CHAPTER 4

METHODOLOGY

ASSESSMENT OF EFFICACY OF MINE REHABILITATION PLAN

For the above assessment, vegetation survey of the study area to record natural regeneration was done, and performance of the planted species in terms of their growth was studied. Understorey succession beneath plantations in rehabilitated areas was recorded and for comparison purpose, this was done in undisturbed area, plantation without mining area and nearby forest areas also. Growth of planted species was compared with plantations in nearby areas. The objective wise detailed methodology is discussed below:

4.1 STUDY OF UNDERSTOREY SUCCESSION

The ability to reconstruct or restore a piece of damaged land following disturbance relies heavily on strong ecological knowledge, and the basis of this acquired knowledge is research related to the particular problem sites and the objectives presented for the restoration of that site. Of specific importance is that native organisms have inherent capacities to tolerate local climatic and edaphic conditions and are generally preferable to introduced species in revegetation programmes. Second, amelioration of the post-disturbance habitat can ensure establishment of plants under difficult circumstances. And, third, the long-term functional aspects of the post-mining areas may be of great importance to the future well-being of the region and must be a major consideration of restoration programs (Bell and Hobbs, 2007).

Vegetation is an important part of the ecosystem that integrates the effects of the total environment (Billings, 1952). It is predominantly a result of physico-climatic conditions of a region. In other words, vegetations represent a true image of a terrain and seasonal variation of temperature and precipitation, and provide a basis for understanding of a regional development. Vegetation has a highly functional role in providing nutrients for an ecosystem and provides suitable habitat, food and shelter for
other biota. Vegetation monitoring can provide information on species composition and structure and its functional role in the landscape as a whole.


The vegetation studies of the mines have been conducted by several workers in different parts of India also (Prasad and Pandey, 1985; Singh and Jha, 1987; Soni et al., 1989a; Jha, 1990; Veeranjaneyulu and Dhanaraju, 1990; Jha, 1992; Nandeshwar et al., 1996; Banerjee and Mishra, 1999; Das Gupta et al., 2002; etc.).

On the bauxite mine plateau, there were three types of sites. First site was Virgin Area (VA), i.e., area where mining has not yet been done but would be done in future. As already discussed in chapter 3, the plateau is completely devoid of tree vegetation due to heavy biotic pressure since time immemorial.

Second site was the southern part of Panchpatmali plateau, where plantation of Eucalyptus hybrid, was done in 1997 to create greenery, but due to presence of very thick and hardy ferruginous silicious and aluminous lateritic material beneath the top soil, scarification with the help of heavy machineries was done for digging trenches in which Eucalyptus hybrid was planted. For study purpose this site has been designated as Unmined Area Plantation (UAP).
Third site was the area of various years of plantations, which were done after mining the area for bauxite and refilling the excavations with overburden materials. Before blasting the area for mining, top soil was scrapped and spread over already filled excavation. Plantation was done thereafter and for study purpose this type of plantation area was designated as OB Area Plantation mentioning their respective ages.

Earlier NALCO administration had informed that around 800 ha area was afforested under mine rehabilitation plan. But later they acknowledged that only 165 ha area was rehabilitated after mining with afforestation activities till 2009. Remaining 635 ha plantation area was in and around their township, which was not the part of this study. Therefore, the study area accordingly got reduced. Area of plantation after mining varied in different years of plantation. Therefore, stratified random sampling with proportional allocation was used, due to which number of quadrats varied in different years of surveyed plantations. For stratification, alternate years of plantations starting from 1-yr-old plantation were taken up for the present study.

Following areas were visited repeatedly from November, 2009 to May, 2011 and phyto-sociological data were collected:

(i) area to be mined in future without any plantation (Virgin Area- VA),
(ii) area with plantation of 13 years of age without mining (Un-mined Area Plantation- UAP),
(iii) reclaimed areas with plantations of 1, 3, 5, 7, 9, 11, 13, 15, 17, 19 and 21 years of age (OB Area Plantations), and
(iv) three forest sites of different years of plantations (FA Plantations) near the study area.

Herbaria of plant species were prepared and deposited in the FRI after their identification and completion of this study. Identification of the species was done with the help of ‘The Flora of Orissa’ (Saxena and Brahmam, 1994-1996) and the experts at FRI, Dehradun.

For the shrub species quadrats of 5m x 5m were laid. For the herbaceous species, the size of the quadrats was 1m x 1m. For trees, quadrat size was 10 m x 10m. Planted
trees were not considered for phyto-sociological analysis as only natural regeneration was to be studied. The quadrats were laid randomly in nested form, i.e., quadrats for shrubs and herbs were taken up inside tree quadrats. Herbs and lianas were clubbed together for the present study purpose. Very few tree species were available as natural regeneration in the rehabilitated mined out sites; however, none of them were in tree form. Hence, natural regeneration of tree species was recorded as per their habit visible.

Map of the rehabilitated mined out areas procured from NALCO was digitized (Fig. 4.1) for knowing the exact area of plantations of different years, so that proportional allocation of number of quadrats could be done.

Quantitative community characteristics such as frequency, density, abundance, and importance value index (IVI) of each species were determined, following the methods as described by Misra (1968).

4.1.1 Frequency

As introduced by Raunkiaer in 1934, frequency indicates the number of quadrats in which a particular species occur. It mainly expresses the distribution or dispersion of various species in the community. It is generally expressed as percentage and was calculated as follows:

\[
\% \text{ frequency} = \frac{\text{Number of quadrats in which the species occurred}}{\text{Total number of quadrats studied}} \times 100
\]

4.1.2 Density and Abundance

The terms density and abundance represent the numerical strength of a species in the community. While density indicates the number of individuals per unit area, abundance when considered with frequency gives an idea of the distribution pattern of the species. Density and abundance were calculated for each species by the following formulae:

\[
\text{Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats studied}}
\]
Abundance = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats of occurrence}}

4.1.3 Basal Area

Basal area refers to the ground actually penetrated by the stems. It is one of the chief characteristics determining dominance and the nature of the community (Misra, 1968). The diameter values recorded were converted to basal area through following formula:

\text{Average basal area} = \pi r^2, \text{ where } r = \frac{\text{Average diameter}}{2}

The values obtained by the above formula were multiplied by density to calculate the basal area of a species per unit area.

4.1.4 Importance Value Index (IVI)

This expresses dominance or the ecological success of a particular species in a given stand/ community. This index utilizes three characteristics, viz., relative frequency, relative density, and relative dominance. After evaluating frequency, density and basal area for all the species growing in the study site, relative frequency (RF), relative density (RDe) and relative dominance (RDo) were calculated using the following formulae:

Relative Frequency (RF) = \frac{\text{Frequency of a species}}{\text{Frequency of all the species}} \times 100

Relative Density (RDe) = \frac{\text{Density of a species}}{\text{Density of all the species}} \times 100

Relative Dominance (RDo) = \frac{\text{Basal area of a species}}{\text{Total basal area of all the species}} \times 100

IVI = RF + RDe + RDo

Importance Value Index (IVI) was calculated for the species in each vegetational stratum.
Fig. 4.1: Digital representation of the rehabilitated areas in the Study Area.
4.1.5 Whitford’s Index

Abundance, when considered along with frequency, gives an idea of distribution pattern of the species. The distribution pattern of the species was studied by using Whitford’s index as suggested by Whitford in 1948, and each species was categorized accordingly:

\[ W_X = \frac{A}{F}, \]

where, \( W_X = \) Whitford’s index
\( A = \) Abundance
\( F = \) Frequency

If Whitford’s index is less than 0.025, the distribution pattern of the species is ‘Regular distribution’. If Whitford’s index is 0.025 to 0.05, the distribution pattern of the species is ‘Random’. Similarly, the species with Whitford’s index greater than 0.05 is categorized in ‘Contagious’ or ‘Clumped distribution’.

4.1.6 Similarity Index (S)

Sorensen (1948) has given a simple formula to establish the index of similarity between two stands of vegetation (Ambasht and Ambasht, 2008):

\[ S = \frac{2C}{A+B} \times 100, \]

where, \( S = \) Sorensen’s index of similarity (%)
\( A = \) number of species in stand A
\( B = \) number of species in stand B
\( C = \) number of species common to both the stands A and B.

Since, similarity index has been calculated in percentage; therefore, it has been multiplied by 100 in the calculation.
4.1.7 Species Diversity

Information on species diversity is important for understanding the mechanism and effects of certain ecological phenomena. It is a function of the number of species present (i.e. species richness or number of species) and the evenness with which the individuals are distributed among these species. This is based on the rationale that the diversity, or information, in a natural system can be measured in a similar way to the information contained in a coded message. Species diversity was calculated as Shannon-Wiener diversity index by using the formula:

\[ H' = - \sum (ni/N) \ln (ni/N) \]

Where, \( H' \) = Shannon-Wiener diversity index
\( ni \) = IVI of species \( i \), and
\( N \) = total IVI of all species.

4.1.8 Concentration of Dominance (Cd)

Those species which have strongest control over energy flow and the environment in a given habitat are known as ecological dominants. Simpson has given the following formula to estimate the Concentration of Dominance (Cd):

\[ Cd = \sum (ni/N)^2 \]

where, \( ni \) is the corresponding IVI of the \( i^{th} \) species and \( N \) is the total of IVI of all the component species in the same area and period (Ambasht and Ambasht, 2008). As \( Cd \) increases, diversity decreases, and hence, in the present study Simpson’s index has been expressed as 1- Cd for ease of expressing the situation.

4.1.9 Species Richness (Sr)

Species richness can refer to the number of species present in a given area or in a given sample, without implying any particular regard for the number of individuals examined in each species. The concept of species richness (i.e. the number of species) gives as much information that is related to biodiversity as the concept of species
diversity. Species richness was calculated following the formula suggested by Margalef in 1958:

$$Sr = \frac{S-1}{\ln N} ,$$

where, $S$ = total number of species in the given stand, and $N$ = total no. of individuals.

4.1.10 Evenness Index (E)

Evenness refers as to how the species’ abundances are distributed among the species of the community. This index (E) was calculated as suggested by Pielou (1969):

$$E = \frac{H'}{\ln N} ,$$

where , $H'$ = Shannon-Wiener index, $N$ = Number of species in the community.

4.2 GROWTH OF PLANTED SPECIES

The expression “plant growth” is a broad term and it is difficult to be used as a measure of growth. However, certain dimensional characters were taken into consideration for this analysis. The dimensional growth is generally interpreted in terms of annual increments. The scope of forest mensuration gives not only the volume of forest crop at present, but also helps in the forecast of future yields. The volume of crop at present depends upon the volume of tree growing in it (Chaturvedi and Khanna, 2000). The technique of plant growth analysis in terms of biological production is based on the “compound interest law” (Blackman, 1919) which was also followed in calculating dimension increment percentage.

Structural measurement of plantation and forest is an important factor which throws a new light to the visual form and helps in analyzing the successional status of the community. Veblen (1986) has stated that structural analysis of any stand structure based on its age and size is very useful for reconstruction of history of the stand development and assessment of tree population stability, besides predictions of
successional trends. The important dimensional parameters namely, tree height, diameter at breast height (DBH), girth at breast height (GBH), timber height and volume, etc. are used in forest mensuration for the assessment of the growing stock (Mahapatro, 1999).

Plant cover and growth were the most frequent indicators used to gauge mineland restoration success (Seo et al., 2008). Growth and yield of any stand is mainly affected by management regime, genetic variation, stand age, stand density and site quality (Shah Nawaz and Kamaluddin, 2006). Structural/ dimensional parameters (viz., density, height, DBH and basal area) of different plantations of the world have been reviewed by various workers.

Many workers in the country have studied growth of different species in different types of edaphic and climatic conditions (e.g., Singh, 1982 a, b; Chaturvedi, 1983a; Rai, 1983; Pande et al., 1986; Jha and Singh, 1993; Chaturvedi and Sood, 1995; Chaturvedi and Behl, 1996; Singh et al., 1996a; Panwar and Bhardwaj, 1999; Jha et al., 2000; Singh et al., 2004c; Dogra and Upadhyay, 2005; Roy et al., 2006; Shah Nawaz and Kamaluddin; 2006; Piare Lal, 2007; Umrao et al., 2010; etc.). In India, growth of pine plantations has been studied by several workers (Singh and Raman, 1979; Pande, 1982; Abdul Bari and Prasad, 1987, 1989; Misra et al., 1997, Mahapatro, 1999, etc.). The production and growth studies in forests and plantations have been carried out with dimensional analysis (Bandhu, 1970; Singh, 1981; Rai, 1983; Kondas et al., 1985). In Orrisa, the history and performance of different pine species have been reported by Das (1982) and Das and Stephan (1986).

In the study area, it was found that till the middle of the last decade, mostly exotic tree species like Eucalyptus hybrid, Grevillea robusta, Acacia auriculiformis, Pinus kesiya, Simarouba glauca, Casuarina equisetifolia, Jatropha curcas, etc. were planted in rehabilitated areas. Many species like Acacia nilotica, Aegle marmelos, Anacardium occidentale, Artocarpus heterophyllus, Bambusa sp., Cassia fistula, Cassia siamea, Casuarina equisetifolia, Madhuca indica, Mangifera indica, Melia azedarach, Michelia champaca, Phyllanthus emblica, Syzygium cumini, Syzygium jambos, Tamarindus indica and Terminalia arjuna were planted since 2007 onward, and hence,
their growth measurement was not of any significance as none of them could attain height of more than 30 cm.

For growth analysis, quadrats of 10 m x 10 m were laid. The structural parameters such as density, tree height and diameter at breast height (DBH) were recorded in 2010 in all the quadrats of the plantations in the unmined area (UAP), reclaimed areas with plantations of 1, 3, 5, 7, 9, 11, 13, 15, 17, 19 and 21 years of age (OB Area Plantations), and four forest area plantations of different years and four different species, viz., *Eucalyptus* hybrid, *Acacia auriculiformis*, *Grevillea robusta* and *Pinus kesiya* near the study area (FA Plantations). As mentioned earlier in Chapter 3, the plateau top is devoid of trees, other than those planted as rehabilitation measures after mining. No forest area plantation of these tree species could be found on the plateau top for comparison of growth of rehabilitated area plantations other than the 13-yr-old unmined area plantation of *E. hybrid* by NALCO on the plateau top. Hence, plantations of above mentioned four species were selected at comparable altitudes of about 900 m from MSL for comparison of growth data with those of rehabilitated areas.

Above structural parameters were recorded again in 2011 in the same plantations and same quadrats, however, in 2011 they were recorded for *Eucalyptus* hybrid, *Acacia auriculiformis*, *Grevillea robusta*, *Pinus kesiya*, *Syzygium cumini*, *Pongamia pinnata* and *Casuarina equisetifolia* only. Other species, like *Tamarindus indica*, *Terminalia arjuna*, *Madhuca indica*, *Phyllanthus emblica*, etc. were either present in 1-year-old plantations only or had not attained height above 1.37 m at other sites also, and hence, measurement of their DBH was not possible. In the present study, DBH and height of alternate years of plantations starting from 1-yr-old plantation were recorded in 2010 and 2011 in 10 m x 10 m quadrats. Since, plantations of 2007 and 2009 could not attain height of 1.37 m in 2011 also; hence, growth data of those sites were not recorded in 2011. For selection of quadrats in rehabilitated areas, stratified random sampling with proportional allocation, as mentioned in earlier paragraphs for shrub and herb/lianas, was adopted. In UAP and FA Plantations, 3 to 5 quadrats were selected randomly for this study purpose. On the basis of these data, basal area (BA), parabolic volume (PV), CAI, MAI, increment percent (P) and relative growth rate
(RGR) in different growth parameters of the above species were calculated for further study and comparison.

4.2.1 Basal Area (BA)

Basal area refers to the ground actually penetrated by the stem. It is one of the chief characters determining the dominance or otherwise of a particular species in a community or vegetation stand. Basal area (BA) of individual tree was calculated using the formula:

$$BA = \frac{\pi (\text{DBH})^2}{4}$$

Total basal area per unit land area was calculated by multiplying the basal area per tree with corresponding density.

4.2.2 Parabolic Volume (PV)

The ultimate object of all mensurational activity in forest is to calculate or estimate quantity of wood contained in trees and consequently in crops not only for sale but also for research, predicting future yields, estimating increment to assess return on capital, etc. Volume has been the traditional measure of wood quantity and continues to be the most important measure in spite of increasing use of weight or biomass as a measure of forest productivity. For calculating volume of standing trees, parabolic volume (PV) using Smalian’s formula (Chaturvedi and Khanna, 2000) was calculated as below:

$$PV = \frac{BA \times H}{2}$$

where, \(BA = \text{Basal Area of the tree (cm}^2\) \)

\(H = \text{Height of the tree (m).}\)

The increment, whether in diameter, height or volume is expressed in terms of current annual increment (CAI), mean annual increment (MAI) and increment percent (P). Current annual increment is the increment which a tree or a crop puts on in a single year. Mean annual increment is the total increment upto a given age divided by that
age. Increment percent is defined as the average annual growth in a particular parameter over a specified period and is calculated using the compound interest formula (Ibid, 2000):

\[
P = 100 \times \left[ \sqrt[n]{\frac{X_2}{X_1}} - 1 \right]
\]

where, \( X_1 \) = Initial size of the parameter (biomass / DBH / height / BA / PV)
\( X_2 \) = Size of the parameter after the time period (n), which is one year in the present study
\( P \) = Increment percent (%)

### 4.2.3 Relative Growth Rate (RGR)

Relative growth rate (RGR) in dimensions such as DBH, tree height, BA and PV was calculated following Phillips et al. (1986).

\[
RGR = \frac{M_2 - M_1}{M_2(T_2 - T_1)};
\]

where, \( M_2 \) and \( M_1 \) are dimensions during current and previous year, respectively, and \( (T_2 - T_1) \) is the time period (one year in the present study) between the two measurements.

### 4.2.4 Tree growth comparisons at different sites

Growth data (DBH and height) were taken for planted species at OB rehabilitated sites. These data were recorded for corresponding species at nearest possible forest area plantations for comparison of growth data. In case of Eucalyptus hybrid, one more site, i.e., unmined area plantation (UAP) was available for comparison. The means of the observations were compared through Student’s t-test using following hypothesis:

(a) Two sample (independent) t-test : where the data of the same age were available:

Null hypothesis: \( H_0: \mu_1 = \mu_2 \)
Alternative hypothesis: \( H_a: \mu_1 \neq \mu_2 \)

(b) One sample t-test: where the data of the same age were not available for OB sites, and hence, the reference mean of the same age was predicted (by linear/curvilinear regression):

Null hypothesis: \( H_0: \mu = \text{predicted mean} \)

Alternative hypothesis: \( H_a: \mu \neq \text{predicted mean} \)

These two-tailed t-tests were processed at 95% level of confidence and the null hypothesis was rejected if the P-value was found more than 0.025.

4.3 STUDY OF IMPORTANCE OF PLANTED SPECIES FOR THE PEOPLE OF THE STUDY AREA

For study of impact of mine rehabilitation plan on the socio-economy of the local people, a questionnaire based study was conducted to assess the importance of planted species for the local people along with various other plant species being used by them, so that emphasis may be given for their plantation while prescribing a suitable package. The research study was based on both primary and secondary sources of information. Primary sources were a questionnaire survey and data collected from Panchayat office. Secondary sources consisted of published materials in books, theses, journals and government reports/records. In the selected villages, demographic details were collected from the Panchayat office.

In the present study Stratified Random Sampling technique was applied to collect the data. In this technique heterogeneous population was first divided into subpopulation of different strata and then sampling units were selected from each of them in proportion to their sizes. The villages were selected in the first stage and households in the second stage.

Data related to use of forest produces by local people were collected to analyze the importance of those species for them. Stratified random sampling was used to select the villages and the households. The area adjoining the Panchpatmali bauxite mine was
differentiated into zones depending on the distance from the boundary of the mine as follows:

Zone- 1: zone of maximum impact: 5 km from the periphery of the mine;
Zone- 2: zone of moderate impact: between 5 and 10 km from the periphery of the mine;
Zone- 3: zone of least impact: between 10 to 15 km from the periphery of the mine.

A questionnaire (Appendix-I) was designed to collect data on use of different plant species by the local people so that emphasis may be given for plantation of those species. Data related to the questionnaire were collected from the selected families of selected villages and from the local ‘haat’/bazaars usually visited by the villagers of the surveyed villages. As explained by Anitha (1996), the present scholar also encountered the problem of illiteracy among the local people, especially the ‘Disaries’. Hence, help of NALCO officials as interpreter was sought for translation. This problem has also resulted in lesser information on uses of various medicinal plants by those surveyed ‘Disaries’, and hence, secondary sources were relied upon more.

Sampling intensity in selection of villages decreased with distance. 15% of villages in Zone- 1, 10% in Zone- 2 and 5% in Zone- 3 were covered. Families were selected on the basis of their dependence on forests for livelihood. The data collected were analyzed on percentage basis. There were 14 villages in Zone- 1, 38 in Zone- 2 and 41 in Zone- 3 in total. Hence, 3 villages (15 %) in Zone- 1, 4 (10 %) in Zone- 2 and 2 (5 %) in Zone- 3 were selected randomly for the present study. These are mentioned below:

Zone-1 - Sananeraka, Lataput and Girliput.
Zone-2 - Lachhamani, Bilaput, Dangayatput and Ariputraghati.
Zone- 3 - Amlabadi and Kusumpadar.

4.3.1 Selection of households (HH)

Depending on the total number of households in the selected villages and taking into consideration their dependence on nearby forests for their day-to-day needs, one-
third of the total households in each village with a maximum of 30 households (in Lachhamani) were selected. The scholar interviewed only one member, either male or female from each of the selected households through a well-structured questionnaire at their doorstep or during health camp organized by NALCO in the selected villages. The questionnaire sought information on options being used for source of energy for cooking, species generally used for firewood, timber, for agricultural implements, food, medicinal purposes and other NTFPs for own consumption or sale, so that those species may be preferred during future plantation activities after mining. Data obtained were expressed in percentage and were accordingly analyzed.

The local names, their utility as medicinal plant in folk medicine and their uses by local people were also surveyed. For this study help from people practicing as ‘Vaidya’ (called ‘Disari’ in local language) were sought through continuous persuasion and request as they were reluctant to divulge information. No person acting as ‘Disari’ was present in Lataput and Dangayatput.

Selected ‘haats’ for survey of NTFPs being sold there were Kakariguma (Monday ‘haat’), Damanjodi (Thursday ‘haat’), Semliguda (Sunday ‘haat’), Sunabeda (daily ‘haat’) and Mathalput (daily ‘haat’).

4.4 STUDIES FOR SUITABLE PACKAGE FOR MINE REHABILITATION

Soil may be defined as a thin layer of earth’s crust, resulting from the transformation of surface rock by the combination of climate, plant and animal life, and time; and it serves as a natural medium for growth of plants (Zonn, 1986). It serves as a reservoir of nutrients and water for plants, and provides mechanical anchorage. The physical properties of soil such as texture, structure, porosity, water content, consistency, temperature and color are dominant factors affecting the use of soil. These properties determine the availability of oxygen in the soil, the mobility of water into or through the soil, and ease of root penetration. In assessing the fertility of soil, data of their physical properties are important.

Ecosystem development is an evolutionary process. Both soil formation and community development are interdependent. The positive effects of vegetation on soil
formation and organic matter accumulation have been well documented (Stevenson 1965; Woodmansee et al., 1980; Aweto, 1981 b). Aweto (1981c) suggested that in view of the fact that soil textural composition affects plant growth, the afforestation schemes should be soil specific.

Texture (soil particle-size distribution) is one of the most permanent of all soil physical properties. It is defined as the percentage by weight of the various soil particle sizes. It influences aeration, permeability, soil moisture relations, erosion characteristics, bulk densities, nutrient contents and availability (Jha, 1990). Moisture content of the soil is one of the basic physical parameters of the soil which affects the establishment of plant. Soil pH is an important aspect and in certain areas, it is the main factor in preventing vegetation from becoming established (Singh et al., 2002). Soil fertility is a major factor, which regulates plant growth. Nitrogen is a major factor limiting the rate of vegetation development (Bradshaw et al., 1975).

Soil quality indices are useful for ascertaining temporal changes in soil properties in relation to land use and management, especially for drastically disturbed soils, and for designing the best management systems for mine soil reclamation (Shukla et al., 2004). Success in establishing a self-sustaining vegetative cover on material that has been mechanically and chemically altered to an unnatural condition depends on careful analysis of the physical and chemical characteristics of the new growing medium (Lyle, 1987).

Hence, knowledge of soil quality is important to rehabilitate a site disturbed by mining. Therefore, data on physico-chemical properties (soil texture, bulk density, pH, EC, total nitrogen, available phosphorous, available potassium and organic carbon) of virgin area, i.e., the site where mining will be done in future and from where top soil will be brought to be spread over the OB material for rehabilitation, and fresh mine spoil (FOB) ready for plantation activity are essential for prescribing suitable plant species for rehabilitation package of the mining area.
4.4 Soil sampling

Soil samples were collected in triplicate randomly from above mentioned two types of sites, viz., VA and fresh overburden (FOB) material ready for plantation. At each location, soil samples were collected from three spots, like three corners of a triangle, at a distance of approximately 3 m from each other. At each spot, soils were collected from top 15 cm and from 15-30 cm levels. The three samples from the top 15 cm layer of the three spots at each site were then composited at the site itself to make a true representative of that site. Large pieces of stones and plant materials were hand-picked while mixing the soil samples. Samples were kept in totally opaque plastic zipper bags and were coded for identification. Soil samples brought to the laboratory were spread out on a plastic sheet. Large lumps of moist soil were broken by hand. Coarse concretions, stones and pieces of roots, leaves and other under-decomposed organic residues were removed. After air-drying, the soil samples were crushed gently and were sieved through a 2 mm sieve. The material larger than 2 mm was discarded. Soil samples were air-dried and sieved through a 2 mm mesh screen for analyzing other physical and chemical parameters. Similar procedures were adopted for samples collected from 15-30 cm soil depth. The samples were analyzed for texture, pH, EC, bulk density, total nitrogen, available phosphorous, available potassium and organic carbon.

4.4.2 Soil analysis

Texture

Particle-size distribution (texture) was analyzed by Pipette method as described by Piper (1944).

Determination of bulk density

Bulk density of the soil samples were measured by core sample method. A metal core cylinder of known volume and weight was used to determine it.
Determination of soil pH

Twenty gram of sieved soil sample was taken in a 100 ml beaker and 50 ml of water was poured. The mixture was stirred for 10 minutes and left for 30 minutes undisturbed. Then it was stirred again for 2 minutes. pH meter was calibrated with neutral pH and pH knob was adjusted for the temperature. pH of the supernatant was determined by a pH meter and the value was recorded (Piper, 1944).

Determination of soil electrical conductivity

Electrical conductivity (EC) is the most common measure of soil salinity and is indicative of the ability of an aqueous solution to carry an electric current. 20gm of sieved soil was taken in small beaker and then 40 ml distilled water was added to it. It was shaken intermittently for one hour on a shaker. Conductivity bridge was calibrated with a standard KCl solution and cell constant was determined. EC of the saturation extract was recorded at room temperature with an EC-meter (Champan and Part, 1961).

Estimation of soil organic matter

The amount of organic matter in soil sample was determined by using Walkley and Black rapid titration method (Jackson, 1958). 1g sieved soil sample was transferred to a 500 ml Erlenmeyer flask and to it were added 10 ml of 1N K$_2$Cr$_2$O$_7$ solution and 20 ml of concentrated sulfuric acid. The mixture was swirled until soil and reagent were mixed fully. After 30 minutes, 200 ml of distilled water was added to the flask. Then 10 ml of o-phosphoric acid was added to it and carbon was determined by titrating the solution with 0.5 N ferrous sulphate and using few drops of diphenylamine as indicator.

Estimation of total nitrogen

Total soil nitrogen was analysed by Kjeldahl method. NH$_2$SO$_4$ was used as a catalyst and total nitrogen was determined by an auto-analyser.

Estimation of available phosphorus

Estimation of available phosphorus in the soil was determined by ammonium molybdate stannous chloride method as suggested by Subba Rao and Sammi Reddy
(2009). 2.5 g of soil sample was shaken with 50 ml of 0.5 M NaHCO₃ solution and pinch of charcoal for 1 hour. The solution was then filtered through Whatman filter paper. Then 5 ml of clear aliquot was taken into 50 ml of volumetric flask. To it 10 ml of ammonium molybdate and 0.5 ml of stannous chloride were added and the solution was diluted to 50 ml with distilled water. After 10 minutes of SnCl₂ solution addition, optical density of the solution was measured in a photoelectric colorimeter. Standard curve for available phosphorus was prepared by making the solution of KH₂PO₄ with different dilutions

**Estimation of available potassium**

Potassium can be quickly determined by flame emission acetate as suggested by Subba Rao and Sammi Reddy (2009). 5 g of soil sample was taken in 150 ml volumetric flask and 25 ml of ammonium acetate was added. It was shaken for 5-10 minutes and was filtered with ordinary filter paper. Reading was taken in flame photometer. Standard curve for available potassium was prepared by using the solutions of K₂SO₄ with different dilutions.

A suitable rehabilitation package was prescribed with the help of above studies. For suitability of species to be planted successfully in the study area, established literatures were also consulted.
Photo 9: Growth measurement of *Syzygium cumini* planted in rehabilitated area

Photo 10: Survey for phyto-sociology in rehabilitated area plantation

PLATE- 5
Photo 11: Latitude-longitude recording of the quadrat

Photo 12: *Grevillea robusta* planted in rehabilitated area

PLATE- 6
Photo 13: Growth measurement of *Grevillea robusta* planted in forest area

Photo 14: Growth measurement of *Acacia auriculiformis* planted in forest area

PLATE-7
Photo 15: Survey for phyto-sociology in forest area plantation

Photo 16: *Lantana camara* in rehabilitated area plantation

PLATE- 8