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Recovery of plant diversity and soil nutrients during stand development in subtropical forests of Mizoram, Northeast India

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Abstract. *Singh ShB, Mishra BP, Tripathi SK. 2015. Recovery of plant diversity and soil nutrients during stand development in subtropical forests of Mizoram, Northeast India. Biodiversitas 16: 205-212.* The present study assessed the recovery of tree species diversity and soil nutrient dynamics with stand development in subtropical semi-evergreen forest of Mizoram. The study was carried out in two regenerating forest stands following disturbance and one undisturbed forest. *Schima wallichii* was the dominant species in all stands showing IVI of 63.8, 83.3 and 75.9 in undisturbed, moderately disturbed and highly disturbed stands, respectively. *Castanopsis tribuloides* was co-dominant species in the undisturbed and the moderately disturbed but this species was replaced by *Sterculia villosa* in the highly disturbed stand. The shift in position of species and families from undisturbed to highly disturbed stands could be linked with degree of disturbance. Log-normal dominance-distribution curves in the undisturbed and moderately disturbed stand indicating the stability of community, while short hooked curve in the highly disturbed stand indicates unstable nature of the community. The soil properties (organic C, total nitrogen, and available phosphorus) increased significantly during the course of stand development, whereas, decrease with the depth in these forest stands.

Keywords: Community, disturbance, plant diversity, tropical semi-evergreen forest

INTRODUCTION

Biodiversity provides many essential goods and services to the mankind particularly in densely populated tropical ecosystems. Rapid decrease in tropical biodiversity is recorded in many forest ecosystems over the world as a result of human activities like habitat destruction, over exploitation, pollution and species introduction (Pimm et al. 1995; Pragasan and Parthsarthy 2010). These human activities have led to the conversion of natural forest areas into different stages of forest degradation that exhibited significantly different structural and functional characteristics at local and regional levels (Sapkota et al. 2010). Therefore, proper species diversity along with other characteristics need to recorded in different ecosystems to account multi-dimensional aspect of biodiversity that should take into account the variation in environmental factors, taxonomic variations among species, compositional diversity and functional diversity (Roy et al. 2004). The extents of deforestation in recent years in tropical regions draw attention to the urgent need for intervention to restore and protect biodiversity, ecological functioning and the supply of goods and services used by poor rural communities (Lamb et al. 2005; Cayuela et al. 2006).

The North-east India is known for its rich biodiversity with high level of endemism (Khan et al. 1997). Several studies have been carried out to quantify plant diversity and to understand the ecology of forest communities of different areas (Mishra et al. 2004; Laloo et al. 2006; Mishra 2010; Tynsong and Tiwari 2010, 2011). The plant inventory and community characteristics of tropical semi-evergreen forest of Mizoram have been studied by some workers (Lalramnghinglova 2003; Singh et al. 2011, 2012). In Mizoram, one of the states of North-east India, an extensive sandstone quarry has been carried out for the many developmental activities like construction of roads and buildings in the last few decades that converted large tract of forest area into degraded forest and created an unfavorable habitat conditions for plant growth and development. The unfavorable habitat conditions prevailing in the mined areas have reduced the chances of regeneration of many species, thereby reducing the number of species in mined areas.

Anthropogenic disturbance is one of the significant impacts arising out of mining and quarrying activities and is mainly in the form of alteration of land structure due to excavation, stacking of top soil and loss of fertile soil due to dumping of mined overburden on top soil. Sandstone mining causes damage to property, depletion of forest land, adverse effects on the aquatic biodiversity and public health. The present study aimed to determine the recovery of plant community characteristics and soil nutrients in secondary successional forests with stand development in relation to a reference forest in semi-evergreen tropical region of Mizoram, Northeast India.

MATERIAL AND METHODS

The study was conducted during 2009 to 2011 in the forest patches within and outside the Mizoram University campus situated in Tanhril area (23°45'25" N-23°43'37" N latitude and 92°38'39''E-92°40'23"E longitude) of Aizawl District, Mizoram, India (Figure 1). For detailed investigation, a total of three study sites were selected along age gradient after disturbance in terms of sandstone quarry, representing undisturbed (UD), moderately disturbed (MD) and highly disturbed (HD) stands. The natural forest stand where no sandstone mining activity was done in the past referred to as undisturbed stand. The moderately disturbed forest stand is a secondary forest developed naturally after the abandonment of sandstone quarry (mining operation about 7 years back in 2002). The highly disturbed forest stand is an open mining area where sandstone mining is continued. Tree species (≥15 cm girth at breast height, GBH, i.e. 1.3 m above ground) were recorded using 70 quadrats of 10 x 10m size at each site. The plant species were identified with the help of herbarium of the concerned University Department; herbarium of the Botanical Survey of India (BSI), Eastern circle, Shillong, and counter checked with the help of regional floras (Kanjilal et al. 1934-1940; Haridasan and Rao 1985). The field data on vegetation was quantitatively analyzed for phyto-sociological attributes namely, frequency, density and abundance as proposed by Curtis and Mclntosh (1950). The Importance value index (IVI) was determined as per Philips (1959). Species diversity and dominance indices were determined following the methods as outlined in Misra (1968); Mueller-Dombois and Ellenberg (1974). The soil samples were collected with the help of soil corer for top-soil (0-10 cm depth) and sub-soil (10-20 cm depth). The physico-chemical characteristics of soil have been analyzed by the methods outlined by Allen et al. (1976) and Anderson and Ingram (1993). Correlation was also developed between different vegetational and soil parameters across different sites.

RESULTS AND DISCUSSION

Plant diversity and community characteristics

Altogether, a total of 71 woody plant species belonging to 59 genera and 33 families of angiosperms were recorded from undisturbed, moderately disturbed and highly disturbed forest stands. Of this, 50 species representing 43 genera and 29 families, 49 species belonging to 41 genera and 22 families and 24 species belonging to 21 genera and 17 families were reported from the undisturbed, moderately disturbed and highly disturbed stand, respectively. It was found that *Wendlandia tinctoria* (Roxb.) DC., *Schima wallichii* (DC.) Korthals., *Emblica officinalis* Gaertn., *Callicarpa arborea* Roxb., *Castanopsis tribuloides* DC, and *Sterculia villosa* Roxb. ex Smith species were common in all three stands, and *Acacia farnesiana, Debregeasia velutina, Murraya koenigii, Turpinia nepalensis* and species *Cassia laevigata, Melia azedarach, Pterospermum acerifolium* and species *Lepionurus oblongifolius, Ficus virens, Grewia macrophylla* were restricted to undisturbed, moderately disturbed and highly disturbed stand, respectively. There was shift in dominance of plant species and families from undisturbed to highly disturbed

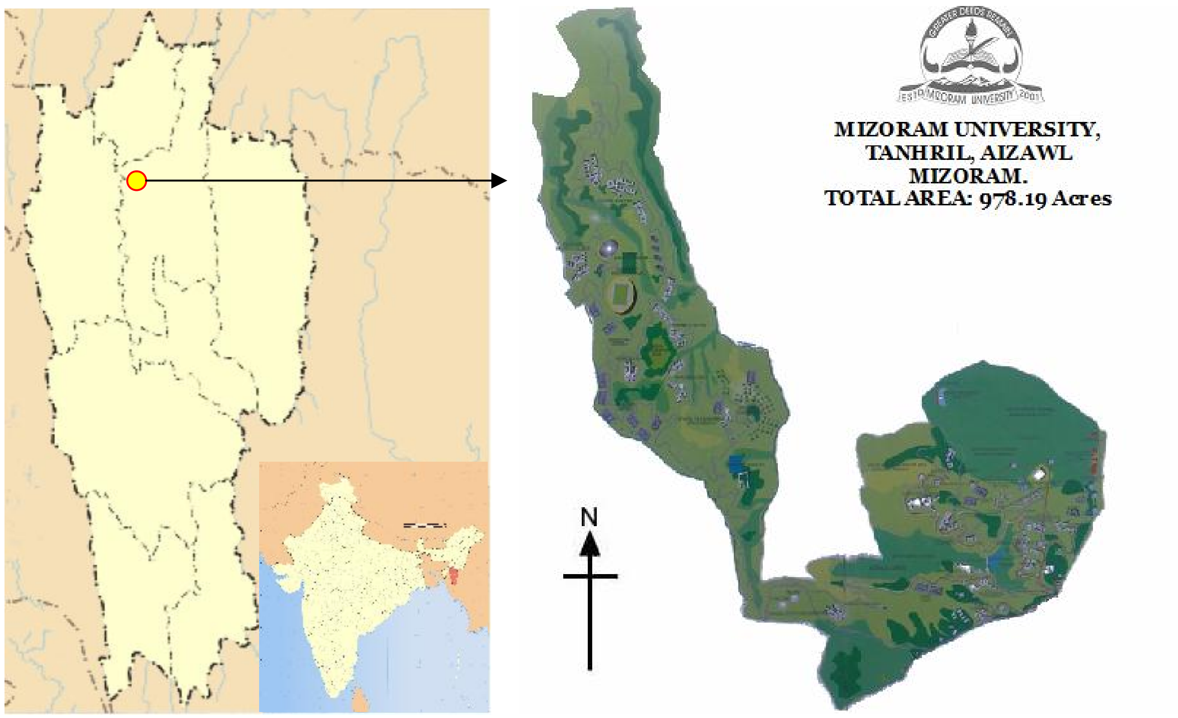

Figure 1. Map of Mizoram, India showing the study area

stand. *S. wallichii* was the dominant species (IVI 63.76) in the undisturbed stand. The co-dominant species were *C. tribuloides* (IVI 19.99) and *C. arborea* (IVI 19.44). In the moderately disturbed stand, *S. wallichii* was dominant species (IVI 83.31) and it was followed by co-dominant species namely, *C. tribuloides* (IVI 39.81) and *C. arborea* (IVI 17.54). In the highly disturbed stand, *S. wallichii* was recorded as a dominant species (IVI 75.87), and it was followed by co-dominant species namely, *S. villosa* (IVI 39.04) and *C. arborea* (IVI 24.89). *S. wallichii*, the dominant species in all three stands, contributed maximum tree density in the undisturbed stand (225 ind. ha^{-1} and basal area 5.04 m^2ha^{-1}), moderately disturbed stand (222 ind. ha^{-1} and basal area 3.28 m^2ha^{-1}) and highly disturbed stand (105 ind. ha^{-1} and basal area 1.59 m^2ha^{-1}) (Table 1). The distribution pattern of species differed from undisturbed to the highly disturbed stand. There was preponderance of contagious distribution. Whereas, few species namely, *C. arborea* and *E. officinalis* showed random distribution.

Euphorbiaceae was the dominant family with maximum number of species in the undisturbed (5) and moderately disturbed (5) stands. However, it was replaced by Mimosaceae (3) in the highly disturbed stand. The co-dominant families were Fagaceae (4), Lauraceae (4), Mimosaceae (4) in the undisturbed stand; Caesalpinaceae (4), Fagaceae (4), Lauraceae (4) in the moderately disturbed stand; Anacardiaceae (2), Rubiaceae (2), Papilionaceae (2) in the highly disturbed stand (Table 2).

There was sharp decline in tree density from the undisturbed stand (970±3.2 ind. ha^{-1}) to the moderately disturbed stand (742±3.4 ind. ha^{-1}) and finally to the highly disturbed stand (410±3.2 ind. ha^{-1}). A similar trend in results was also observed for total tree basal area which was highest in the undisturbed stand (20.8 m^2 ha^{-1}) followed by moderately disturbed stand (9.85 m^2 ha^{-1}) and highly disturbed stand (5.38 m^2 ha^{-1}). Shannon-Wiener diversity index was maximum (3.3) in the undisturbed stand and minimum in the highly disturbed stand (2.6). The species richness Index was highest in moderately disturbed stand followed by undisturbed stand and highly disturbed stands. The Evenness Index did not show much variation in results with respect to the degree of disturbance. The Sorenson's Index of similarity for tree species was maximum (0.58) between undisturbed and moderately disturbed stands. On contrary, value was minimum (0.46) between moderately disturbed and highly disturbed stands (Table 3).

Findings on the girth class distribution of trees showed a decreasing trend in the number of individuals from lower to higher girth classes, irrespective of stands, except in case of the undisturbed stand where number of individuals was highest in girth classes 50-70 cm and 30-50 cm. The moderately disturbed stand showed maximum number of adult trees (girth classes 30-50 cm). However, mature trees (girth classes 50-70 cm) were maximum in the undisturbed stand. There was a sharp decline in the number of individuals in the higher girth classes with increase in degree of disturbance (Figure 2).

The log-normal dominance-diversity curve (based on IVI) was found in the undisturbed and moderately disturbed stands; however, it was short hooked in case of highly disturbed stand (Figure 3).

Soil characteristics

The average soil moisture on different stands ranged from 23.66 to 28.84%. pH ranged from 4.45 to 6.18 which indicated that the soils on all stands were acidic. Compared to the moderately disturbed and highly disturbed stands, the undisturbed stand has the highest values of soil in organic carbon, total nitrogen, available phosphorus, exchangeable potassium as given in Table 4.

Correlation between vegetation and soil parameters

The correlation between different vegetation parameters along disturbance gradient is given in Figure 4. The tree density was positively correlated with the tree basal area, tree diversity and tree richness (Figure 4 A, B, D), whereas, tree basal area was negatively correlated with concentration of dominance (Figure 4). Tree richness was positively correlated with diversity and negatively with concentration of dominance but the relationship was rather weak (Figure 4 E, F).

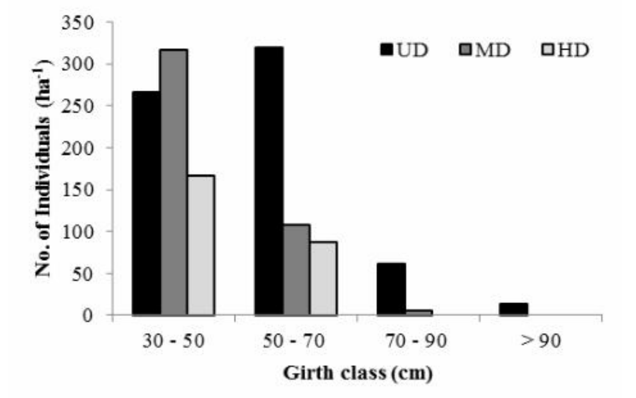

Figure 2. Distribution of tree species in different girth classes in the undisturbed (**UD**), moderately disturbed (**MD**) and highly disturbed (**HD**) forest stands

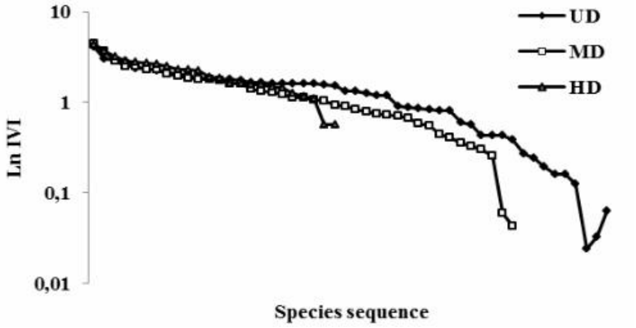

Figure 3. Dominance-diversity curves of tree species along disturbance gradient

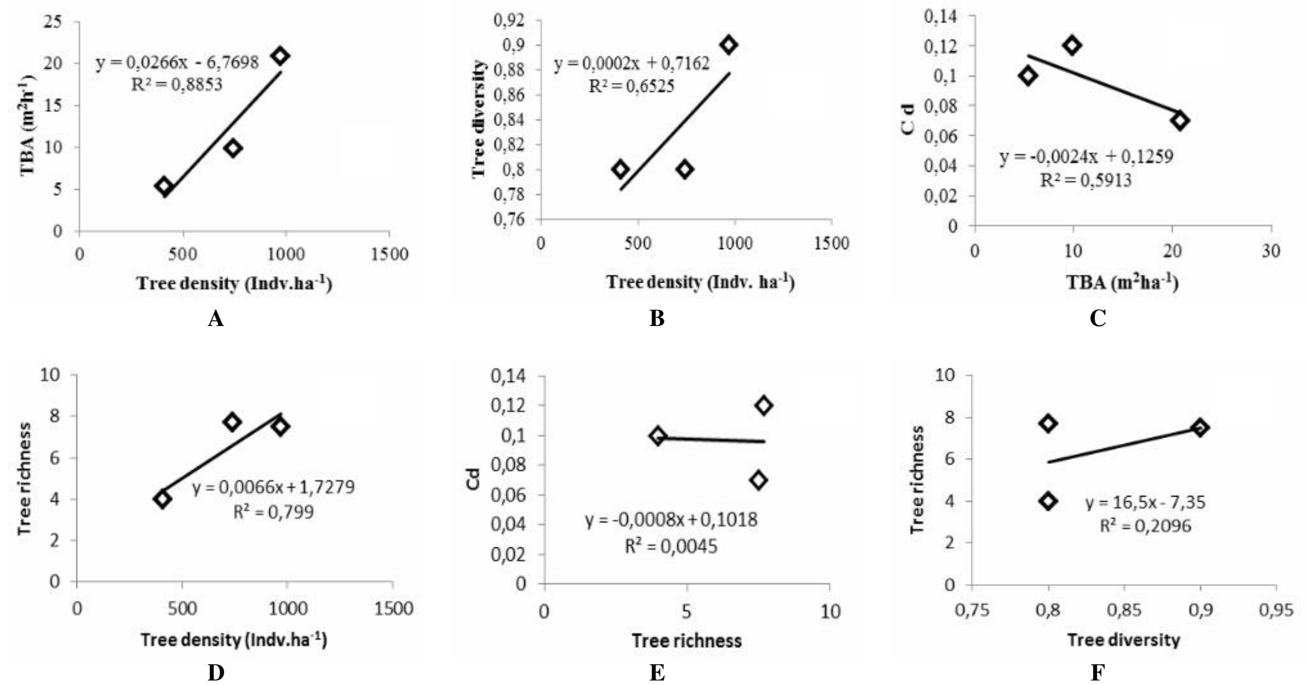

Figure 4. Correlation between various vegetational parameters along disturbance gradient

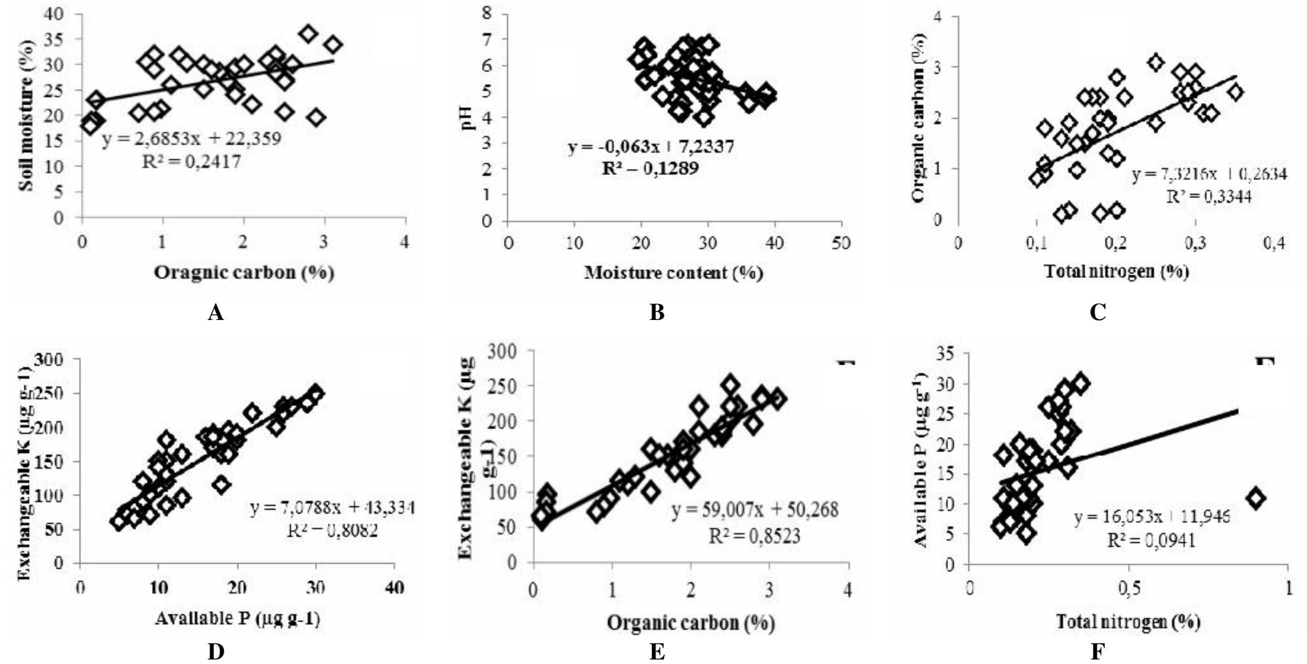

Figure 5. Correlation between various soil parameters for top-soil along disturbance gradient

The correlation between various soil parameters for top-soil and sub-soil along disturbance gradient is given in Figure 5 and 6. The soil moisture content showed a positive correlation with soil organic carbon and negative correlation with pH (Figure 5 A, B). However, soil organic carbon showed significant and positive correlation with total nitrogen and exchangeable potassium (Figure 5 C, E). Available phosphorus showed positive and significant correlation with exchangeable potassium, and the total nitrogen showed positive correlation with available phosphorus (Figure 5 D, F). Correlation among different nutrients showed similar trends in top-and sub-soil with varying degree of coefficients (Figure 5, 6).

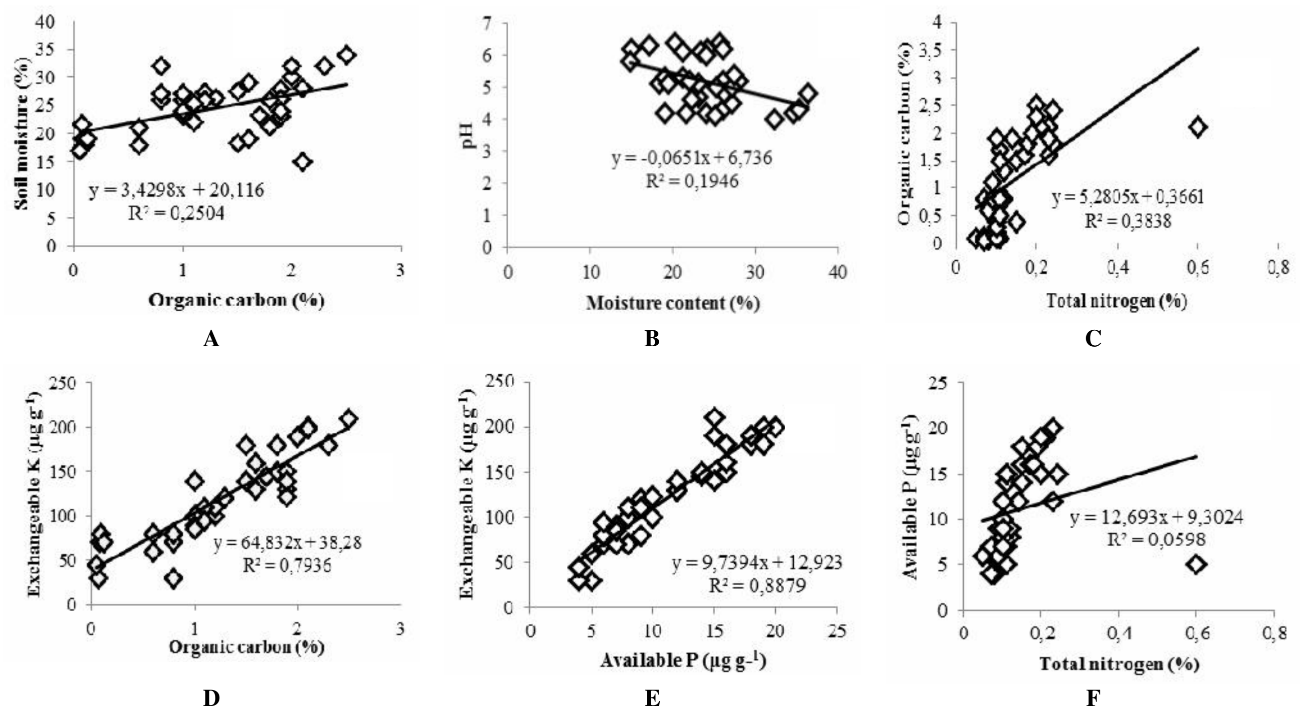

Figure 6. Correlation between various soil parameters for sub-soil along disturbance gradient

Discussion

The sandstone mining impacted vegetation composition, community organization to a great extent, and there was decrease in species richness, tree density and basal area from undisturbed to the highly disturbed stand. *S. wallichii* was the dominant tree species in all the stands. However, *C. tribuloides,* the co-dominant species of the undisturbed and moderately disturbed stands was replaced by *S. villosa* in the highly disturbed stand. Moreover, the species tolerant to stress showing better growth and survival under disturbed condition, such species express greater IVI in the disturbed stand. Similarly, Euphorbiaceae was the dominant family in both undisturbed and moderately disturbed stands, whereas, it was replaced by Mimosaceae that was the dominant family in the highly disturbed stand. The shift in position of the species and families along the disturbance gradient could be linked with the levels of anthropogenic disturbance and similar trends was also reported by number of workers in the past (Kadavul and Parthasarathy 1999; Mishra et al. 2003, 2004, 2005; Mishra and Laloo 2006).

During present investigation, it has been found that majority of the species showed contagious distribution pattern and few were distributed randomly. Similar, distribution pattern has also been reported by other workers (Singh and Yadav 1974; Metha et al. 1997). The trend in tree population structure observed during present study is similar to those reported from the forest at Costa Rica (Nadakarni et al. 1995), Brazalian Amazon (Campbell et al. 1992), Eastern Ghats (Kadavul and Parthasarathy 1999) and sub-tropical humid forest of Meghalaya (Mishra et al. 2004). The log-normal dominance distribution curve in the undisturbed and moderately disturbed stands indicates stable community. However, short hooked curve in the highly disturbed stand depicts un-stabile community. The past workers have also reported a similar trend in results (Khera et al. 2001; Tripathi et al. 2004; Mishra et al. 2004, 2005).

The soil properties greatly varied from undisturbed to highly disturbed stand. High pH value in highly disturbed stand could be due to low accumulation of decomposed organic matter and extraction of sand stone. The soil organic carbon, total nitrogen, available phosphorus and exchangeable potassium varied greatly along disturbance gradient and decreased from undisturbed to highly disturbed stand and higher values were reported from top-soil. This could be linked with presence of thick humus layer on forest floor of the undisturbed stand. Litter accumulation on forest floor is positively linked with litter decomposition and plays a significant role in maintenance of soil moisture content and other micro-environmental conditions (Arunachalam and Pandey 2003; Reddy 2010; Mishra 2010; Tripathi et al. 2012). Nayak and Srivastava (1995) have also reported a similar trend in results from the humid sub-tropical soils in north east India.

A positive correlation of species richness with diversity index was observed with few exceptions, and findings are in conformity with the report of Tripathi et al. (1989) that the species richness is positively correlated with Shannon diversity index in majority of cases in western Himalayan forests. Various diversity indices also followed similar trend (Jha et al. 2005; Yu-Hai et al. 2009). A positive correlation was observed between total basal area and organic carbon in top-soil and sub-soil. The findings are supported by Sharma et al. (2009).

Table 1. Phyto-sociological attributes of tree species along disturbance gradient

Species	Undisturbed		Moderately disturbed		Highly distrubed	
	Density (Ind. ha^{-1})	IVI	Density (Ind. ha^{-1})	IVI	Density (Ind. ha^{-1})	IVI
Acacia auriculiformis A. Cunn. ex Benth.	-	-	3	1.36		
Acacia farnesiana (L.) Willd.	5	1.17	-	-		
Albizia chinensis Osb. Merr.			4	2.04	15	10.19
Albizia lebbeck (L.) Benth.	8	2.37	13	4.95	6	4.78
Albizia procera (R.) Benth.	10	3.73	12	6.39	12	9.38
Antidesma diandrum B.Hey. ex (Roxb.)	18	6.39	2	0.96		
Aporosa roxburghii Baill	3	0.88				
Artocarpus heterophyllus Lam	4	1.53				
Bauhinia purpurea L.	3	1.21				
Beilschmiedia assamica Meisn.	7	1.53				
Bombax ceiba L.	7	2.24			4	3.48
Bridelia cuneata Gehrm	15	4.99				
Bridelia stipularis Bl.	20	6.3	6	2.56		
Bursera serrata Wall.ex Colebr.	2	0.78				
Callicarpa arborea Roxb.	58	19.44	42	17.54	32	24.89
Callicarpa macrophylla Vahl.	4	1.32				
Cassia laevigata Willd			5	1.73		
Castanopsis hystrix A.DC.	31	10.41	8	3.2		
Castanopsis tribuloides A.DC.	62	19.99	102	39.81	24	18.05
Clausena excavata Burn.f.			5	2.95		
Colona floribunda (Wall.ex Kurz) Craib					7	6.23
Combretum dasystachyum Kurz.	18	4.92				
Crotalaria linifolia L.	13	3.5	4	2.45		
Debregeasia velutina Gaud.	11	4.96				
Delonix regia (Boj)Rafin.			1	0.86		
Derris robusta Roxb.exDC.			2	0.93	6	4.44
Dipterocarpus turbinatus Gaertn.	7	2.26			1	1.77
Emblica officinalis Gaertn.	32	10.45	30	11.87	20	13.78
Engelhardia spicata Lechen ex Bl.	2	0.72				
Erythrina stricta Roxb.	15	5.17			4	2.96
Eucalyptus globulus Labill.			1	0.75		
Eugenia macrocarpa Schltdl. & Cham.	20	6.05				
Eugenia malaccensis L.			5	2.18		
Ficus elastica Roxb.ex Hornem			6	2.83		
Ficus virens Ait.	6	2.45			5	4.83
Glochidion velutinum Wt.	5	1.53	15	6.14	1	1.77
Grevillea robusta A.Cunn.ex R.Br.			2	0.75		
Grewia macrophylla G.Don	2	0.54			5	3.22
Lagerstroemia parviflora Roxb.	2	1.17	2	0.91	5	4.19
Lepionurus oblongifolius (Griff.) Mast	8	2.42			8	5.09
Litsea chinensis (Lour.) C.B.Rob.	6	1.75	14	5.83		
Litsea citrata Bl.	15	4.73	8	3.63		
Macaranga denticulata (Bl.) Mull. Arg.			2	1.06		
Machilus bombycina King ex Hook.f.			4	1.57		
Mangifera indica Linn.			4	2.29		
Melia azedarach Linn.			5	2.07		
Meliosma pinnata Roxb.	18	5.04	5	2.09		
Michelia champaca Linn.			3	1.36		
Michelia panduana Hook.Thamn.			5	1.95		
Micromelum integerrimum (B-Ht.ex Can.)Wt.	11	3.8	5	1.78		
Murraya koenigii (L.)Spreng.	15	3.35	17	7.11		
Oroxylum indicum Benth.ex Kurz.	9	2.33				
Phoebe cooperiana Pc. Kanj. & Das.	14	4.98	8	4.09		
Plumeria acutifolia Poir.			2	1.42		
Psidium guajava Linn.	4	1.48	5	3.08		
Pterospermum acerifolium Linn.	9	3.38				
Quercus semiserrata Roxb.	14	4.63	10	3.84	7	5.04
Quercus spicata Sm.	32	8.72	2	0.86		
Rhus succedanea Linn.	21	7.44	22	8.11	21	14.67
Sarcochlamys pulcherrima Roxb.			2	1.29		
Saurauia napaulensis D.C.			12	5.07		
Schefflera wallichiana (Wight & Arn.) Harms	18	5.76	2	1.5		
Schima wallichii (DC.) Korthals.	225	63.76	222	83.31	105	75.87
Sterculia villosa Roxb.ex Smith.	57	17.07	24	10.15	58	39.04
Syzygium cumini Linn.			2	0.61		
Tapiria hirsuta Hook.f	17	6.18	2	0.86	9	6.7
Taxus wallichiana Zucc.	12	3.35				
Terminalia arjuna Roxb.W & A	3	1.27				
Toona ciliata M.Roem.	15	5.24	12	6.02	12	10.33
Turpinia nepalensis Wall.ex Wight & Arn.	7	1.83				
Wendlandia paniculata (Roxb.) DC.	26	7.34	28	10.02	26	17
Wendlandia tinctoria (Roxb.) DC.	33	9.53	36	12.49	17	12.3

Table 2. Ranking of families of angiosperm in the undisturbed, moderately disturbed and highly disturbed forest stands

Family rank	Forest stands					
	Undisturbed		Moderately disturbed		Highly disturbed	
	Family	No. of species	Family	No. of species	Family	No. of species
1	Euphorbiaceae	5	Euphorbiaceae	5	Mimosaceae	3
2	Fagaceae	4	Fagaceae	4	Anacardiaceae	2
3	Lauraceae	4	Mimosaceae	4	Fagaceae	2
4	Mimosaceae	3	Lauraceae	4	Papilionaceae	2
5	Caesalpiniaceae	2	Myrtaceae	4	Rubiaceae	2
6	Combretaceae	2	Caesalpiniaceae	4	Tiliaceae	2
7	Moraceae	2	Anacardiaceae	3	Verbenaceae	1
8	Myrtaceae	2	Rubiaceae	3	Dipterocarpaceae	1
9	Verbenaceae	2	Rutaceae	2	Euphorbiaceae	1
10	Anacardiaceae	2	Meliaceae	2	Sterculiaceae	1
11	Papilionaceae	2	Sterculiaceae	2	Caesalpiniaceae	1
12	Bombacaceae	2	Papilionaceae	2	Bombacaceae	1
13	Rubiaceae	2	Theaceae	1	Lythraceae	1
14	Rutaceae	2	Lythraceae	1	Theaceae	1
15	Tiliaceae	1	Magnoliaceae	1	Meliaceae	1
16	Urticaceae	1	Verbenaceae	1	Olacaceae	1
17	Olacaceae	1	Apocynaceae	1	Moraceae	1
18	Lythraceae	1	Araliaceae	1		
19	Juglandaceae	1	Sabiaceae	1		
20	Meliaceae	1	Proteaceae	1		
21	Sapindaceae	1	Saurauiaceae	1		
22	Dipterocarpaceae	1	Moraceae	1		
23	Sterculiaceae	1				
24	Taxaceae	1				
25	Theaceae	1				
26	Burseraceae	1				
27	Araliaceae	1				
28	Bignoniaceae	1				
29	Sabiaceae	1				

Table 3. Tree community structure in the undisturbed, moderately disturbed and highly disturbed forest stands

Parameter	Forest stands		
	Undisturbed	Moderately disturbed	Highly disturbed
No. of family	29	22	17
No. of genera	43	41	21
No. of species	50	49	24
Tree density (Indv.ha^{-1})	970±3.2	742±3.4	410±3.2
Tree basal area (m^{2}h^{-1})	20.83	9.85	5.38
Shannon-Wiener index	3.3	2.9	2.6
Simpson dominance index	0.07	0.12	0.1
Simpson index of diversity	0.9	0.8	0.8
Simpson reciprocal index	13.3	8.2	9.1
Species richness (Margalef's index)	7.5	7.7	4
Evenness index (Pielou)	0.84	0.74	0.81

Table 4. Physico-chemical characteristics of soil along the disturbance gradient

Stands	Depth (cm)		Moisture content (%)	pH (H_20)	Org-C (%)	TN (%)	Avail P µg g^{-1}	K µg g^{-1}
Undisturbed	0-10	Mean	30.45	4.57	2.5	0.26	26.08	210
		SE ±	2.47	0.08	0.14	0.02	1.36	12.85
	10-20	Mean	27.23	4.34	1.89	0.2	17.41	171.58
		SE ±	2.65	0.09	0.15	0.02	1.88	7.44
Moderately disturbed	0-10	Mean	27.28	5.5	1.8	0.2	14.41	163.33
		SE ±	1.56	0.04	0.16	0.02	1.16	10.56
	10-20	Mean	24.15	5.1	1.55	0.16	12.16	133.25
		SE ±	1.57	0.04	0.12	0.01	1.15	11.24
Highly disturbed	0-10	Mean	25.79	6.35	1	0.29	10.25	88.33
		SE ±	2	0.04	0.14	0.17	1.43	9.93
	10-20	Mean	21.53	6.01	0.76	0.48	6.75	75.83
		SE ±	2.28	0.05	0.06	0.23	0.49	9.39

Present investigation showed that there is a considerable reduction in the number of species from natural forest to disturbed sites due to unfavorable habitat conditions for plants created by disturbance. The disturbance adversely affected the juvenile stage, leading to arrested survival and growth of seedlings and saplings. The findings of the present study would be an important tool for formulation of appropriate strategies for management of abandoned mined areas through re-vegetation with suitable dominant and co-dominant species of the present study for effective management strategy. Such site-specific selection of species will add a new dimension for rehabilitating of abandoned land and conservation of biodiversity.

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