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VASCULAR FLORA OF NATURALLY REVEGETATED COALMINE SPOILS IN A DRY TROPICAL ENVIRONMENT

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ABSTRACT : A list of vascular plant species was compiled for an age-series of coalmine spoils on different microsites at Jhingurda colliery in Madhya Pradesh. Species were assigned an abundance rating based on their occurrence in quadrats viz: 1=occasional, 2=frequent, and 3=abundant. A total of 81 species representing 23 families were found at different sites/microsites. Poaceae, Fabaceae ano Asteraceae were the predominant families. *Butea monosperma* was the most frequent woody component of the vegetation. The frequent/abundant herbs and forbs were *Xanthium strumarium, Cassia tora, Tephrosia purpurea, Aristida adscensionis, Dactyloctenium aegyptium, Bothriochloa pertusa* and *Eragrostis tenella*. *Colotropis procera, Zizyphus glaberrima* and *Woodfordia fruticosa* were the important shrubs.

Keywords : Coalmine spoil, flora, natural revegetation, vascular plant species.

INTRODUCTION

Coal India Limited has projected a total land requirement for coal mining till 1994-1995 of 116691.60 ha of which 31.18 per cent is the forest land and rest is non-forest land. Coal production is projected at 226 x 10^6 t by 1989-1990 and 417 x 10^6 t by 2000 A. D The contribution of open-cast coal mining has increased to 50 per cent by 1984-1985 and will go upto 57 per cent by 1989-1990 (Sinha, 1987).

Land degradation is caused by open-cast coal mining and dumping of huge amounts of overburden materials on adjacent unmined lands. The adverse effects are the disruption of the geology-soil-plant stability circuit (Harthill and McKell, 1979); drastic disturbance of the flora, fauna, hydrological relations and soil biological systems; disequilibrium in the geomorphic system (Soulliere and Toy, 1986); increased nutrient export from the system (O'Neill *et al.*, 1979) and depletion of soil organic pool (Parkinson, 1979). Usually the coalmine spoils are physically, nutritionally and microbiologically recalcitrant medium for plant growth.

The unrehabilitated post-mining physical, chemical and biological characteristics create a specific mining ecology (Wali and Kollman, 1977). Understanding the site specific ecology, including plant succession, and soil development is crucial for expedient rehabilitation. Thompson *et al.* (1984) argued that natural plant invasion and succession can be an important part of the vegetation development of disturbed sites. Wali and Freeman (1973) and Imes and Wali (1977, 1978) have suggested that an adequate understanding of natural revegetation processes should be included in all reclamation efforts.

Vegetation potential of any area is dependent upon physical environmental limitations and edaphic-biotic components and their interactions. Soil surface characteristics, climate and vegetation after open-cast coalmining. Individual species successes and community composition are governed by local site variables. The substrate conditions on individual mine sites act as an "environmental seive" (Harper and White, 1970; Hulst, 1978). Most suited species are able to establish and become an important component of the community

A consideration of flora of naturally revegetated coalmine spoils has not received the level of attention required in restoration programmes in India.

An integrated study dealing with the assessment of natural vegetation and the environmental characteristics of coalmine spoils was undertaken. The present paper is a part of this study and documents the vascular plant species that colonized an age-series of coalmine spoils in a dry tropical environment in Madhya Pradesh.

STUDY SITES

The study sites are located within a radius of about 5 km in Jhingurda block, north-eastern part of Northern Coal Field Ltd. Singrauli, between 24°10′ 20″-24° 12′ 31″ N lat. and 82° 42′-82° 44′ 30″ E long, and at 350-450 m altitude in Madhya Pradesh, India. The climate is tropical monsoonal. Mean daily minimum temperature within the annual cycle ranges from 6.4-28°C and mean daily maximum from 20-42°C. The annual rainfall averages 934 mm, of which 795 mm occurs between late June-September. The rocks are medium to coarse-grained sand stone clays with ferruginous bands and carbonaceous shales. The soils are ultisols.

The native vegetation is a typical mixed dry deciduous forest dominated by *Boswellia serrata* Roxb ex Colebr., *Lagerstroemia parviflora* Roxb., *Wrightia tomentosa* R. and S. and *Anogeissus latifolia* Wall.

Open-cast coalmining was started in 1965 at Jhingurda colliery and overburden materials were haphazardly dumped on adjacent unmined deforested lands. No attempt was made to reclaim the abandoned landscape. Only recently, from 1986, plantations of *Eucalyptus* sp., *Acacia auriculiformis* A. Cunn. ex Benth., *Cassia siamea* Lamk., *Dalbergia sissoo* Robx., *Prosopis juliflora* (*Swartz.* DC and *Dendrocalamus strictus* (Roxb.) Nees have been started on coalmine spoils.

An age-series of coalmine spoils (5, 10, 12, 16 and 20 yr) were selected for the present study. Following the criteria of Barth and Martin (1984) these spoils were characterised as 'generic' in nature and were found non-toxic to plants (Singh and Jha, 1987). In rainy season herbaceous vegetation covers the mine spoils rapidly and biomass peaks in late September or early October (Jha and Singh, 1988).

MATERIAL AND METHODS

A list of vascular plant species occurring on different microsites was compiled during 1986 and 1987 for each of the coalmine spoils. The microsites were slope (about 35 per cent), coalpatch, undulating surface and flat surface.

Herbaceous species were assigned a gross abundance rating based on their presence in 1 x 1 m square quadrats placed at random on each microsite. Nine quadrats were used per microsite in each mine spoil. Species occurring in 1, 2–5, and > 5 quadrats were rated as 1 occasional, 2 frequent, and 3 abundant, respectively. Species which did not occur in quadrats but were present on the mine spoiles were also listed and called rare. Only a few shrub and tree species were found, therefore, their presence on sites were recorded separately.

RESULTS AND DISCUSSION

A total of 81 species representing 23 families of vascular plants occurred in the study sites. The largest plant families were : Poaceae (25), Fabaceae (12), Asteraceae (9), Amaranthaceae (4) and Convolvulaceae (4). The predominance of Asteraceae and Poaceae on mined lands has also been reported by Brierly (1956), Wali and Freeman (1973), Alvarez *et. al.* (1974), Gleen-Lewin (1979), Jonescu (1979), Russell (1985) and Prasad and Pandey (1985).

20–yr old flat surface was the richest microsite with 21 herbaceous species. On the 20-yr old site, number of tree species was also high. 10-yr old coal-patch microsite was the poorest with only 9 herbaceous species.

On the > 12-yr old sites *Butea monosperma* was the most frequent species among the woody components. Colonization by this leguminous tree increased with the age of the mine spoil. Alongwith *Butea monosperm, Dalbergia sissoo, Holoptelia integrifolia* and *Acacia nilotica* occurred on the 16-yr old site. *Cassia fistula, Carissa carandas, Holoptelia integrifolia, Diospyros melanoxylon, Azadirachta indica* and one unidentified tree species and two unidentified shrubs occurred on the 20-yr old site in addition to *Butea monosperma*.

Calotropis procera, Woodfordia fruticosa and *Zizyphus glaberrima* were the most frequent shrubs on all sites. Presence and abundance of grasses and forbs are given in Table 1. Some important frequent/abundant grasses and forbs on different sires/microsites were :

5–yr old : *Dactyloctenium aegyptium, Aristida adscensionis, Digitaria setigera, Tridax procumbens, Cassia tora, Cassia pumila, Xanthium strumarium* and *Tephrosia purpurea.*

10–yr old : *D. aegyptium, A. adscensionis, D. setigera, T procambens, C. pumila, X. strumarium, T. purpurea, Bothriochloa pertusa, Indigofera linifolia. Lepidagathis hamiltoniana* and *Zornia gibbosa.*

12–yr old : *A. adscensionis B. pertusa, T. procumbens D. aegyptium, Eragrostis tenella. Alysicarpus monilifer, Uroehloa penicoidcs, C. tora, C. pumila T. purpurea, Borreria stricta, X. strumarium, Desmodium, triflorum, Sida cordata* and *Hetoropogon contortus.*

Table 1 : Presence and abundance of vascular plant species on different sites / microsites.

Microsites	5-yr old site				10-yr old site				12-yr old site				16-yr old site				20-yr old site			
	Slope	Coal patch	Undulating surface	Flat surface	Slope	Coal patch	Undulating surface	Flat surface	Slope	Coal patch	Undulating surface	Flat surface	Slope	Coal patch	Undulating surface	Flat surface	Slope	Coal patch	Undulating surface	Flat surface
Total No. of grasses and forbs	13	13	10	10	11	9	13	14	13	10	15	17	14	11	16	19	17	14	18	21
Dactyloctenium aegyptium	3	3	2	3	...	3	2	3	3	2	1	2	2	...	2	1	2	1	2	2
Bothriochloa pertusa	1	1	...	2	3	2	2	2	2	3	3	3	3	3	3	3	3	2	3	3
Cassia tora	2	2	2	2	2	...	1	...	...	...	2	2	2	2	2	2	2	2	1	2
Urochloa penicoides	1	...	...	...	...	...	...	...	...	2	2	...	...	...	...	...	2	...	...	...
Cassia pumila	3	...	...	2	2	...	2	...	...	...	2	2	...	...	2	...	...	...	...	2
Tephrosia purpuratea	3	1	...	2	2	...	2	3	2	...	2	2	2	3	2	3	2	2	2	2
Borreria stricta	2	...	2	...	2	...	...	1	...	...	2	2	2	2	2	...	...	2	1	...
Tridax procumbens	3	3	2	2	...	3	3	...	2	2	3	2	2	2	2	2	1	...	...	2
Indigofera linifolia	1	2	...	...	...	...	2	2	1	...	...	2	2	...	2	2	2	1	...	...
Digitaria setigera	2	2	2	1	...	...	2	2	2	...	...	1	2	...	...	1	...	...	...	2
Zornia gibbosa	1	...	2	...	2	...	2	2	1	...	...	...	1	2	2	2	1	...	1	1
Aristida adscensionis	2	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Xanthium strumarium	2	2	2	2	2	1	1	...	2	...	2	...	...	2	2	2	2	1	2	2
Evolvulus alsinoides	...	2	...	...	2	2	...	...	...	...	...	...	1	...	...	1	...	...	...	2
Alysicarpus monilifer	...	3	2	...	...	...	...	3	2	2	1	1	...	2	2	3	2	2	2	1
Desmodium triflorum	...	2	...	...	...	...	...	2	...	2	2	...	...	...	2	2	2	2	1	2
Sida cordata	...	2	...	...	...	...	...	1	...	2	2	...	1	2	...	...	...	2	...	...
Echinops echinatus	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cyperus compreisus	...	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Heteropogon contortus	...	...	...	...	2	...	...	...	...	...	2	2	...	...	...	...	...	...	2	...
Euphorbia hirta	...	...	...	...	...	2	...	...	...	2	...	...	...	...	...	...	...	...	...	2

Phyllanthes simplex	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Lepidagathis hemiltoniana	...	...	...	...	...	...	1	2	...	...	...	...	...	...	...	...	...	...	...	...
Atylosia scarabaeoides	...	...	...	...	...	...	1	...	...	...	...	2	...	...	...	...	...	...		...
Eragrostis tenella	...	...	...	...	...	...	...	2	1	2	2	2	...	3	3	1	...	3	2	2
Cynodon dactylon	...	...	...	...	...	...	...	1	...	...	...	2	...	...	...	...	2	...	...	...
Glossocardia bosvallea	...	...	...	...	...	...	...	...	1	...	...	2	2	...	2	2	...	...	...	...
Leucas aspera	...	...	...	...	...	...	...	...	2	...	...	...	2	...	...	...	...	...	1	...
Melanocenchris jacquemontii	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	1	...
Rungia repens	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	1	...	...	...
Crotalaria albida	...	...	...	...	...	...	...	...	...		...	...	...	...	...	2	...	2	...	...
Dichanthium annulatum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	2	...	
Cenchrus ciliaris	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	2
Corchorus conniveans	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	1	...
Merrammia tridentata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...
Setaria glauca	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...		...
Aeschynomene indica	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...
Hackclochloa granularis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...
Ipomaea eriocarpa	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...
Eclipta alba	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...
Brachiaria reptans	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2
Celosia argentea	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2
Eleusine indica	...	...	...	...	...	...	...	...	...	...	...	...			...	...	...	...	...	2
Launaea procumbens	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2
Sporobolus diander	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1

16-yr old : *A. adscensionis*, *B pertusa*, *T. purpurea*, *C. tora*, *T. procumbens*, *Z. gibbosa*, *X. strumarium*, *A. monilifer*, *E. tenella*, *Glossocardia bosvallea*, *D. triflorum*, *I. linifolia* and *B stricta*.

20-yr old : *A. adscensionis*. *B pertusa*, *T. purpurea* *C. tora*, *D. aegyptium*, *X. strumarium*, *A. monilifer*, *D. triflorum* and *E. tenella*.

Aristida adscensionis, *Bothriochloa pertusa*, *Dactyloctenium aegyptium*, *Tephrosia purpurea*. *Tridax procumbens*, *Cassia tora* and *Xanthium strumarium* were the most abundant species on most of the microsites/sites. Other grasses and forbs listed in Appendix 1 were rare on different sites / microsites

Leisman (1957), Harrington (1982) and Gibson *et al.* (1985) have emphasized the importance of surrounding vegetation and the dissemination efficiency of propagules upon spoil seed banks. It has been observed that the spoils are typically colonized by plants adapted for long-distance or efficient seed dispersal, for example lead and zinc mine spoils in Oklahoma (Gibson, 1982), and coal mine spoil in Pennsylvania (Bramble and Ashly, 1955), New Mexico (Wanger *et. al.* 1978) and Great Britain (Brierley, 1956; Hall, 1957).

The proportions of annual and perennial species fluctuated considerably between the microsites and between the spoil ages With the exception of coalpatch microsite the proportion of annual species was lower on the 20-yr old site compared to 5-yr old site. Reverse was true for perennial species. Annuals comprised, across the age series of spoil, 63.1. 47.7, 65.2 and 54.2 per cent of total species recorded in quadrats, respectively on slope, coalpatch, undulating surface and flat surface.

The proportion of legumes in the vascular flora across spoils ages was 35.1, 27.5, 36.2, and 33.3 per cent on slope, coalpatch undulating surface and flat surface, respectively. Grassess comprised 33.6, 35.4, 32.9 and 41.9 per cent of the flora across spoil ages on slope. coalpatch, undulating surface and flat surface, respectively. These statistics show a prevalence of grasses and legumes on revegetating coalmine spoils. The grass : legume : other forbs ratio was 0.9:0.1, 0.9:0.9:1, 0.75:0.75:1, 1.1:0.75:1 for slope, coalpatch, undulating surface and flat surface, respectively. This ratio for the total vascular flora was (Appendix Table 1) 0.75:0.33:1. The grasses are beneficial in checking erosion and the legumes have ameliorative benefits on both the physical and chemical properties of spoils because majority of them are potential N-fixeres. Alexander (1989a, b) has compared the beneficial effect of *Acacia albida* and *Eucalyptus camaldulensis* on the Ten-mine spoil in Jos Plateau, Nigeria, and recommended that *A. albida* has an ability to improve both the nutrient status and physical conditions in the top 20 cm of the soil beneath its canopy, whereas *E. camaldulensis* caused a progressive increase in soil acidity and reduction of base content, although organic C increased. *Robinia pseudoacacia* an N-fixing legume raised soil N levels considerably more than the other non-leguminous species in Ohio coalmine spoil, U.S.A. (Vimmerstedt *et al.*, 1989).

APPENDIX Table 1 :

Acacia nilotica L. Willd. ex Delile	Mimosaceae
Achyranthes aspera L.	Amaranthaceae
Aeschynomene indica L.	Fabaceae
Ageratum conyzoides L.	Asteraceae
Alternanthera pungeus HBK	Amaranthaceae
Alternthera sessilis (L.) R. Br. ex DC.	Amaranthaceae
Alysicarpus monilifer (L.) DC.	Fabaceae
Apluda mutica L	Poaceae
Argemone mexicana L.	Papaveraceae
Aristida adscensionis L.	Poaceae
Atylosia scarabaeoides (L.) Benth.	Fabaceae
Azadirachta indica A. Juss.	Meliaceae
Bidens biternata (Lour.) Merrill and Sheriff	Asteraceae
Borreria articularis (L. F.) F. N. Will.	Rubiaceae
Borreria stricta (L.F.) K. Schum.(=*Borreria pusilla* (Wall) DC.)	Rubiaceae
Bothriochloa pertuns L.	Poaceae
Brachiaria reptans (L.) Gardner and Hubbard	Poaceae
Butea monosperma (Lamk.) Taub.	Fabaceae
Calotropis procera (Ait.) Ait f.	Asclepiadaceae
Carissa carand L. var. congesta (W.) Bedd. (=*C. congesta* W.)	Apocynaceae
Cassia fistula L.	Caesalpiniaceae
Cassia pumila Lamk.	Caesalpiniaceae
Cassia tora L.	Caesalpiniaceae

Celosia argentea L.	Amaranthaceae
Cenchrus ciliaris L.	Poaceae
Corchorus conniveans L.	Tiliaceae
Crotalaria albida Heyne.	Fabaceae
Cynodon dactylon (L.) Pers.	Poaceae
Cyperus compressus L.	Cyperaceae
Dactyloctenium aegyptium (L.) Willd.	Poaceae
Dalbergia sissoo Roxb.	Fabaceae
Desmodium motorium (Houtt.) Merr.	Fabaceae
Desmodium triflorum (L.) DC.	Fabaceae
Dichanthium annulatum (Forssk.) Stapf.	Poaceae
Digitaria biformis Willed. (=*D. bicornis* (Lamk.) R. and S.)	Poaceae
Digitaria setigera R. and S.	Poaceae
Diospyros melanoxylon Roxb.	Ebenaceae
Echinops echinatus Roxb.	Asteraceae
Eclipta alba (L.) Hassk. *E prostrata* (L.) L.	Asteraceae
Eleusine indica (L.) Gaertn.	Poaceae
Eragrostis gangatica (Roxb.) Steud.	Poaceae
Eragrostis tenella (L.) P. Beauv.	Poaceae
Eragrostis unioloides (Retz.) Nees and Steud.	Poaceae
Erogrostiella bifaria (Vahl.) Bor.	Poaceae
Euphorbia hirta L.	Euphorbiaceae
Evolvulus alsinoides (L.) L.	Convolvulaceae
Evolvulus nummutaria (L.) L.	Convolvulaceae

Fimbristylis alboviridis Clarke	Cyperaceae
Glossocardia bosvallea (L. f.) DC	Asteraceae
Hackclochloa granularis (L.) O. Ketze.	Poaceae
Heteropogon contortus (L.) P. Beauv, ex R. and S.	Poaceae
Holoptelia integrifolia Planch	Ulmaceae
Indigofera linifolia (L. f.) Retz.	Fabaceae
Indigofera linnaei Ali	Fabaceae
Ipomoea eriocarpa R. Br. (=*I hispida*, R. and S.)	Convolvulaceae
Launaea procumbens (Roxb.) Ramayya and Rajagopal	Asteraceae
Lepidagathis hamiltoniana Nees.	Acanthaceae
Leucas aspera Link. (=*L. plukenetii* Roth.) Spreng.	Lamiaceae
Melanocenchris jacquemontii Jaub and Spach	Poaceae
Merremia tridentata (L.) Hall. f.	Convolvulaceae
Ocimum basilicum L.	Lamiaceae
Oldenlandia affinis (R.and S.)DC.(=*Hedyotis affinis* R. and S.)	Scrophulariaceae
Parthenium hysterophorus L.	Asteraceae
Phyllanthus simplex Retz. (=*P. virgatus* Forst. f.)	Euphorbiaceae
Plectranthus mollis (Ait.) Spreng.	Lamiaceae
Rungia repens (L.) Nees.	Acanthaceae
Saccharm munja Roxb. (=*S. arundinaceum* Retz.)	Poaceae
Saccharum spontaneum L	Poaceae
Setaria glauca (auct.)	Poaceae
Setaria intermedia R. and S.	Poaceae
Setaria pumila (Poir.) R. and S.	Poaceae

Sida cordata (Burm. f.) Borss.	Malvaceae
Solanum xanthocarpum Schrad and Wendl. (= *S. surattense* Burm. f.)	Solanaceae
Sporobolus diander (Retz.) P. Beauv. (=*S. indicus* (L.) R. Br. var. diander (Retz.) Jov and Gued.	Poaceae
Tephrosia purpurea (L.) Pers	Poaceae
Tridex procumbens L.	Asteraceae
Urochloa panicoides P. Beauv.	Poaceae
Woodfordia fruticosa (L.) Kutz.	Lythraceae
Xanthium strumarium L.	Asteraceae
Zizyphus glabetrima (Sedgw.) Santapau	Rhamnaceae
Zornia gibbosa Span.	Fabaceae

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