitability, and

anthropogenic disturbances [10, 11]. Disturbances strongly influence forest dynamics, community attributes, structure, and diversity at both local and regional scales [12, 13], evident in changing size class distributions of the most sought-after species [14].

Most of the quantitative vegetation inventories were conducted in species-rich forests and data on species-poor forests or forest fragments are inadequate [15]. In addition, species richness and abundance data are crucial for assessing the impacts of disturbance or fragmentation on local biodiversity, conservation priority setting, and long-term vegetation monitoring [16]. Moist deciduous forest is one of the crucial habitat types of India, and most of the earlier studies were reported from Western Ghats, Eastern Ghats, and Andaman Island [17–20]. Data on community composition and population structure in lowland moist deciduous forests are limited. Since remaining fragmented forests are quickly shrinking or modifying under several manmade influences, immediate attention was felt necessary to gather quantitative inventories for tree diversity and stand structure in fragmented lowland forests to better understand its nature and dynamics. Hence, present objectives were designed to investigate (1) the status of woody plant diversity and structure in fragmented forests, (2) to draw the structural changes under present level of disturbance intensity, and (3) to test the hypothesis that species diversity, stand population, and dominance increased during restoration following intermediate disturbance hypothesis of Connell (1978) [21].

2. Materials and Methods

2.1. Study Site. Present study was conducted in Tripura, which is a small hilly state belonging to the northeastern part of India. The state is surrounded by Bangladesh on three sides and only northeast part of the state is connected through Assam and Mizoram with the country, accounting for barely 0.342% of the total area of the country. In terms of area, it is the third smallest state in the country, after Goa and Sikkim. The geographical area of the state is only 10,492 km² and has 4 districts. The state is located in biogeographic zone of 9B-North-East hills, endowed with rich and diverse forest resources. About 59.98% of the geographical area of the state is under the forest. The forests are mainly semievergreen, moist deciduous, mixed sal, and dry deciduous forests. The present study sites located between 23°57'55" and 24°05'34" north latitude and 91°17'18" and 91°29'22" east longitude. The area is bordered by Bangladesh on northwest side and located in extreme northwest part of state. The study area falls under low physiographic zone: slope is < 40° and the altitude is <100 m (ranging from 18.59 to 90.22 m amsl). The climate of the area is characterized by highly humid atmosphere and temperatures range from 10°C to 35°C. The monsoon season is mainly from June to September with an annual average rainfall around 2400 mm mostly due to southwest monsoon. Forest characteristic of the study area is similar to moist deciduous forest (I/I₃C/C₃b). Total forest area recorded for West Tripura is 1155.409 km² out of 6292.681 km². Actual study locations belong to Mohanpur and Hezamara block

FIGURE 1: Map of the study area showing eleven different sites in fragmented forests of West Tripura, India.

under Sadar forest division of West Tripura (Figure 1). North part of this area particularly the Hezamara block inhabited by *Tripura* and *Reang* tribe, many of them still practicing traditional shifting cultivation. Hence, both the marginal and interior forest areas are under threat of severe degradation. Large forest areas have been converted from time to time into tea plantation especially in Mohanpur block and only few forest patches still exist [22].

2.2. Field Sampling. Eleven 0.5 ha belt transects (500 m × 10 m) were established in the inventory of woody vegetation of fragmented moist deciduous forest of West Tripura district during April 2011, and thus the total sampling area was 5.5 ha (Table 1(A)). Plots were laid randomly within remaining fragmented forests surrounding village boundary, plantation, and roads. In each plot, all woody plants ≥10 cm girth at breast height (GBH) were measured in centimeter and counted individually at 1.3 m height from the ground level using a tape; height for all individuals was measured to the nearest meter [23]. We restricted our analysis and interpretation of diversity and community composition to species that had successfully established a minimum girth class. We also included those woody shrubs, bamboos, and lianas that attained our girth category. The GPS locations of the plots and physical condition of every individual were noted under alive, cut, and dead categories; sites disturbance scores were also recorded to obtain quantitative disturbance intensity [24, 25]. Specimens were identified with the help of the Flora of Tripura State and the Flora of Assam [26, 27]. The reference herbarium was deposited in herbarium of Botany Department, Tripura University.

2.3. Data Analysis. The field data was analyzed for number of species and quantitative analysis of frequency; density per ha and basal area per ha and their relative values were calculated and summed to get Importance Value Index (IVI) using Mueller-Dombois and Ellenberg [28]. Relative density = (Density of the species/Total density of all species) × 100.

TABLE 1: Site characteristics and disturbance intensity within the fragmented forests.

Fragmented forest sites	A. Locations			B. Site disturbances*									
	Latitude (ddmss)	Longitude (ddmss)	Altitude (m)	Fire	Grazing	Fuel wood collection	Thatch collection	Soil removal	NTFP collection	Number of cut trees	Number of dead trees	Total score	Disturbance intensity (%)
Simna (Sim)	24°05'34.98"	91°26'10.14"	68.57	2	2	3	1	1	2	20	2	33	9.24
Diggyatila (Dig)	24°05'15.36"	91°26'39.66"	67.36	1	3	2	1	1	1	36	8	53	14.85
Taranagar (Tar)	24°05'14.11"	91°24'30.10"	28.95	1	3	3	3	1	1	12	2	26	7.28
Katamara (Kat)	24°04'13.20"	91°23'19.70"	29.56	1	2	2	2	2	2	10	0	21	5.88
Subalshing (Sub)	24°00'16.00"	91°27'37.50"	75.59	2	1	3	1	2	2	36	6	53	14.85
Montala (Mon)	24°01'10.40"	91°26'12.10"	55.77	2	3	1	3	1	1	4	0	15	4.20
Bijohnagar (Bij)	24°00'23.80"	91°23'39.00"	30.78	1	2	2	2	1	1	16	0	25	7.00
Gajapara (Gaj)	23°55'45.00"	91°29'22.80"	90.22	2	2	2	2	2	1	26	4	41	11.48
Borkathal (Bor)	23°57'55.00"	91°24'04.00"	35.96	1	3	3	3	2	2	22	2	38	10.64
Lonkamura (Lon)	23°52'32.50"	91°14'54.30"	18.59	1	3	2	3	2	1	32	0	44	12.32
Salbagan (Sal)	23°53'01.80"	91°17'18.20"	35.35	1	2	1	1	2	1	0	0	8	2.24
Total				15	26	24	22	17	15	214	24	357	100
Mean				1.33	2.33	2.11	2.22	1.67	1.33	17.56	1.56	30.11	8.43
Standard error				0.17	0.24	0.26	0.28	0.17	0.17	4.12	0.73	4.92	1.38
Standard deviation				0.50	0.71	0.78	0.83	0.50	0.50	12.36	2.19	14.75	4.13

* Scoring: rare: 1, occasional: 2, and recurrent: 3 and 1 score for every cut and dead stem.

Relative frequency = (Frequency of the species/Total frequency of all species) $\times$ 100. Relative dominance = (Basal area of the species/Total basal area for all species) $\times$ 100. Important Value Index (IVI) = Relative Frequency + Relative Density + Relative Basal Area. General diversity was calculated using Shannon and Wiener index [29] and the index of dominance of the community was calculated by Simpson's index [30]. Shannon and Wiener's index = $-\sum\{(ni/N)\log_2(ni/N)\}$; ni = IVI of the species i , N = IVI of all species in the community. Simpson dominance index = $\sum\{(ni/N)^2\}$; ni = IVI of species i , N = IVI of all species in the community. Species richness index was computed using Menhinick [31] and Evenness index of the forest community was calculated following Pielou [32]. Menhinick richness index = $S/\sqrt{N}$; S = total number of species, N = total number of individuals. Pielou evenness index = Shannon and Wiener's index/ $\log(S)$; S = total number of species.

The number of species was plotted on y -axis against the number of individuals on the x -axis for comparing species richness among the fragmented forests [33] and species abundance data was plotted against species rank to develop diversity versus dominance curves [34], using BioDiversity Pro version 2 [35]. Woody species was grouped among ten girth classes (≥ 10 – <30 , 30 – <60 , 60 – <90 , 90 – <120 , 120 – <150 , 150 – <180 , 180 – <210 , 210 – <240 , 240 – <270 , and >270 cm) and height classes (<3 , 3 – <6 , 6 – <9 , 9 – <12 , 12 – <15 , 15 – <18 , 18 – <21 , 21 – <23 , 24 – <26 , and >26 m) to observe the distribution of population at different age and height classes. To examine the pattern of changes in community types and stand structure across the studied sites, regression curve fitting was used with midvalue of overall stem density ha^{-1} girth and height classes on x -axis and log transformed density ha^{-1} on y -axis [36]. In addition to test intermediate disturbance hypothesis, we examined the relationship by curve fitting between density, diversity, and dominance on y -axis and disturbance intensity on x -axis for those fragmented forests using Origin and PAST software [37, 38].

3. Results

3.1. Status of Species Richness and Habitat Diversity Attributes. A total of 134 woody species (≥ 10 cm GBH) representing 93 genera and 43 families were recorded within 5.5 ha fragmented moist deciduous forest of West Tripura. Habit-wise, out of 134 woody species 118 species (88.06%) were trees, 7 (5.22%) species were woody liana, 4 (2.99%) species were woody shrub, and 5 (3.73%) species were bamboo. Species richness ranged from 31 to 61 species in eleven sites. Both Dig and Gaj had 61 species, which was two times greater than Sal (31). The observed family richness was the greatest in Gaj (37). The rarefaction curves confirmed that sites Gaj, Sim Dig, and Kat were steeper than the others, suggesting high species richness (Figure 2). Whereas Sim did not asymptote at similar numbers of individual, which revealed that sufficient number of species might not covered by our sampling effort and there was possibility to get additional species in Sim compared to other sites. Gaj scored high value of Shannon diversity index (3.92), while Sal recorded low value (2.20) compared to the

FIGURE 2: Rarefaction curves for comparing the species richness in eleven fragmented forest stands.

rest of the sites. Mean Simpson dominance index was 0.06 and was recorded high in Sub (0.07), which was recorded low in Gaj (0.02). Species were more evenly distributed in Sim, Tar, Gaj, and Mon, with a mean value of Evenness index of 1.94 (range 1.47–2.16), while Menhinick's species richness varied from 1.31 to 2.64 along the fragment sites with mean value of 1.85 (Table 2).

The diversity-dominance curve displayed a log series distribution where species ranked (1–100) from most to least abundant, and majority of the species had lower abundance and population, while few species showed higher values. *Tectona grandis* appeared to be the most abundant in Sim, Sub, and Mon; *Schima wallichii* in Dig, Kat, and Gaj; *Syzygium cerasoides* in Bij and Bor; and *Microcos paniculata*, *Gmelina arborea*, and *Shorea robusta* in Tar, Lon, and Sal, respectively. *Holarrhena antidysenterica*, *Microcos paniculata*, *Terminalia bellirica*, *Glochidion multiloculare*, *Chaetocarpus castanicearpus*, *Syzygium cerasoides*, and *Ziziphus rugosa* were observed as codominant association, although *Aporosa obovata*, *Canthium glabrum*, *Desmos dumosus*, *Elaeocarpus prunifolia*, *Elaeocarpus robustus*, *Bhesa robusta*, *Leea guineensis*, *Litsea cubeba*, and *Litsea laeta* were recorded with very low abundance and population (Figure 3).

3.2. Patterns of Stand Density, Basal Area, and Important Value Index (IVI). A total of 7,134 individuals were encountered with mean density of 648.55 trees ha^{-1} (ranged from 428 to 884 ha^{-1}) in eleven 0.5 ha of fragmented forest sites. The highest woody density was recorded for Bor (884 ha^{-1}) and lowest for Sal (428 ha^{-1}). Top ten dominant trees, namely, *Microcos paniculata* (43.82 ha^{-1}), *Tectona grandis* (43.09 ha^{-1}), *Holarrhena antidysenterica* (30.36 ha^{-1}), *Syzygium cerasoides* (27.64 ha^{-1}), *Shorea robusta* (24.91 ha^{-1}), *Schima wallichii* (23.45 ha^{-1}), *Syzygium fruticosum* (21.45 ha^{-1}), *Melocanna baccifera* (17.82 ha^{-1}), *Gmelina arborea* (17.45 ha^{-1}), and *Terminalia bellirica* (16.55 ha^{-1}),

TABLE 2: Consolidated details of woody plant diversity inventory (≥ 10 cm GBH) in eleven fragmented moist deciduous forests of Tripura.

Parameters	Fragmented forest sites											Mean	Standard error	Standard deviation
	Sim	Dig	Tar	Kat	Sub	Mon	Bij	Gaj	Bor	Lon	Sal			
Number of woody species	60	61	41	45	45	40	37	61	39	47	31	46.09	3.11	10.32
Number of genera	50	54	31	42	39	37	29	54	33	41	31	40.09	2.76	9.16
Number of families	29	32	22	26	32	28	23	37	25	28	25	27.91	1.34	4.44
Shannon index	3.73	3.57	3.33	3.49	3.32	3.47	2.75	3.92	2.58	3.38	2.2	3.25	0.16	0.52
Simpson index	0.03	0.04	0.05	0.04	0.07	0.04	0.02	0.02	0.02	0.06	0.3	0.06	0.02	0.08
Evenness index	2.1	2	2.06	2.1	2.01	2.16	1.64	2.2	1.62	2.01	1.47	1.94	0.07	0.25
Richness index	2.64	2.08	1.64	2.2	1.63	1.7	1.42	2.47	1.31	1.71	1.5	1.85	0.13	0.44
Density (ha^{-1})	518	854	628	436	762	552	680	608	884	784	428	648.55	47.87	158.78
Basal area (m^2ha^{-1})	5.28	14.08	6.8	14.5	12.55	9	16.44	23.6	14.04	16.6	47.08	16.36	3.43	11.37

FIGURE 3: Diversity-dominance curve and species ranking based on species abundance.

contributed in 41.10% of overall density. Mean basal area was $16.36 \text{ m}^2 \text{ ha}^{-1}$ for the whole study of which top ten dominant trees grasped $9.44 \text{ m}^2 \text{ ha}^{-1}$ (57.68%) of total basal area and it recorded the minimum for Sim ($5.28 \text{ m}^2 \text{ ha}^{-1}$) and was the greatest in case of Sal ($47.08 \text{ m}^2 \text{ ha}^{-1}$). Based on the IVI, top ten dominant and codominant trees contributed in 110.11 of total IVI (300). *Shorea robusta* grasps the maximum IVI (30.53), which was predominant only in Sal, followed by *Tectona grandis* (11.70), *Microcos paniculata* (11.22), *Schima wallichii* (10.20), *Syzygium cerasoides* (9.80), *Holarrhena antidysenterica* (8.15), *Artocarpus heterophyllus* (7.54), and *Terminalia bellirica* (7.12). While 18 species sowed IVI value < 0.30 , *Desmos dumosus*, *Leea aequata*, *Elaeocarpus robustus*, and *Actinodaphne obovata* were recorded with very low IVI contribution to the fragmented forest. Overall 27 species were selected (top five most dominant species from each site) based on their IVI contribution to those fragmented forests, which suggested that *Microcos paniculata*, *Holarrhena antidysenterica*, *Chaetocarpus castanicarpus*, *Glochidion multilocure*, *Syzygium cerasoides*, and *Ziziphus rugosa* were increasing their IVI over previously predominant

trees. These small tress species showed very little differences in terms of IVI contribution with key dominant species, namely, *Shorea robusta*, *Schima wallichii*, *Tectona grandis*, and *Gmelina arborea* (Figure 4).

3.3. Changes in Girth or Age-Class and Height-Class Distributions. Stem density across girth classes in all sites decreases almost from smallest to largest trees. While occurrences of mean stems ha^{-1} at lower girth class ($10\text{--}30$ cm) were 50.88% (330 ± 9.54), followed by 29.10% (188.73 ± 96.94) in $30\text{--}60$ cm girth class and 10.96% (71.09 ± 37.98) in $60\text{--}90$ cm girth class, only 0.06% stems were shown in the highest ($240\text{--}300$ cm) girth classes. Maximum number of individuals at lower girth class was recorded for Bor (468) and minimum for both Kat and Gaj (212). While few individuals were recorded at higher girth class (> 270 cm), some higher girth classes were absent in Sim, Tar, Sub, Mon, Bor, and Lon. Stems were more frequently distributed in all the eleven sites within the $10\text{--}120$ cm girth classes. The overall stem density ha^{-1} at different age classes was significant ($r_{\text{adj}}^2 = 0.93$; $P < 0.0001$) among the studied sites and showed inverse quadratic relationship (Figure 5). The distribution of stems by height class intervals showed that maximum trees (82.47%) were widely distributed within $3\text{--}12$ m range; 31.46% of individuals were > 3 m, followed by 23.63% between 3 and < 6 m and 14.35% within $6\text{--}9$ m, whereas 7.20% of individuals distributed between 12 and < 15 m, only 0.42% individuals were attained > 26 m. Density of trees was linearly declined across the height classes ($r_{\text{adj}}^2 = 0.95$; $P < 0.0001$) among the fragmented sites (Figure 6).

3.4. Effects of Disturbances and Recovery Processes. Besides serious past logging experience for timber, several other anthropogenic disturbances were still ongoing in those fragmented forests sites. Grazing and fuelwood collection were more intense due to closeness of village. A total of $214 \text{ trees ha}^{-1}$ (19.45 ± 12.36) were recorded as cut or logged and 24 trees ha^{-1} (2.18 ± 2.75) as injured out of overall $7,134$ individuals; maximum number of cut and injured trees were recorded both from Dig and Sub. Both cut and injured trees were 238 (21.64 ± 14.50) for overall study but were absent in case of Sal. Site disturbance intensity was obtained

FIGURE 4: Dominance and codominance competition of 27 tree species (mean and standard error of IVI). Five most dominant species were selected from each fragmented forest site based on highest IVI contribution to the community.

FIGURE 5: Relationship between population density (log transformed) and midvalue of girth class intervals across the fragmented forest sites.

FIGURE 6: Relationship between population density (log transformed) and midvalue of height class intervals across the fragmented forest sites.

qualitatively by summing the disturbance scores along and the number of cut and injured individuals (Table 1(B)). It could be assumed that the proportion of scores that showed maximum value revealed comparatively high level of anthropogenic disturbance or fragmentation than the lower value. The highest intensity was recorded for Sub and Dig (14.85%), followed by Lon (12.32%), Gaj (11.48%), and Bor (10.46%), and the lowest in case of Sal (2.24%). While the number

of species (that occurred on each site) was significantly increased with disturbance intensity ($\chi^2 = 0.06$; $F = 3.92$; $P = 0.05$) at 15% level and declining trend was observed when intensity level was increased among the sites (Figure 7), initially, declining trend of the dominance of key community species was observed, and at midlevel of disturbance (10%) few fragmentation tolerant species significantly ($\chi^2 = 0.36$; $F = 8.72$, $P = 0.009$) increased in dominance with disturbance

FIGURE 7: Relationship between species richness and disturbance intensity.

FIGURE 8: Relationship between species dominance and disturbance intensity.

intensity (Figure 8). In addition, relationship between stem density and disturbance intensity also suggested that present number of stems per ha were increased significantly with fragmentation intensity ($\chi^2 = 0.05$; $F = 6.65$; $P = 0.02$) during restoration (Figure 9).

4. Discussion

Rarefaction curves suggested that the maximum number of species was counted for Gaj, Sim, and Dig, while Sim did not show asymptote and species richness was much lower in the relatively managed Sal forest. Higher species richness in the fragmented sites might attribute to intermediate disturbance hypothesis [21]. Species richness might be enhanced in some of the sites through quick accumulation of some locally adaptable early successional species. The range of species richness (31–61) recorded within the present study was more than Puerto Rico, 30–35 species [39], and moist deciduous forest of Western Ghats was 24–26 species [40]. However, overall 134 species encountered in this inventory were higher than the number of species reported from some well-protected Indian forests [41–43]. The value of Shannon-Winner diversity index ranged from 2.20 to 3.92; whereas this value generally ranges between 0.83 and 4.1 for Indian forests [41], hence, present studies' value was fallen within the reported range. Species diversity was increased in case of Gaj, Sim, Dig, Lon, and Sub (Figure 7) along the disturbance intensity ($r_{adj}^2 = 0.49$; $P = 0.05$) because diversity in communities increases under intermediate disturbance regime [21]. Instead of protection and management in Sal by Forest Department, it showed minimum species richness, which might be due to presence of high density of voluminous *S. robusta*, which generally has strong competitive effects on seedling growth and regeneration of other species [36, 42]. However, disturbances allow species to grow well in new environment, recruited and established by increasing the number of species that are not found in managed areas [43]; hence, species richness fairly increased in those fragmented forests.

Stem density ha^{-1} at ≥ 10 cm girth class in tropical forest generally varies from 245 to 859 trees ha^{-1} [44, 45]; present

mean stand density of 648.55 trees ha^{-1} (range 428–884 ha^{-1}) was observed higher than protected Western Ghats moist deciduous forest [46, 47]. Such relatively higher density of the present fragmented forests might be due to their patchy condition which resulted from past disturbances, since the trend of smaller trees' density was reported to increase after historic disturbances [48]. Significant inverse relation of overall stem density-age classes suggested that 50.88% of stems were at lower girth classes, that is, 10–<30 cm (Figure 5) which was the indication of advance regeneration stages and possibly those small fragmented forests were recuperating from past disturbances. 214 trees ha^{-1} were recorded as logged or cut in the whole study, which also suggested illegal logging and heavy timber requirements. Lower abundance or absence of upper canopy forming or old mature trees was also evident from overall stem density-height classes (Figure 6) and so forth, which might result in enough gaps or forest openings, where fragmentation tolerant small tree species were facilitated to regenerate quickly and increase in their stem density [36, 42]. After removal of mature or old aged key dominant tree species especially for timber, many opportunistic species might gather through seeded or nonseeded multiplication in absence of previously key dominant species. Hence, stem density was significantly increased with disturbance intensity ($r_{adj}^2 = 0.62$; $P = 0.02$) in those sites as an early successional stage and the trend possibly declined very slowly from this level towards forest maturation (Figure 9).

Mean basal area value of 16.36 $\text{m}^2 \text{ha}^{-1}$ obtained in the present study (range 5.28–47.08 $\text{m}^2 \text{ha}^{-1}$) was close to moist deciduous forests of Western Ghats 14.7 $\text{m}^2 \text{ha}^{-1}$ and 12.83 $\text{m}^2 \text{ha}^{-1}$ [46, 47] and was less than 49 $\text{m}^2 \text{ha}^{-1}$ in tropical moist deciduous forest of Eastern Ghats [49]. Dominance and codominance association in those fragmented forest suggested that *S. robusta*, *T. grandis*, *S. wallichii*, and so forth still have the control over upper canopy structure and basal area. But simultaneously locally adapted small oligarchic species were increasing their population density to keep the codominant rank by maximum IVI contribution, which might lead to the variation in community association over existing forest structure by shifting of codominant species

FIGURE 9: Relationship between stem density and disturbance intensity.

into the most dominant species rank at such intensity of disturbances (Figure 4). Species dominance generally increases as a function of stress or past disturbance [50], and these species have vital role in the microenvironment within the community [51]. Higher abundance of several local oligarchic small tree species as codominant associations in those fragmented forests was increased dominance especially in case of Sub, Lon, and Dig (Figure 8) due to strong adaptability of those species with fragmentation intensity ($r^2_{\text{adj}} = 0.68$; $P = 0.009$). The intensity of disturbances greatly influenced species dominance in those fragmented forests which may affect future forest structure and composition, succession phases, and species restoration. Fragmentation may establish several transitional community associations which are mostly dominated by few local adaptable species through direct or indirect competitions through increasing IVI over previously key dominated species.

5. Conclusions

Bamboo shared 91.25% of overall IVI of the present fragmented forest, which contributed enormously in rural livelihood by fulfilling the NTFPs and fuelwood demand for the people living proximate of those fragmented forests. Many bamboo patches were dried due to flowering especially in *Melocanna baccifera*, *Bambusa balcooa*, and *B. tulda* which in turn drastically changed the trend of demands for forest resources in those fragmented forests. Demands for fuelwoods, thatches, and structural and fencing materials were more or less likely to shift into the small and medium sized trees in absence of bamboo in those fragmented forests (after flowering), which may further influence the natural process of restoration in those fragmented forests, may restrict the possibilities of species richness, and locally enhance the process of either species monodominance or rareness. Fragmented forest plays a crucial role for conservation and sustaining local plant genetic diversity, which may be the only remaining store for many natural products and threatened species beyond protected areas. Monitoring of fragmented tree species and plantation of locally prioritized species in the

opened patches will contribute towards effective management between forest dependent people and fragmented forests.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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