INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCES Volume 1, No 4, 2010

Research article ISSN 0976 – 4402

Role of Soil Physical Properties in Ecological Succession of Restored Mine Land – A Case Study

Shikha Uniyal Gairola, Prafulla Soni
Forest Ecology and Environment Division
Forest Research Institute, Dehradun, Uttarakhand, India.
shikhaa.fri@gmail.com

ABSTRACT

Minerals are the gift of nature which occurs either in thick forest areas or adjacent to it. During the course of mining, vegetation/forest gets destroyed and gets replaced by huge quantities of overburden dumps. Restoration of these dumps becomes necessary so that the land may come back to its original topography. Soil has the significant role in restoration process. Present paper focuses on how the physical characteristics of soil affect the restoration intervention in a derelict mined land. The study was carried out with an objective of evaluating the role of soil physical properties in ecological succession of an age series of 23, 22, 21 and 20 years old restored mine sites in Dehradun district, Uttarakhand, India. Adjoining natural forest was also studied for comparison of some selected soil physical properties (texture, porosity, electrical conductivity, bulk density). Data of the present investigation reveals that as the physical properties of soil improve with age of bio-restoration, the successional processes also advance culminating into successful restoration of mine derelict sites. The results of the present study will be helpful in further understanding the successional processes and how soil properties play significant role in successional processes.

Keywords: Age series; Bio-restoration; Derelict sites; Ecological succession; Natural forest; Overburden dumps

1. Introduction

The mining industry contributes natural resources to meet societal needs, while causing drastic alterations of the landscape which result in unproductive land. Unfortunately, in most of the mining areas in India, exploitation of mineral resources had been carried out in early days with least regards to land protection and even without any plan for future land use. Mining operations degrade significant areas of land and replace existing ecosystem with undesirable waste materials in form of mine spoil dumps (Singh et al., 2007). Mining also disturb soil sequences as well as due to loosening of the ground, the natural compactness of the soil reduces as a result the soil become prone to erosion due to the rain and wind. Mined sites have special problems due to the removal of an entire ecosystem, changes in slope and the potential for toxic soil. Restoration of mined areas is essential to restore the ecological balance of the system and maintain a self sustain ecosystem wherein all the essential ecological processes take place (Verma, 2003).

Understanding successional processes in order to be able to control them more effectively is one of the key requirements in restoration ecology. A wide range of factors, including the nature of the overburden, the availability of topsoil and its handling, the development of soil fertility and the control of soil air and water content determine the suitability of reclaimed sites for revegetation and its successful successional development .

Research article ISSN 0976 – 4402

Vegetation potential of any area is dependent upon edapho-biotic components and their interaction, soil surface characteristics, climate and vegetation after open-cast mining (Nath, 2004). Improved soil condition i.e. improvement in the chemical and physical properties of soil helps in the faster recovery of the derelict soil. Present paper focuses on the physical properties o f the derelict soil in an age series of mined land and its role in the successional development.

2. Materials and methods

2.1 Study site

Study site is located in Doon Valley, Uttarakhand (India) which is bounded by lesser Himalayas in north and younger siwaliks in the south and is limited by rivers Ganga and Yamuna in east and west respectively. It lies between longitude $77^0$38' to $78^0$20' east and latitude $29^0$35' and $30^0$30' north and covers an area of more than 2000 sq.km (Figure 1). The present study has been undertaken in restored area of rock phosphate mine at Maldeota in Doon Valley, Uttarakhand (India) that has an elevation ranging from 650m to about 1050m above MSL. It is situated in the north east of Dehradun at a distance of about 18km on the west bank of perennial river Bandal. The mean maximum temperature in 2006 went up to 26.5^0C in July and minimum 12.5^0C in January. While in 2007 the mean maximum temperature was 34.6^0C in May and June while minimum mean temperature was 11.1^0C in January. Total annual rainfall for the year 2006 was 1530.1 mm while in the year 2007 it was 2173.3 mm with a maximum of 489.6 mm and 843.0 mm in the month of July in both the years. The area affected by open cast mining was about 15 hectares till 1982 when ecorestoration was initiated (Soni and Vasistha, 1985). For the present investigation, the restored areas of different ages were selected, besides the adjoining natural forest (undisturbed by mining) as control site for comparing the successional development in all age series of restoration.

Present study was done in the year 2005-2006. A comparative study of soil physical properties has been done between a 23 years old restored site (site1), 22 years old restored site (site 2), 21 years old restored site (site3) and 20 years old restored site (site 4). For comparison an adjoining natural forest (site 5) has also been studied.

In each site five 1x1 m quadrat was laid (Misra, 1968) and the soil sample was collected in poly bags and brought to laboratory for the determination of texture, porosity, electrical conductivity and bulk density. Texture was determined after air drying the samples, big stones were removed and the soil was passed through 2 mm sieve. Part of the soil samples having particle size less than 2 mm were subjected for texture analysis by Hygrometer method (Black, 1965) for estimation of percentage of different fractions viz. sand, silt and clay. Bulk density (BD) of the soil was determined by core sampler. Electrical conductivity (EC) was determined in 1:25 soil-water ratio by Century Digital Conductivity Meter. (Wilde et al., 1985). Porosity was determined indirectly from the bulk density and particle density values.

$$Porosity = 1 - (\frac{Bulkdensity}{Particledensity}) * 100 \quad (1)$$

Research article ISSN 0976 – 4402

3. Results and discussions

3.1 Texture

In the present study the texture class (Table 1) of all the restored sites i.e. 23 years old restored site 22 years old restored site, 21 years old restored site and 20 years old restored site, was found to be sandy loam with 63.70%, 68.70%, 66.60 % and 62.29% of sand respectively whereas texture class of natural forest area is clay loam with 48.25% of sand, 25.39% of silt and 26.36% of clay. Percentage of silt in restored sites (23 years old restored site, 22 years old restored site, 21 years old restored site and 20 years old restored site) came out to be 17.00, 13.40, 15.00 and 19.23 respectively. Similarly clay was found 19.30%, 17.90% 18.40 and 18.48% respectively. Although difference in the mean values was observed but statistically, no significant difference in texture between the sites was found. However, variation between sand, silt and clay content was highly significant ($p < 0.001$) between all the sites. The statistical tests were done by using the SPSS (Statistical Package for Social Sciences software) programme for Windows version 15.0.

Table 1: Percentage of sand, silt, clay and texture class of soil of restored and natural forest

Sites	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Texture class**
Site 1	63.70±1.55	17.00±1.46	19.30±0.88	Sandy loam
Site 2	68.7±0.74	13.40±0.51	17.9±1.51	Sandy loam
Site 3	66.6±1.37	15.0±0.72	18.40±0.88	Sandy loam
Site 4	62.29±1.56	19.24±0.48	18.48±1.28	Sandy loam
Site 5	49.22±1.04	26.42±2.14	24.35±1.76	Clay loam

The data represents the mean value of five replicates.± standard deviation

3.2 Bulk density

Bulk density was calculated highest for site 1 (1.54) while it was lowest for site 4 (1.43). The trend of bilk density was in the order site1 > site 3 > site 5 > site 2 > site 4. Statistical analysis reveals that difference in bulk density vary significantly between the sites ($p < 0.001$). Though the bulk density of sites differs among sites but there was no change in the during the study period.

3.3 Porosity

In the present study porosity of the soil as shown in Table 2 varies significantly ($p < 0.001$) between the sites. The highest porosity was recorded for site 4 (46.12**%**).

3.4 Electrical conductivity

Site 1 exhibits the highest electrical conductivity (0.032). The lowest electrical conductivity was exhibited by site 3 (0.013). The electrical conductivity analysis shows that the order of the site with respect to this parameter is site1 > site 4 > site 2 > site 5 > site 3. Statistical analysis reveals that difference in electrical conductivity vary significantly between the sites ($p < 0.001$).

Research article ISSN 0976 – 4402

Table 2: Mean values of selected physical properties of soil in different ages of restored sites and adjoining natural forest

Site	Bulk density (g/cm^{-3})	Porosity(%)	Electrical conductivity (mhos/cm)
Site 1	1.54±0.09	41.67±3.55	0.032±0.004
Site 2	1.46±0.12	44.83±4.56	0.017±0.002
Site 3	1.48±0.14	44.29±5.42	0.013±0.001
Site 4	1.43±0.13	46.12±5.20	0.027±0.002
Site 5	1.47±0.20	44.55±7.76	0.016±0.002
CD	0.179	6.798	3.706
Significance	***	***	***

The data represents the mean value of five replicates.± standard error, *** (p<0.001)

Restored area was totally derelict due to mining activities at pre restoration phase but restoration interventions have ameliorated the soils. The soil profile was totally disturbed and moisture content decreased due to exposure. In the present study the texture of the restored mine site came out to be sandy loam and clayey loam in the natural forest. It is well known fact that on establishment of vegetation in an area, climate and vegetation interact and influence the pattern of the soil development. The process of weathering of the parent rock in the mine spoil favours the soil forming process in order to reach a steady state resulting in maximum productivity (Annon, 1981). The present study area initially had no soil or very little soil but ecorestoration interventions, introduction of vegetation had a favorable impact on spoil and it turned to sandy loam. At present, study area has dense vegetation and the measures taken to improve the soil have positively worked on and the condition of the soil has improved in all the restored sites.

In the present study increased bulk density of the soil in the restored sites is observed while natural forest area has comparatively lower bulk density (Table 2). The increase in bulk density of the soil at restored site can be attributed to high percentage of sand and comparatively less organic matter in the soil as compared to mine free area. Improvement in the soil porosity of restored area with increasing years of restoration has been reported by many researchers. The increasing organic matter may also have contributed to the overall improvement in porosity of restored area. The improvement in electrical conductivity of restored area may be attributed to downward salt movement from surface with age and thus providing soil with the essentials salts.

Improvement of soil conditions promoted plant succession and sustained stable, productive plant communities (Schafer and Neilson, 1979). The results of physical analysis of soil from restored mine sites show that they have attained marked improvement in their properties with the age of bio-restoration (Table 1 and Table 2). Prach et al., (2007) followed the successional development of urban restoration projects and link changes in soil and plant properties. This study provides a general guide for the development of plant communities and makes the connection between restoration trajectories and easily manipulated soil

Research article ISSN 0976 – 4402

properties. The accumulation and subsequent decomposition of plant residues has resulted in building the organic matter with an associated increase in nutrient enrichment. The rapid changes in physical properties may have been caused due to the accumulation of organic matter with the age of bio-restoration. This organic matter might have undergone a rapid process of humification with its end products being capable of reacting with the inorganic constituents and thus contributing to the development of soil (Varela et al., 1993).Thus, as the age of restoration is increasing, the physical properties of derelict soil are also improving and successional process also advances, culminating into successful restoration of mine derelict sites.

4. Conclusions

Whenever forestlands have been diverted for mining, the lives and economy of all those dependent on such lands for their livelihood have suffered adversely as mining naturally involves stripping the land of its vegetation before extraction of minerals. Mining results into dumps of mine spoil having no intrinsic value at all. Restoration of mined site implies ecological amelioration of the resource depleted ecosystems. A fundamental understanding of ecosystem structure and functioning include the process of primary and secondary succession is essential in order to achieve a quick and reliable ecosystem. Physical and chemical properties of soil play a significant role in restoration success. Productivity of the sites restored using successional approaches develops to the optimum level without a need for regular maintenance and external

5. References

1. Anonymous, National Research Council. Surface mining, soil and coal society. National Academy Press. Washington D.C. 1981.
2. Black, C.A. Methods of Soil Analysis. *American Society*. 1965, Agron. U.S.A.(Exchangeable Calcium and magnesium).
3. Misra, R. *Ecology Work Book*, Oxford and IBH Publishing Co. 1968, New Delhi.
4. Nath,S. Ecosystem approach for rehabilitation of coal mine areas. In Proc, "*National seminar on environmental engineering with special emphasis on mining environment NSEEME*" In (eds) Indra N. Sinha, Mrinal K. Ghose and Gurdeep Singh. 2004. pp. 1-12.
5. Prach, K., P. Pysek., and V. Jarosik. Climate and pH as determinants of vegetation succession in Central European man-made habitats. Journal of Vegetation Science 2007, 18, pp. 701–710.
6. Schafer, W.M. and Nielson, G.A. Soil development and plant succession on 1-50 year old strip mine spoils in Southern Montana. In. : M.K. Wali (ed) *Ecology and Coal Resources Development* , Pergamon press, New York, 1979, 2, pp. 541-549.
7. Singh, R., Singh, P.R. and Singh, G. Evaluation of land degradation due to coal mining-A vibrant issue. First international conference on MSECCMI, New Delhi, India, 2007. pp.129-133.

Research article ISSN 0976 – 4402

8. Soni, P. and Vasistha, H.B. Reclamation of rock phosphate mine at Maldeota. In: (Eds) Sharma, M.R. and Gupta, B.K. Proc. *Recent advances in plant science*. 1985.Bishen Singh and Mahendra Pal Singh, Dehradun.

9. Varela, C., Vazquez, C., Sangreogria, G.V.M., Leiros, C.M. and Stores, G.F. Chemical and physical properties of open cast lignite mine soils. *Soil Science*, 1993,156(3), pp. 193-204.

10. Verma, P.K., 2003, Population dynamics and successional changes in restored limestone mines in Mussoorie hills. Ph.D. thesis submitted to Forest Resarch Institute (Deemed University), Dehradun.

11. Wilde, S.A., Corey, R.B., Iyer, J.G. and Voigt, G.K. S*oil and Plant Analysis for tree culture*. Oxford and IBH publishing co., 1985. New Delhi.