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Assessing the changes in plant community composition after the completion of restoration of coal mine overburden area in Dhanbad, India

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Abstract
To address the concern of environmental loss, Bharat Coking Coal Ltd. (BCCL) Dhanbad and Forest Research Institute (FRI), Dehradun initiated restoration of Tetulmari coal mine. Restoration began in 2011 continued till 2014 and an ecological restoration model was developed in 8ha coal mined OB dumps at Tetulmari, Sijua area of Dhanbad to bring back life. Further, for attaining a more stable and sustainable ecosystem at the site, a biodiversity enhancement initiative was taken up by FRI in year 2016-2018 to develop aself sustaining ecosystem at the degraded site. Interventions such as weed eradication, mulching, top soil spread, pitcher irrigation technique were applied to create congenial conditions for plant establishment, survival and growth. In comparison to 58 species recorded in 2013-14, the restoration site in 2018 was observed to be enriched with a total of 103 plant species of which 37 are trees, 15 shrubs, 27 herbs, 9grasses, 2 bamboo, 2 fern, 1 creeper and 10 climber species. Occurrence of native species other than planted species such as *Bombaxceiba*, *Ficus glauca*, *Ficus racemosus*and *Butea monosperma* has shown that the ecologicallyrestored site have started facilitating the inflow of native species which was one of the mainaim of restoration programme.The enhanced biodiversity has facilitated occurrence of manyfaunal species of birds, butterflies, insects, reptiles and few of animals like foxes and rabbits,etc. have naturally recolonized or visiting at restored site. Results of this study suggest thatmining sites can be recovered and forests can be restored to a self-sustaining ecosystems, if appropriate managementstrategies are adopted.

Keywords: restoration, open cast mining, vegetation diversity, self-sustaining ecosystems

Introduction

Leave nature to heal itself said someone. However, natural succession is a time taking process, making human intervention necessary sometimes to hasten the recovery of damage caused by himself. Ecological restoration may be equated with secondary succession after the site recovers sustainably on its own (Cairns, 1991) [2]. The presence of populations of plant species in a particular site will depend on the ability of propagules to be transported to the site and to germinate, and of the young plants to survive and reproduce. The timescales involved are often long and the initial colonization phase, in particular, can show a considerable lag depending on substrate conditions (Ash *et al.*, 1994) [1]. Most studies have focused on techniques used for vegetation establishment, phytoremediation and few researches have examined spontaneous revegetation in mine spoil through soil amendments (Kumar *et al.*, 2008) [7]. Also, studies have suggested that sustainable mine restoration programme requires establishment of self-sustainable ecosystem, by means of improved ecosystem structure and function with respect to ecological integrity (Juwarkar *et al.*, 2016) [7].

The end result for mining activities on the surface is mining wastes and alteration of land forms which is a concern to the society and it is desired that the pristine conditions are restored (Sheoran *et al*., 2010) [9]. The mining disrupts the aesthetics of the landscape along with it disrupts soil components such as soil horizons and structure, soil microbe populations, and nutrient cycles those are crucial for sustaining a healthy ecosystem and hence results in the destruction of existing vegetation and soil profile (Kundu and Ghose, 1997) [4]. Based on a study in the Nokrek Biosphere Reserve in Meghalaya, India, it is revealed that coal mining has adversely affected the vegetation and the density of trees, shrubs and herbs in mined areas (Sarma and Barik, 2011). Acidic dumps may release salt or contain sulphidic material, which can generate acid-mine drainage (Ghose, 2005) [4]. The effects of mine wastes can be multiple, such as soil erosion, air and water pollution, toxicity, geo-environmental disasters, loss of biodiversity, and ultimately loss of economic wealth (Wong, 2003; Sheoran *et al.*, 2008) [11, 9]. An increase in the concerns for environment has made concurrent post-mining reclamation of the degraded land as an integral feature of the whole mining spectrum (Ghose, 1989) [5].

Ecological restoration, which aims to restore the over-exploited or degraded ecosystems, has been a crucial approach to mitigate human pressures on natural ecosystems and to enhance ecosystem services (Holl *et al*., 2003; Feng *et al*., 2013) [6, 3]. Restoration of vegetation cover on overburden dumps can fulfil the objectives of stabilization, pollution control, visual improvement and removal of threats to human beings (Wong, 2003) [11]. Although many restoration practices have been widely incorporated into natural resource strategies from the local to global scales, there are still uncertainties as to how effective restoration programs actually are (Suding, 2011; Wortley *et al*., 2013) [10, 12].

Bharat Coking Coal Limited (BCCL), a subsidiary of Coal India Limited is the major coal mining company and the only producer of prime coking coal in India. It operates in Jharia coal fields which has thickest concentrations of coal fields in the world at

relatively short depths. This work would serve the purpose of guiding future ecological restoration initiatives by BCCL to enhance the biodiversity and its conservation, so that a self-sustained ecosystem could be developed like surrounding undisturbed forests. Such an ecosystem should contain indigenous species, functional groups and capacity to ensure sustainable, stable and viable populations. It should become an integral part of surrounding landscape. Restoration efforts would also help to minimize or manage threats for survival of newly built landscape till it can sustain on its own.

Although the previously carried out ecological restoration efforts had begun to attract some species of birds, animals, reptiles and insects, there was a need to enhance the species richness of the site. This could only be done by increasing the density and diversity of plant species.

Study Area

The area has undulating topography. The maximum and minimum elevation from the mean sea level is 210 m and 170 m respectively. The general slope of the area is towards south along Damodar River. Tetulmari collieries restoration sitesare in Jharia coalfields. The Jharia Coalfield represents the Middle East part of coal basin in the Damodar Valley Basin Belt. It is roughly sickle shaped on plane and covers an area of 450 sq.km. The area belongs to sub-humid tropical climate region. The maximum temperature during summer shoots upto 45°C and falls upto a minimum 5°C during winter. The maximum rainfall occurs between June and September.

Natural Vegetation in the area

Characteristic forest types of the area are tropical moist deciduous forests and tropical dry deciduous forests. Distribution of forests is fragmented and restricted to the patches between west and toward southwest portion of the area. Within the forest there are large patches of open scrubs with rural settlements. At several places, the forest boundary is fragmented due to roads.

Materials and methods

As a part of land and soil management practices various activities were performed as under: •

Weeding and Hoeing

The problem of weed infestation on the project site was a primary concern. The weeds like *Lantana camara, Eupatorium odoratum* and *Hyptis suaveolens* were eradicated from the site, throughout the period. The eradication was done manually i.e. uprooting. Besides weeding, hoeing was carried out and mixture of manure and soil was added to the plants.

Irrigation

Watering and mulching was particularly done on the slopes to enhance the soil moisture status of barren exposed slopes, mulch material containing straw of rice, grasses, leaf and twigs. Digging and manuring of pits with the mixture of soil and manure in the ratio 3:1 was carried out during the month of April-May. Almost 2560 pits of size 2′×2′ were dug out for the plantation activities.

Plantation depending upon seed source, seed size and regenerative capacity of the species, the selective plant species were propagated by adopting following methods:

Plantation

The species whose seeds were very small in size and difficult to regenerate by direct seed broadcast, their seeds were first mixed with soil and manure and then slurry was prepared. These seed mixed slurry were then spread over the area. About two grass species were propagated by using this practice.

For bio fencing, seeds of shrubs were sown along the trenches dug around boundary of the project site.

Tree seedlings were bought from forest nursery at Lodhara nursery of Dhanbad Forest Division and medicinal plants from private nurseries. The seedlings were gently placed in the pits after removing the polythene bags. A total of 20,000 plants of various species having multiple use value were planted during the period of three years (2011-2014). In addition to seed broadcasting either by direct seed sowing or seed mixed slurry, 6060 plant species including tree species horticultural and medicinal plants were propagated through seedling planting in 2016-17. These plants have been successfully established in the site with survival percentage of 80%. In addition to the seedling plantation, other methods of plant propagation were also applied like broadcasting and dispersal of seeds either directly or through slurry mixture and seed balls. The success of the germination was remarkable.

Certain shrub species were propagated in the area through stem cuttings. About 1000 stem cuttings were planted particularly along the boundary of the area including 29 plant species including 24 tree species, one bamboo species, two shrubs and two grass species. These species are of multiple uses like timber, fodder, medicine, food, soil binding and soil enrichment, etc.

The plants in the project site have been under continuous supervision and monitoring since the initiation of the project. Also, the project site was protected from any biotic interference for its proper growth and development.

Vegetation analysis

To assess the species composition and diversity of the ecological restoration site at Tetulmari, quadrats each of dimension, 10 x 10 m for trees, 5 x 5 m for shrubs, saplings, and seedlings while 1 x 1 m for herbaceous were randomly laid in the whole project site. The individuals with more than 5 cm diameter at DBH (1.73 m) were considered as tree, individuals with diameter between 2.0 to 4.9 cm were considered as saplings, and plants less than 2.0 cm in diameter were considered as seedling.

To determine the growth pattern, girth of planted and natural species were measured and all plants were divided in different diameter size class. The occurrence percent frequency of all individuals of each species was estimated.

Results

Status of vegetation diversity in 2014

The ecological restoration work at Tetulmari (08 ha), Sijua was completed in July, 2014. A total of 20,000 plants of various species had been planted during the period of three years these plants had been successfully established in the site with survival percentage of 80%. In addition to the seedling plantation, other methods of plant propagation were also applied while executing the ecological restoration work at the project site. Other methods included broadcasting and dispersal of seeds either directly or through slurry mixture and seed balls. The success of the germination was remarkable. Total 58 species including 32 trees,

8 shrubs, 7 herbs and 11 grass species were recorded at restoration site Tetulmari.

Tree Species

Acacia catechu, Acacia nilotica, Aegle marmelos, Albizia lebbeck, Albizia procera, Artocarpusheterophyllus, Azadirachta indica, Bauhinia purpurea, Bombax ceiba, Butea monosperma, Cassia fistula, Dalbergia sissoo, Delonix regia, Diospyros melanoxylon, Ficus benghalensis, Ficus religiosa, Gmelina arborea, Madhuca longifolia, Mangifera indica, Melia azederachta, Moringa oleifera, Morus alba, Neolamarckia cadamba, Peltophorumpterocarpum, Pongamia pinnata, Psidium guajava, Pthecolobium dulce, Swieteniamahagoni, Syzygium cumini, Terminalia arjuna, Terminalia bellirica (Table 1).

Table 1: Tree diversity in 2014

S. No.	Tree	Common Name	Family	Uses
1.	*Acacia catechu*	Khair	Mimosaceae	Fodder, Medicinal
2.	*Acacia nilotica*	Babul	Mimosaceae	Tooth brushing, fodder
3.	*Aegle marmelos*	Bel	Rutaceae	Medicinal
4.	*Albizzia lebbeck*	Kala sirus	Mimosaceae	Medicinal, Timber
5.	*Albizzia procera*	Safed siris	Mimosaceae	Medicinal, Timber
6.	*Artocarpusheterophyllus*	Kathal	Moraceae	Culinary, medicinal
7.	*Azadirachta indica*	Neem	Meliaceae	Medicinal, Timber
8.	*Bombax ceiba*	Semal	Malvaceae	Fibers
9.	*Butea monosperma*	Palas	Fabaceae	Timber, Fodder, Medicinal and Dye
10.	*Cassia fistula*	Amaltas	Fabaceae	Ornamental
11.	*Dalbergia sissoo*	Rosewood	Fabaceae	Timber
12.	*Delonix regia*	Gulmohar	Caesalpinioideae	Ornamental
13.	*Diospyros melanoxylon*	Beedi leaf	Ebenaceae	Wrapping the tobacco
14.	*Ficus benghalensis*	Bargad	Moraceae	Medicinal
15.	*Ficus religiosa*	Pipal	Moraceae	Medicinal
16.	*Gmelina arborea*	Gamhar	Lamiaceae	Medicinal, Timber
17.	*Mangifera indica*	Aam	Anacardiaceae	Fruit edible, timber
18.	*Melia azadirachta*	Bakain	Meliaceae	Timber
19.	*Moringa oleifera*	Drumstick	Moringaceae	Fruit edible
20.	*Morus alba*	Shahtoot	Moraceae	Fruit edible
21.	*Neolamarckia cadamba*	Kadam	Rubiaceae	Medicinal
22.	*Peltophorumpterocarpum*	Peelagulmohar	Fabaceae	Timber, Fodder
23.	*Pongamia pinnata*	Karanj	Fabaceae	Medicinal
24.	*Pithecellobium dulce*	Manila tamarind	Fabaceae	Fruit edible
25.	*Swieteniamahagoni*	Mahagony	Meliaceae	Timber
26.	*Syzygium cumini*	Jamun	Myrtaceae	Fruit edible
27.	*Terminalia arjuna*	Arjuna	Combretaceae	Medicinal
28.	*Terminalia bellirica*	Bahera	Combretaceae	Medicinal

Shrub Species: *Annona squamosa, Carissa carandas,Indigofera tinctoria, Ricinus communis, Zizyphusnummularia* (Table 2).

Table 2: Shrub diversity in 2014

S. No.	Shrub	Common Name	Family	Uses
1.	*Annona squamosa*	Sarifa	Annonaceae	Fruit edible
2.	*Carissa carandas*	Karonda	Apocynaceae	Medicinal
3.	*Indigofera tinctoria*	Neel	Fabaceae	Medicinal, Dye
4.	*Ricinus communis*	Arandi	Euphorbiaceae	Medicinal
5.	*Zizyphusnummularia*	Beri	Rahmnaceae	Fruit edible

Herbaceous Species: *Agave sislana, Abrusprecatorius, Coccinia indica, Datura stramonium, Mimosa pudica, Withania somnifera, Ziziphus jujube, Trifolium repens* (Table 3).

Table 3: Herb diversity in 2014

S. No.	Herb	Common Name	Family	Uses
1.	*Agave sislana*	Sisal	Asparagaceae	Hedges
2.	*Abrusprecatorius*	Ratti	Fabaceae	Medicinal
3.	*Coccinia indica*	Kundru	Cucurbitaceae	Antidiabetic
4.	*Datura stramonium*	Datura	Solanaceae	Medicinal
5.	*Mimosa pudica*	Chui-mui	Leguminaceae	Used in Diabetes
6.	*Trifolium repens*	Dutch Clover	Fabaceae	Medicinal

7.	*Withania somnifera*	Ashwagandha	Solanaceae	Medicinal
8.	*Ziziphus jujube*	Red Date	Rahmnaceae	Fruit edible

Grass Species

Arundo donax, Cenchrus ciliaris, Cenchrussetigerus, Cymbopogon citratus, Cymbopogon nardus, Cynodon dactylon, Panicum antidotale, Saccharum bengalense, Vetiveriazizaniodesand bamboo species including Bambusa bamboos, Dendrocalmusstrictus (Table 4).

Table 4: Grass diversity in 2014

S. No.	Grass	Common Name	Family	Uses
1.	*Arundo donax*	Elephant grass	Poaceae	Medicinal
2.	*Cenchrus ciliaris*	Dhaman	Poaceae	Forage
3.	*Cymbopogon citratus*	lemon grass	Poaceae	Medicinal
4.	*Cymbopogon nardus*	citronella grass	Poaceae	Food flavoring
5.	*Cynodon dactylon*	Dhoob	Poaceae	Medicinal, fodder
6.	*Panicum antidotale*	Kutki	Poaceae	Medicinal
7.	*Saccharum bengalense*	Sarkanda	Poaceae	Medicinal
8.	*Vetiveriazizanioides*	Khas grass	Poaceae	Cooling agent
9.	*Bambusa bamboos*	Thorny Bamboo	Poaceae	construction purposes
10.	*Dendrocalmusstrictus*	Male bamboo	Poaceae	Fences, Agricultural implements

Vegetation status recorded in 2018

At present the restoration site is enriched with a total 103 plant species of which 37 are trees, 15 shrubs, 27 herbs, 9 grasses, 2 bamboo, 2 fern, 1 creeper and 10 climber species.

Tree species

Albizia lebbeck, Albizia procera, Albizia chinensis, Alstonia scholaris, Azadirachta indica, Bauhinia variegata, Bauhinia racemosa, Bombax ceiba, Butea monosperma, Cassia fistula, Dalbergia paniculata, Dalbergia sissoo, Ficus benghalensis, Ficus racemosa, Ficus religiosa, Gmelina arborea, Grewia optiva, Grewia tiliifolia, Helicteres isora, Holoptelea integrifolia, Lannea coromandelica, Lagerstroemia parviflora, Leucaena leucocephala, Madhuca latifolia, Melia azadirachta, Mitrogyna parviflora, Moringa oleifera, Morus alba, Neolamarckia cadamba, Psidium guajava, Phyllanthus emblica, Pongamia pinnata, Syzygium cumini, Tamarindus indica, Tectona grandis, Terminalia arjuna, Trema orientalis (Table 5).

Table 5: Tree diversity in 2018

S No.	Tree	Common Name	Family	Uses
1.	*Albizia lebbeck*	Kala sirus	Mimosaceae	Medicinal, Timber
2.	*Albizia procera*	Safed siris	Mimosaceae	Medicinal, Timber
3.	*Albizia chinensis*	Kala siris	Mimosaceae	Medicinal, Timber
4.	*Alstonia scholaris*	Devil tree	Apocynaceae	Medicinal
5.	*Bauhinia variegata*	Kachnar	Caesalpiniaceae	Medicinal
6.	*Bauhinia recemosa*	Katmauli	Caesalpiniaceae	Medicinal
7.	*Butea monosperma*	Palas	Fabaceae	Timber, Fodder, Medicinal and Dye
8.	*Cassia fistula*	Amaltas	Fabaceae	Ornamental
9.	*Dalbergia peniculata*	Rosewood	Fabaceae	Timber
10.	*Phyllanthus emblica*	Amla	Phyllanthaceae	Medicinal
11.	*Ficus racemosa*	Gular	Moraceae	Medicinal
12.	*Grewia optiva*	Bhimal	Tiliaceae	Fibers
13.	*Grewia tiliifolia*	Dhamani	Tiliaceae	Medicinal
14.	*Helicteres isora*	Marorphali	Malvaceae	Medicinal
15.	*Holoptelea integrifolia*	Papdi	Ulmaceae	Ethnobotanical
16.	*Lannea coromandelica*	Indian ash tree	Anacardiaceae	Ethnobotanical
17.	*Lagerstroemia parviflora*	Bakli	Lythraceae	Ornamental
18.	*Madhuca latifolia*	Mahua	Sapotaceae	Medicinal, Timber
19.	*Mitragyna parvifolia*	Faldu	Rubiaceae	Medicinal
20.	*Psidium guajava*	Amrud	Myrtaceae	Fruit edible
21.	*Pongamia pinnata*	Karanj	Fabaceae	Medicinal
22.	*Syzygium cumini*	Jamun	Myrtaceae	Medicinal
23.	*Tamarindus indica*	Imli	Fabaceae	Fruit edible
24.	*Tectona grandis*	Teak	Lamiaceae	Timber
25.	*Trema orientalis*	Charcoal tree	Cannabaceae	Medicinal
26.	*Ziziphus mauritiana*	Ber	Rahmnaceae	Fruit edible

Shrub species: *Breynia vitis-idaea, Calotropis gigantea, Dodonaea viscosa, Elaine polygonum, Flueggeavirosa,Holarrhena antidysenterica, Hyptissuaveolens, Indigofera tinctoria, Ipomoea carnea, Lantana camara,*

Triumfetta rhomboidea, Vitex negundo, Wattakaka volubilis, Woodfordia fruticosa, Zizyphusjujube(Table 6).

Table 6: Shrub diversity in 2018

Sr. No.	Shrub	Common Name	Family	Uses
1.	*Asparagus racemosus*	Shatavari	Asparagaceae	Medicinal
2.	*Breynia vitis-idaea*	Breynia	Phyllanthaceae	Medicinal
3.	*Calotropis gigantean*	Aak	Apocynaceae	Medicinal
4.	*Desmodiumgangeticum*	salpani	Fabaceae	Medicinal
5.	*Dodonaea viscosa*	Hopbush	Sapindaceae	Medicinal
6.	*Flueggeavirosa*	Bushweed	Euphorbiaceae	Medicinal
7.	*Holarrhena antidysenterica*	Kurchi	Apocynaceae	Medicinal
8.	*Indigofera tinctoria*	Neel	Fabaceae	Medicinal, Dye
9.	*Ipomoea carnea*	Behaya	Convolvulaceae	Anti-bacteria, anti-fungal
10.	*Sidacordata*	Bariar	Malvaceae	Medicinal
11.	*Streblus asper*	Daheya	Moraceae.	Used in Cancer
12.	*Triumfetta rhomboidea*	Burr Bush	Malvaceae	Medicinal
13.	*Vitex negundo*	Nirgundi	Lamiaceae	Medicinal
14.	*Woodfordia fruticosa*	Fire Flame Bush	Lythraceae	Good Soil binder

Herbaceous species

Achyranthes aspera, Abrusprecatorius, Aervalanata, Ageratum conyzoides, Alternanthera sessilis, Alysicarpusmonilifera, Asparagus racemosus,Boerhavia diffusa, Chloris dolichostachya, Cissampelospareira, Coccinia indica, Crotalaria retusa, Desmodiumgangeticum, Desmodiumtriflorum, Eupatorium adenophorum, Evolvulus sericeus, Galium album, Momordica charantia, Phyllanthus amarus, Phyllanthus spontaneous, Rhynchosia minima, *Sidacordata, Streblus asper, Tornia cordifolia, Vernonia cinerea, Xanthium indicum,* (Table 7).

Table 7: Herb diversity in 2018

S. No.	Herb	Common Name	Family	Uses
1.	*Achyranthes aspera*	Aandhijhara	Amaranthaceae	Medicinal
2.	*Aervalanata*	Kapurijadi	Amaranthaceae	Leaves edible
3.	*Ageratum conyzoides*	Goat weed	Compositae	Medicinal
4.	*Alternanthera sessilis*	Garundi	Amaranthaceae	Medicinal
5.	*Boerhavia diffusa*	Punarnava	Nyctaginaceae	Medicinal
6.	*Centellaasiatica*	Brahmi	Apiaceae	Medicinal
7.	*Chloris dolichostachya*	Nomi comuni	Poaceae	Medicinal
8.	*Cissampelospareira*	Velvet Leaf	Menispermaceae	Medicinal
9.	*Coccinia indica*	Kundru	Cucurbitaceae	Antidiabetic
10.	*Commelinabenghalensis*	Dayflower	Commelinaceae	Medicinal
11.	*Crotalaria retusa*	Rattlebox	Fabaceae	Forage plant
12.	*Cyanotistuberosa*	Dew-Grass	Poaceae	Medicinal
13.	*Desmodiumtriflorum*	Kudaliya	Fabaceae	Medicinal
14.	*Eupatorium adenophorum*	Crofton weed	Asteraceae	Biopesticides
15.	*Euphorbia hirta*	Duddhi	Euphorbeaceae	Use in Asthma
16.	*Evolvulus sericeus*	morning-glory	Convolvulaceae	Medicinal
17.	*Galium album*	Hedge Bedstraw	Rubiaceae.	Medicinal
18.	*Phyllanthus amarus*	Hurricane weed	Phyllanthaceae	Medicinal
19.	*Phyllanthus amarus*	Bhuiamla	Phyllanthaceae	Medicinal
20.	*Phyllanthus niruri*	Bhuiamla	Phyllanthaceae	Medicinal
21.	*Phyllanthus tenellus*	Bhuiamla	Phyllanthaceae	Medicinal
22.	*Polygonum* spp.		Polygonaceae	Medicinal
23.	*Rhynchosia minima*	kulata	Fabaceae	Medicinal
24.	*Streblus asper*	Daheya	Moraceae.	Used in paper making
25.	*Torenia cordifolia*	Wishbone Flower	Linderniaceae	Medicinal
26.	*Vernonia cinerea*	Dandotapala	Asteraceae	Used in Malaria
27.	*Xanthium indicum*	Chotadhatura	Asteraceae	Medicinal

Grasses species: *Brachystegiamutica, Cenchrussetigerus, Cynodon dactylon, Oplismenuscompositus, Saccharum munja, Seteria glauca, Sporobolus asper, Cyanotistuberosa, Cyperuscompressus, Cyperus nutans and bamboo species which included Bambusa bambos and Dendrocalamus strictus*were found in addition to the species already present in 2014.

Ferns, creepers and climber species: *Adiantum incisum, Asplenium nidus, Alysicarpusmonilifer, Ichinocarpusfrutescents,*

Dioscoreabulbifera, Ipomoea alba, Ipomoea purpurea, Cryptolepisbuchanani, Cucumis trigonus were observed.

Natural Occurring Species around the Mined Area

To know about the natural wealth of species growing in and around the mined-out area, a reconnaissance survey was undertaken, and species present in the area were recorded. A similarity was found in the naturally occurring species and the restored sites. Many species which are naturally occurring in and around the mined areas are also well established in the restored mining area.

Comparison of vegetation species

Enhancement of biodiversity was clearly indicated by improvement of vegetation state on the site. Since the beginning of this project, a considerable increase in number of plant species and diversity can be noticed. Before the biodiversity enhancement project, there were no climbers, ferns and creeper on the site but then their presence was seen at the site. Number of trees, shrubs and herbaceous species has been increased in large number. Medicinal plants which have high economic value have also been increased in significant amount.

Conclusion

Vegetation analysis carried out during 2017 revealed, a maximum density of *Dalbergia sissoo* (514.3 tree/ha) followed by *Dalbergia paniculata* (257.1 tree/ha). Amongthe saplings *Albizia lebbeck* (42.85%) and *Dalbergia sissoo* (42.85%) were the most frequentat the site and density of saplings found was 1054.14 tree/ha. Total density of shrub was 1114.28 Ind./ha (8914.24 in 8ha) and total density ofherb was 6.79/m^2.

In comparison to 58 species recorded in 2013-14, at present the restoration site isenriched with a total of 103 plant species of which 37 are trees, 15 shrubs, 27 herbs, 9grasses, 2 bamboo, 2 fern, 1 creeper and 10 climber species are there. Among all, 80 recordedplant species have medicinal use in one or other way. Out of these following 21 species viz.,*Azadirachta indica*, *Cassia fistula*, *Moringa oleifera*, *Terminalia arjuna*, *Terminaliabellerica*, *Euphorbia hirta*, *Abrusprecatorius*, *Asparagus racemosus*, *Boerhavia diffusa*, *Breynia vitis-idaea*, *Cucumis trigonus*, *Desmodiumgangiticum*, *Emblica officinalis*,*Gymnemasylvestre*are, *Holarrhena antidysenterica Sidacordata*, *Phyllanthus niruri*,*Phyllanthus amarus*, *Phyllanthus tenellus*and *Centellaasiatica*, are highly medicinal plants.

The occurrence of native species other than planted species such as *Bombax ceiba*,*Ficus glauca*, *Ficus racemosus*and *Butea monosperma* showed that the ecologically restoredsite have started facilitating the growth and establishment of native species which is one of main aim ofrestoration programme. This would facilitate regeneration of native species that could not otherwise establish in open micrositesor in competition by herbaceous species. Increase in biodiversity at the project siteis of great importance due to the functional role, especially of soil fauna, soil physicochemicalproperties and self-regulation potential of intensive forest ecosystems. Theenhanced biodiversity has promoted recolonizationof many species of birds,butterflies, insects, reptiles and few of animals etc. visiting at therestored site.

References

1. Ash HJ, Gemmell RP, Bradshaw AD. The introduction of native plant species on industrial waste heaps: a test of immigration and other factors affecting primary succession. Journal of Applied Ecology. 1994; 31:74-84.
2. Cairns J. The status of the theoretical and applied science of restoration ecology. *Environment Professional*. 1991; 13:186-194.
3. Feng XM, Fu BJ, Lu N. How ecological restoration alters ecosystem services: An analysis of carbon sequestration in China′s Loess Plateau. *Scientific Reports*. 2013; 3:2846.
4. Ghose MK. Land reclamation and protection of environment from the effect of coal mining operation. *Mine technology*. 1989; 10(5):35-39.
5. Ghose MK. Soil conservation for rehabilitation and revegetation of mine-degraded land. *TIDEE – TERI Information Digest on Energy and Environment*. 2005; 4(2):137-150.
6. Holl KD, Crone EE, Schultz CB. Landscape restoration: Moving from generalities to methodologies. *Bio Science*. 2003; 53(5):491-502.
7. Juwarkar AA, Singh L, Kumar GP, Jambhulkar HP, Kanfade H, Jha AK. *et al*. Biodiversity Promotion in Restored Mine Land through Plant-Animal Interaction. Journal of Ecosystem &Ecography. 2016; 6:12.
8. Kumar GP, Yadav SK, Singh SK, Thawale PR, Juwarkar AA. Growth of Jatropha curcas on heavy metal contaminated soil amended with industrial wastes &Azotobacter- A greenhouse study. *Bio resource Technology*. 2008; 99:2078-2082.
9. Sheoran AS, Sheoran V, Poonia P. Rehabilitation of mine degraded land by metallophytes. Mining Engineers Journal. 2008; 10(3):11-16.
10. Suding KN. Toward an era of restoration in ecology: Successes, failures, and opportunities ahead. *Annual Review of Ecology, Evolution, and Systematics*. 2011; 42:465-487.
11. Wong MH. Ecological restoration of mine degraded soils, with emphasis on metal contaminated soils. *Chemosphere*. 2003; 50:775-780.
12. Wortley L, Hero J, Howes M. Evaluating ecological restoration success: A review of the literature. *Restoration Ecology*. 2013; 21(5):537-543.