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TAXONOMIC AND PHYTOCLIMATIC SURVEILLANCE OF THE NATURALIZED VEGETATION IN AN OPENCAST COAL MINE SITE OF BURDWAN DISTRICT, WEST BENGAL

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ABSTRACT

An opencast coal mine site at Sonepur Bazari in Raniganj, West Bengal was investigated for the taxonomic and phytoclimatic analyses of its naturalized vegetation. Two overburdens of age 5 years (OB_05) and 10 years (OB_10) respectively were studied and compared with an ocp peripheral zone (OPZ) for the enumeration of Magnoliophyta (angiosperms). As per taxonomic census, 10, 30 and 28 plant species were recorded from OB_05, OB_10 and OPZ respectively which revealed dicots dominated over monocots in all the cases. The phytoclimate was determined for the three data points that showed OB_05 and OB_10 to be crypto-chamaephytic while OPZ to be phanero-chamaephytic, this finding when compared with other phytoclimatic regions of India in order to understand the present status of the OBs with respect to the OPZ revealed affinity of OB_05 and OB_10 with arid regions while that of OPZ with a forest of Bankura district, West Bengal. From the present analyses, a trend of floral succession was observed which speaks of a possibility of successful revegetation and restoration of the area studied.

KEYWORDS: Opencast coal mine, Overburden (OB), Magnoliophyta, Census, Phytoclimate, Restoration

Ecosystem destruction by coal mining is an inevitable consequence of development. Mining, especially of opencast type, disrupts the landscape pattern along with derangement of edaphic components, depletion of indigenous vegetation and soil microbes. The overburden dumps, the heaps of mine spoils formed as a result of open cast mining, convert fertile lands into wastelands by their poor and detrimental physico-chemical (Jha and Singh, 1991; Maiti and Saxena, 1998; Maiti and Ghose, 2005) and microbiological characteristics (Visser et al., 1979; 1983; Urbanova et al., 2011). Never the less, on the dumps operate the natural process of ecological succession to convert the overburden spoils to soils which however, is a time consuming affair (Bradshaw and Chadwick, 1980; Dobson et al., 1997). So far natural ecological succession has been observed in few studies (Hazarika et al., 2006; Borpujari, 2008; Roy and Mukherjee, 2011; Ekka and Behera, 2011; Biswas et al., 2013; Roy and Mukherjee, 2014). It is apparent from several studies that the overburden of spoils in the vicinity of an opencast coal mining area set up a scenario of dynamism in the temporal scale in relation to its floristic composition, physical environment and microbial organization. Whether the biological quality and direction of such changes co-integrate with the self-designing capacity of nature constitute a subject of great interest.

In view of the foregoing, the present work was undertaken in the Sonepur Bazari opencast coal mining area in Raniganj coalfield, Burdwan district, West Bengal. The objective was to prepare an inventory of the existing vegetation and determine the phytoclimate of the overburdens (OB) lying in the selected mining area as well as an associated OCP peripheral zone in order to compare and understand the pace of restoration.

MATERIALS AND METHODS

Study Site

For the present study, we selected the Sonepur Bazari opencast coal mining project (OCP) area in the Raniganj coalfield of West Bengal, India (23^{O}41'16.56" N; 87^{O}13'12.20" E). The study site is 75 m above the sea level, the topography of which is slightly undulating and rolling marked by small ridges and valleys. The climate is tropical monsoonal with very high summer having an average temperature of 42^{o} C and a cold winter often experiencing temperature as low as 6^{o}C. The average rainfall amounts to 1450 mm/year.

Qualitative vegetation analyses were carried out in two Overburdens (5 and 10 years old respectively) ranging from 0.2 to 0.25 sq km (approximately) plus an OCP peripheral zone (OPZ) adjacent to the mining site to understand the ongoing natural succession process.

Sampling and Data Analysis

Field work was performed during 2010-2011 in the opencast coal mining project (OCP) area of

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Sonepur Bazari, Raniganj covering overburdens (data points OB_05 and OB_10) and the OCP peripheral zone (data point OPZ). Specimens of the plant species inhabiting these sites were collected and identified with the help of pertinent taxonomic literature (Prain, 1903; Guha Bakshi, 1984; Bennet, 1987; Murti and Panigrahi, 1999) and authentic specimens preserved in BURD (Burdwan University Herbarium). After identification, the plant species were enumerated under respective families arranged according to Cronquist's system of classification (1988). Further taxonomic analyses were done for revealing the ratios of dicot/monocot in terms of family, genus and species. The percentage distribution of the constituent species in different life-forms was calculated for preparation of the biological spectrum of the three data points as described elsewhere (Roy and Mukherjee, 2011). The values thus determined, were compared with the normal spectrum given by Raunkiaer (1934) and spectra of other phytoclimatic regions of India following cluster analysis (Bhattacharya and Mukherjee, 2013) by PAST software (Hammer et al., 2001).

RESULTS

Plant species were recorded from OB_05 and OB_10 and compared with those registered in the OPZ. OB_05 had 10 species affiliated to 10 genera and 8 families, OB_10 encompassed 30 species distributed over 30 genera and 18 families and OPZ, in its turn, had 28 species belonging to 28 genera and 19 families. These species were assigned their respective systematic positions according to Cronquist's system of classification (1988) (Table 1). Upon comparing the vegetation composition data of the 3 data points; OB_05, OB_10 and OPZ, it was observed that only 2 plant species *Saccharum spontaneum* (Poaceae) and *Croton bonplandianum* (Euphorbiaceae) had adequate potential to thrive in all the data points. Interestingly three groups, viz. S1 *Achyranthes aspera* (Amaranthaceae); S2 *Cyperus rotundus* (Cyperaceae), *Desmodium triflorum* (Fabaceae), *Evolvulus nummularius* (Convolvulaceae), *Solanum surratense* (Solanaceae) and *Tridax procumbens* (Asteraceae); and S3 *Boerhavia repens* (Nyctaginaceae), *Butea monosperma* (Fabaceae), *Cajanus scarabeoides* (Fabaceae), *Calotropis gigantea* (Asclepiadaceae), *Cassia alata* (Fabaceae), *Clerodendrum viscosum* (Verbenaceae), *Digitaria bicornis* (Poaceae), *Euphorbia hirta* (Euphorbiaceae), *Lantana camara* (Verbenaceae), *Parthenium hysterophorus* (Asteraceae), *Pennisetum pedicellatum* (Poaceae), and *Zizyphus oenoplia* (Rhamnaceae) could be recognized with 1, 5 and 12 species which were able to live in habitats prevailing in two data points in such combinations as OPZ and OB_05; OB_05 and OB_10; and OB_10 and OPZ respectively.

Table 1: An enumeration of the angiospermic plants (Magnoliophyta) thriving in mine overburden of different ages (OB_05 and OB_10) in comparison to the ocp peripheral zone (OPZ)

OB_05	OB_10	OPZ
Class Magnoliposida	**Class Magnoliposida**	**Class. Magnoliposida**
Subclass 3. Caryophyllidae	**Subclass 1. Magnoliidae**	**Subclass 2. Hamamelidae**
Order. Caryophyllales	**Order. Papaverales**	**Order. Urticales**
Family. Amaranthaceae	**Family. Papaveraceae**	**Family. Moraceae**
1. *Achyranthes aspera* L.	1. *Argemone mexicana* L.	1. *Ficus benghalensis* L.
Subclass 5. Rosidae	**Subclass 3. Caryophyllidae**	**Subclass 3. Caryophyllidae**
Order. Fabales	**Order. Caryophyllales**	**Order. Caryophyllales**
Family. Fabaceae	**Family. Nyctaginaceae**	**Family. Nyctaginaceae**
2. *Desmodium triflorum* (L.) DC.	2. *Boerhavia repens* L.	2. *Boerhavia repens* L.
Order. Euphorbiales	**Molluginaceae**	**Amaranthaceae**
Family. Euphorbiaceae	3. *Glinus lotoides* L.	3. *Achyranthes aspera* L.
3. *Euphorbia heyneana* Spreng.	**Subclass 4. Dilleniidae**	**Subclass 4. Dilleniidae**
4. *Croton bonplandianum* Baill.	**Order. Malvales**	**Order. Malvales**
Subclass 6. Asteridae	**Family. Malvaceae**	**Family. Malvaceae**
Order. Solanales	4. *Sida acuta* Burm.f.	4. *Urena sinuata* L.
Family. Solanaceae	**Subclass 5. Rosidae**	**Subclass 5. Rosidae**
5. *Solanum surattense* Burm. f.	**Order. Fabales**	**Order. Fabales**
Convolvulaceae	**Family. Mimosaceae**	**Family. Mimosaceae**
6. *Evolvulus nummularius* (L.) L.	5. *Mimosa pudica* L.	5. *Albizia lebbeck* (L.) Benth.
Order. Asterales	**Caesalpiniaceae**	**Caesalpiniaceae**
Family. Asteraceae	6. *Senna alata* (L.) Roxb.	6. *Senna alata* (L.) Roxb.
7. *Tridax procumbens* L.	**Fabaceae**	**Fabaceae**
Class. Liliopsida	7. *Butea monosperma* (Lam.) Taub.	7. *Alysicarpus monilifer* (L.) DC.

Subclass 3. Commelinidae **Order. Cyperales** **Family. Cyperaceae** 8. *Cyperus rotundus* L. **Poaceae** 9. *Saccharum spontaeneum* L. 10. *Cynodon dactylon* (L.) Pers.	8. *Cajanus scarabaeoides* (L.) Thou. 9. *Tephrosia purpurea* (L.) Pers. 10. *Alysicarpus vaginalis* (L.) DC. 11. *Desmodium triflorum* (L.) DC. **Order. Euphorbiales** **Family. Euphorbiaceae** 12. *Euphorbia hirta* L. 13. *Croton bonplandianum* Baill. **Order. Rhamnales** **Family. Rhamnaceae** 14. *Zizyphus oenoplia* (L.) Mill. **Order. Geraniales** **Family. Oxalidaceae** 15. *Biophytum sensitivum* L. **Subclass 6. Asteridae** **Order. Gentianales** **Family. Asclepiadaceae** 16. *Calotropis gigantia* R. Br. **Order. Solanales** **Family. Solanaceae** 17. *Solanum surattense* Burm. f. **Convolvulaceae** 18. *Evolvulus nummularius* (L.) L. **Order. Lamiales** **Family. Verbenaceae** 19. *Lantana camara* L. **Lamiaceae** 20. *Clerodendrum viscosum* Vent. **Order. Asterales** **Family. Asteraceae** 21. *Tridax procumbens* L. 22. *Parthenium hysterophorus* L. 23. *Chromolaena odorata* (L.) King & Robin. **Class. Liliopsida** **Subclass 3. Commelinidae** **Order. Cyperales** **Family. Cyperaceae** 24. *Dactyloctenium aegyptium* (L.) Willd. 25. *Cyperus rotundus* L. **Poaceae** 26. *Saccharum spontaeneum* L. 27. *Pennisetum pedicellatum* Trin. 28. *Eragrostis tenella* L. 29. *Digitaria bicornis* (Lam.) Roem. & Schult. 30. *Brachiaria ramosa* (L.) Stapf.	8. *Butea monosperma* (Lam.) Taub. 9. *Cajanus scarabaeoides* (L.) Thou. 10. *Dalbergia sisso* Roxb. **Order. Euphorbiales** **Family. Euphorbiaceae** 11. *Euphorbia hirta* L. 12. *Croton bonplandianum* Baill. **Order. Rhamnales** **Family. Rhamnaceae** 13. *Zizyphus oenoplia* (L.) Mill. **Order. Sapindales** **Family. Meliaceae** 14. *Azadirachta indica* A. Juss. **Subclass 6. Asteridae** **Order. Gentianales** **Family. Asclepiadaceae** 15. *Calotropis gigantia* R. Br. **Order. Solanales** **Family. Convolvulaceae** 16. *Ipomoea carnia* Jacq. *var fistulosa* (Mart.ex Choisy) D. Austin **Order. Lamiales** **Family. Verbenaceae** 17. *Lantana camara* L. 18. *Chlerodendrum viscosum* Vent. **Lamiaceae** 19. *Leonotis nepetifolia* (L.) R. Br. 20. *Hyptis suaviolens* (L.) Poit. **Order. Rubiales** **Family. Rubiaceae** 21. *Spermacocci hispida* L. **Order. Asterales** **Family. Asteraceae** 22. *Parthenium hysterophorus* L. **Class. Liliopsida** **Subclass 2. Arecidae** **Order. Arecales** **Family. Arecaceae** 23. *Phoenix sylvestris* (L.) Roxb. **Subclass 3. Commelinidae** **Order. Cyperales** **Family. Cyperaceae** 24. *Fimbristylis bisumbellata* (Cyperaceae) (Forrsk.) Bub. **Poaceae** 25. *Saccharum spontaeneum* L. 26. *Pennisetum pedicellatum* Trin. 27. *Digitaria bicornis* (Lam.) Roem. & Schult. 28. *Dichanthium annulatum* (Forrsk.) Stapf.

Moreover, 2 species, viz. *Cynodon dactylon* (Poaceae) and *Euphorbia heyneana* (Euphorbiaceae) were found to be unique to OB_05, whereas 11 species, viz. *Alysicarpus vaginalis* (Fabaceae), *Argemone mexicana* (Papaveraceae), *Biophytum sensitivum* (Oxalidaceae), *Brachiaria ramosa* (Poaceae), *Chromolaena odorata* (Asteraceae), *Dactyloctenium aegyptium* (Poaceae), *Eragrostis tenella* (Poaceae), *Glinus lotoides* (Molluginaceae), *Mimosa pudica* (Fabaceae), *Sida acuta* (Malvaceae), *Tephrosia* *purpurea* (Fabaceae) and 13 species *Spermacocci hispida* (Rubiaceae), *Dicanthium annulatum* (Poaceae), *Urena sinuata* (Malvaceae), *Leonotis hepetifolia* (Lamiaceae), *Azadirachta indica* (Meliaceae), *Hyptis suaveolensis* (Lamiaceae), *Phoenix sylvestris* (Arecaceae), *Alysicarpus monilifer* (Fabaceae), *Albizia lebbeck* (Fabaceae), *Ipomoea carnea* var *fistulosa* (Convolvulaceae), *Fimbristylis bisumbellata* (Cyperaceae), and *Ficus benghalensis* (Moraceae) were exclusively present in OB_10 and OPZ respectively. Ratio of dicot/monocot at family, genus and species level showed that dicots dominated over monocots in all the cases (Table 2).

Table 2: Taxonomic analysis of vegetation in different data points of the study site

OB_05			
TAXON	**DICOT**	**MONOCOT**	**DICOT:MONOCOT**
Family	6	2	3:1
Genus	7	3	2.3:1
Species	7	3	2.3:1
OB_10			
Family	16	2	8:1
Genus	23	7	3.3:1
Species	23	7	3.3:1
OPZ			
Family	16	3	5.3:1
Genus	22	6	3.7:1
Species	22	6	3.7:1

In this study, the life-forms of 10, 30 and 28 species from data points OB_05, OB_10 and OPZ were determined according to Raunkiaer (1934), to obtain the Biological Spectrum (Table 3). The biological spectrum data on comparison with the normal spectrum as given by Raunkiaer (Fig. 1) revealed much lower abundance of phanerophytes and much higher abundance of chamaephytes and cryptophytes in general, thus, indicating stressful conditions. High abundance of hemicryptophytes in OB_05 speaks of high aridity wherein they play important role in soil, nutrient and water retention.

Table 3: Biological spectra of the three data points - OB_05, OB_10 and OPZ

Life-forms	No. of representative plant species			Obtained Biological Spectrum (%)			Raunkiaer's standard (%)
	OB_05	**OB_10**	**OPZ**	**OB_05**	**OB_10**	**OPZ**	
Phanerophyte	1	4	9	10	13.33	32.14	46
Therophyte	1	5	3	10	16.67	10.71	13
Hemicryptophyte	3	6	3	30	20	10.71	26
Chamaephyte	3	10	9	30	33.33	32.14	9
Cryptophyte	2	5	4	20	16.67	14.30	6

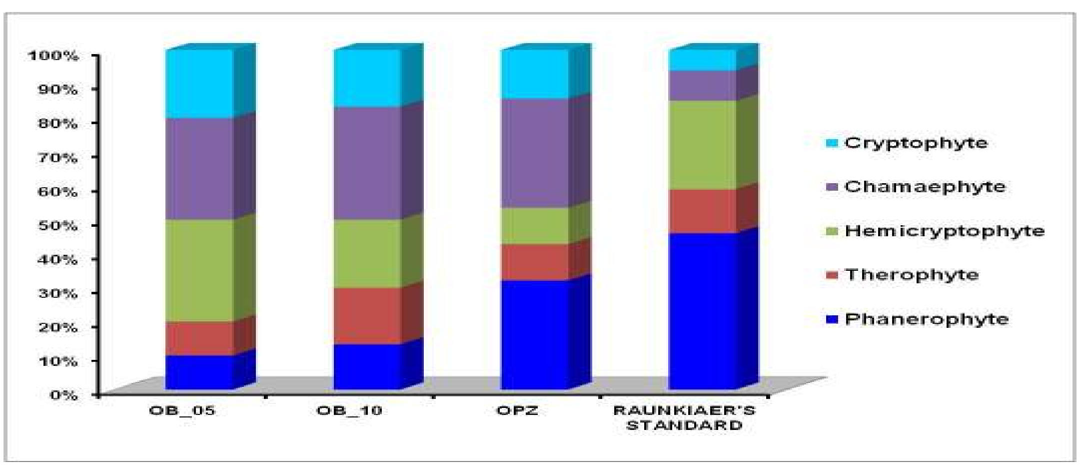

Figure 1: Comparison of the Biological spectra of OB_05, OB_10 and OPZ with Raunkiaer's standard

In order to understand the relatedness of the floristic composition in terms of phyto-climate of the data points considered in the present study with those of other phyto-climatic zones of India (refered to as 26 Operational Site Units) cluster analysis was performed (Table 4). The dendogram thus obtained from cluster analysis (Fig. 2) shows that at the linkage distance of 140, two major groups are recognizable, viz. group Gp I and II. Gp I in its turn links together the forest areas from various districts of West Bengal including the normal spectrum in the same cluster, while Gp II gets composed of mainly dry and arid regions of India. Gp I is further divisible at linkage distance 44 into two subgroups: Ia and Ib. Interestingly, Ia includes OPZ and Sonamukhi forest of Bankura district, West Bengal whereas, different forest areas and the normal spectrum got in the process clustered into Ib. Moreover, Bethuadahari wildlife sanctuary of Nadia district and Bhalki-Machan forest of Burdwan district show maximum affinity with the normal spectrum. Group II is divisible into two subgroups, viz. IIc and IId at linkage distance 90. OB_05 and OB_10 were closely related to each other as well as another overburden of Belbaid patch in Raniganj coalfields of Burdwan district and were clustered together into group IIc. However, it in its turn appears to be distantly related to group IId that included the arid and desert regions of India.

Table 4: Biological spectra of different eco-climatic zones in India

	Eco-climatic zones in India	Percentage distribution of life-forms					Phytoclimate or Bioclimate
		Ph	Ch	Hcr	Cr	Th	
1	Normal spectrum (Raunkiaer, 1934)	46	9	26	6	13	Normal spectrum
2	Semi-arid zone of N. India (Meher-Homji, 1964)	30.3	18.3	10.4	8.2	33	Thero-chamaephytic
3	Semi-arid zone of S. India (Meher-Homji, 1964)	38.3	12.4	11	10	28	Thero-chamaephytic
4	Extreme arid regions of Indian desert (Mertia and Bhandari, 1978)	34	9	6	2	49	Therophytic
5	N-E Rajasthan (Sharma and Tyagi, 1979)	20	8.8	9.7	15.3	46.2	Thero-cryptophytic
6	N-E Haryana (Jain and Singh, 1984)	23.9	22.8	5.1	5.2	42.5	Thero-chamaephytic
7	Rajasthan Desert (Pandey et al., 1985)	31	3	13	14	39	Thero-cryptophytic
8	Punjab State (Sharma and Rajpal, 1991)	21.7	4.4	7.4	19.2	47.3	Thero-cryptophytic
9	Semi-arid Punjab (Sharma et al, 1987)	13.7	6.7	13.9	10.9	54.8	Thero-cryptophytic
10	Punjab Shivaliks (Sharma, 1990)	29.9	3.5	8.4	18.3	39.9	Thero-cryptophytic
11	Berhampur (Mishra and Mishra, 1979)	5.7	25.7	14.5	5.7	48.6	Thero-chamaephytic
12	Indian desert (Das and Swarup, 1951)	22.1	18.9	15.5	3.5	40	Thero-chamaephytic
13	West Rajasthan desert (Charan et al, 1978)	24	19	9	2	46	Thero-chamaephytic
14	Pilani (Singh and Joshi, 1983)	0	17	4.9	9.8	68.3	Thero-chamaephytic
15	Sonamukhi forest, Bankura, West Bengal (Banerjee et al., 2005)	38.4	25.32	6.75	13.08	16.46	Phanero-chamaephytic
16	Chandur forest, Hooghly, West Bengal (Malik et al., 2006)	46.2	20	8.97	20	4.83	Phanero-chamaephytic
17	Bahadurpur forest, Nadia , West Bengal (Ghosh et al., 2007)	57.59	6.33	8.23	22.15	5.7	Phanero-cryptophytic
18	Bethudahari sanctuary, Nadia, West Bengal (Ghosh et al., 2008)	61.16	15.7	5.79	4.13	13.22	Phanero-chamaephytic
19	Ramnabagan sanctuary, Burdwan, West Bengal (Palit et al., 2002)	51.4	16.78	9.09	9.19	13.28	Phanero-chamaephytic
20	Bhalki-Machan forest, Burdwan (Bhatt. and Mukherjee, 2007_a)	52.78	10.19	12.96	5.56	18.52	Phanero-therophytic
21	Bishtupur forest, Burdwan (Bhattacharya and Mukherjee, 2007_b)	48.21	17.86	9.82	12.5	11.61	Phanero-chamaephytic
22	Garh forest, Burdwan (Bhattacharya and Mukherjee, 2013)	50.47	17.29	11.21	12.62	8.41	Phanero-chamaephytic
23	Belbaid patch, Burdwan (Roy and Mukherjee, 2011)	14.29	10.71	39.29	7.14	28.57	Thero-hemicryptophytic
24	OB_05, in this study	10	30	30	20	10	Crypto-chamaephytic
25	OB_10, in this study	13.33	33.33	20	16.67	16.67	Crypto-chamaephytic
26	OPZ, in this study	32.14	32.14	10.71	14.3	10.71	Phanero-chamaephytic

Ph-Phanerophytes, Ch-Chamaephytes, Hcr-Hemicryptophytes, Cr-Cryptophytes, Th-Therophytes

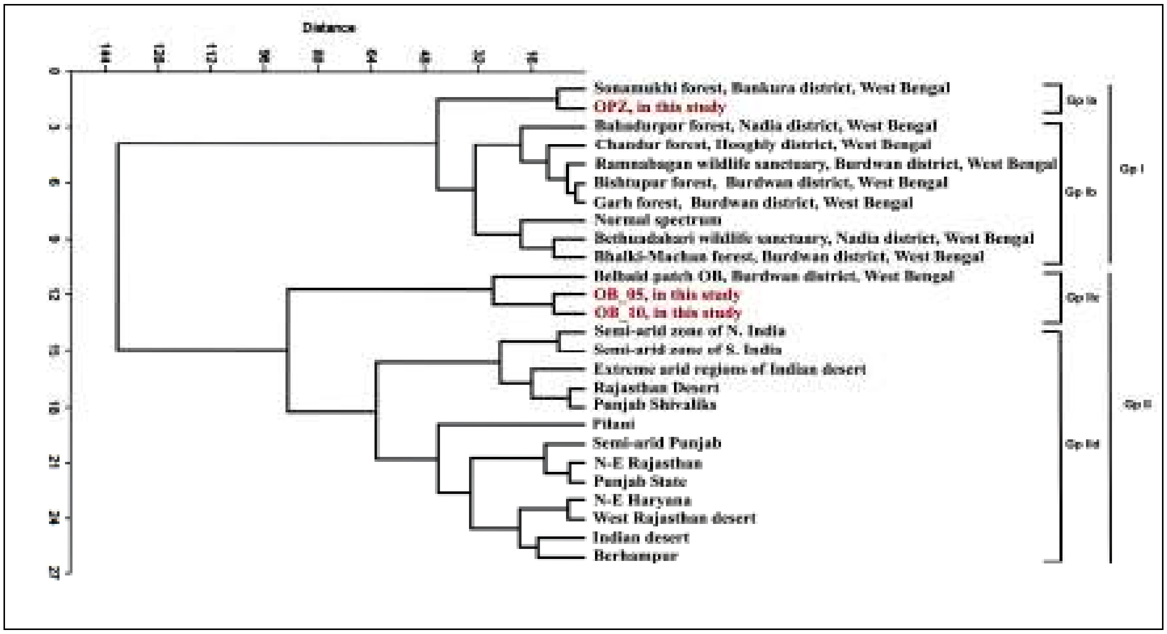

Figure 2: A dendogram of relationship covering the 26 phytoclimatic zones of India

DISCUSSION

Considering the naturalized flora in the overburdens of coal mining areas as an important indicator of the progress towards establishment of a stable ecosystem, a long-term periodic survey for documentation of floristic diversity is essential. In conformity with this concept the floristic analyses of the three data points clearly indicated the ongoing ecological succession in the age-gradient of the data points OB_05, OB_10 and OPZ. Moreover study of native vegetation is necessary for planning programmes of revegetation in any site affected by opencast coal mining with a view to maintain essential processes and life support system, preservation of genetic diversity and to ensure sustainable utilization of species and ecosystem (Soni et al., 1989; Jha and Singh, 1990; Bannerjee et al., 1996; Sheoran et al., 2010).

Phytoclimate which gives an indication of the micro-environmental state prevailing in the vegetation of concern, when analyzed in the age-gradient of the data points the results speak of positive approach of the ongoing phytoremediation. Initially, the chamae-cryptophytic type of phytoclimate in OB_05 and OB_10 proceeded in the direction of phanero-chamaephytic type. The future seems to have a bright prospect as and when the chamaephyte gets replaced by the hemicryptophyte. Comparison of the 26 phytoclimates revealed that opencast coal mining has perturbed the data points OB_05 and OB_10 so drastically that they have now developed aridity to show affinity with such regions existing in India. However the affinity of OPZ with the Sonamukhi forest of Bankura district is encouraging since the forest thus named had a very close relationship with the forest that existed in the study site in the pre-mining time which was tropical dry deciduous dominated by Sal (Champion and Seth, 1968; Bhattacharya and Mukherjee, 2006). Thus OPZ at present reflects a positive trend toward recovery from the initial set back.

This study revealed that in spite of several stress factors such as aridity, low nutrients and other environmental constraints, the plant communities were not only thriving in the mine overburdens but also proceeding towards the stability of the same.

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