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Impact of mining on tree diversity of the coal mining forest area at Raniganj coal field area of West Bengal, India

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ABSTRACT

Mining triggers landscape and natural ecosystems to suffer significant damage. Plant populations are affected by mining practices and the ecosystems become devastated following the mining process, creating a very stringent situation for their production. Nutritionally-deficient sandy spoils resulting from extraction are sensitive to it and very late activities are revegetation and reclamation methods other than natural colonization. Since ages, the coal has been extensively mined in West Bengal's Paschim Bardhaman district. The forests are the biggest victims of such operations that can be measured in all the mine belts from the depletion of the forests. As a consequence, most areas of the district were turned into mine spoils from the original lush green landscape. The primary objective of this research is to evaluate the tree composition of the Durgapur forest coal mining region at both disturbed and undisturbed sites and to understand the extent of tree cover and its status in mined and non-mined coal areas.Vast areas of the study area were transformed into degraded land due to extensive coal mining, creating adverse habitat conditions for plant life. Due to mining activity, the quantity of tree and shrub species has decreased. It has been found that the number of herbaceous plants that colonize the mined areas is much greater than in unmined areas. In mining areas, *B. monosperma* suggests its ability to grow in disturbed environments. The high importance value of *B. monosperma* in mining areas suggests its ability to grow in the disturbed environments. Shannon-Weaver diversity index in the mined areas was lower than the unmined areas due to the prevalence of one or two plant species. The contagious distribution trend of species throughout the mining area indicates a rise in natural vegetation fragmentation due to mining. The phytosociological indices even showed the effect of extraction on the area's tree structure. The current study has concluded that the subsequent analysis of tree growth can be used as an important tool to predict the suitability of specific species to revegetate the mined areas.

Key words: *Coal mine, Reclamation, Tree composition, Vegetation study, Species diversity*

Introduction

Mining continues to have a direct environmental impact, the effects vary massively based on whether the mine is operating or closed, the methods of mining used and the geographical circumstances (Bell *et al.*, 2001). This causes serious harm to the Earth's ecosystems and biological communities (Down 1974). Natural plant populations are disrupted and because of mining the ecosystems are degraded, creating a really stringent situation for growing plants. The inaccurate extraction of minerals represents a threat to the climate, which results in reduced forest cover, increased soil erosion, air, land and water contamination and reduced biodiversity (UNESCO, 1985). The problems of spoil damps creates devastating problems to the around mining sites (Goretti, 1998). Mining practices involving mining from the crust of the earth are second just to agriculture as the earliest and most significant activity in the world. The history of mining is in a sense the history of civilization (Khoshoo, 1984). The study area (a part of Raniganj Coal Field Area, Paschim Bardhaman District of West Bengal State of India) is famous for its coal mines and the quality of the coal deposits found in the Study area. Comprehensive open cast mining of the area ended in large dry, unproductive and profoundly erratic messy lands and great forest destruction as well as local productivity. The restoration of this mining area thus becomes a concern for countering environmental challenges and restoring the ecological equilibrium. The regeneration of these mined areas is typically hampered by the lack of basic data on the wide range of native plant species characterizing these woodlands. The privileges of disturbance ecology and biological restoration is also mandated to construct efficient initiatives for restoration. In addition, suitable choice of the species is a crucial step for rehabilitation functions that will conform to the atmospheric and regional soil conditions (Maiti *et al.*, 2006). The present study was carried out to analyze the tree structure of the coal mining region of both the disturbed and undisturbed site with the goal of selecting environmentally acceptable, economically sustainable and environmentally stress tolerant species and to explain the disparity between disturbed and undisturbed sites in tree structure.

Materials and Methods

The vegetation survey was conducted at undisturbed compartments of nearby forest of coal mining site (at DURGAPUR subdivision) and disturbed site both (Fig. 1), by using standard quadrate method (Srivastava, 2001) during peak growth season in September and October. The disturbed sites account for the area adjacent to the active mining site where active mining operation is going on. For tree component, quadrates of 10 m × 10 m size were laid randomly. 30 replications were taken in both cases (disturbed and undisturbed sites). The tree species found in the quadrates were identified. Quantitative community characteristics such as fre-

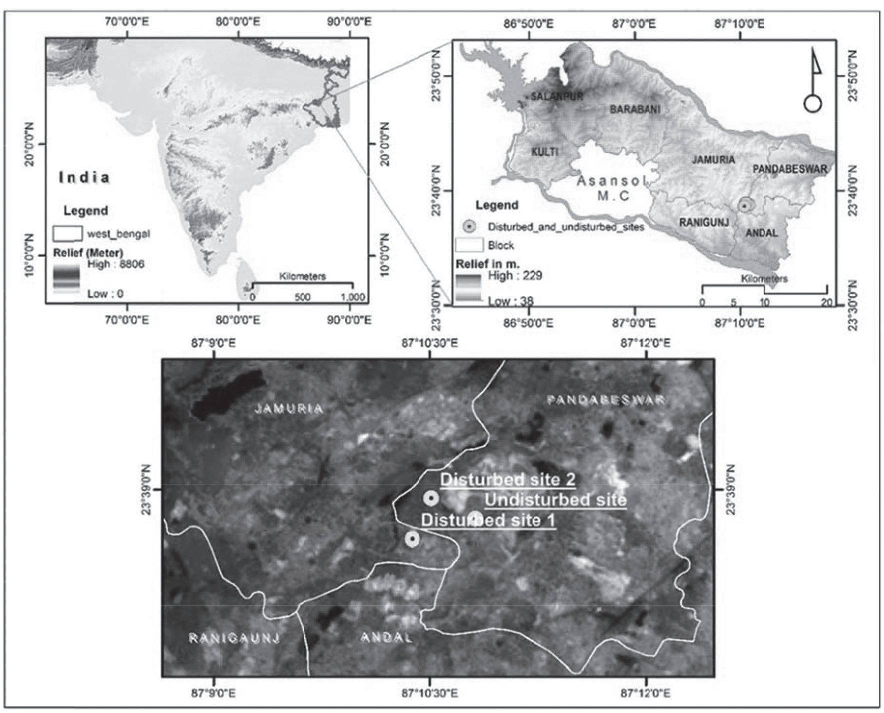

Fig. 1. Location map of the study area

quency, density, abundance and importance value index (IVI) of each species were determined, following the methods as described by Misra (1968). The importance value index IVI) for each species was determined as the sum of the relative frequency and relative density only which were calculated by using the following formula (Kohli *et al.,* 2004). The density and frequency values of recorded species were calculated and resultant frequency values were classified into frequency classes, viz.: class A (1%–20%), class B (21%–40%), class C (41%–60%), class D (61%–80%) and class E (81%-100%). A total of 19 tree species distributed among 12 families and 17 genera were encountered in undisturbed forest area while a total of 13 tree species distributed among 8 families and 12 genera were encountered in disturbed forest area (Table 4). Species diversity (Shannon and Weiner, 1963), Species richness (Margalef 1978) and Evenness index (Pielou, 1966) were calculated for undisturbed and disturbed sites (Table 4). The distribution pattern of the species was studied by using Whitford's index (Whitford, 1948). Similarity index between tree composition of disturbed and undisturbed sites was determined by using Sorenson's index of similarity (Sorenason, 1948; Krebs, 1999).

Results

Vegetation analyses

The tree vegetation characteristics of the disturbed area were compared with that of an adjacent undisturbed forest of the area. A total of 364 trees were encountered in the study sites from eight temporary sample plots of size 10 m x 10 m. The results showed that the mean Dbh is 102.923 ± 27.20 cm and 75.278 ± 34.38 cm for undisturbed and disturbed area of the study area respectively (Table 1). The mean basal area were for undisturbed area and disturbed area is listed in Table 1. The high value of the standard deviation for undisturbed forest is an indication of varied disparity in tree size. This agreed with the report of Adekunle *et al.*, (2004) in Ala and Omo Forest Reserve in southwest Nigeria that high standard deviation is an indication of wide variation in tree sizes. Plant species diversity of tree was more in undisturbed forest of the area than that in the disturbed area. The relative density, relative frequency, frequency class, abundance, importance value index (IVI), Whitford's index of each tree vegetation at undisturbed forest area and disturbed area are shown in Table 2 and 3 respectively. At undisturbed forest area, the most dominating tree species of the area was *Azadirachta indica* with the highest IVI value followed by *Cassia siamea, Albizia lebbeck* were also the major species of the area. *A. indica* shows random distribution pattern with 0.027 Whitford index. Whereas, in case of tree vegetation of disturbed area, *B. monosperma* was the most dominating species with highest IVI, followed by *Streblus asper, Senna siamea* and *Albizzia lebbek*. In this case, *B. monosperma* shows a regular distribution pattern with Whitford's index value<0.025 (Table 3). The high importance value of *B. monosperma* represents its dominance in disturbed areas and shows its ability to grow in the disturbed environments and its dominance in the harsh conditions. The similar ecology of *B. monosperma* was also documented by Orwa *et al.,* (2009) that *B. monosperma* is a tree of tropical and subtropical climate. *B. monosperma* is found throughout the drier parts of India, often gregarious in forests, open grasslands and wastelands. It is resistance to browsing and can grow in the open grounds disturbed with biotic interferences like grazing and other man made interferences. This escaping extermination is owing to its ability to reproduce from seed and root suckers. It can grow on a wide variety of soils including shallow and gravelly sites. The tree is very drought resistant and frost hardy and can thrive in disturbed environment (Orwa *et al.,* 2009; Hocking, 1993).

Species Diversity

Total species, genera, family, total density, Simpson Dominance Index, Shannon-Weaver index for spe-

Table 1. Stand growth characteristics of undisturbed and disturbed area

	Undisturbed Area				Disturbed Area			
	MAX	MIN	MEAN	STD DEV	MAX	MIN	MEAN	STD DEV
DBH (Cm)	146	68	102.923	27.20	156	25.37	75.278	34.38
BASAL AREA (M^2)	10.20	0.05	0.54	0.45	11.51	0.36	.89	0.45

cies diversity, Species richness (Margalef Index), and Evenness Index (Pielous Index) for disturbed and undisturbed sites, are given in Table 3. The tree species showed a drastic reduction in their number in disturbed sites with that of the undisturbed sites. In the undisturbed site, 19 tree species belonging to 17 genera and 12 families were present. There were total 13 tree species belonging to 12 genera and 8 families were recorded in the disturbed areas. The undisturbed regions have higher plant density than the disturbed areas due to the stress of moisture and soil deficient in nutrients. Low growth shape, low density and the ability to tolerate low levels of nutrients and low humidity are likely the adaptations to the tough physical nature of the substrate. Lyngdoh (1995); Das Gupta (1999) and Sarma (2002) works lend support to the present findings.

Species Similarity Index

Sorenson's similarity index between undisturbed and disturbed forest areas was 31.25 % (Table 5). This value indicates that there is wide variation in the species composition of the two forest areas. This implies that about 31.25 % of the species in the two

Table 2. Structure and composition of tree species at undisturbed area

Species name	Family	RD	RF	RDO	BA	F	FC	A/F	IVI
Acacia auriculiformis	Fabaceae	10.063	12.360	3.560	0.363	73.33	D	0.020	25.983
Aegle marmelos	Rutaceae	1.887	2.809	3.056	0.312	16.67	A	0.072	7.752
Albizia lebbeck	Fabaceae	6.918	9.551	15.966	1.628	56.67	C	0.023	32.434
Alstonia scholaris	Apocynaceae	3.459	4.494	9.658	0.985	26.67	B	0.052	17.612
Azadirachta indica	Meliaceae	25.157	16.854	4.684	0.478	100.00	E	0.027	46.696
Borassus flabellifer	Arecaceae	0.629	0.562	5.177	0.528	3.33	A	0.600	6.368
Cassia fistula	Fabaceae	0.314	0.562	0.648	0.066	3.33	A	0.300	1.524
Cassia siamea	Fabaceae	24.214	20.787	0.496	0.051	123.33	E	0.017	45.496
Dalbergia sissoo	Fabaceae	8.491	10.674	4.805	0.490	63.33	D	0.022	23.970
Ficus hispida	Moraceae	0.943	1.124	0.943	0.096	6.67	A	0.225	3.010
Ficus religiosa	Moraceae	0.314	0.562	18.737	1.910	3.33	A	0.300	19.614
Madhuca longifolia	Sapotaceae	1.572	1.685	4.447	0.453	10.00	A	0.167	7.705
Mangifera indica	Anacardiaceae	2.201	2.247	7.244	0.739	13.33	A	0.131	11.693
Phoenix acaulis	Arecaceae	1.258	1.124	1.559	0.159	6.67	A	0.300	3.941
Polyalthia longifolia	Annonaceae	0.629	1.124	1.112	0.113	6.67	A	0.150	2.864
Syzigium cumini	Myrtaceae	2.516	2.809	3.628	0.370	16.67	A	0.096	8.952
Tamarindus indica	Fabaceae	3.459	4.494	3.281	0.335	26.67	B	0.052	11.235
Tectona grandis	Lamiaceae	2.201	2.247	5.695	0.581	13.33	A	0.131	10.143
Terminalia arjuna	Combretaceae	3.774	3.933	5.304	0.541	23.33	B	0.073	13.010

Table 3. Structure and composition of tree species at disturbed area

Species name	Family	RD	RF	RDO	BA	F	FC	A/F	IVI
Acacia auriculiformis	Fabaceae	8.654	8.235	3.536	0.407	23.33	B	0.055	20.425
Acacia nilotica	Fabaceae	5.769	4.706	3.154	0.363	13.33	A	0.113	13.629
Aegle marmelos	Rutaceae	2.885	2.353	11.886	1.368	6.67	A	0.225	17.124
Ailanthus excelsa	Simaroubaceae	5.769	4.706	4.813	0.554	13.33	A	0.113	15.288
Alangium salviifolium	Cornaceae	6.731	7.059	3.536	0.407	20.00	A	0.058	17.326
Albizia lebbeck	Fabaceae	7.692	5.882	13.562	1.561	16.67	A	0.096	27.137
Alstonia scholaris	Apocynaceae	0.962	1.176	10.153	1.168	3.33	A	0.300	12.291
Butea monosperma	Fabaceae	20.192	21.176	6.287	0.723	60.00	C	0.019	47.656
Dalbergia sissoo	Fabaceae	4.808	4.706	9.022	1.038	13.33	A	0.094	18.535
Streblus asper	Moraceae	17.308	20.000	9.022	1.038	56.67	C	0.019	46.329
Ziziphus jujuba	Rhamnaceae	4.808	4.706	4.587	0.528	13.33	A	0.094	14.100
Phoenix dactylifera	Arecaceae	0.962	1.176	5.900	0.679	3.33	A	0.300	8.038
Senna siamea	Fabaceae	6.731	5.882	14.541	1.673	16.67	A	0.084	27.154

*RD: Relative density; RF: Relative frequency; RDO: Relative dominance; BA: Basal area; F: Frequency; FC: Frequency class; IVI: Important value index areas are similar, which means that undisturbed and disturbed forest areas have low floristic similarity. The reduced the species resemblance index values, the greater the variability in the species structure of two forest communities.

Table 4. Summary of the Various Diversity indices computed for Undisturbed and Disturbed Forest Area

Characteristic	Undisturbed Forest Area	Disturbed Forest Area
No. of family	12	8
No. of genus	17	12
No. of species	19	13
Species Richness (D)	3.124	2.623
Evenness Index (E)	2.204	1.985

Table 5. Sorenson's Index of Undisturbed and Disturbed Forest Area

Site	Undisturbed Forest Area	Disturbed Forest Area
Undisturbed Forest Area	-	31.25
Disturbed Forest Area	31.25	-

Dominance-diversity curve

Dominance-diversity curves have been used to define species dominance in the population with respect to resource allocation and niche space (Whittaker, 1975). The log normal series defines the division of realized niche space between different species and is the product of the evolution of variation in the organism along the niche parameters it utilizes (Whittaker (1965). The graph for tree species (Fig. 2) in the undisturbed sites is similar to the lognormal curve; thus, it demonstrates that the resource distribution among the members of the important species was more or less even. The curves for the disturbed site are similar to the broken-stick model series (Poole, 1974). This can be ascribed to the smaller number of species that exist in these areas and also reflect a strained environment where circumstances for plant growth were not favorable. Species diversity on these stands was low, but again the species growing here seem to have established tolerance that allows them to thrive in such an atmosphere. This figuring reaffirms Sarma's finding (Sarma, 2002).

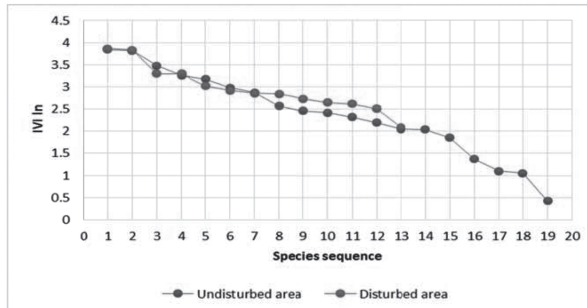

Fig. 2. Dominance-diversity curves of trees in disturbed and undisturbed forest areas

Statistical analysis

Data are analyzed for correlation analysis in order to monitor the interconnectedness among phytosociological attributes. From the correlation study of the disturbed area, it was observed that relative density is significantly correlated with relative frequency and important value index. Frequency was positively correlated with IVI. A/F ratio is positively correlated with IVI (Table 6). Whereas at undisturbed area, relative density is positively correlated with relative frequency and IVI. Relative frequency was positively correlated with IVI (Table 7).

Conclusion

The vegetation capacity of any region depends on physical and edapho-biotic limitations and their as-

Table 6. Correlations between various phytosociological parameter of tree species at disturbed area

	RD	RF	RDO	BA	F	A/F	IVI
RD	1						
RF	0.989172	1					
RDO	-0.06198	-0.08153	1				
BA	-0.06222	-0.08179	1	1			
F	0.989177	1	-0.08138	-0.08165	1		
A/F	-0.76792	-0.71958	0.179948	0.18002	-0.71956	1	
IVI	0.948287	0.942639	0.249112	0.248867	0.942686	0.66532	1

Table 7. Correlations between various phytosociologicalparameter of tree species at undisturbed area

	RD	RF	RDO	BA	F	A/F	IVI
RD	1						
RF	0.958919	1					
RDO	-0.12565	-0.07094	1				
BA	-0.12541	-0.07069	1	1			
F	0.958919	1	-0.07094	-0.0707	1		
A/F	-0.49899	-0.59924	-0.00018	-0.0004	-0.59928	1	
IVI	0.917532	0.93289	0.2601	0.26034	0.932889	-0.53332	1

sociation, soil substrate features, weather and vegetation following open-cast extraction. Individual species success and population structure are governed by local site factors. Substratum situations function as an ecological sieve on individual mine sites (Harper and White, 1970; Nath, 2009). Most suitable species are capable of establishing and becoming a significant community element. In this study, large parts of the forest area have been transformed into degraded forests due to massive coal mining, generating adverse environment for organisms. The adverse environmental conditions in the mined regions have reduced most species ' prospects of recovery, resulting in a decrease in the number of species in the mined regions. The results of this study demonstrates that phytosociological research can also be used to forecast the competency of mined ecosystems for plant growth as effective tools. The information collected on different facets of regional vegetation and plant colonization would aid to revegetate the mined regions.

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Conflict of Interest

As an author we do not have any conflict of interest in the present communication.

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