Assessment of plant species assemblages with their distribution in an open cast mining area of Raniganj coalfield, West Bengal, India

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Abstract: The present work reveals in all 57 species belonging to 22 families on an overburden dump in Bankola area in Raniganj coalfield of West Bengal, India. The sampling procedure was performed according to the quadrat method. Nine plots were sampled and tree, shrub and herb species were identified. Species frequency, density, dominance and importance value index (IVI) were calculated using standard methods. The most dominant species in the area was Solanum sisymbriifolium (23.02). The lowest IVI value was found in Tribulus terrestris (1). Fabaceae and Asteraceae were the most dominant families recorded. Agglomerative hierarchical clustering (AHC) analysis represents the relationship among all species and heterogeneity of dominance of species was noticed throughout the study area. Availability of the existing plantation in the wastelands enables initiation of the remediation process through revegetation of desired plant species in the concerned spaces to accomplish restoration of the habitat conditions to a stable state.

Index Terms - Plant species, Bankola area, Raniganj coalfield, Importance value index, AHC analysis, dominant species, heterogeneity, remediation, restoration.

INTRODUCTION

Opencast mining involves removal of the overlying soil and rock debris along with existing vegetation, and deposition of it into another fresh area, heaped in the form of dumps, and is called mine spoil. Mining operations degrade significant areas of land and replace existing ecosystem with undesirable waste materials in form of mine spoil dumps [1]. Every year, opencast mining for extracting tons of coal damages a surface area of about 4 hectares in India [2]. This large amount of land loses its original potential and quality of soil degrades [3]. As the dump materials are generally loose lacking vegetation cover, they become highly prone to erosion by wind or water [4], [5], spread over the surrounding fertile land and disturb their natural quality [6]. These dumps change the natural land topography and affect the drainage system of the mining area [7]. Natural succession of plant species on these dumps is often prevented or takes place at a very slow rate [8], [4], [9] because of adverse physico-chemical and biological properties of mine spoil [10]. Overburden top soil is usually deficient in major nutrients [6], an important factor for limiting plant growth [11].

Massive destruction of forest vegetation is done by large scale mechanized open cast mining, which destroys a large area by putting the top fertile soil upside down. Open cast mining destroys the original land ecosystem and microbial community due to mining and stockpiling of mine rejects on adjoining land, which is a matter of great environmental concern since it is associated with the pollution of terrestrial and aquatic ecosystems. Due to stockpiling of mine rejects, the landscapes that emerge are devoid of supportive and nutritive capacity for biomass development [10]. Development of vegetation cover on the dumps is essential for the conservation of biodiversity and stable environment in the coalfield areas [12] and to make the land productive. There are several studies on different innovative approaches for vegetation development on coal mine spoil dumps [13], [14], besides, specific use of native and indigenous species for re-vegetation of mine spoil has also been suggested [15], [16]. There are reports on the natural succession of different plant species on the over burden dumps after certain interval of time [17], [18], [19], [20]. Restoration of mined areas is essential to restore the ecological balance of the system and maintain a self sustaining ecosystem wherein all the essential ecological processes take place [21]. A wide range of factors, including the nature of the overburden, the availability of topsoil and its handling, the development of soil fertility and the control of soil air and water content determine the suitability of reclaimed sites for revegetation and its successful successional development. Top soil should be preserved in order to restore and reclaim the mined land [2], [22]. Knowledge about natural succession of plant species on mine spoil is quite essential to initiate successful revegetation program on dumps [19].

Considering the above facts in mind the present study was aimed to determine the status of vegetation on an open cast coal mining area of Raniganj coalfield, West Bengal, India.

MATERIALS AND METHODS

This study has been carried out in Bankola area of Raniganj Coalfield which falls under ECL (Eastern Coal Field Limited) and is the birth place of coal mining of India. Geographically Raniganj Coalfield lies between latitudes 23°25' and 23°50' N and longitudes 86°38' and 87°20' E. The geographical location of Bankola area lies between latitude 23°39'52.9"N and longitude 87°14'32"E. The climate in general is dry tropical with three prominent seasons, summer (middle of March to middle of June), rain (middle of June to Middle of October) and winter (November to February). In summer average temperature ranges between 38° C to 43° C, may rise to 48° C. The area receives average annual rainfall between 1240 to 1500 mm. The naturally occurring plants on the selected overburden dumps were studied during 2012 to 2013. A quadrat of $10m^2$ was considered within the selected wasteland sites, which were sampled for the presence of the plant species, irrespective of being trees, shrubs and herbs. The number of plants were counted and recorded for the purpose of analysis following the identification and confirmation using herbarium reference and morphological features. The relative values of density, frequency and dominance were determined following the method of Philips [23].

Importance value index (IVI) of all plants was calculated by summing up the relative values of density, frequency and abundance or dominance [24]. A graphical representation was found to show the general distribution of families present in the open cast mining site. Agglomerative Hierarchical Cluster (AHC) analysis of all species and their distribution trends were determined using XLSTAT 10^{TM} software.

RESULTS AND DISCUSSION

A summary of phytosociological data of an open cast mining area of Raniganj coalfield was tabulated in Table 1. The plant community represents 57 species belonging to 22 families. *Solanum sisymbriifolium* (23.02) was found to be the most frequent, dominant and important species among the plant community of the concerned study area. *Calotropis gigantea* (19.85) and *Cnicus wallichii* (16.33) were the next dominant species followed by *Solanum sisymbrifolium.*

The decreasing trends of Important Value Index (IVI) were in the order of *Saccharum spontaneum* (10.36), *Hyptis suaveolens* (8.5), *Acacia auriculaeformis* (8.28), *Cassia tora* (7.77), *Vernonia cinerea* (7.21) and *Clerodendrum viscosum* (7.1).

The highest IVI score of *Solanum sisymbriifolium* deserves special mention for its frequent occurrence in the study area. *Tribulus terrestris* (1) have the lowest IVI value with minimum occurrence in study area. The lowest IVI scores were in the following order Desmodium gangeticum (2), *Vitax negundo* and *Solanum nigram* (1.98), *Pedalium murex*, *Cassia siamea* and *Ailanthus excelsa* (1.9), *Pergularia daemia* and *Amaranthus viridis* (1.55).

Table 1: Importance Value Indices (IVI) on an open cast mining area in Raniganj Coalfield, West Bengal

Sl. No.	Plant species name	Family	RF	RD	RDo	IVI
1	*Acacia auriculaeformis* Benth.	Fabaceae	2.59	3.2	2.48	8.27
2	*Acacia nilotica* (L.) Delile	Fabaceae	1.28	0.67	1.02	2.97
3	*Acalypha indica* L.	Euphorbiaceae	1.63	0.67	1.02	3.32
4	*Ailanthus excelsa* Roxb.	Simaroubaceae	0.96	0.33	0.68	1.97
5	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	0.96	0.88	1.82	3.66
6	*Alternanthera tenella* Colla	Amaranthaceae	1.95	1.88	1.93	5.76
7	*Alternanthera pungens* Kunth	Amaranthaceae	1.63	0.67	0.82	3.12
8	*Amaranthus spinosus* L.	Amaranthaceae	1.95	1.55	1.59	5.09
9	*Amaranthus viridis* L.	Amaranthaceae	0.64	0.22	0.68	1.54
10	*Azadirachta indica* A.Juss.	Meliaceae	2.27	1.32	1.17	4.76
11	*Cnicus wallichii* Hook.f.	Asteraceae	2.91	7.95	5.46	16.32
12	*Calotropis gigantea* (L.) W.T.Aiton	Asclepiadaceae	2.91	10.04	6.89	19.84
13	*Calotropis procera* W.T.Aiton	Asclepiadaceae	1.95	1.78	1.82	5.55
14	*Cassia obtusifolia* L.	Fabaceae	1.95	1.55	1.59	5.09
15	*Cassia tora* L.	Fabaceae	1.95	2.87	2.95	7.77
16	*Cassia siamea* Lam.	Fabaceae	0.32	0.22	1.36	1.9
17	*Cleome viscosa* L.	Capparaceae	1.95	0.99	1.02	3.96
18	*Clerodendrum viscosum* Vent.	Verbenaceae	2.59	2.54	1.96	7.09
19	*Coccinia cordifolia* Cogn.	Cucurbitaceae	2.27	1.32	1.17	4.76
20	*Croton bonplandianus* Baill.	Euphorbiaceae	1.63	1.32	1.64	4.59
21	*Cynodon dactylon* (L.) Pers.	Poaceae	2.59	2.42	1.88	6.89
22	*Dalbergia sissoo* Roxb.	Papilionaceae	1.63	1.66	2.05	5.34
23	*Datura metel* L.	Solanaceae	2.59	1.21	0.94	4.74
24	*Desmodium gangeticum* (L.) DC.	Fabaceae	0.64	0.33	1.02	1.99
25	*Eclipta alba* (L.) Hassk.	Asteraceae	1.63	0.67	0.82	3.12
26	*Eupatorium odoratum* L.	Asteraceae	2.91	2.21	1.51	6.63
27	*Euphorbia hirta* L.	Euphorbiaceae	1.63	0.67	0.82	3.12
28	*Ficus benghalensis* L.	Moraceae	1.63	0.77	0.95	3.35

29	*Ficus cunea* Steud.	Moraceae	2.91	1.32	0.91	5.14
30	*Gomphrena celosioides* Mart.	Amaranthaceae	1.63	0.67	0.82	3.12
31	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	2.91	3.31	2.27	8.49
32	*Jatropha gossypiifolia* L.	Euphorbiaceae	2.91	1.55	1.06	5.52
33	*Lantana camara* L.	Verbenaceae	2.59	2.31	1.79	6.69
34	*Leonurus sibiricus* L.	Lamiaceae	1.95	0.88	0.91	3.74
35	*Leucas aspera* (Willd.) Link	Lamiaceae	1.31	0.88	1.36	3.55
36	*Mikania scandens* (L.) Willd.	Asteraceae	0.96	0.44	0.91	2.31
37	*Ocimum canescens* A.J.Paton	Lamiaceae	1.63	1.21	1.5	4.34
38	*Panicum maximum* Jacq.	Poaceae	0.32	0.33	2.05	2.7
39	*Pedalium murex* L.	Pedaliaceae	0.32	0.22	1.36	1.9
40	*Pergularia daemia* (Forssk.) Chiov.	Asclepiadaceae	0.64	0.22	0.68	1.54
41	*Phoenix sylvestris* (L.) Roxb.	Arecaceae	2.27	0.88	0.78	3.93
42	*Phyllanthus amarus* Schumach. & Thonn.	Euphorbiaceae	0.96	0.99	2.05	4
43	*Saccharum munja* Roxb.	Poaceae	2.27	2.10	1.85	6.22
44	*Saccharum spontaneum* L.	Poaceae	2.91	4.41	3.03	10.35
45	*Scoparia dulcis* L.	Scrophulariaceae	0.96	0.99	2.05	4
46	*Sida acuta* Burm.f.	Malvaceae	2.27	1.66	1.46	5.39
47	*Solanum nigrum* L.	Solanaceae	0.96	0.33	0.68	1.97
48	*Solanum sisymbriifolium* Lam.	Solanaceae	2.91	11.92	8.18	23.01
49	*Spilanthes paniculata* Wall.	Asteraceae	0.32	0.33	2.05	2.7
50	*Tephrosia purpurea* (L.) Pers.	Fabaceae	1.63	1.66	2.05	5.34
51	*Tephrosia villosa* (L.) Pers.	Fabaceae	0.96	0.77	1.59	3.32
52	*Tribulus terrestris* L.	Zygophyllaceae	0.32	0.33	0.68	1.33
53	*Tridax procumbens* L.	Asteraceae	2.27	1.77	1.56	5.6
54	*Triumfetta rhomboidea* Jacq.	Tiliaceae	2.59	2.21	1.70	6.5
55	*Vernonia cinerea* (L.) Less.	Asteraceae	2.91	2.54	1.75	7.2
56	*Vitex negundo* L.	Verbenaceae	0.96	0.33	0.68	1.97
57	*Xanthium strumarium* L.	Asteraceae	0.96	1.55	3.18	5.69

Fig.1 represents the distribution of families that were situated throughout the study area. The most dominant families were Fabaceae and Asteraceae. Amaranthaceae and Euphorbiaceae are next most distributed families. Among monocots Poaceae tends to increase their dominancy in the site, which reflects the colonizing ability of the members of this family in hostile coal mine spoil habitat. Helm [25] and Skeel & Gibson [26], represents similar observations for family Poaceae which may contribute to their success in colonizing the mines spoil and initialized as a colonizers during restoration of mined land. Due to their fibrous root systems, such species reported to slow down the pace of erosion and help to stabilize soil and conserve the level of moisture [25].

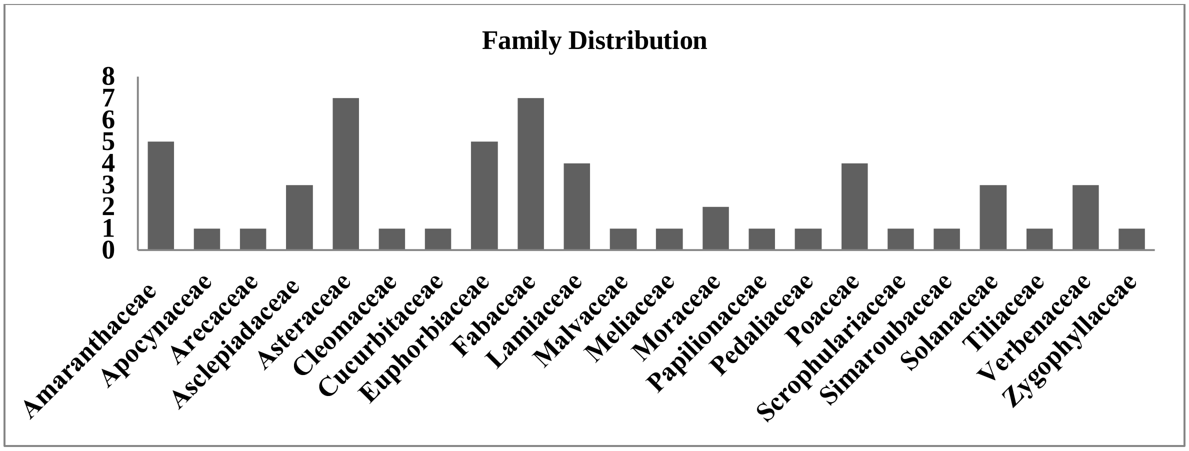
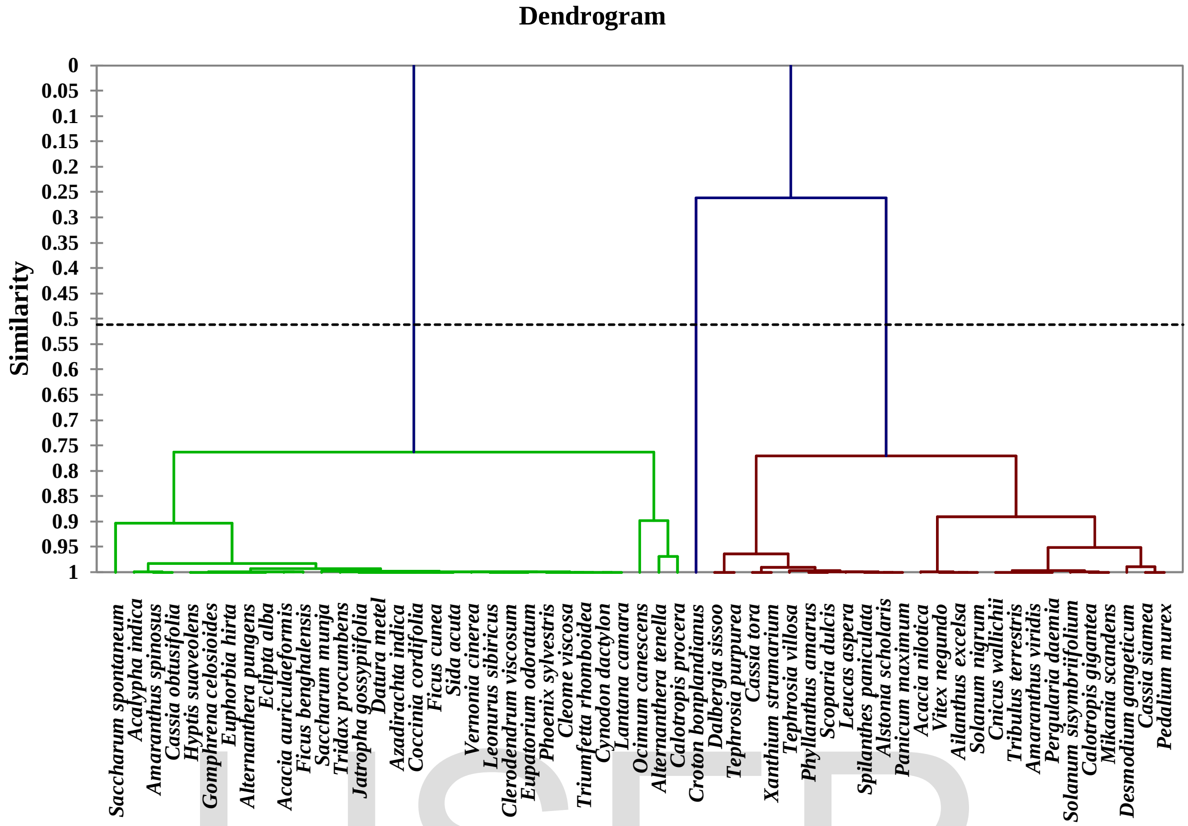
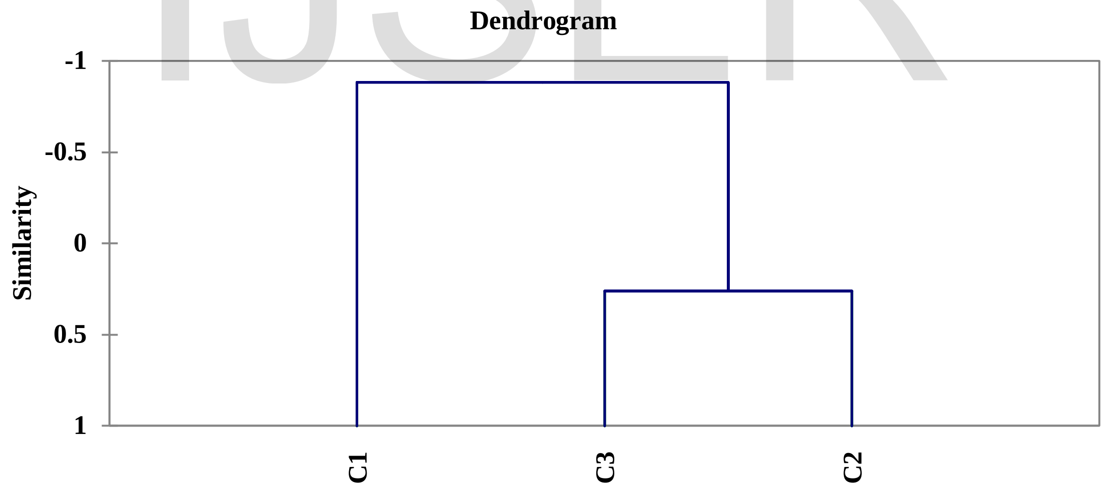


Fig 1: Graphical representation of presence of different families in the site of Raniganj Coalfield

The results of the cluster analysis is shown in Fig 2 indicating the total number of plant species could be grouped into three different clusters with varying representation of the species numbers. While cluster 1consisted of thirty one species, the other two clusters 2 and 3 consisted of twenty five and one species respectively (Fig 2). Cluster 1 negatively correlated with cluster 2 and 3. Using the proximity matrix representing the similarity in the abundance of the plants. Thus from the results it is apparent that the open cast area in the Raniganj Colliery, West Bengal, considerable heterogeneity of the plant species ensembles. The variations in the plant species assemblages observed in the present instance remained similar to the observations made earlier on different coal mining sites of India, extending from Jharkand [27], [28], [29], Assam [20], [17], [30] and Central Indian [31], [32], [33], [34] coalfields. Plant species assemblages in abandoned coal mine soils in Poland [35], [36], China [37], [38], [39], [40] and Australia [41] remained similar in terms of heterogeneity of abundance at a spatial scale. However, the enhancement of the land transformation to a stable community was achieved through addition of desired variety of plant species in the barren spaces.

While the present survey of the wasteland indicates the presence of several tolerance species, the ability of the plants and there selection should be judiciously done to reinstate the dynamics of the ecological succession in orderly manner. Assessment and further monitoring of the habitats is an essential part of tracking the changes in the habitat conditions, such that the suitability of the region for the colonization and establishment of desired variety of plants can be made.





Distances between the central objects:

	1 (*Sida acuta*)	2 (*Dalbergia sissoo*)	3 (*Croton bonplandianus*)
1 (*Sida acuta*)	0	0.8705	0.7467
2 (*Dalbergia sissoo*)	0.8705	0	0.5326
3 (*Croton bonplandianus*)	0.7467	0.5326	0

Results by class:

Class	1	2	3
Objects	**31**	**25**	**1**
Sum of weights	**31**	**25**	**1**
Within-class variance	**1.3361**	**14.4783**	**0.0000**
Minimum distance to centroid	**0.0348**	**0.5292**	**0.0000**
Average distance to centroid	**0.9660**	**2.5501**	**0.0000**
Maximum distance to centroid	**3.2194**	**11.8673**	**0.0000**
	Acacia auriculaeformis	***Acacia nilotica***	***Croton bonplandianus***
	Acalypha indica	***Ailanthus excelsa***	
	Alternanthera tenella	***Alstonia scholaris***	
	Alternanthera pungens	***Amaranthus viridis***	
	Amaranthus spinosus	***Cnicus wallichii***	
	Azadirachta indica	***Calotropis gigantea***	
	Calotropis procera	***Cassia tora***	
	Cassia obtusifolia	***Cassia siamea***	
	Cleome viscosa	***Dalbergia sissoo***	
	Clerodendrum viscosum	***Desmodium gangeticum***	
	Coccinia cordifolia	***Leucas aspera***	
	Cynodon dactylon	***Mikania scandens***	
	Datura metel	***Panicum maximum***	
	Eclipta alba	***Pedalium murex***	
	Eupatorium odoratum	***Pergularia daemia***	
	Euphorbia hirta	***Phyllanthus amarus***	
	Ficus benghalensis	***Scoparia dulcis***	
	Ficus cunea	***Solanum nigrum***	
	Gomphrena celosioides	***Solanum sisymbriifolium***	
	Hyptis suaveolens	***Spilanthes paniculata***	
	Jatropha gossypiifolia	***Tephrosia purpurea***	
	Lantana camara	***Tephrosia villosa***	
	Leonurus sibiricus	***Tribulus terrestris***	
	Ocimum canescens	***Vitex negundo***	
	Phoenix sylvestris	***Xanthium strumarium***	
	Saccharum munja		
	Saccharum spontaneum		
	Sida acuta		
	Tridax procumbens		
	Triumfetta rhomboidea		
	Vernonia cinerea		

Fig 2: Agglomerative hierarchical clustering of the plant species observed in the study area of Raniganj coalfield, West Bengal

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