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Vegetation dynamics in Bishrampur collieries of northern Chhattisgarh, India: eco-restoration and management perspectives

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Abstract Phytosociological study in and around reclaimed coal mine site is an essential requirement for judging restoration impact on a disturbed site. Various studies have been aimed towards assessing the impact of different restoration practices on coal mine wastelands. Plantation scheme in a scientific way is the most suitable approach in this context. During the present investigation, an effort have been made to assess the vegetation dynamics through structure, composition, diversity, and forest floor biomass analysis in and around Bishrampur collieries, Sarguja division, northern Chhattisgarh, India. We have tried to develop strategies for eco-restoration and habitat management of the concerned study sites. Four sites were randomly selected in different directions of the study area. We classified the vegetation community of the study sites into various strata on the basis of height. Two hundred forty quadrats were laid down in various directions of the study area to quantify vegetation under different strata. During our investigation, we found eight different tree species representing four families in the different study sites. The density of the various tree species ranged between 40 and 160 individuals ha^{-1}. The density of sapling, seedling, shrub, and herb ranged between 740 and 1620; 2000 and 6000; 1200 and 2000; and 484,000 and 612,000 individuals ha^{-1}, respectively, in different directions. The diversity indices of the tree reflected highest Shannon index value of 1.91. Simpsons index ranged between 0.28 and 0.50, species richness ranged between 0.27 and 0.61, equitability up to 1.44, and Beta diversity ranged between 2.00 and 4.00. Total forest floor biomass ranged between 4.20 and 5.65 t/ha among the study sites. Highest forest floor biomass occurred in the south direction and lowest at east direction. Total forest floor biomass declined by 6.19% in west, 13.10% in north, and 25.66% in east direction, respectively. The mining activities resulted significant damage to natural vegetation and its dynamics. The study indicated that *Acacia mangium*, *Cassia siamea*, and *Dalbergia sissoo* can be recommended for effective eco-restoration of the concerned sites due to cosmopolitan distribution, high regeneration potential, as well as existence in the form of various girth classes with stable population structure.

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Introduction

Mining has negative impact in its various phases of operations. The diverse nature of deterioration of environment due to mining is a major issue and challenges in modern context. Any alteration in the habitat quality in the form of physical, chemical, and biological processes has significant impact on living entity of the ecosystem.

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Surface mining imparts significant impact on soil environment that leads to total destruction in soil ecosystem structure and functioning. Several reports on vegetation composition and diversity in mining areas of Chhattisgarh (Singh et al. 2013; Jhariya et al. 2013 and 2016; Kumar et al. 2015 and 2016), Madhya Pradesh (Singh et al. 2004a & b), Jharkhand (Ghose 2004; Guha 2014; Singh et al. 2014), Rajasthan (Kumar et al. 2014), Orissa (Swain et al. 2011; Mohaptra and Goswami 2012), West Bengal (Sadhu et al. 2012), North East India (Rai 2002; Sarma et al. 2010) and other countries (Donggan et al. 2011; Milder et al. 2011; Tom-Dery et al. 2012) are available.

Mining activity imposes its impact on various dimension of environment including biodiversity along with ecological interactions among species. The impact includes reduction in the diversity and abundance of vegetation, plant productivity, and promoting invasive species on the concerned area (Jhariya et al. 2013; Kumar et al. 2015). Such events lead to higher level of deforestation rendering mismanagement and loss of productivity (Jhariya et al. 2016). Coal extraction significantly alters the physico-chemical and biological nature of the excavated site. Surface mining leads to complete denudation of indigenous vegetation due to damage of the soil and its biota (Corbett et al. 1996). Comparative study reflects the nature of intensive pollution of surface mining in comparison to underground mining. Mining activities throughout the world leads to 20% deforestation in developing countries (Bahrami et al. 2010). Scientific effort needs to be developed to quantify the impact of mining activity on biotic systems that would lead to eco-restoration and proper resource management.

A proper understanding of vegetation composition, structure, and community dynamics is vital to address conservation, management, and facilitate restoration of mined out landscape. This study provides an opportunity to understand the changes in vegetation dynamics related with open-cast mining activity in the concerned study site along with proper reclamatory measures.

Material and methods

Study site

The present study focussed on assessing vegetational structure and dynamics of selected study sites of Bishrampur collieries (23° 21 N and 82.85° E with an average elevation of 527 m) in the district of Surajpur of Northern Hill Zone, Chhattisgarh during the year 2014–2015. Bishrampur is highly concentrated with opencast and underground mining centers (Kumar et al. 2015 and 2016). The climate of this area is sub-tropical in nature with summer from April to June, monsoon season from July to September, post-monsoon from October to December, and winter from January to March. The maximum and minimum temperature generally occurs on May and December, respectively. The Surajpur district receives annual rainfall of 1192.3 mm with 73 normal rainy days.

Sampling design

The directional impact on vegetation of Bishrampur collieries and its surrounding (Fig. 1) was analyzed for its structure, composition, and dynamics in south, north, east, and west wards. Vegetation stands were stratified on the basis of height. Total of 240 quadrats were laid across the sites for quantification of vegetation at different stratum. Random quadrats of 10 × 10 m size were laid for quantification of trees and saplings. In each of this quadrat, a sub-quadrat of 5 × 5 m size was randomly laid for measuring seedling and shrubs. Similarly another quadrat of 50 × 50 cm size within 10 × 10 m quadrat was laid for measuring herbs and forest floor, respectively.

Data collection

The girth at breast height (above 1.37 m from the ground) of all the trees and saplings were measured. For tree species, the individuals >30 cm GBH were categorized as tree, <30 cm but >10 cm as saplings. The seedlings (<10 cm GBH) and shrubs were measured at the collar height. The data were collected up to species level separately in each quadrats in different directions.

Data analysis

Vegetational structure and composition analysis

Vegetational structure and composition were quantitatively analyzed through frequency, density, abundance values (Curtis and McIntosh 1950), and A/F ratio (Whiteford 1949). The relative frequency,
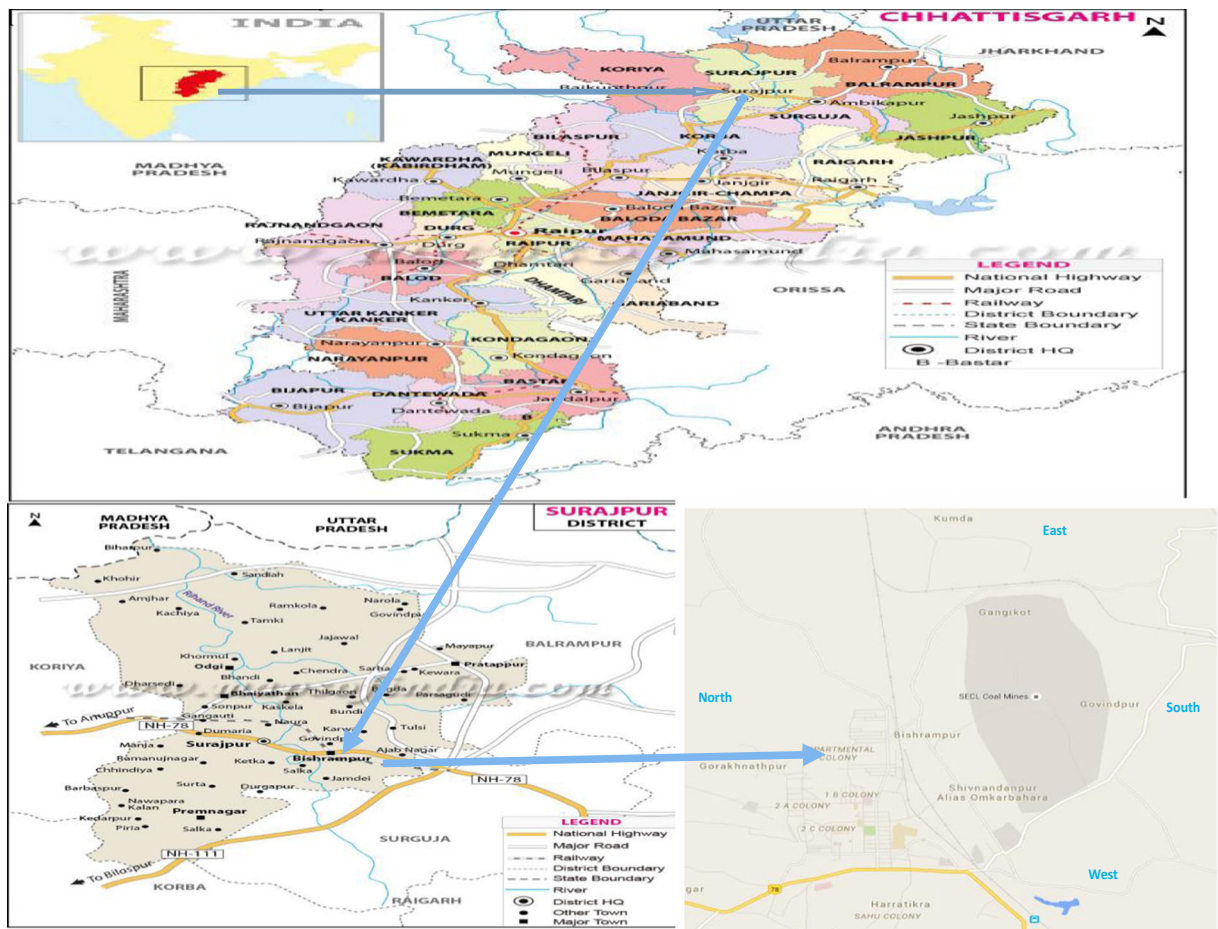
Fig. 1 Location map of the study site

relative density, and relative basal area values were calculated following standard methods (Phillips 1959). The sum of relative frequency, relative density, and relative basal area values was used to calculate importance value index (IVI) for the species. The species found in the quadrats were identified with the help of standard text materials (Regional floras of Chhattisgarh & Madhya Pradesh, Handbook of Weeds of Chhattisgarh, flora/encyclopedia; Hooker's 1875; Pullaiah 2006; Singh et al. 2010).

Raunkiaer (1934) frequency class analysis was used to assess the rarity or commonness of the tree species (Hewit and Kellman 2002). In this classification, the percentage frequency of the species was classified as A, B, C, D, and E, where A represents rare (0–20%), B represents low frequency (20–40%), C represents intermediate frequency (40–60%), D represents moderately high frequency (60–80%),

and E represents high frequency or common (80–100%). The population structures were based on different girth classes. The total number of individuals belonging to these girth classes were calculated for each species on each site following Saxena and Singh (1984), Tripathi et al. (1991) and Jhariya et al. (2012).

Diversity indices analysis

The data generated were synthesized to represent the diversity of each direction of mining area for each stratum. Diversity parameters were determined using the Shannon-Weaver information function (Shannon and Weaver 1963). Concentration of dominance was measured following Simpson's index method (Simpson 1949). Vegetations were also measured for species richness (Marglef 1958), equitability (Pielou 1966) and Beta diversity (Whittaker 1972).

Statistical analysis

To observe the inter-relationship between phytosociological attributes, data were subjected to correlation analysis. Multivariate analysis of the data was done through two-way cluster analysis and principle component analysis through MINITAB presents version 15.0-statistical computer software.

Results and discussion

Impact on overstory

Vegetation structure of tree layer

In four different directions, eight tree species representing four families were recorded during the present investigation (Table 1). The total density of trees ranged between 40 and 160 individuals ha^{-1} among the various study sites. Highest and lowest total density values were recorded for north and south directions, respectively. The dominant representatives were *Dalbergia sissoo*, *Syzygium cumini*, *Peltophorum ferrugineum*, and *Cassia siamea* in east, west, north, and south directions, respectively, contributing the higher basal area and IVI in the respective directions. It was apparent from the study that all species were distributed randomly in east and west direction. The A/F ratio for west direction showed random distribution pattern. Results reveal directional influence with respect to tree species distribution.

Development of vegetal cover is a suitable policy towards improving soil health through alteration of various pedogenic factors including increase of soil organic matter, biological nitrogen fixation, nutrient utilization efficiency of herbaceous vegetation, increase water storage and recharge, and building up of soil nutrient pool. Formation of new self-sustaining top soils is mediated by trees. Plant litter and root exudates provide efficient nutrient-cycling to soil (Mertens et al. 2007). During our present investigation, we found that *Acacia mangium* and *Casia siamea* can be effectively utilized for eco-restoration of respective study sites. Lower density of tree species in the degraded habitat may be due to intensive logging and felling for mining purpose as well as improper seed dispersal in the degraded habitat from the adjoining forest areas (Robinson and Handel 2000).

Vegetation structure of sapling layer

Sapling layer comprises of ten species representing six families in the different sites (Table 1). The total density ranged between 740 and 1620 individuals ha^{-1} in different directions. Maximum and minimum total density values were recorded for north and east directions, respectively. *Acacia mangium* (560 individuals ha^{-1}) recorded higher density in east and south direction, *Cassia siamea* (400 individuals ha^{-1}) in west direction while *Eucalyptus* spp. (540 individuals ha^{-1}) in north direction, respectively. The total basal area of sapling among the site ranged between 1.36 and 3.02 m^2 ha^{-1}. Highest total basal area was observed in north direction and lowest value was recorded in east direction. *Acacia mangium* were found to be the most suitable species in terms of establishment and further propagation followed by *Cassia siamea*.

Phytosociology of vegetation community is a good indicator of ecological condition of land ecosystem. Alteration in the abiotic factors may lead to changes in the community structure in a short span of time (Hassan et al. 2007). Present study reflected density of tree was very low for all the study sites. Majority of species showed random as well as contagious distribution pattern in the study sites. Rahman et al. (2010) reported a total of 715 individuals and 22 invasive species representing 17 families in mining areas. During the investigation, ten species of shrubs, nine species of herbs, and three species of vines were recorded. Sobuj and Rahman (2011) reported a total of 52 (16 tree species, 15 shrubs, 21 herbs) in the natural forest; on the contrary, 31 species of plants (11 trees, 8 shrubs, 12 herb species) were identified in plantation forest. Kumar et al. (2014) found the tree density of 11.67/100 m^2, shrub density was 8.33/9 m^2, and herb density was 41.11/m^2, respectively, in Rajasthan.

The number of tree species was low in all the mining sites due to various mining activities (Sarma et al. 2010). The tree density was more (1040 stems ha^{-1}) in the unmined area in comparison to mined areas (515 and 646 stems ha^{-1}) while density of herbaceous species was higher in mined areas than the unmined area. The trees of medium girth class contributed to the maximum stand density in the mined areas, while in the unmined site, the trees of low girth class contributed to the maximum stand density. In the mined areas it was found that in spite of low stand density, higher basal area were recorded due to existence of trees of high girth class as

Table 1 Structure and composition of overstory vegetation in collieries

Species	East				West				North				South			
	D	IVI	BA	A/F	D	IVI	BA	A/F	D	IVI	BA	A/F	D	IVI	BA	A/F
Tree layer																
Acacia mangium	20	41.05	0.15	0.05	–	–	–	–	40	68.97	0.324	0.025	20	144.63	0.186	0.050
Ailanthus excelsa	20	47.18	0.28	0.05	–	–	–	–	–	–	–	–	–	–	–	–
Butea monosperma	20	57.76	0.51	0.05	–	–	–	–	–	–	–	–	–	–	–	–
Cassia siamea	–	–	–	–	20	84.28	0.199	0.050	20	34.85	0.168	0.050	20	155.39	0.231	0.050
Dalbergia sissoo	80	154.0	1.24	0.05	–	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus spp.	–	–	–	–	–	–	–	–	40	72.58	0.385	0.025	–	–	–	–
Peltophorum ferrugineum	–	–	–	–	20	84.08	0.197	0.050	60	123.62	0.830	0.017	–	–	–	–
Syzygium cumini	–	–	–	–	20	131.66	0.736	0.050	–	–	–	–	–	–	–	–
Total	140	300	2.19	0.2	60	300	1.132	0.15	160	300	1.707	0.12	40	300	0.417	0.1
Sapling layer																
Acacia catechu	–	–	–	–	–	–	–	–	–	–	–	–	40	14.36	0.05	0.100
Acacia mangium	560	193.62	0.85	0.056	280	57.57	0.38	0.078	340	71.41	0.68	0.034	560	138.56	1.03	0.056
Butea monosperma	140	85.67	0.45	0.039	–	–	–	–	–	–	–	–	20	14.42	0.09	0.050
Cassia siamea	–	–	–	–	400	90.99	0.64	0.040	120	21.06	0.24	0.300	540	132.67	0.94	0.054
Eucalyptus spp.	–	–	–	–	160	40.73	0.24	0.044	540	94.41	1.01	0.054	–	–	–	–
Peltophorum ferrugineum	–	–	–	–	300	73.43	0.45	0.030	260	46.53	0.42	0.072	–	–	–	–
Pongamia pinnata	–	–	–	–	–	–	–	–	360	66.64	0.67	0.056	–	–	–	–
Saccopetalum tomentosum	40	20.72	0.06	0.100	–	–	–	–	–	–	–	–	–	–	–	–
Syzygium cumini	–	–	–	–	80	16.45	0.09	0.200	–	–	–	–	–	–	–	–
Tectona grandis	–	–	–	–	60	21.03	0.11	0.038	–	–	–	–	–	–	–	–
Total	740	300	1.36	0.19	1280	300	1.92	0.43	1620	300	3.02	0.52	1160	300	2.117	0.26

F frequency, D density (individuals ha^{-1}), BA basal area m^2 ha^{-1}, A/F abundance to frequency ratio, IVI importance value index

they were not damaged by the miners during the mining operations (Sarma et al. 2010). From the result, it appears that highest density of tree and sapling layer were recorded in north direction. Therefore, higher regeneration as well as early establishment of species for eco-restoration perspectives can be fruitful in north direction in comparison to other directions.

Impact on understory/ground vegetation

Vegetation structure of seedling layer

In seedling layer, 12 species representing six families were recorded from the different sites (Table 2). The total density of seedling layer in east direction were 2000 individuals ha^{-1}, and the maximum density was recorded by *A. mangium* (1780 individuals ha^{-1}) and minimum by *B. monosperma* (80 individuals ha^{-1}). The IVI of individual species ranged between 33.681 and 218.99. In west direction, a sum of 4480 seedlings ha^{-1} was recorded. The maximum density was recorded by *C. siamea* (1280 individuals ha^{-1}) and minimum by *A. catechu* and *P. ferrugineum* (240 individuals ha^{-1}), respectively. The IVI value ranged between 23.239 and 70.387 in west direction. In north direction, a sum of 5040 individuals ha^{-1} were observed, and the maximum density was recorded by

A. mangium and *Eucalyptus* spp. (1840 individuals ha^{-1}) and minimum by *C. siamea* (80 individuals ha^{-1}). The IVI of individual species ranged between 12.803 and 90.704. In south direction, 6000 individuals ha^{-1} was observed, and the maximum density was recorded by *A. mangium* (13,440 individuals ha^{-1}), while the minimum by *C. fistula* and *S. cumini* (160 individuals ha^{-1}). The IVI of individual species ranged between 21.989 and 146.253. For seedling stage, the highest density of plants was found in south direction representing higher regeneration rate. This therefore may be fruitful for eco-restoration practices for the concerned study sites.

Vegetation structure of herb layer

A total of 48 herb species representing 17 families were recorded in different directions of mining areas (Table 3). East direction comprising 24 species representing 12 families, west direction contains 30 species representing 12 families, and 32 species representing 15 families were recorded towards north direction and 25 species representing 10 families in south direction. The total density of herb species in east direction was 572,000 individuals ha^{-1}. The maximum density was recorded by *M. coromandelianum* and *O. burmannii* (96,000 individuals ha^{-1}) and minimum by *X. strumarium*,

Table 2 Structure and composition of seedling layer in different direction of collieries

Species	East			West			North			South		
	D	IVI	A/F	D	IVI	A/F	D	IVI	A/F	D	IVI	A/F
Acacia catechu	–	–	–	240	26.122	0.150	–	–	–	–	–	–
Acacia mangium	1760	218.99	0.122	1200	68.060	0.083	1840	90.704	0.072	3440	146.253	0.086
Azadirecta indica	–	–	–	–	–	–	240	24.527	0.038	–	–	–
Butea monosperma	80	33.68	0.050	560	39.761	0.039	–	–	–	–	–	–
Cassia fistula	–	–	–	–	–	–	–	–	–	160	21.989	0.1
Cassia siamea	–	–	–	1280	70.387	0.032	80	12.803	0.050	2240	109.769	0.056
Dalbergia sissoo	160	47.36	0.100	–	–	–	–	–	–	–	–	–
Eucalyptus spp.	–	–	–	640	43.299	0.044	1840	90.704	0.072	–	–	–
Peltophorum ferrugineum	–	–	–	240	23.239	0.038	480	37.289	0.075	–	–	–
Pongamia pinnata	–	–	–	–	–	–	560	43.974	0.022	–	–	–
Syzygium cumini	–	–	–	–	–	–	–	–	–	160	21.989	0.1
Tectona grandis	–	–	–	320	29.149	0.022	–	–	–	–	–	–
Total	2000	300	0.27	4480	300	0.408	5040	300	0.328	6000	300	0.342

F frequency, *D* density (individuals ha^{-1}), *A/F* abundance to frequency ratio, *IVI* importance value index

Table 3 Structure and composition of herb layer in different direction of collieries

Species	East			West			North			South		
	D	IVI	A/F	D	IVI	A/F	D	IVI	A/F	D	IVI	A/F
Alternanthera sessilis (L.) R.Br. ex DC.	40,000	18.49	0.056	12,000	7.73	0.038	56,000	21.82	0.028	36,000	20.46	0.028
Anisomeles indica (L.) Kuntze	—	—	—	—	—	—	12,000	7.46	0.038	24,000	13.78	0.075
Apluda mutica L.	—	—	—	8000	5.60	0.1	8000	5.67	0.100	—	—	—
Apluda varia L.	16,000	10.17	0.050	24,000	11.38	0.075	16,000	8.77	0.050	12,000	9.45	0.038
Aycicarpus vaginalis (L.) DC.	32,000	16.22	0.044	12,000	7.38	0.15	16,000	8.77	0.050	4000	4.62	0.050
Bidens pilosa Linn.	—	—	—	20,000	10.94	0.25	—	—	—	—	—	—
Cajanus scarabaeoides (L.) Thouars	—	—	—	—	—	—	8000	5.67	0.100	—	—	—
Cassia tora Linn.	44,000	19.65	0.138	44,000	18.45	0.034	36,000	15.19	0.050	64,000	28.40	0.050
Crotalaria juncea L.	—	—	—	8000	5.60	0.1	—	—	—	—	—	—
Crotolaria calycina Schank.	—	—	—	8000	5.60	0.1	—	—	—	—	—	—
Cynodon dactylon L.	16,000	10.17	0.050	32,000	15.65	0.025	68,000	23.95	0.053	32,000	16.66	0.100
Cyperus compressus L.	—	—	—	—	—	—	32,000	14.99	0.025	36,000	21.08	0.450
Cyperus rotundus Linn.	12,000	8.40	0.150	100,000	31.55	0.078	36,000	15.98	0.028	28,000	15.22	0.088
Desmodium pulchellum DC.	16,000	10.41	0.200	20,000	10.17	0.063	8000	5.67	0.100	12,000	8.74	0.150
Desmodium triflorum (L.) DC.	—	—	—	8000	5.60	0.1	12,000	7.63	0.150	8000	6.68	0.100
Dinebra retroflexa (Vahl.) Panz	—	—	—	16,000	9.16	0.2	8000	6.14	0.025	—	—	—
Eragrostis diarrhena (Schult. & Schult.f.) Steud.	20,000	11.53	0.063	8000	5.60	0.1	—	—	—	4000	4.62	0.050
Erysimum hieraciifolium L.f	—	—	—	4000	3.82	0.05	8000	5.67	0.100	—	—	—
Euphorbia hirta L.	—	—	—	—	—	—	16,000	8.77	0.050	4000	4.62	0.050
Evolvulus nummularius (L.)	12,000	8.40	0.150	20,000	10.17	0.063	—	—	—	12,000	8.74	0.150
Fimbritylis dichotoma L.	20,000	11.53	0.063	8000	5.60	0.1	20,000	11.54	0.250	40,000	21.60	0.031
Hemidesmus indicus (L.) R. Br. ex Schult.	8000	6.39	0.100	4000	3.82	0.05	—	—	—	—	—	—
Ludwigia octovalis (Jacq.) P.H.Raven	16,000	10.41	0.200	—	—	—	44,000	17.97	0.034	—	—	—
Malvastrum coromandelianum (L.) Garcke	96,000	34.96	0.048	68,000	24.06	0.053	8000	5.67	0.100	8000	6.68	0.100
Mellilotus alba Medikus	12,000	8.40	0.150	8000	5.60	0.1	—	—	—	8000	6.68	0.100
Mellilotus indica (Linn.) All.	—	—	—	—	—	—	—	—	—	12,000	8.74	0.150
Mimosa pudica L.	—	—	—	—	—	—	60,000	23.25	0.188	12,000	8.74	0.150
Oplismenus burmannii (Retz.) P.Beauv	96,000	37.24	0.300	—	—	—	—	—	—	44,000	25.19	0.550
Parthenium hysterophorus L.	—	—	—	4000	3.82	0.05	8000	5.67	0.100	—	—	—
Paspalidium flavidum (Retz.)	16,000	10.17	0.050	16,000	8.95	0.05	—	—	—	—	—	—

Table 3 (continued)

Species	East			West			North			South		
	D	IVI	A/F	D	IVI	A/F	D	IVI	A/F	D	IVI	A/F
A.Camus												
Phyllanthus niruri L.	—	—	—	—	—	—	8000	5.67	0.100	—	—	—
Physallis minima L.	—	—	—	—	—	—	8000	5.67	0.100	—	—	—
Pteris vittata L.	8000	6.39	0.100	24,000	11.38	0.075	24,000	11.41	0.075	—	—	—
Rumex dentatus L.	—	—	—	—	—	—	8000	5.67	0.100	—	—	—
Sachharum spontaneum L.	—	—	—	20,000	10.94	0.25	—	—	—	—	—	—
Setaria glauca L.	—	—	—	56,000	26.97	0.7	—	—	—	—	—	—
Setaria homonyma L.	—	—	—	—	—	—	8000	5.67	0.100	32,000	19.02	0.400
Sida acuta Burm.f.	—	—	—	—	—	—	12,000	7.63	0.150	—	—	—
Sida cordata Brum.f.	—	—	—	32,000	13.82	0.1	—	—	—	—	—	—
Sphaeranthus indicus L.	8000	6.39	0.100	—	—	—	12,000	7.63	0.150	8000	6.68	0.100
Tectaria macrodonta (Fee.) C. Chr.	—	—	—	—	—	—	4000	3.71	0.05	—	—	—
Themeda arguens (L.) Hack.	8000	6.39	0.100	—	—	—	—	—	—	12,000	8.74	0.150
Themeda quadrivalvis (L.) O. Ktze.	32,000	16.22	0.044	4000	3.82	0.05	8000	5.67	0.100	16,000	10.79	0.200
Tridex procumbence L.	12,000	8.82	0.038	16,000	9.16	0.2	4000	3.71	0.050	4000	4.62	0.050
Urena lobata L.	16,000	10.41	0.200	4000	3.82	0.05	8000	5.67	0.100	12,000	9.45	0.038
Vigna pilosa Willd.	8000	6.39	0.100	4000	3.82	0.05	—	—	—	—	—	—
Vigna trilobata (L.) Verdc.	8000	6.39	0.100	—	—	—	—	—	—	—	—	—
Xanthium strumarium L.	8000	6.39	0.100	—	—	—	8000	5.67	0.100	—	—	—
Total	572,000	300.0	2.59	612,000	300	3.40	592,000	300.0	2.794	484,000	300.0	3.397

F frequency, D = density (individuals ha^{-1}), A/F = abundance to frequency ratio, IVI importance value index

V. trilobata, *T. quadrivalvis*, *T. macrodonta*, *P. vittata*, and *H. indicus* (8000 individuals ha^{-1}). The IVI of individual herb ranged between 6.39 and 37.24; highest value was recorded by *O. burmannii* and lowest by *H. indicus, P. vittata, T. macrodonta, T. quadrivalvis, V. trilobata,* and *X. strumarium*, respectively. A/F ratio of individual species ranged between 0.038 and 0.300. It appears that 29.27% species were distributed randomly and remaining (70.83%) were contagiously distributed. In the west direction, herb density was 612,000 individuals ha^{-1}. The maximum density was recorded by *C. rotundus* (100,000 individuals ha^{-1}) and minimum by *E. hieraciifolium*, *H. indicus*, *P. hysterophorus*, *T. procumbene*, *V. pilosa*, and *V. trilobata* (4000 individuals ha^{-1}). The IVI of individual herb species ranged between 3.82 and 31.55, highest value were recorded by *C. rotundus* and lowest by *E. hieraciifolium*, *L. octovalis*, *P. hysterophorus*, *T. procumbene*, *V. pilosa*, and *V. trilobata*, respectively. The north direction reflected 592,000 individuals ha^{-1}. The maximum density was recorded by *C. dactylon* (68,000 individuals ha^{-1}) and minimum by *T. macrodonta* and *T. procumbene* (4000 individuals ha^{-1}). The IVI of individual herb species ranged between 3.71 and 23.25, highest for *C. dactylon* and *O. burmannii* and lowest for *T. macrodonta* and *T. procumbene*, respectively. The south direction has total herb density of 484,000 individuals ha^{-1}, and the maximum density was recorded by *C. tora* (64,000 individuals ha^{-1}) and minimum by *B. pilosa, E. diarrhena, E. hirta,* and *T. procumbene* (4000 individuals ha^{-1}). The IVI of individual species ranged between 4.62 and 28.40, highest for *C. tora* and lowest for *B. pilosa, E. diarrhena, E. hirta,* and *T. procumbene*, respectively.

From the result, it appears that towards west direction, successful establishment and propagation of herb layer is more prominent due to lower density of tree species providing more light as available resources for the ground vegetation. Findings further supported by the fact that west direction is little bit cooler in comparison to other directions thereby promoting herbaceous growth. The higher number of herbaceous species in the mined areas in comparison to unmined areas could be due to colonizing ability of herbs in the degraded area (Sarma et al. 2010).

Vegetation structure of shrub layer

A sum of nine shrub species representing eight families were found in different directions of study sites

(Table 4). The density of shrub species in east direction was 2000 individuals ha^{-1}. The maximum density was recorded by *L. camara* (1040 individuals ha^{-1}) and minimum by *C. gigantea, C. opaca,* and *L. asiatica* (80 individuals ha^{-1}). The total basal area of shrub species in east direction was 0.60 m^2 ha^{-1}. The IVI of individual shrub species ranged between 14.24 and 130.96. Highest IVI was recorded for *L. camara* and lowest for *C. gigantea*, respectively. In the west direction, total density was 1840 individuals ha^{-1}, and the maximum density was recorded by *L. camara* (1040 individuals ha^{-1}) and minimum by *I. carnea* (80 individuals ha^{-1}). The total basal area of shrub species in west direction was 1.060 m^2 ha^{-1}. The IVI of individual shrub species ranged between 17.73 and 130.52. Highest IVI value was recorded by *L. camara* and lowest by *I. carnea*, respectively. In north direction, a sum of 1600 individuals ha^{-1} were recorded. The maximum density was recorded for *L. camara* (720 individuals ha^{-1}) and minimum for *Z. rotundifolia* (240 individuals ha^{-1}). The total basal area was 0.789 m^2 ha^{-1} towards north direction. The IVI value of shrub species was higher for *L. camara* and least for *Z. rotundifolia*. The density of shrub was 1200 individuals ha^{-1} towards south direction. The maximum density was recorded for *L. camara* (1040 individuals ha^{-1}) and minimum for *V. negundo* (160 individuals ha^{-1}). The total basal area for shrub species in south direction was 0.543 m^2 ha^{-1}. The IVI of individual species ranged between 44.46 and 255.61, respectively.

Sarma et al. (2010) reported that due to mining, higher number of herbaceous species (31–41) were found in the mining area in comparison to unmined area (23 species). Majority of species showed contagious distribution pattern in the unmined and mined areas. Gupta and Sharma (2015) studied the plant assemblages along an altitudinal gradient in north-west Himalaya and found that the density and basal area of herbage in grassland at different elevations ranged between 649.6 and 1347.9 tillers/m^2, 30.0, and 65.7cm^2/m^2, respectively. Density and basal area of the herbage and plant communities decreased along the elevation.

Lower value of basal area in mining site is a characteristic feature of young stand with low girth class gradation and the density of stand, thereby serves as a reflection of low performance of the trees. Development of extensive root system promotes higher nutrient absorption as well as inhibits growth of ground vegetation due to higher interception of light by the tree species.

Table 4 Structure and composition of shrub layer in different direction of collieries

Species	East				West				North				South			
	D	IVI	BA	A/F	D	IVI	BA	A/F	D	IVI	BA	A/F	D	IVI	BA	A/F
Calotropis gigantea (L.) R.Br.	80	14.24	0.019	0.050	–	–	–	–	–	–	–	–	–	–	–	–
Carissa opaca Stapf ex Haines	80	27.72	0.099	0.050	240	54.05	0.223	0.038	320	79.21	0.354	0.050	–	–	–	–
Cassia angustifolia M. Vahl	–	–	–	–	160	24.58	0.062	0.1	–	–	–	–	–	–	–	–
Grewia rothii DC.	160	24.11	0.054	0.100	–	–	–	–	–	–	–	–	–	–	–	–
Ipomoea carnea Jacq. Ssp. fistulosa (Mart. & Choisy) Austin	–	–	–	–	80	17.73	0.036	0.050	–	–	–	–	–	–	–	–
Lantana camara L.	1040	130.96	0.259	0.026	1040	130.52	0.360	0.041	720	126.0	0.357	0.018	1040	255.61	0.530	0.026
Leea asiatica L.	80	15.22	0.024	0.050	–	–	–	–	–	–	–	–	–	–	–	–
Vitex negundo L.	160	30.44	0.049	0.025	–	–	–	–	320	52.75	0.033	0.013	160	44.46	0.014	0.025
Ziziphus rotundifolia Lamk.	400	57.47	0.096	0.028	320	73.14	0.379	0.050	240	42.0	0.044	0.017	–	–	–	–
Total	2000	300	0.60	0.329	1840	300	1.060	0.278	1600	300	0.789	0.097	1200	300	0.543	0.051

F frequency, *D* density (individuals ha⁻¹), *BA* basal area m² ha⁻¹, *A/F* abundance to frequency ratio, *IVI* importance value index

Absence of tree species may lead to availability of higher solar insolation to the younger plants. There is a gap of knowledge in the context of abundance and distribution of herb, shrub, sapling, and seedling in mining sites both at local and regional level. The reported densities of these vegetation layer of the present investigation are well comparable with some earlier work (Mishra et al. 2008). The fewer number of saplings recorded in relation to seedlings in this study implies that most of the saplings are transiting into young trees. Intense competition leads to mortality of seedling at very early stage (Weidelt 1988; Jhariya et al. 2012, 2014). Among the various girth classes, saplings and seedlings reflect high regeneration potential of the stand (Mishra et al. 2005; Khumbongmayum et al. 2006).

In most of the plant life forms, there were high number of species that occurred singly. The distribution of tree species into Raunkiaer's frequency classes reflected that most of the species were of rare category and of low frequency class; intermediate class was represented only in the north direction while moderately high and high or common frequency class were totally absent in the study area (Table 5).

Importance value index (IVI) reflects species dominance and ecological succession. High IVI values of a species indicate its high regeneration capacity and greater ecological amplitude. In our study, *Acacia mangium* and *Cassia siamea* reflected the highest IVI value. Therefore, these species can be considered as capable of higher regeneration potential in the concerned study sites. The low IVI may be attributed towards rarest occurrence of species (Pascal and Pellissier 1996; Oyun et al. 2009), as confirmed by Raunkiaer's frequency distribution of the tree species. The rarity of species may be attributed to the occurrence of abundant sporadic species with low frequency in the stands (Oyun et al. 2009). The high percentage of rare species observed in different stratum of vegetation in the collieries confirms that most of the species in an ecological community are rare, rather than common (Magurran and Henderson 2003).

Relationship of density to GBH in collieries

Tree species density-GBH distribution followed an exponential model [$Y = exp. (a − bx)$] on all the direction of the collieries. The sites thus exhibited a small structure as 69.44–83.33% individuals had ≤10 cm girth, and only 16.67–30.56% were in girth classes exceeding

Table 5 Distribution of vegetation layers according to Raunkiaer's classification scheme

Layers	Sites	A	B	C	D	E
Tree	East	3	1	0	0	0
	West	3	0	0	0	0
	North	1	2	1	0	0
	South	2	0	0	0	0
Sapling	East	1	0	1	0	1
	West	1	1	2	0	2
	North	1	0	1	1	2
	South	2	0	0	0	2
Seedling	East	2	0	1	0	0
	West	1	1	4	0	0
	North	1	2	0	3	0
	South	2	0	0	0	2
Herb	East	12	8	3	0	1
	West	19	7	0	4	0
	North	19	7	1	4	1
	South	17	5	0	3	0
Shrub	East	4	1	1	0	1
	West	2	2	0	1	0
	North	0	1	1	1	1
	South	0	1	0	0	1

10 cm GBH (Fig. 2), while 0.0–1.39% individuals were exceeding >50 cm GBH. When data were pooled, the woody species density was related to GBH according to:

(1.) Y = exp. [2289.1–0.784×] for east direction, r^2 = 0.790, $p < 5\%$

(2.) Y = exp. [13799–1.424×] for west direction, r^2 = 0.911, $p < 5\%$

(3.) Y = exp. [18078–1.339×] for north direction, r^2 = 0.966, $p < 5\%$

(4.) Y = exp. [31464–1.794×] for south direction, r^2 = 0.936, $p < 5\%$

Exponential relationship between density and GBH reflected small structure of vegetation where only 0.0–1.39% individuals were in classes >50 cm GBH. This may be related to faster turnover, biotic removal, and low capacity of biomass accumulation in the concerned study sites. Relating woody species density with GBH in dry tropics Singh and Singh (1991) similarly reported same pattern where minor (3–5%) individuals exceeded

50 cm GBH. Similar findings were also reported by Chaturvedi et al. (2011) for tropical dry forest of India. Relating tree density with GBH, in Puerto Rican sub tropical dry forest, Murphy and Lugo (1986) also found a similar pattern where 2–3% individuals exceeded 10 cm GBH. Oraon (2012) reported that nearly 89–94% individuals had ≤10 cm girth and only 1.5–3.7% were in girth classes exceeding 50 cm GBH. Jhariya (2014) found that the forest exhibited a small structure as 86.37–91.71% individuals had ≤10 cm girth, and only 8.29–13.63% were in girth classes exceeding 10 cm GBH, while 1.58–2.18% individuals were exceeding >50 cm GBH. In our study, each tree species is devoid of different girth classes which indicates younger population of tree species. These therefore suggest that it has the potential for frequent reproduction (Knight 1975).

Population structure in mining sites

The population structure revealed the regeneration pattern of a stand or site. The proportion of seedling size class (A) was found to be dominant in east direction (Fig. 3). The older size classes (D) and (E) were totally absent in this direction. The single size class was represented by *Saccopetalum tomentosum* and *Ailanthus excelsa*. The sapling size class (B) was nil for *Dalbergia sissoo*, while the size classes (A), (B), and (C) were represented by *Acacia mangium* and *Butea monosperma*.

Similar to east direction, the population structure of tree species in west direction (Fig. 4) revealed that there is no single species which represent the older size classes (D) and (E). Some species reflected only seedling size class (A) exemplified by *Acacia catechu*, *Butea monosperma*, and *Eucalyptus* spp. The young size classes (A) and (B) were represented by *Acacia mangium* and *Tectona grandis* while the subsequent class was absent. *Sygygium cumini* have sapling (B) and young tree class (C) and is devoid of seedling class (A). *Casia siamea* and *Peltophorum ferrugineum* were represented by size classes (A), (B), and (C).

In the north direction, seedling class (A) was represented by all the species while the older classes (D) and (E) were totally absent (Fig. 5). The tree class (C) was represented by *Acacia mangium*, *Cassia siamea*, *Eucalyptus* spp., and *Peltophorum ferrugineum*. The sapling class (B) was represented by each species except
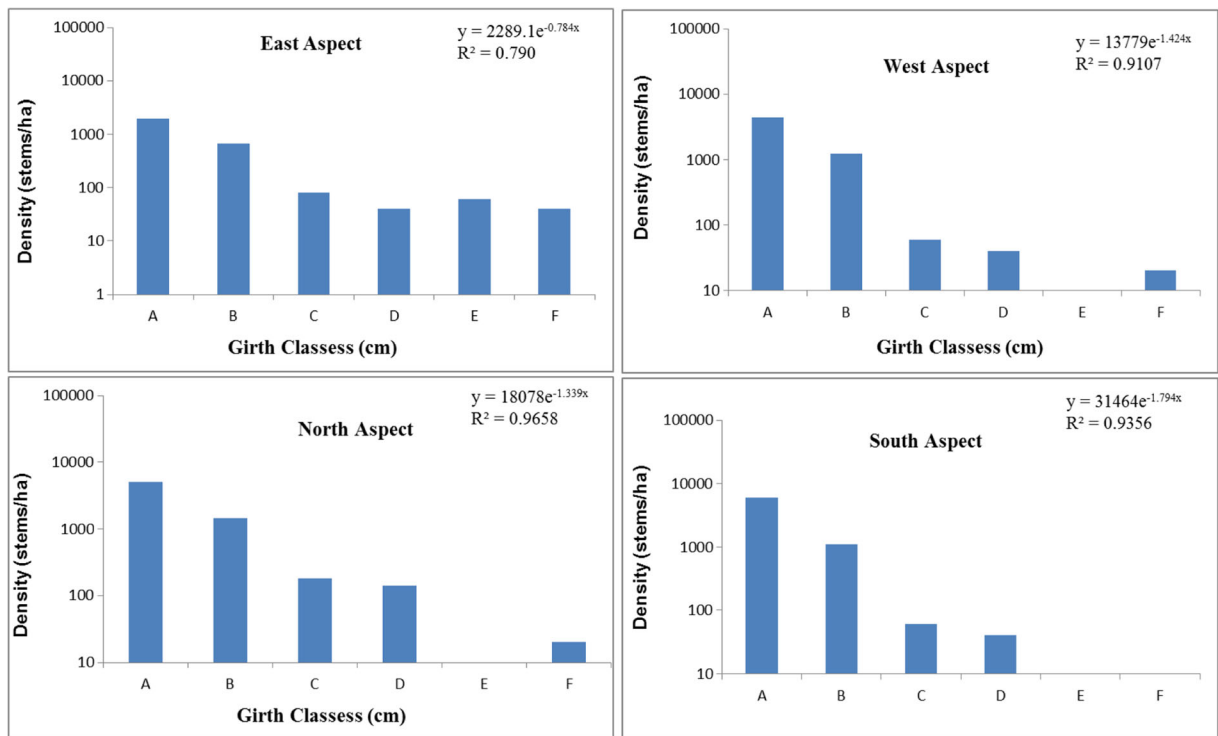
Fig. 2 Relationship between density of seedling, sapling, and trees with mean girth class (cm) are: *A* = <10; *B* = >10 − <20; *C* = >20 − <30; *D* = >30 − <40; *E* = > 40 − <50; = >50

Azadirecta indica which were found only in seedling stage.

In the south direction (Fig. 6), most of the species representing single size class only exemplified by *Acacia catechu, Butea monosperma, Cassia fistula,* and *Syzygium cumini. Acacia mangium* and *Casia siamea* represented by size classes (A), (B), and (C), while the older size classes (D) and (E) were found to be totally absent.

The three life stages (seedlings, saplings, and trees) for different species suggested their possible future status in the given site. The diameter class gradation or distribution of trees has been the significant criteria for assessing the population structure of forests or stand (Saxena and Singh 1984; Khan et al. 1987, Dhaulkhandi et al. 2008; Jhariya et al. 2012). In all the concerned study sites of collieries, it showed that the individuals with small girth class A (<10 cm) were high. A greater population of individuals in lower size classes compared to larger classes as the structure represents frequent reproduction (Knight 1975; West et al. 1981). Due to this heavy stress, the species could not reach in the tree or sapling layer as a dominant species. The hump in the middle size classes may indicate

comparatively fast growth or less mortality in individuals. The prevailing habitat conditions in these areas have reduced the chances of regeneration of many species, reducing the number of species in the mined areas (Sarma et al. 2010) once they successfully crosses the sapling layer and attained the first tree size class. According to West et al. (1981), such types of patterns indicate the heavy exploitation of older individuals and greater mortality among young individuals. This species has produced abundant population in the past with better conversion rate from one size class to another but at present, though the seedlings are not comings up frequently, the species might have produced the seeds but, the environment is not supporting their proper establishment.

According to Saxena and Singh (1984), the concentration of individuals in intermediate size classes with general absence or negligible representation of individuals both towards higher and lower size classes reflects the degenerative nature of the concerned population. Khurana (2007) concluded that biotic disturbances impose the site nutrient poor, and top soil erosion makes the inadequate regeneration pattern. Regeneration of a species both depends
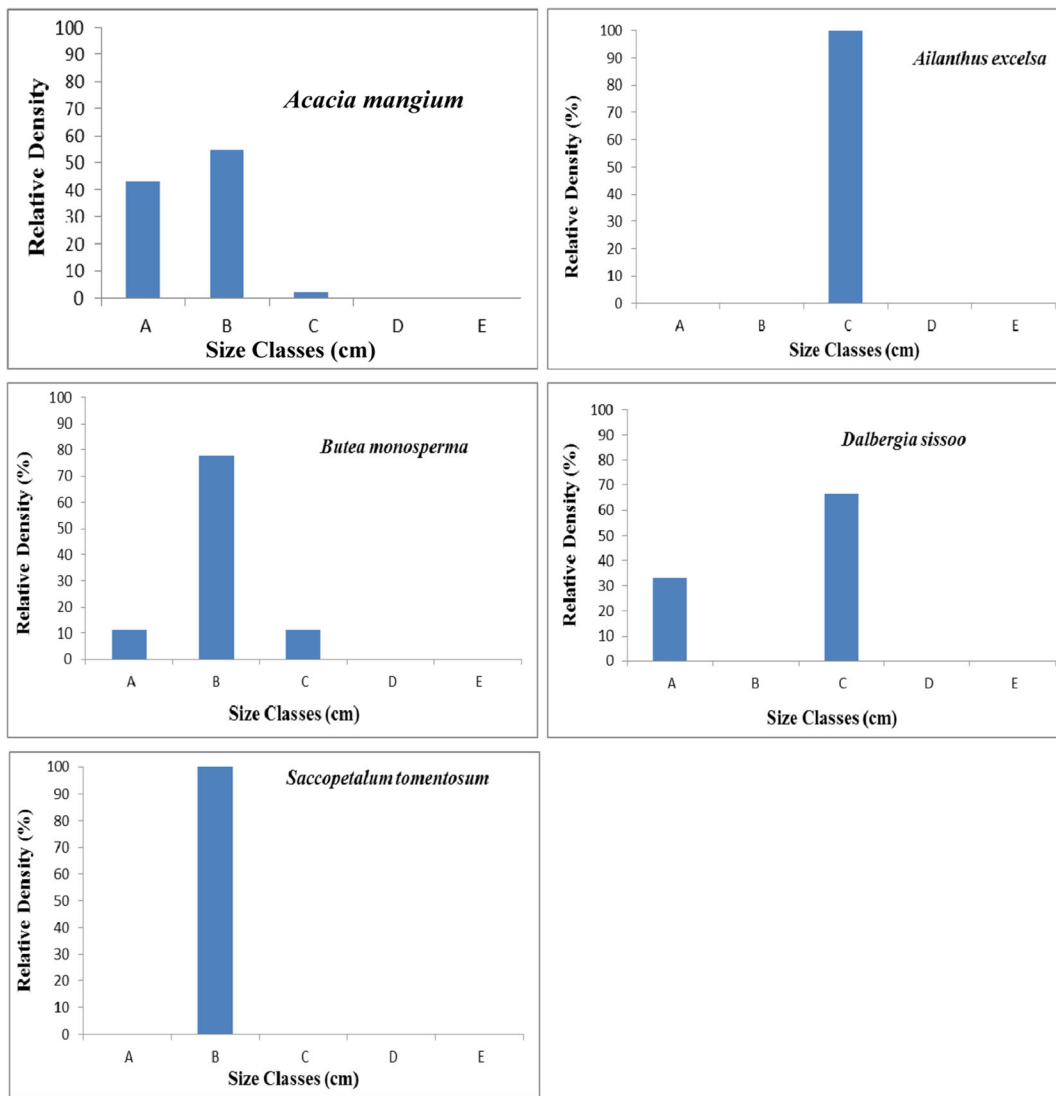
Fig. 3 Population structures of tree species in east aspect of collieries

upon internal forest process and exogenic disturbance (Barker and Kirk Patrick 1994). Local extinction in the forest stands is reflected by the abundance or absence of adult individual or very low population of seedlings and saplings (Dalling et al. 1998). The density values of seedlings and saplings are considered as regeneration potential of the species. Suitability of a species to a given environment is reflected through the presence of good regeneration potential (Dhaulkhandi et al. 2008). Climatic factors and biotic interference influence the regeneration of different species in the vegetation. Higher seedling density values get reduced to sapling due to biotic disturbance and competition for space and nutrients. The greater tree diversity and

density towards north direction could be due to the presence of a large number of young individuals in the concerned sites whereas tree diversity declined in other directions due to logging activity during mining and dumping of coal.

Consequences on vegetational diversity

Diversity is considered to be an heterogeneous nature of the gene pool prevailing over a particular area. It is admixture of synthetic measure of the structure, complexity, and stability of a community (Hubble and Foster 1983). It is reflected in two ways, the number of species present, referred to as
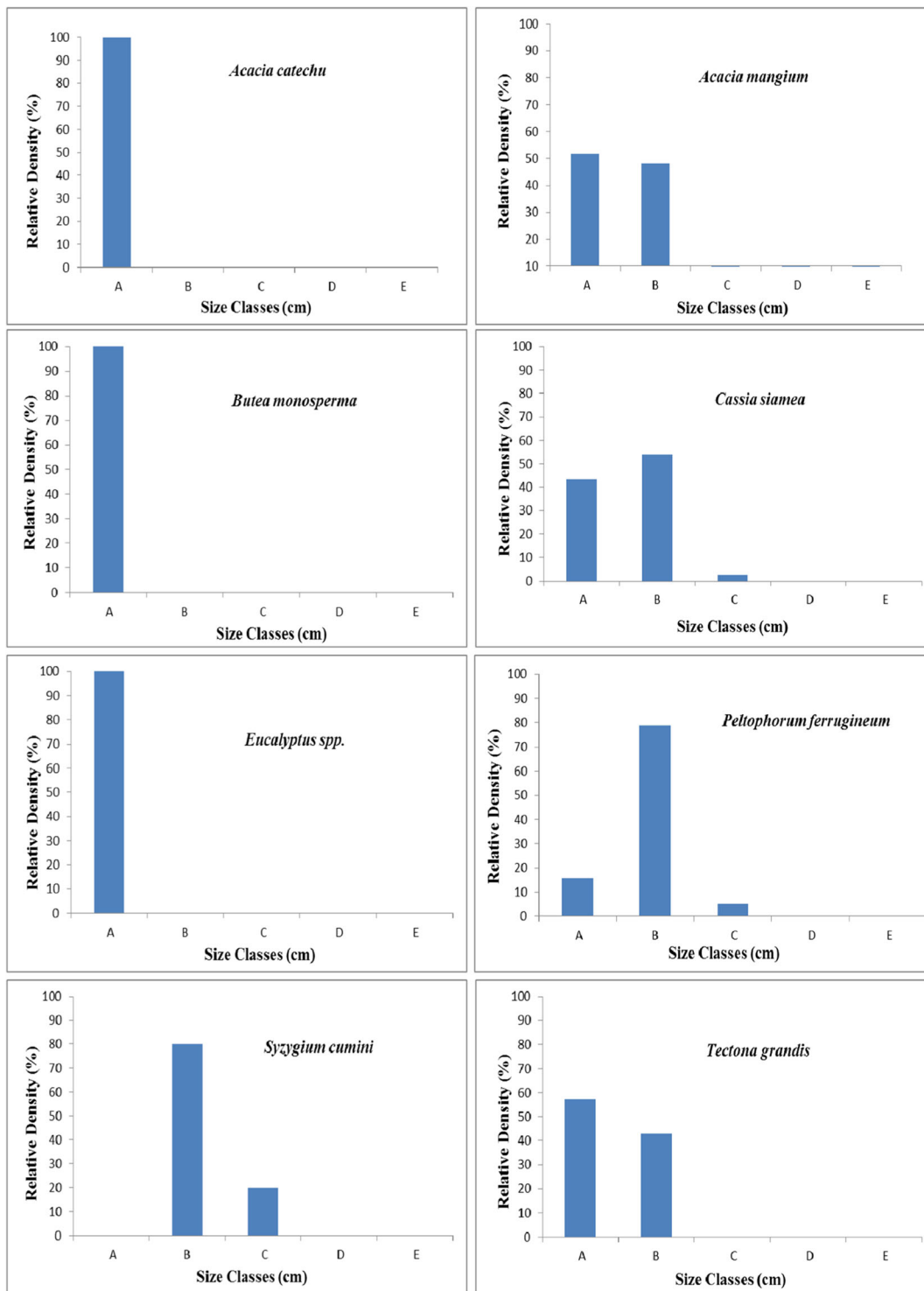
Fig. 4 Population structures of tree species in west aspect of collieries

species richness and the distribution of individuals among species, referred to as species evenness or

equability. Species diversity therefore, refers to the variation that exists among the different life forms.
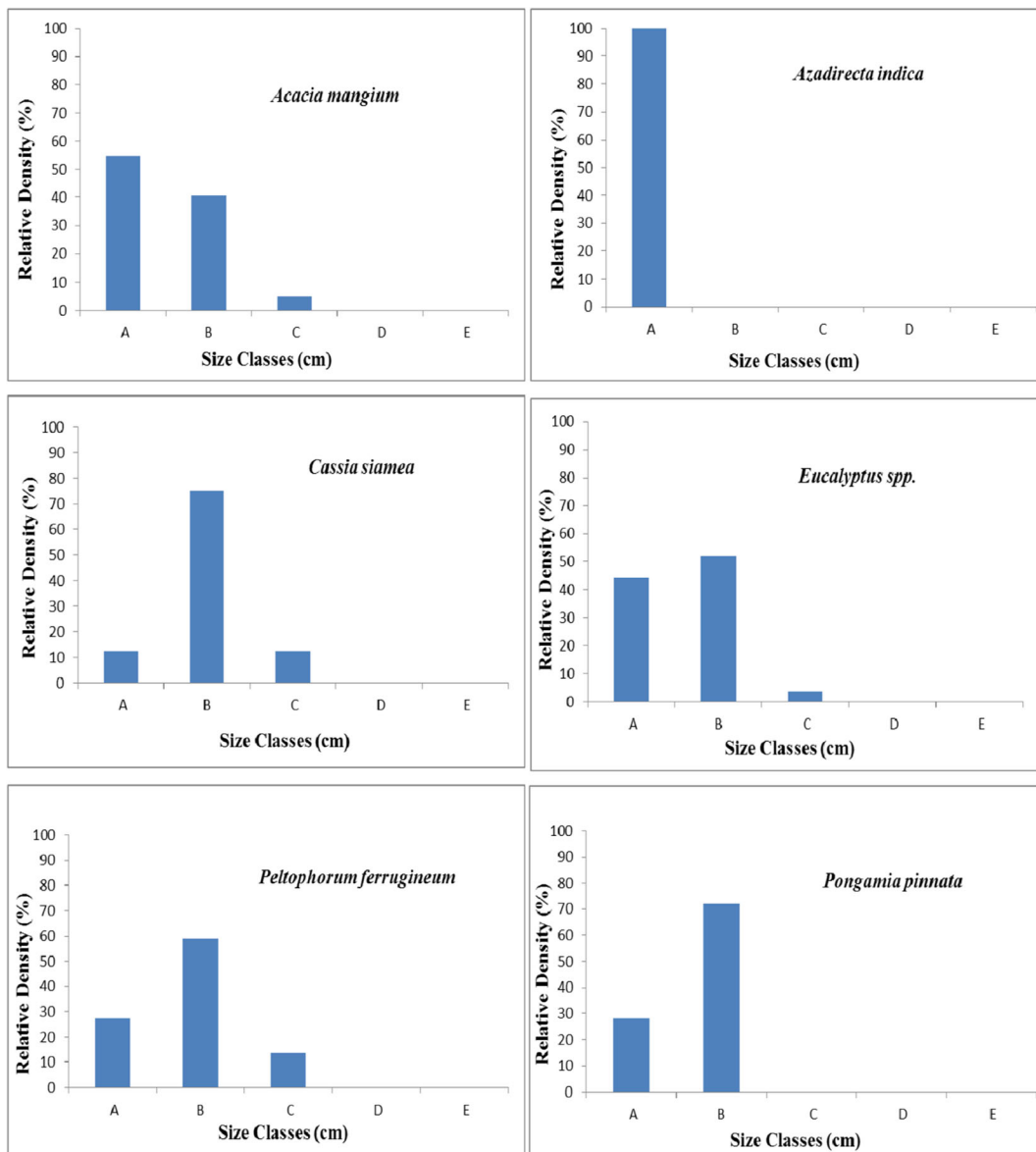
Fig. 5 Population structures of tree species in north aspect of collieries

During our present investigation, diversity indices (Fig. 7) of tree species reflected significant level of variation among various sites. Shannon index in different directional sites ranged up to 1.91, Simpsons index from 0.28–0.5, species richness from 0.27–0.61, equitability up to 1.44, and beta diversity from 2.00–4.00, respectively. For sapling layer, the value of Shannon index in different sites varied up to 2.33, Simpsons index 0.22–0.61, species richness up to 0.70, equitability up to 1.36, and beta diversity 1.66–2.50, respectively. In seedling layer, Shannon index varied from 0.64 to 2.53, Simpsons index 0.08–2.20, species richness 0.26–0.71, equitability 0.58–1.30, and beta diversity 1.71–4.00, respectively. Shannon index for herb layer in different directional sites ranged between 4.07 and 4.52, Simpsons index from 0.06 to 0.08, species richness from 1.73 to 2.33, equitability from 1.27 to 1.32, and beta diversity from 1.5 to 2.0, respectively. Shrub layer revealed that the Shannon index values in different directional sites varied from 0.57 to 2.10, Simpsons index from 0.31 to 0.77, species richness from 0.14
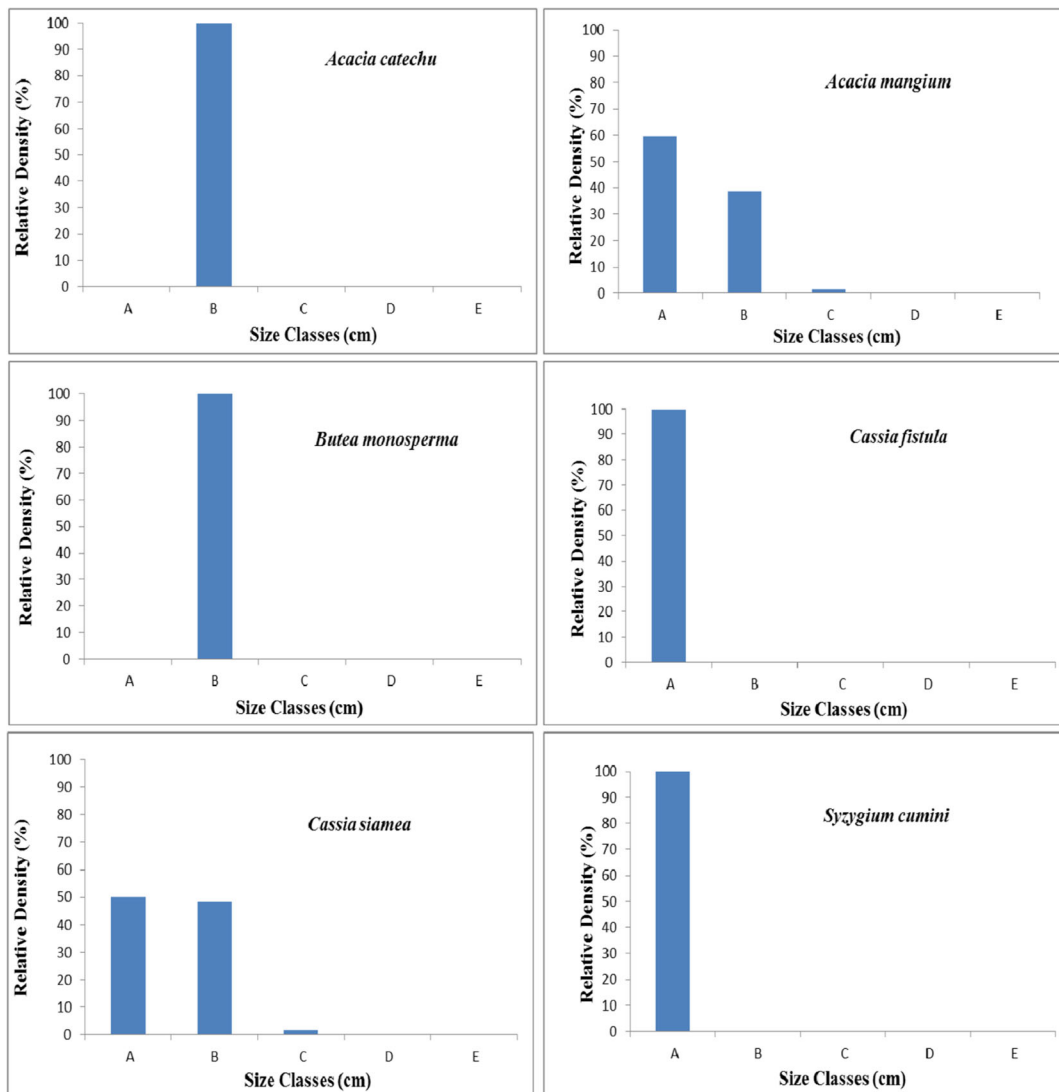
Fig. 6 Population structures of tree species in south aspect of collieries. **a** Shannon diversity indices at various directions. **b** Simpson diversity indices at various directions. **c** Species richness at various directions. **d** Equitability indices at various directions. **e** Variation in beta diversity at various directions

to 0.79, equitability from 0.82 to 1.34, and beta diversity from 1.28–4.50, respectively.

During the present investigation, Shannon index value was found to be lower in case of sapling, seedling, and herb towards east direction, and minimum diversity was recorded for tree and shrub species towards south direction. This may be due to lower rate of evolution and diversification of communities (Simpson 1964) and severity in environment (Connel and Oris 1964). The east direction represents less herbaceous vegetation as compared to other directions because of reduction in competition for space and resources.

Sarma et al. (2010) reported that the Shannon diversity index for tree and shrub species was low in mined areas as compared to unmined area. However, diversity index of ground vegetation did not differ among the mined and unmined areas. Simpson's dominance index shows a reverse trend to that of diversity index. Sobuj and Rahman (2011) compared the plant diversity of natural forest and plantations of Rema-kalenga wildlife sanctuary of Bangladesh and reported that Shannon index were 2.70, 2.72, and 3.12 for trees, shrubs, and herbs, respectively, in the natural forest. However, it was
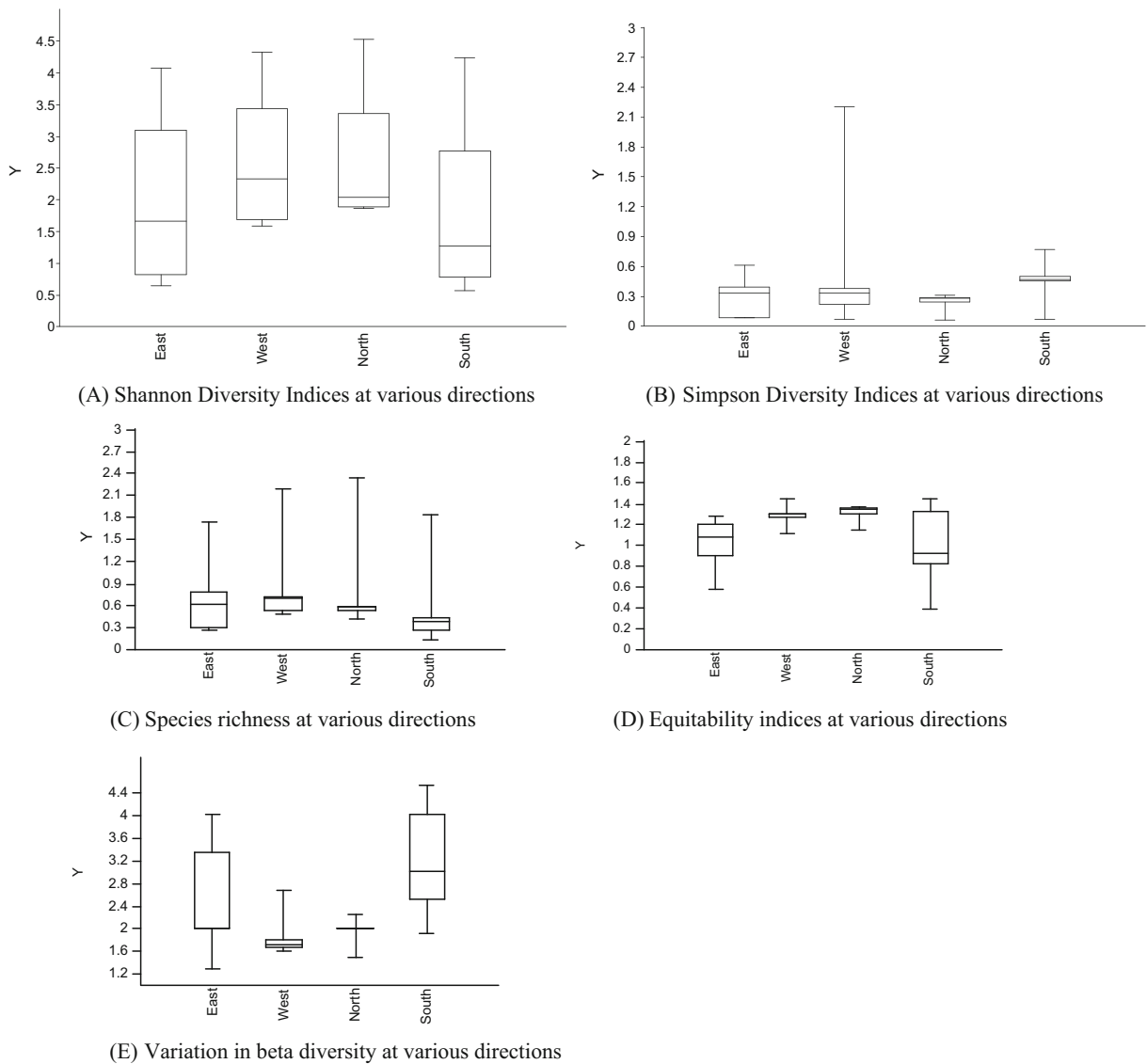
(A) Shannon Diversity Indices at various directions

(B) Simpson Diversity Indices at various directions

(C) Species richness at various directions

(D) Equitability indices at various directions

(E) Variation in beta diversity at various directions

Fig. 7 Diviersity indices in the collieries. **a** Shannon index. **b** Simpson diversity. **c** Species richness. **d** Equitability. **e** Beta diversity

2.35 for tree species, 2.31 for shrub species, and 2.81 for herb species in the plantation forest.

Study of vegetational structure and composition provides necessary ecological information for various ecosystems along with their ecological health status (Silver et al. 2004; Wang et al. 2004). As large forest have been clear felled in the Bishrampur for opencast coal mining, the major challenges include top soil loss, forest cover reduction, and habitat destruction, essential for maintaining nutrient cycling and ecological balance. Soil stratification, reduced biotic diversity, and alteration of structure and functioning of ecosystems are the major environmental impacts associated with mining (Almas

et al. 2004; Ghose 2004). The habitat conditions in these sites have reduced the chances of regeneration of many species, thereby reducing the presence of higher number

Table 6 Forest floor biomass (t/ha) in different aspect of collieries

Site/direction	Leaf litter	Wood litter	Total
East	4.00 ± 0.20	0.20 ± 0.09	4.20 ± 0.20
West	4.84 ± 0.24	0.46 ± 0.07	5.30 ± 0.23
North	3.86 ± 0.10	1.05 ± 0.13	4.91 ± 0.12
South	4.17 ± 0.22	1.48 ± 0.58	5.65 ± 0.25

Table 7 Correlations between various phytosociological parameter of tree species in Bishrampur collieries

	F	D	IVI	BA
D	*0.867*			
IVI	*0.832*	*0.763*		
BA	0.378	0.695	0.444	
A/F	0.610	0.459	*0.861*	0.044

Values italicized are significant at *p*>0.05

Table 9 Correlations between various phytosociological parameters of shrub species in Bishrampur collieries

	F	D	IVI	BA
D	*0.962*			
IVI	*0.970*	*0.996*		
BA	*0.909*	*0.947*	*0.965*	
A/F	0.406	0.427	0.472	0.626

Values italicized are significant at *p*>0.05

of species in this region. Sarma et al. (2010) reported that the number of tree species was low in all the mining sites due to various activities during the mining as compared to adjacent unmined area. Majority of species showed contagious distribution pattern in the unmined and mined areas. The tree density was more (1040 stems ha^{-1}) in the unmined area than the mined areas (515 and 646 stems ha^{-1}). The trees of medium girth class contributed maximum stand density in the mined areas, while in the unmined site, the trees of low girth class contributed to the maximum stand density. Hashemi (2010) investigated the plant species diversity in north of Iran and reported a total number of 114 plant species, belonging to 76 genus and 31 families that were gathered in the region of study. Oraon et al. (2015) reported that natural regeneration potential of shrubs was more in disturbed site as compared to undisturbed site.

Suitable environment promotes optimum distribution of species along with its adaptive potential. Distribution pattern of species may be regulated by habitat condition and biological interaction. A/F ratio was used to assess the distribution pattern of the species. In the collieries, it was found that most of the species were distributed contagiously and randomly, whereas, a few species distributed regularly. This can be attributed to the interaction of various factors that are acting together on the population. Inefficient mode of seed dispersal is

reflected through clumping nature of distribution (Richards 1996). Comparison of dispersal pattern of trees in tropical and temperate forest of the world, Armesto et al. (1986) recommended prevalent contagious distribution of species in the natural forest, may be attributed by clumping. Odum (1971) emphasized that contagious distribution is the most prevalent pattern observed in nature. Likewise, Kumar et al. (2015), Sinha et al. (2015), Oraon et al. (2014), Kittur et al. (2014), and Jhariya (2014) described that most of the recorded species followed contagious and random distribution pattern, whereas regular distribution was found almost negligible or insignificant.

Disturbance regimes strongly influence biodiversity of an area. Species diversity is the key factor of ecosystems and its functioning (Scherer-Lorenzen et al. 2005). The species diversity reflects trophic relationship and possibilities of invasion (Nicholas and Nicholas 2003). Species diversity in this mining landscape often fluctuates to a considerable amount due to various biotic changes and abiotic factors.

Impact on litter biomass

Forest floor biomass in different site of mining areas (east, west, north, and south direction) was calculated and presented in Table 6. Total forest floor biomass was 4.20 t/ha in east direction. 95.23% of the forest floor biomass comprises of leaf litter and remaining (4.77%)

Table 8 Correlations between various phytosociological parameters of sapling species in Bishrampur collieries

	F	D	IVI	BA
D	*0.989*			
IVI	*0.978*	*0.979*		
BA	*0.990*	*0.995*	*0.985*	
A/F	0.549	0.601	0.576	0.588

Values italicized are significant at *p*>0.05

Table 10 Correlations between various phytosociological parameters of seedling species in Bishrampur collieries

	F	D	IVI
D	*0.954*		
IVI	*0.926*	*0.992*	
A/F	0.662	0.834	*0.863*

Values italicized are significant at *p*>0.05

Table 11 Correlations between various phytosociological parameters of herb species in Bishrampur collieries

	F	D	IVI
D	*0.873*		
IVI	*0.903*	*0.986*	
A/F	0.137	0.448	0.485

Values italicized are significant at $p>0.05$

by wood litter. In the west direction, the total forest floor biomass was 5.30 t/ha, of which 90.5% was contributed by leaf litter and remaining (9.5%) by wood litter. In the north direction, the total forest floor was 4.91 t/ha, of which 72.8% was represented by leaf litter and remaining (27.2%) by wood litter. Similarly in the south direction, the total forest floor biomass was 5.65 t/ha, of which 64.51% shared by leaf litter and remaining (35.49%) by wood litter, respectively. The average values of litter biomass across the sites were 4.22 t/ha for leaf, 0.78 t/ha for wood, and 5.02 t/ha total litter mass.

Disturbances have various impact upon vegetation and its dynamics. This includes changes in the structure, composition, their litter production capacity, accumulation, and decomposition rate of tropical forests (Xuluc-Tolosa et al. 2003; Dezzeo et al. 2004; Yadav et al. 2008). Anthropogenic factors significantly influence accumulation of organic matter in the forest floor (Jordan 1985; Aguiar et al. 2010). Quantifying litter fall rate and quality describing any change are due to natural as well as anthropogenic disturbances (Sizer et al. 2000).

The value measured for litter biomass was comparable to 3.00–10.00 t ha^{-1} for tropical forest as previously reported by Murphy and Lugo (1986). The litter biomass for tropical forests ranged between 0.8 and 15.3 t ha^{-1} (Vitousek 1984) and 4.88 to 6.71 t ha^{-1} of dry tropical forest (Singh and Singh 1991). Sahu et al. (2013) reported the forest floor biomass in different sites varied from 2.19 to 2.66 t ha^{-1}. Lower levels of fresh leaf litter were found in highly disturbed site. In comparison, fresh leaf litter content appeared to be of same level in the least and moderately disturbed sites. The wood litter ranged from 0.70 to 1.03 t ha^{-1} in different sites (Pawar et al. 2014). Strategies for eco-restoration may include plantation of well adapted species to the local condition of degraded land. Locally adapted species may promote high litter deposition and decomposition rates and therefore improving the soil health (Kumar et al. 2010).

From our results, it appears that in Bishrampur collieries, soil quality can be effectively restore through addition of organic matter into the soil through addition of litter biomass. Decomposition of litter biomass leads to gradual build-up of nutrient pool in the soil ecosystem (Jhariya 2017). Therefore, litter biomass acts as a effective recycling agent of nutrient under natural condition. More litter is added to the soil, more probability of development of better quality of soil can be achieved. From this perspective, litter biomass assessment is very much significant in restoration studies.

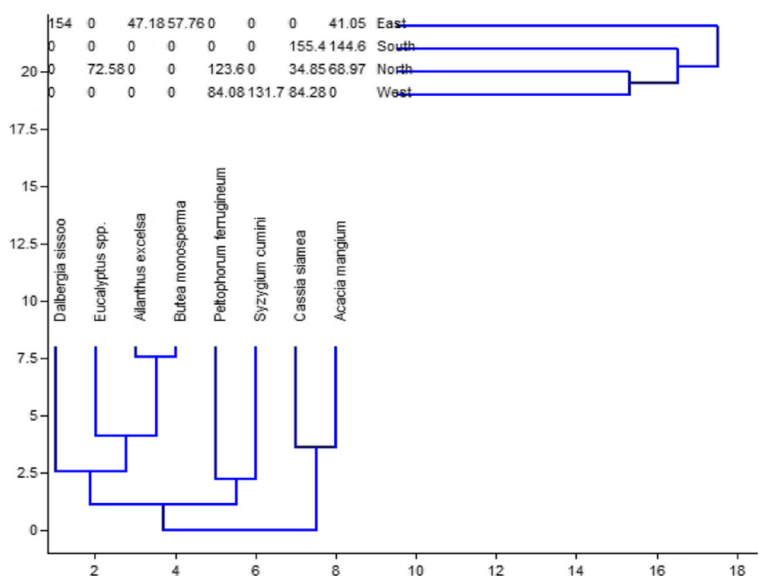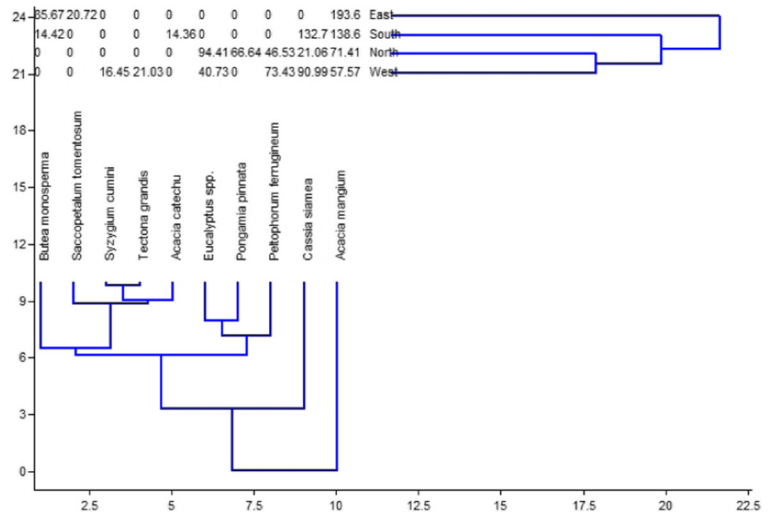**Fig. 8** Cluster analysis for tree layer in Bishrampur collieries

Fig. 9 Cluster analysis for sapling layer in Bishrampur collieries

Statistical analysis

From the correlation study, it was observed that tree layer density, frequency is significantly correlated with important value index. Density was positively correlated with frequency. A/F ratio is positively correlated with IVI (Table 7). For sapling layer, density is positively correlated with IVI and basal area. Frequency was found to be positively correlated with IVI and basal area. Basal area was also positively correlated with IVI (Table 8). In shrub layer, almost similar trend was observed for the phytosociological parameters (Table 9). For seedling and herb layer, density and important value index were found to be significantly and positively correlated (Tables 10 and 11).

Two-way cluster analysis was done for the different stratified layer of the vegetation surrounding Bishrampur collieries. In tree layer (Fig. 8), north and west direction framed the smaller cluster, and three major clusters were formed among different species. Cluster 1 comprises of *Cassia siamea* and *Acacia mangium*, cluster 2 comprises of *Peltophorum ferrugineum* and *Syzgium cumini*, and cluster 3 comprises of *Ailanthus excelsa* and *Butea monosperma*, respectively. In sapling layer (Fig. 9), closely spaced clustering of vegetation was observed for north and west direction. Two major clusterings of species were observed in case of sapling layer on the basis of vegetation characteristics. Cluster 1 comprises of *Eucalyptus* sp., *Pongamia pinnata*, and *Peltophorum ferrugineum*, and cluster 2 comprises of *Acacia catechu,*

Fig. 10 Cluster analysis for seedling layer in Bishrampur collieries
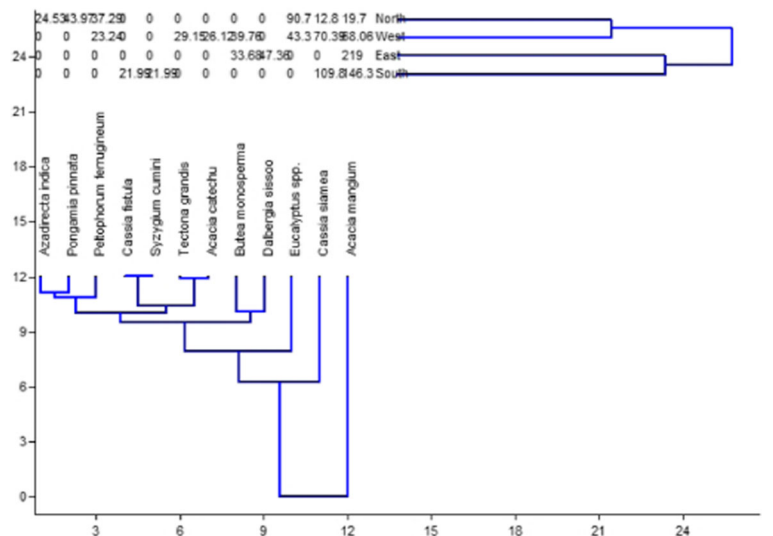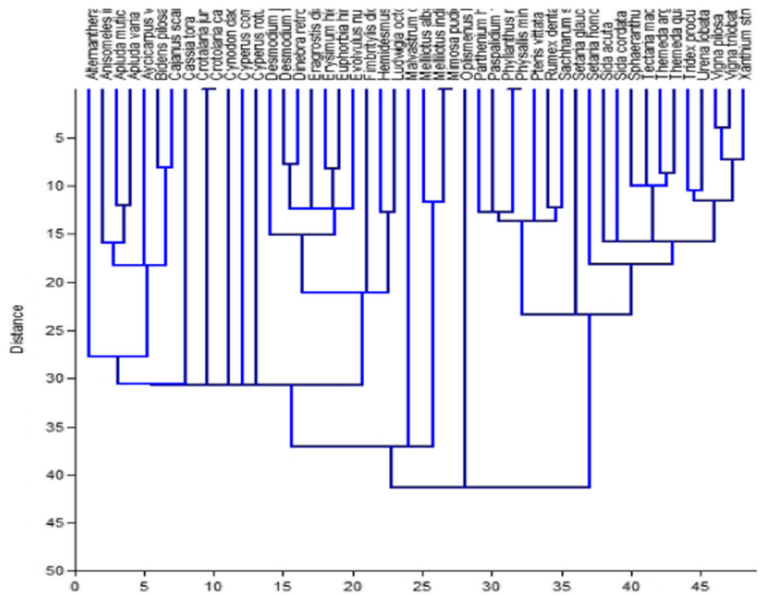
Fig. 11 Clustering of herb layer
in Bishrampur collieries

Tectona grandis, Syzygium cumini, and *Saccopetalum tomentosum*, respectively. For the seedling layer (Fig. 10), two smaller clusters were framed between north and west direction, east and south direction, respectively. Four major clusterings of species were observed for the seedling layer. *Azadirachta indica, Pongamia pinnata*, and *Peltophorum ferrugineum* formed the cluster1, cluster 2 comprises of *Cassia fistula* and *Syzygium cumini*, cluster 3 comprises of *Tectona grandis* and *Acacia catechu*, cluster 4 comprises of *Butea monosperma* and *Dalbergia sissoo*. Cluster analyses of the herb layer (Fig. 11) represent numerous cluster formations due to

occurrence of higher number of species. In shrub layer (Fig. 12), east and west direction formed smallest cluster, and the vegetational type reflected distant clustering towards the south direction when compared to other directions. Smaller clusters were formed between *Cassia angustifolia* and *Ipomea carnea, Grewia rothi, Leea asiatica*, and *Calotropis gigantea, Carissa opaca*, and *Zizypus rotundifolia*. Vegetation stratification studies were similarly reported by Palit and Banerjee (2013) in Senchal wildlife sanctuary, W.B. in India which reflected clustering of plant species in different beats of concerned forest area.

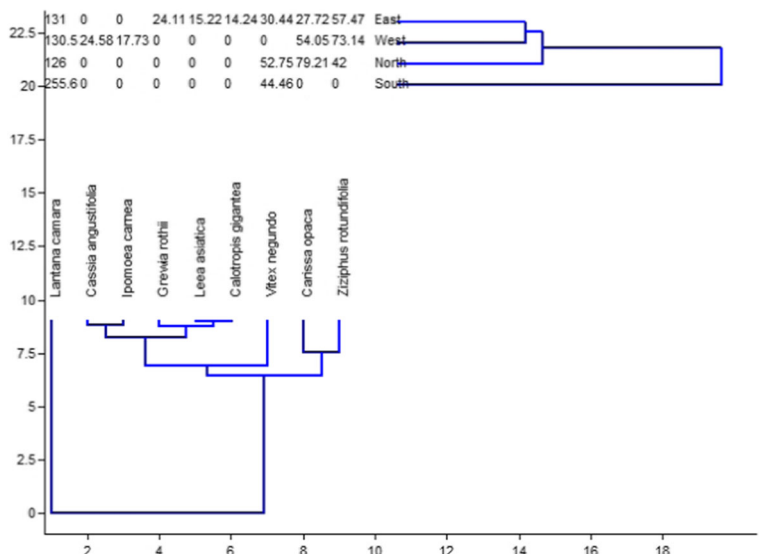Fig. 12 Clustering of shrub layer
in Bishrampur collieries

Table 12 PCA applied to the correlation matrix of the phytosociological parameters of tree layer in concerned study sites

Axis	Eigen value	% variance			
1	3.4695	69.39			
2	1.08352	21.67			
3	0.360864	7.2173			
4	0.0684812	1.3696			
5	0.0176396	0.35279			
Factor	1	2	3	4	5
F	−0.4908	0.06219	−0.6332	0.4216	0.4202
D	−0.4921	−0.2881	−0.3095	−0.7014	−0.2949
IVI	−0.2949	0.2037	0.268	0.4347	−0.6602
BA	−0.3127	−0.7244	0.4951	0.1614	0.3261
A/F	−0.3965	0.589	0.4317	−0.3395	0.4408

Principle component analysis of the phytosociological attributes of vegetation types of Bishrampur collieries reflected significant level of variation among themselves in various stratified layer of vegetation. Similar studies on PCA analysis of vegetation parameters were reported by Eni et al. (2012) in order to establish the inter-relationship between soil and vegetation of forest of Nigeria. Such studies act as fact finding tool which helps to reduce the complexity in data analysis as well as helps to screen out variables which have made significant contribution in the results. Bi-plot PCA-ordination diagram was plotted for the different phytosociological attributes of plant species belonging to various stratified layer of vegetation. For the tree layer (Table 12 and Fig. 13), the first two principle components account for 91.06% of the total variance in the data set. Therefore, 69 and 21% of variance were accounted for the first and second principle components, respectively. This means that the first principle component is far by most important for representing the variation within the phytosociological attributes in the tree layer for the concerned study sites. In the study area, phytosociological attributes in *Ailanthus excelsa* and *Butea monosperma* have similarity in comparison to other tree species. These two species as reflected from the four quarter diagram, both have high correlation with first axis. Therefore, these
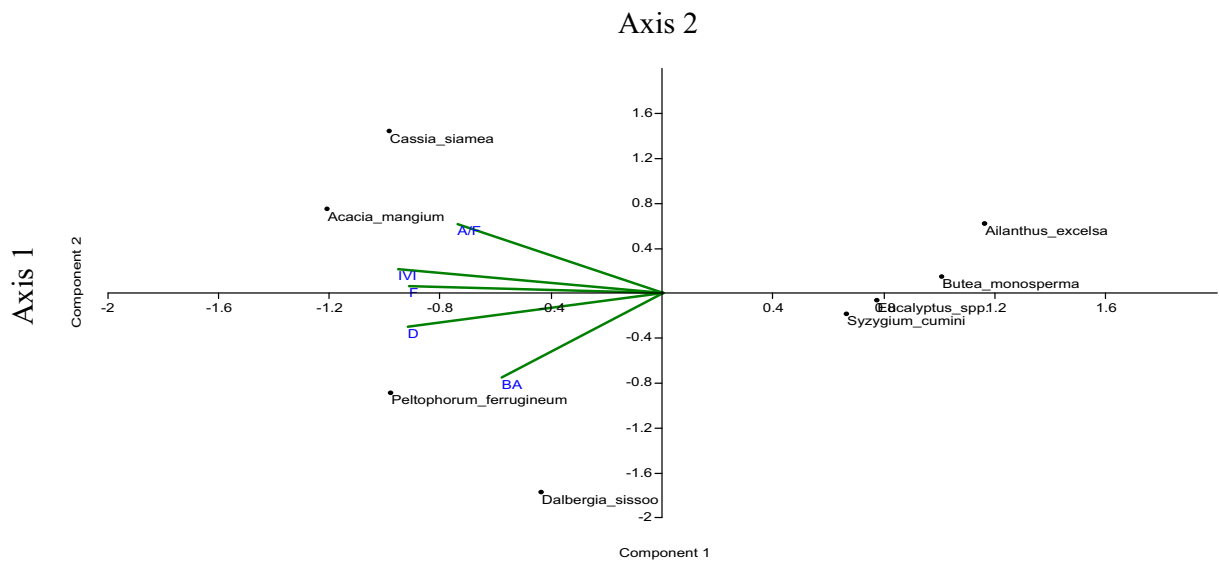

Fig. 13 Bi-plot PCA-ordination diagram of the tree layer related to the phytosociological parameters in the study sites

Table 13 PCA applied to the correlation matrix of the phytosociological parameters of sapling layer in concerned study sites

Axis	Eigen value	% variance			
1	4.35692	87.138			
2	0.603526	12.071			
3	0.0252903	0.50581			
4	0.00994032	0.19881			
5	0.00432569	0.086514			
Factor	1	2	3	4	5
F	0.9819	−0.1632	0.05585	−0.07772	0.003989
D	0.9915	−0.09908	0.05844	0.0434	−0.04331
IVI	0.9827	−0.1261	−0.1354	−0.00672	−0.009786
BA	0.9907	−0.1173	0.02032	0.04406	0.04835
A/F	0.6801	0.7331	0.0002758	−0.005538	0.001086

species reflects strong relation with the variables of the first axis. *Acacia mangium* and *Cassia siamea* reflected inverse correlation for the same phytosociological variables of the first axis. *Acacia catechu* showing positive correlation with A/F ratio.

In sapling layer (Table 13 and Fig. 14), first two principle components account for 99.209% of the total variance in the data set. Therefore, 87.138 and 12.071% of variance were accounted for the first and second principle components, respectively. This means that the first principle component is far by most important for representing the variation within the phytosociological attributes in the sapling layer for the concerned study sites. Due to higher distance between *Acacia*

mangium type from the second axis, this species has a weak relation with factors such as A/F ratio. *Butea monosperma, Tectona grandis, Peltophorum ferrugianum,* and *Eucalyptus* spp. showed negative correlation with respect to A/F ratio in axis 2. *Syzygium cumini* reflected positive correlation with A/F ratio in axis 2.

In seedling layer (Table 14 and Fig. 15), first two principle components account for 99.389% of the total variance in the data set. Therefore, 90.626 and 8.763% of variance were accounted for the first and second principle components, respectively. This means that the first principle component is far by most important for representing the variation within the
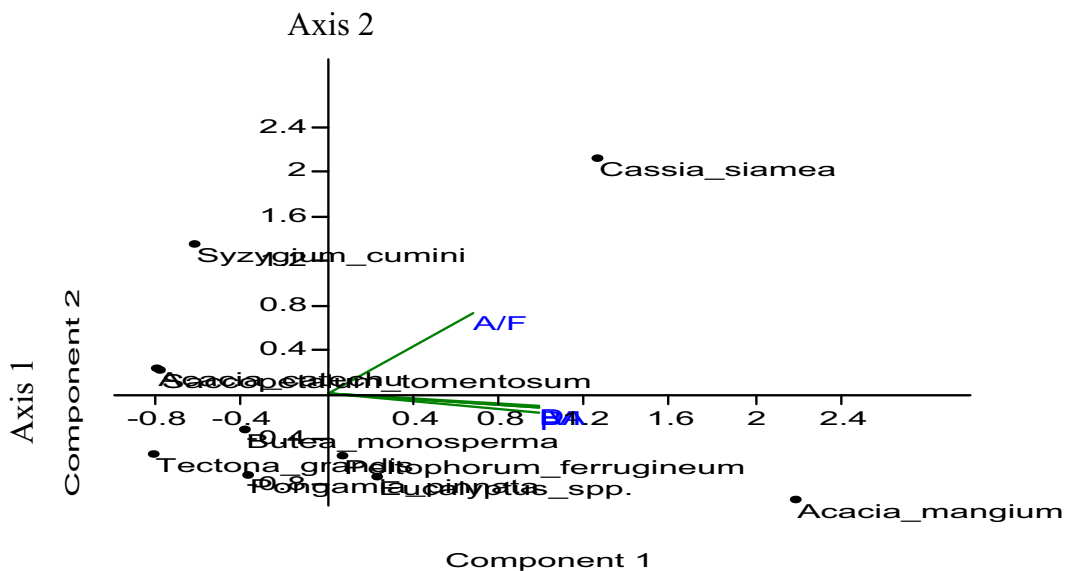
Fig. 14 Bi-plot PCA-ordination diagram of the sapling layer related to the phytosociological parameters in the study sites

Table 14 PCA applied to the correlation matrix of the phytosociological parameters of seedling layer in concerned study sites

Axis	Eigen value	% variance		
1	3.62506	90.626		
2	0.350522	8.763		
3	0.0208402	0.521		
4	0.00358252	0.089563		
Factor	1	2	3	4
F	0.9344	−0.3453	0.08592	0.01523
D	0.995	−0.08136	−0.0315	−0.04864
IVI	0.9947	−0.0129	−0.09742	0.03117
A/F	0.8789	0.4738	0.05456	0.003595

Table 15 PCA applied to the correlation matrix of the phytosociological parameters of Herb layer in concerned study sites

Axis	Eigen value	% variance		
1	3.03498	75.874		
2	0.891443	75.874		
3	0.0706981	1.7675		
4	0.00288284	0.072071		
Factor	1	2	3	4
F	−0.899	0.3975	−0.1829	0.01549
D	−0.9826	0.05291	0.1762	0.02628
IVI	−0.9982	0.03032	0.02903	−0.04358
A/F	−0.5147	−0.8542	−0.07318	0.007288

phytosociological attributes in the sapling layer for the concerned study sites. Due to higher distance between *Acacia mangium* type from the second axis, this species has a weak relation with factors such as frequency. *Butea monosperma, Azadirachta indica, Tectona grandis*, and *Pongamia pinnata* being located on axis 2 thereby reflecting strong negative correlation.

For the herb layer (Table 15 and Fig. 16), components 1 and 2 reflected higher level of variation equally. Therefore, both the components accounted for 75.874% of variance. Most of the herb species were located on or near of axis 1 and 2. This, therefore, reflects the strong positive correlation of the concerned species along with the study variable represented by the respective axis.

Principle component analysis for shrub layer (Table 16 and Fig. 17) reflects variable scenario with respect to herb layer. *Zizyphus rotundifolia* and *Vitex negundo* showed higher correlation for axis 2. These species therefore, are strongly correlated with IVI. Component 1 accounted for 99.908% of variance.

Management perspectives

Eco-restoration of degraded habitat is a major challenge towards sustainable development. Plantation is the most suitable strategy among various practices available in eco-restoration program. Plantations promote biological reclamation of mine spoil. For plantation, priority must
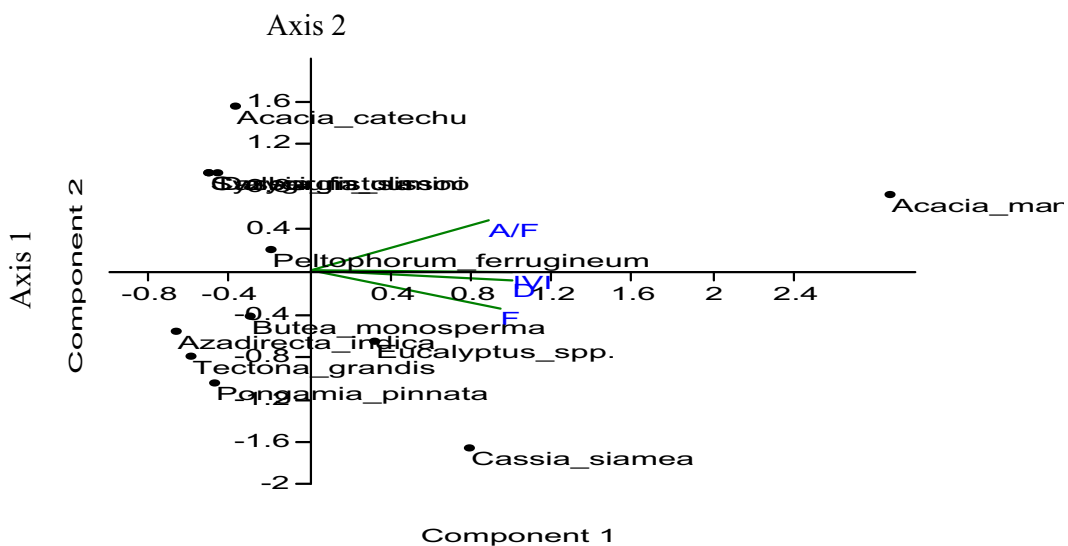

Fig. 15 Bi-plot PCA-ordination diagram of the seedling layer related to the phytosociological parameters in the study sites
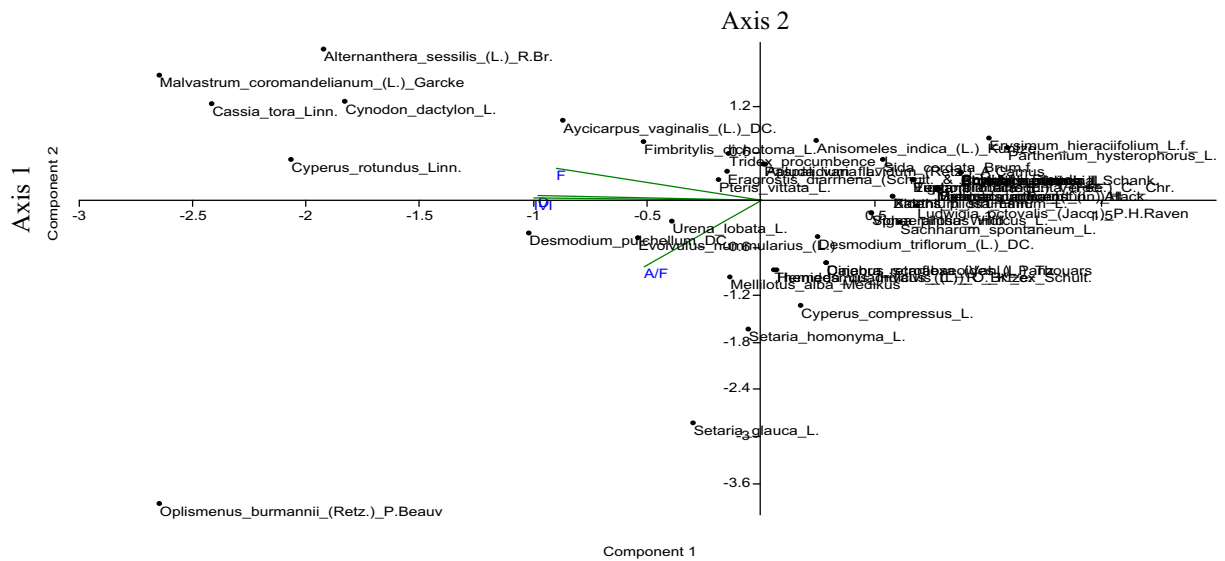
Fig. 16 Bi-plot PCA-ordination diagram of the herb layer related to the phytosociological parameters in the study sites

be given to native species, those having fast growth rate and ability to fix atmospheric nitrogen. Scenario in the mining sector often reflects ill management of the concerned habitat. The features of the site and its subsequent management policies are the most important aspects for eco-restoration and eco-development. As per the rule of ecological interactions, diverse nature of species imposes more stability to the habitat. These should be given due consideration while going for plantation in the coal waste piles and promote mixed plantation (tree, shrub, and grasses) instead of mono species plantation (Li et al. 2006b). Proper management practices should be applied for the betterment of the site. During our present investigation, data revealed natural

regenerative potential of *Dalbergia sissoo*, *Syzygium cumini*, and *Butea monosperma* in concerned study sites at various growth stages. Therefore, such indigenous species should be promoted for plantation purpose with the aim of eco-restoration of mined wastelands. Our findings were further supported by Harrington (1999)) who mentioned that indigenous species are much more preferable in comparison to exotics due to their local adaptation of the extreme conditions (Wong 2003; Gonzalez and Gonzalez-Chavez 2006; Mendez and Maier 2008; Ghose 2004; Maiti 2007; Juwarkar and Jumbalkar 2008). Previous study suggests that vegetal cover introduction in the mining areas may promote rhizo-deposition of toxic elements. Future research and

Table 16 PCA applied to the correlation matrix of the phytosociological parameters of shrub layer in concerned study sites

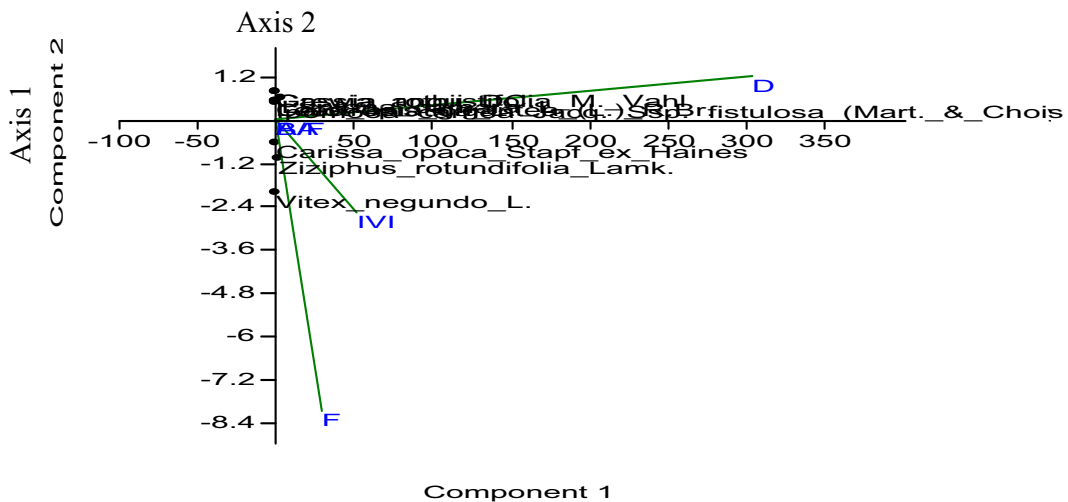| Axis	Eigen value	% variance			
1	94,467.4	99.908			
2	73.3584	0.077583			
3	13.8599	0.014658			
4	0.00037708	3.988E-07			
5	2.09592E-05	2.2166E-08			
Factor	1	2	3	4	5
F	0.09497	−0.9434	0.3178	−0.002584	−2.528E-06
D	0.9819	0.1413	0.1262	−0.0008788	4.048E-05
IVI	0.1639	−0.3	−0.9397	0.00911	1.786E-05
BA	0.0003873	−0.000415	−0.009404	−0.9904	−0.1378
A/F	1.104E-05	−6.049E-05	−0.001295	−0.1378	0.9905

Fig. 17 Bi-plot PCA-ordination diagram of the shrub layer related to the phytosociological parameters in the study sites.

development activities are required for application of suitable technology from lab to land scale. Banning of mining in eco-sensitive areas should be discouraged always. In our present study, directional impact on population structure is clearly revealed through statistical interpretation of data. Different girth classes are prevalent in different direction. Selection of suitable species on the basis of high growth rate, regeneration capacity, and stable population structure needs to be emphasized for eco-restoration of mined wastelands.

Conclusion

Surface mining of coal in Bishrampur and adjoining areas has led to significant changes in the land-use pattern. It also promoted alteration of soil quality through higher accumulation of mine spoils. The effect was significant in all the four directions during present investigation. The degradation of habitat has reduced regeneration potential of indigenous plant population. There was predominance of herbaceous species in comparison to other vegetative strata which suggest that mining operations lead to colonization of specific species in newly altered habitat. The study further suggests detrimental impact of mining activities on vegetation on an area. Therefore, such activities need to be regulated properly. Improvement in the site quality is the key prerequisite from management perspective of mined wastelands. Further, regular monitoring and appropriate regulations are indispensable to alleviate the negative effects of the mining upon ecology and environment to make this practice a sustainable one. The major findings of the present investigation include screening of *Acacia mangium*, *Cassia siamea*, and *Dalbergia sissoo* species to be recommended for effective eco-restoration of the concerned sites with due consideration of cosmopolitan distribution in the study sites, high regeneration potential, as well as existence in the form of various girth classes of stable population structure.

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