Tropical Ecology **47**(1): 37-46, 2006 ISSN 0564 -3295
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Natural colonization of plant species on coal mine spoils at Tikak Colliery, Assam

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Abstract: Coal mine spoils of 1, 5, 10 and 15 year old at Tikak Colliery, Margherita, Assam, were surveyed for naturally occurring plant species. Three adjacent natural forest (NF) sites were also surveyed. The plant species diversity, similarity and Importance Value Index (IVI) values were compared between mine spoils and natural forest sites. Diversity of naturally occurring plant species increased and dominance values decreased with the increasing age of mine spoils. Plant density and abundance values also varied among or between the spoils and adjacent natural forest. The number of plants species in 1-15 year old mine spoils varied between 12 and 14. In contrast, 43 plant species were recorded in the natural forest. These results suggest that only a few naturally occurring plant species of the Tikak Colliery can adapt to the harsh physico-chemical and biological conditions of young mine spoils. These plant species may prove useful in speedy revegetation programs of mine spoils.

Resumen: Se hizo una prospección de las especies de plantas que se presentan de manera natural en depósitos de desechos de minas de carbón con edades de 1, 5, 10 y 15 años en Tikak Colliery, Margherita, Assam. La prospección también se realizó en tres sitios adyacentes de bosque natural (BN). Se compararon la diversidad de especies de plantas, los valores de similitud y el Índice de Valor de Importancia (IVI) entre los desechos de minas y los sitios de bosque natural. La diversidad de especies vegetales que están presentes de manera natural aumentó y los valores de dominancia decrecieron conforme aumentó la edad de los desechos de las minas. Los valores de densidad de plantas y de abundancia también variaron entre depósitos de desechos, o entre ellos y el bosque natural adyacente. El número de especies de plantas en los desechos mineros con edades de entre 1 y 15 años varió entre 12 y 14. Por el contrario, 43 especies de plantas fueron registradas en el bosque natural. Estos resultados sugieren que sólo pocas especies de plantas que están presentes de manera natural en el Tikak Colliery pueden adaptarse a las duras condiciones fisico-químicas y biológicas de los desechos mineros de corta edad. Estas especies de plantas pueden resultar útiles en programa de revegetación rápida de los desechos mineros.

Resumo: Os detritos das minas de carvão com 1, 5, 10 e 15 anos de idade na mina de Tikak, Margherita, Assam foram investigados quanto às espécies vegetais ocorrendo naturalmente. Foram igualmente inventariadas três estações em florestas naturais (NF) adjacentes. Os valores da diversidade em plantas, a semelhança e o índice do valor de importância foram comparados entre os detritos da mina e as estações da floresta natural. Os valores da densidade das plantas e da abundância também variaram entre os

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detritos e a floresta natural adjacente. O número das espécies vegetais nos detritos entre as parcelas de 1-15 anos de idade variou entre as 12 e as 14. Em contraste, foram registadas 43 espécies vegetais na floresta natural. Estes resultados sugerem que só poucas espécies vegetais ocorrendo naturalmente na mina de carvão de Tikak se podem adaptar às difíceis condições físico-químicas e biológicas dos detritos mineiros jovens. Estas espécies vegetais podem provar-se úteis na aceleração de programas de revegetação em detritos mineiros.

Key words: Coal mine spoils, plant diversity, plant invasion, revegetation.

Introduction

Opencast mining is generally practiced for commercial exploitation of coal. In this process, overburden materials, i.e. the overlying soil layer with existing vegetation are removed and deposited in another fresh area. Thus, the deposition of million tons of overburdens in the forms of rocks, shale, course tailing results in barren, biologically inert overburden dumps, called mine spoils. Revegetation of these mine spoils is essential for conservation of environment, biodiversity and to make the land productive. But, the revegetation of these mine spoils is difficult because, they are deficient in nutrients such as nitrogen (N), phosphorus (P) and devoid of organic matter with adverse physico-chemical properties. Root symbionts such as *Rhizobium* and arbuscular mycorrhizal fungi (AMF) are also reduced or absent in mine sites (Noyd *et al.* 1995). High acidity in mine spoils due to oxidation of residual elemental or iron sulphur is also a constraint to revegetation, which hampers root-growth of plant and reduces the population of beneficial microorganisms such as free-living N-fixers (Aleaxander 1964; Arminger *et al.* 1996; Barnishel 1977; Choudhury 1996). In the recent times, increased ecological awareness among researchers, have resulted in search for innovative approaches for revegetation of coal mine area in India and abroad (Dugaya *et al.* 1996; Gupta *et al.* 1994; Kumar & Jena 1996; Pandya *et al.* 1997; Prasad & Mahammad 1990; Sonkar *et al.* 1998; Zak & Parkinson 1983). The use of native and indigenous plant species have been emphasized in revegetation programs with a view to maintain essential processes and life support system, preservation of genetic diversity and to ensure sustainable utilization of species and ecosystem (Banerjee *et al.* 1996; Jha & Singh 1993; Soni *et al.* 1989). Plant species also emerge naturally on the barren mined land after certain intervals of time from the initiation of dump, but succession of plant species under such situation proceeds at a much slower rate (Bradshaw & Chadwick 1980; Singh & Jha 1992; Roberts *et al.* 1981). Therefore, it is essential to understand the structure and function of an ecosystem with its primary and secondary succession patterns for a successful revegetation programs (Gibson *et al.* 1985; Thomson *et al.* 1984). The present survey was done to document naturally occurring tree and other plant species on mine spoils of different ages at Tikak Colliery, Margherita, Assam. It was expected that such study would lead to identify plant species having potentials in future revegetation programs of coal mine spoils of Assam.

Materials and methods

The Margherita Coal field is located in Tinsukia district of Assam, India in the border of Arunachal Pradesh. The area lies between the latitudes 27°15′ and 27°25′N and longitudes 95°40′ and 96°5′E. The general elevation above msl near the plains of river Buri-Dihing is 140 m rising to 300 to 500 m on the Patkai Naga Range. The climate is tropical monsoon. The annual temperature in winter falls up to 4°C and the maximum summer temperature is 36°C. The rainy season is confined mainly from

June to September with an average annual rainfall ranging from 3000 to 4250 mm. The average humidity ranges from 87-91 per cent during wet months. The main drainage of this area is controlled by river Buri-Dihing.

Survey of composition of naturally occurring plant species and planted species in four mine spoils of different ages (1, 5, 10 and 15 year old after dumping) and three adjacent natural forest sites (NF-1, NF-2, NF-3) was conducted during 1997-98. Plant species were recorded using a randomly placed circular quadrat of 5.09 m radius for trees and 2.53 m for shrub by density quadrat method described according to the Chambers & Brown (1983). For grasses and herbs 1 m^2 quadrats were used (Soni & Sharma 1994). The relative values of density, frequency and dominance were determined following the method described by Phillips (1959). Importance Value Index (IVI) of individual plant species was calculated summing up the relative values of density, frequency and dominance (Curtis 1959).

The species diversity index (H^{-}) was calculated by Shannon & Weaver formula (1963) for plant species recorded invading naturally in each site.

$$H' = \sum_{i=1}^{S} P_i \log P_i - \frac{S-1}{N}$$

where, P_i = the proportion of individuals in the i^{th} species; S = the number of species; N = the number of individuals; $P_i = n_i/N$; n_i = the number of individuals in the i^{th} species.

Concentration dominance (D) was measured by Simpson Index (Simpson 1949):

$$D = \sum_{i=1}^{S} (N_i/N)^2$$

where, N_i = importance value of species i, and N = total of importance value of all species.

Similarity Index between mine spoils and adjacent natural forests (reference area) were calculated by using Sorenson's similarity coefficient (Ss) as described by Khatry (1998):

$$Ss = 2a/(2a+b+c)$$

where, a = number of species occurring in both habitat; b = species occurring only in habitat B; c = species occurring only in habitat C.

Results

Naturally occurring plant species on mine spoils

Altogether 24 naturally occurring plant species were observed in different mine spoils of Tikak Colliery (Table 1). In 1 year old mine spoil, 12 plant species were recorded, of which, one (*Macaranga denticulata*) was tree, 8 were herbs and 3 grasses. No shrub was observed on this dump. In the 5 year old mine spoil, out of 13 plant species recorded, 1 was tree (*Schima wallichii*), 1 shrub, 5 herbs, 3 ferns and 3 grass species. In 10 year old spoil the 15 plant species included 2 tree species (*Macaranga denticulata* and *Schima wallichii*), 1 shrub, 8 herbs, 1 fern and 3 grass species. Fourteen naturally occurring plant species were observed in 15 year old mine spoil, of which 2 were trees, 2 shrubs, 4 herbs, 4 ferns and 2 grass species. In this site seedlings of tree species *Schima wallichii* and *Syzygium* sp. were also recorded. *Chromolaena odorata* and *Axonopus compressus* occurred naturally on all four mine spoils. More tree and shrub species were found to occur naturally on the older mine spoils. Out of 24 plant species, only 9, 8, 10 and 9 plant species had IVI more than 10 in 1, 5, 10 and 15 year old mine spoils, respectively.

Planted species on mine spoils

North eastern coal fields (CIL), Margherita also raised few plant species on these mine spoils as their usual revegetation practice. A total of 22 planted tree species were recorded in the four mine spoils of Tikak Colliery (Table 2). Planted species such as *Acacia auriculiformis, Eucalyptus* spp. were exotic. Eight species were leguminous (e.g. *Acacia auriculiformis, Pongamia glabra, Cassia siamea* etc.*)*. Number of planted species recorded in 1, 5, 10 and 15 year old spoils was 12, 16, 9 and 6 respectively.

Plant species composition on natural forest sites

A total of 43 plant species were recorded in the three adjacent natural forest sites (Table 3) and plant species composition was also different from the adjacent spoils. In the NF-1, adjacent to 10 yr and 15 year old spoils, 26 plant species were recorded, of which 8 were trees, 5 shrubs,

Table 1. Importance Value Index (IVI) of naturally occurring plant species recorded on the mine spoils.

Species	Coal mine spoil age (yr)			
	1	5	10	15
Tree				
Macaranga denticulata Muell.	14	–	23	–
Schima wallichii Choisy.	–	35	23	13
Syzygium sp.	–	–	–	80
Shrub				
Psidium guyava Linn.	–	–	–	31
Melastoma malabathricum L.	–	85	31	27
Herb				
Mimosa pudica L.	10	26	21	–
Borreria articularis (L.) Will.	10	17	–	14
Scoparia dulcis L.	23	7	–	10
Oxalis corniculata Linn.	13	–	–	–
Chromolaena odorata L.	14	9	40	11
Mikania mikantha L.	7	–	10	9
Crotalaria striata DC.	–	10	11	–
Corton caudatus Geisel.	–	–	8	–
Ageratum conyzoides L.	6	–	24	–
Cufia balsamina	23	–	12	–
Solanum khasianum (L.) Clarke	–	–	2	–
Fern and Bryophyte				
Lycopodium sp.	–	8	9	10
Gliechenia liniearis L.	–	18	–	14
Adiantum sp.	–	5	–	8
Lygodium flexuosum (L.) Swartz.	–	–	–	9
Grass				
Axonopus compressus Sw(Beauv).	120	64	44	55
Thysanoalena maxima O.Ktze	17	13	8	–
Saccharum spontaneum Linn.	45	–	33	11
Commelina benghalensis Linn.	–	5	–	–

3 herbs, 3 ferns, 1 bryophyte and 6 grasses. In the NF-site 2, adjacent to 5 year old spoil, 25 plant species were recorded (10 trees, 3 shrubs, 4 herbs, 4 ferns and 4 grasses). The NF-site 3, adjacent to 1 year old spoil, showed 28 plant species including 13 trees, 2 shrubs, 4 herbs, 3 ferns, 5 grass and 1 *Calamus* species. In NF- 1 site, out of 26 plant species, 2 species had IVI values more than 40. In NF- 2 site, out of total 25, 2 plant species had IVI more than 40. In NF- 3 site, 2 plant species out of total 28 had IVI value more than 40.

Density and abundance of naturally occurring plant species on mine spoils

Density and abundance of naturally occurring plant species are presented in Fig.1. Among the spoils tree species density was highest in 10 year old (148 ha^{-1}) and minimum in 1 year old (37 ha^{-1}). Density of *Macaranga denticulata* was maximum in 10 year old spoil (92 ha^{-1}) and minimum in 1 year old spoil (37 ha^{-1}). No individual of *M. denticulata* was observed in 5 and 15 year old spoils. *Schima wallichii* was common in three spoils with density 68 ha^{-1} in 5 year old spoil, 56 ha^{-1} in 10 yr old spoil and 25 ha^{-1} in 15 year old spoil. *Syzygium* sp. was recorded only in 15 year old spoil (density 49 ha^{-1}). Maximum density of shrub species was recorded in 5 year old spoil (925 ha^{-1}). No shrubs were recorded in 1 year old spoil. Likewise, density for herb species was maximum in 10 year old spoil (23,600 ha^{-1}) and minimum in 1 year old spoil (1,300 ha^{-1}

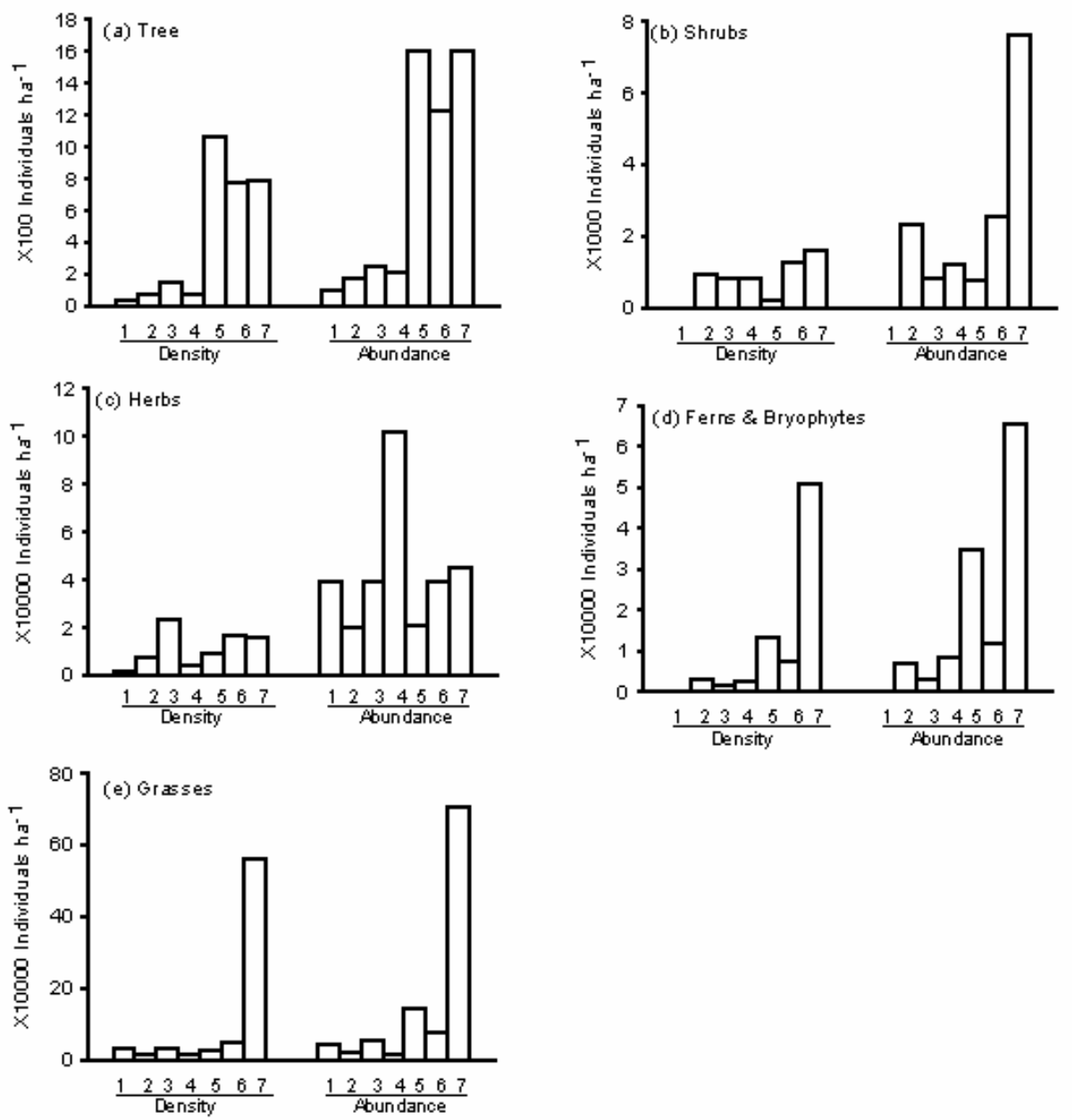

Fig. 1. Density and abundance of trees, shrubs, herb, fern+bryophytes and grasses in coal mine spoils and natural forests. Respective site codes: 1-4 are mine spoils of 1, 5, 10 and 15 yr age; 5-7 are natural forest sites NF-1, NF-2 and NF-3.

^{1}). No fern species was observed in 1 year old spoil. Density of fern species was maximum in 5 year old spoil (3,000 ha^{-1}) and minimum in 10 year old (1,700 ha^{-1}) spoil. Maximum density of grasses was recorded in 10 year old spoil and minimum in 15 year old spoil.

The recoded density for all plant species among the spoils was recorded highest 56,673 ha^{-1} on 10 yr old spoils. Abundance of tree species was minimum in 1 year old spoil and maximum in 10 year old spoil (Fig. 1). Maximum abundance of shrub species was recorded in 5 year old spoil (2,312 ha^{-1}).Herb and grass species showed maximum abundance in 1 year old spoil.

Density and abundance of plant species of natural forest

Table 2. Importance Value Index (IVI) of planted tree species on coal mine spoils.

Species	Coal mine spoil age (yr)			
	1	5	10	15
Acacia auriculiformis A. Cunn.	17	48	91	71
Syzygium cumini Skeels.	–	–	47	47
Terminalia bellerica (Gaertn.) Roxb.	24	15	50	–
Pongamia glabra Vent.	–	6	31	75
Cassia siamea Lamk.	–	21	34	–
Mangifera indica Linn.	17	17	15	–
Ficus bengalensis L.	–	20	7	–
Gmelina arborea Roxb.	–	8	7	–
Samanea saman (Jacq.) Merr.	–	–	17	41
Baccaurea sapida Muell.-Arg.	–	6	–	–
Chickrassia tabularis Andr. Juss.	–	16	–	–
Delonix regia Raf.	28	27	–	–
Azadirachta indica Juss.	15	38	–	–
Litchi chinensis Lam.	–	14	–	–
Dalbargia sisso Roxb.	10	14	–	–
Eucalyptus tereticornis Labil.	27	37	–	–
Bischofia javanica Bl.	–	8	–	–
Albizzia lucida (Roxb.) Benth.	70	7	–	–
Tectona grandis Linn. f.	9	–	–	36
Albizzia procera Benth.	41	–	–	30
Lagerostroemia speciosa (L.) Pers	34	–	–	–
Duabanga sonneratioides Ham.	7	–	–	–

Tree species densities in three natural forest sites were 1066 ha^{-1} in NF-1, 774 ha^{-1} in NF-2 and 786 ha^{-1} in NF-3. Shrub species density varied from 200 ha^{-1} in NF-1 to 1,616 ha^{-1} in NF-3. Herb species density values ranged 9,000 ha^{-1} in NF-1 to 16,900 ha^{-1} in NF-2. Fern and bryophytes density varied from 13,500 ha^{-1} in NF-1 to 50,700 ha^{-1} in NF-3. Density of grass species ranged 27,900 ha^{-1} in NF-1 to 5,58,500 ha^{-1} in NF-3.

Total plant species density values in three natural forest sites were 51,666 ha^{-1} in NF-1; 72,044 ha^{-1} in NF-2; 6,27,602 ha^{-1} in NF-3.

Species diversity, dominance and similarity index

Species diversity, concentration dominance and similarity index values of naturally occurring plant species are presented in Table 4. As the age of the spoils increased, there was an increasing trend of diversity index (H′), and decreasing trend in concentration of dominance (D). Among the plant species that occur naturally, 10 year old spoil had highest diversity index (2.19) with lowest concentration dominance (0.10). There was a variation in diversity of plant species even among the three natural forest sites. The NF-2 exhibited highest diversity index 2.15. Similarly, naturally occurring plant species of 10 year old spoil showed highest similarity index (0.63) with its reference to NF-2 site.

Discussion

Different groups of plants appeared naturally on coal mine spoils of Tikak Colliery, Margherita Coalbelt, Assam. It was observed that greater number of tree and shrub species appeared in older spoils; however, no specific trend was observed with respect to age of the spoils and occurrence of herbs, ferns and grasses. Banerjee *et al*. (1996) also reported that number of tree and shrub species increased with the age of spoils. Common occurrence of *Axonopus compressus* and *Chromolaena odorata* in all four spoils indicated that these two plant species might have more adaptability to thrive in harsh conditions of spoils.

There was no sharp trend of overall plant density and abundance of naturally occurring trees, shrubs, herbs, ferns and grasses with respect to age of the mine spoils (Fig. 1). While plant density was maximum in 10 year old spoil, being greater than in adjacent natural forest, it decreased to the 15 year old spoil. The grasses were more dominant in young spoils, particularly in 1 year old spoil but in 15 year old spoil, trees, shrubs and herb species were dominant and grasses were shaded out and could not compete with the perennial plant species, as a result, overall plant density was reduced. At early successional stage, major component of vegetation

Table 3. Importance Value Index of plant species of natural forests adjacent to the coal mine spoils.

Plant Species	Natural Forest Sites		
	NF-1	NF-2	NF-3
Tree			
Anthrocephelus cadamba Miq	–	–	9
Artocarpus chaplacha Roxb.	–	–	4
Alstonia scholaris R.Br.	4	–	24
Castanopsis indica (Roxb.) DC.	–	10	6
Castanopsis sp. (D.Don) Spach.	–	15	–
Canarium resiniforum Brace ex King	–	23	–
Callicarpa arborea Roxb.	21	13	10
Cinnamomum obtusifolium Nees.	–	6	5
Chickrassia tabularis Andr. Juss.	6	–	10
Dillenia indica. Linn.	–	–	2
Dipterocarpus retusus Bl.	–	22	4
Duabunga sonneratioides Ham.	26	20	–
Ficus glomarata Roxb.	7	–	–
Litsea monopatela (Roxb.)Pers.	–	–	2
Macaranga denticulata Muell	41	–	22
Syzygium sp.	18	9	–
Schima wallichii Choisy.	8	35	10
Sapium baccatum Roxb.	–	11	8
Shrub			
Crotalaria striata DC	4	4	–
Corton caudatus Geisel.	3	–	–
Dalbergia stipulacea Roxb.	–	–	3
Lantana camara Linn.	3	8	–
Melastoma malabathricum L	4	4	5
Osbakia nepalensis Hk.	4	–	–
Herb			
Clerodendrum coleobrookianum Gaertn	–	–	6
Chromolaena odorata L.	3	3	6
Argyeria speciosa Sw	–	2	–
Ageratum conyzoides L.	7	19	8
Urena repanda Roxb.	4	–	4
Borreia articularis Will.	–	4	–
Fern and Bryophyte			
Adiantum sp.	7	8	55
Gliechenia liniearis L.	7	7	12
Lygodium flexuosum (L.) Swartz.	6	6	–
Lycopodium sp.	8	–	–
Cyathea sp.	–	4	3
Grass and Cane			
Calamus sp.	–	8	7
Canna sp.	2	5	–
Thysanolaena maxima O.Kuntze	7	7	3
Axonopus compressus Sw(Beauv).	25	51	62
Saccharum sponteneum Linn.	9	–	4
Grass sp. (Unidetified)	61	–	–
Bambusa sp. Schreb.	–	–	5
Phragmites karka (Retz) Trin	4		4

Table 4. Diversity and similarity indices of naturally occurring plant species on mine spoils.

Site	No. of species	Shannon's Diversity Index	Simpson's Concentration Dominance	Sorenson's Similarity Index
Mine Spoils				
1 yr old	12	1.62	0.18	0.30
5 yr old	13	1.70	0.14	0.47
10 yr old	15	2.19	0.10	0.63
15 yr old	14	2.05	0.11	0.45
Natural forest				
NF-1	26	1.82	0.08	ND
NF-2	25	2.15	0.06	ND
NF-3	28	1.77	0.06	0.60

ND = Not determined. (Reference sites: NF-3 for 1 yr spoil, NF-2 for 5 yr spoil; NF-1 for 10 and 15 yr spoils)

were grasses and herbs, which contributed major share to the total plant density. The lignite coal mine spoils of Margherita Coalbelt were highly acidic due to oxidation of residual elemental sulphur; reacting with rainwater to produce sulphuric acid. The acidity of spoils increased with the age of the spoils and attained maximum in 5 year old spoil (Choudhury 1996; Hazarika *et al.* 1996). Therefore, acidic condition of spoils might have hampered the growth, survival and establishment of plant species in young spoils. pH value of 5 year old spoil was around 3.0 (Hazarika *et al.* 1996), this might have caused the poor plant density in 5 year old spoil. During the transition from 1 year old spoil to 5 year old spoil, the accompanying increase in acidity probably caused death of several of plant species. However, the same reason may not hold good in case of 15 year old spoil, where the value of plant density was observed to be even lesser than the 1 year old spoils. Therefore, factors other than acidity might be influencing plant density in older spoils. Such factors could be propagule, seed source, dispersal pattern, direction of the wind, topography, nearest vegetation type and nature of plant species in natural forest areas, soil physico-chemical properties of spoils etc.

No definite trend was observed in the IVI of the plant species with respect to spoils age. However, the grasses, and herbs species showed grater importance values in younger coal mine spoils, which was found to be replaced by the occupation of shrub and tree species in older spoils (Table 1) may be as the natural successional tendency of the plant species.

The results of the present study indicated that diversity of naturally occurring plant species increased with the increase in age of the spoils (Table 4) and on the other hand, dominance of plant species decreased with the age of the spoils. Thus, diversity and dominance of plant species were inversely proportional. In 5 yr and 15 year old spoils grasses and herb species diversity were less than other mine spoils. However, overall plant diversity was always more in either natural forest or older spoils.

The similarity index of the plant species were increased with the mine spoil age with respect to their reference area- the adjacent natural forest sites (Table 4). This indicates that the mine spoils were colonized by the plant propagules of the nearest natural forest area and tend to maintain similar diversity of the plant species. However, a remarkable feature of the succession stages was noticed that the three dominant tree species of this region, *Dipterocarpus retusus, Mesua ferrea* and *Michelia champaca* (typical of the natural forest of the region described by Champion & Seth 1968) were not able to establish themselves on spoils. Not a single seedling of these plant species was encountered in any spoil during the survey. The three evergreen tree species that commonly observed in natural forests and spoils (*Macaranga denticulata, Schima wallichii* and *Syzygium*

sp.) might be potential candidates in revegetation programs of coal mine spoils of Tikak Colliery, Margherita Coalbelt.

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