Bio-restoration and its Impact on Species Diversity and Biomass Accumulation of Ground Flora Community of Degraded Ecosystem of Coalmines

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Abstract

The opencast mining has resulted to destruction of habitats, particularly for ground flora species, which is essential for maintaining nutrient cycling and ecological balance. The ground flora species are themselves capable of modifying site conditions to some extent. The floristic composition and luxuriance of ground flora in degraded ecosystem are largely dependent upon the secondary site conditions. In the present study, attempts have been made to assess the floristic composition and biomass accumulation of ground flora in age series of OB dump plantations and plain plantations of opencast mined out projects of NCL Singrauli. The frequently occurring ground flora species among different reclaimed sites were Ageratum conyzoides L., *Hyptis suaveolens* (L.) Poit., *Tridex procumbens* L., *Alternanthera sessilis* (L.) R.Br.ex DC., *Desmodium triflorum* (L.) DC., *Justicia simplex* D.Don., *Sida cordifolia* L., *Achyranthes aspera* L., *Cassia tora* L., *Tephrosia purporea* (L.) Pers., *Euphorbia hirta* L., *Atylosia scarabaeoides* (L.) Benth., *Oplismenus burmanii* (Retz.) P.Beauv., *Eragrotis tenella* (L.) P.Beauv. ex Roem. & Schult., *Imperata cylindrical* (L.) P.Beauv., *Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult., *Bothriochloa purtusa* (L.) A. Camus., *Apluta mutica* L., *etc. In general, the biomass was found to show the increasing trend with the advancement of age of plantations. The diversity index values are falling in the middle range which indicates ambiguous distribution between all the species. The maximum and minimum values of total biomass varied from 0.339 tonnes per ha. (2 year old plantation of Dudhichua) to 1.993 tonnes/ha (16 year old plantation of Amlohri). The value of carbon content in ground flora was found to be varied from 0.169 tonnes per ha. (2 year old plantation of Dudhichua) to 0.997 tonnes/ha (16 year old plantation of Amlohri).*

Keywords: *Bio-restoration, coal mine spoil, overburden dumps, age series of plantations, ground flora, biomass, floristic composition*

1. Introduction

As large forest have been clear felled for opencast mining of coal, the major challenges include loss of top soil, reduction of forest cover and destruction of habitats of ground flora species, which is essential for maintaining nutrient cycling and ecological balance. These are chemically, physically and biologically unstable and deficient. The ground flora forms an important structural component of forest ecosystem. The ground flora community not only

indicates the fertility status but also gives an idea of the growth and development of tree seedlings as it is intimately related to it. In literature, considerable importance has been attached to the study of ground flora in relation to availability of light, amount of soil moisture and organic carbon in the soil. Ground flora gives some indications of site conditions and its study is, therefore, of value in considering methods of reclamation. The ground flora species are themselves capable of modifying site condition to some extent. The floristic composition and luxuriance of ground flora in degraded ecosystem are largely dependent upon the secondary site conditions. In the present study, attempts have been made to assess the floristic composition and biomass accumulation of ground flora in age series of OB dump plantations and plain plantations of opencast mined out projects of NCL Singrauli.

2. Materials and Methods

Singrauli is the 50th district of Madhya Pradesh State of Union Republic India. The Singrauli coalfields (Lat 24^{o} 46' 60''- 24^{o} 78' 33''N and Long- 82^{o} 49' 59''- 82^{0} 83' 30''E) is spread over an area of 2200 km^{2} falling in Madhya Pradesh (eastern part of Sidhi district) and Uttar Pradesh (southern part of Sonebhadra district). The entire Singrauli coalfield is divided into 11 mining blocks, which are located both in M.P. and U.P. Vegetation during pre-mining period was very dense and covered with sal and mixed deciduous forests. Due to mining, the large forest areas have been clear felled and laid barren. The forest of Singrauli can be classified into following types –

1. Northern tropical dry sal forests (5 B/C)
2. Northern tropical dry mixed deciduous forests (5 B/C 2)

A large number of mixed plantations were raised by M.P. State Forest Development Corporation/ U.P. forest department, in different areas of Singrauli coalfields. The over burden plantations of all 8 mining blocks have been taken for assessment of ground flora under tree cover of different aged plantations. For enumeration of herbaceous flora particularly herbs, forbs and grasses, total 50 quadrats each of 50 x 50 cm size were laid during winter season (October to February) for assessment of ground flora in terms of species composition, density, biodiversity index (Shannon-Wiener Index of Diversity) and biomass estimation in each plantation studied.

The density of different species in various OB dumps was determined using standard ecological method (Mishra, 1989) using following formula:

No. of Density = No. of individuals of a species in total sampled quadrates / Total number of quadrates studied.

The diversity index was calculated using the following formula H= - £Pi(lnPi), where Pi is the proportion of density of each species in the sample.

In order to determine aboveground biomass, fifty 0.5 x 0.5 m plots, were harvested at random. For underground parts, 25 x 25 x 30 cm monoliths were excavated from clipped plots and washed thoroughly. All such materials were oven dried at 80°C till obtaining the constant weight, after determining the green weight (Mishra, 1989).

The amount of carbon sequestered was calculated by reducing the biomass yield to its 50% as per the guidelines of IPCC, 2006. Biomass value was converted to carbon stocks using 0.5 carbon fraction are default values (IPCC 2006) and it was expressed in tonnes per hectare.

3. Results

3.1. Floristic Composition of Tree Cover

The names of species planted in different years old plantations were mainly *Acacia catechu, Acacia mangium* Willd., *Acacia nilotica* (L.) Del., *Aegle marmelos* (L.) Correa., *Albizia procera* (Roxb.) Benth., *Anthocephalus cadamba* (Roxb.) Miq., *Azadirachta indica* A. Juss., *Bauhinia variegata* Linn., *Bombax ceiba* L., *Cassia fistula* L., *Cassia siamea* Lamk., *Dalbergia sissoo* Roxb., *Delonix regia* (Hook.) Raf., *Emblica officinalis* Gaertn., *Eucalyptus camaldulensis* Dehnh., *Gmelina arborea* Roxb., *Holoptelea integrifolia* (Roxb.) Planch, *Leucaena leucocephala* (Lam.) de Wit., *Madhuca indica* J.F. Gimelin., *Mangifera indica* L., *Peltaphorum ferruginium* Benth., *Pongamia pinnata* L.Pierre, *Prosopis juliflora* (Sw.) DC, *Syzygium cumini* (L.) Skeels, *Tectona grandis* Linn. f., *Terminalia arjuna* (Roxb. ex DC.) Wight., *Terminalia belerica* (Gaertn.) Roxb., etc. The dominant species of different opencast projects of Singrauli in terms of IVI were *Dalbergia sissoo* Roxb., *Tectona grandis* Linn.f., *Pongamia pinnata* (Linn.) Pierre, *Azadirachta indica* A. Juss., *Cassia siamea* Lamk. and *Gmelina arborea* Roxb.

3.2. Floristic Composition of Ground Flora

The details regarding distribution of ground flora species in different aged plantation of different OCP projects are given below:

3.2.1. Jayant Opencast Project: Table 1 shows the floristic composition and density (plants/sqm) of ground flora comprising herbs, climbers, shrubs and grasses found in different aged OB dump plantations of Jayant OCP. The data reveals that there are 14 species of herbs and climbers and 3 species of grasses found in different plantations viz., OB 2001-02, OB 1996-97 and OB 1991-92. The number of ground flora species found in OB 2001-02, OB 1996-97 and OB 1991-92 were 10, 10 and 16 respectively. The common species found in all the three OB plantations studied were *Ageratum conyzoides* L., *Atylosia scarabaeoides* (L.) Benth., *Euphorbia hirta* L., *Hyptis suaveolens* (L.) Poit., *Tridex procumbens* L., *Eragrotis tenella* (L.) P.Beauv. ex Roem. & Schult., *Oplismenus burmanii* (Retz.) P.Beauv. The species exclusive to 1996-97 and 1991-92 OB plantations were *Pergularia daemia* (Forssk.) Chiov. and *Marsdenia tenacissima* (Roxb.) Moon, respectively. The data on plant density of these common species showed that the density increases with the increase of age of plantations. The plant density (plants/sqm) of herbs and climbers in OB 2001-02, OB 1996-97 and OB 1991-92 were 12.26, 15.72 and 24.04 respectively. However, for grasses, it was 25.87, 30.49 and 46.45 plantsm^{-2} in OB 2001-02, OB 1996-97 and OB 1991-92 respectively. The diversity index was found to be 1.9796, 1.6768 and 1.7452 with plantations of 17 years, 12 years and 7 years respectively.

Table 1. Density (plants /m^2) of Different Ground Flora Species Occurring in Overburden (OB) Plantations at Jayant, NCL Singrauli

S. N.	Species	Density (plants /m^2) of different ground flora species occurring in overburden (OB) plantations		
		17 years (1991-92)	12 years (1996-97)	7 years (2001-02)
Herbs and climbers				
1.	*Adiantum lunulatum*	1.25	-	1.11
2.	*Ageratum conyzoides*	1.15	3.23	2.20
3.	*Alternanthera sessilis*	1.00	1.10	2.02
4.	*Atylosia scarabaeoides*	1.00	2.10	2.12
5.	*Corchorus astuens*	1.85	-	-
6.	*Euphorbia hirta*	2.33	2.85	1.23
7.	*Hemidesmus indicus*	2.99	1.45	-
8.	*Heylandia latebrosa*	1.22	1.10	-
9.	*Hyptis suaveolens*	1.73	1.56	2.36
10.	*Justicia simplex*	2.55	-	-
11.	*Marsdenia tenacissima*	1.23	-	-
12.	*Heylandia latebrosa*	3.22	-	-
13.	*Pergularia daemia*	1.23	-	-
14.	*Tridex procumbems*	1.29	2.33	1.22
	Sub total	**24.04**	**15.72**	**12.26**
Grasses				
15.	*Eragrostis tenella*	5.23	6.89	7.22
16.	*Oplismenus burmanii*	41.22	23.6	10
17.	*Pennisetum pedicillatum*	-	-	8.65
	Sub total	**46.45**	**30.49**	**25.87**
		1.7452	**1.6768**	**1.9796**

3.2.2. Dudhichua Opencast Project: Table 2 shows the floristic composition and density (plants/sqm) of ground flora comprising herbs, climbers, shrubs and grasses found in different aged OB dump plantations of Dudhichua OCP. The data reveals that there are 7 species of herbs and climbers, 1 species of shrub and 2 species of grasses found in different plantations viz., OB 2000-01, OB 2004-05 and OB 2007-08. The number of herb and climber species found in OB 2000-01, OB 2004-05 and OB 2007-08 were 05, 04 and 03 respectively. The common species found in all the three OB plantations studied were *Alternanthera sessilis* (L.) R.Br. ex DC., *Hyptis suaveolens* (L.) Poit., *Imperata cylindrica* (L.) P. Beauv. and *Oplismenus burmanii* (Retz.) P.Beauv. The plant density (plants/sqm) of herbs and climbers in OB 2000-01, OB 2004-05, OB 2007-08 were 8.65, 8.22 and 7.93 respectively. However, for grasses, it was 9.27, 8.46 and 4.81 plants per sqm in OB 2000-01, OB 2004-05 and OB 2007-08 respectively. The diversity index was found to be 1.8861, 1.5703 and 1.7090 with plantations of 9 years, 4 years and 2 years respectively.

Table 2. Density (plants /m$^{2)}$ of Different Ground Flora Species Occurring in Overburden (OB) Plantations at Dudhichua, NCL Singrauli

S.N.	Species	Density (plants /m^2) of different ground flora species occurring in overburden (OB) plantations		
		9 years (2000-01)	4 years (2004-05)	2 years (2007-08)
Herbs and climbers				
1.	*Alternanthera sessilis*	3.20	2.67	2.12
2.	*Cassia tora*	01	-	-
3.	*Hyptis suaveolens*	1.78	3.20	3.31
4.	*Sida cordifolia*	1.67	1.10	-
5.	*Vernonia cineria*	01	-	-
6.	*Aeschynomene indica*	-	1.25	-
7.	*Tridex procumbens*	-	-	2.50
	Sub total	**8.65**	**8.22**	**7.93**
Shrubs				
8.	*Calotropis gigantea*	1.11	-	1.37
	Sub total	**1.11**	-	**1.37**
Grasses				
9.	*Imperata cylindrica*	3.60	1.56	1.11
10.	*Oplismenus burmanii*	5.67	6.90	3.70
	Sub total	**9.27**	**8.46**	**4.81**
	Shannon-Wiener Index of Diversity in different OB years plantations	**1.8861**	**1.5703**	**1.7090**

3.2.3. Amlohri opencast project: Table 3 shows the floristic composition and density (plants/sqm) of ground flora comprising herbs, climbers, shrubs and grasses found in different aged OB dump plantations of Amlohri OCP. The data reveals that there were 10 species of herbs and climbers, and 3 species of grasses found in different plantations viz., OB 1993-94, OB 2002-03 and OB 2005-06. These were namely *Aeschynomene indica* L., *Ageratum conyzoides* L., *Cassia tora* L., *Desmodium triflorum* (L.) DC., *Hemidesmus indicus* (L.) R.Br., *Hyptis suaveolens* (L.) Poit., *Justicia simplex* D.Don., *Sida cordifolia* L., *Tephrosia purpurea* (L.) Pers., *Vernonia cineria* (L.) Less., *Eragrotis tenella* (L.) P.Beauv. ex Roem. & Schult., *Oplismenus burmanii* (Retz.) P.Beauv., *Pennisetum pedicillatum* L. The common species found in all the 3 OB plantations studied was *Hyptis suaveolens* (L.) Poit. The plant density (plants/sqm) of herbs and climbers in OB 1993-94, OB 2002-03 and OB 2005-06 were 74.61, 51.83 and 45.88 respectively. However, for grasses, it was 8.45, 3.25 and 3.23 plants per sqm in OB 1993-94, OB 2002-03 and OB 2005-06 respectively. The data reveals that the density of ground flora species in OB plantation was found to increase with the increase of age of plantation. The diversity index was found to be 1.3431, 1.1747 and 0.9453 with plantations of 15 years, 6 years and 3 years respectively.

Table 3. Density (plants /m^2) of Different Ground Flora Species Occurring in Overburden (OB) plantations at Amlohri, NCL Singrauli

S.N.	Species	Density (plants /m^2) of different ground flora species occurring in overburden (OB)plantations		
		15 years (1993-94)	6 years (2002-03)	3 years (2005-06)
Herbs and climbers				
1.	*Aeschynomene indica*	1.63	-	-
2.	*Ageratum conyzoides*	10.57	13.26	12.37
3.	*Cassia tora*	1.90	1.20	-
4.	*Desmodium triflorum*	-	2.79	-
5.	*Hemidesmus indicus*	1.37	-	-
6.	*Hyptis suaveolens*	54.23	32.59	32.15
7.	*Justicia simplex*	1.23	-	-
8.	*Sida cordifolia*	2.57	-	-
9.	*Tephrosia purporea*	-	1.99	-
10.	*Vernonia cineria*	1.11	-	1.36
	Sub total	**74.61**	**51.83**	**45.88**
Grasses				
11.	*Eragrostis tenella*	2.37	-	1.11
12.	*Oplismenus burmanii*	3.12	-	2.12
13.	*Pennisetum pedicillatum*	2.96	3.25	-
	Sub total	**8.45**	**3.25**	**3.23**
	Shannon-Wiener Index of Diversity in different OB years plantations	**1.3431**	**1.1747**	**0.9453**

3.2.4. Jhingurdah Opencast Project: Table 4 shows the floristic composition and density (plants/sqm) of ground flora comprising herbs, climbers, shrubs and grasses found in different aged OB dump plantations of Jhingurdah OCP. The data reveals that there were 06 species of herbs and climbers and 4 species of grasses found in different plantations viz., OB 2003-04, OB 2000-01 and OB 1990-91. These were namely *Achyranthes aspera* L., *Ageratum conyzoides* L., *Hyptis suaveolens* (L.) Poit., *Justicia simplex* D.Don., *Launaea nudicalis* (L.) Hook., *Tephrosia purpurea* (L.) Pers., *Apluta mutica* L., *Aristida adscensionis* L., *Bothriochloa pertusa* (L.) A.Camus, *Heteropogon contortus (L.) P.Beauv ex Roem. & Schult.*,. The common species found in all the 3 stands (OB plantations) studied were *Achyranthes aspera* L., *Ageratum conyzoides* L., *Hyptis suaveolens* (L.) Poit., *Justicia simplex* D.Don., *Launaea nudicalis* (L.) Hook., *Tephrosia purpurea* (L.) Pers., *Apluta mutica* L., *Aristida adscensionis* L., *Bothriochloa purtusa* (L.) A. Camus., *Heteropogon contortus* (L.) P.Beauv ex Roem. & Schult. The plant density (plants/sqm) of herbs and climbers in OB 2003-04, OB 2000-01 and OB 1990-91 were 33.4, 39.64 and 50.81 respectively. However, for grasses, it was 15.67, 18. 52 and 23.99 plants per sqm in OB 2003-04, OB 2000-01 and OB 1990-91 respectively. The diversity index was found to be 2.2409, 2.1989 and 2.2321 with plantations of 5 years, 8 years and 19 years respectively.

Table 4. Density (plants /m^2) of Different Ground Flora Species Occurring in Overburden (OB) Plantations at Jhingurdah, NCL Singrauli

S.N.	Species	Density (plants /m^2) of different ground flora species occurring in overburden plantations		
		5 years (2003-04)	8 years (2000-01)	19 years (1990-91)
Herbs and climbers				
1.	*Achyranthes aspera.*	3.12	5.37	6.25
2.	*Ageratum conyzoides*	6.20	8.76	9.98
3.	*Hyptis suaveolens*	7.12	9.10	11.20
4.	*Justicia simplex*	8.67	10.36	13.16
5.	*Launaea nudicaulis*	5.19	4.52	6.72
6.	*Tephrosia purporea*	3.10	1.53	3.50
	Sub total	**33.40**	**39.64**	**50.81**
Grasses				
7.	*Apluda mutica*	4.39	3.79	4.90
8.	*Aristida adscensionis*	3.63	4.23	5.74
9.	*Bothriochloa pertusa*	3.52	4.78	6.10
10.	*Heteropogon contortus*	4.13	5.72	7.25
	Sub total	**15.67**	**18.52**	**23.99**
	Shannon-Wiener Index of Diversity in different OB years plantations	**2.2409**	**2.1989**	**2.2321**

3.2.5. Nigahi Opencast Project: Table 5 shows the floristic composition and density (plants/sqm) of ground flora comprising herbs, climbers, shrubs and grasses found in 4 stands different aged OB dump plantations of Nigahi OCP. The data reveals that there were 7 species of herbs and climbers, and 5 species of grasses found in different stands viz., OB 2007-08, OB 2003-04, OB 1999-2000 and OB 1994-95. These were namely *Achyranthes aspera* L., *Alternanthera sessilis* (L.) R.Br.ex DC., *Biophytum sensitivum* (L.) DC., *Cassia tora* L., *Hyptis suaveolens* (L.) Poit., *Tridex procumbens L.*, *Vernonia cineria* (L.) Less., *Eragrotis tenella* (L.) P.Beauv. ex Roem. & Schult., *Eragrostis uniloides* (Retz.) Nees ex Steud., *Heteropogon contortus* (L.) P.Beauv ex Roem. & Schult., *Imperata cylindrica* (L.) P. Beauv., *Oplismenus burmanii* (Retz.) P.Beauv. The common species found in all the 4 stands of OB plantations studied were *Alternanthera sessilis* and *Eragrostis tenella.* The plant density (plants/sqm) of herbs and climbers in OB 2007-08, OB 2003-04, OB 1999-2000 and OB 1994-95 were 13.71, 7.13, 7.25 and 10.99 respectively. However, for grasses, it was 2.85, 24.80, 40.99 and 48.99 plants per sqm in OB 2007-08, OB 2003-04, OB 1999-2000 and OB 1994-95 respectively. The diversity index was found to be 2.0269, 0.9737, 1.1397 and 1.3364 with plantations of 2 years, 4 years 10 years and 14 years respectively.

Table 5. Density (plants /m^2) of Different Ground Flora Species Occurring in Overburden (OB) at Nigahi, NCL Singrauli

S. N.	Species	Density (plants /m^2) of different ground flora species in different years plantations raised on OB areas			
		2 years (2007-08)	4 years (2003-04)	10 years (1999-2000)	14 years (1994-95)
Herbs and climbers					
1.	*Achyranthes aspera.*	3.21	1.65	-	1.11
2.	*Alternanthera sessilis*	2.31	2.65	3.63	2.61
3.	*Biophytum sensitivum*	-	1.28	-	2.00
4.	*Cassia tora*	2.13	1.55	-	1.32
5.	*Hyptis suaveolens*	2.36	-	-	3.95
6.	*Tridex procumbems*	2.59	-	-	-
7.	*Vernonia cineria*	1.11	-	3.62	-
	Sub total	**13.71**	**7.13**	**7.25**	**10.99**
Grasses					
8.	*Eragrostis tenella*	1.56	1.11	3.11	3.66
9.	*Eragrostis uniloides*	-	-	3.65	-
10.	*Heteropogon contortus*	-	-	-	3.42
11.	*Imperata cylindrica*	1.29	-	1.62	2.66
12.	*Oplismenus burmanii*	-	23.69	32.61	39.25
	Sub total	**2.85**	**24.80**	**40.99**	**48.99**
	Shannon-Wiener Index of Diversity in different OB years plantations	**2.0269**	**0.9737**	**1.1397**	**1.3364**

3.2.6. Bina Opencast Project: Table 6 shows the floristic composition and density (plants/sqm) of ground flora comprising herbs, climbers, shrubs and grasses found in 4 stands different aged OB dump plantations of Bina OCP (U.P.). The data reveals that there were 07 species of herbs and climbers, 1 species of shrub and 03 species of grasses found in different stands viz., OB 2007-08, OB 2003-04, OB 1998-99 and OB 1994-1995. These were namely *Achyranthes aspera* L., *Alternanthera sessilis* (L.) R.Br.ex DC., *Cassia tora* L., *Euphorbia hirta* L., *Hyptis suaveolens* (L.) Poit., *Launaea nudicaulis* (Linn.) Hook. f., *Tridex procumbens L., Lantana camara* Auct.non L., *Eragrotis tenella* (L.) P.Beauv. ex Roem. & Schult., *Imperata cylindrica* (L.) P. Beauv., *Oplismenus burmanii* (Retz.) P.Beauv. The common species found in all the 4 stands (OB plantations) studied were *Alternanthera sessilis* (L.) R.Br.ex DC., *Hyptis suaveolens* (L.) Poit. and *Oplismenus burmanii* (Retz.) P.Beauv. The plant density (plants/sqm) of herbs and climbers in OB 2007-08, OB 2003-04, OB 1998-99, OB 1994-1995 were 7.62, 26.23, 38.35 and 33.40 respectively. However, for grasses, it was 113.79, 39.46, 97.71 and 36.76 plants /m^2 in OB 2007-08, OB 2003-04, OB 1998-99 and OB 1994-1995 respectively. The diversity index was found to be 1.8016, 1.5233, 1.6392 and 1.2259 with plantations of 14 years, 10 years, 5 years and 1 years respectively.

Table 6. Density (plants /m^2) of Different Ground Flora Species Occurring Inoverburden (OB) Plantations at Bina, NCL Singrauli

S.N.	Species	Density (plants /m^2) of different ground flora species occurring in overburden (OB) plantations			
		14 years (1994-95)	10 years (1998-99)	5 years (2003-04)	1 years (2007-08)
Herbs and climbers					
1.	*Achyranthes aspera.*	1.53	2.97	-	-
2.	*Alternanthera sessilis*	3.90	1.67	3.62	3.15
3.	*Cassia tora*	1.12	-	-	1.67
4.	*Euphorbia hirta*	2.30	3.57	6.20	-
5.	*Hyptis suaveolens*	23.16	25.90	11.60	2.80
6.	*Launaea nudicalis*	-	-	1.25	-
7.	*Tridex procumbems*	1.23	4.24	3.56	-
	Sub total	**33.24**	**38.35**	**26.23**	**7.62**
Shrubs					
8.	*Lantana camara*	11.60	12.30	-	-
	Sub total	**11.60**	**12.30**	**-**	-
Grasses					
9.	*Eragrostis tenella*	10.50	-	17.10	15.37
10.	*Imperata cylindrica*	2.30	32.10	-	42.10
11.	*Oplismenus burmanii*	23.96	65.61	22.36	56.32
	Sub total	**36.76**	**97.71**	**39.46**	**113.79**
	Shannon-Wiener Index of Diversity in different OB years plantations	**1.8016**	**1.5233**	**1.6392**	**1.2259**

3.2.7. Kakari Opencast Project: Table 7 shows the floristic composition and density (plants/sqm) of ground flora comprising herbs, climbers, shrubs and grasses found in 4 stands (different aged OB dump plantations) of Kakari OCP (U.P.). The data reveals that there were 11 species of herbs and climbers, 02 species of shrub and 9 species of grasses found in different stands viz., OB 1994-95, OB 1998-99, OB 1990-1991 and OB 2004-05. These were namely *Ageratum conyzoides* L., *Alternanthera sessilis* (L.) R.Br.ex DC., *Blumea lacera, (*Burm.f.) DC. *Cassia tora* L., *Desmodium triflorum* (L.) DC., *Euphorbia hirta* L., *Gomphrena celosioides* Mart., *Hyptis suaveolens* (L.) Poit., *Justicia simplex* D.Don., *Tridex procumbens L., Vernonia cineria* (L.) Less., *Calotropis gigantea* (Ait.) Ait. f., *Carissa opaca* Stapf. ex Haines., *Apluta mutica* L., *Aristida adscensionis* L., *Bothriochloa pertusa* (L.) A.Camus, *Chloris barbata* Sw., *Digitaria adscendens* (H.B.K.) Henr. *Eragrostis uniloides* (Retz.) Nees ex Steud., *Imperata cylindrica* (L.) P. Beauv., *Oplismenus burmanii* (Retz.) P.Beauv., *Paspalum longifolium* Roxb. The common species found in all the 4 stands (OB plantations) studied was *Alternanthera sessilis* (L.) R.Br.ex DC. The plant density (plants/sqm) of herbs and climbers in OB 1994-95, OB 1998-99, OB 1990-1991 and OB 2004-05 were 57.96, 58.32, 24.30 and 20.62 respectively. However, for grasses, it was 19.98, 15.22, 11.21 and 7.56 plants /m^2 in OB 1994-95, OB 1998-99, OB 1990-91 and OB 2004-05 respectively. The diversity index was found to be 2.1709, 2.1056, 1.5820 and 1.9132 with plantations of 14 years, 10 years, 18 years and 4 years respectively.

Table 7. Density (plants /m^2) of Different Ground Flora Species Occurring in Overburden (OB) Plantations at Kakari, NCL Singrauli

S.N.	Species	Density (plants /m^2)of different ground flora species occurring in overburden (OB) plantations			
		14 years (1994-95)	10 years (1998-99)	18 years (1990-91)	4 years (2004-05)
Herbs and climbers					
1.	*Ageratum conyzoides*	12.23	11.67	11.53	6.23
2.	*Alternanthera sessilis*	14.34	7.13	6.57	2.66
3.	*Blumea lacera*	1.53	2.67	-	-
4.	*Cassia tora*	-	-	3.22	-
5.	*Desmodium triflorum*	-	-	-	5.36
6.	*Euphorbia hirta*	5.64	15.99	-	2.39
7.	*Gomphrena celosioides*	3.21	-	-	-
8.	*Hyptis suaveolens*	16.35	19.89	-	-
9.	*Justicia simplex*	-	-	-	2.88
10.	*Tridex procumbems*	4.66	1.97	-	1.10
11.	*Vernonia cineria*	-	-	2.98	-
	Sub total	**57.96**	**59.32**	**24.30**	**20.62**
Shrubs					
12.	*Calotropis gigantea*	1.44	-	-	-
13.	*Carissa opeca*	-	4.77	-	-
	Sub total	**1.44**	**4.77**	**-**	**-**
Grasses					
14.	*Apluda mutica*	6.45	-	-	-
15.	*Aristida adscensionis*	-	2.10		6.33
16.	*Bothriochloa pertusa*	4.66	-	-	1.23
17.	*Chloris barbata*	-	2.33	-	-
18.	*Digitaria adscendens*	-	-	1.33	-
19.	*Eragrostis uniloides*	8.87	-	-	-
20.	*Imperata cylindrica*	-	-	9.88	-
21.	*Oplismenus burmanii*	-	6.55	-	-
22.	*Paspalum longifolium*	-	4.24	-	-
Sub total		**19.98**	**15.22**	**11.21**	**7.56**
	Shannon-Wiener Index of Diversity in different OB years plantations	**2.1709**	**2.1056**	**1.5820**	**1.9132**

3.2.8. Khadia Opencast Project: Table 8 shows the floristic composition and density (plants/sqm) of ground flora comprising herbs, climbers, shrubs and grasses found in 4 stands (different aged OB dump plantations) of Khadia OCP (U.P.). The data reveals that there were 08 species of herbs and climbers, 01 species of shrub and 04 species of grasses found in different stands viz., OB 1994-95, OB 1998-99, OB 2002-03 and OB 2005-06. These were namely *Achyranthes aspera* L., *Aeschynomene indica* L., *Ageratum conyzoides* L., *Hyptis suaveolens* (L.) Poit., *Sida acuta* Burm.F., *Sida cordifolia* L., *Tephrosia purpurea* (L.) Pers., *Tridex procumbens L., Lantana camara* Auct.non L., *Eragrotis tenella* (L.) P.Beauv. ex Roem. & Schult., *Heteropogon contortus* (L.) P.Beauv ex Roem. & Schult., *Imperata cylindrica* (L.) P. Beauv., *Oplismenus burmanii* (Retz.) P.Beauv. The plant density (plants/sqm) of herbs and climbers in OB 1994-95, OB 1998-99, OB 2002-03 and OB 2005-06 were 23.64, 9.21, 3.99 and 6.33 respectively. However, for grasses, it was 40.59, 26.43, 34.89 and 22.66 plants /m^2 in OB 1994-95, OB 1998-99, OB 2002-03 and OB 2005-06

respectively. The diversity index was found to be 1.6953, 1.4132, 0.8390 and 0.7575 with plantations of 14 years, 10 years, 6 years and 3 years respectively.

Table 8. Density (plants /m^2) of Different Ground Flora Species Occurring in Overburden (OB) Plantations at Khadia, NCL Singrauli

S.N.	Species	Density (plants /m^2) of different ground flora species occurring in overburden (OB) plantations			
		14 years (1994-95)	10 years (1998-99)	6 years (2002-03)	3 years (2005-06)
Herbs and climbers					
1.	*Achyranthes aspera.*	5.35	5.10	-	-
2.	*Aeschynomene indica*	3.26	-	-	2.89
3.	*Ageratum conyzoides*	-	-	2.33	-
4.	*Hyptis suaveolens*	6.99	-	-	-
5.	*Sida acuta*	3.56	-	-	1.78
6.	*Sida cordifolia*	-	1.33	-	-
7.	*Tephrosia purpurea*	3.26	-	-	1.66
8.	*Tridex procumbems*	1.22	2.78	1.66	-
	Sub total	**23.64**	**9.21**	**3.99**	**6.33**
Shrubs					
9.	*Lantana camara*	5.66	2.22	3.12	-
	Sub total	**5.66**	**2.22**	**3.12**	**-**
Grasses					
10.	*Eragrostis tenella*	6.56	3.88	2.33	-
11.	*Heteropogon contortus*	1.70	1.22	-	-
12.	*Imperata cylindrica*	-	-	-	22.66
13.	*Oplismenus burmanii*	40.33	21.33	32.56	-
	Sub total	**48.59**	**26.43**	**34.89**	**22.66**
	Shannon-Wiener Index of Diversity in different OB years plantations	**1.6953**	**1.4132**	**0.8390**	**0.7575**

3.3. Biomass of Ground Flora: Table 9 shows the site wise and age wise ground flora biomass of both above ground and below ground was determined in different aged OB plantations. In general, the biomass was found to show the increasing trend with the advancement of age of plantations. Though, the values of both above ground and below ground biomass were found to vary with the variation of locality. The value of above ground biomass was comparatively higher than the below ground biomass in each plantation. The maximum and minimum values of total biomass varied from 0.339 tonnes per ha. (2 year old plantation of Dudhichua) to 1.993 tonnes per ha (16 year old plantation of Amlohri). The value of carbon content in ground flora was found to be varied from 0.169 tonnes per ha. (2 year old plantation of Dudhichua) to 0.997 tonnes per ha (16 year old plantation of Amlohri). The linear correlation between Age vs total ground flora biomass was found to be significant with the values of $R^2 = 0.604$ as depicted in Figure 1. The values of R^2 are greater than 0.5 which indicates that the better the line fits the data.

Table 9. Oven Dry Biomass (above ground and below ground) of Ground Flora in Different Aged OB Plantations at Different Project Sites of NCL Singrauli

S.N.	Site	Age (years)	Above Ground Biomass (tonnes/ha)	Below Ground Biomass (tonnes/ha)	Total Biomass (tonnes/ha)	Carbon content (tonnes/ha)
1	Jayant	18	0.924	0.707	1.631	0.815
		13	0.648	0.496	1.144	0.572
		8	0.517	0.396	0.913	0.456
2	Dudhichua	8	0.259	0.198	0.457	0.228
		5	0.227	0.173	0.400	0.200
		2	0.192	0.147	0.339	0.169
3	Amlohri	16	1.130	0.864	1.993	0.997
		7	0.749	0.573	1.322	0.661
		4	0.668	0.511	1.179	0.589
4	Jhingurdah	6	0.667	0.510	1.178	0.589
		9	0.796	0.609	1.404	0.702
		19	1.780	0.920	2.700	1.350
5	Nigahi	14	0.816	0.624	1.440	0.720
		10	0.656	0.502	1.158	0.579
		5	0.434	0.332	0.766	0.383
		2	0.225	0.172	0.397	0.199
6	Bina	14	1.110	0.849	1.958	0.979
		6	0.893	0.683	1.577	0.788
7	Kakri	15	1.080	0.826	1.905	0.953
		11	1.079	0.825	1.903	0.952
		5	0.383	0.293	0.676	0.338
8	Khadia	15	1.059	0.810	1.869	0.935
		11	0.515	0.394	0.909	0.454
		7	0.571	0.437	1.008	0.504
		4	0.394	0.301	0.696	0.348

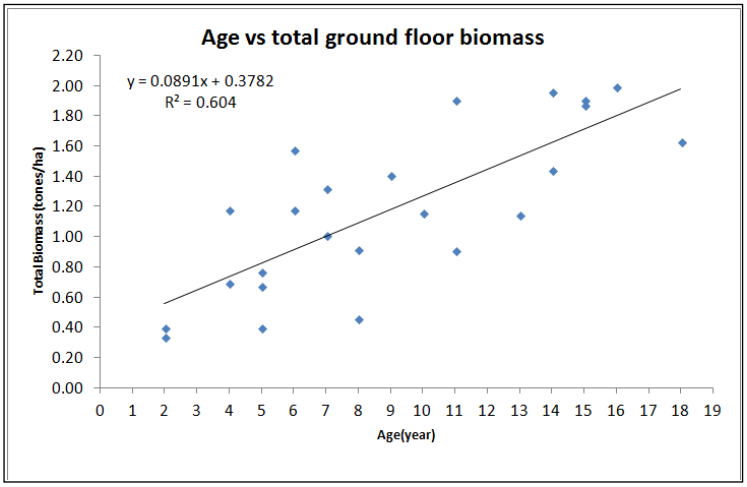

Figure 1. Age vs Total Ground Floor Biomass

4. Discussion

In the present study total 44 ground flora species were enumerated from all aged overburden plantations. Of which, 17 species viz; *Achyranthes aspera, Aeschynomene indica, Ageratum conyzoides, Alternanthera sessilis, Aristida adscensionis, Cassia tora, Eragrostis tenella, Euphorbia hirta, Heteropogon contortus, Hyptis suaveolens Imperata cylindrical, Justicia simplex, Oplismenus burmanii, Sida cordifolia, Tephrosia purporea, Tridex procumbems* and *Vernonia cineria* were found common at different project sites in most of the overburden plantations. However, the 21 species viz; *Apluda mutica, Atylosia scarabaeoides, Biophytum sensitivum, Blumea lacera, Bothriochloa, pertusa, Calotropis gigantea, Carissa opeca, Chloris barbata, Corchorus astuens, Digitaria adscendens, Eragrostis uniloides, Gomphrena celosioides, Hemidesmus indicus, Heylandia latebrosa, Lantana camara, Launaea nudicalis, Marsdenia tenacissima, Paspalum longifolium, Pennisetum pedicillatum, Pergularia daemia* and *Sida acuta* are almost common in old age plantations, probably due to availability of good soil moisture and high organic matter content in the soil. The majority of the ground flora species in most of the plantations are consisted of forbs as they can adapt themselves according ot their respective habitats (Misra, 1959). Prasad (1976) also reported the mechanism of survival of ground flora species under different growing conditions. He stated that food and water reserves form the bulbs, thicker and longer tap roots and vast lateral roots enable the ground flora species to survive in difficult sites. The total density of ground flora species per sq/m was found to be comparatively higher with the advancement of age of plantations. The study of the development and succession of ground flora communities in forest plantations is of practical importance to forestry. The ground flora community not only indicates the fertility status of the forest but also gives an idea of the growth and development of ground flora species as it is intimately related to it. Normally, environmental factors determine the distribution of ground flora which in turn, appears to be related with woody vegetation and soil conditions (Godall, 1952). In literature, considerable importance has been attached to the study of ground flora in relation to availability of light, amount of soil moisture, organic carbon in soil, crown cover, stand structure, etc (Cajander, 1926; Mohan and Puri, 1955, 56; Puri and Gupta, 1951; Upadhyay, 1955; Mishra and Joshi, 1952; Mathur *et al*., 1976; Rajavanshi *et al.*, 1983; Mathur and Soni, 1983; Whitehead, 1981, 1982). Vegetation potential of any area is dependent upon physical environmental limitations and edapho-biotic components and their interaction, soil surface characteristics, climate and vegetation after opencast coal mining. Success of individual species and community composition are governed by local site variables. The substrate conditions on individual mine site act as an environmental sieve (Harper and white, 1977; Nath, 2009). Most suited species are able to establish and become an important component of the community.

Diversity index shows the ratios between the number of species and total density of individual of all species. Species diversity tends to be low in physically controlled communities and high in biologically control communities. It is directly correlated with stability, but it is not certain to what extent this relationship is a cause - and - effect one. Normally the Shannon-Wiener Index values (H) can range of 0 to 4.6 using the natural log(ln). A value near 0 would indicate that every species in the sample is the same. A value near 4.6 would indicate that the number of individuals are evenly distributed between all the species. Values in the middle are ambiguous which an obvious flaw of this index (Odum and Barrett, 2005). In general, the current values of diversity index in different plantations indicate towards middle score and are ambiguous which an obvious flaw of this index.

Although evidence has indicated unassisted process of natural colonization to deliver fully developed and functional ecosystems within 100 years (Bradshaw, 2000), the adverse and

fragile mine wastelands often require human assistance if restoration goal is expected to achieve within a reasonable time frame.

Natural revegetation studies in coalmines overburdens were mainly confined to dry deciduous zone of M.P. In un-reclaimed and un-rehabilitated overburden spoils, ground flora and coming up naturally and increase in number of species in a function of the age of the overburdens. Jha and Singh (1990), while investigating vascular flora of naturally vegetated coal mine spoils in Jhingurda block, Singrauli (NCL), M.P., found the richest diversity at 20 year old site with 21 herbaceous species. Number of trees was also high. spoils of 5 and 10 years of age favored growth of only 9 herbaceous species. *Aristida adscensionis, Bothriochloa pertusa, Dactyloctenium aegyptium, Tephrosia purpurea, Tridexprocumbens, Cassia tora* and *Xanthium strumarium* were the most abundant species at most of the microsites (slope, coal patch, undulating surface and flat surface). *Butea monosperma* was the most frequent woody component of the vegetation. Prasad and Srivastava (1991) enumerated ground flora in Dhanpuri coal mine, M.P. from an age-series (2 to 8 years) of re-vegetated and barren micro-sites of coal mine spoils. The newer sites favored fewer occurrences of species, which increased with age of spoil. The community structure differs from place to place. Banerjee *et al.* (1996, 2001) reported different community structure from Singrauli, Sidhi and Gevra, Bilaspur, M.P. They observed less proportion of legumes than non-legumes and the increasing trend of legumes indicates gradual improvement in fertility status of the spoil. The presence of seedlings of different tree species *(Azadiracta indica, Butea monosperma, Diospyros melanoxylon, Terminalia belerica*, etc) is reflection of gradual venture of invading the dumps by tree species. In the present study, the no. and density of ground flora species (plants/sqm) was found increasing with increase in age of plantations on reclaimed OB dumps plantations. The findings are in agreement with the study of floristic composition, species diversity and distributional pattern of ground flora under teak plantations of different ages in Madhya Pradesh (Chaubey, 1986), which indicated that no. of species and species diversity was increased with the advancement of age of plantations and in due course, members of Gramiae becomes prominent and with the advancement of crown cover the nature of species composition and their abundance changed as per the ecological conditions of the site.

5. Conclusion

The brief accounts of the findings are summarized below:

1. Ecological succession of ground flora in terms of number of species was comparatively faster on reclaimed OB sites. The frequently occurring ground flora species among different reclaimed sites were *Ageratum conyzoides* L., *Hyptis suaveolens* (L.) Poit., *Tridex procumbens* L., *Alternanthera sessilis* (L.) R.Br.ex DC., *Desmodium triflorum* (L.) DC., *Justicia simplex* D.Don., *Sida cordifolia* L., *Achyranthes aspera* L., *Cassia tora* L., *Tephrosia purporea* (L.) Pers., *Euphorbia hirta* L., *Atylosia scarabaeoides* (L.) Benth., *Oplismenus burmanii* (Retz.) P.Beauv., *Eragrotis tenella* (L.) P.Beauv. ex Roem. & Schult., *Imperata cylindrical* (L.) P.Beauv., *Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult., *Bothriochloa purtusa* (L.) A. Camus., *Apluta mutica* L., *etc.*
2. The density of ground flora species (plants/sqm) was found increasing with increase in age of plantations on reclaimed OB dumps plantations.

3. The diversity index values are falling in the middle range which indicates ambiguous distribution between all the species.
4. In general, the biomass was found to show the increasing trend with the advancement of age of plantations. The maximum and minimum values of total biomass varied from 0.339 tonnes per ha. (2 year old plantation of Dudhichua) to 1.993 tonnes per ha (16 year old plantation of Amlohri). The value of carbon content in ground flora was found to be varied from 0.169 tonnes per ha. (2 year old plantation of Dudhichua) to 0.997 tonnes per ha (16 year old plantation of Amlohri).

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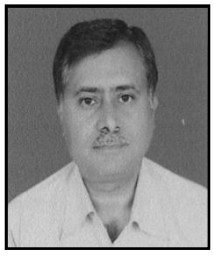

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