*Eco. Env. & Cons. 29 (1) : 2023; pp. (229-240)*

*ISSN 0971–765X*

**DOI No.: http://doi.org/10.53550/EEC.2023.v29i01.037**

# Impact of surface coal mining on soil properties of the region at Talabira mining area, Sambalpur, Odisha

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(Received 23 August, 2022; Accepted 11 October, 2022)

**ABSTRACT**

Large scale surface coal mining activities result in disturbance of the local ecosystem by creating different land uses that alter soil properties and hydrological balance of the mining area and surrounding environment. This study aims to evaluate the changes in soil properties in mining affected lands (mine face topsoil, wasteland and agriculture land) and reclaimed mine soil (RMS), and to quantify the changes of the selected soil properties with respect to reference Sal forest (*Shorearobusta* Gaertn. F.). Changes in soil properties were analyzed on a profile basis (0–20, 20–40 and 40–60 cm). The study indicates that soil pH, electrical conductivity, and bulk density were increased significantly, while a decrease in nutrient content (N, P, and K) was observed in the mining affected lands. The overall findings of this study indicated that conversion of Sal forest into other land uses due to mining significantly reduced the nutrient content and soil quality of the area. Reclamation of the mine degraded land in short duration does not restore the overall properties of the soils, which has long term impacts on the surrounding ecosystem.

***Key words :*** *Coal mining, Soil properties, Reclamation, Land use*

## Introduction

Land is one of the most important resources on which human beings depend. The rate of consumption of mineral resources is continuously increasing with the advancement of science and technology, economic development, industrial expansion, acceleration of urbanization and growth of population. Growth of our society and civilization thus heavily rely upon the mining industry to operate and maintain comfort. The result for mining activities on the surface is mining wastes and alteration of landforms, which is a concern to the society and it, is desired that the pristine conditions be restored. Mine wasteland generally comprises the bare stripped area, loose soil piles, waste rock and overburden surfaces, subsided land areas, other degraded land by mining facilities, among which the waste rocks often pose extremely stressful conditions for restoration. The mining disrupts the aesthetics of the landscape as well as the soil components such as soil horizons and structure, soil microbe populations, and nutrient cycles that are crucial for sustaining a healthy ecosystem and hence results in the destruction of existing vegetation and soil profile. The overburden dumps include adverse factors such as elevated bioavailability of metals; elevated sand content; lack of moisture; increased compaction; and relatively low organic matter content. Acidic dumps may release salt or contain sulphidic material, which may generate acid-mine drainage.

The physical and chemical characteristics of soil play a big role in the plant's ability to extract water and nutrients. High quality soils not only produce better food and fiber, but also help to establish natural ecosystems and enhance air and water quality. The physical properties of the soil depend upon the amount, shape, structure, size, pore spaces, organic matter and mineral composition of soil. The chemical properties of the soil are the interactions of various chemical constituents among soil particles and the soil solution. These physical and chemical properties are soil texture, bulk density, soil structure, soil color, pH, electrical conductivity, cation exchange capacity, organic carbon, organic matter and soil nutrients. All soils have different properties and working with them requires understanding of these properties. The knowledge of the physical and chemical properties of soil helps in managing resources while working with a particular soil

Coal is the second largest source of energy accounts for 24% of total energy consumed globally and fulfils 67% of the electricity demand in India (CEA, 2015). In 2014, India produced 654 million tonnes (Mt) of coal (ranked 3rd), next to China (3474 Mt) and USA (924 Mt) (Enerdata, 2015). Coal India Limited (CIL) accounts for around 80% of India's total coal production and committed to an ambitious target ofone billion tonnes by 2019–20, from the current level of 556 Mt. in 2013–14 (MoC, 2015). CIL depends largely on two of its subsidiaries; Mahanadi coalfield limited (MCL) and South eastern coalfield limited (SECL), which can contribute nearly half of the target production. Switching to full mechanization and adoption of the latest technology to meet the target, massive expansion of opencast mines is envisaged and 90% of the coal is extracted by the opencast mining (MoC, 2015). Mining is site specific and the method of extraction depends on the occurrence of the coal deposits (Maiti, 2013). Direct and indirect activities of mining totally change the land use of the area. Direct activities include deforestation, topsoil removal followed by excavation of overburden and coal, resulted the creation of deep voids, external dumps and internal overburden (OB) dumps (backfilled) (Maiti, 2006). Consequently, these dumps are reclaimed with an aim to develop forestry (Maiti, 2013). These reclaimed sites are characterized by high rock fragments, deprived of soil nutrients, high bulk density, very low infiltration due to compaction, change in entire drainage and undulating topography (Mummey *et al.,* 2002; Reynolds and Reddy, 2012; Shrestha and Lal, 2008). Indirect activities like timber felling during construction of the approach road, houses and other infrastructure facilities, such as school, hospital and residential colony, which cause migration of population due to the creation of job opportunities that increase anthropogenic or biotic pressure in the periphery of the open cast project (OCP) and creates different types of land uses.

In the present study, we hypothesized that conversion of forest land into different land uses due to surface mining activities directly and indirectly alter the physicochemical and hydrological properties of the area. Thus, the magnitude of changes in soil quality due to direct and indirect impacts of surfacemining were evaluated by comparing with a pristine Sal (*Shorea robusta* Gaertn. F.) forest. We also assess whether reclamation of overburden dumps improves overall soil quality in short duration or it is just a cosmetic work for the natural esthetics. The present study was undertaken to quantify the changes in soil quality under different land uses in Talabira mining area with respect to the nearby Sal forest, The study further  attempts identify the soil parameters which was modified due to changes in land use as a result of mining activities and further assess whether reclamation of overburden dumps, in short duration improves the overall soil quality and ecosystem functions.

## Materials and Methods

### Study Area

Talabira coal block  is present at (altitude 21°44'37"N to 21°47'29"N and Longitude 83°32'45" E to 83°59'00"E. The block is covered under Survey of India topo sheet No.64 O/13 and 64 O/14 on and fall within Jharsuguda and Sambalpur Districts of Odisha State. The maximum extents of the block is about 7 km is along the strike direction. The limits of Talabira – II and III Coal Blocks are given below:

**East :** The Eastern boundary of the block is marked by no coal zone area.

**West :** Western boundary of the block is fixed along the fault F1F1 and no coalzone

**North :** Northern boundary is marked by Rampur block/Ib-River and no coalzone

**South :** Southern boundary is marked by block boundary between Talabira – I and Talabira II and III block.

The description of land uses is as follows:

(i) Reclaimed mine soil (RMS): Dump sites were reclaimed in the year 2010 by planting fast growing tree saplings, such as Cassia seamea Lamk., *Dalbergia sissoo* Roxb., *Gmelina arborea* Roxb., *Acacia nilotica* (L.) Delile, and *Acacia mangium* Willd. (Fig. 2). Newly developed RMS has poor soil quality with high rock and boulders, compacted surface and promotes the invasion of xeric weeds. Ground vegetation consists of shrubs (*Calotropis procera* (Aiton) WT Aiton, *Datura spcemonium* L., *Crotalaria retusa* L., and *Lantana camara* L.) and herbaceous plants (*Tephrosia purpurea* (L.) Pers., *Dactyloctenium aegyptium* (L.) Willd., *Cyperus rotundus* L., *Allotropis semialata* (R.Br.) Hitchc. and *Borreriahispida* L. The density of saplings were 2500/ha

(ii) Wasteland is the part of Sal forest, which was deforested by the local communities and migrated population for the shelter (Fig. 3). The area is mostly barren and infrequent saplings of *S. robusta* along with under shrubs *Chromolaena odorata* (L.) King and Robins, *C. procera*, *Sidahipsida L.*, *Clerodendrum infortunatum L.*, and *L. camara* were noticed.

(iii) Agriculture land: Mostly used for single crop (Paddy; *Oryza sativa L.*) cultivation by the local communities (Fig. 4).

(iv) Mine face topsoil is a disturbed soil, located towards the direction of development of mine face which will be subsequently removed with the expansion of mine (Fig. 5). These areas are located inside the project boundary (core zone). The vegetation cover consists of saplings of *S. robusta,Butea monosperma* (Lam.) Taub., and *Lagerstroemia speciose*

(v) Sal forest (Reference forest site): Sal forest is a unique ecosystem characterized by laterite soil, low pH, sandy soil, rich in Fe and Al contents, and high IR (compared to wasteland and agriculture land) with high recharge potential (Chitale *et al.*, 2014; Maiti and Maiti, 2015; Singh *et al*., 2001) (Fig. 6). *S. robusta* forest represents the climax species, along with other associates such as *Haldina cordifolia*

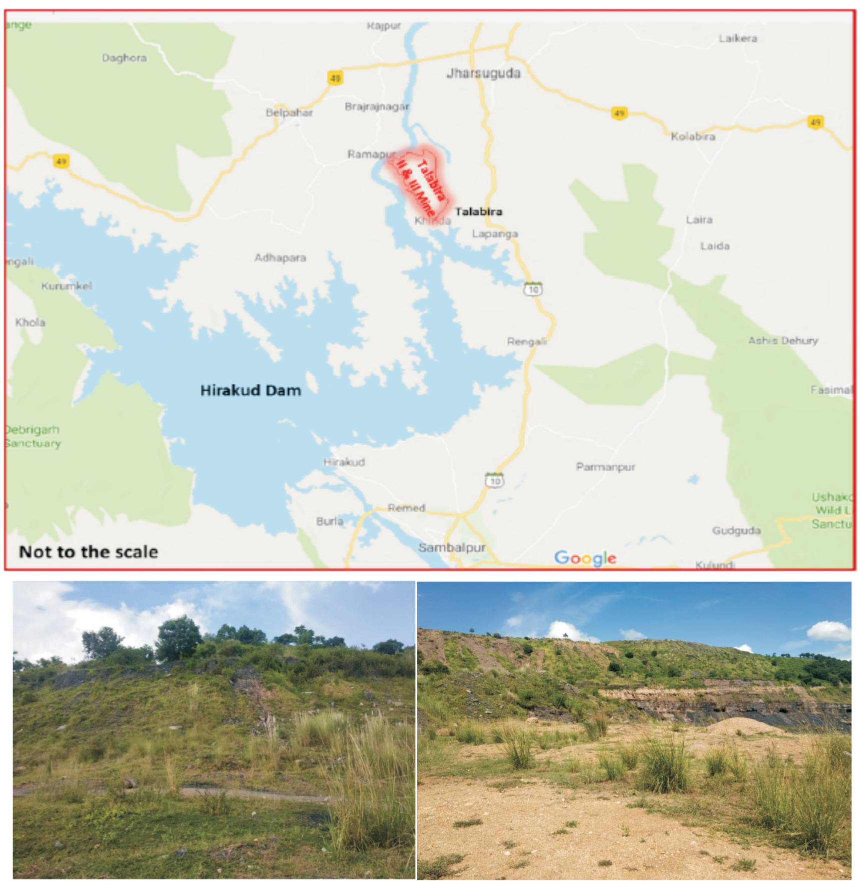


**Fig. 1.** Location Map of Talabira Coal Mines, Sambalpur, Odisha

(Roxb.) Ridsdale, *Aegle marmelos* L., *Terminalia elliptica* Willd. and *Acacia catechu* L., *Ziziphus jujuba* Mill., *Ziziphus mauritiana* Lam. The dominant understory species include M*urrayakoenigii* (L.) Sprengel, *Tiliacora acuminate* L.,*C. infortunatum*, *Ichnocarpus frutescens* (L.) W.T. Aiton, and B. *monosperma.*

**Sample collection**

In five land use types (i.e., RMS, Mine face topsoil, wasteland, agriculture land and Sal forest), five random grids (10 m × 10 m) were laid down based on surface topography, vegetation cover and colour, which is representative to the area. From each grid, subsamples were collected on profile basis; 0–20 cm, 20–40 cm, and 40–60 cm and mixed thoroughly at the spot, and weight was reduced to 0.5 kg by using the Coning and quartering method (Maiti, 2013). Thus, from each land use type, soil samples from three profiles were collected (Fig: 7-10). All the samples were transferred in air tight polypropylene zip bags and taken to the laboratory. Field survey was conducted and soil samples were collected from various locations in and around the proposed mining sites by random sampling design method (Tripathy *et al.,* 1998).

**Sample Preparation**

The soil sample was spread on an aluminum tray, plastic or a thick brown paper. Coarse concretions, stones and pieces of roots, leaves and other unrecompensed organic residue were removed. The sample were air dried at 20 °C to 25 °C and 20% to 60 % relative humidity. After air drying the soil was crushed gently in pestle and mortar and sieved through a 2 mm sieve. The material larger than 2 mm was discarded.

**Analysis of soil samples**

Samples were air-dried at room temperature, lightly crushed with a mortar and pestle and passed through a 2-mmsieve and kept for further analysis. Samples were analysed for coarse fraction (N2 mm size) by sieving method using the standard mesh size (Indian Standard, 1985) and particle size was analysed by the international pipette method (Gee and Bauder, 1986). Bulk density was determined by estimating the dry weight of the unit volume of soil in metallic core (Sobek *et al.,* 1978) and the field moisture was estimated by gravimetric method (Dakshinamurthi and Gupta, 1968). Soil pH and electrical conductivity (EC) were determined in soil: water (1:2.5, w/v) suspension with a pH meter and Conductivity meter (LabMan Scientific Instruments, LMMP-30), respectively. Soil organic carbon (SOC) was determined by rapid dichromate oxidation technique (Nelson and Sommers, 1996), available nitrogen (N-$NH_4$) by alkaline potassium permanganate method (Subbiah and Asija, 1956) and available phosphorus was extracted by Brays reagent and determined by spectrophotometer (Shimadzu UV Spectrophotometer, UV-1800) (Bray and Kurtz, 1966). Exchangeable potassium (K+), calcium($Ca^{2+}$), and magnesium ($Mg^{2+}$) were extracted by ammonium acetate solution followed by flame photometer (Microprocessor flame photometer, ESICO-1388) determination for $K^+$ and $Ca^{2+,}$ and $Mg^{2+}$ is determined in atomic absorption spectrophotometer (GBC Avanta, Australia) (Jackson, 1973). Cation exchange capacity (CEC) was estimated by the Na saturation method (Jackson, 1973). A soil auger was used to obtain volume samples with a minimum of 0.5 kg of soil per sampling area. Soil samples were placed in tightly sealed plastic bags and kept at 4 °C to keep them field moist and to preserve biological properties. Soil moisture content was determined gravimetrically after drying soil samples at 105 °C. The chemical and physical analyses for the characterization of soil cover layers of the respective sites were done. The air dried topsoil samples were ground and pass through 2 mm sieve. The collected topsoil samples after coning and quartering then sieving (2 mm) were used for analysis of different soil quality parameters. The following methods are briefly mentioned underlined.

**pH of the Soil**

The Soil sample received from the field is taken and mixed thoroughly and sieved on a 425 micron IS sieve. Weigh 30g of the soil from the sample in a 100 ml beaker. 75 ml of distilled water is added and stirred for a few seconds and cover the beaker with watch glass and allow standing for one hour. pH is calibrated meter by using the buffer solution. After calibration pH electrode immerse the sample suspension and measure the pH value directly as per the pH meter manufacturer instruction.

**Moisture Content of the soil**

The container with lid was cleaned, dried and weighted (W1). The required quantity of the soil specimen was taken in the container and weigh with lid ($W_2$). The lid was removed and kept the sample in hot air oven at 110 °C. The specimen was dried in the oven for 24h. The lid was replaced on the container and cool the container in a desiccator. The final mass ($W_3$) of the container with lid andwith dried soil sample was measured.

**Calculation**

The percentage of Moisture (Water content) was calculated as follows.

$$W = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Where W = Moisture (Water Content)
$W_1$ = Mass of container with lid in g
$W_2$ = Mass of container with lid with wet soil in g.
$W_1$ = Mass of container with lid with dry soil in g

**Estimation of Bulk Density of soil**

Bulk density was determined by estimating the dry weight of the unit volume of soil in metallic core (Sobek *et al*., 1978). After drying in oven at 105 °C for 18-24 hours the sample was sieved in 1mm size sieve. 100 g soil was taken in dried 100 ml cylinder tapping in 1 min. The volume of sample was measured.

**Calculation**

$Gm/Cm^3$ = Weight of sample (g )/Volume of sample (ml)

**Measurement of Organic carbon content**

The pre-airdried soil sample was passed through 425 micron IS sieve.0.2 to 1 g was taken in a dry 500 ml conical flask.10 ml 1 N Potassium dichromate solution and 20 ml of Con. $H_2SO_4$ were added very carefully using the measuring cylinder. The mixture thoroughly swirled for about one minute and allowed to stand on an asbestos sheet for 30 minutes. It was then diluted with 200 ml distilled water and 10 ml phosphoric acid and one ml of indicator solution was added to it. The solution was titrated with 0.5 N ferrous sulfate until color change form blue to green.

**Calculation**

Organic Carbon = 10 (B-S) × 0.003 ×100/B × Weight of Soil

Organic Matter = 1.724 × Organic Carbon
B- Titer value of Blank
S- Titer value of Sample

**Electrical Conductivity in Soil**

20.0 g of sample was weighed and transferred to 100 ml conical flask to which 40 ml of distilled water was added. The bottle was closed and placed it in a horizontal position in the shaking machine and was shaken for 30 minutes. The soil water suspension was transferred into a 100 ml beaker. The conductivity was measured in electrical conductivity meter as per manufacturer instruction.

**Estimation of Available phosphorus**

To 5g of soil sample 50 ml of citro-molybdate and 5 drops of quinoline hydrochloride solution was added, stirred and boiled. After crystalline formation it was allowed to stand on the hot-plate for 15 minutes and was cooled to room temperature. The mixture was filtered through a filter paper, the flask was washed and precipitated with cold water until free from acid. 100 ml distilled water and 50 ml of 0.5 N NaOH was added, shaken vigorously until all the precipitate dissolved. The solution was titrated with 0.5 N Hydrochloric acid using mixed indicator changes from violet to green-blue and very sharply to yellow.

**Calculation**

Phosphorous as P (%) = $0.05965 (V_1 - V_2 - (V_3 - V_4)/5)/M$

$V_1$ = Vol. of 0.5 N NaOH used in sample
$V_1$ = Vol. of 0.5 N NaOH used in sample
$V_2$ = Vol. of 0.5 N HCL used in sample .
$V_3$ = Vol. of 0.1 N NaOH used in sample
$V_4$ = Vol. of 0.1 N HCL used in sample
M = Weight of sample

**Estimation of Calcium content of soil**

5 g of soil sample was taken. The weighed sample was taken in a 150 ml Erlenmeyer flask. 25 ml of Ammonium acetate was added and shaken on a shaker (180+ oscillations/ min) for 5 min and then an aliquot of the extract was pipetted out in a conical flask. 10 drops of EBT triethanolamine solution was added and titrated with EDTA until blue color was observed.

**Calculation**

$$\text{Calcium as Ca} = \frac{\text{T. value} \times \text{N of EDTA} \times 10^3 \times 40.08 \times \text{Extract vol.}}{\text{Vol. taken} \times \text{Wt of soil}}$$

**Estimation of EX. Magnesium**

Soil sample (5 g) was taken in a 150 ml Erlenmeyer flask. 25 ml of Ammonium acetate was added and shaken on a shaker (180+ oscillations/min) for 5 min, and an aliquot of the extract pipetted out in a conical flask. 10 drops of triethanolamine was added to potassium ferrocyanide solution and gently warmed for 3 min. The solution was cooled and 10 drops of EBT solution was added and titrated with EDTA until blue colour was observed.

### Calculation

$$\text{Magnesium as Mg} = \frac{\text{T.value} \times \text{N of EDTA} \times 10^3 \times 24.43 \times \text{Extract vol.}}{\text{Vol. taken} \times \text{Wt of soil}}$$

### Estimation of Available Nitrogen

5 g of the sample was taken in the digestion tube and little water was added to it. 25 ml of 0.32% $KMnO_4$ solution was added to the sample and fitted the tube in the distillation unit. 25 ml of 2.5% NaOH solution was added through the distillation unit. 25 ml of 2.5% of boric acid was pipetted out and mixed with indicator in a conical flask and dipped the receiving end of the Distillation unit. Ammonia gas from the tube was distilled and collected in the receiver solution, and titrated the solution and collected distilled with 0.02 N $H_2SO_4$.

### Calculation

$$\text{Nitrogen (mg/kg)} = \frac{14 \times (\text{Nor.of Acid}) \times (\text{Titrant Value}) \times 10^3}{\text{Sample wt (g)}}$$

$$\text{Nitrogen (Kgs/hec)} = \frac{14 \times (\text{Normality of Acid}) \times (\text{Titrant Value}) \times 2.24 \times 10^6}{\text{Sample wt} \times 1000}$$

### Soil Texture

10 g of soil sample was taken in 500 ml beaker. 125 ml of distilled water was added and boiled for 10 minutes. After cooling the supernatant was discarded. 20 ml of $H_2O_2$ was added to the pellet and digested on water bath till nofrothing was developed 20-30 ml of 2M HCl was added and diluted with 100 ml distilled water. The solution was allowed to stand for 1 hour and the liquid portion was removed and the residue was washed with distilled water. 5 ml of 2 M NaOH was added in soil residue and shaken for ½ hour. The residue in 1000 ml measuring cylinder was transferred and mixed with distilled water and the solution was shaken thoroughly for 1 minute and allowed to stand. 25 ml of solution was pipetted out and evaporated at 105 °C in oven, the difference weight. (clay + Silt ) was noted down. The remaining solution was shaken for 1 minutes and allow edto stand. 5 ml of solution at 10 cm depth after 6 hours was pippetted out in a preweighed bowel, evaporated at 105 °C in oven, note down the difference weight. (clay)

### Calculation

% Clay = (Difference wt. of clay + Silt) x 1000 x 100/ wt. of soil x vol. solution.
% Silt = (Difference wt. of clay - Difference wt. of clay + silt) × 400/10
% Sand = 100 – (% Clay+% Silt)

## Results

### Change in physical properties

The soil physico-chemical characteristics of RMS, mine face topsoil, wasteland, and agriculture land were analysed and compared with Sal Forest. In this study, soil showed higher percentage of sand and characterized as sandy clay loam, sandy loam and loamy sand. Decrease in sand percentage was more pronounced in agriculture land, RMS, and mine face topsoil, whereas it increases in the wasteland than that of Sal Forest (Table 1). Likewise, in different soil profiles sand proportion decreases from 11 to 23% in RMS and 10–23% in mine face topsoil (Fig. 1). Silt content was relatively higher in the mine face topsoiland agriculture soils, and lower in RMS and wasteland compared to Sal Forest (Table 1).

While no clear trends were observed between silt content and soil depths (Fig. 1). Clay content was found to be high in RMS and decline with the soil

**Table 1.** Result of Sand, Silt and Clay

| Land use | Sand % | | | Silt% | | | Clay % | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0-20 | 20-40 | 40-60 | 0-20 | 20-40 | 40-60 | 0-20 | 20-40 | 40-60 |
| Reclaimed Mine Soil | 24.2 | 25.77 | 26.23 | 0.72 | 0.57 | 0.38 | 75 | 71.68 | 70.62 |
| Mine Face Topsoil | 54.8 | 60.5 | 60.61 | 0.93 | 0.779 | 0.606 | 44.2 | 34.54 | 89.2 |
| Waste Lands | 42.6 | 41.27 | 41.29 | 0.65 | 0.74 | 0.71 | 56.7 | 79.62 | 76.16 |
| Sal Forest | 18.7 | 20.8 | 20.7 | 0.84 | 0.83 | 0.844 | 80.4 | 77.5 | 79.33 |
| Agriculture Land | 14.4 | 12.54 | 12.26 | 0.61 | 0.557 | 0.478 | 84.6 | 87.1 | 87.26 |

depth (Fig. 1). Change in sand %, clay % and silt % with respect to Sal Forest are shown in graph (Fig. 1 and 2).

A significant difference was found in soil bulk density that ranged from 1.10–1.34 $Mgm^3$ in different land uses. The increase in bulk density was more pronounced in RMS (18%) and did not show any clear patterns with soil depths (Table 2, Fig. 2). Higher moisture content was exhibited by RMS followed by mine face topsoil, agricultural land, Sal Forest and wasteland.

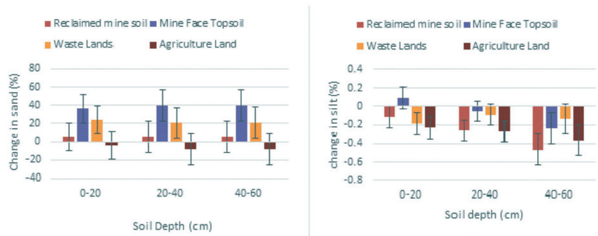


**Fig. 1.** Changes in Sand % and Silt % with increases in Soil depth

## Change in chemical properties

Soils of all the sites were acidic ranged from 4.5 to 6.5 and significantly different in different land uses. The decrease in pH was more pronounced in the 20–40 cm soil depth of RMS and agriculture soil (Table 3). For EC comparatively higher values were found at all the sites compared to Sal forest. EC showed the increasing patterns from 0 to 20 cm to 20–40 cm in RMS, mine face topsoil and agriculture soil. Whereas, no clear patterns were observed in all the three profiles of the different land uses studied (Table 3).

The land uses studied as compared to the natural Sal forest and exhibited a strong trend of decreasing nutrient content with soil depth. In comparison to Sal forest, SOC concentration decreases in, mine face

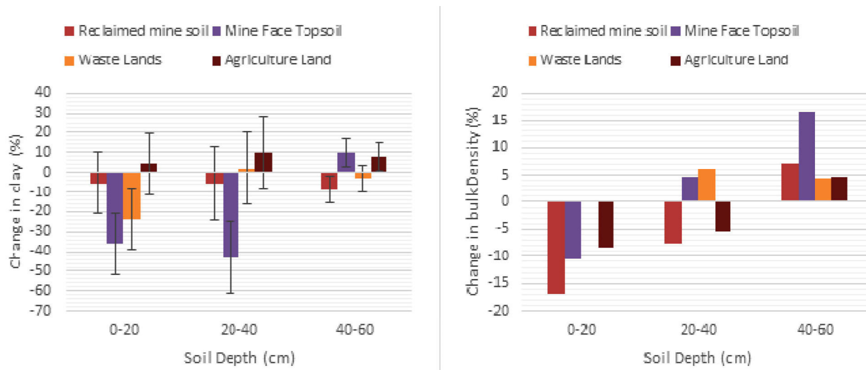


**Fig. 2.** Changes in Clay % with increase in soil depth

**Table 2.** Result of Bulk Density and Moisture %

| Land use | Bulk density | | | Moisture % | | |
|---|---|---|---|---|---|---|
| | 0-20 | 20-40 | 40-60 | 0-20 | 20-40 | 40-60 |
| Reclaimed mine soil | 1.19 | 1.21 | 1.36 | 3 | 3.43 | 3.63 |
| Mine Face Topsoil | 1.28 | 1.37 | 1.48 | 2.19 | 2.57 | 0.27 |
| Waste Lands | 1.43 | 1.391 | 1.326 | 0.42 | 0.49 | 0.43 |
| Sal Forest | 1.43 | 1.31 | 1.27 | 0.65 | 1.07 | 1.19 |
| Agriculture Land | 1.31 | 1.24 | 1.329 | 1.52 | 1.62 | 1.53 |

**Table 3.** Result of pH and EC (µs/cm)

| Land use | pH | | | ECµs/cm | | |
|---|---|---|---|---|---|---|
| | 0-20 | 20-40 | 40-60 | 0-20 | 20-40 | 40-60 |
| Reclaimed mine soil | 5.56 | 5.05 | 5.46 | 42.2 | 52.29 | 47.7 |
| Mine Face Top soil | 5.53 | 5.49 | 5.31 | 109 | 128.8 | 227.8 |
| Waste Lands | 5.98 | 6.95 | 6.39 | 48.3 | 36.3 | 36.3 |
| Sal Forest | 5.27 | 6.62 | 6.57 | 42.14 | 52 | 34.66 |
| Agriculture Land | 5.08 | 4.82 | 4.78 | 80 | 106.6 | 74.62 |

topsoil, wasteland, and agriculture soil, respectively (Fig. 3).

In all the soil types except RMS, increases in depth followed decreasing trends in SOC concentration. Av. N decreases significantly in order of in RMS, 50% in mine face topsoil and 34% inwasteland in 0–20 cm soil depth. Similarly, P content was found in the order of 54–60% in RMS, 30–34% inmine faceand 26–70% in wasteland in all the three soil profiles compared to Sal forest (Table 4).

Concentration of $K^+$ ions was found below detectable limit. $Mg^{2+}$ ions also followed a decreasing trend with soil depth and lower values were found at 40–60 cm depth. $Ca^{2+}$ concentrations were found higher in RMS than that of Sal forest soil (Table 5).

## Discussion

Anthropogenic pressure results in conversion of natural forest into agriculture land, wasteland and

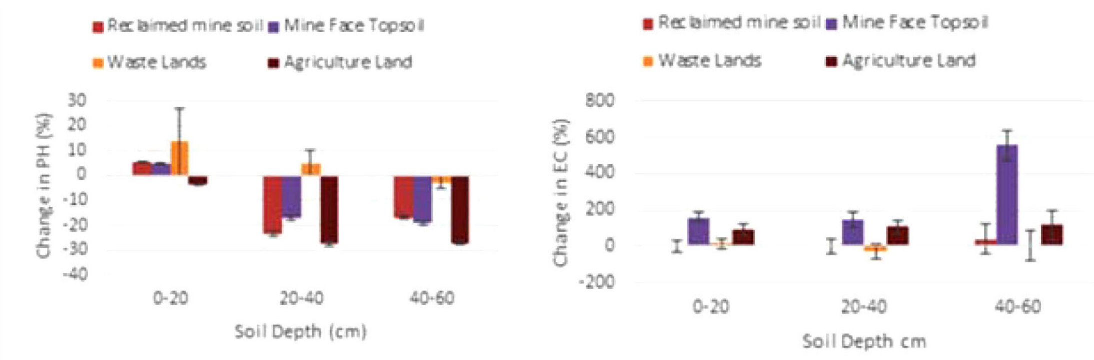


**Fig. 3.** Showing alteration in pH and EC with increase in depth of mining

| Land use | AV.N mg kg$^{-1}$ | | | AV.P mg kg$^{-1}$ | | | SOC mg kg$^{-1}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0-20 | 20-40 | 40-60 | 0-20 | 20-40 | 40-60 | 0-20 | 20-40 | 40-60 |
| Reclaimed mine soil | 34.1 | 31.23 | 25.52 | 0.8 | 0.878 | 0.718 | 3.29 | 3.83 | 2.57 |
| Mine Face Topsoil | 57 | 28.4 | 25.4 | 1.3 | 1.23 | 1.176 | 0.3 | 0.248 | 0.1762 |
| Waste Lands | 22.6 | 14.8 | 12.37 | 1.2 | 1.36 | 0.501 | 0.19 | 0.109 | 0.07 |
| Sal Forest | 45.4 | 28.3 | 23.89 | 1.6 | 0.4 | 0.37 | 0.98 | 0.49 | 0.473 |
| Agriculture Land | 108 | 83.53 | 60.22 | 1.4 | 1.6 | 0.963 | 0.62 | 0.525 | 0.43 |

**Table 4.** Result of AV.N, AV.P and SOCμs/cm


| Land use | AV.N mg kg$^{-1}$ | | | AV.P mg kg$^{-1}$ | | | SOC mg kg"1 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0-20 | 20-40 | 40-60 | 0-20 | 20-40 | 40-60 | 0-20 | 20-40 | 40-60 |
| Reclaimed mine soil | 34.1 | 31.23 | 25.52 | 0.8 | 0.878 | 0.718 | 3.29 | 3.83 | 2.57 |
| Mine Face Topsoil | 57 | 28.4 | 25.4 | 1.3 | 1.23 | 1.176 | 0.3 | 0.248 | 0.1762 |
| Waste Lands | 22.6 | 14.8 | 12.37 | 1.2 | 1.36 | 0.501 | 0.19 | 0.109 | 0.07 |
| Sal Forest | 45.4 | 28.3 | 23.89 | 1.6 | 0.4 | 0.37 | 0.98 | 0.49 | 0.473 |
| Agriculture Land | 108 | 83.53 | 60.22 | 1.4 | 1.6 | 0.963 | 0.62 | 0.525 | 0.43 |


**Table 5.** Result of Ex. Mg and Ex.Ca

| Land use | EX.Mg | | | EX.Ca | | |
|---|---|---|---|---|---|---|
| | 0-20 | 20-40 | 40-60 | 0-20 | 20-40 | 40-60 |
| Reclaimed mine soil | 0.6 | 0.4216 | 0.299 | 0.24 | 0.18 | 0.114 |
| Mine Face Topsoil | 0.28 | 0.326 | 0.2608 | 0.097 | 0.09489 | 0.09279 |
| Waste Lands | 0.097 | 0.0855 | 0.05985 | 0.015 | 0.01019 | 0.00769 |
| Sal Forest | 0.02 | 0.017 | 0.017 | 0.083 | 0.13 | 0.12 |
| Agriculture Land | 0.017 | 0.017 | 0.0085 | 0.039 | 0.0339 | 0.026 |

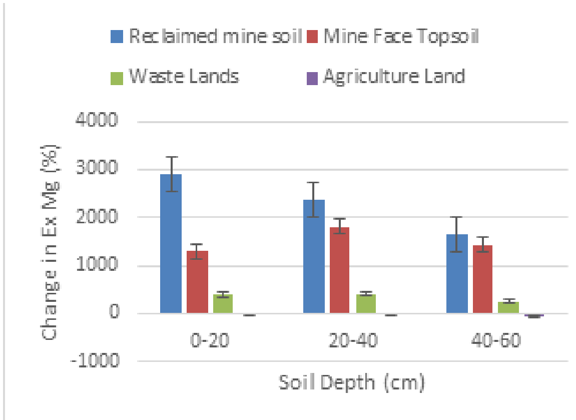


**Fig. 5.** Changes in Ex Mg with increase in soil depth

establish the human habitat that leads to range of ecological consequences. Many studies have investigated the impact of surface coal mining and reclamation on the soil quality and ecological processes. The present study showed the changes in physicochemical properties in the core and buffer zone of the mining areas. Sand content was found significantly different in various land uses and insignificant among all the three soil depths no significant difference was found between the sand content of Sal forest and wasteland, and RMS and mine face top soil. Sand percentage was found low in mine face topsoil and it increases slightly in the wasteland among all the soil depths as compared to Sal forest. Silt content of the RMS was found significantly different and found lower as compared to the Sal forest in all the three soil depths.

In mine face topsoil silt content was found higher, however, changes were not significant in the wasteland as compared to the Sal Forest. Clay content was found up to six hundred times higher in RMS. RMS did not show any clear pattern with depth possibly due to its heterogeneity. The vertical increase in the clay content of different land uses agreed with the simultaneous decrease in silt content of surface and subsurface horizons in different lands. High clay content in subsurface horizons is the result of the percolation of water along the cracks in the parent material (Shaw *et al.,* 2004). Bulk density was significantly higher in the RMS and it increases with soil depths. This change may be associated with the compaction of the soil due to the movement of the heavy earth moving vehicles (Maiti, 2013). Field moisture content that was observed high in the RMS may be due to high clay content, litter accumulation and canopy cover (Maiti, 2013). Soil moisture plays a vital role in the ecosystem functioning and it may depend on the time of sampling, height of the dump, texture, OC, vegetation cover and thickness of litter layer (Huang *et al.,* 2016; Mukhopadhyay *et al.,* 2013). In this study, soil moisture content increased with increases in soil depths in all the land use patterns.

There was no significant difference observed between the soil pH of RMS and mine face topsoil, maybe due to a similar kind of soil texture and parent materials. Soil pH in agriculture landwas found close to neutral compared to Sal forest and wasteland (acidic). PH of the soil mainly depends on the geology and parent material of the rock (Mukhopadhyay *et al.,* 2014). Natural Sal Forest soils were more acidic due to the intense leaching of the base cations (Islam and Weil, 2000). There were no significant changes observed in pH with the soil depth in mine face topsoil and Sal forest. Increase in EC from Sal forest in all the three soil depths possibly due to the mixing of the top soils and salty subsurface soil that enhance the salt concentration of the soils and further watering and degradation of organic material solubilized these salts that increase the EC (Mummey *et al.,* 2002).

SOC concentrations in the Sal forest agriculturel and were found significantly different. The higher concentration of SOC in Sal forest due to higher amount of litter accumulation and decomposition, and higher microbial biomass carbon compared to agriculture land. Conversion of native forest into wasteland and agriculture land results inmarked changes in the SOC and nutrients. In natural forest, litter fall and biomass increase the SOC content, however, in agriculture soil; it was removed periodically for consumption that may reduce the SOC content in agriculture soil (Tripathi and Singh, 2009). Decrease in the SOC with an increase in soil depths was found in all the land uses and similar results were also reported by the Richter *et al.* (1999) and Jobbagy and Jackson (2000).

The soil profile study showed reduction of N in RMS, mine face topsoil and wasteland in all the soil depths comparedto the Sal forest. N was significantly decreased with increases insoil depths in all the land use studied. The decrease in the N may be associated with the decline in humus content and organic matter with the depth. N is an important nutrient for the plant growth, although it does not occur in the mineral form in the soil (Bradshaw,

1997) and supplied externally to improve the fertility of the soils that may increase the N concentration in the agriculture soils. The impact of mining on soil N were also studied by Singh *et al.* (2012) and Shrestha and Lal (2011), and found 52% and 61% decline in soil N, respectively. Tripathi and Singh (2009) have also reported low levels of organic matter and total N in cultivated soils.

Av. P was found low in RMS, mine face topsoil and wasteland compared to Sal forest. Variation in P content was observed with increase in soil depths in different land uses. The factors like plant species, plantation age and spoil characteristics significantly affect the amount of P in the soil (Singh and Zeng, 2008). The distribution of the P may vary with the depth mainly due to the substrate abundance, abiotic condition and root activity (Jobbagy and Jackson, 2001).

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Study inferred that surface mining directly creates anthropogenic soil (RMS) and indirectly generates other forms of land uses (waste land) that originated from Sal forest. These newly formedland use significantly alters soil characteristics and ecosystem functions of the area. Increase in soil pH, EC and bulk density, and decrease in SOC, and soil nutrients are major impacts of opencast coal mining. While reclaiming mine degraded land, mine soil gets compacted (as indicated high bulk density) and there is an overall decrease in soil ground water recharge and moisture regime of the area. The study concludes that removal of natural *S. robusta* prior to mining and reforestation with fast growing tree species during reclamation, will not lead to the regeneration of original ecosystem, due to complete alteration in the soil properties. Therefore, the habitat transfer method could be a viable technique to restore the *S. robusta* forest ecosystem. During restoration of mine degraded land in the dry tropical climate, proper regrading of spoil material, topsoil blanketing, use of grass legume mixture as pioneer species and organicamendments can enhance the overall properties of the soils and mimic the attributes of the ecosystem prior to the mining.

## Acknowledgement

The authors mining authority, Talabira mines Sambalpur for co-operating during sampling.

### Conflict of Interest

The authors declare no conflict of interest.

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