REVEGETATION AND ECOLOGICAL MONITORING OF AN OPEN CAST ROCK PHOSPHATE MINE[1]

BY

[2]P. Soni, H.B. Vasistha, O. Kumar, V. Bhatt and M. Negi

Abstract. The paper presents results of a revegetation programme to stabilize on excavated rock phosphate mine area. The programme emphasized on using ecologically, economically and socially viable plant species which resulted in "Green revolution" of the degraded mined area within a short span of six years.

Details of reclaimation methods adopted, results of ecological monitoring of floral and faunal density and diversity in revegetated areas have been presented.

Additional Key Words : Revegetation, diversity, ecological monitoring.

Introduction

Mining is one of the important industries of India, next only to agriculture in importance and is hence linked directly with country's rapid industrial and energy development.

Large areas are subjected to mining of minerals like coal, iron, manganese, copper, gold, rock, phosphate, limestone etc. in about 5000 mining leases spread over about .7 million hactares area of the country (Mathur 1978).

It is also a fact that most of the mining leases occur in heavily wooded areas and hence damage to forests is inevitable. Once the area is subjected to mining, the ecological impacts are much more diverse depending on the type of mining, ore excavated, ore: overburden ratio, geology and terrain of the area where mining is being done.

Due to lack of stringent environmental regulations in our country, most of the mined areas are in an environmentally disturbed state. Erosion of abandoned, underclaimed mine sites has resulted in the degadation of aquatic life in receiving streams (Brenner et.al.1978; Kimmel 1983; Muncy 1986). In India reclamation of mined areas is of recent origin and hence there are only a few mining companies which have undertaken reclamation of their mined areas in a scientific manner.

Reclamation of excavated mine areas basically involves two steps - i) site preparation by grading, construction of check dams, gabions or other mechanical structures depending on site condition, geology etc. ii) revegetation of the site by planting, seed sowing of suitable species of trees, shrubs and grasses etc.

In the present study reclamation of an open cast rock phosphate mined area was under taken with the collaboration of the mining company, M/s Pyrites Phosphate and Chemicals Ltd., Dehradun. This reclamation project was under taken with following major objectives :-

1 Since the area has slopes of 30-40°, erosion control was the foremost requirement.

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[2]Scientist, Forest Research Institute, New Forest Dehradun, 248006, India.

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2. Water quality of a stream flowing down below was to be controlled.
3. Restoration of site ecology.
4. Socioeconomic return from the area on a sustainable basis.

Experimental Site

The mining site about 10 ha. in size, is located about 18 km. North east of Dehradun town. The elevation of the site ranges between 750 and 1050 mean sea lavel. The area is represented by tropical monsoon type climate, with an average annual rainfall of 2500 mm.

On the basis of geological formation, three sub sites of the mined area were selected, as well as one natural forest plot, which is not affected by mining, for comparison of results -

1. Overburden dumps containing mainly shale (60-70%), limestone and chert (20%) and about 10% soil.
2. Exposed black pyritic shale
3. Weathered limestone
4. Natural forest

Reclamation Methods

To control erosion of soil, a series of gabion check dams and stone walls were constructed along the slope length so that loose overburden may be partially retained. Along the perennial river flowing below the mining area, a 200 m long stone wall was erected to check the inflow of debris into the stream water.

Once the mechanical measures were complete, biological reclamation of the area was begun. Since the aim of this particular reclamation project was to be ecologically based, the biological reclamation process was carried out in the following sequence:

1. Ecologicaly survey of the adjoining undisturbed forests to select ecologically adapted species of the region which are useful for the localinhabitants wildlife and humans both and have high colonizing and erosion control capability.

2. Based on the above survey, seeds and cuttings of species from adjoining areas were collected.

3. The seeds of the following species were broadcast seeded over the whole area :

Buddleja asiatica, Eriophorum comosum, Crotolaria sericea, Mimosa himalayana, Rumex hastatus, Trema politoria and Wendlandia exserta.

Cuttings of the following species were collected and planted as indicated against each :-

Ipomoea carnea	in contour trenches
Jatropha curcas	for gully
Moringa pterygosperma	plugging
Salix tetrasperma	Along water courses
Saccharum spontaneum	Root tiller on lime stone areas
Vitex negundo	Shoot cutting

Besides local grasses, shrubs and trees, some other species were also planted in contour tremches i.e. Arundo donax and Pennisetum purpureum,

With the introduction of the fast growing species listed above, the area was partially stabilized in one year. Subsequnet planting of following tree seedlings on a large scale was undertaken;

Acacia catecheu, Moringa pteruygosperma, Dalbergia sissoo, Melia azadiracht, Caraya arborea, Leuceana leucucephala, Tropical Pines:

Pinus caribaea bahamensis var, Queensland, Australia, P.elliottii Queensland Australia, P. Caribaea var,hondurensis Poptun-paten Guatamala P.Caribaea a var. hondurensis lostimones and P.Caribaea var hodurensis Brazil.

List of ornamental species planted at the mining site:

Bauhimia variegata	Cinnamomum camphora
Bauhinis retcusa	Jacaranda acutifolia
Callistemon viminalis	Legerstroemia indica
Cassia glauca	Delonix regia
Cassia fistuala	Francia sp.
Cassia javanica	Gardenia florida

After a period of 5 years of reclaimation in 1987, when the site turned completely green and was erosion free, the following ecological monitoring of the site was initiated

i) Plant and soil faunal population changes: Quadrats of 10 sqm.,5 sqm.and 1 sqm. were

TABLE -1 Name of species and mode of propagation

Herbs, shrubs & grasses	Seed	Cutting	Root stock	Bulbils	Seed ling	Total No.of plant	%sur vival
Buddleia asiatica	✓	-	-	-	-		60-70
Mimosa himalayana	✓	-	-	-	-		60-70
Pennisetum purpureum (Hybrid napier)	-	-	✓	-	-	2400	100
Rumex hastatus	✓	-	-	-	-		90
Saccharum spontaneum		-	✓	-	-	500	100
Vitex negundo		-	-	-	-	1000	30
Tree species		-	-	-	-		
Acacia catechu		-	-	-	✓	3000	98
Dalbergia sissoo		-	-	-	✓	4800	98
Leuceana leucocaphala		-	-	-	✓	500	98
Salix tetrasperma		-	-	-	✓	4000	80

used to ascertain density and frequency of trees, shrubs and grasses respectively in all the sites.

A core of 10 cm was taken and faunal population was estimated by dry sieving, by use of hand sorting and a Berlese funnel.

ii) Litter production and nutrient composition:

Litter production in all the areas was collected from 1 sqm. plots and analyzed for nitrorogen, phosphorus, calcuim, pottassium magnesium (Wilde et.al.1985).

Litter production, and nutrient composition A core of 10 cm was taken and the faunal population was estimated by dry sieving, and by use of hand sorting and a Berlese funnel.

Results and Discussion

Results of the study are presented in two parts, firstly the results of bioreclamation and then ecological monitoring of reclamation sites.

Percentage survival of plants on mined out areas and overburden dumps was found to be very encouraging especially for local species (Table-I) of trees like Dalbergia sissoo, Acacia catechu. However Pinus sp. showed very poor survival rate of only 10-15%.

Similarly, local shrub species showed very encouraging results. Ipomoea carnea and Vitex negundo raised from cuttings gave almost 95% survival. Besides these Pennisetum purpureum, Arundo donax and Sacoharum spontaneum showed 90-95% survival.

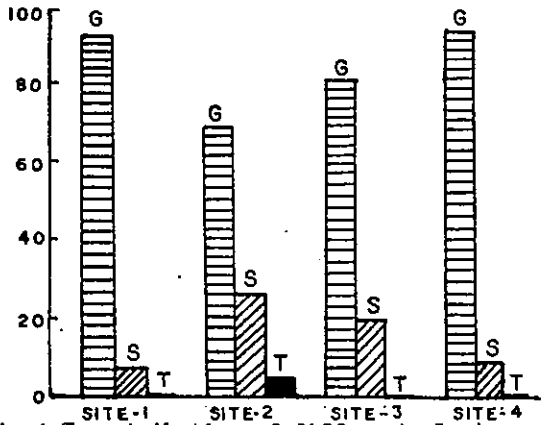

Fig.1 % contribution of different plant groups

Resutls of floristic composition have shown that diversity of plants has increased significantly from the initial zero level. In reclaimed areas, besides the species of trees, shrubs and grasses planted/raised for reclaiming the area, quite a good number of species in all categories have invaded.(Table 2,fig. 1) Vegetation survery of all the mine sites and that of adjoining natural forest shows that the reclamation process has favoured the increasing diversity levels(Table 3).

The floristic structure of the mined area shows that the total number of plant species on the reclaimed site is nearly equal to, or more than the undisturbed forest. Herbs and grasses are the highest contributors to total density followed by shrubs and trees. The data thus clearly indicate the initiation of natural succession in a short span of 4-5 years after

TABLE – 2 Floristic composition of all sites after five years.

Group of plants(No. of spicies)		Site I	Site II	Site III	Site IV
herbs and grasses.	Planted	* 23,300	** 7,128	** 13,300	–
	Natural	5,34,500	43,464	89,800	1,86,400
Shrubs	Planted	29,596	1,600	*** 12,792	
	Natural	8,256	17,316	11,564	7,864
Trees	Planted	2,833	3,199	499	–
	Natural	33	–	–	1,561
Total		5,98,518	72,707	1,27,955	1,95,825

* Represents shrub seedlings raised on the site
** Includes planted shrub and tree seedlings besides planted grass species
*** Includes planted/raised tree seedlings

reclamation. Further, the development of vegetation on the sites has resulted in litter production through leaf fall (Table 4). It is well known that litter production and its subsequent decomposition is of great significance in improving the site conditions through nutrient enrichment and for establishment and growth of vegetation on surface mine sites (Brenner, Werner and Pike 1984).

TABLE 3– Number of species of each plant group and their percentage contribution to total plant density hectare.

	Site I	Site II	Site III	Site IV
Herbs & grasses	16 (93.19%)	9 (69.58%)	9 (80.57%)	9 (95.18%)
Shrubs	11 (6.32%	7 (26.01%)	14 (19.03%)	11 (4.01%)
Trees	4 (0.47%)	4 (4.39%)	4 (0.39%)	8 (0.80%)
Total No. of species	31	20	27	29

Table 4 and fig.2 give the amount of litter (in kg/ha) produced in different sites and also nutrient content: Nitrogen, phosphorus, potassium, calcium and magnesium (kg/ha) in the respective sites. Litter production per hectare is found to be maximum in site III followed by site 1. This is much more than the amount of litter collected from the natural forest which is only 433.0 kg/ha. These results further support the observations that reclamation through ecologically adapted species is valuable in ameliorating the mined sites and providing food and cover for faunal species. As the floral density increases, the same trend is being followed by faunal density.

TABLE – 4 Production of liter (kg./ha) and nutrient content(kg/he) in mined and natural forestr areas

	Site I	Site II	Site III	Site IV
Oven dry litter	789.00	513.00	1025.00	433.00
Nitrogen	1.32	1.16	0.84	1.09
Phosphorus	0.33	0.20	0.30	0.27
Potassium	0.26	0.18	0.27	0.26
Calcium	2.33	1.41	0.93	1.00
Megneshium	0.50	0.77	0.50	0.30

This preliminary survey has shown that site I has the maximum faunal communities,where density of herbs and grasses was maximum and contribution of shrubs and trees was comparatively low. It may be presumed that the acquired stability from erosion and sliding results in higher biomass production, subsequent decomposition of litter and this helps in enrichment of the mine spoil fauna. The final

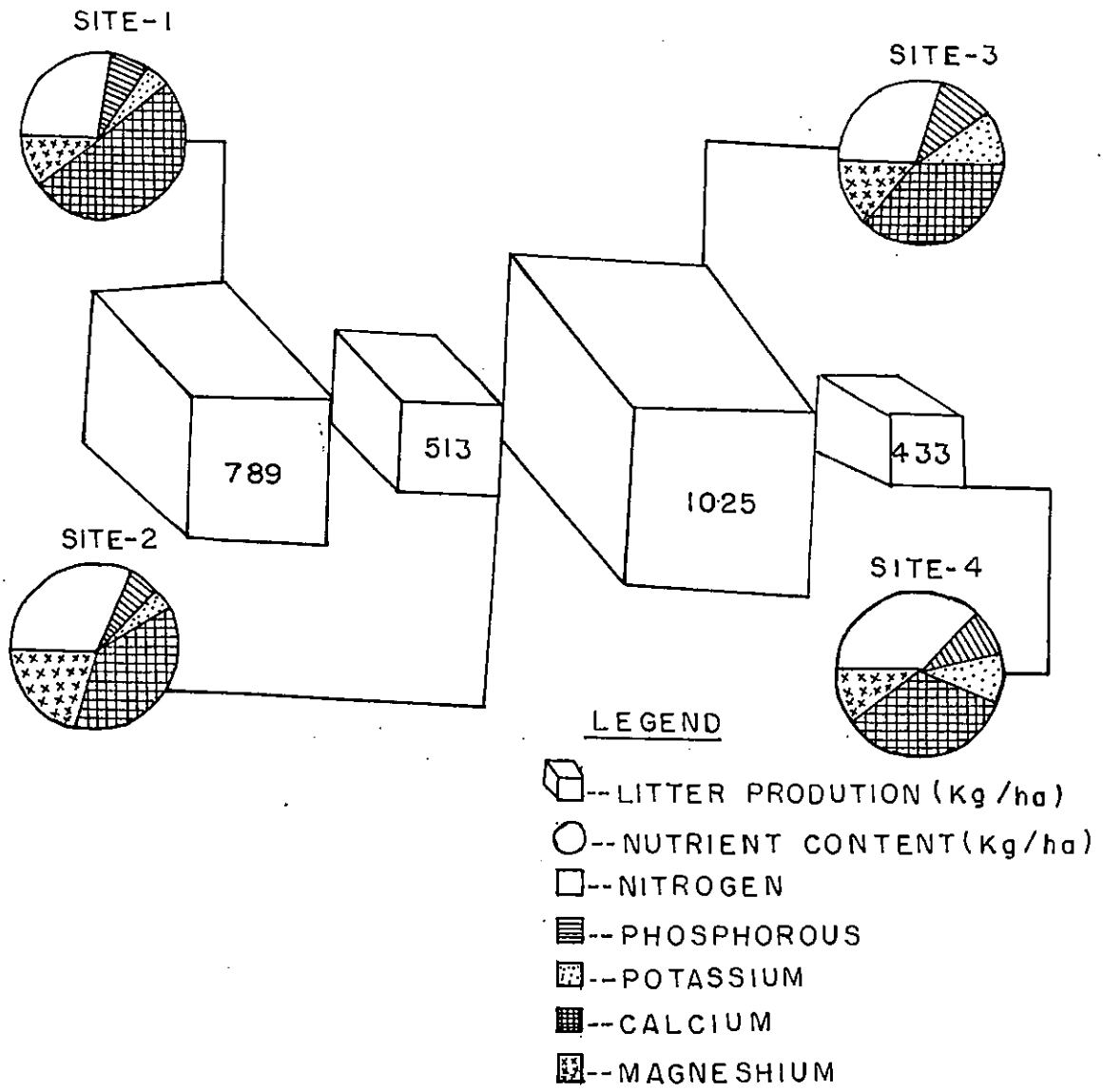

FIG.2 LITTER PRODUCTION AND NUTRIENT CONTENT IN Kg/ha

influence of vegetation (Neumann 1977) supports that the area planted with trees producing high amounts of readily decomposable litter support more decomposer organisms (Cruestacea). The results of the survery indicate that site 1(Table 5 has the maximum soil fauna. The major soil inhabiting group observed is the same as in the natural forest (fig.3) but site 1 has the maximum density/cum. in comparison to natural forest. It was also noted that Myriopoda and Mollusca are totally absent in site 2 and 3 but these two groups are present in site 1 and site 4 (adjacent natural forest). The most dense and diverse plant cover in site 1 shows the composition of the fauna also increases proposttionately and through it the quality of the humus may be improved for plant growth (Table 3). These findings are also supported by Murphy (1953 and 1966)). In the course of the further development of the soil Formicomus castigator (Coleoptera),Cremastogaster wroughtom (formicidae) forms large clumps in which a rich soil fauna can develop. Animals appearing here include Rhysida nuda (Scolopendromorpha), Isopoda(families not yet identified), Arneae (Cyrotophora Gnaphosa, Meta sp.) because they are the first coloniziers which bring about mixing of humus, clay and enrich the fertility

TABLE-5 Density of different faunal groups in different sites.

Soil faunal group	Density/cum Site I	Site II	Site III	Site
Arachnida	1499	833	1833	833
Crusracea	500	500	166	1500
Myriopoda	333	-	-	333
Insects	13999	6833	6166	3166
Mollusca	1333	-	-	3833
Total	17666	8166	8166	9666

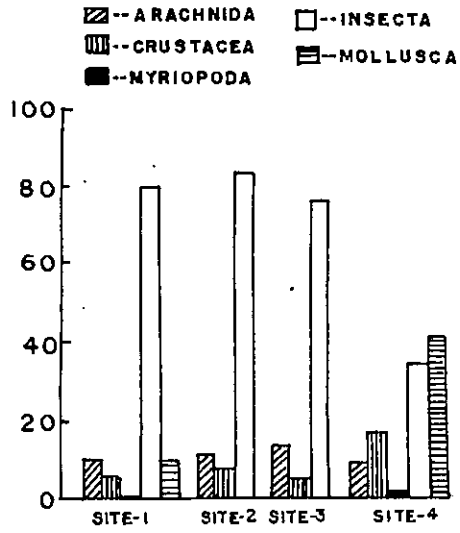

Fig.3 % contribution of soil faunal groups

of soil.

Ecological findings of the reclaimed plots and their comparison with the adjoining natural-forest plot lead to the conclusion that reclamation of mined sites with local species of herbs, shrubs, grasses and trees builds up the ecosystem in a favourable manner such that succession of flora and fauna starts. This further results in stabilizing the area from sliding and erosion as well as ameliorating the soil conditions.

Further use of local colonizing species restores the site in an inexpensive manner ($.16/cum of overburden reclaimed in the present study) and fulfill the requirements of local inhabitants in a sustained manner.

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