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Tree Species Richness, Population Structure and Regeneration Status along the Disturbance Gradient in Tropical Forests of South Territorial Division, Sikkim, Eastern Himalaya

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ABSTRACT

This study is an attempt to find the impact of disturbances on tree species richness, population structure and regeneration status in the tropical forest of Sikkim. On the basis of Disturbance indices forest were categorised into Highly Disturbed (HD), Moderately Disturbed (MD) and Least Disturbed (LD). While, number of species was considered as species richness in different disturbance gradient, population structure was determined using density diameter relation. Similarly, regeneration status was seen based on the density of seedling, sapling and adult tree species along the disturbance gradient. Species richness was highest (29) at LD sites and lowest in HD (24) and 25 in MD. Population structure of the forest across the sites were normal with densities of seedling>sapling>adult, but densities in all growth form were higher in LD followed by MD and HD. Seedlings of *Shorea robusta, Schima wallichi* and *Tectona grandis* dominated the forest floor, comprising of 85% of all the seedling density. Although most of the species regenerated better in LD sites, species like *Schima wallichii, Tectona grandis, Terminalia bellirica* and *Lagerstroemia parviflora* had better seedling densities in MD sites. LD sites showed highest percentage of good (31 %), fair (17 %) and new (20 %) regeneration. Highest percentage of poor regeneration was observed in HD (27) sites followed by MD (23) and LD (11) while 29 % of the species were not regenerating and MD sites followed by HD (27) and LD (20). This study concludes that the anthropogenic disturbance is detrimental for species richness, population structure and regeneration of tree species yet moderate disturbances may be beneficial for regeneration of few selected species.

Key words: *Anthropogenic pressure, Forest disturbance, Tropical forest, Regeneration, Territorial forest*

Introduction

Various ecological and anthropogenic factors determine the forest structure (Dolezal and Srutek, 2002). People in the Himalayan region have lived in close proximity with the forest since very long and has been dependent on them for sustenance of life. Due to the rise in population the demand for the forest resource has also increased many folds in recent times, which alter the forest composition in various ways. With the increase in population pressure, natural and socioeconomic systems in the Himalaya are at threat, especially with reference to rapid globalization (Roy and Rathore, 2019). Understanding the structure and composition of native forests is a prerequisite in developing an adaptive forest management plan for Himalayan forest ecosystems where climate change is rapid (Bhutiya *et al.,* 2019). Population demography is crucial to understand current species distribution patterns (Bell *et al.,* 2013) and to predict their future dynamics (Pagel and Schurr 2012; Normand *et al.,* 2014). In fact, the population structure (age or size) of tree species is a well-known way to provide valuable information about the population dynamics (Dang *et al.,* 2010; Dolanc *et al.,* 2013), and regeneration is considered the determinant factor driving population dynamics at the range limits (Rickebusch *et al.,* 2007) because the regenerating individuals of long lived trees are most sensitive or fragile to environment variability (Castro *et al.,* 2004).

According to Sundriyal and Sharma (1996) less than 50 % of tree species in the forest of Mamlay watershed, South Sikkim are regenerating. Those regenerating are secondary species and are less preferred for daily use by local people for fuelwood, fodder and timber purpose. Bhutia *et al.* (2019) reported lower density of large size trees in lower elevation in forest of Sikkim and disparity in size class distribution among forest along altitudinal gradient. Popradit *et al.* (2015) reports that due to the anthropogenic factors plant diversity reduces linearly towards the village boundary, which caused a loss of individual density because of severe declines in small saplings compared with adult trees and large saplings in proximity to the village. Present study describes the population structure and regeneration status of tree species in sal dominated tropical forest of south Sikkim.

Materials and Methods

Study area

This study was conducted in the tropical forest of south territorial forest division of Sikkim state of India in eastern Himalaya. Study area is dotted with the patches of reserve forests and a wildlife sanctuary. Total reserve forest in study area is 27.6 km^2 spread along the tropical belt in fragments of varying sizes with a total population of 38548 persons from 13 different Gram Panchayat Units (Census of India, 2011; SBFP, 2015). Average livestock holding per family in the study area is 3.69 while average land holding is 1.67 acre per family (VDAP). The study sites were selected at the radius of 2000 m in three fringe villages viz. Aambotey, Danak and Panchgharey and the elevation of the effective study area ranges from 250m to 700 m. Study sites have been categorised into Highly disturbed (HD), Moderately Disturbed (MD) and Least Disturbed (LD) based on the degree of disturbances at different distance i.e. 500 m, 1000 m, and 2000 m from the village fringe (Table 1). Degree of disturbance was assessed based on the site characteristics of following parameter (i) tree density (ha^{-1}), (ii) cut stump density (ha^{-1}), (iii) canopy cover (%) and (iv) goat droppings and cow dung density (ha^{-1}) following Mishra *et al.* (2004) and Bhat *et al.* (2012). Forest type of the study area is East Himalayan Sal Forest and East Himalayan Moist Mixed Deciduous forest. The average annual rainfall for ten year period from 2011 to 2020 of the South District Sikkim is 2179.6 mm, of which 71-72% is received during monsoon period i.e. June to September (IMD). Maximum temperature of the study area in summer month reach upto 35^{o}C while minimum of winter temperature is 6 ^{o}C (Pradhan, 2007).

Table 1. Disturbance parameter used for categorizing the sites.

Disturbance parameter measured	LD	MD	HD
Stump density (ha^{-1})	33	53	97
Dungs/droppings (ha^{-1})	50	47	63
Lopped trees density (ha^{-1})	7	10	17
Canopy cover (%)	76	67	54

Sampling

Phyto-sociological data of the trees species were collected using quadrat method. 30 quadrat each of size 10 x 10 m, 5 x 5 m and 1 x 1 m were placed randomly for adult trees (>30 cm GBH), sapling (11-30 cm) and seedlings (1-10 cm) respectively at each sites (Curtis and McIntosh, 1950; Phillips, 1959; Saxena *et al.,* 1984). Tree GBH (Girth at Breast Height) was measured using measuring tape at 1.37 m from base. Sum of GBH of individual species was used to calculate Total Basal Area (TBA). To know the complete structure and composition of the forest, the quantitative parameters frequency, density, TBC, and importance value index (IVI) were calculated following Cottam and Curtis (1956). Using the IVI value Shannon-Wiener diversity index (Shannon and Weaver, 1963), and evenness (Pielou 1966) for each sites were determined. To understand the population structure and regeneration pattern, GBH classes were established on the basis of range of available data. The density of trees, saplings, and seedlings was calculated for each sites to verify the regeneration status. Different regeneration categories (fair, good, not, new, and poor) were created to assess the regeneration status of each species. Regeneration of tree species was determined based on population size of seedlings, saplings, and adults and categorized as per Dutta and Devi (2013) modified from Khan *et al.* (1987), Shankar (2001), and Khumbongmayum *et al.*, (2006). The categories identified were: (i) Good: if seedling > sapling > adults; (ii) Fair: if seedlings >or ≤ saplings ≤ adults or seedlings ≤ saplings > adults or seedlings ≥ saplings and the species had no adults, (iii) Poor: if a species survives only in the sapling stage, but no seedlings (though saplings may be <, >, or = adults) (iv) None: if it is absent both in seedling and sapling stages but found only in adults and (v) New: if the species has no adult, but only saplings or seedlings.

Results

Species composition and phyto-sociology

A total of 41 species in 26 families were recorded along the disturbance gradient. With respect to species richness, maximum number of tree species (29 species, 19 families) was recorded in LD, followed by 25 species in 17 families in MD and 24 species in 17 families in HD sites. Frequency, density and IVI were found highest for *Shorea robusta* in the entire disturbance gradient. Phyto-sociological parameter of each species is given in Table 2.

Highest index of diversity (Shannon-Wiener) was shown by LD followed by MD and least in HD; while species were even in MD followed by LD and HD (Figure 1).

Population Structure

Size class based density of tree species along with seedlings and saplings showed that the density of trees decreased with the increase in size class and stayed more or less stable at the higher diameter class. Density of adult trees decreased drastically as compared to seedling and sapling represented. Marked difference in seedlings, saplings and lower diameter class trees along disturbance gradient, with HD sites having lowest densities in different size class is observed. LD has the highest seedling sapling and overall density among all the sites (Figure 2).

Population structure of individual species along the disturbance gradient showed that *Shorea robusta*,

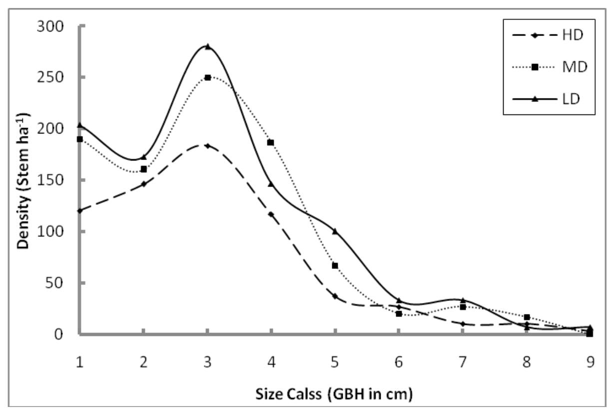


Fig. 2. Density diameter distribution of all species in study area (Density of seedling reduced by 100 folds and sapling by 10 folds to fit proportionately in the graph).

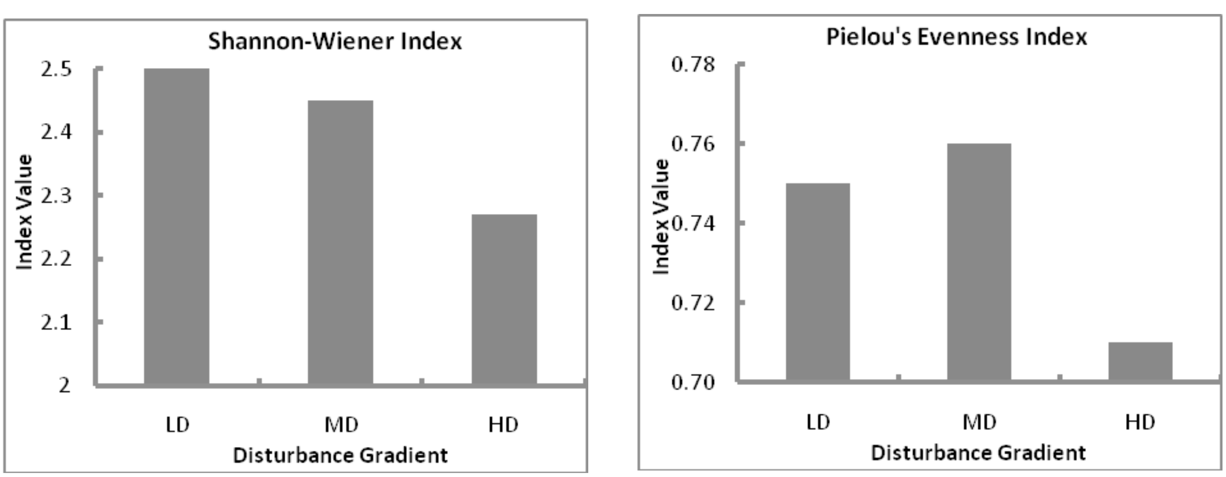
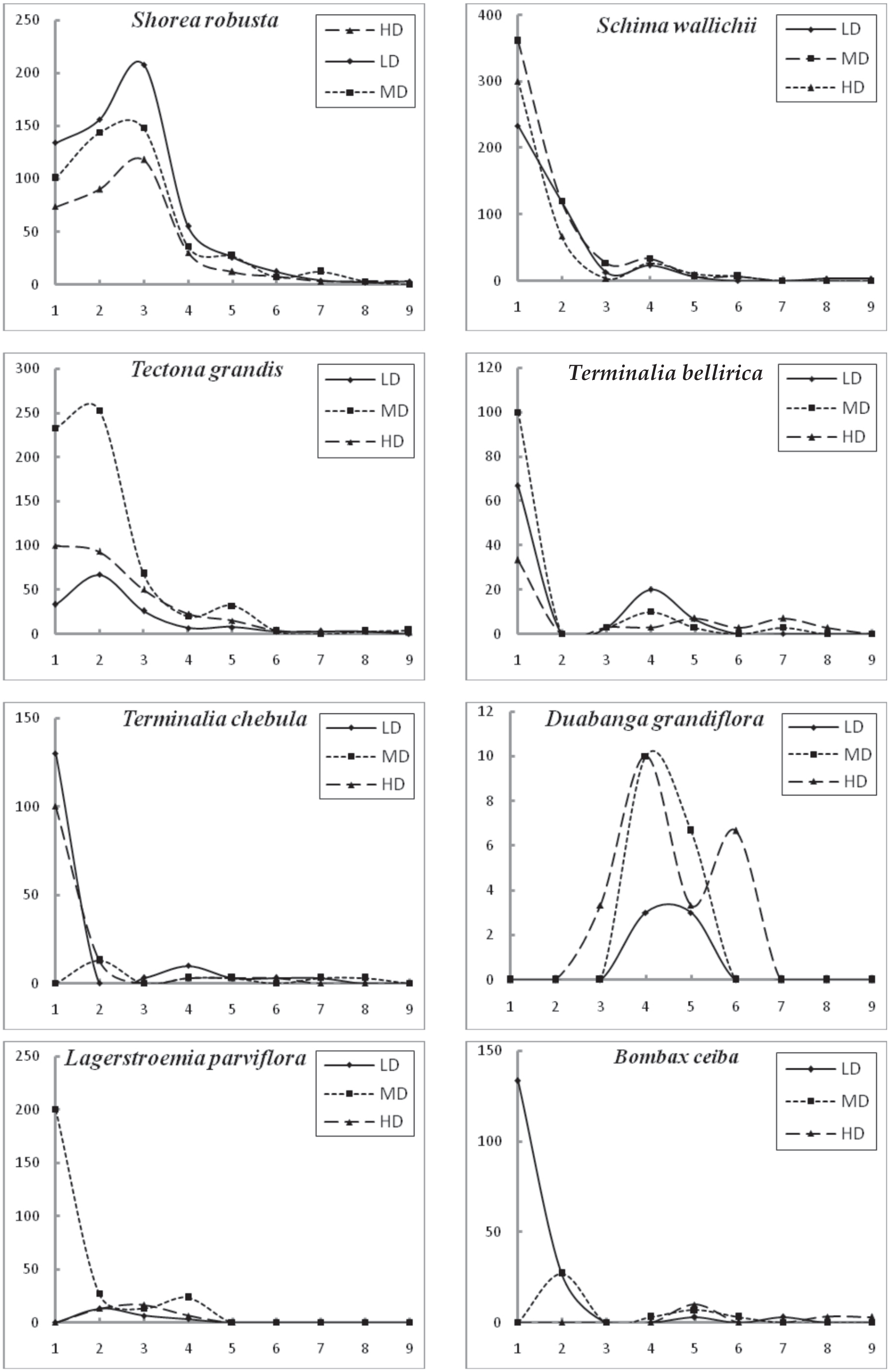


Fig. 1. Diversity and Evenness index of trees in different disturbance gradient

Table 2. Frequency, density and IVI of each species across disturbance gradient

Species	Frequency			Density			IVI		
	LD	MD	HD	LD	MD	HD	LD	MD	HD
Ailanthus integrifolia	10.00	3.33	6.67	0.20	0.07	0.13	6.75	2.47	3.85
Albizia procera	10.00			0.10			4.88		
Alstonia scholaris	10.00		6.67	0.13		0.10	4.38		2.81
Amoora wallichi	6.67			0.07			2.40		
Artocarpus lacoocha	6.67			0.10			3.04		
Bischofia javanica		6.67	6.67		0.07	0.07		4.61	2.65
Bombax ceiba	6.67	16.67	16.67	0.07	0.17	0.17	3.35	8.75	7.65
Bridelia retus		3.33			0.03			1.25	
Chukrasia tabularis	13.33		10.00	0.13		0.17	5.59		5.23
Dillenia indica		6.67			0.07			2.86	
Diploknema butyracea	3.33	6.67		0.03	0.07		1.32	3.18	
Duabanga grandiflora	3.33	16.67	16.67	0.07	0.17	0.23	2.19	8.40	8.62
Ficus benghalensis	3.33			0.03			2.66		
Ficus religiosa	3.33			0.03			1.86		
Ficus semicordata		13.33	13.33		0.17	0.17		6.00	5.39
Garuga pinnata	16.67	6.67		0.17	0.07		6.20	2.58	
Grewia optiva			13.33			0.23			6.09
Gmelina arborea		10.00			0.10			4.39	
Lagerstroemia parviflora	10.00	36.67	23.33	0.10	0.37	0.23	3.73	15.85	8.76
Litsea monopetala		3.33	16.67		0.03	0.20		1.59	6.63
Mallotus philipinensis			10.00			0.10			3.51
Macaranga denticulata	20.00	13.33		0.57	0.47		12.65	11.00	
Oroxylum indicum		3.33	6.67		0.07	0.10		1.97	3.19
Phyllanthus embellica	3.33	10.00	10.00	0.03	0.10	0.10	1.34	3.80	3.70
Pandanus fruticosa			10.00			0.13			4.01
Pinus roxburghii	13.33			0.53			13.75		
Pterospermum acerifolium	10.00			0.13			4.38		
Schima wallichii	36.67	50.00	33.33	0.50	0.73	0.47	18.74	29.14	16.78
Semecarpus anacardium		10.00			0.13			4.43	
Shorea robusta	100.00	90.00	90.00	3.80	2.87	3.83	112.31	98.21	126.14
Sterculia villosa	3.33		3.33	0.03		0.03	1.36		1.47
Syzygium kurzii	3.33			0.07			1.88		
Tectona grandis	56.67	66.67	70.00	1.03	1.30	1.60	33.04	48.25	44.25
Termianlia myriocarpa	6.67	13.33		0.13	0.17		5.56	10.87	
Terminalia bellirica	23.33	13.33	30.00	0.30	0.20	0.33	11.19	9.37	15.29
Terminalia chebula	20.00	13.33	10.00	0.23	0.13	0.10	10.48	9.62	4.51
Terminalia crenata	3.33			0.07			1.91		
Terminalia tomentosa		3.33	13.33		0.03	0.17		3.17	5.82
Tetrameles nudiflora	10.00		6.67	0.20		0.07	4.63		6.27
Toona ciliata	23.33	6.67	6.67	0.30	0.10	0.10	10.60	4.35	3.31
Toxicodendron wallichii	20.00	10.00	10.00	0.27	0.10	0.13	7.84	3.88	4.08

Tectona grandis and *Schima wallichii* has the normal population structure while that of *Terminalia chebula, Terminalia, bellirica, Lagerstroemia grandiflora, Bombax ceiba* and *Pinus roxburghii* showed skewed pattern. All life stages density of *Shorea robusta* increased from high to low disturbance gradient, while *Tectona grandis* and *Schiima walichii* were found performing better in moderately disturbed sites. *Terminalia bellirica* regenerates better in MD sites while *Terminalia chebula* regenerates better in LD sites, buts fails to get established as there is an absence of sapling of *T. bellirica* across all sites and T. *chebula* in LD. *Lagerstroemia parviflora* was found regenerating only in MD sites. There is a complete lack of regeneration in *Duabanga grandiflora* across all sites; trees are present in middle size class with highest density in MD and HD and lowest in LD site. *Pinus roxburghii* is present only in LD sites with seedling and adult


Shorea robusta
HD
LD
MD
Schima wallichii
LD
MD
HD
Tectona grandis
LD
MD
HD
Terminalia bellirica
LD
MD
HD
Terminalia chebula
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Duabanga grandiflora
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Lagerstroemia parviflora
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Bombax ceiba
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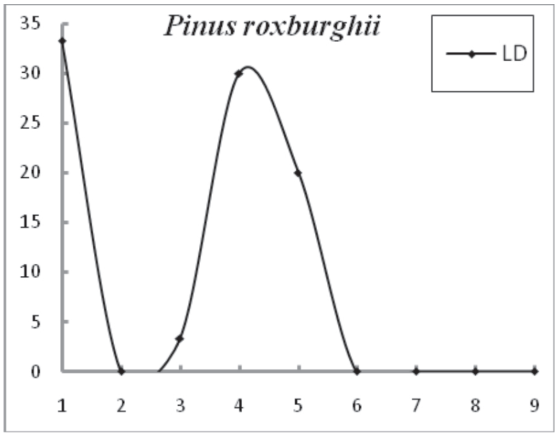

Fig. 3. Density diameter relation, along disturbance gradient, of representative tree species of study area. In Y axis: Density (Stem ha^{-1}); In x axis: Girth Class {1: 1-10 cm (Seedlings: reduced 100 times for *Shorea robusta* and 10 times for rest); 2: 11-30 cm (Saplings: reduced 10 times for *Shorea robusta*); 3: 31-60 cm; 4: 61-90 cm; 5: 91-120 cm; 6: 121-150 cm; 7: 151-180 cm; 8: 181-210 cm; 9: >210 cm}.

population and devoid of saplings. Population of *Bombax ceiba* is normally distributed in LD sites, seedlings absent in MD and both seedling and saplings are absent in HD sites (Figure 3).

Regeneration Status

In general seedling density is highest followed by sapling and adult trees across disturbance gradient (Figure 4). Densities of seedling, sapling and adult trees are highest in LD sites followed by MD and HD. 31% of the species in LD sites have good regeneration while it is 16% and 19% in MD and HD sites. 54 % of the species in HD, 52 % in MD and 31% in LD sites have poor or no regeneration. 15, 16 and 17 % of the species have fair regeneration, while 12, 16

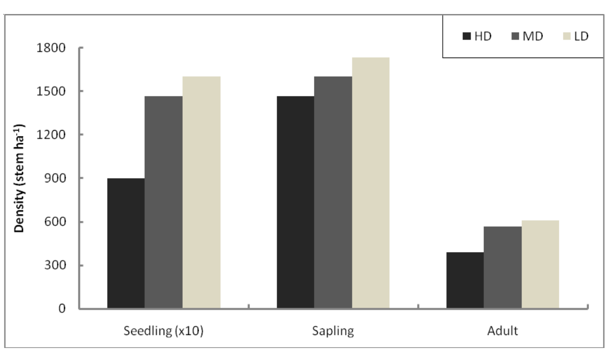

Fig. 4. Variation in density of seedling, sapling and adult tree species in study sites. Seedling density reduced 10 folds.

and 20 % regeneration are new in HD, MD and LD sites respectively (Figure 5). Regeneration status of Individual species across sites is given in table 3. On an average 85 % of all the regeneration in all the sites are dominated by three species i.e. *Shorea robusta*, *Tectona grandis* and *Schima wallichii*.

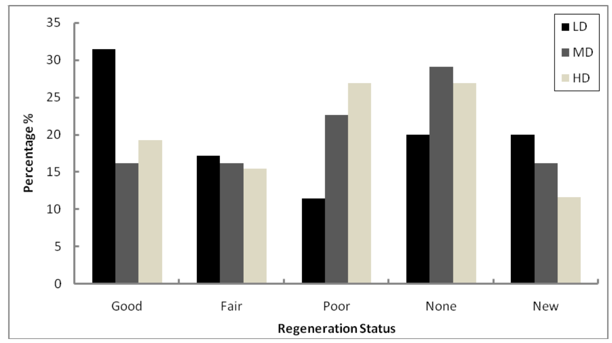

Fig. 5. Proportion of different regeneration status across sites.

Discussion

Maintenance of healthy forest is vital for its continued existence and service to mankind and ecosystem at large. Healthy forest implies composition, population structure and the regeneration status of species within a forest. Therefore this study tried to acknowledge the impact on composition, structure and regeneration behaviour of the tropical forest of Sikkim in Eastern Himalaya along disturbance gradient. In present study 41 tree species of size >30 cm GBH from 0.9 ha is recorded which is quite high than that from sal forest of Assam (25 trees in 1.2 ha) as reported by Deka *et al.,* 2012; while lesser than (76) reported by Shankar, 2001 from the Mahananda Wildlife Sanctuary which could be due to larger sampling size. Species richness, diversity and evenness decreased with the increasing disturbances. Shannon-Wiener diversity index ranged from 2.27 in HD to 2.5 in LD sites which are lower than the moist sal bearing forest of North Bengal (3.1) i.e. adjacent to present study site as reported by Kushwaha and Nandy, 2012. Trees in MD showed highest (0.76) evenness followed by LD (0.75) and HD (0.72). Population structure of all the tree species revealed that the population of seedling is highest followed by sapling and adult across site which is considered to be the indicator of good population structure with fairly good regeneration status (Teketay 1997, Tesfaye *et al.,* 2010). However, this

Table 3. Regeneration status of individual species across sites

Species	LD	MD	HD
Ailanthes integrifolia	New	Fair	Good
Albizia procera	Good	New	-
Alstonia scholaris	None	-	Poor
Amoora wallichi	Good	-	-
Artocarpus lacoocha	Fair	New	New
Bischofia javanica	New	None	-
Bombax ceiba	Good	Poor	None
Bridelia retus	-	None	New
Chukrasia tabularis	None	New	Poor
Dillenia indica	-	None	-
Diploknema butyracea	Poor	None	
Duabanga grandiflora	None	None	None
Ficus benghalensis	None		
Ficus religiosa	None		
Ficus semicordata	New	Fair	Good
Garuga pinnata	Poor	None	
Gmelina arborea	New	Poor	
Grewia optiva		Poor	Poor
Lagerstroemia parviflora	Good	Good	Poor
Litsea monopetala	New	Fair	Fair
Macaranga denticulata	Poor	Good	New
Mallotus philipinensis	New	New	Good
Oroxylon indicum		None	None
Pandanus fruticosa			Poor
Phyllanthus embellica	Fair	Fair	Fair
Pinus roxburghii	Fair		
Pterospermum acerifolium	Poor		
Schima wallichii	Good	Good	Good
Semecarpus anacardium	New	None	
Shorea robusta	Good	Good	Good
Sterculia villosa	Fair		Poor
Syzygium kurzii	Good	New	
Tectona grandis	Good	Good	Fair
Termianlia myriocarpa	Good	Poor	
Terminalia bellirica	Fair	Fair	Fair
Terminalia chebula	Fair	Poor	Poor
Terminalia crenata	None		
Terminalia tomentosa		None	None
Tetrameles nudiflora	None		None
Toona ciliata	Good	Poor	None
Toxicodendron wallichii	Good	Poor	None

shape is due to the very high percentage of regeneration concentrated to three species, i.e. *Shorea robusta*, *Tectona grandis* and *Schima wallichii*. These three species contribute 85% of all the regeneration across sites. Population structure of some of the representative species of the study area showed that *Shorea robusta* regenerated profusely across all sites but highest density of seedling sapling and adult was in LD followed by MD and HD suggesting that the disturbance has a negative impact on regeneration and density. Similarly *Tectona grandis* had a good population structure with density of seedling>sapling>adult across sites, but highest density of seedling and sapling was observed in MD sites, meaning moderate level of disturbance good is better for regeneration of *Tectona grandis* which could be due to the canopy gaps allowing lights to forest floor. Similarly density of *Schima wallichii* seedling was better in MD and HD sites as compared to LD, which which is in line with the study by Dani and Baniya, 2022 from foothills of central India. While *Terminalia bellirica* and *Lagerstroemia parviflora* showed good regeneration in MD sites, *Terminalia chebula*, *Pinus roxburghii* and *Bombax ceiba* were regenerating better in LD sites. *Duabanga grandiflora* lacked seedling and sapling across site. Disturbance was also seen impacting regeneration status of tree species as the percentage of species having good regeneration was highest in LD sites while poor or none combined was highest in HD sites. New regeneration was seen in all the sites with the highest percentage in LD followed by MD and HD Sites. It implies that there is as such no considerable difference in diversity and evenness along the disturbance gradient, but there is a marked difference in population structure and regeneration status between the species in a site and among the sites.

Conclusion

This study concludes that the disturbance in the form of resource utilization by local community impacts the composition, population and regeneration of the tree species. Through the selection of species for utilization by community higher disturbance is seen near the human settlement and least away from the settlement. Higher the disturbance lesser is the diversity and density trees in all stages of growth. Though some species were favoured by the moderate disturbance for regeneration, overall population structure is hampered by the degree of disturbances. Further dominance by seedling of *Shorea robusta*, *Tectona grandis* and *Schima wallichi* may lead to changed composition of tropical moist mixed forest in future, for which regeneration of other representative species could be worked on.

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